SIGNIFICANT ASPECTS OF GEOTECHNICAL AND SEISMIC ENGINEERING AND MANAGEMENT OF BRIDGES AND STRUCTURES IN THE U.S.

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Abstract

It is important to integrate the knowledge and experience of geotechnical and seismic engineering and management of bridges to make sound decisions to reduce earthquake damages to highways, bridges and structures. Research continues to play important roles in developing modern bridge seismic design criteria, detailing practices and seismic retrofit strategies for reducing structural damages and casualties. Bridge management systems can be used effectively to incorporate seismic assessment data for prioritizing seismic retrofit needs.

Introduction

Major earthquakes, such as the 1964 Alaska Earthquake, Anchorage, Alaska; the 1989 Loma Prieta Earthquake, California; the 1994 Northridge Earthquake, California; the 1995 Kobe Earthquake, Japan; and so on, have taken thousands of lives, caused billions of dollars in damages, and incurred other indirect costs as a result of damage to bridges and structures, highways, and other public facilities. It is necessary to integrate the knowledge and experience in geotechnical and seismic engineering, and the management of bridges and structures, and other public facilities to mitigate seismic hazards.

The important seismic hazards are strong ground shaking, ground failures (such as, liquefaction, lateral spread, differential settlement, landslides), soil-structure interaction, and other indirect effects caused by ground shaking and failures, such as, tsunamis, seiches, floods and fires. The engineers and code writers must take these seismic hazards into account in developing earthquake-resistant design, construction and management.

Seismologic and Geologic Aspect of Earthquakes

When an earthquake occurs, seismic waves traveled from the source to the earth's surface through body waves and surface waves. The body waves travel through the interior of the earth in the form of P-waves and S-waves. The P-waves or compressional waves shake the earth back and forth in the direction the waves are moving. The S-waves or shear waves shake the earth back and forth perpendicular to the direction the waves are moving. The S-waves cause shear deformations in the materials through which they travel. The surface waves travel near the earth's surface in the form of Rayleigh waves and Love waves. Rayleigh waves cause the ground to shake in an elliptical motion with no transverse of perpendicular motion. Love waves cause the ground to shake in a horizontal motion that is transverse or perpendicular to the direction the waves are traveling. These waves cause seismic hazards directly or indirectly to bridges and structures and other facilities.

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Predicting the nature – size, intensity, duration, location – of an earthquake, and the accompanying amplitude and frequency content of the seismic waves are very complex. Currently there is no method that can predict ground motion of an earthquake accurately. Seismologists use historical records of past earthquakes predict or forecast future earthquakes. However, historical records of earthquakes in the United States are barely over 300 years. In recent years, the U.S. Geological Survey (USGS) in collaboration with other agencies has installed strong-motion instruments across the country, especially in high seismicity regions. The California Division of Mines and Geology installs and operates an extensive array of strong-motion instruments across the state. Several states have installed instruments in bridges and structures.

The USGS now publishes strong-motion records from North American earthquakes from 1933 through 2002. USGS also produces national maps of seismic hazards. The latest map was published in 2002. The maps which are of most interest to the engineers are the peak ground accelerations (PGA) with 10% probability of exceedance in 50 years. USGS can prepare page-sized seismic hazard maps of other accelerations and probabilities on request.

Estimating Earthquake Magnitude and Duration

Earthquakes occur on faults. A fault is a thin zone of crushed rock between two tectonic plates. It can also be a fracture within a tectonic plate or in the crust of the earth where rocks move relative to one another. A fault can be of any length, from inches to thousands of miles. Active faults move at an average of a fraction of an inch to 4 inches per year. For example, the Juan de Fuca plate is subducting beneath the North American plate along the Cascadia Subduction Zone off the coast of Washington State at a rate of 1.2 to 1.6 inches per year. When the rock on one side of a fault suddenly slips with respect to the other, energy is released abruptly, causing ground motions that shake bridges and structures. Larger rupture length results in larger earthquake magnitude. For example, the San Andreas Fault in California has a length of over 650 miles (1046 km), extending to a depth of more than 10 miles (16km). It has been the source of many large earthquakes, including the famous 1906 San Francisco earthquake, which had a magnitude 8.3 on the Richter Scale.

