MCEER
EARTHQUAKE ENGINEERING TO EXTREME EVENTS

U.S. Department of Transportation
Federal Highway Administration

ISSN 1520-295X

# Damage to the Highway System from the Pisco, Peru Earthquake of August 15, 2007

by
Jerome S. O'Connor,
Lucero Mesa and
Monique Nykamp

Technical Report MCEER-07-0021

December 10, 2007

This research was conducted at the University at Buffalo, State University of New York and was supported by the Federal Highway Administration under contract number DTFH61-98-C-00094.

MCEER

EARTHQUAKE ENGINEERING TO EXTREME EVENTS

*MCEER is a national center of excellence dedicated to establishing disaster-resilient communities through the application of multidisciplinary, multi-hazard research. Headquartered at the University at Buffalo, State University of New York, the Center was originally established by the National Science Foundation (NSF) in 1986, as the National Center for Earthquake Engineering Research (NCEER).*

*Comprising a consortium of researchers from numerous disciplines and institutions throughout the United States, the Center's mission has expanded from its original focus on earthquake engineering to address a variety of other hazards, both natural and man-made, and their impact on critical infrastructure and facilities. The Center's goal is to reduce losses through research and the application of advanced technologies that improve engineering, pre-event planning and post-event recovery strategies. Toward this end, the Center coordinates a nationwide program of multidisciplinary team research, education and outreach activities.*

*Funded principally by NSF, the State of New York and the Federal Highway Administration (FHWA), the Center derives additional support from the Department of Homeland Security (DHS)/Federal Emergency Management Agency (FEMA), other state governments, academic institutions, foreign governments and private industry.*

# Damage to the Highway System from the Pisco, Perú Earthquake of August 15, 2007

by

Jerome S. O'Connor,[1] Lucero Mesa[2] and Monique Nykamp[3]

December 10, 2007

Technical Report MCEER-07-0021

Task Number 094-F-4.1

FHWA Contract Number DTFH61-98-C-00094
Contract Officer's Technical Representative: W. Phillip Yen, Ph.D., P.E. HRDI-7
Senior Research Structural Engineer/Seismic Research Program Manager
Federal Highway Administration

1 MCEER, University at Buffalo, State University of New York
2 South Carolina Department of Transportation, Columbia, South Carolina
3 Shannon & Wilson, Inc., Seattle, Washington

MCEER
University at Buffalo, The State University of New York
Red Jacket Quadrangle, Buffalo, NY 14261
Phone: (716) 645-3391; Fax (716) 645-3399
E-mail: *mceer@buffalo.edu*; WWW Site: *http://mceer.buffalo.edu*

# Overview

This damage assessment report is the product of a field investigation undertaken in September 2007 after the $M_w$ 8.0 August 15, 2007 Pisco, Perú earthquake. It provides a brief description of the event and the consequential damage to the highway system. It relies on government reports issued immediately after the event that include investigations from leaders in Perú's academia, and the authors' field observations. The purpose of the report is to document the performance of structures designed according to AASHTO specifications and to help assess the adequacy of the standards used at the time of construction. Another important benefit of the task is the exchange of information for the mutual benefit of engineers and policy makers here in the U.S. and in Perú.

Although there was widespread destruction of buildings in the Ica region of Perú, damage to the highway system was less severe. Traffic on the Pan-American Highway, which is the backbone of the highway system, was interrupted at numerous points but most repairs were made within a few weeks. The one exception was the Huamani Bridge, which was still closed for repair six weeks after the earthquake.

Highway infrastructure suffered some damage from shaking, but most damage resulted from earthquake induced liquefaction, which was accentuated by the earthquake's unusually long duration (>170 seconds). Liquefaction likely caused one major slope failure on the Pan-American Highway that led to 75 mm (3") wide shear cracks in a three-cell concrete box culvert. It also caused some parts of the roadway to shift laterally and the pavement to be broken up and faulted. It most likely precipitated damage to one abutment of the Huamani Bridge that was observed. This five-span bridge also had shear cracking of piers and a 100 mm (4") lateral movement of the superstructure.

There were 15 significant rockfalls that blocked roads, but most travel ways were opened again by the time of the field investigation. There were at least two instances of failed retaining walls observed by the team. At least two large bridges were hit by falling boulders, causing serious damage.

Although this report is produced in English, it contains a translation of technical terms so that it is more useful to a Spanish speaker. It also contains a set of suggestions from the authors on how to manage Perú's highway infrastructure for better performance in the future.

Both U.S. Customary (English) and SI (metric) units are used in this report. Perú uses SI units, but U.S. readers of this report may be more comfortable with English units. All dimensions noted from field observations should be considered to be approximate.

The photographs herein were taken by Jerome O'Connor unless otherwise noted.

# Acknowledgments

The post-earthquake investigation was funded by the Federal Highway Administration (FHWA) under Project DTFH61-98-C-00094, which is led by MCEER Special Tasks Director George C. Lee, Ph.D., under the direction of Phil Yen, Ph.D., FHWA Contract Officer's Technical Representative.

The authors would like to thank the organizers of the investigation: Alex Tang, L&T Engineering & Project Management Consultant, ASCE's Team Leader; Jack López Acuña, Jack López Ingenieros; Lucero Mesa; and Jack López Jara, T.Y. Lin International, Inc. in Lima Perú. Jack, in particular, is to be thanked for his diligence in arranging travel and lodging accommodations, and providing for site access and meetings with local officials. Milton Córdova Cóndor, from Condorco SRL is to be thanked for his untiring service providing safe and efficient transportation for the field inspections.

The authors wish to thank the other members of the ASCE Field Investigation Team for sharing information and photographs. They were: Alex Tang, Tom Cooper, Mark Pickett, Michael Salmon, and Carl Sepponen.

Within Perú, the following individuals provided much information, and shared photographs as well as extending their hospitality.

- Carlos Valdez Velasquez-López and Juan Carlos Paz Cardenas, and others at the Ministry of Transportation (Ministerio de Transporte y Comunicaciones - MTC) for reporting on their experiences dealing with the earthquake and during the recovery efforts.
- Ing. Jack López Acuña, Jack López Ingenieros S.A.C.
- Ing. Jack López Jara, T. Y. Lin International, Inc.
- Dr. Julio Kuroiwa, Professor Emeritus, National University of Engineering and Scientific Advisor to Perú's Civil Defense
- Dr. Ing. Jorge E. Alva Hurtado, Dean of the School of Engineering at Perú National University (Universidad Nacional de Ingenieria).
- Ing. Juan Pedro Andía Morón, Regional Director of Transportation and Communication for the Ica regional government.
- Ing. Niser Macedonio Quispe Arias, Ica Region, who accompanied the team for several days as they toured the region and inspected bridges and highway features.
- Manuel A. Olcese Franzero, Director of Soil Mechanics Laboratory and Daniel Quiun Wong at Catholic University of Perú (Pontificia Universidad Católica del Perú – PUCP).
- Ing. Gladys Villa Garcia, Director of Laboratory for Seismic-resistant Structures at Catholic University of Perú (Pontificia Universidad Católica del Perú - PUCP.

- Other professors at Catholic University and Perú National University who shared their personal experience and documentation that will help to provide a complete account of the event and its impacts.
- Visiting professors from the University of Tokyo, Drs. Paola Mayorca and Jorgen Johansson.

El Comité Investigador del Sistema Vial agradece y quiere darle las gracias a sus anfitriones y a la gente del Perú, por su hospitalidad y su cordialidad durante su estadía en el país. Les deseamos mucha suerte en el futuro y esperamos volver un día a disfrutar de su hermoso país bajo mejores circunstancias.

# Contents

# 1.0 Introduction

This report is the product of a field investigation undertaken about five weeks after the August 15, 2007 Pisco, Perú earthquake. The reconnaissance trip was sponsored by Federal Highway Administration under Project DTFH61-98-C-00094 being carried out by MCEER, University at Buffalo. The investigation took place September 21, 2007 through September 28, 2007.

The MCEER investigation was performed jointly with the American Society of Civil Engineers (ASCE)'s lifeline's field reconnaissance, led by Alex Tang, P.E. A subgroup of the ASCE team (Lucero Mesa and Monique Nykamp) joined Jerome O'Connor to form the highway system investigation team (see figure 1-1). The team was assisted by the firm Jack López Ingenieros, S.A.C. and others in gathering preliminary information and scheduling meetings with local authorities. The Acknowledgment section of this report recognizes individuals and agencies that provided assistance and Appendix A describes the experience of the team members.


*Figure 1-1. Highway System Investigation Team:*
*J. O'Connor, M. Nykamp and L. Mesa*

The purpose of the investigation was two-fold:

*Data Collection:* to observe and document damage to the highway system from ground shaking, soil instability, liquefaction, lateral spreading, landslides, and rock falls. This data will lead to a better understanding of the threats to the highway system and the behavior of bridges designed according to American Association of State Highway and Transportation Officials (AASHTO) specifications (used in Perú). It can enhance our understanding of the loads imposed by hazards, the response of structures, conditions that affect a structure's ability to resist those loads (e.g., the presence of scour and or corrosion), and the presence of more than one load effect.

*Information Sharing:* to publish information and disseminate to others in the U.S. and abroad for our mutual benefit. During meetings with the Perú Ministry of Transportation, the government expressed a desire to see the final report. Sharing knowledge and technical expertise with our neighbors to the south will foster better international relationships and help develop personal contacts in countries that are exposed to the same hazards as we are.

At the suggestion of one transportation official in Perú, this report contains an Appendix C with a translation of technical terms. Although not as beneficial as a complete English-to-Spanish translation of this report, it will aid Spanish speakers in the comprehension of its content. The terms will also be useful to English speakers who wish to better understand engineering terms used in Perú.

# 2.0 Background

The country of Perú has a land mass of 496,000 square miles and is situated on the west coast of South America. The capital Lima is located at S. Lat. 12° - W. Long. 77°. Ica Department, where the effect of the earthquake was most severe, is approximately four hours south of Lima (S.Lat. 14° - W. Long. 75.5°). The cities of Pisco and Ica are 236 km (147 mi.) and 303 km (188 mi.) south of Lima, respectively. The country has a population of 28 million, who mostly live in Lima.

The country of Perú is divided into 24 departments, which are analogous to states in the U.S. The departments are divided into provinces, which are similar to counties in the U.S., and finally, small governmental entities, districts.

The earthquake was felt in much of the country but damage was most evident in the Ica Department, where over 688,000 people reside (see table 2-1)[1]. Within the Ica Department, the cities of Pisco and Ica were most affected.

*Table 2-1. Population of Ica Department*

| Province | (Number of Political districts) | Population in 2002 |
|---|---|---|
| Chincha | (11) | 177,000 |
| Pisco | (8) | 127,000 |
| Ica Province | (14) | 304,000 |
| Palpa | (5) | 18,000 |
| Nasca | (5) | 62,000 |
| | **Total** | 688,000 |

The county's climate is affected by its coastal frontage and the Andes Mountains. Along the coast there are arid deserts and sand dunes, whereas in the eastern part of the country, there is rough terrain with abundant water from mountain streams. Rainfall along the coast in the Ica region is typically less than 15 mm (~1/2") per year.

Perú has a long history of earthquakes. In 1650, a strong earthquake destroyed the city of Cusco, which was the capital of the Incan empire that stretched from what is now Chile to Colombia. In 1664, an earthquake devastated the city of Ica. As recently as 2001, a $M_w$ 8.4 earthquake struck off the coast.[2] Most of the earthquakes are subduction zone earthquakes caused by subduction of the Nasca plate under the South American Plate.

[1] *Ica Perú Tourist Guide* (2002). 2nd Edition, Slyt Grafic E.I.R.L. Ica, Perú.
[2] ASCE Atico, Perú Earthquake Monograph No. 23.

The Ica region also suffers from occasional El Niño rains and subsequent flooding. Ica was devastated by flooding of the Ica River in 1963, then again, in 1983 and 1998, when rains from El Niño resulted in inundation of 80% of the city.

Figure 2-1 shows the location of Perú, and the location of the earthquakes' epicenter.

The soils near the coast consist largely of liquefiable silts and sand. Where firm ground exists near Lima, it is an alluvial deposit locally known as "Lima conglomerate," a dense, slightly cemented gravel. In the Ica/Piso area, fine soils are cemented eolian deposits. Away from the coast, the ground is very rocky with very little arable soil.


*Figure 2-1. Map of South America and Perú with Epicenter of the August 15, 2007 Pisco Earthquake*

No report on Perú is complete without some mention of Machu Picchu (see figure 2-2). At 2,430 m (7,970 ft), this pre-Columbian site is in the "highlands" of the Andes and considered one of the seven new wonders of the world. Fortunately, the ancient city was not damaged by the Pisco earthquake.

a. Ancient Incan city on the slopes of the Andes,
Huayna Picchu in the background

b. Buildings and terraces built by Incan craftsmen using
advanced stone masonry techniques

*Figure 2-2. Incan Capital of Machu Picchu*

# 3.0 The Highway System

The Ministry of Transportation and Communication (MTC) is the administrative branch of government with responsibility for the highway system in Perú. The MTC was gracious enough to meet with the investigation team at their offices in Lima to give an overview of the consequences of the earthquake.

Their explanation started with a description of the road network. There are three classes of roadways in Perú (refer to table 3-1 and figure 3-1).

*Table 3-1. Road Classifications in Perú*[3]

| Classification | Type of Road | Km in Ica |
|---|---|---|
| National Highway System (Nacional) | Primary | 527,300 (100% is paved) |
| Departmental (Departamental) | Secondary | 342,440 (25% is paved) |
| Rural (Vecinal) | Rural | 1,488,490 (4% is paved) |

*Gobierno Regional de Ica 2004*

*National:* The primary highways are part of the National Highway System (NHS). The backbone of the NHS is the Pan-American Highway (Carretera Panamericana Sur, also known as Route 1S) the country's major North-South route. The NHS roads are run by concession. This means that the national government has a long-term (30-year) contract with a private company that serves as an operator and collects tolls in exchange for maintaining the roads in good condition. In the event of an earthquake, the contractor has a contractual obligation to restore the highway system to its original condition. Other routes on the NHS are the E-W routes Los Libertadores (Route 24), and San Juan-Nazca-Cusco (Route 26)

*Departmental:* Departmental (regional) roadways are secondary roads, and because of the nature of the terrain, are often unpaved. The Ica Departmental system includes Routes 100 (i.e., Chincha Alta-Huachinga-Huanchos Highway), 102 (Chincha-Tambo de Mora), 106 (Los Aquijes-Huambo), 107 (Tulin-Agua Perdida-Ayacucho), 108 (El Engenio-Huarasaca), 109 (Muelle Acari-EMP R1S km 518), and 110 (Ica-Parcona-Tinguina-Los Molinos-Tambillos).

*Rural:* Rural roads (caminos vecinales) are lightly traveled, farm-to-market roads, typically dirt.

[3] *Plan Vial Departamental Participativo* (2004) Gobierno Regional de Ica, Perú


*Figure 3-1. Peru's highway system with area of interest noted.*

There are four major rivers in Ica. All carry rain water and snow melt west from the Andes Mountains toward the Pacific Ocean. The rivers are Rio Chincha (or San Juan), Rio Pisco, Rio Ica, and Rio Grande. In 1998, during the El Niño, these rivers carried great flood waters and well as a debris flow known as *huayco (or huaico)*. During the 2007 reconnaissance, the water level in the river was very low but the riverbeds were wide, indicating a history of occasional heavy flooding (see figure 3-2). As one travels east (i.e., upstream) there is more water and vegetation in an otherwise barren region.

Since bridges are a vital yet vulnerable link of the highway infrastructure, much of the investigation focused on the performance of bridges. In Perú, a structure is considered a bridge if the span is greater than 10 m (32.8′). (See table 3-2 for definitions used in Perú to describe structures carrying roads over water.) According to records in the Ica Department, there are 31 bridges, totaling approximately 850 m (2,789′) in length.

*Photograph by Monique Nykamp*

*Figure 3-2. The wide riverbed of Rio San Juan is indicative of the large volume of water that the river carries in years when El Niño returns.*

*Table 3-2. Drainage Structure Classifications Used in Perú*

| English Term | Spanish Term | Span Length (meters) |
|---|---|---|
| Bridge | Puentes | > 10 m |
| Culverts | Pontones | 1m < span < 10m |
| Pipes | Alcantarillados | < 1m |

Perú relies on AASHTO specifications for the design of its bridges.[4] The 475-year event found in the Standard Specification for Highway Bridges has typically been used. The team observed bridges with wide bridge seats and transverse restraints such as concrete shear blocks. Piles or caissons are not typically used for foundations, apparently due to a of lack of necessary equipment.

The building code[5] in Perú divides the country into three seismic zones (see figure 3-3), for both building and bridge design. Peak ground accelerations (PGA) specified for each zone are indicated.

[4] AASHTO
[5] Perú, Ministry of Housing, Construction and Sanitation, NTE E.30, 2003

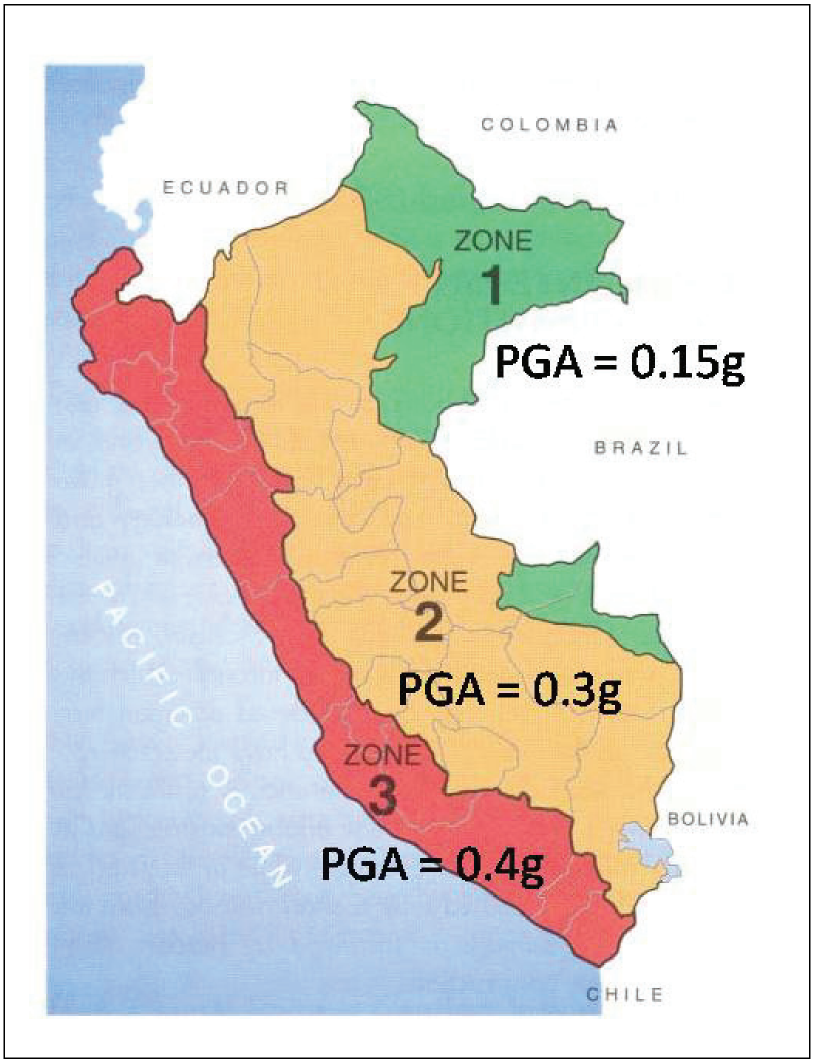



*Image courtesy of Dr. Julio Kuroiwa*[6]

*Figure 3-3. Seismic hazard zones in Perú's design code*

[6] Kuroiwa, Julio (2004). *DISASTER REDUCTION. Living in Harmony with nature, Quebecor World Perú S.A, ISBN 9972-9999-0-4.*

# 4.0 The Earthquake of August 15, 2007

Perú sits on a subduction zone where the oceanic Nazca Plate is moving under the South American continental plate (see figure 4-1). On August 15, 2007, an earthquake occurred at 6:41 pm local time (23:41 GMT).[7] The epicenter of the earthquake was located at S. Lat. 13.4° - W. Long. 76.5°. This is 50 km (31 miles) W-NW of Chincha Alta, Perú or 150 km (93 miles) SSE of Lima. The length of this subduction was reportedly 150 km (93 miles).

The earthquake resulted in at least 519 deaths and 1,874 injuries (National Civil Defense Institute (INDECI). In addition, 54,926 buildings were destroyed and 20,958 were seriously damaged. In the city of Pisco, over 80% of the buildings were destroyed or damaged.

The earthquake's moment magnitude ($M_w$) was 8.0, producing the greatest ground motion in the Ica region where the Modified Mercalli Intensity (MMI) was VIII. Shaking was also very strong in Lima (MMI=V) and was felt 1,100 km away in the Andes highlands city of Cusco (MMI=III). There were reports of some damage to buildings in Lima, and a small tsunami was generated near Lagunilla, on the south coast of the Paracas peninsula.

The ground motions of the earthquake were recorded at about 16 stations in Perú. Most of the strong motion stations are located in the Lima area, about 170 km north of the north end of the fault rupture zone. Only two ground motion recording stations are present within the fault rupture zone. These two stations are located in the town of Ica, near the south end of the rupture zone.

Peak ground accelerations (PGA) as high as 0.49 g (approximately half the acceleration due to gravity) were recorded on accelerometers at the PCN station in Parcona, Ica. This is higher than the PGA specified in the building code for seismic zone 3. Time history graphs of the earthquake show two distinct phases of strong ground motion (see figure 4-2). The earthquake had an unusually long duration, resulting in shaking that lasted >170 seconds (measured at the PUCP seismograph station).

The primary geotechnical impacts of the earthquake were due to the phenomenon of liquefaction. Liquefaction occurs during ground shaking in loose, saturated, sandy soil when the water pressure in the pore spaces increases to a level that is sufficient to separate the soil grains from each other. This phenomenon results in a reduction of the shear strength of the soil (a quicksand-like condition). Liquefaction can result in ground settlement, lateral spreading, landsliding, localized ground disruptions from sand boils (ejection of sand and water at the ground surface), and reduced vertical and lateral capacity for structure foundations. Buildings, bridges, and other structures founded on or in the liquefied soils may settle, tilt, move laterally, or collapse.

[7] USGS: *http://earthquake.usgs.gov/eqcenter/recenteqsww/Quakes/us2007gbcv.php*

Because much of the affected area consists of fine grained, water saturated sediments, the geotechnical aspects of the earthquake were most dramatic. There was evidence of widespread liquefaction, especially along the coastal regions where the water table was not far from the surface. Newspapers had accounts of water spouting 2 m (6.5′) up from the ground during the earthquake in Ica. Even near Lima where the PGA's were less than 0.1 g, there were utility poles tipped from liquefaction of the supporting soils.