The following table gives an approximate relationship between earthquake magnitude and length of fault that has slipped.

Magnitude	Length of Slipped Fault (miles)
8.8	1,000 (1,600 km)
8.5	530 (853 km)
8.0	190 (306 km)
7.0	25 (40 km)
6.0	5 (8 km)
5.0	2.1 (3.4 km)
4.0	0.83 (1.3 km)

Several investigators had studied the influence of earthquake magnitude on the duration of strong motion. Duration of shaking is influenced by earthquake magnitude because shaking is likely to continue at least as long as rupture propagates along the fault. Housner presents values for the maximum acceleration and the duration of shaking for different earthquake magnitude as summarized in the following table:

Magnitude	Maximum Acceleration (%g)	Duration (second)
8.5	50	37
8.-0	50	34
7.5	45	30
7.0	37	24
6.5	29	18
6.0	22	12
5.5	15	6
5.0	9	2

Seismicity In The U.S.

The seismicity in the U.S. is shown in the following map. All or parts of 40 states are in earthquake risk zones!

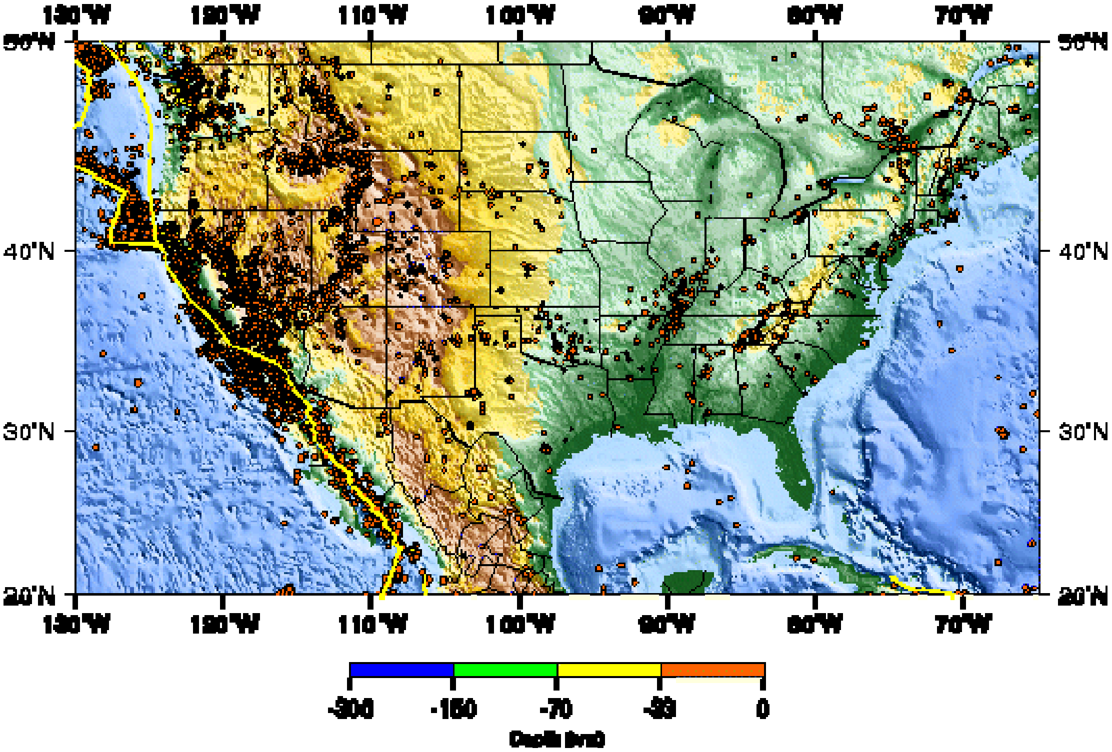

Figure 1 Seismicity in the United States

The earthquake characteristics vary from region to region. An understanding of these characteristics can help develop better design provisions, seismic retrofits and overall earthquake risk mitigation. Brief descriptions of representative earthquakes of the various regions are given below.