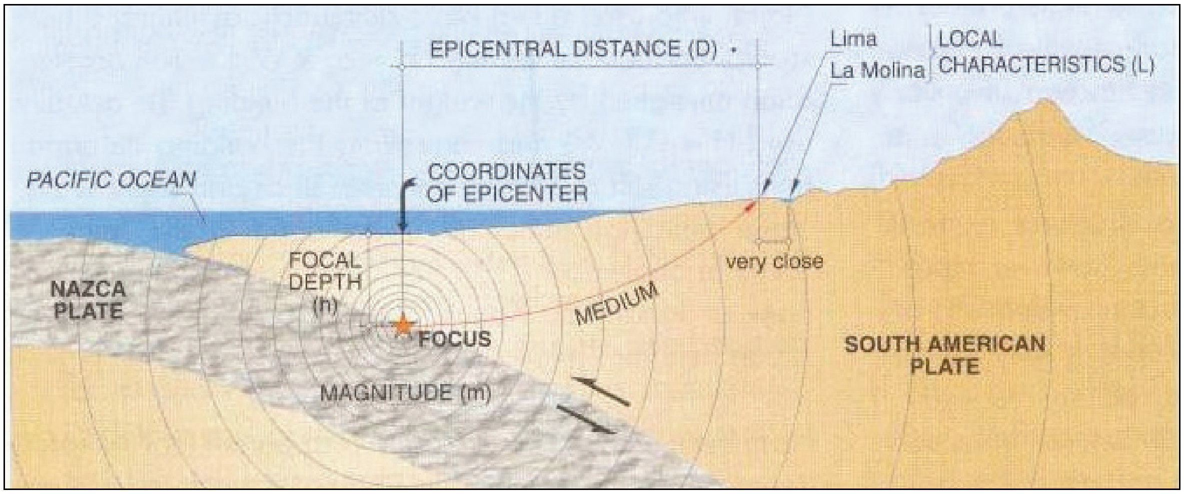



*Image courtesy of Dr. Julio Kuroiwa*

*Figure 4-1. Illustration of the Subduction Process*

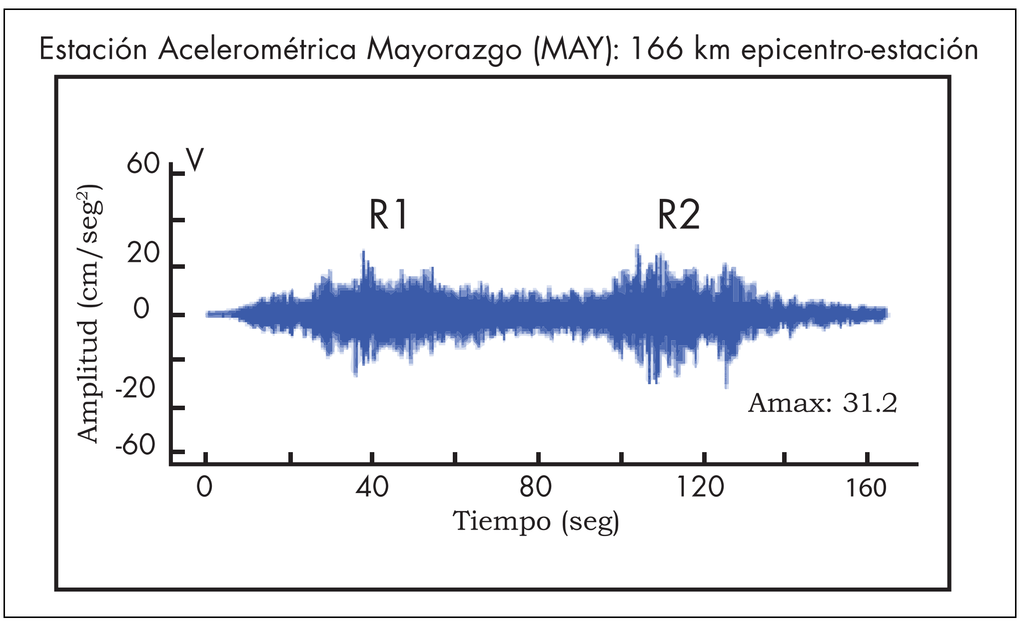



*Figure 4-2. Time history with two distinct peaks and a very long duration*[8]

[8] Tavera, H., Bernal, I., Salas, H. (2007). *El Sismo de Pisco del 15 de Agosto, 2007 (7.9Mw),* Dirección de Sismología – CNDG.

# 5.0 Damage to the Highway System

The highway system reconnaissance team was charged with assessing the extent of damage to roads and bridges due to the earthquake. Field investigation began after conferring with the MTC in Lima, professors from Catholic University and National University who had completed preliminary investigations, and local officials in the Department of Ica. This assisted greatly in prioritizing investigative efforts, and understanding the types of problems that resulted from the earthquake.

MTC reported that essentially all highway damage that occurred was in the Ica Department, the region closest to the epicenter of the earthquake. Therefore, the investigation was conducted in this region. Routes surveyed include the Pan-American Highway (on the National Highway System), Ica Departmental Route 100, Ica Departmental Route 110, National Route 24, and local streets carried by bridges within the City of Ica (see figure 5-1).

Although there was widespread destruction of buildings in Ica, structural damage to the highway system was less severe. Most damage resulted from geotechnical issues. Along the coast, liquefaction was induced by the presence of loose, sandy soils, a high ground water table, and the unusually long duration of motion. This resulted in slope failures, lateral spreading, shifting of the pavement as well as failure of buried culverts. There were 15 significant rockfalls that blocked other roads but most were opened again by the time of the field investigation. There were at least two instances of failed retaining walls observed by the team, and at least two large bridges were hit by falling boulders, causing serious damage.

Approximately twenty-four sites were inspected. This includes bridge structures and other highway features such as culverts, roadways, embankments, and retaining walls. 62% of these sites had evidence of damage. The MTC was not able to provide an estimated cost of damage to the highway system and the investigators did not try to quantify the value of the damaged facilities.

A brief summary of the findings is presented in table 5-1. The site number was assigned according to the sequence of the field inspections. The “km” column is the distance along the highway as indicated by road markers.

*Table 5-1. Summary of Field Inspection Findings*

| Site No. / Name | Highway | Coordinates | km | Damage | Comment |
|---|---|---|---|---|---|
| 1 | Pan-American Highway | S13°19′44” W76°14′00” | 182 | Evidence of cracking in cut-slope parallel to roadway | Lateral spread. |
| 2 | Pan-American Highway | | 185 | Distortion and cracking of pavement | Caused by liquefaction. Repaired. |
| 3 | Pan-American Highway | S13°23′42” W76°11′52” | 188 | Cracks from lateral spread along 200m length of road. One meter (3′) lateral displacement of edge line. | Caused by liquefaction. |
| 4 | Pan-American Highway | S13°24′48” W76°11′20” | 190 | Embankment failure & shear failure of 3-cell concrete box culvert. | Road repaired. Culvert shored. Caused by liquefaction/ lateral spread. |
| 5 Puente Huamani over Rio Pisco | Pan-American Highway | S13°41′13” W76°09′31” | 224 | Shear cracking in piers. Tipped abutment. 100mm (4”) lateral movement of superstructure halted by shear blocks on piers. | Closed for repair. Traffic is being detoured over riverbed with pipes carrying low flow water. |
| 6 Puente Aylloque | Route 100 | S13°24′13” W75°57′03” | | Minor cracking of abutment. | 1-span 10m (33′) timber bridge is subjected to overloads. |
| 7 Puente over Rio San Juan | Route 100 | S13°23′57” W75°56′24” | 27 | none | 2-span timber bridge is subjected to overloads. |
| 8 Puente Huachinga over Rio San Juan | Route 100 | S13°22′08” W75°50′60” | 39 | Severe damage to lower chord of 1-lane steel truss from boulder impact. Cracked welds at gusset plates; Severe erosion at abutment. | Evidence of previous impact damage to bottom chord, either from rockfall or El Niño debris flow (huayco). |
| | Route 100 | | 27 | Failure of retaining wall. | |
| 9 Puente Ica over Rio Ica | Pan-American Highway (Ave. Los Maestros) | S14°05′25” W75°43′11” | 305 | none | 3-span CIP; 29m (95′) |
| 10 Puente over Rio Ica | Ave. Cutero in Ica City | | | none | 2-span CIP; 31m (100′) |
| 11 Puente Grau | Ave. in Ica City | | | none | 1-span concrete;25m (80′) |

| Site No. / Name | Highway | Coordinates | km | Damage | Comment |
|---|---|---|---|---|---|
| 12 Puente Socorro | Ave. in Ica City | S14°03′20” W75°43′36” | | none | 3-span CIP; 33m (110′) |
| 13 Puente over Canal | Route 110 | S13°58′48” W75°41′53” | | none | 1-span CIP; 12m (40′) |
| 14 Puente over Canal | Route 110 | S13°57′40” W75°41′39” | | none | 1-span CIP; 10m (33′) |
| 15 | Route 110 | | 14 | Failed retaining wall. | |
| 16 Puente Los Molinos over Rio Ica | Route 110 | S13°55′29” W75°40′43” | | Three significant shear cracks in P/S beams at supports; Lateral displacement, Tipped pier from previous scour. | 5-span, 1-lane, non redundant 2-girder P/S; Built in 1932. |
| 17 Puente Quinga over Rio Pisco | Route 24 | S13°38′27” W75°43′06” | 54 | Rockfall may have initiated failure of rock wingwall. Previous erosion at wingwalls. | 36.5m (120′) P/S; Posted for 60T max. |
| 18 Suspension bridge over Rio Pisco | Pedestrian trail, not on highway system. | S13°41′42” W75°48′38” | | none | 91m (300′) Suspension ped bridge built 2001. |
| 19 Puente Toro over canal | Route 24 | | | none | 2-lane concrete bridge 18m, (60′) |
| 20 | Road to Pisco from Pan-American Highway at km 233. | S13°42′47” W76°09′18” | | Liquefaction resulted in faulted pavement & N-S cracking. | Broken watermain. |
| 21 | Just off Pan-American Highway on road to Pisco. | S13°42′47” W76°09′18” | | Damage to pavement due to liquefaction; ruptured waterline. | Excavated for paleoliquefac-tion study. |
| 22 | Pan-American Highway | S13°36′27” W76°09′01” | 218 | Road damage due to liquefaction; tipped poles. | Pavement has been repaired. |
| 23 Puente Cruz Verde | In Tambo de Mora. | | | Minor(1 inch) wingwall displacement. | Newer bridge. |
| 24 | Road to the beach at Sunampe. | S13°25′54” W76°10′56” | | Vertical shift as great as 10′ due to liquefaction. | Road repaired; escarpment, sand boils, cracking are evident in the vicinity |

*Note: If data was not readily available, the cell was left blank.*

In Ica, the team was able to conduct a damage assessment of the highway system by traveling five routes in a 4x4 vehicle (see figure 5-1):

- Pan-American Highway
- Departmental Route No. 100 (Carretera Chincha)
- Departmental Route No. 110
- National Route No. 24 (Los Libertadores)
- Local Streets in the city of Ica

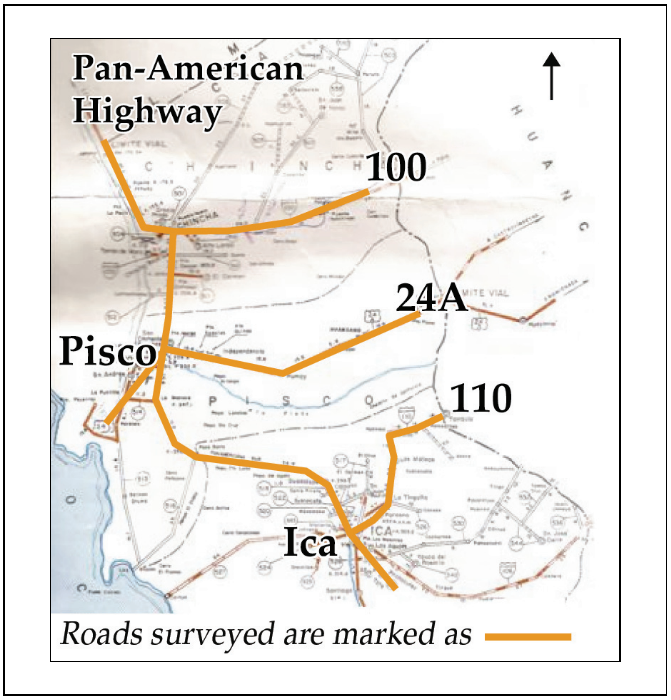



*Figure 5-1. Ica Roads Surveyed During Damage Assessment of the Highway System*

What follows is a description of the findings along each route. Photographs are used extensively to illustrate the conditions that were found. In cases where repair of damaged features had already taken place, photographs of the condition immediately following the earthquake are provided courtesy of the team's in-country contacts. The findings are presented in same order that the routes were traveled.

There were a few bridges that were not able to be inspected because of time limitations. To provide a complete picture of the situation, additional pictures are added that were provided by others.

### 5.1 Pan-American Highway

On September 25, 2007 the highway system investigation team drove south on this main North-South route from Lima to the Department (state) of Ica, where earthquake damage was most evident. In the Ica region, it is a two lane road, paved with asphalt.

Locations along the Pan-American Highway are conveniently posted as the number of kilometers (km) south of the capital Lima.

The Pan-American Highway parallels the coastline, and as such, is built upon sandy and silty soils. The terrain is coastal desert with large sand dunes and sparse vegetation. The Pacific Ocean is as close as 100 m (328′) to the west. The road is bordered on the east by large dunes consisting of cemented sand formations (see figure 5-2).

*Photograph by Dr. Ing. Jorge E Alva Hurtado*

*Figure 5-2. East shoulder of Pan-American Highway at km 178 pushed up onto sand dune after lateral displacement of roadway during liquefaction and "sloshing" of supporting ground.*

At numerous stops along the highway, the team encountered evidence of earthquake-induced liquefaction and lateral spreading. Lateral spreading occurs on gentle slopes as a result of soil liquefaction. When the soil liquefies, gravity causes the land to move downslope.

Conversations with individuals that had conducted inspections immediately following the earthquake recounted stories from locals stating that the water table was high prior to the event. Acceleration records of the event show that there were ground vibrations for an extended period (over 170 seconds). This ground motion, soil amplification and liquefaction resulted in damage to the pavement, embankment and cut slopes, drainage structures and shoulders, as evident from the photographs in figures 5-2 through 5-26. The photographs are in order based on a journey in a southerly direction from Lima. Sites referenced are listed in table 5-1.

*Photograph by Dr. Ing. Jorge E Alva Hurtado*

*Figure 5-3. Sand boils such as this are left behind as evidence of liquefaction in the area. This one was discovered at km178 near Jajuay Beach (Playa Jahuay)*

*Photograph by Dr. Mark Pickett (Site No. 3)*

*Figure 5-4. Note the white edge line. This is evidence of lateral displacement of the roadway at km 188 due to liquefaction at the toe of slope and reflection of seismic ground waves against the more rigid sand dune on the east side of the highway.*


*(Site No. 3)*

*Figure 5-5. Fissure along the northbound road shoulder at km 188 resulting from lateral spread away from the more rigid sand dunes in the left of the picture (Tom Cooper inspects). The ocean is out of view on the right.*


*Photograph by Jack López Jara (Site No. 4)*

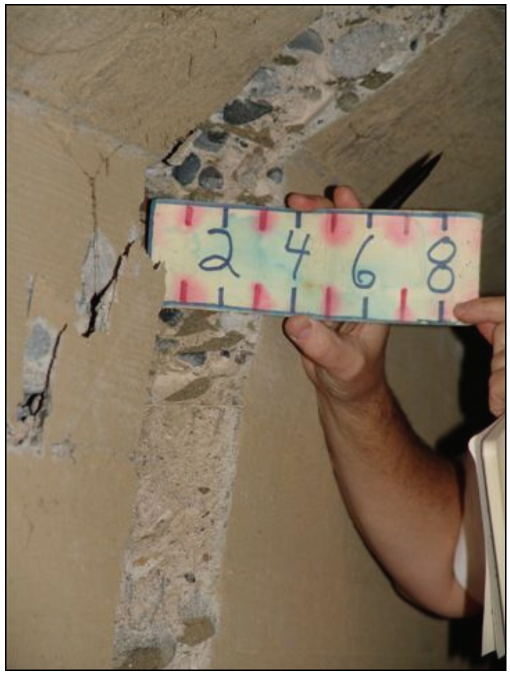
*Figure 5-6. Embankment and roadway failure at km 190. The picture was taken facing north. Note the Pacific Ocean in the top left of the photo. The damage was caused by amplification of the ground shaking. Liquefaction of the wet coastal silts and sands led to lateral spreading and the embankment failure.*

*Photograph by Dr. Mark Pickett (Site No. 4)*

*Figure 5-7. View from the Pan-American Highway looking West toward the Pacific Ocean. Notice the cracking of the earth from liquefaction and lateral spreading that led to the massive embankment failure at km190*

*Photograph by Dr. Mark Pickett (Site No. 4)*

*Figure 5-8. Outlet end of failed box culvert at km 190.*




*Photograph by Dr. Mark Pickett (Site No. 4)*

*Figure 5-9. Shear failure resulted in a 3-inch wide crack in the three-celled concrete box culvert at km 190*

*Photograph by Dr. Mark Pickett (Site No. 4)*

*Figure 5-10. Timber shoring and a horizontal crack in a concrete box culvert km 190.*

*Photograph by Dr. Ing. Jorge E Alva Hurtado*

*Figure 5-11. Pan-American Highway near San Clemete Approximately km 220.*


*Photograph by Dr. Ing. Jorge E Alva Hurtado*

*Figure 5-12. Pan-American Highway near San Clemente Approximately km 220.*

*Photograph by Dr. Ing. Jorge E Alva Hurtado*

*Figure 5-13. Pan-American Highway Near San Clemente Approximately km 220.*

*Photograph by Dr. Julio Kuroiwa*

*Figure 5-14. Pan-American Highway near San Clemente Approximately km 220.*


*Figure 5-15. This is one of the many sections of the Pan-American Highway that needed pavement repairs after the earthquake. Paving was still going on six weeks after the event.*

### 5.1.1 Huamani Bridge

Huamani Bridge (Puente Huamani) is a significant link of the highway system that was taken out of service by the earthquake. It is located at km 224 of the Pan-American Highway and is located directly east of the epicenter. This concrete structure was built in 1950 to cross the Rio Pisco (Pisco River) to join the city of Pisco with the village of San Clemente to the north. It is 136 meters (446′) long and two lanes wide (6.7 m or 22′). The bridge was designed to an H-15 AASHTO loading and had been posted with a 36 ton weight limit.

Although all five spans of the bridge remain standing, there was evidence of liquefaction in the sandy soils and evidence of strong shaking (see figures 5-16 through 5-26). The abutments and piers are built on massive walls, similar to caissons but are not supported by piles. According to record plans obtained by Ing. Jack López Jara, the 4 m (13.1′) high pier stems rest on solid concrete caissons that are founded 7.8 m (25.6′) into the stream bed. There was no indication of tipping or settlement of the piers.

There was cracking of the top of the pier caps, concrete diaphram and shear blocks, apparently resulting from lateral movement of the superstructure. The second pier from the south end had particularly severe damage from this lateral loading. The fact that the superstructure was only moderately displaced is evidence of the successful use of shear blocks.

The south abutment tipped toward the stream as a result of liquefaction of the sandy soil at that end of the bridge. During the inspection, the superstructure was temporarily supported and the south abutment was being rehabilitated. The north abutment is on a more competent material (a lightweight siltstone) that did not liquefy. There was only hairline cracking of that abutment.

Immediately after the earthquake, the bridge was reopened with traffic restricted to just one lane. Shortly thereafter, however, it was closed to all traffic as a precautionary measure and so that repair work could be accomplished. The bridge was under repair at the time of the inspection. Bridge damage can be summarized as:

- Severe cracking of one pier stem
- Severe cracking of transverse concrete diaphragms
- Minor to severe cracking and spalling of horizontal shear blocks and pier caps (see figure 5-20)
- Tipping of the south abutment toward the stream bed (approximately 100 mm (4") at the top)
- Lateral displacement of the superstructure (approximately 100 mm or 4")
- Damage to approach pavement, especially at south end of the bridge

Had the bridge not been part of a lifeline transportation route, this performance could be considered acceptable. The bridge did not collapse and was successful in preventing loss of life. The damage it suffered, though severe, is repairable.

Prior to the earthquake, the government had already been planning to build a new bridge at this site within the next few years. A few suggestions are provided in Appendix B of this report.


a. This bridge was still closed for repair five weeks after the earthquake

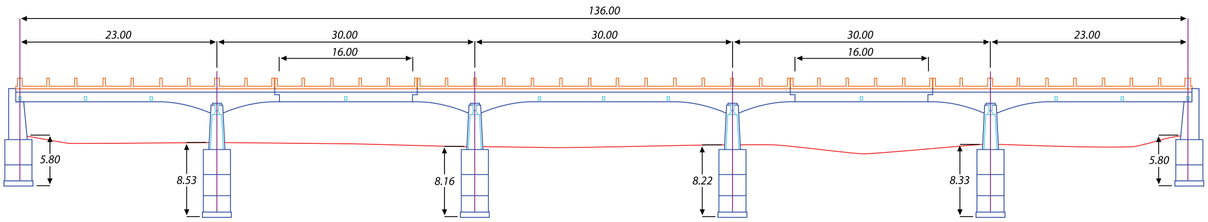



*Image courtesy of Ing. Jack López*

b. Elevation view of Humani Bridge showing two suspended spans

*Figure 5-16. Five-span Humani Bridge on the Pan-American Highway at km 224*

*Photograph by Dr. Alva (Site No. 5)*

*Figure 5-17. Pavement damage at the approach to the Huamani Bridge caused by soil liquefaction and lateral spread of embankments.*

*Photograph by Dr. Julio Kuroiwa (Site No. 5)*

*Figure 5-18. Approach pavement at the south abutment of Huamani Bridge has settled dramatically due to liquefaction of supporting soils and lateral spread of the embankment.*

*Photograph by Dr. Ing. Jorge E Alva Hurtado (Site No. 5)*

*Figure 5-19. Sand boils in the stream bed at the Huamani Bridge indicate that the soil liquefied.*

*Photograph by Dr. Ing. Jorge E Alva Hurtado (Site No. 5)*

*Figure 5-20. Severe cracking of Pier 2 (from South end) necessitates extensive repair but the horizontal shear blocks managed to retrain lateral movement of the superstructure. This pier has roller expansion bearings.*


*(Site No. 5)*

*Figure 5-21. Horizontal displacement of the superstructure is evident by the shift in the centerline at a joint*


*(Site No. 5)*

*Figure 5-22. Cracked deck due to horizontal movement of the span.*


*Photograph by Dr. Julio Kuroiwa (Site No. 5)*

*Figure 5-23. Broken railing and shift in curbline resulting from lateral movement of the span. Corrosion probably played a role in failure of the barrier.*

*Photograph by Dr. Julio Kuroiwa (Site No. 5)*

*Figure 5-24. Shear failure of pier due to lateral loading imposed by the superstructure. Note that this pier has roller expansion bearings.*


a. Interior beam


b. Fascia beam

*(Site No. 5)*

*Figure 5-25. Crack at end of concrete beam due to horizontal loading at a pier with fixed bearings.*


a. South end of span is supported while tipped abutment is replaced


b. Ongoing reconstruction of South Abutment

*(Site No. 5)*

*Figure 5-26. Puente Huamani over Rio Pisco*

## 5.2 Departmental Route No. 100 (Carretera Chincha)

Departmental Route 100 is a secondary road on the Ica Departmental Road Network (see figures 5-1 and 5-27 through 5-38). It starts at the Pan-American Highway in Chincha and heads in an easterly direction. This is an unpaved road with no appurtenances such as signage or guiderailing. Km posts denote the distance away from Chincha. As one travels east, the terrain becomes more and more rugged. The road winds around the rocky foothills of the Andes mountains and generally follows the San Juan River, which is also known as the Chincha River. The river carries water down from the Andes mountains towards the ocean but most of the time the volume of water is very low. By the time it gets to the ocean, the water seeps underground and the river is almost dry. Flooding, however, does occasionally occur. The El Niño effect, which last occurred in 1998, has left a very wide riverbed as its legacy (see figure 3-28).