Earthquakes of California

California is the most seismically active state in the United States. In the past 100 years, there were more than 120 large earthquakes with Richter magnitude 6.0 or greater, including the largest Great 1906 San Francisco Earthquake with magnitude 8.2 and the most recent October 16, 1999 Hector Mine Earthquake with magnitude 7.1. California is a full-sized field laboratory for the testing and study of seismic resistant designs. The bridge engineering community owes it to California for the big strides in advancing the state-of-the-knowledge in earthquake engineering and seismic risk reduction in the highway bridges.

Three large earthquakes in California are of particular significance to the bridge engineering community. These are the 1971 San Fernando Earthquake, the 1989 Loma Prieta Earthquake and the 1994 Northridge Earthquake. Case histories on the performance of highway steel bridges in these three earthquakes of bridge engineering importance will be reviewed and discussed in the following sections.

1971 San Fernando Earthquake

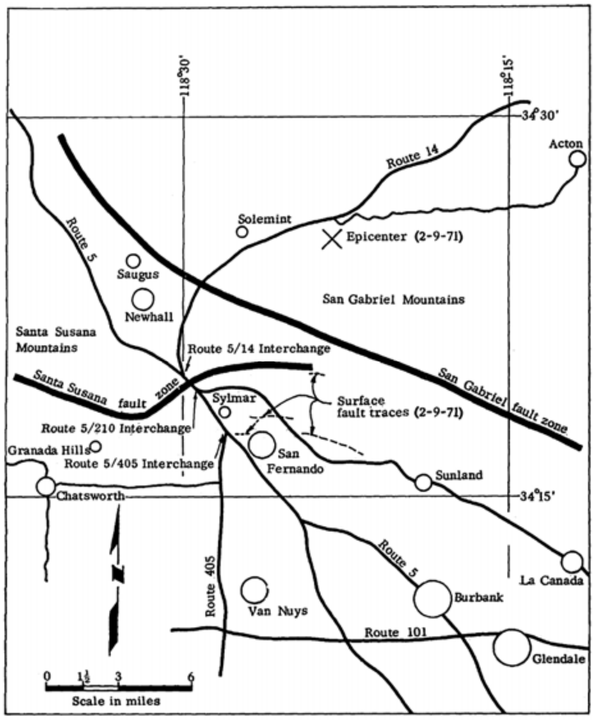

Figure 2 San Fernando Earthquake

The February 9, 1971 San Fernando Earthquake shook up the residents of the Los Angeles area at 6:00 a.m. with a Richter magnitude of 6.5. After about 12 seconds of strong shaking, the damages amounted to over 60 deaths, over 2,400 injuries and over $500 million of structural and property damages. The greatest casualty occurred at the collapses of the Veterans Administration Hospital in the foothills of the San Fernando Valley. Faulting, ground fracturing and landslides were responsible for the extensive damage in highway overpasses, railroads, pipelines and other structures. The main shock of the San Fernando Earthquake was felt over approximately 80,000 square miles of California, Nevada and Arizona. The earthquake occurred at the center of the largest concentration of strong-motion recording instruments in the United States Cooperative Network. As a result, more records of engineering significance were obtained during this one earthquake than during the previous 39-year history of the recording programs. The benefits derived from the applications of these data to earthquake and structural engineering are still evident today.

The 1971 San Fernando Earthquake provided the impetus for revising building codes, improving seismic resistant bridge design specifications and developing strategies for seismic retrofit of existing bridges.

1989 Loma Prieta Earthquake

The October 17, 1989 Loma Prieta Earthquake with a magnitude 7.1 disrupted 62,000 fans who filled the Candlestick Park for the third game of the World Series. The earthquake struck at 5:04 p.m., Pacific daylight saving time. The epicenter was located about 10 miles (16 km) northeast of Santa Cruz along a segment of the San Andreas Fault, near Loma Prieta in the Santa Cruz Mountains. The 20-second earthquake was centered about 60 miles (97 km) south of San Francisco, and was felt as far away as San Diego, western Nevada and Oregon State line. It was the largest to occur in the San Francisco Bay area since the great San Francisco Earthquake of April 1906. The Loma Prieta Earthquake caused over 62 deaths, over 3,700 injuries, over $6.0 billion of property damage and widespread disruption of transportation, utilities and communications.