*Photograph by Monique Nykamp*

*Figure 5-27. Unpaved Departmental Route 100 in Ica.*

Photograph by Monique Nykamp

*Figure 5-28. Typical terrain along Departmental Route 100. The road tracks the mountain on the left and is subject to rockfalls as is seen in this photo.*

*Figure 5-29. Monique Nykamp and remains of several rockfalls that blocked Departmental Route 100 at km 29.*


a. Failed retaining wall

*Photograph by Lucero Mesa*

b. Road damage from failed retaining wall

*Figure 5-30 Damage on Route 100 at km 27*

*Photograph by Monique Nykamp*

*Figure 5-31. Heavily packed passenger bus illustrates the number of people counting on having Route 100 passable.*


*(Site No. 6)*

*Figure 5-32. Being relatively light, this one-span log bridge fared well in the earthquake.*


(Site No. 6)

*Figure 5-33. Slight cracking may have been from horizontal loads imposed by the superstructure.*

Photograph by Monique Nykamp (Site No. 6)

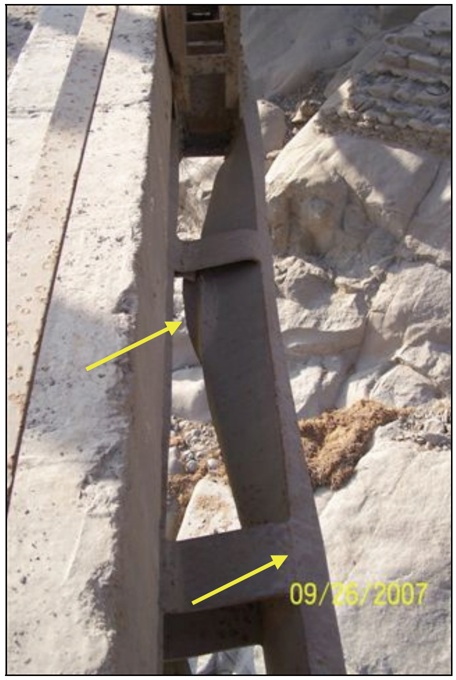
*Figure 5-34. This log bridge could be seen deflecting under heavy truckloads in this rural area. It is much more likely to fail from overload than earthquake.*


(Site No. 8)

*Figure 5-35. Puente Huachinga at km 39 built in 1966.*


(Site No. 8)

*Figure 5-36. Puente Huachinga at km 39. This steel truss bridge has suffered severe damage to the bottom chord from presumably previous debris impact (top arrow). There is a large granite boulder jammed between the two channels of the bottom chord that has fallen from the adjacent mountain from this earthquake (bottom arrow).*




*(Site No. 8)*

*Figure 5-37. Puente Huachinga at km 39. It is uncertain whether this bottom chord damage was caused by falling boulders from this event or whether it remains from a previous hazard, such as El Niño effect flooding that last occurred in 1998. This deformation can limit the capacity of this tension member and put additional stress in the undamaged channel. Figure 5-38 shows a close-up of the crack that the lower arrow is pointing to.*

*(Site No. 8)*

*Figure 5-38. Cracked weld along bottom chord resulting from distortion of the channel after impact from debris. There is potential for this type of crack to propagate into the primary member and cause sudden failure.*

## 5.3 Departmental Route No. 110

The most significant finding on route 110 was at the site of the Puente Los Molinos over the Rio Ica (see figures 5-1 and 5-39 through 5-46). This is a five span, one lane bridge that was built in 1932. The superstructure is structurally non-redundant, consisting of two cast-in-place concrete girders.

The bridge may have been more vulnerable to earthquake damage because of unrepaired damage stemming from the flooding that accompanied the 1998 El Niño. Scour at Pier No. 1 exceeds two meters and Pier No. 2 is tipped. There is a noticeable kink in the alignment of the bridge, partially because of the tipped pier but possibly because of a lateral shift from the recent earthquake. According to a local resident, "it was like that before but worse now."

At three different locations, there are shear cracks that appear to be new. Although they could be a result of truck loading, they appear to be from a lateral stress to the girders applied at the supports. Although there was not excessive displacement, this type of damage is consistent with earthquake induced lateral loading.

Evidence of liquefaction was noted at this bridge by several sand boils (see figure 5-43). Liquefaction of the alluvial soils in the riverbed may have also contributed to observed damage to the bridge. Liquefaction likely resulted in reduced lateral support to the bridge piers.

Although the bridge could be considered fragile because of the previous scour and the newer cracking of the structural members, it is a vital link in the transportation system. During the inspection, several fully loaded trucks crossed the bridge hauling out rubble from nearby towns.


(Site No. 16)

*Figure 5-39. Puente Los Molinos. Note the pre-existing scour (>2m or 6') at Pier No. 1 (as identified from left to right) (see arrow) and tipped Pier No. 2 shown with the arrow on the right.*


(Site No. 16)

*Figure 5-40. Tipped pier resulting from El Niño flooding of 1998.*


a. What appears to be a fresh shear crack in concrete beam at Pier No. 1 pedestal


b. Another serious shear crack probably caused by earthquake-induced lateral motion

*(Site No. 16)*

*Figure 5-41. Puente Los Molinos over Rio Ica*

*Photograph by Lucero Mesa (Site No. 16)*

*Figure 5-42. Two girder, non redundant, CIP concrete superstructure.*


*(Site No. 16)*

*Figure 5-43. The scour monitoring device painted red is an example of good bridge management practice.*


*(Site No. 16)*

*Figure 5-44. Monique Nykamp pointing to sand boil as evidence of liquefaction in river bed of Rio Ica at Puente Los Molinos.*


*(Site No. 16)*

*Figure 5-45. Lateral shift of the superstructure.*


(Site No. 16)

*Figure 5-46. Heavy trucks continue to rely on the Los Molinos bridge to haul debris from damaged villages nearby.*

### 5.4 National Route No. 24 (Los Libertadores)

Route 24 is a two lane paved highway that runs from the Pan-American Highway at San Clemente easterly toward the mountains. Although there are several bridges along this route, no significant damage was discovered (figures 5-47 through 5-49).


(Site No. 17)

*Figure 5-47. The rocky terrain above Puente Quinga presents a danger of impact from boulders. The bridge showed evidence of slight lateral motion that resulted in minor cracking of the approach curbing.*


a. Loss of rock wingwall and backfill at the left side of the abutment, possibly aggravated by the earthquake


b. Erosion at the right side of the same abutment. Round rocks in the gravel make the site more susceptible to loss of material

*(Site No. 17)*

*Figure 5-48. Puente Quinga over Rio Pisco*

*(Site No. 19)*

*Figure 5-49. This example of newer bridge construction performed well.*

### 5.5 Local Streets in the City of Ica

Several streets and bridges were inspected within the City of Ica. Although the team saw numerous adobe buildings that had failed, the bridges did not show any evidence of damage. The bridges inspected were cast-in-place concrete built within the past twenty years, so the type of construction probably played an important part in their good performance.


*(Site No. 9)*

*Figure 5-50. Concrete bridge near the epicenter that performed well.*


(Site No. 12)

*Figure 5-51. Concrete bridges like the Puente Socorro within the City of Ica performed well.*

### 5.6 Other Significant Sites

Due to time constraints, the highway system inspection team was not able to traverse every road in the affected area. Through reports provided by the MTC, the team was able to focus on the most significant damage, reported earlier in this report. This section provides additional information about performance of features that were not inspected personally (figures 5-52 through 5-58).


(Site No. 21)

*Figure 5-52. Geologist Dr. Carlos Costa, UNSL in Argentina pointing out soil layers within cross section of sand boil during paleoliquefaction study. He was working with Patricio Valderrama, Perú Geological Survey.*


a. Three meter (10′) escarpment remaining at Sunampe after coastal shelf slid toward the ocean


b. Surface cracks remaining at Sunampe after coastal shelf slid toward the ocean

*(Site No. 24)*

*Figure 5-53. Road to the beach at Sunampe.*

*Photograph by Drs. Jorgen Johansson & Paola Mayorca*

*Figure 5-54. Huaytara Bridge TsejTsi – no reported damage.*


*Photograph by Drs. Jorgen Johansson & Paola Mayorca*

*Figure 5-55. Huaytara Bridge Tranca II – no reported damage.*


*Photograph by Dr. Ing. Jorge E Alva Hurtado*

*Figure 5-56. This photo is indicative of the extensive disruption of an urban street in Pisco. It is Calle Independencia.*

*Photograph by Dr. Ing. Jorge E Alva Hurtado*

*Figure 5-57. Damage from a tsunami that swept up on Paracas.*

*Figure 5-58. In the mountainous Andean highlands, several pedestrian suspension bridges survived the earthquake without damage.*

# 6.0 Summary

The $M_w$ 8.0 earthquake that struck on August 15, 2007 has been labeled the Pisco Earthquake. The highway system investigation team visited 24 sites in the state of Ica, Perú to assess the performance of roads and bridges that were subjected to ground motion with a duration as long as 170 seconds and accelerations as great as 0.49g. Perú's building code specifies a PGA of 0.4 for construction in Seismic Zone 3 (reference figure 3-3).

The Pan-American Highway, which tracks the coastline, is built on liquefiable soil and suffered damage. Considering the intensity and duration of shaking, damage to bridges was minimal. The Huamani Bridge suffered the greatest damage and was still closed for repair six weeks after the event.

Observed damage included:

- Rockfalls at fifteen or more locations. Although most roads had been cleared of rock debris, there were still numerous locations where fractured, unstable blocks of rock above the roadway pose a hazard.

- Liquefaction of sandy/silty soils leading to tipping of utility poles, and tipping of a bridge abutment (Puente Huamani). It also initiated lateral spread that displaced an entire section of roadway, sheared a three-cell concrete box culvert, caused an embankment slope failure, and severe cracking and faulting of asphalt pavement.

- Two or more were bridges damaged by boulders falling from an adjacent mountain (Puente Huachinga and one other in the north reported by MTC).

- Cracking of concrete pier caps and shear blocks (Puente Huamani). The shear blocks, designed to provide lateral resistance to the bridge superstructure, successfully restrained the bridge so that damage is repairable.

- Shear cracking of concrete girders at supports (Puente Los Molinos). This appears to have been from lateral movement of the superstructure.

- Lateral displacement of bridge superstructures (about 100 mm or 4") (Puente Huamani and Puente Los Molinos).

# 7.0 Additional Resources

American Association of State and Highway Transportation Officials, (2002), *AASHTO Standard Specifications for Highway Bridges,* 17th Edition, 01-Sep-2002, 1028 pages, ISBN: 1560511710.

AASHTO Subcommittee on Bridges and Structures website
*http://bridges.transportation.org/?siteid=34*

Barrionuevo, A. and Puertas, L. *New York Times*, Peru Family's Struggle Reflects Hardships After Quake, 8/22/07, Vol. 156, Issue 54044, pages A3.

Buckle, I.G. (Coordinating Author), Friedland, I., Mander, J., Martin, G., Nutt, R. and Power, M. (2006), *Seismic Retrofitting Manual for Highway Structures: Part 1 – Bridges*, MCEER-06-SP10, MCEER, University at Buffalo, State University of New York, 656 p.

Buckle, I.G., Constantinou, M., Dicleli, M. and Ghasemi, H., (2006) *Seismic Isolation of Highway Bridges*, MCEER-06-SP07, MCEER, University at Buffalo, State University of New York, 190 p.

Constantinou, M.C., Whittaker, A.S., Kalpakidis, Y., Fenz, D.M. and Warn, G.P. (2007), *Performance of Seismic Isolation Hardware Under Service and Seismic Loading*, MCEER-07-0012, MCEER, University at Buffalo, State University of New York, 468 p.

Economist, *After Disaster Struck*, 8/25/07, Vol. 384, Issue 8543, pages 35-36.

Edwards, C. L. (Ed.) (2002). *Atico, Peru Mw 8.4 Earthquake of June 23, 2001*, American Society of Civil Engineers, 176 pages, ISBN: 0-7844-0661-8.

Edwards, C., Eidinger, J., and Schiff, A. (2003). "Lifelines," paper from *Southern Peru Earthquake of 23 June 2001 Reconnaissance Report*, *Earthquake Spectra, Supplement A* to Volume 19, January 2003, pages 73-96.

Edwards, C., Yashinsky, M., and Byers, W. (2003). "Highways and Railroads," paper from *Southern Peru Earthquake of 23 June 2001 Reconnaissance Report*, *Earthquake Spectra, Supplement A* to Volume 19, January 2003, pages 97-114.

EERI Team (2007). "Learning from Earthquakes, The Pisco Perú Earthquake of August 15, 2007," *EERI Special Earthquake Report*, October 2007, National Science Foundation.

Ho, T., Donikian, R., Ingham, T., Seim, C. and Pan, A., (2006), *Seismic Retrofitting Guidelines for Complex Steel Truss Highway Bridges*, MCEER-06-SP05, MCEER, University at Buffalo, State University of New York, 188 p.

Instituto Nacional de Defensa Civil, Emergencias & Peligros, website.
*http://sinadeci.indeci.gob.pe/UploadPortalSINPAD/COEN_Noticia/Situaci%F3n%20actual.pdf*

Maccaferri SA (PTY) Ltd (2006). "Roadworks, Problems and Solutions, Rockfall Protection," brochure, Durban, South Africa, July 2006 http://www.africangabions.co.za

Perú Transportation and Communications, Ministerio de Transportes & Comunicaciones (MTC), http://www.mtc.gob.pe/portal/flashes.html

Power, M. (Coordinating Author), Fishman, K., Makdisi, F., Musser, S. Richards, R. and Youd, T.L. (2006), *Seismic Retrofitting Manual for Highway Structures: Part 2 – Retaining Structures, Slopes, Tunnels, Culverts and Roadways*, MCEER-06-SP11, MCEER, University at Buffalo, State University of New York, 370 p.

Universidad Nacional de Ingeniería Facultad de Ingenieria Civil, Centro Peruano Japonés de Investigaciones Sísmicas y Mitigación de Desastres - CISMID, website: http://www.cismid-uni.org

Wartman, J., Rodriguez-Marek, A., Repetto, P. C., Keefer, D.K., Rondinel, E., Zegarra-Pellane, J., and Baures, D. (2003). "Ground Failure," paper from *Southern Peru Earthquake of 23 June 2001 Reconnaissance Report*, *Earthquake Spectra, Supplement A* to Volume 19, January 2003, pages 35-56.

Youd, T.L. and Idriss, I.M., (editors), (1997), *Proceedings of the NCEER Workshop on Evaluation of Liquefaction Resistance of Soils*, NCEER-97-0022, MCEER, University at Buffalo, State University of New York, 310 p.

## Appendix A:  Team Member Biographies

**Jerome S. O'Connor (Team Leader)**

Jerome is Senior Program Officer for Transportation Research with the MCEER at the University at Buffalo. He earned his Bachelors and Masters Degrees in Civil Engineering from Rensselaer Polytechnic Institute. During his 20 years with the New York State Department of Transportation, he led a 24-member team in Bridge Management, Inspection and Vulnerability Assessments and became known as a champion of fiber reinforced polymer composites for bridge applications. At MCEER, he manages a $13.8M research project for the Federal Highway Administration (FHWA) with the objective of reducing the vulnerability of our nation's highway infrastructure to damage from earthquakes and improving "multiple hazard" performance. One week after Hurricane Katrina in 2005, he led a bridge damage reconnaissance team supported by the National Science Foundation and FHWA, and a month later joined a Lifelines Team for the Department of Commerce's National Institute of Standards and Technology.

He serves on FHWA's Virtual Team for Earthquake Engineering. He has spoken and written internationally on the subject of vulnerability assessment. Past honors include an Award of *Meritorious Service* by NY's Department of Civil Service, selection as NYSATE statewide "Engineer of the Year," and project leader for the Civil Engineering Research Foundation's *2000 Charles Pankow Award for Innovative Applications*. He is a Fellow of the American Society of Civil Engineers.

**Lucero Mesa**

Lucero Mesa is a senior bridge engineer and the team leader for the Seismic Engineering Support Group at the South Carolina Department of Transportation, (SCDOT). She earned her Bachelors Degree in Civil Engineering from the University del Valle, in Cali, Colombia. Lucero worked several years in Venezuela before moving to the United States where she earned her Master of Science in Civil Engineering from the University of South Carolina. During her 18 years with SCDOT, she has worked on numerous bridge projects, including the Arthur Ravenel Jr. cable stayed bridge over the Cooper River in Charleston, South Carolina, which is the longest span cable stayed bridge in North America. As part of this bridge project, she worked very closely with the Seismic Resource Panel of experts that advised SCDOT on the seismic issues.

Lucero's major area of interest has been earthquake engineering as applied to transportation infrastructure, and the ways in which other hazards affect bridge performance. She led the development and implementation of the SCDOT Seismic Design Specifications for Highway Bridges in 2001, and the Probabilistic Seismic Hazard Maps research project for seismic analysis in 2002.

Lucero has served as chair of several committees and tasks forces. She is currently serving as chair of the Pile to Pile-Cap Connection research project for SCDOT (2007-2009), and Technical Committee co-chair of the 6th National Seismic Conference (6NSC) to be held in Charleston, South Carolina in July, 2008. She is also a member of the Transportation Research Board Seismic committee and the Geo-Seismic Subcommittee, the Federal Highway Administration Virtual Team for Earthquake Engineering, ASCE Technical Council on Lifeline Earthquake Engineering, and ASCE Infrastructure Champion for Region 4. She served on the AASHTO Task Force 193 that reviewed the new seismic guidelines, and she is currently serving on the LRFD Seismic Guide Specification Improvement Team (SGSIT).

**Monique A. Nykamp, P.E.**

Monique Nykamp, P.E. is a geotechnical engineer with Shannon & Wilson, Inc., Seattle, Washington. She earned her Bachelors degree in Civil Engineering and Masters degree in Geotechnical Engineering from University of California at Berkeley.

Monique Nykamp has about 17 years of experience at Shannon & Wilson, Inc. She has worked on numerous domestic and international geotechnical projects involving bridges, embankments, buildings, piers, retaining walls, landslides, dams, roadways, shoring systems, and excavations for a variety of clients. Her field experience includes coordinating and supervising subsurface explorations, performing and monitoring numerous types of field tests, installing and reading instrumentation, performing condition surveys, and monitoring construction activities. Monique has served as project engineer and project manager for a variety of large and small projects giving her extensive experience in shallow and deep foundation design, slope and embankment stability and settlement studies, liquefaction evaluations, and retaining wall and shoring design.

Ms. Nykamp has authored several publications on topics such as foundations, shoring, compaction grouting, liquefaction and lateral spreading. She is active in the American Society of Civil Engineers and serves on the Technical Council on Lifeline Earthquake Engineering.

# Appendix B: Recommendations

The main body of this investigative report provides factual information primarily from observations. In contrast, this appendix lists subjective recommendations based on the authors' collective experience. It comes from a request from a local transportation engineer to reciprocate this assistance with something specific that would help them. For instance, they asked for technology transfer assistance. In response, the authors have provided copies of manuals, URL addresses of informative websites, the translation of technical terms found in Appendix C and the following advice. The points offered below may help improve system performance, reduce risk of failure, and generally better manage highway infrastructure. The authors' realize that lack of resources may prevent full adoption of these suggestions, but list them for consideration regardless.

1) Establish a bridge management system
   a) Create a detailed bridge inventory in digital format that is available to managers and inspectors. This could start as a simple spreadsheet in Microsoft Excel. Contact the authors for information to track.
   b) Assign a unique bridge number to each bridge and record information such as: precise longitude and latitude, length, orientation, structure type, materials, year built, length, width, etc.
   c) Create a bridge history folder for each bridge and maintain a copy locally. Include a set of the original design, construction drawings, as-built drawings, a record of any changes that have been made (e.g., maintenance, repairs or retrofits).
   d) Create maps with precise location of bridges.
   e) Perform an engineering analysis to determine the actual load capacity of each bridge in its current condition. Update after any changed condition.
   f) Post bridges with a weight restriction that is based on calculations and enforce the posting.

2) Establish a bridge inspection program
   a) Conduct a thorough baseline inspection of all existing bridges and large culverts.
   b) Monitor the condition of each bridge by having them inspected regularly by a trained engineer (e.g., every two years). The objective is to monitor any changes so deficiencies can be corrected before it results in a catastrophic collapse or gets very costly to fix.
   c) Conduct a thorough inspection of bridges after any major event such as an earthquake or flood. Monitor bridges closely during a flood so that it can be closed before a failure becomes imminent.
   d) Institute a "flagging" system whereby bridge inspectors issue a red flag for structural conditions that need immediate attention, a yellow flag for lesser structural concerns, and a safety flag for things that are non-structural but potentially unsafe.

3) Establish a bridge repair and maintenance program
   a) Address conditions that could lead to failure of a bridge.
   b) Repair erosion and scour locations before they get worse.
   c) Retrofit bridges to correct existing deficiencies or to strengthen them to carry loads they are being subjected to.

4) To mitigate rockfall and landslides:
   a) Bring down precarious rock overhangs where practical.
   b) Flatten cut and fill slopes (rock 1.5:1, compacted fill 2:1)
   c) Always compact fill material.
   d) Consider steel catch fences, draperies, and rock protection embankments when practical and cost effective.

5) For construction of new bridges:
   a) If at all possible, avoid damage from flooding, local scour, liquefaction, tsunami, huayco, etc. by choosing an alignment and/or elevation that minimizes the risk. If an ideal location is not feasible, take appropriate measures to protect the bridge by using piles, deep foundations, etc.
   b) Conduct a subsurface investigation by taking borings at the proposed location of each substructure unit.
   c) Assess liquefaction potential of the local soils.
   d) Avoid building bridges on silty or sandy soils without piles.
   e) Design a deep foundation using drilled shafts, prestressed piles.
   f) Minimize the number of piers in the water
   g) Raise the elevation of the bridge deck to protect from flooding, huayco, or tsunami.
   h) Provide scour protection.
   i) Make the superstructure continuous over piers.
   j) Utilize wide bridge seats.
   k) Utilize shear blocks to restrict lateral movement.
   l) Include a detailed plan for routine inspection and maintenance
   m) Consider incorporating a monitoring system on the bridge. For instance, install accelerometers on the bridge.

6) Provide training to staff or consultant engineers
   a) How to assess the severity of damage to bridges.
   b) Advanced training on seismic design (including seismic performance, service and damage levels), fracture critical design, fatigue, etc.
   c) Assign at least one structural engineer to each Department office to oversee technical matters related to bridges.

7) Use web sites such as *http://mceer.buffalo.edu* to obtain recent information on seismic design and retrofit.

8) Contact FHWA's International office for possible future assistance and collaboration.

9) Assign a point of contact for future dialogue with FHWA and other U.S. engineers.

Steps that can be taken immediately by the authors to assist officials in Perú are listed below. This communication has already been initiated and several resources have been provided.

- Share CD's with manuals in electronic format (easiest way to carry to them).
- Provide websites for technical information (so they can research what's available to them).
- Send manuals by ground mail (e.g., basic bridge inspection manuals with pictures).
- Translate technical terms to facilitate their use of material that is written in English (or provide a version of the report in Spanish).
- Provide any technical material that may be available in Spanish.

# Appendix C: Translations

**English-Spanish Translation**

The following vocabulary is provided to facilitate use of this document and facilitate communication with professional counterparts in Spanish speaking countries. It includes technical terms that are pertinent to transportation engineering, bridge inspection, and geotechnical engineering. It also contains a few general terms that may be useful in an earthquake reconnaissance mission.

| **English** | **Spanish** |
|---|---|
| | |
| abutment | estribo, contrafuerte |
| aftershock | réplica |
| aggregate / crushed stone for concrete | grava |
| American Association of State Highway and Transportation Officials (AASHTO) | AASHTO |
| angular rock | grava, roca con ángulos |
| asphalt | asfalto |
| ATM (Automated Teller Machine) | cajero automático |
| be careful | tenga cuidado |
| beach | playa |
| boundary | límite |
| bridge | puente (in Perú, >10m) |
| bump | jiba, chichón |
| channel | canal |
| CIP (cast in place concrete) | concreto fundido en sitio |
| closed | cerrado |
| collapsed bridge | puente colapsado |
| compaction | compactación |
| concrete | concreto |
| conglomerate | conglomerado |
| construction project | proyecto de construcción |
| county | provincia |
| crack | grieta |
| cross section | sección transversal |
| culvert | pontón (in Perú,>3m but <10m) |
| cut | corte |
| damage | daño |
| debris flow | huayco |
| debris flow (mud flow with large rocks) | huaico |
| deck | losa |
| design | diseño |
| detour | desvío |
| displaced | desplazado |
| earthquake | terremoto / sismo |

| English | Spanish |
|---|---|
| edge line / fog line | linea del borde, linea en el pavimento, linea de la niebla |
| elevation | elevación |
| epicenter | epicentro |
| excavator | excavadora |
| fill | relleno |
| flat | plano |
| flood | inundación |
| fog | neblina, niebla |
| foot (feet) | pie (pies) (1 metro ~ 3.1 feet (3.1′) |
| freeway / expressway | autopista |
| girder | viga |
| GIS (Geographic Information System) | SIG (Sistema de Información Geográfica) |
| GPS (global positioning system) | Sistema de Posicionamiento Global |
| ground level | superficie del terreno |
| guiderail / guardrail | barandilla de metálico, riel metálico |
| gutter | cuneta |
| heavy equipment | equipo pesado |
| height | cota |
| highway | carretera |
| kilometers | kilómetros |
| landslide | deslizamiento de terreno, derrumbamiento |
| lateral spread | movimiento lateral |
| latitude | latitud |
| length | longitud |
| liquefaction | licuacíon / licuefacción |
| longitude | longitud |
| maintenance | mantenimiento |
| MTC (Ministry of Transportation & Communication | MTC (Ministerio de Transporte y Comunicaciones) |
| overweight | sobrecarga |
| P/S (pre-stressed concrete) | concreto pretensado |
| painted line | línea pintada |
| paved road | carretera asfaltada o pavimentada |
| pavement | pavimento |
| pier / bent | pilar |
| pile | pilote |
| pongo, barranco, hendidura profunda | ravine |
| railroad | ferrocarril |
| rain | lluvia |
| retaining wall | muro de contención |
| retrofit | actualizar, modernizarse |
| river | rio |
| road | via, carretera |
| rock | roca |

| English | Spanish |
|---|---|
| rock fall or rock slide | derrumbe |
| rock slide | desprendimiento de roca |
| rounded river rock, boulder | canto rodado |
| route | ruta |
| rubble, debris | escombros |
| sand | arena |
| sand boil / sand cone | volcancito |
| scour | erosión |
| secondary road | carretera secundaria |
| shoulder | hombrillo |
| sidewalk | calzada/ande'n/acera |
| silt | limo (lodo) |
| slope | talud |
| small gravel / pea gravel | gravita / gravilla |
| soft soil (ground) | suelos blandos |
| soil (ground) | suelo (terreno) |
| span | luz, ojos |
| speed limit | velocidad límite |
| stability | estabilidad |
| state | departamento |
| store / shop | tienda /almace'n |
| strong | fuerte, resistente |
| swale ( in road in lieu of a bridge) | balén |
| toll road | carretera con caseta de peaje |
| tremor | temblor |
| truck | camión |
| undermining | socavación |
| unpaved road | carretera afirmada |
| water level | nivel de agua |
| weight limit | carga máxima / peso máximo / tonaje límite |
| width | ancho |
| wingwall | pantalla |

**Spanish-English Translation**
**(Traducción Español-Inglés de términos técnicos)**

El propósito del siguiente vocabulario es facilitar el uso de este documento y hacer más fácil la comunicación con nuestros colegas ingenieros en los países de habla Hispana. El documento incluye términos técnicos relacionados con ingeniería de transporte, inspección de puentes y geotecnia.

También contiene términos generales que pueden ser útiles en una misión de reconocimiento después de un terremoto.

| Español | Inglés |
|---|---|
| | |
| AASHTO | American Association of State Highway and Transportation Officials (AASHTO) |
| actualizar, modernizarse | retrofit |
| ancho | width |
| arena | sand |
| asfalto | asphalt |
| autopista | freeway / expressway |
| balén | swale ( in road in lieu of a bridge) |
| barandilla de metálico, riel metálico | guiderail / guardrail |
| cajero automático | ATM (Automated Teller Machine) |
| calzada/ande'n/acera | sidewalk |
| camión | truck |
| canal | channel |
| canto rodado | rounded river rock, boulder |
| carga máxima / peso máximo / tonaje límite | weight limit |
| carretera | highway |
| carretera afirmada | unpaved road |
| carretera asfaltada o pavimentada | paved road |
| carretera con caseta de peaje | toll road |
| carretera secundaria | secondary road |
| cerrado | closed |
| compactación | compaction |
| concreto | concrete |
| concreto fundido en sitio | CIP (cast in place concrete) |
| concreto pretensado | P/S (pre-stressed concrete) |
| conglomerado | conglomerate |
| corte | cut |
| cota | height |
| cuneta | gutter |
| daño | damage |
| departamento | state |
| derrumbe | rock fall or rock slide |
| deslizamiento de terreno, derrumbamiento | landslide |

| **Español** | **Inglesa** |
|---|---|
| desplazado | displaced |
| desprendimiento de roca | rock slide |
| desvío | detour |
| diseño | design |
| elevación | elevation |
| epicentro | epicenter |
| equipo pesado | heavy equipment |
| erosión | scour |
| escombros | rubble, debris |
| estabilidad | stability |
| estribo, contrafuerte | abutment |
| excavadora | excavator |
| ferrocarril | railroad |
| fuerte, resistente | strong |
| grava | aggregate / crushed stone for concrete |
| grava, roca con ángulos | angular rock |
| gravita / gravilla | small gravel / pea gravel |
| grieta | crack |
| hombrillo | shoulder |
| huaico | debris flow (mud flow with large rocks) |
| huayco | debris flow |
| inundación | flood |
| jiba, chichón | bump |
| kilómetros | kilometers |
| latitud | latitude |
| licuacíon / licuefacción | liquefaction |
| límite | boundary |
| limo (lodo) | silt |
| linea del borde, linea en el pavimento, linea de la niebla | edge line / fog line |
| línea pintada | painted line |
| lluvia | rain |
| longitud | length |
| longitud | longitude |
| losa | deck |
| luz, ojos | span |
| mantenimiento | maintenance |
| movimiento lateral | lateral spread |
| MTC (Ministerio de Transporte y Comunicaciones) | MTC (Ministry of Transportation & Communication |
| muro de contención | retaining wall |
| neblina, niebla | fog |
| nivel de agua | water level |
| pantalla | wingwall |
| pavimento | pavement |

| **Español** | **Inglesa** |
|---|---|
| pie (pies) (1 metro ~ 3.1 feet) | foot (feet) |
| pilar | pier / bent |
| pilote | pile |
| plano | flat |
| playa | beach |
| pontón (in Perú,>3m but <10m) | culvert |
| provincia | county |
| proyecto de construcción | construction project |
| puente (in Perú, >10m) | bridge |
| puente colapsado | collapsed bridge |
| ravine | pongo, barranco, hendidura profunda |
| relleno | fill |
| réplica | aftershock |
| rio | river |
| roca | rock |
| ruta | route |
| sección transversal | cross section |
| SIG (Sistema de Información Geográfica) | GIS (Geographic Information System) |
| Sistema de Posicionamiento Global | GPS (global positioning system) |
| sobrecarga | overweight |
| socavación | undermining |
| suelo (terreno) | soil (ground) |
| suelos blandos | soft soil (ground) |
| superficie del terreno | ground level |
| talud | slope |
| temblor | tremor |
| tenga cuidado | be careful |
| terremoto / sismo | earthquake |
| tienda /almace'n | store / shop |
| velocidad límite | speed limit |
| via, carretera | road |
| viga | girder |
| volcancito | sand boil / sand cone |

## MCEER Technical Reports

MCEER publishes technical reports on a variety of subjects written by authors funded through MCEER. These reports are available from both MCEER Publications and the National Technical Information Service (NTIS). Requests for reports should be directed to MCEER Publications, MCEER, University at Buffalo, State University of New York, Red Jacket Quadrangle, Buffalo, New York 14261. Reports can also be requested through NTIS, 5285 Port Royal Road, Springfield, Virginia 22161. NTIS accession numbers are shown in parenthesis, if available.


NCEER-87-0001 "First-Year Program in Research, Education and Technology Transfer," 3/5/87, (PB88-134275, A04, MF-A01).

NCEER-87-0002 "Experimental Evaluation of Instantaneous Optimal Algorithms for Structural Control," by R.C. Lin, T.T. Soong and A.M. Reinhorn, 4/20/87, (PB88-134341, A04, MF-A01).

NCEER-87-0003 "Experimentation Using the Earthquake Simulation Facilities at University at Buffalo," by A.M. Reinhorn and R.L. Ketter, to be published.

NCEER-87-0004 "The System Characteristics and Performance of a Shaking Table," by J.S. Hwang, K.C. Chang and G.C. Lee, 6/1/87, (PB88-134259, A03, MF-A01). This report is available only through NTIS (see address given above).

NCEER-87-0005 "A Finite Element Formulation for Nonlinear Viscoplastic Material Using a Q Model," by O. Gyebi and G. Dasgupta, 11/2/87, (PB88-213764, A08, MF-A01).

NCEER-87-0006 "Symbolic Manipulation Program (SMP) - Algebraic Codes for Two and Three Dimensional Finite Element Formulations," by X. Lee and G. Dasgupta, 11/9/87, (PB88-218522, A05, MF-A01).

NCEER-87-0007 "Instantaneous Optimal Control Laws for Tall Buildings Under Seismic Excitations," by J.N. Yang, A. Akbarpour and P. Ghaemmaghami, 6/10/87, (PB88-134333, A06, MF-A01). This report is only available through NTIS (see address given above).

NCEER-87-0008 "IDARC: Inelastic Damage Analysis of Reinforced Concrete Frame - Shear-Wall Structures," by Y.J. Park, A.M. Reinhorn and S.K. Kunnath, 7/20/87, (PB88-134325, A09, MF-A01). This report is only available through NTIS (see address given above).

NCEER-87-0009 "Liquefaction Potential for New York State: A Preliminary Report on Sites in Manhattan and Buffalo," by M. Budhu, V. Vijayakumar, R.F. Giese and L. Baumgras, 8/31/87, (PB88-163704, A03, MF-A01). This report is available only through NTIS (see address given above).

NCEER-87-0010 "Vertical and Torsional Vibration of Foundations in Inhomogeneous Media," by A.S. Veletsos and K.W. Dotson, 6/1/87, (PB88-134291, A03, MF-A01). This report is only available through NTIS (see address given above).

NCEER-87-0011 "Seismic Probabilistic Risk Assessment and Seismic Margins Studies for Nuclear Power Plants," by Howard H.M. Hwang, 6/15/87, (PB88-134267, A03, MF-A01). This report is only available through NTIS (see address given above).

NCEER-87-0012 "Parametric Studies of Frequency Response of Secondary Systems Under Ground-Acceleration Excitations," by Y. Yong and Y.K. Lin, 6/10/87, (PB88-134309, A03, MF-A01). This report is only available through NTIS (see address given above).

NCEER-87-0013 "Frequency Response of Secondary Systems Under Seismic Excitation," by J.A. HoLung, J. Cai and Y.K. Lin, 7/31/87, (PB88-134317, A05, MF-A01). This report is only available through NTIS (see address given above).

NCEER-87-0014 "Modelling Earthquake Ground Motions in Seismically Active Regions Using Parametric Time Series Methods," by G.W. Ellis and A.S. Cakmak, 8/25/87, (PB88-134283, A08, MF-A01). This report is only available through NTIS (see address given above).

NCEER-87-0015 "Detection and Assessment of Seismic Structural Damage," by E. DiPasquale and A.S. Cakmak, 8/25/87, (PB88-163712, A05, MF-A01). This report is only available through NTIS (see address given above).

NCEER-87-0016 "Pipeline Experiment at Parkfield, California," by J. Isenberg and E. Richardson, 9/15/87, (PB88-163720, A03, MF-A01). This report is available only through NTIS (see address given above).

NCEER-87-0017 "Digital Simulation of Seismic Ground Motion," by M. Shinozuka, G. Deodatis and T. Harada, 8/31/87, (PB88-155197, A04, MF-A01). This report is available only through NTIS (see address given above).

NCEER-87-0018 "Practical Considerations for Structural Control: System Uncertainty, System Time Delay and Truncation of Small Control Forces," J.N. Yang and A. Akbarpour, 8/10/87, (PB88-163738, A08, MF-A01). This report is only available through NTIS (see address given above).

NCEER-87-0019 "Modal Analysis of Nonclassically Damped Structural Systems Using Canonical Transformation," by J.N. Yang, S. Sarkani and F.X. Long, 9/27/87, (PB88-187851, A04, MF-A01).

NCEER-87-0020 "A Nonstationary Solution in Random Vibration Theory," by J.R. Red-Horse and P.D. Spanos, 11/3/87, (PB88-163746, A03, MF-A01).

NCEER-87-0021 "Horizontal Impedances for Radially Inhomogeneous Viscoelastic Soil Layers," by A.S. Veletsos and K.W. Dotson, 10/15/87, (PB88-150859, A04, MF-A01).

NCEER-87-0022 "Seismic Damage Assessment of Reinforced Concrete Members," by Y.S. Chung, C. Meyer and M. Shinozuka, 10/9/87, (PB88-150867, A05, MF-A01). This report is available only through NTIS (see address given above).

NCEER-87-0023 "Active Structural Control in Civil Engineering," by T.T. Soong, 11/11/87, (PB88-187778, A03, MF-A01).

NCEER-87-0024 "Vertical and Torsional Impedances for Radially Inhomogeneous Viscoelastic Soil Layers," by K.W. Dotson and A.S. Veletsos, 12/87, (PB88-187786, A03, MF-A01).

NCEER-87-0025 "Proceedings from the Symposium on Seismic Hazards, Ground Motions, Soil-Liquefaction and Engineering Practice in Eastern North America," October 20-22, 1987, edited by K.H. Jacob, 12/87, (PB88-188115, A23, MF-A01). This report is available only through NTIS (see address given above).

NCEER-87-0026 "Report on the Whittier-Narrows, California, Earthquake of October 1, 1987," by J. Pantelic and A. Reinhorn, 11/87, (PB88-187752, A03, MF-A01). This report is available only through NTIS (see address given above).

NCEER-87-0027 "Design of a Modular Program for Transient Nonlinear Analysis of Large 3-D Building Structures," by S. Srivastav and J.F. Abel, 12/30/87, (PB88-187950, A05, MF-A01). This report is only available through NTIS (see address given above).

NCEER-87-0028 "Second-Year Program in Research, Education and Technology Transfer," 3/8/88, (PB88-219480, A04, MF-A01).

NCEER-88-0001 "Workshop on Seismic Computer Analysis and Design of Buildings With Interactive Graphics," by W. McGuire, J.F. Abel and C.H. Conley, 1/18/88, (PB88-187760, A03, MF-A01). This report is only available through NTIS (see address given above).

NCEER-88-0002 "Optimal Control of Nonlinear Flexible Structures," by J.N. Yang, F.X. Long and D. Wong, 1/22/88, (PB88-213772, A06, MF-A01).

NCEER-88-0003 "Substructuring Techniques in the Time Domain for Primary-Secondary Structural Systems," by G.D. Manolis and G. Juhn, 2/10/88, (PB88-213780, A04, MF-A01).

NCEER-88-0004 "Iterative Seismic Analysis of Primary-Secondary Systems," by A. Singhal, L.D. Lutes and P.D. Spanos, 2/23/88, (PB88-213798, A04, MF-A01).

NCEER-88-0005 "Stochastic Finite Element Expansion for Random Media," by P.D. Spanos and R. Ghanem, 3/14/88, (PB88-213806, A03, MF-A01).

NCEER-88-0006 "Combining Structural Optimization and Structural Control," by F.Y. Cheng and C.P. Pantelides, 1/10/88, (PB88-213814, A05, MF-A01).

NCEER-88-0007 "Seismic Performance Assessment of Code-Designed Structures," by H.H-M. Hwang, J-W. Jaw and H-J. Shau, 3/20/88, (PB88-219423, A04, MF-A01). This report is only available through NTIS (see address given above).

NCEER-88-0008 "Reliability Analysis of Code-Designed Structures Under Natural Hazards," by H.H-M. Hwang, H. Ushiba and M. Shinozuka, 2/29/88, (PB88-229471, A07, MF-A01). This report is only available through NTIS (see address given above).

NCEER-88-0009 "Seismic Fragility Analysis of Shear Wall Structures," by J-W Jaw and H.H-M. Hwang, 4/30/88, (PB89-102867, A04, MF-A01).

NCEER-88-0010 "Base Isolation of a Multi-Story Building Under a Harmonic Ground Motion - A Comparison of Performances of Various Systems," by F-G Fan, G. Ahmadi and I.G. Tadjbakhsh, 5/18/88, (PB89-122238, A06, MF-A01). This report is only available through NTIS (see address given above).

NCEER-88-0011 "Seismic Floor Response Spectra for a Combined System by Green's Functions," by F.M. Lavelle, L.A. Bergman and P.D. Spanos, 5/1/88, (PB89-102875, A03, MF-A01).

NCEER-88-0012 "A New Solution Technique for Randomly Excited Hysteretic Structures," by G.Q. Cai and Y.K. Lin, 5/16/88, (PB89-102883, A03, MF-A01).

NCEER-88-0013 "A Study of Radiation Damping and Soil-Structure Interaction Effects in the Centrifuge," by K. Weissman, supervised by J.H. Prevost, 5/24/88, (PB89-144703, A06, MF-A01).

NCEER-88-0014 "Parameter Identification and Implementation of a Kinematic Plasticity Model for Frictional Soils," by J.H. Prevost and D.V. Griffiths, to be published.

NCEER-88-0015 "Two- and Three- Dimensional Dynamic Finite Element Analyses of the Long Valley Dam," by D.V. Griffiths and J.H. Prevost, 6/17/88, (PB89-144711, A04, MF-A01).

NCEER-88-0016 "Damage Assessment of Reinforced Concrete Structures in Eastern United States," by A.M. Reinhorn, M.J. Seidel, S.K. Kunnath and Y.J. Park, 6/15/88, (PB89-122220, A04, MF-A01). This report is only available through NTIS (see address given above).

NCEER-88-0017 "Dynamic Compliance of Vertically Loaded Strip Foundations in Multilayered Viscoelastic Soils," by S. Ahmad and A.S.M. Israil, 6/17/88, (PB89-102891, A04, MF-A01).

NCEER-88-0018 "An Experimental Study of Seismic Structural Response With Added Viscoelastic Dampers," by R.C. Lin, Z. Liang, T.T. Soong and R.H. Zhang, 6/30/88, (PB89-122212, A05, MF-A01). This report is available only through NTIS (see address given above).

NCEER-88-0019 "Experimental Investigation of Primary - Secondary System Interaction," by G.D. Manolis, G. Juhn and A.M. Reinhorn, 5/27/88, (PB89-122204, A04, MF-A01).

NCEER-88-0020 "A Response Spectrum Approach For Analysis of Nonclassically Damped Structures," by J.N. Yang, S. Sarkani and F.X. Long, 4/22/88, (PB89-102909, A04, MF-A01).

NCEER-88-0021 "Seismic Interaction of Structures and Soils: Stochastic Approach," by A.S. Veletsos and A.M. Prasad, 7/21/88, (PB89-122196, A04, MF-A01). This report is only available through NTIS (see address given above).

NCEER-88-0022 "Identification of the Serviceability Limit State and Detection of Seismic Structural Damage," by E. DiPasquale and A.S. Cakmak, 6/15/88, (PB89-122188, A05, MF-A01). This report is available only through NTIS (see address given above).

NCEER-88-0023 "Multi-Hazard Risk Analysis: Case of a Simple Offshore Structure," by B.K. Bhartia and E.H. Vanmarcke, 7/21/88, (PB89-145213, A05, MF-A01).

NCEER-88-0024 "Automated Seismic Design of Reinforced Concrete Buildings," by Y.S. Chung, C. Meyer and M. Shinozuka, 7/5/88, (PB89-122170, A06, MF-A01). This report is available only through NTIS (see address given above).

NCEER-88-0025 "Experimental Study of Active Control of MDOF Structures Under Seismic Excitations," by L.L. Chung, R.C. Lin, T.T. Soong and A.M. Reinhorn, 7/10/88, (PB89-122600, A04, MF-A01).

NCEER-88-0026 "Earthquake Simulation Tests of a Low-Rise Metal Structure," by J.S. Hwang, K.C. Chang, G.C. Lee and R.L. Ketter, 8/1/88, (PB89-102917, A04, MF-A01).

NCEER-88-0027 "Systems Study of Urban Response and Reconstruction Due to Catastrophic Earthquakes," by F. Kozin and H.K. Zhou, 9/22/88, (PB90-162348, A04, MF-A01).

NCEER-88-0028 "Seismic Fragility Analysis of Plane Frame Structures," by H.H-M. Hwang and Y.K. Low, 7/31/88, (PB89-131445, A06, MF-A01).

NCEER-88-0029 "Response Analysis of Stochastic Structures," by A. Kardara, C. Bucher and M. Shinozuka, 9/22/88, (PB89-174429, A04, MF-A01).

NCEER-88-0030 "Nonnormal Accelerations Due to Yielding in a Primary Structure," by D.C.K. Chen and L.D. Lutes, 9/19/88, (PB89-131437, A04, MF-A01).

NCEER-88-0031 "Design Approaches for Soil-Structure Interaction," by A.S. Veletsos, A.M. Prasad and Y. Tang, 12/30/88, (PB89-174437, A03, MF-A01). This report is available only through NTIS (see address given above).