Two of the most dramatic impacts of the earthquake were the collapse of the elevated Cypress Street section of Interstate 880 in Oakland, and the drop of the link span of the San Francisco-Oakland Bay Bridge. Both of these structures were located about 60 miles from the epicenter.

1994 Northridge Earthquake

The January 17, 1994 Northridge Earthquake woke up residents in the greater Los Angeles area at 4:31 a.m., Pacific Standard Time, with a Richter magnitude of 6.7. After 20 seconds of shaking, the death toll was over 65 and over 5,000 people were injured, some seriously. Property damage was estimated in the range of $15 to $30 billion. This earthquake was the most costly single natural disaster in the history of the United States.

The epicentral region was the same area that had rocked the San Fernando Valley in the 1971 San Fernando Earthquake as shown in Fig. 2. Northridge is about 20 miles northwest of downtown Los Angeles and is within the suburban San Fernando Valley, which is a sprawling region of residential neighborhoods, apartment complexes, low-rise business and industrial parks, and shopping malls. Fortunately, the earthquake occurred in the early morning and on a holiday. The effects of the earthquake were dramatically reduced from what they could have been.

The earthquake occurred in one of the well-prepared regions in the United States. Most of the structures in the affected area were built during the past three decades, and were considered to be reasonably earthquake resistant. The percentage of structures totally destroyed by the strong ground motion was very small, and most of the serious damage occurred within about 10 miles (16 km) of the epicentral area.

1964 Alaska Earthquake

The Alaska Earthquake of March 27, 1964 with a magnitude of 8.4 has been classified as among the world's great earthquakes recorded. These great earthquakes include:

The 1906 San Francisco Earthquake with magnitude 8.2
The 1923 Tokyo Earthquake with magnitude 8.2
The 1960 Chile Earthquake with magnitude 8.5
The 1964 Alaska Earthquake with magnitude 8.4
The 1976 Tangshan, China Earthquake with magnitude 8.2

The epicenter of the main shock of the Alaska Earthquake was at the north shore of Prince William Sound about 80 miles (129 km) east of Anchorage. The focal depth was estimated at about 12 miles (19 km). The ground movement along the fault was apparently vertical, with the southeast side moving upward and the northwest side downward. This earthquake was unique not only of its large magnitude but also its damage zone of 50,000 square miles and its duration of 3 to 4 minutes.

Anchorage, Valdez, Cordova, Kodiak, Seward and Whittier were the hardest hit communities. Seismic sea wave damage was heavy in these cities. Many highway and railway bridges, mostly of timber construction, between Anchorage and Seward were destroyed. The earthquake triggered avalanches and landslides, which caused extensive damage to shorelines, buildings and other facilities. The strong and long ground shaking caused severe damage to tall or massive structures. Dwellings and small buildings generally escaped significant vibration damage.

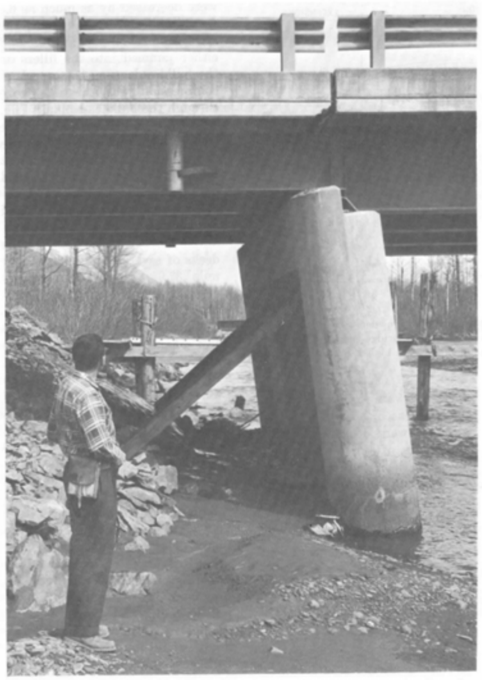

Figure 3 Damage from land spreading

All the major highways and secondary roads in South Central Alaska were seriously affected. About 186 (299 km) of 830 miles (1336 km) of roadway and 141 of 204 bridges in the area were damaged. Repairing and replacement cost was estimated to total more than $46 million.