NCEER-88-0032 "A Re-evaluation of Design Spectra for Seismic Damage Control," by C.J. Turkstra and A.G. Tallin, 11/7/88, (PB89-145221, A05, MF-A01).

NCEER-88-0033 "The Behavior and Design of Noncontact Lap Splices Subjected to Repeated Inelastic Tensile Loading," by V.E. Sagan, P. Gergely and R.N. White, 12/8/88, (PB89-163737, A08, MF-A01).

NCEER-88-0034 "Seismic Response of Pile Foundations," by S.M. Mamoon, P.K. Banerjee and S. Ahmad, 11/1/88, (PB89-145239, A04, MF-A01).

NCEER-88-0035 "Modeling of R/C Building Structures With Flexible Floor Diaphragms (IDARC2)," by A.M. Reinhorn, S.K. Kunnath and N. Panahshahi, 9/7/88, (PB89-207153, A07, MF-A01).

NCEER-88-0036 "Solution of the Dam-Reservoir Interaction Problem Using a Combination of FEM, BEM with Particular Integrals, Modal Analysis, and Substructuring," by C-S. Tsai, G.C. Lee and R.L. Ketter, 12/31/88, (PB89-207146, A04, MF-A01).

NCEER-88-0037 "Optimal Placement of Actuators for Structural Control," by F.Y. Cheng and C.P. Pantelides, 8/15/88, (PB89-162846, A05, MF-A01).

NCEER-88-0038 "Teflon Bearings in Aseismic Base Isolation: Experimental Studies and Mathematical Modeling," by A. Mokha, M.C. Constantinou and A.M. Reinhorn, 12/5/88, (PB89-218457, A10, MF-A01). This report is available only through NTIS (see address given above).

NCEER-88-0039 "Seismic Behavior of Flat Slab High-Rise Buildings in the New York City Area," by P. Weidlinger and M. Ettouney, 10/15/88, (PB90-145681, A04, MF-A01).

NCEER-88-0040 "Evaluation of the Earthquake Resistance of Existing Buildings in New York City," by P. Weidlinger and M. Ettouney, 10/15/88, to be published.

NCEER-88-0041 "Small-Scale Modeling Techniques for Reinforced Concrete Structures Subjected to Seismic Loads," by W. Kim, A. El-Attar and R.N. White, 11/22/88, (PB89-189625, A05, MF-A01).

NCEER-88-0042 "Modeling Strong Ground Motion from Multiple Event Earthquakes," by G.W. Ellis and A.S. Cakmak, 10/15/88, (PB89-174445, A03, MF-A01).

NCEER-88-0043 "Nonstationary Models of Seismic Ground Acceleration," by M. Grigoriu, S.E. Ruiz and E. Rosenblueth, 7/15/88, (PB89-189617, A04, MF-A01).

NCEER-88-0044 "SARCF User's Guide: Seismic Analysis of Reinforced Concrete Frames," by Y.S. Chung, C. Meyer and M. Shinozuka, 11/9/88, (PB89-174452, A08, MF-A01).

NCEER-88-0045 "First Expert Panel Meeting on Disaster Research and Planning," edited by J. Pantelic and J. Stoyle, 9/15/88, (PB89-174460, A05, MF-A01).

NCEER-88-0046 "Preliminary Studies of the Effect of Degrading Infill Walls on the Nonlinear Seismic Response of Steel Frames," by C.Z. Chrysostomou, P. Gergely and J.F. Abel, 12/19/88, (PB89-208383, A05, MF-A01).

NCEER-88-0047 "Reinforced Concrete Frame Component Testing Facility - Design, Construction, Instrumentation and Operation," by S.P. Pessiki, C. Conley, T. Bond, P. Gergely and R.N. White, 12/16/88, (PB89-174478, A04, MF-A01).

NCEER-89-0001 "Effects of Protective Cushion and Soil Compliancy on the Response of Equipment Within a Seismically Excited Building," by J.A. HoLung, 2/16/89, (PB89-207179, A04, MF-A01).

NCEER-89-0002 "Statistical Evaluation of Response Modification Factors for Reinforced Concrete Structures," by H.H-M. Hwang and J-W. Jaw, 2/17/89, (PB89-207187, A05, MF-A01).

NCEER-89-0003 "Hysteretic Columns Under Random Excitation," by G-Q. Cai and Y.K. Lin, 1/9/89, (PB89-196513, A03, MF-A01).

NCEER-89-0004 "Experimental Study of `Elephant Foot Bulge' Instability of Thin-Walled Metal Tanks," by Z-H. Jia and R.L. Ketter, 2/22/89, (PB89-207195, A03, MF-A01).

NCEER-89-0005 "Experiment on Performance of Buried Pipelines Across San Andreas Fault," by J. Isenberg, E. Richardson and T.D. O'Rourke, 3/10/89, (PB89-218440, A04, MF-A01). This report is available only through NTIS (see address given above).

NCEER-89-0006 "A Knowledge-Based Approach to Structural Design of Earthquake-Resistant Buildings," by M. Subramani, P. Gergely, C.H. Conley, J.F. Abel and A.H. Zaghw, 1/15/89, (PB89-218465, A06, MF-A01).

NCEER-89-0007 "Liquefaction Hazards and Their Effects on Buried Pipelines," by T.D. O'Rourke and P.A. Lane, 2/1/89, (PB89-218481, A09, MF-A01).

NCEER-89-0008 "Fundamentals of System Identification in Structural Dynamics," by H. Imai, C-B. Yun, O. Maruyama and M. Shinozuka, 1/26/89, (PB89-207211, A04, MF-A01).

NCEER-89-0009 "Effects of the 1985 Michoacan Earthquake on Water Systems and Other Buried Lifelines in Mexico," by A.G. Ayala and M.J. O'Rourke, 3/8/89, (PB89-207229, A06, MF-A01).

NCEER-89-R010 "NCEER Bibliography of Earthquake Education Materials," by K.E.K. Ross, Second Revision, 9/1/89, (PB90-125352, A05, MF-A01). This report is replaced by NCEER-92-0018.

NCEER-89-0011 "Inelastic Three-Dimensional Response Analysis of Reinforced Concrete Building Structures (IDARC-3D), Part I - Modeling," by S.K. Kunnath and A.M. Reinhorn, 4/17/89, (PB90-114612, A07, MF-A01). This report is available only through NTIS (see address given above).

NCEER-89-0012 "Recommended Modifications to ATC-14," by C.D. Poland and J.O. Malley, 4/12/89, (PB90-108648, A15, MF-A01).

NCEER-89-0013 "Repair and Strengthening of Beam-to-Column Connections Subjected to Earthquake Loading," by M. Corazao and A.J. Durrani, 2/28/89, (PB90-109885, A06, MF-A01).

NCEER-89-0014 "Program EXKAL2 for Identification of Structural Dynamic Systems," by O. Maruyama, C-B. Yun, M. Hoshiya and M. Shinozuka, 5/19/89, (PB90-109877, A09, MF-A01).

NCEER-89-0015 "Response of Frames With Bolted Semi-Rigid Connections, Part I - Experimental Study and Analytical Predictions," by P.J. DiCorso, A.M. Reinhorn, J.R. Dickerson, J.B. Radziminski and W.L. Harper, 6/1/89, to be published.

NCEER-89-0016 "ARMA Monte Carlo Simulation in Probabilistic Structural Analysis," by P.D. Spanos and M.P. Mignolet, 7/10/89, (PB90-109893, A03, MF-A01).

NCEER-89-P017 "Preliminary Proceedings from the Conference on Disaster Preparedness - The Place of Earthquake Education in Our Schools," Edited by K.E.K. Ross, 6/23/89, (PB90-108606, A03, MF-A01).

NCEER-89-0017 "Proceedings from the Conference on Disaster Preparedness - The Place of Earthquake Education in Our Schools," Edited by K.E.K. Ross, 12/31/89, (PB90-207895, A012, MF-A02). This report is available only through NTIS (see address given above).

NCEER-89-0018 "Multidimensional Models of Hysteretic Material Behavior for Vibration Analysis of Shape Memory Energy Absorbing Devices, by E.J. Graesser and F.A. Cozzarelli, 6/7/89, (PB90-164146, A04, MF-A01).

NCEER-89-0019 "Nonlinear Dynamic Analysis of Three-Dimensional Base Isolated Structures (3D-BASIS)," by S. Nagarajaiah, A.M. Reinhorn and M.C. Constantinou, 8/3/89, (PB90-161936, A06, MF-A01). This report has been replaced by NCEER-93-0011.

NCEER-89-0020 "Structural Control Considering Time-Rate of Control Forces and Control Rate Constraints," by F.Y. Cheng and C.P. Pantelides, 8/3/89, (PB90-120445, A04, MF-A01).

NCEER-89-0021 "Subsurface Conditions of Memphis and Shelby County," by K.W. Ng, T-S. Chang and H-H.M. Hwang, 7/26/89, (PB90-120437, A03, MF-A01).

NCEER-89-0022 "Seismic Wave Propagation Effects on Straight Jointed Buried Pipelines," by K. Elhmadi and M.J. O'Rourke, 8/24/89, (PB90-162322, A10, MF-A02).

NCEER-89-0023 "Workshop on Serviceability Analysis of Water Delivery Systems," edited by M. Grigoriu, 3/6/89, (PB90-127424, A03, MF-A01).

NCEER-89-0024 "Shaking Table Study of a 1/5 Scale Steel Frame Composed of Tapered Members," by K.C. Chang, J.S. Hwang and G.C. Lee, 9/18/89, (PB90-160169, A04, MF-A01).

NCEER-89-0025 "DYNA1D: A Computer Program for Nonlinear Seismic Site Response Analysis - Technical Documentation," by Jean H. Prevost, 9/14/89, (PB90-161944, A07, MF-A01). This report is available only through NTIS (see address given above).

NCEER-89-0026 "1:4 Scale Model Studies of Active Tendon Systems and Active Mass Dampers for Aseismic Protection," by A.M. Reinhorn, T.T. Soong, R.C. Lin, Y.P. Yang, Y. Fukao, H. Abe and M. Nakai, 9/15/89, (PB90-173246, A10, MF-A02). This report is available only through NTIS (see address given above).

NCEER-89-0027 "Scattering of Waves by Inclusions in a Nonhomogeneous Elastic Half Space Solved by Boundary Element Methods," by P.K. Hadley, A. Askar and A.S. Cakmak, 6/15/89, (PB90-145699, A07, MF-A01).

NCEER-89-0028 "Statistical Evaluation of Deflection Amplification Factors for Reinforced Concrete Structures," by H.H.M. Hwang, J-W. Jaw and A.L. Ch'ng, 8/31/89, (PB90-164633, A05, MF-A01).

NCEER-89-0029 "Bedrock Accelerations in Memphis Area Due to Large New Madrid Earthquakes," by H.H.M. Hwang, C.H.S. Chen and G. Yu, 11/7/89, (PB90-162330, A04, MF-A01).

NCEER-89-0030 "Seismic Behavior and Response Sensitivity of Secondary Structural Systems," by Y.Q. Chen and T.T. Soong, 10/23/89, (PB90-164658, A08, MF-A01).

NCEER-89-0031 "Random Vibration and Reliability Analysis of Primary-Secondary Structural Systems," by Y. Ibrahim, M. Grigoriu and T.T. Soong, 11/10/89, (PB90-161951, A04, MF-A01).

NCEER-89-0032 "Proceedings from the Second U.S. - Japan Workshop on Liquefaction, Large Ground Deformation and Their Effects on Lifelines, September 26-29, 1989," Edited by T.D. O'Rourke and M. Hamada, 12/1/89, (PB90-209388, A22, MF-A03).

NCEER-89-0033 "Deterministic Model for Seismic Damage Evaluation of Reinforced Concrete Structures," by J.M. Bracci, A.M. Reinhorn, J.B. Mander and S.K. Kunnath, 9/27/89, (PB91-108803, A06, MF-A01).

NCEER-89-0034 "On the Relation Between Local and Global Damage Indices," by E. DiPasquale and A.S. Cakmak, 8/15/89, (PB90-173865, A05, MF-A01).

NCEER-89-0035 "Cyclic Undrained Behavior of Nonplastic and Low Plasticity Silts," by A.J. Walker and H.E. Stewart, 7/26/89, (PB90-183518, A10, MF-A01).

NCEER-89-0036 "Liquefaction Potential of Surficial Deposits in the City of Buffalo, New York," by M. Budhu, R. Giese and L. Baumgrass, 1/17/89, (PB90-208455, A04, MF-A01).

NCEER-89-0037 "A Deterministic Assessment of Effects of Ground Motion Incoherence," by A.S. Veletsos and Y. Tang, 7/15/89, (PB90-164294, A03, MF-A01).

NCEER-89-0038 "Workshop on Ground Motion Parameters for Seismic Hazard Mapping," July 17-18, 1989, edited by R.V. Whitman, 12/1/89, (PB90-173923, A04, MF-A01).

NCEER-89-0039 "Seismic Effects on Elevated Transit Lines of the New York City Transit Authority," by C.J. Costantino, C.A. Miller and E. Heymsfield, 12/26/89, (PB90-207887, A06, MF-A01).

NCEER-89-0040 "Centrifugal Modeling of Dynamic Soil-Structure Interaction," by K. Weissman, Supervised by J.H. Prevost, 5/10/89, (PB90-207879, A07, MF-A01).

NCEER-89-0041 "Linearized Identification of Buildings With Cores for Seismic Vulnerability Assessment," by I-K. Ho and A.E. Aktan, 11/1/89, (PB90-251943, A07, MF-A01).

NCEER-90-0001 "Geotechnical and Lifeline Aspects of the October 17, 1989 Loma Prieta Earthquake in San Francisco," by T.D. O'Rourke, H.E. Stewart, F.T. Blackburn and T.S. Dickerman, 1/90, (PB90-208596, A05, MF-A01).

NCEER-90-0002 "Nonnormal Secondary Response Due to Yielding in a Primary Structure," by D.C.K. Chen and L.D. Lutes, 2/28/90, (PB90-251976, A07, MF-A01).

NCEER-90-0003 "Earthquake Education Materials for Grades K-12," by K.E.K. Ross, 4/16/90, (PB91-251984, A05, MF-A05). This report has been replaced by NCEER-92-0018.

NCEER-90-0004 "Catalog of Strong Motion Stations in Eastern North America," by R.W. Busby, 4/3/90, (PB90-251984, A05, MF-A01).

NCEER-90-0005 "NCEER Strong-Motion Data Base: A User Manual for the GeoBase Release (Version 1.0 for the Sun3)," by P. Friberg and K. Jacob, 3/31/90 (PB90-258062, A04, MF-A01).

NCEER-90-0006 "Seismic Hazard Along a Crude Oil Pipeline in the Event of an 1811-1812 Type New Madrid Earthquake," by H.H.M. Hwang and C-H.S. Chen, 4/16/90, (PB90-258054, A04, MF-A01).

NCEER-90-0007 "Site-Specific Response Spectra for Memphis Sheahan Pumping Station," by H.H.M. Hwang and C.S. Lee, 5/15/90, (PB91-108811, A05, MF-A01).

NCEER-90-0008 "Pilot Study on Seismic Vulnerability of Crude Oil Transmission Systems," by T. Ariman, R. Dobry, M. Grigoriu, F. Kozin, M. O'Rourke, T. O'Rourke and M. Shinozuka, 5/25/90, (PB91-108837, A06, MF-A01).

NCEER-90-0009 "A Program to Generate Site Dependent Time Histories: EQGEN," by G.W. Ellis, M. Srinivasan and A.S. Cakmak, 1/30/90, (PB91-108829, A04, MF-A01).

NCEER-90-0010 "Active Isolation for Seismic Protection of Operating Rooms," by M.E. Talbott, Supervised by M. Shinozuka, 6/8/9, (PB91-110205, A05, MF-A01).

NCEER-90-0011 "Program LINEARID for Identification of Linear Structural Dynamic Systems," by C-B. Yun and M. Shinozuka, 6/25/90, (PB91-110312, A08, MF-A01).

NCEER-90-0012 "Two-Dimensional Two-Phase Elasto-Plastic Seismic Response of Earth Dams," by A.N. Yiagos, Supervised by J.H. Prevost, 6/20/90, (PB91-110197, A13, MF-A02).

NCEER-90-0013 "Secondary Systems in Base-Isolated Structures: Experimental Investigation, Stochastic Response and Stochastic Sensitivity," by G.D. Manolis, G. Juhn, M.C. Constantinou and A.M. Reinhorn, 7/1/90, (PB91-110320, A08, MF-A01).

NCEER-90-0014 "Seismic Behavior of Lightly-Reinforced Concrete Column and Beam-Column Joint Details," by S.P. Pessiki, C.H. Conley, P. Gergely and R.N. White, 8/22/90, (PB91-108795, A11, MF-A02).

NCEER-90-0015 "Two Hybrid Control Systems for Building Structures Under Strong Earthquakes," by J.N. Yang and A. Danielians, 6/29/90, (PB91-125393, A04, MF-A01).

NCEER-90-0016 "Instantaneous Optimal Control with Acceleration and Velocity Feedback," by J.N. Yang and Z. Li, 6/29/90, (PB91-125401, A03, MF-A01).

NCEER-90-0017 "Reconnaissance Report on the Northern Iran Earthquake of June 21, 1990," by M. Mehrain, 10/4/90, (PB91-125377, A03, MF-A01).

NCEER-90-0018 "Evaluation of Liquefaction Potential in Memphis and Shelby County," by T.S. Chang, P.S. Tang, C.S. Lee and H. Hwang, 8/10/90, (PB91-125427, A09, MF-A01).

NCEER-90-0019 "Experimental and Analytical Study of a Combined Sliding Disc Bearing and Helical Steel Spring Isolation System," by M.C. Constantinou, A.S. Mokha and A.M. Reinhorn, 10/4/90, (PB91-125385, A06, MF-A01). This report is available only through NTIS (see address given above).

NCEER-90-0020 "Experimental Study and Analytical Prediction of Earthquake Response of a Sliding Isolation System with a Spherical Surface," by A.S. Mokha, M.C. Constantinou and A.M. Reinhorn, 10/11/90, (PB91-125419, A05, MF-A01).

NCEER-90-0021 "Dynamic Interaction Factors for Floating Pile Groups," by G. Gazetas, K. Fan, A. Kaynia and E. Kausel, 9/10/90, (PB91-170381, A05, MF-A01).

NCEER-90-0022 "Evaluation of Seismic Damage Indices for Reinforced Concrete Structures," by S. Rodriguez-Gomez and A.S. Cakmak, 9/30/90, PB91-171322, A06, MF-A01).

NCEER-90-0023 "Study of Site Response at a Selected Memphis Site," by H. Desai, S. Ahmad, E.S. Gazetas and M.R. Oh, 10/11/90, (PB91-196857, A03, MF-A01).

NCEER-90-0024 "A User's Guide to Strongmo: Version 1.0 of NCEER's Strong-Motion Data Access Tool for PCs and Terminals," by P.A. Friberg and C.A.T. Susch, 11/15/90, (PB91-171272, A03, MF-A01).

NCEER-90-0025 "A Three-Dimensional Analytical Study of Spatial Variability of Seismic Ground Motions," by L-L. Hong and A.H.-S. Ang, 10/30/90, (PB91-170399, A09, MF-A01).

NCEER-90-0026 "MUMOID User's Guide - A Program for the Identification of Modal Parameters," by S. Rodriguez-Gomez and E. DiPasquale, 9/30/90, (PB91-171298, A04, MF-A01).

NCEER-90-0027 "SARCF-II User's Guide - Seismic Analysis of Reinforced Concrete Frames," by S. Rodriguez-Gomez, Y.S. Chung and C. Meyer, 9/30/90, (PB91-171280, A05, MF-A01).

NCEER-90-0028 "Viscous Dampers: Testing, Modeling and Application in Vibration and Seismic Isolation," by N. Makris and M.C. Constantinou, 12/20/90 (PB91-190561, A06, MF-A01).

NCEER-90-0029 "Soil Effects on Earthquake Ground Motions in the Memphis Area," by H. Hwang, C.S. Lee, K.W. Ng and T.S. Chang, 8/2/90, (PB91-190751, A05, MF-A01).

NCEER-91-0001 "Proceedings from the Third Japan-U.S. Workshop on Earthquake Resistant Design of Lifeline Facilities and Countermeasures for Soil Liquefaction, December 17-19, 1990," edited by T.D. O'Rourke and M. Hamada, 2/1/91, (PB91-179259, A99, MF-A04).

NCEER-91-0002 "Physical Space Solutions of Non-Proportionally Damped Systems," by M. Tong, Z. Liang and G.C. Lee, 1/15/91, (PB91-179242, A04, MF-A01).

NCEER-91-0003 "Seismic Response of Single Piles and Pile Groups," by K. Fan and G. Gazetas, 1/10/91, (PB92-174994, A04, MF-A01).

NCEER-91-0004 "Damping of Structures: Part 1 - Theory of Complex Damping," by Z. Liang and G. Lee, 10/10/91, (PB92-197235, A12, MF-A03).

NCEER-91-0005 "3D-BASIS - Nonlinear Dynamic Analysis of Three Dimensional Base Isolated Structures: Part II," by S. Nagarajaiah, A.M. Reinhorn and M.C. Constantinou, 2/28/91, (PB91-190553, A07, MF-A01). This report has been replaced by NCEER-93-0011.

NCEER-91-0006 "A Multidimensional Hysteretic Model for Plasticity Deforming Metals in Energy Absorbing Devices," by E.J. Graesser and F.A. Cozzarelli, 4/9/91, (PB92-108364, A04, MF-A01).

NCEER-91-0007 "A Framework for Customizable Knowledge-Based Expert Systems with an Application to a KBES for Evaluating the Seismic Resistance of Existing Buildings," by E.G. Ibarra-Anaya and S.J. Fenves, 4/9/91, (PB91-210930, A08, MF-A01).

NCEER-91-0008 "Nonlinear Analysis of Steel Frames with Semi-Rigid Connections Using the Capacity Spectrum Method," by G.G. Deierlein, S-H. Hsieh, Y-J. Shen and J.F. Abel, 7/2/91, (PB92-113828, A05, MF-A01).

NCEER-91-0009 "Earthquake Education Materials for Grades K-12," by K.E.K. Ross, 4/30/91, (PB91-212142, A06, MF-A01). This report has been replaced by NCEER-92-0018.

NCEER-91-0010 "Phase Wave Velocities and Displacement Phase Differences in a Harmonically Oscillating Pile," by N. Makris and G. Gazetas, 7/8/91, (PB92-108356, A04, MF-A01).

NCEER-91-0011 "Dynamic Characteristics of a Full-Size Five-Story Steel Structure and a 2/5 Scale Model," by K.C. Chang, G.C. Yao, G.C. Lee, D.S. Hao and Y.C. Yeh," 7/2/91, (PB93-116648, A06, MF-A02).

NCEER-91-0012 "Seismic Response of a 2/5 Scale Steel Structure with Added Viscoelastic Dampers," by K.C. Chang, T.T. Soong, S-T. Oh and M.L. Lai, 5/17/91, (PB92-110816, A05, MF-A01).

NCEER-91-0013 "Earthquake Response of Retaining Walls; Full-Scale Testing and Computational Modeling," by S. Alampalli and A-W.M. Elgamal, 6/20/91, to be published.

NCEER-91-0014 "3D-BASIS-M: Nonlinear Dynamic Analysis of Multiple Building Base Isolated Structures," by P.C. Tsopelas, S. Nagarajaiah, M.C. Constantinou and A.M. Reinhorn, 5/28/91, (PB92-113885, A09, MF-A02).

NCEER-91-0015 "Evaluation of SEAOC Design Requirements for Sliding Isolated Structures," by D. Theodossiou and M.C. Constantinou, 6/10/91, (PB92-114602, A11, MF-A03).

NCEER-91-0016 "Closed-Loop Modal Testing of a 27-Story Reinforced Concrete Flat Plate-Core Building," by H.R. Somaprasad, T. Toksoy, H. Yoshiyuki and A.E. Aktan, 7/15/91, (PB92-129980, A07, MF-A02).

NCEER-91-0017 "Shake Table Test of a 1/6 Scale Two-Story Lightly Reinforced Concrete Building," by A.G. El-Attar, R.N. White and P. Gergely, 2/28/91, (PB92-222447, A06, MF-A02).

NCEER-91-0018 "Shake Table Test of a 1/8 Scale Three-Story Lightly Reinforced Concrete Building," by A.G. El-Attar, R.N. White and P. Gergely, 2/28/91, (PB93-116630, A08, MF-A02).

NCEER-91-0019 "Transfer Functions for Rigid Rectangular Foundations," by A.S. Veletsos, A.M. Prasad and W.H. Wu, 7/31/91, to be published.

NCEER-91-0020 "Hybrid Control of Seismic-Excited Nonlinear and Inelastic Structural Systems," by J.N. Yang, Z. Li and A. Danielians, 8/1/91, (PB92-143171, A06, MF-A02).

NCEER-91-0021 "The NCEER-91 Earthquake Catalog: Improved Intensity-Based Magnitudes and Recurrence Relations for U.S. Earthquakes East of New Madrid," by L. Seeber and J.G. Armbruster, 8/28/91, (PB92-176742, A06, MF-A02).

NCEER-91-0022 "Proceedings from the Implementation of Earthquake Planning and Education in Schools: The Need for Change - The Roles of the Changemakers," by K.E.K. Ross and F. Winslow, 7/23/91, (PB92-129998, A12, MF-A03).

NCEER-91-0023 "A Study of Reliability-Based Criteria for Seismic Design of Reinforced Concrete Frame Buildings," by H.H.M. Hwang and H-M. Hsu, 8/10/91, (PB92-140235, A09, MF-A02).

NCEER-91-0024 "Experimental Verification of a Number of Structural System Identification Algorithms," by R.G. Ghanem, H. Gavin and M. Shinozuka, 9/18/91, (PB92-176577, A18, MF-A04).

NCEER-91-0025 "Probabilistic Evaluation of Liquefaction Potential," by H.H.M. Hwang and C.S. Lee," 11/25/91, (PB92-143429, A05, MF-A01).

NCEER-91-0026 "Instantaneous Optimal Control for Linear, Nonlinear and Hysteretic Structures - Stable Controllers," by J.N. Yang and Z. Li, 11/15/91, (PB92-163807, A04, MF-A01).

NCEER-91-0027 "Experimental and Theoretical Study of a Sliding Isolation System for Bridges," by M.C. Constantinou, A. Kartoum, A.M. Reinhorn and P. Bradford, 11/15/91, (PB92-176973, A10, MF-A03).

NCEER-92-0001 "Case Studies of Liquefaction and Lifeline Performance During Past Earthquakes, Volume 1: Japanese Case Studies," Edited by M. Hamada and T. O'Rourke, 2/17/92, (PB92-197243, A18, MF-A04).

NCEER-92-0002 "Case Studies of Liquefaction and Lifeline Performance During Past Earthquakes, Volume 2: United States Case Studies," Edited by T. O'Rourke and M. Hamada, 2/17/92, (PB92-197250, A20, MF-A04).

NCEER-92-0003 "Issues in Earthquake Education," Edited by K. Ross, 2/3/92, (PB92-222389, A07, MF-A02).

NCEER-92-0004 "Proceedings from the First U.S. - Japan Workshop on Earthquake Protective Systems for Bridges," Edited by I.G. Buckle, 2/4/92, (PB94-142239, A99, MF-A06).

NCEER-92-0005 "Seismic Ground Motion from a Haskell-Type Source in a Multiple-Layered Half-Space," A.P. Theoharis, G. Deodatis and M. Shinozuka, 1/2/92, to be published.

NCEER-92-0006 "Proceedings from the Site Effects Workshop," Edited by R. Whitman, 2/29/92, (PB92-197201, A04, MF-A01).

NCEER-92-0007 "Engineering Evaluation of Permanent Ground Deformations Due to Seismically-Induced Liquefaction," by M.H. Baziar, R. Dobry and A-W.M. Elgamal, 3/24/92, (PB92-222421, A13, MF-A03).

NCEER-92-0008 "A Procedure for the Seismic Evaluation of Buildings in the Central and Eastern United States," by C.D. Poland and J.O. Malley, 4/2/92, (PB92-222439, A20, MF-A04).

NCEER-92-0009 "Experimental and Analytical Study of a Hybrid Isolation System Using Friction Controllable Sliding Bearings," by M.Q. Feng, S. Fujii and M. Shinozuka, 5/15/92, (PB93-150282, A06, MF-A02).

NCEER-92-0010 "Seismic Resistance of Slab-Column Connections in Existing Non-Ductile Flat-Plate Buildings," by A.J. Durrani and Y. Du, 5/18/92, (PB93-116812, A06, MF-A02).

NCEER-92-0011 "The Hysteretic and Dynamic Behavior of Brick Masonry Walls Upgraded by Ferrocement Coatings Under Cyclic Loading and Strong Simulated Ground Motion," by H. Lee and S.P. Prawel, 5/11/92, to be published.

NCEER-92-0012 "Study of Wire Rope Systems for Seismic Protection of Equipment in Buildings," by G.F. Demetriades, M.C. Constantinou and A.M. Reinhorn, 5/20/92, (PB93-116655, A08, MF-A02).

NCEER-92-0013 "Shape Memory Structural Dampers: Material Properties, Design and Seismic Testing," by P.R. Witting and F.A. Cozzarelli, 5/26/92, (PB93-116663, A05, MF-A01).

NCEER-92-0014 "Longitudinal Permanent Ground Deformation Effects on Buried Continuous Pipelines," by M.J. O'Rourke, and C. Nordberg, 6/15/92, (PB93-116671, A08, MF-A02).

NCEER-92-0015 "A Simulation Method for Stationary Gaussian Random Functions Based on the Sampling Theorem," by M. Grigoriu and S. Balopoulou, 6/11/92, (PB93-127496, A05, MF-A01).

NCEER-92-0016 "Gravity-Load-Designed Reinforced Concrete Buildings: Seismic Evaluation of Existing Construction and Detailing Strategies for Improved Seismic Resistance," by G.W. Hoffmann, S.K. Kunnath, A.M. Reinhorn and J.B. Mander, 7/15/92, (PB94-142007, A08, MF-A02).

NCEER-92-0017 "Observations on Water System and Pipeline Performance in the Limón Area of Costa Rica Due to the April 22, 1991 Earthquake," by M. O'Rourke and D. Ballantyne, 6/30/92, (PB93-126811, A06, MF-A02).

NCEER-92-0018 "Fourth Edition of Earthquake Education Materials for Grades K-12," Edited by K.E.K. Ross, 8/10/92, (PB93-114023, A07, MF-A02).

NCEER-92-0019 "Proceedings from the Fourth Japan-U.S. Workshop on Earthquake Resistant Design of Lifeline Facilities and Countermeasures for Soil Liquefaction," Edited by M. Hamada and T.D. O'Rourke, 8/12/92, (PB93-163939, A99, MF-E11).

NCEER-92-0020 "Active Bracing System: A Full Scale Implementation of Active Control," by A.M. Reinhorn, T.T. Soong, R.C. Lin, M.A. Riley, Y.P. Wang, S. Aizawa and M. Higashino, 8/14/92, (PB93-127512, A06, MF-A02).

NCEER-92-0021 "Empirical Analysis of Horizontal Ground Displacement Generated by Liquefaction-Induced Lateral Spreads," by S.F. Bartlett and T.L. Youd, 8/17/92, (PB93-188241, A06, MF-A02).

NCEER-92-0022 "IDARC Version 3.0: Inelastic Damage Analysis of Reinforced Concrete Structures," by S.K. Kunnath, A.M. Reinhorn and R.F. Lobo, 8/31/92, (PB93-227502, A07, MF-A02).

NCEER-92-0023 "A Semi-Empirical Analysis of Strong-Motion Peaks in Terms of Seismic Source, Propagation Path and Local Site Conditions, by M. Kamiyama, M.J. O'Rourke and R. Flores-Berrones, 9/9/92, (PB93-150266, A08, MF-A02).

NCEER-92-0024 "Seismic Behavior of Reinforced Concrete Frame Structures with Nonductile Details, Part I: Summary of Experimental Findings of Full Scale Beam-Column Joint Tests," by A. Beres, R.N. White and P. Gergely, 9/30/92, (PB93-227783, A05, MF-A01).

NCEER-92-0025 "Experimental Results of Repaired and Retrofitted Beam-Column Joint Tests in Lightly Reinforced Concrete Frame Buildings," by A. Beres, S. El-Borgi, R.N. White and P. Gergely, 10/29/92, (PB93-227791, A05, MF-A01).

NCEER-92-0026 "A Generalization of Optimal Control Theory: Linear and Nonlinear Structures," by J.N. Yang, Z. Li and S. Vongchavalitkul, 11/2/92, (PB93-188621, A05, MF-A01).

NCEER-92-0027 "Seismic Resistance of Reinforced Concrete Frame Structures Designed Only for Gravity Loads: Part I - Design and Properties of a One-Third Scale Model Structure," by J.M. Bracci, A.M. Reinhorn and J.B. Mander, 12/1/92, (PB94-104502, A08, MF-A02).

NCEER-92-0028 "Seismic Resistance of Reinforced Concrete Frame Structures Designed Only for Gravity Loads: Part II - Experimental Performance of Subassemblages," by L.E. Aycardi, J.B. Mander and A.M. Reinhorn, 12/1/92, (PB94-104510, A08, MF-A02).

NCEER-92-0029 "Seismic Resistance of Reinforced Concrete Frame Structures Designed Only for Gravity Loads: Part III - Experimental Performance and Analytical Study of a Structural Model," by J.M. Bracci, A.M. Reinhorn and J.B. Mander, 12/1/92, (PB93-227528, A09, MF-A01).

NCEER-92-0030 "Evaluation of Seismic Retrofit of Reinforced Concrete Frame Structures: Part I - Experimental Performance of Retrofitted Subassemblages," by D. Choudhuri, J.B. Mander and A.M. Reinhorn, 12/8/92, (PB93-198307, A07, MF-A02).

NCEER-92-0031 "Evaluation of Seismic Retrofit of Reinforced Concrete Frame Structures: Part II - Experimental Performance and Analytical Study of a Retrofitted Structural Model," by J.M. Bracci, A.M. Reinhorn and J.B. Mander, 12/8/92, (PB93-198315, A09, MF-A03).

NCEER-92-0032 "Experimental and Analytical Investigation of Seismic Response of Structures with Supplemental Fluid Viscous Dampers," by M.C. Constantinou and M.D. Symans, 12/21/92, (PB93-191435, A10, MF-A03). This report is available only through NTIS (see address given above).

NCEER-92-0033 "Reconnaissance Report on the Cairo, Egypt Earthquake of October 12, 1992," by M. Khater, 12/23/92, (PB93-188621, A03, MF-A01).

NCEER-92-0034 "Low-Level Dynamic Characteristics of Four Tall Flat-Plate Buildings in New York City," by H. Gavin, S. Yuan, J. Grossman, E. Pekelis and K. Jacob, 12/28/92, (PB93-188217, A07, MF-A02).

NCEER-93-0001 "An Experimental Study on the Seismic Performance of Brick-Infilled Steel Frames With and Without Retrofit," by J.B. Mander, B. Nair, K. Wojtkowski and J. Ma, 1/29/93, (PB93-227510, A07, MF-A02).

NCEER-93-0002 "Social Accounting for Disaster Preparedness and Recovery Planning," by S. Cole, E. Pantoja and V. Razak, 2/22/93, (PB94-142114, A12, MF-A03).

NCEER-93-0003 "Assessment of 1991 NEHRP Provisions for Nonstructural Components and Recommended Revisions," by T.T. Soong, G. Chen, Z. Wu, R-H. Zhang and M. Grigoriu, 3/1/93, (PB93-188639, A06, MF-A02).

NCEER-93-0004 "Evaluation of Static and Response Spectrum Analysis Procedures of SEAOC/UBC for Seismic Isolated Structures," by C.W. Winters and M.C. Constantinou, 3/23/93, (PB93-198299, A10, MF-A03).

NCEER-93-0005 "Earthquakes in the Northeast - Are We Ignoring the Hazard? A Workshop on Earthquake Science and Safety for Educators," edited by K.E.K. Ross, 4/2/93, (PB94-103066, A09, MF-A02).

NCEER-93-0006 "Inelastic Response of Reinforced Concrete Structures with Viscoelastic Braces," by R.F. Lobo, J.M. Bracci, K.L. Shen, A.M. Reinhorn and T.T. Soong, 4/5/93, (PB93-227486, A05, MF-A02).

NCEER-93-0007 "Seismic Testing of Installation Methods for Computers and Data Processing Equipment," by K. Kosar, T.T. Soong, K.L. Shen, J.A. HoLung and Y.K. Lin, 4/12/93, (PB93-198299, A07, MF-A02).

NCEER-93-0008 "Retrofit of Reinforced Concrete Frames Using Added Dampers," by A. Reinhorn, M. Constantinou and C. Li, to be published.

NCEER-93-0009 "Seismic Behavior and Design Guidelines for Steel Frame Structures with Added Viscoelastic Dampers," by K.C. Chang, M.L. Lai, T.T. Soong, D.S. Hao and Y.C. Yeh, 5/1/93, (PB94-141959, A07, MF-A02).

NCEER-93-0010 "Seismic Performance of Shear-Critical Reinforced Concrete Bridge Piers," by J.B. Mander, S.M. Waheed, M.T.A. Chaudhary and S.S. Chen, 5/12/93, (PB93-227494, A08, MF-A02).

NCEER-93-0011 "3D-BASIS-TABS: Computer Program for Nonlinear Dynamic Analysis of Three Dimensional Base Isolated Structures," by S. Nagarajaiah, C. Li, A.M. Reinhorn and M.C. Constantinou, 8/2/93, (PB94-141819, A09, MF-A02).

NCEER-93-0012 "Effects of Hydrocarbon Spills from an Oil Pipeline Break on Ground Water," by O.J. Helweg and H.H.M. Hwang, 8/3/93, (PB94-141942, A06, MF-A02).

NCEER-93-0013 "Simplified Procedures for Seismic Design of Nonstructural Components and Assessment of Current Code Provisions," by M.P. Singh, L.E. Suarez, E.E. Matheu and G.O. Maldonado, 8/4/93, (PB94-141827, A09, MF-A02).

NCEER-93-0014 "An Energy Approach to Seismic Analysis and Design of Secondary Systems," by G. Chen and T.T. Soong, 8/6/93, (PB94-142767, A11, MF-A03).

NCEER-93-0015 "Proceedings from School Sites: Becoming Prepared for Earthquakes - Commemorating the Third Anniversary of the Loma Prieta Earthquake," Edited by F.E. Winslow and K.E.K. Ross, 8/16/93, (PB94-154275, A16, MF-A02).

NCEER-93-0016 "Reconnaissance Report of Damage to Historic Monuments in Cairo, Egypt Following the October 12, 1992 Dahshur Earthquake," by D. Sykora, D. Look, G. Croci, E. Karaesmen and E. Karaesmen, 8/19/93, (PB94-142221, A08, MF-A02).

NCEER-93-0017 "The Island of Guam Earthquake of August 8, 1993," by S.W. Swan and S.K. Harris, 9/30/93, (PB94-141843, A04, MF-A01).

NCEER-93-0018 "Engineering Aspects of the October 12, 1992 Egyptian Earthquake," by A.W. Elgamal, M. Amer, K. Adalier and A. Abul-Fadl, 10/7/93, (PB94-141983, A05, MF-A01).

NCEER-93-0019 "Development of an Earthquake Motion Simulator and its Application in Dynamic Centrifuge Testing," by I. Krstelj, Supervised by J.H. Prevost, 10/23/93, (PB94-181773, A-10, MF-A03).

NCEER-93-0020 "NCEER-Taisei Corporation Research Program on Sliding Seismic Isolation Systems for Bridges: Experimental and Analytical Study of a Friction Pendulum System (FPS)," by M.C. Constantinou, P. Tsopelas, Y-S. Kim and S. Okamoto, 11/1/93, (PB94-142775, A08, MF-A02).

NCEER-93-0021 "Finite Element Modeling of Elastomeric Seismic Isolation Bearings," by L.J. Billings, Supervised by R. Shepherd, 11/8/93, to be published.

NCEER-93-0022 "Seismic Vulnerability of Equipment in Critical Facilities: Life-Safety and Operational Consequences," by K. Porter, G.S. Johnson, M.M. Zadeh, C. Scawthorn and S. Eder, 11/24/93, (PB94-181765, A16, MF-A03).

NCEER-93-0023 "Hokkaido Nansei-oki, Japan Earthquake of July 12, 1993, by P.I. Yanev and C.R. Scawthorn, 12/23/93, (PB94-181500, A07, MF-A01).

NCEER-94-0001 "An Evaluation of Seismic Serviceability of Water Supply Networks with Application to the San Francisco Auxiliary Water Supply System," by I. Markov, Supervised by M. Grigoriu and T. O'Rourke, 1/21/94, (PB94-204013, A07, MF-A02).

NCEER-94-0002 "NCEER-Taisei Corporation Research Program on Sliding Seismic Isolation Systems for Bridges: Experimental and Analytical Study of Systems Consisting of Sliding Bearings, Rubber Restoring Force Devices and Fluid Dampers," Volumes I and II, by P. Tsopelas, S. Okamoto, M.C. Constantinou, D. Ozaki and S. Fujii, 2/4/94, (PB94-181740, A09, MF-A02 and PB94-181757, A12, MF-A03).

NCEER-94-0003 "A Markov Model for Local and Global Damage Indices in Seismic Analysis," by S. Rahman and M. Grigoriu, 2/18/94, (PB94-206000, A12, MF-A03).

NCEER-94-0004 "Proceedings from the NCEER Workshop on Seismic Response of Masonry Infills," edited by D.P. Abrams, 3/1/94, (PB94-180783, A07, MF-A02).

NCEER-94-0005 "The Northridge, California Earthquake of January 17, 1994: General Reconnaissance Report," edited by J.D. Goltz, 3/11/94, (PB94-193943, A10, MF-A03).

NCEER-94-0006 "Seismic Energy Based Fatigue Damage Analysis of Bridge Columns: Part I - Evaluation of Seismic Capacity," by G.A. Chang and J.B. Mander, 3/14/94, (PB94-219185, A11, MF-A03).

NCEER-94-0007 "Seismic Isolation of Multi-Story Frame Structures Using Spherical Sliding Isolation Systems," by T.M. Al-Hussaini, V.A. Zayas and M.C. Constantinou, 3/17/94, (PB94-193745, A09, MF-A02).

NCEER-94-0008 "The Northridge, California Earthquake of January 17, 1994: Performance of Highway Bridges," edited by I.G. Buckle, 3/24/94, (PB94-193851, A06, MF-A02).

NCEER-94-0009 "Proceedings of the Third U.S.-Japan Workshop on Earthquake Protective Systems for Bridges," edited by I.G. Buckle and I. Friedland, 3/31/94, (PB94-195815, A99, MF-A06).

NCEER-94-0010 "3D-BASIS-ME: Computer Program for Nonlinear Dynamic Analysis of Seismically Isolated Single and Multiple Structures and Liquid Storage Tanks," by P.C. Tsopelas, M.C. Constantinou and A.M. Reinhorn, 4/12/94, (PB94-204922, A09, MF-A02).

NCEER-94-0011 "The Northridge, California Earthquake of January 17, 1994: Performance of Gas Transmission Pipelines," by T.D. O'Rourke and M.C. Palmer, 5/16/94, (PB94-204989, A05, MF-A01).

NCEER-94-0012 "Feasibility Study of Replacement Procedures and Earthquake Performance Related to Gas Transmission Pipelines," by T.D. O'Rourke and M.C. Palmer, 5/25/94, (PB94-206638, A09, MF-A02).

NCEER-94-0013 "Seismic Energy Based Fatigue Damage Analysis of Bridge Columns: Part II - Evaluation of Seismic Demand," by G.A. Chang and J.B. Mander, 6/1/94, (PB95-18106, A08, MF-A02).

NCEER-94-0014 "NCEER-Taisei Corporation Research Program on Sliding Seismic Isolation Systems for Bridges: Experimental and Analytical Study of a System Consisting of Sliding Bearings and Fluid Restoring Force/Damping Devices," by P. Tsopelas and M.C. Constantinou, 6/13/94, (PB94-219144, A10, MF-A03).

NCEER-94-0015 "Generation of Hazard-Consistent Fragility Curves for Seismic Loss Estimation Studies," by H. Hwang and J-R. Huo, 6/14/94, (PB95-181996, A09, MF-A02).

NCEER-94-0016 "Seismic Study of Building Frames with Added Energy-Absorbing Devices," by W.S. Pong, C.S. Tsai and G.C. Lee, 6/20/94, (PB94-219136, A10, A03).

NCEER-94-0017 "Sliding Mode Control for Seismic-Excited Linear and Nonlinear Civil Engineering Structures," by J. Yang, J. Wu, A. Agrawal and Z. Li, 6/21/94, (PB95-138483, A06, MF-A02).

NCEER-94-0018 "3D-BASIS-TABS Version 2.0: Computer Program for Nonlinear Dynamic Analysis of Three Dimensional Base Isolated Structures," by A.M. Reinhorn, S. Nagarajaiah, M.C. Constantinou, P. Tsopelas and R. Li, 6/22/94, (PB95-182176, A08, MF-A02).

NCEER-94-0019 "Proceedings of the International Workshop on Civil Infrastructure Systems: Application of Intelligent Systems and Advanced Materials on Bridge Systems," Edited by G.C. Lee and K.C. Chang, 7/18/94, (PB95-252474, A20, MF-A04).

NCEER-94-0020 "Study of Seismic Isolation Systems for Computer Floors," by V. Lambrou and M.C. Constantinou, 7/19/94, (PB95-138533, A10, MF-A03).

NCEER-94-0021 "Proceedings of the U.S.-Italian Workshop on Guidelines for Seismic Evaluation and Rehabilitation of Unreinforced Masonry Buildings," Edited by D.P. Abrams and G.M. Calvi, 7/20/94, (PB95-138749, A13, MF-A03).

NCEER-94-0022 "NCEER-Taisei Corporation Research Program on Sliding Seismic Isolation Systems for Bridges: Experimental and Analytical Study of a System Consisting of Lubricated PTFE Sliding Bearings and Mild Steel Dampers," by P. Tsopelas and M.C. Constantinou, 7/22/94, (PB95-182184, A08, MF-A02).

NCEER-94-0023 “Development of Reliability-Based Design Criteria for Buildings Under Seismic Load,” by Y.K. Wen, H. Hwang and M. Shinozuka, 8/1/94, (PB95-211934, A08, MF-A02).

NCEER-94-0024 “Experimental Verification of Acceleration Feedback Control Strategies for an Active Tendon System,” by S.J. Dyke, B.F. Spencer, Jr., P. Quast, M.K. Sain, D.C. Kaspari, Jr. and T.T. Soong, 8/29/94, (PB95-212320, A05, MF-A01).

NCEER-94-0025 “Seismic Retrofitting Manual for Highway Bridges,” Edited by I.G. Buckle and I.F. Friedland, published by the Federal Highway Administration (PB95-212676, A15, MF-A03).

NCEER-94-0026 “Proceedings from the Fifth U.S.-Japan Workshop on Earthquake Resistant Design of Lifeline Facilities and Countermeasures Against Soil Liquefaction,” Edited by T.D. O’Rourke and M. Hamada, 11/7/94, (PB95-220802, A99, MF-E08).

NCEER-95-0001 "Experimental and Analytical Investigation of Seismic Retrofit of Structures with Supplemental Damping: Part 1 - Fluid Viscous Damping Devices," by A.M. Reinhorn, C. Li and M.C. Constantinou, 1/3/95, (PB95-266599, A09, MF-A02).

NCEER-95-0002 "Experimental and Analytical Study of Low-Cycle Fatigue Behavior of Semi-Rigid Top-And-Seat Angle Connections," by G. Pekcan, J.B. Mander and S.S. Chen, 1/5/95, (PB95-220042, A07, MF-A02).

NCEER-95-0003 "NCEER-ATC Joint Study on Fragility of Buildings," by T. Anagnos, C. Rojahn and A.S. Kiremidjian, 1/20/95, (PB95-220026, A06, MF-A02).

NCEER-95-0004 "Nonlinear Control Algorithms for Peak Response Reduction," by Z. Wu, T.T. Soong, V. Gattulli and R.C. Lin, 2/16/95, (PB95-220349, A05, MF-A01).

NCEER-95-0005 "Pipeline Replacement Feasibility Study: A Methodology for Minimizing Seismic and Corrosion Risks to Underground Natural Gas Pipelines," by R.T. Eguchi, H.A. Seligson and D.G. Honegger, 3/2/95, (PB95-252326, A06, MF-A02).

NCEER-95-0006 "Evaluation of Seismic Performance of an 11-Story Frame Building During the 1994 Northridge Earthquake," by F. Naeim, R. DiSulio, K. Benuska, A. Reinhorn and C. Li, to be published.

NCEER-95-0007 "Prioritization of Bridges for Seismic Retrofitting," by N. Basöz and A.S. Kiremidjian, 4/24/95, (PB95-252300, A08, MF-A02).

NCEER-95-0008 "Method for Developing Motion Damage Relationships for Reinforced Concrete Frames," by A. Singhal and A.S. Kiremidjian, 5/11/95, (PB95-266607, A06, MF-A02).

NCEER-95-0009 "Experimental and Analytical Investigation of Seismic Retrofit of Structures with Supplemental Damping: Part II - Friction Devices," by C. Li and A.M. Reinhorn, 7/6/95, (PB96-128087, A11, MF-A03).

NCEER-95-0010 "Experimental Performance and Analytical Study of a Non-Ductile Reinforced Concrete Frame Structure Retrofitted with Elastomeric Spring Dampers," by G. Pekcan, J.B. Mander and S.S. Chen, 7/14/95, (PB96-137161, A08, MF-A02).

NCEER-95-0011 "Development and Experimental Study of Semi-Active Fluid Damping Devices for Seismic Protection of Structures," by M.D. Symans and M.C. Constantinou, 8/3/95, (PB96-136940, A23, MF-A04).

NCEER-95-0012 "Real-Time Structural Parameter Modification (RSPM): Development of Innervated Structures," by Z. Liang, M. Tong and G.C. Lee, 4/11/95, (PB96-137153, A06, MF-A01).

NCEER-95-0013 "Experimental and Analytical Investigation of Seismic Retrofit of Structures with Supplemental Damping: Part III - Viscous Damping Walls," by A.M. Reinhorn and C. Li, 10/1/95, (PB96-176409, A11, MF-A03).

NCEER-95-0014 "Seismic Fragility Analysis of Equipment and Structures in a Memphis Electric Substation," by J-R. Huo and H.H.M. Hwang, 8/10/95, (PB96-128087, A09, MF-A02).

NCEER-95-0015 "The Hanshin-Awaji Earthquake of January 17, 1995: Performance of Lifelines," Edited by M. Shinozuka, 11/3/95, (PB96-176383, A15, MF-A03).

NCEER-95-0016 "Highway Culvert Performance During Earthquakes," by T.L. Youd and C.J. Beckman, available as NCEER-96-0015.

NCEER-95-0017 "The Hanshin-Awaji Earthquake of January 17, 1995: Performance of Highway Bridges," Edited by I.G. Buckle, 12/1/95, to be published.

NCEER-95-0018 "Modeling of Masonry Infill Panels for Structural Analysis," by A.M. Reinhorn, A. Madan, R.E. Valles, Y. Reichmann and J.B. Mander, 12/8/95, (PB97-110886, MF-A01, A06).

NCEER-95-0019 "Optimal Polynomial Control for Linear and Nonlinear Structures," by A.K. Agrawal and J.N. Yang, 12/11/95, (PB96-168737, A07, MF-A02).

NCEER-95-0020 "Retrofit of Non-Ductile Reinforced Concrete Frames Using Friction Dampers," by R.S. Rao, P. Gergely and R.N. White, 12/22/95, (PB97-133508, A10, MF-A02).

NCEER-95-0021 "Parametric Results for Seismic Response of Pile-Supported Bridge Bents," by G. Mylonakis, A. Nikolaou and G. Gazetas, 12/22/95, (PB97-100242, A12, MF-A03).

NCEER-95-0022 "Kinematic Bending Moments in Seismically Stressed Piles," by A. Nikolaou, G. Mylonakis and G. Gazetas, 12/23/95, (PB97-113914, MF-A03, A13).

NCEER-96-0001 "Dynamic Response of Unreinforced Masonry Buildings with Flexible Diaphragms," by A.C. Costley and D.P. Abrams," 10/10/96, (PB97-133573, MF-A03, A15).

NCEER-96-0002 "State of the Art Review: Foundations and Retaining Structures," by I. Po Lam, to be published.

NCEER-96-0003 "Ductility of Rectangular Reinforced Concrete Bridge Columns with Moderate Confinement," by N. Wehbe, M. Saiidi, D. Sanders and B. Douglas, 11/7/96, (PB97-133557, A06, MF-A02).

NCEER-96-0004 "Proceedings of the Long-Span Bridge Seismic Research Workshop," edited by I.G. Buckle and I.M. Friedland, to be published.

NCEER-96-0005 "Establish Representative Pier Types for Comprehensive Study: Eastern United States," by J. Kulicki and Z. Prucz, 5/28/96, (PB98-119217, A07, MF-A02).

NCEER-96-0006 "Establish Representative Pier Types for Comprehensive Study: Western United States," by R. Imbsen, R.A. Schamber and T.A. Osterkamp, 5/28/96, (PB98-118607, A07, MF-A02).

NCEER-96-0007 "Nonlinear Control Techniques for Dynamical Systems with Uncertain Parameters," by R.G. Ghanem and M.I. Bujakov, 5/27/96, (PB97-100259, A17, MF-A03).

NCEER-96-0008 "Seismic Evaluation of a 30-Year Old Non-Ductile Highway Bridge Pier and Its Retrofit," by J.B. Mander, B. Mahmoodzadegan, S. Bhadra and S.S. Chen, 5/31/96, (PB97-110902, MF-A03, A10).

NCEER-96-0009 "Seismic Performance of a Model Reinforced Concrete Bridge Pier Before and After Retrofit," by J.B. Mander, J.H. Kim and C.A. Ligozio, 5/31/96, (PB97-110910, MF-A02, A10).

NCEER-96-0010 "IDARC2D Version 4.0: A Computer Program for the Inelastic Damage Analysis of Buildings," by R.E. Valles, A.M. Reinhorn, S.K. Kunnath, C. Li and A. Madan, 6/3/96, (PB97-100234, A17, MF-A03).

NCEER-96-0011 "Estimation of the Economic Impact of Multiple Lifeline Disruption: Memphis Light, Gas and Water Division Case Study," by S.E. Chang, H.A. Seligson and R.T. Eguchi, 8/16/96, (PB97-133490, A11, MF-A03).

NCEER-96-0012 "Proceedings from the Sixth Japan-U.S. Workshop on Earthquake Resistant Design of Lifeline Facilities and Countermeasures Against Soil Liquefaction, Edited by M. Hamada and T. O'Rourke, 9/11/96, (PB97-133581, A99, MF-A06).

NCEER-96-0013 "Chemical Hazards, Mitigation and Preparedness in Areas of High Seismic Risk: A Methodology for Estimating the Risk of Post-Earthquake Hazardous Materials Release," by H.A. Seligson, R.T. Eguchi, K.J. Tierney and K. Richmond, 11/7/96, (PB97-133565, MF-A02, A08).

NCEER-96-0014 "Response of Steel Bridge Bearings to Reversed Cyclic Loading," by J.B. Mander, D-K. Kim, S.S. Chen and G.J. Premus, 11/13/96, (PB97-140735, A12, MF-A03).

NCEER-96-0015 "Highway Culvert Performance During Past Earthquakes," by T.L. Youd and C.J. Beckman, 11/25/96, (PB97-133532, A06, MF-A01).

NCEER-97-0001 "Evaluation, Prevention and Mitigation of Pounding Effects in Building Structures," by R.E. Valles and A.M. Reinhorn, 2/20/97, (PB97-159552, A14, MF-A03).

NCEER-97-0002 "Seismic Design Criteria for Bridges and Other Highway Structures," by C. Rojahn, R. Mayes, D.G. Anderson, J. Clark, J.H. Hom, R.V. Nutt and M.J. O'Rourke, 4/30/97, (PB97-194658, A06, MF-A03).

NCEER-97-0003 "Proceedings of the U.S.-Italian Workshop on Seismic Evaluation and Retrofit," Edited by D.P. Abrams and G.M. Calvi, 3/19/97, (PB97-194666, A13, MF-A03).

NCEER-97-0004 "Investigation of Seismic Response of Buildings with Linear and Nonlinear Fluid Viscous Dampers," by A.A. Seleemah and M.C. Constantinou, 5/21/97, (PB98-109002, A15, MF-A03).

NCEER-97-0005 "Proceedings of the Workshop on Earthquake Engineering Frontiers in Transportation Facilities," edited by G.C. Lee and I.M. Friedland, 8/29/97, (PB98-128911, A25, MR-A04).

NCEER-97-0006 "Cumulative Seismic Damage of Reinforced Concrete Bridge Piers," by S.K. Kunnath, A. El-Bahy, A. Taylor and W. Stone, 9/2/97, (PB98-108814, A11, MF-A03).

NCEER-97-0007 "Structural Details to Accommodate Seismic Movements of Highway Bridges and Retaining Walls," by R.A. Imbsen, R.A. Schamber, E. Thorkildsen, A. Kartoum, B.T. Martin, T.N. Rosser and J.M. Kulicki, 9/3/97, (PB98-108996, A09, MF-A02).

NCEER-97-0008 "A Method for Earthquake Motion-Damage Relationships with Application to Reinforced Concrete Frames," by A. Singhal and A.S. Kiremidjian, 9/10/97, (PB98-108988, A13, MF-A03).

NCEER-97-0009 "Seismic Analysis and Design of Bridge Abutments Considering Sliding and Rotation," by K. Fishman and R. Richards, Jr., 9/15/97, (PB98-108897, A06, MF-A02).

NCEER-97-0010 "Proceedings of the FHWA/NCEER Workshop on the National Representation of Seismic Ground Motion for New and Existing Highway Facilities," edited by I.M. Friedland, M.S. Power and R.L. Mayes, 9/22/97, (PB98-128903, A21, MF-A04).

NCEER-97-0011 "Seismic Analysis for Design or Retrofit of Gravity Bridge Abutments," by K.L. Fishman, R. Richards, Jr. and R.C. Divito, 10/2/97, (PB98-128937, A08, MF-A02).

NCEER-97-0012 "Evaluation of Simplified Methods of Analysis for Yielding Structures," by P. Tsopelas, M.C. Constantinou, C.A. Kircher and A.S. Whittaker, 10/31/97, (PB98-128929, A10, MF-A03).

NCEER-97-0013 "Seismic Design of Bridge Columns Based on Control and Repairability of Damage," by C-T. Cheng and J.B. Mander, 12/8/97, (PB98-144249, A11, MF-A03).

NCEER-97-0014 "Seismic Resistance of Bridge Piers Based on Damage Avoidance Design," by J.B. Mander and C-T. Cheng, 12/10/97, (PB98-144223, A09, MF-A02).

NCEER-97-0015 "Seismic Response of Nominally Symmetric Systems with Strength Uncertainty," by S. Balopoulou and M. Grigoriu, 12/23/97, (PB98-153422, A11, MF-A03).

NCEER-97-0016 "Evaluation of Seismic Retrofit Methods for Reinforced Concrete Bridge Columns," by T.J. Wipf, F.W. Klaiber and F.M. Russo, 12/28/97, (PB98-144215, A12, MF-A03).

NCEER-97-0017 "Seismic Fragility of Existing Conventional Reinforced Concrete Highway Bridges," by C.L. Mullen and A.S. Cakmak, 12/30/97, (PB98-153406, A08, MF-A02).

NCEER-97-0018 "Loss Asssessment of Memphis Buildings," edited by D.P. Abrams and M. Shinozuka, 12/31/97, (PB98-144231, A13, MF-A03).

NCEER-97-0019 "Seismic Evaluation of Frames with Infill Walls Using Quasi-static Experiments," by K.M. Mosalam, R.N. White and P. Gergely, 12/31/97, (PB98-153455, A07, MF-A02).

NCEER-97-0020 "Seismic Evaluation of Frames with Infill Walls Using Pseudo-dynamic Experiments," by K.M. Mosalam, R.N. White and P. Gergely, 12/31/97, (PB98-153430, A07, MF-A02).

NCEER-97-0021 "Computational Strategies for Frames with Infill Walls: Discrete and Smeared Crack Analyses and Seismic Fragility," by K.M. Mosalam, R.N. White and P. Gergely, 12/31/97, (PB98-153414, A10, MF-A02).

NCEER-97-0022 "Proceedings of the NCEER Workshop on Evaluation of Liquefaction Resistance of Soils," edited by T.L. Youd and I.M. Idriss, 12/31/97, (PB98-155617, A15, MF-A03).

MCEER-98-0001 "Extraction of Nonlinear Hysteretic Properties of Seismically Isolated Bridges from Quick-Release Field Tests," by Q. Chen, B.M. Douglas, E.M. Maragakis and I.G. Buckle, 5/26/98, (PB99-118838, A06, MF-A01).

MCEER-98-0002 "Methodologies for Evaluating the Importance of Highway Bridges," by A. Thomas, S. Eshenaur and J. Kulicki, 5/29/98, (PB99-118846, A10, MF-A02).

MCEER-98-0003 "Capacity Design of Bridge Piers and the Analysis of Overstrength," by J.B. Mander, A. Dutta and P. Goel, 6/1/98, (PB99-118853, A09, MF-A02).

MCEER-98-0004 "Evaluation of Bridge Damage Data from the Loma Prieta and Northridge, California Earthquakes," by N. Basoz and A. Kiremidjian, 6/2/98, (PB99-118861, A15, MF-A03).

MCEER-98-0005 "Screening Guide for Rapid Assessment of Liquefaction Hazard at Highway Bridge Sites," by T. L. Youd, 6/16/98, (PB99-118879, A06, not available on microfiche).

MCEER-98-0006 "Structural Steel and Steel/Concrete Interface Details for Bridges," by P. Ritchie, N. Kauhl and J. Kulicki, 7/13/98, (PB99-118945, A06, MF-A01).

MCEER-98-0007 "Capacity Design and Fatigue Analysis of Confined Concrete Columns," by A. Dutta and J.B. Mander, 7/14/98, (PB99-118960, A14, MF-A03).

MCEER-98-0008 "Proceedings of the Workshop on Performance Criteria for Telecommunication Services Under Earthquake Conditions," edited by A.J. Schiff, 7/15/98, (PB99-118952, A08, MF-A02).

MCEER-98-0009 "Fatigue Analysis of Unconfined Concrete Columns," by J.B. Mander, A. Dutta and J.H. Kim, 9/12/98, (PB99-123655, A10, MF-A02).

MCEER-98-0010 "Centrifuge Modeling of Cyclic Lateral Response of Pile-Cap Systems and Seat-Type Abutments in Dry Sands," by A.D. Gadre and R. Dobry, 10/2/98, (PB99-123606, A13, MF-A03).

MCEER-98-0011 "IDARC-BRIDGE: A Computational Platform for Seismic Damage Assessment of Bridge Structures," by A.M. Reinhorn, V. Simeonov, G. Mylonakis and Y. Reichman, 10/2/98, (PB99-162919, A15, MF-A03).

MCEER-98-0012 "Experimental Investigation of the Dynamic Response of Two Bridges Before and After Retrofitting with Elastomeric Bearings," by D.A. Wendichansky, S.S. Chen and J.B. Mander, 10/2/98, (PB99-162927, A15, MF-A03).

MCEER-98-0013 "Design Procedures for Hinge Restrainers and Hinge Sear Width for Multiple-Frame Bridges," by R. Des Roches and G.L. Fenves, 11/3/98, (PB99-140477, A13, MF-A03).

MCEER-98-0014 "Response Modification Factors for Seismically Isolated Bridges," by M.C. Constantinou and J.K. Quarshie, 11/3/98, (PB99-140485, A14, MF-A03).

MCEER-98-0015 "Proceedings of the U.S.-Italy Workshop on Seismic Protective Systems for Bridges," edited by I.M. Friedland and M.C. Constantinou, 11/3/98, (PB2000-101711, A22, MF-A04).

MCEER-98-0016 "Appropriate Seismic Reliability for Critical Equipment Systems: Recommendations Based on Regional Analysis of Financial and Life Loss," by K. Porter, C. Scawthorn, C. Taylor and N. Blais, 11/10/98, (PB99-157265, A08, MF-A02).

MCEER-98-0017 "Proceedings of the U.S. Japan Joint Seminar on Civil Infrastructure Systems Research," edited by M. Shinozuka and A. Rose, 11/12/98, (PB99-156713, A16, MF-A03).

MCEER-98-0018 "Modeling of Pile Footings and Drilled Shafts for Seismic Design," by I. PoLam, M. Kapuskar and D. Chaudhuri, 12/21/98, (PB99-157257, A09, MF-A02).

MCEER-99-0001 "Seismic Evaluation of a Masonry Infilled Reinforced Concrete Frame by Pseudodynamic Testing," by S.G. Buonopane and R.N. White, 2/16/99, (PB99-162851, A09, MF-A02).

MCEER-99-0002 "Response History Analysis of Structures with Seismic Isolation and Energy Dissipation Systems: Verification Examples for Program SAP2000," by J. Scheller and M.C. Constantinou, 2/22/99, (PB99-162869, A08, MF-A02).

MCEER-99-0003 "Experimental Study on the Seismic Design and Retrofit of Bridge Columns Including Axial Load Effects," by A. Dutta, T. Kokorina and J.B. Mander, 2/22/99, (PB99-162877, A09, MF-A02).

MCEER-99-0004 "Experimental Study of Bridge Elastomeric and Other Isolation and Energy Dissipation Systems with Emphasis on Uplift Prevention and High Velocity Near-source Seismic Excitation," by A. Kasalanati and M. C. Constantinou, 2/26/99, (PB99-162885, A12, MF-A03).

MCEER-99-0005 "Truss Modeling of Reinforced Concrete Shear-flexure Behavior," by J.H. Kim and J.B. Mander, 3/8/99, (PB99-163693, A12, MF-A03).

MCEER-99-0006 "Experimental Investigation and Computational Modeling of Seismic Response of a 1:4 Scale Model Steel Structure with a Load Balancing Supplemental Damping System," by G. Pekcan, J.B. Mander and S.S. Chen, 4/2/99, (PB99-162893, A11, MF-A03).

MCEER-99-0007 "Effect of Vertical Ground Motions on the Structural Response of Highway Bridges," by M.R. Button, C.J. Cronin and R.L. Mayes, 4/10/99, (PB2000-101411, A10, MF-A03).

MCEER-99-0008 "Seismic Reliability Assessment of Critical Facilities: A Handbook, Supporting Documentation, and Model Code Provisions," by G.S. Johnson, R.E. Sheppard, M.D. Quilici, S.J. Eder and C.R. Scawthorn, 4/12/99, (PB2000-101701, A18, MF-A04).

MCEER-99-0009 "Impact Assessment of Selected MCEER Highway Project Research on the Seismic Design of Highway Structures," by C. Rojahn, R. Mayes, D.G. Anderson, J.H. Clark, D'Appolonia Engineering, S. Gloyd and R.V. Nutt, 4/14/99, (PB99-162901, A10, MF-A02).

MCEER-99-0010 "Site Factors and Site Categories in Seismic Codes," by R. Dobry, R. Ramos and M.S. Power, 7/19/99, (PB2000-101705, A08, MF-A02).

MCEER-99-0011 "Restrainer Design Procedures for Multi-Span Simply-Supported Bridges," by M.J. Randall, M. Saiidi, E. Maragakis and T. Isakovic, 7/20/99, (PB2000-101702, A10, MF-A02).

MCEER-99-0012 "Property Modification Factors for Seismic Isolation Bearings," by M.C. Constantinou, P. Tsopelas, A. Kasalanati and E. Wolff, 7/20/99, (PB2000-103387, A11, MF-A03).

MCEER-99-0013 "Critical Seismic Issues for Existing Steel Bridges," by P. Ritchie, N. Kauhl and J. Kulicki, 7/20/99, (PB2000-101697, A09, MF-A02).

MCEER-99-0014 "Nonstructural Damage Database," by A. Kao, T.T. Soong and A. Vender, 7/24/99, (PB2000-101407, A06, MF-A01).

MCEER-99-0015 "Guide to Remedial Measures for Liquefaction Mitigation at Existing Highway Bridge Sites," by H.G. Cooke and J. K. Mitchell, 7/26/99, (PB2000-101703, A11, MF-A03).

MCEER-99-0016 "Proceedings of the MCEER Workshop on Ground Motion Methodologies for the Eastern United States," edited by N. Abrahamson and A. Becker, 8/11/99, (PB2000-103385, A07, MF-A02).

MCEER-99-0017 "Quindío, Colombia Earthquake of January 25, 1999: Reconnaissance Report," by A.P. Asfura and P.J. Flores, 10/4/99, (PB2000-106893, A06, MF-A01).

MCEER-99-0018 "Hysteretic Models for Cyclic Behavior of Deteriorating Inelastic Structures," by M.V. Sivaselvan and A.M. Reinhorn, 11/5/99, (PB2000-103386, A08, MF-A02).

MCEER-99-0019 "Proceedings of the 7th U.S.- Japan Workshop on Earthquake Resistant Design of Lifeline Facilities and Countermeasures Against Soil Liquefaction," edited by T.D. O'Rourke, J.P. Bardet and M. Hamada, 11/19/99, (PB2000-103354, A99, MF-A06).

MCEER-99-0020 "Development of Measurement Capability for Micro-Vibration Evaluations with Application to Chip Fabrication Facilities," by G.C. Lee, Z. Liang, J.W. Song, J.D. Shen and W.C. Liu, 12/1/99, (PB2000-105993, A08, MF-A02).

MCEER-99-0021 "Design and Retrofit Methodology for Building Structures with Supplemental Energy Dissipating Systems," by G. Pekcan, J.B. Mander and S.S. Chen, 12/31/99, (PB2000-105994, A11, MF-A03).

MCEER-00-0001 "The Marmara, Turkey Earthquake of August 17, 1999: Reconnaissance Report," edited by C. Scawthorn; with major contributions by M. Bruneau, R. Eguchi, T. Holzer, G. Johnson, J. Mander, J. Mitchell, W. Mitchell, A. Papageorgiou, C. Scaethorn, and G. Webb, 3/23/00, (PB2000-106200, A11, MF-A03).

MCEER-00-0002 "Proceedings of the MCEER Workshop for Seismic Hazard Mitigation of Health Care Facilities," edited by G.C. Lee, M. Ettouney, M. Grigoriu, J. Hauer and J. Nigg, 3/29/00, (PB2000-106892, A08, MF-A02).

MCEER-00-0003 "The Chi-Chi, Taiwan Earthquake of September 21, 1999: Reconnaissance Report," edited by G.C. Lee and C.H. Loh, with major contributions by G.C. Lee, M. Bruneau, I.G. Buckle, S.E. Chang, P.J. Flores, T.D. O'Rourke, M. Shinozuka, T.T. Soong, C-H. Loh, K-C. Chang, Z-J. Chen, J-S. Hwang, M-L. Lin, G-Y. Liu, K-C. Tsai, G.C. Yao and C-L. Yen, 4/30/00, (PB2001-100980, A10, MF-A02).

MCEER-00-0004 "Seismic Retrofit of End-Sway Frames of Steel Deck-Truss Bridges with a Supplemental Tendon System: Experimental and Analytical Investigation," by G. Pekcan, J.B. Mander and S.S. Chen, 7/1/00, (PB2001-100982, A10, MF-A02).

MCEER-00-0005 "Sliding Fragility of Unrestrained Equipment in Critical Facilities," by W.H. Chong and T.T. Soong, 7/5/00, (PB2001-100983, A08, MF-A02).

MCEER-00-0006 "Seismic Response of Reinforced Concrete Bridge Pier Walls in the Weak Direction," by N. Abo-Shadi, M. Saiidi and D. Sanders, 7/17/00, (PB2001-100981, A17, MF-A03).

MCEER-00-0007 "Low-Cycle Fatigue Behavior of Longitudinal Reinforcement in Reinforced Concrete Bridge Columns," by J. Brown and S.K. Kunnath, 7/23/00, (PB2001-104392, A08, MF-A02).

MCEER-00-0008 "Soil Structure Interaction of Bridges for Seismic Analysis," I. PoLam and H. Law, 9/25/00, (PB2001-105397, A08, MF-A02).

MCEER-00-0009 "Proceedings of the First MCEER Workshop on Mitigation of Earthquake Disaster by Advanced Technologies (MEDAT-1), edited by M. Shinozuka, D.J. Inman and T.D. O'Rourke, 11/10/00, (PB2001-105399, A14, MF-A03).

MCEER-00-0010 "Development and Evaluation of Simplified Procedures for Analysis and Design of Buildings with Passive Energy Dissipation Systems, Revision 01," by O.M. Ramirez, M.C. Constantinou, C.A. Kircher, A.S. Whittaker, M.W. Johnson, J.D. Gomez and C. Chrysostomou, 11/16/01, (PB2001-105523, A23, MF-A04).

MCEER-00-0011 "Dynamic Soil-Foundation-Structure Interaction Analyses of Large Caissons," by C-Y. Chang, C-M. Mok, Z-L. Wang, R. Settgast, F. Waggoner, M.A. Ketchum, H.M. Gonnermann and C-C. Chin, 12/30/00, (PB2001-104373, A07, MF-A02).

MCEER-00-0012 "Experimental Evaluation of Seismic Performance of Bridge Restrainers," by A.G. Vlassis, E.M. Maragakis and M. Saiid Saiidi, 12/30/00, (PB2001-104354, A09, MF-A02).

MCEER-00-0013 "Effect of Spatial Variation of Ground Motion on Highway Structures," by M. Shinozuka, V. Saxena and G. Deodatis, 12/31/00, (PB2001-108755, A13, MF-A03).

MCEER-00-0014 "A Risk-Based Methodology for Assessing the Seismic Performance of Highway Systems," by S.D. Werner, C.E. Taylor, J.E. Moore, II, J.S. Walton and S. Cho, 12/31/00, (PB2001-108756, A14, MF-A03).

MCEER-01-0001 "Experimental Investigation of P-Delta Effects to Collapse During Earthquakes," by D. Vian and M. Bruneau, 6/25/01, (PB2002-100534, A17, MF-A03).

MCEER-01-0002 "Proceedings of the Second MCEER Workshop on Mitigation of Earthquake Disaster by Advanced Technologies (MEDAT-2)," edited by M. Bruneau and D.J. Inman, 7/23/01, (PB2002-100434, A16, MF-A03).

MCEER-01-0003 "Sensitivity Analysis of Dynamic Systems Subjected to Seismic Loads," by C. Roth and M. Grigoriu, 9/18/01, (PB2003-100884, A12, MF-A03).

MCEER-01-0004 "Overcoming Obstacles to Implementing Earthquake Hazard Mitigation Policies: Stage 1 Report," by D.J. Alesch and W.J. Petak, 12/17/01, (PB2002-107949, A07, MF-A02).

MCEER-01-0005 "Updating Real-Time Earthquake Loss Estimates: Methods, Problems and Insights," by C.E. Taylor, S.E. Chang and R.T. Eguchi, 12/17/01, (PB2002-107948, A05, MF-A01).

MCEER-01-0006 "Experimental Investigation and Retrofit of Steel Pile Foundations and Pile Bents Under Cyclic Lateral Loadings," by A. Shama, J. Mander, B. Blabac and S. Chen, 12/31/01, (PB2002-107950, A13, MF-A03).

MCEER-02-0001 "Assessment of Performance of Bolu Viaduct in the 1999 Duzce Earthquake in Turkey" by P.C. Roussis, M.C. Constantinou, M. Erdik, E. Durukal and M. Dicleli, 5/8/02, (PB2003-100883, A08, MF-A02).

MCEER-02-0002 "Seismic Behavior of Rail Counterweight Systems of Elevators in Buildings," by M.P. Singh, Rildova and L.E. Suarez, 5/27/02. (PB2003-100882, A11, MF-A03).

MCEER-02-0003 "Development of Analysis and Design Procedures for Spread Footings," by G. Mylonakis, G. Gazetas, S. Nikolaou and A. Chauncey, 10/02/02, (PB2004-101636, A13, MF-A03, CD-A13).

MCEER-02-0004 "Bare-Earth Algorithms for Use with SAR and LIDAR Digital Elevation Models," by C.K. Huyck, R.T. Eguchi and B. Houshmand, 10/16/02, (PB2004-101637, A07, CD-A07).

MCEER-02-0005 "Review of Energy Dissipation of Compression Members in Concentrically Braced Frames," by K.Lee and M. Bruneau, 10/18/02, (PB2004-101638, A10, CD-A10).

MCEER-03-0001 "Experimental Investigation of Light-Gauge Steel Plate Shear Walls for the Seismic Retrofit of Buildings" by J. Berman and M. Bruneau, 5/2/03, (PB2004-101622, A10, MF-A03, CD-A10).

MCEER-03-0002 "Statistical Analysis of Fragility Curves," by M. Shinozuka, M.Q. Feng, H. Kim, T. Uzawa and T. Ueda, 6/16/03, (PB2004-101849, A09, CD-A09).

MCEER-03-0003 "Proceedings of the Eighth U.S.-Japan Workshop on Earthquake Resistant Design f Lifeline Facilities and Countermeasures Against Liquefaction," edited by M. Hamada, J.P. Bardet and T.D. O'Rourke, 6/30/03, (PB2004-104386, A99, CD-A99).

MCEER-03-0004 "Proceedings of the PRC-US Workshop on Seismic Analysis and Design of Special Bridges," edited by L.C. Fan and G.C. Lee, 7/15/03, (PB2004-104387, A14, CD-A14).

MCEER-03-0005 "Urban Disaster Recovery: A Framework and Simulation Model," by S.B. Miles and S.E. Chang, 7/25/03, (PB2004-104388, A07, CD-A07).

MCEER-03-0006 "Behavior of Underground Piping Joints Due to Static and Dynamic Loading," by R.D. Meis, M. Maragakis and R. Siddharthan, 11/17/03, (PB2005-102194, A13, MF-A03, CD-A00).

MCEER-03-0007 "Seismic Vulnerability of Timber Bridges and Timber Substructures," by A.A. Shama, J.B. Mander, I.M. Friedland and D.R. Allicock, 12/15/03.

MCEER-04-0001 "Experimental Study of Seismic Isolation Systems with Emphasis on Secondary System Response and Verification of Accuracy of Dynamic Response History Analysis Methods," by E. Wolff and M. Constantinou, 1/16/04 (PB2005-102195, A99, MF-E08, CD-A00).

MCEER-04-0002 "Tension, Compression and Cyclic Testing of Engineered Cementitious Composite Materials," by K. Kesner and S.L. Billington, 3/1/04, (PB2005-102196, A08, CD-A08).

MCEER-04-0003 "Cyclic Testing of Braces Laterally Restrained by Steel Studs to Enhance Performance During Earthquakes," by O.C. Celik, J.W. Berman and M. Bruneau, 3/16/04, (PB2005-102197, A13, MF-A03, CD-A00).

MCEER-04-0004 "Methodologies for Post Earthquake Building Damage Detection Using SAR and Optical Remote Sensing: Application to the August 17, 1999 Marmara, Turkey Earthquake," by C.K. Huyck, B.J. Adams, S. Cho, R.T. Eguchi, B. Mansouri and B. Houshmand, 6/15/04, (PB2005-104888, A10, CD-A00).

MCEER-04-0005 "Nonlinear Structural Analysis Towards Collapse Simulation: A Dynamical Systems Approach," by M.V. Sivaselvan and A.M. Reinhorn, 6/16/04, (PB2005-104889, A11, MF-A03, CD-A00).

MCEER-04-0006 "Proceedings of the Second PRC-US Workshop on Seismic Analysis and Design of Special Bridges," edited by G.C. Lee and L.C. Fan, 6/25/04, (PB2005-104890, A16, CD-A00).

MCEER-04-0007 "Seismic Vulnerability Evaluation of Axially Loaded Steel Built-up Laced Members," by K. Lee and M. Bruneau, 6/30/04, (PB2005-104891, A16, CD-A00).

MCEER-04-0008 "Evaluation of Accuracy of Simplified Methods of Analysis and Design of Buildings with Damping Systems for Near-Fault and for Soft-Soil Seismic Motions," by E.A. Pavlou and M.C. Constantinou, 8/16/04, (PB2005-104892, A08, MF-A02, CD-A00).

MCEER-04-0009 "Assessment of Geotechnical Issues in Acute Care Facilities in California," by M. Lew, T.D. O'Rourke, R. Dobry and M. Koch, 9/15/04, (PB2005-104893, A08, CD-A00).

MCEER-04-0010 "Scissor-Jack-Damper Energy Dissipation System," by A.N. Sigaher-Boyle and M.C. Constantinou, 12/1/04 (PB2005-108221).

MCEER-04-0011 "Seismic Retrofit of Bridge Steel Truss Piers Using a Controlled Rocking Approach," by M. Pollino and M. Bruneau, 12/20/04 (PB2006-105795).

MCEER-05-0001 "Experimental and Analytical Studies of Structures Seismically Isolated with an Uplift-Restraint Isolation System," by P.C. Roussis and M.C. Constantinou, 1/10/05 (PB2005-108222).

MCEER-05-0002 "A Versatile Experimentation Model for Study of Structures Near Collapse Applied to Seismic Evaluation of Irregular Structures," by D. Kusumastuti, A.M. Reinhorn and A. Rutenberg, 3/31/05 (PB2006-101523).

MCEER-05-0003 "Proceedings of the Third PRC-US Workshop on Seismic Analysis and Design of Special Bridges," edited by L.C. Fan and G.C. Lee, 4/20/05, (PB2006-105796).

MCEER-05-0004 "Approaches for the Seismic Retrofit of Braced Steel Bridge Piers and Proof-of-Concept Testing of an Eccentrically Braced Frame with Tubular Link," by J.W. Berman and M. Bruneau, 4/21/05 (PB2006-101524).

MCEER-05-0005 "Simulation of Strong Ground Motions for Seismic Fragility Evaluation of Nonstructural Components in Hospitals," by A. Wanitkorkul and A. Filiatrault, 5/26/05 (PB2006-500027).

MCEER-05-0006 "Seismic Safety in California Hospitals: Assessing an Attempt to Accelerate the Replacement or Seismic Retrofit of Older Hospital Facilities," by D.J. Alesch, L.A. Arendt and W.J. Petak, 6/6/05 (PB2006-105794).

MCEER-05-0007 "Development of Seismic Strengthening and Retrofit Strategies for Critical Facilities Using Engineered Cementitious Composite Materials," by K. Kesner and S.L. Billington, 8/29/05 (PB2006-111701).

MCEER-05-0008 "Experimental and Analytical Studies of Base Isolation Systems for Seismic Protection of Power Transformers," by N. Murota, M.Q. Feng and G-Y. Liu, 9/30/05 (PB2006-111702).

MCEER-05-0009 "3D-BASIS-ME-MB: Computer Program for Nonlinear Dynamic Analysis of Seismically Isolated Structures," by P.C. Tsopelas, P.C. Roussis, M.C. Constantinou, R. Buchanan and A.M. Reinhorn, 10/3/05 (PB2006-111703).

MCEER-05-0010 "Steel Plate Shear Walls for Seismic Design and Retrofit of Building Structures," by D. Vian and M. Bruneau, 12/15/05 (PB2006-111704).

MCEER-05-0011 "The Performance-Based Design Paradigm," by M.J. Astrella and A. Whittaker, 12/15/05 (PB2006-111705).

MCEER-06-0001 "Seismic Fragility of Suspended Ceiling Systems," H. Badillo-Almaraz, A.S. Whittaker, A.M. Reinhorn and G.P. Cimellaro, 2/4/06 (PB2006-111706).

MCEER-06-0002 "Multi-Dimensional Fragility of Structures," by G.P. Cimellaro, A.M. Reinhorn and M. Bruneau, 3/1/06 (PB2007-106974, A09, MF-A02, CD A00).

MCEER-06-0003 "Built-Up Shear Links as Energy Dissipators for Seismic Protection of Bridges," by P. Dusicka, A.M. Itani and I.G. Buckle, 3/15/06 (PB2006-111708).

MCEER-06-0004 "Analytical Investigation of the Structural Fuse Concept," by R.E. Vargas and M. Bruneau, 3/16/06 (PB2006-111709).

MCEER-06-0005 "Experimental Investigation of the Structural Fuse Concept," by R.E. Vargas and M. Bruneau, 3/17/06 (PB2006-111710).

MCEER-06-0006 "Further Development of Tubular Eccentrically Braced Frame Links for the Seismic Retrofit of Braced Steel Truss Bridge Piers," by J.W. Berman and M. Bruneau, 3/27/06 (PB2007-105147).

MCEER-06-0007 "REDARS Validation Report," by S. Cho, C.K. Huyck, S. Ghosh and R.T. Eguchi, 8/8/06 (PB2007-106983).

MCEER-06-0008 "Review of Current NDE Technologies for Post-Earthquake Assessment of Retrofitted Bridge Columns," by J.W. Song, Z. Liang and G.C. Lee, 8/21/06 06 (PB2007-106984).

MCEER-06-0009 "Liquefaction Remediation in Silty Soils Using Dynamic Compaction and Stone Columns," by S. Thevanayagam, G.R. Martin, R. Nashed, T. Shenthan, T. Kanagalingam and N. Ecemis, 8/28/06 06 (PB2007-106985).

MCEER-06-0010 "Conceptual Design and Experimental Investigation of Polymer Matrix Composite Infill Panels for Seismic Retrofitting," by W. Jung, M. Chiewanichakorn and A.J. Aref, 9/21/06 (PB2007-106986).

MCEER-06-0011 "A Study of the Coupled Horizontal-Vertical Behavior of Elastomeric and Lead-Rubber Seismic Isolation Bearings," by G.P. Warn and A.S. Whittaker, 9/22/06 (PB2007-108679).

MCEER-06-0012 "Proceedings of the Fourth PRC-US Workshop on Seismic Analysis and Design of Special Bridges: Advancing Bridge Technologies in Research, Design, Construction and Preservation," Edited by L.C. Fan, G.C. Lee and L. Ziang, 10/12/06 (PB2007-109042).

MCEER-06-0013 "Cyclic Response and Low Cycle Fatigue Characteristics of Plate Steels," by P. Dusicka, A.M. Itani and I.G. Buckle, 11/1/06 06 (PB2007-106987).

MCEER-06-0014 "Proceedings of the Second US-Taiwan Bridge Engineering Workshop," edited by W.P. Yen, J. Shen, J-Y. Chen and M. Wang, 11/15/06.

MCEER-06-0015 "User Manual and Technical Documentation for the REDARS$^{TM}$ Import Wizard," by S. Cho, S. Ghosh, C.K. Huyck and S.D. Werner, 11/30/06 (PB2007-114766).

MCEER-06-0016 "Hazard Mitigation Strategy and Monitoring Technologies for Urban and Infrastructure Public Buildings: Proceedings of the China-US Workshops," edited by X.Y. Zhou, A.L. Zhang, G.C. Lee and M. Tong, 12/12/06.

MCEER-07-0001 "Static and Kinetic Coefficients of Friction for Rigid Blocks," by C. Kafali, S. Fathali, M. Grigoriu and A.S. Whittaker, 3/20/07 (PB2007-114767).

MCEER-07-0002 "Hazard Mitigation Investment Decision Making: Organizational Response to Legislative Mandate," by L.A. Arendt, D.J. Alesch and W.J. Petak, 4/9/07(PB2007-114768).

MCEER-07-0003 "Seismic Behavior of Bidirectional-Resistant Ductile End Diaphragms with Unbonded Braces in Straight or Skewed Steel Bridges," by O. Celik and M. Bruneau, 4/11/07.

MCEER-07-0004 "Modeling Pile Behavior in Large Pile Groups Under Lateral Loading," by A.M. Dodds and G.R. Martin, 4/16/07.

MCEER-07-0005 "Experimental Investigation of Blast Performance of Seismically Resistant Concrete-Filled Steel Tube Bridge Piers," by S. Fujikura, M. Bruneau and D. Lopez-Garcia, 4/20/07.

MCEER-07-0006 "Seismic Analysis of Conventional and Isolated Liquefied Natural Gas Tanks Using Mechanical Analogs," by I.P. Christovasilis and A.S. Whittaker, 5/1/07.

MCEER-07-0007 "Experimental Seismic Performance Evaluation of Isolation/Restraint Systems for Mechanical Equipment – Part 1: Heavy Equipment Study," by S. Fathali and A. Filiatrault, 6/6/07.

MCEER-07-0008 "Seismic Vulnerability of Timber Bridges and Timber Substructures," by A.A. Sharma, J.B. Mander, I.M. Friedland and D.R. Allicock, 6/7/07.

MCEER-07-0009 "Experimental and Analytical Study of the XY-Friction Pendulum (XY-FP) Bearing for Bridge Applications," by C.C. Marin-Artieda, A.S. Whittaker and M.C. Constantinou, 6/7/07.

MCEER-07-0010 "Proceedings of the PRC-US Earthquake Engineering Forum for Young Researchers," Edited by G.C. Lee and X.Z. Qi, 6/8/07.

MCEER-07-0011 "Design Recommendations for Perforated Steel Plate Shear Walls," by R. Purba and M. Bruneau, 6/18/07.

MCEER-07-0012 "Performance of Seismic Isolation Hardware Under Service and Seismic Loading," by M.C. Constantinou, A.S. Whittaker, Y. Kalpakidis, D.M. Fenz and G.P. Warn, 8/27/07.

MCEER-07-0013 "Experimental Evaluation of the Seismic Performance of Hospital Piping Subassemblies," by E.R. Goodwin, E. Maragakis and A.M. Itani, 9/4/07.

MCEER-07-0014 "A Simulation Model of Urban Disaster Recovery and Resilience: Implementation for the 1994 Northridge Earthquake," by S. Miles and S.E. Chang, 9/7/07.

MCEER-07-0015 "Statistical and Mechanistic Fragility Analysis of Concrete Bridges," by M. Shinozuka, S. Banerjee and S-H. Kim, 9/10/07.

MCEER-07-0016 "Three-Dimensional Modeling of Inelastic Buckling in Frame Structures," by M. Schachter and AM. Reinhorn, 9/13/07.

MCEER-07-0017 "Modeling of Seismic Wave Scattering for Large Pile Groups and Caissons," by I. Po Lam, H. Law and C.T. Yang, 9/17/07.

MCEER-07-0018 "Bridge Foundations: Modeling Large Pile Groups and Caissons for Seismic Design," by G.R. Martin (Coordinating Author), I. Po Lam and H. Law, 12/1/07.

MCEER-07-0019 "Principles and Performance of Roller Seismic Isolation Bearings for Highway Bridges," by G.C. Lee, Y.C. Ou, Z. Liang, T.C. Niu and J. Song, 12/10/07.

MCEER-07-0020 "Centrifuge Modeling of Permeability and Pinning Reinforcement Effects on Pile Response to Lateral Spreading," by L.L Gonzalez-Lagos, T. Abdoun and R. Dobry, 12/10/07.

MCEER-07-0021 "Damage to the Highway System from the Pisco, Perú Earthquake of August 15, 2007," by J.S. O'Connor, L. Mesa and M. Nykamp, 12/10/07.

## ▲ *Acknowledgements*

This report was prepared by MCEER through a contract from the Federal Highway Administration. Neither MCEER, associates of MCEER, its sponsors, nor any person acting on their behalf:

a. makes any warranty, express or implied, with respect to the use of any information, apparatus, method, or process disclosed in this report or that such use may not infringe upon privately owned rights; or
b. assumes any liabilities of whatsoever kind with respect to the use of, or the damage resulting from the use of, any information, apparatus, method, or process disclosed in this report.

Any opinions, findings, and conclusions or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the views of MCEER, the Federal Highway Administration, or other sponsors.

MCEER
EARTHQUAKE ENGINEERING TO EXTREME EVENTS
University at Buffalo, The State University of New York
Red Jacket Quadrangle ▪ Buffalo, New York 14261
Phone: (716) 645-3391 ▪ Fax: (716) 645-3399
E-mail: *mceer@buffalo.edu* ▪ WWW Site *http://mceer.buffalo.edu*
University at Buffalo *The State University of New York*

ISSN 1520-295X