1949 Olympia Puget Sound Earthquake

The Olympia Puget Sound earthquake occurred at 11:55 a.m. Pacific Standard Time on April 13, 1949. With a magnitude of 7.1, the epicenter of this earthquake was located between Olympia and Tacoma, along the southern edge of Puget Sound (See Figure). The focal depth of the earthquake was about 37 miles (60 km). The ground shaking lasted approximately 25 seconds. The area that felt the earthquake extended eastward to western

Montana and southward to Cape Blanco, Oregon, Idaho, and a large portion of Western Canada, covering about 150,000 square miles.

Property damage in Olympia, Tacoma, and Seattle was estimated at $25 million. Eight people were killed and many were injured.

. In Olympia, nearly all the large buildings were damaged to some extent. Falling parapet wall, toppled chimneys, and cracked walls caused heavy property damage. A large portion of the industrial area on man-made land extending out into Puget Sound north of Olympia disappeared during the earthquake.

In Tacoma, about 30 miles (48 km) north of Olympia, many chimneys were knocked to the ground and numerous buildings were damaged. The Tacoma Narrows Suspension Bridge was under construction at that time. A 23-ton cable saddle of the bridge was thrown from the top of the tower into the water below.

In Seattle, houses on filled ground were demolished, many old brick building were damaged, and chimneys toppled. Bascule bridges and lift bridges crossing the Duwamish Waterway at Spokane Street were closed, due to jamming of the mechanical systems resulting from displacement of the supporting abutments. In Tacoma, the Eleventh Street lift bridges across Puyallup and City waterways were knocked out of order by the earthquake. Minor repair was necessary to bring the bridges back into operation.

There was no structural damage to highway bridges.

1965 Seattle Puget Sound Earthquake

On April 29, 1965, at 8:29 a.m., Pacific Daylight Saving Time, the Puget Sound, Washington, region was shaken by the second largest known to have occurred in the area since 1833. The magnitude 6.5 earthquake was centered at 13 miles (21 km) southeast of downtown Seattle. The focal depth of the earthquake was about 37 miles (60 km). It was felt over an area of approximately 130,000 square miles of the western United States and British Columbia, Canada. Three persons were killed from falling debris, three died apparently from heart attacks, and numerous injuries occurred. The property loss was estimated at $12.5 million.

The damage pattern from this earthquake resembled that of the 1949 shock, although the 1949 event was more destructive. Some buildings that had been damaged in 1949 but left unrepaired and some inadequately repaired buildings, sustained additional or repeated damage. Buildings having unreinforced brick bearing walls with sand-lime mortar were damaged most severely and also provided the maximum hazard from falling materials. Performance of wood frame dwellings was excellent with the exception of damage to split-level type construction where differences in stiffness occurred and where large openings reduced lateral building restraint. The damage where occurred was confined mainly to cracks in plaster or to the failure of unreinforced brick chimneys that attached to the side of house. Most major commercial structures and high-rise buildings in the urban areas had only minor or no damage.

In the industrial area, where buildings were situated on sites of hydraulic fill or deep alluvium, damage was caused by the development of incipient liquefaction and settlement, as well as through ground shaking. In some cases, waterfront structures experienced substantial lateral shifting.

In Olympia damage to capitol buildings were severe particularly to the dome of the State Capitol and to the older structures in the capitol complex. A number of bridges were closed temporarily due to slight damage. A major movable span on the Spokane Street viaduct could not be opened for boat traffic because of bent interlocking pins. The 14th Avenue South drawbridge across the Duwamish River had some pier damage. Navy officials closed the Magnolia Bridge to traffic because of damage to the underside of the structure. Both of the Southwest Spokane Street bridges were jammed shut when the shock threw them out of line. Shipping up the Duwamish Waterway was halted. Eastbound lanes of a drawbridge across the Duwamish Waterway were closed to all traffic except transit coaches because of a drop in the road level due to soil subsidence.

There was no structural damage to highway bridges.

The New Madrid Earthquakes

In the early morning hours of December 16, 1811, the 400 residents in the town of New Madrid, Missouri were awaken by violent shaking and a tremendous roar. This was the first of three powerful earthquakes of magnitude 8 and thousands of aftershocks to rock the Mississippi River Valley. The earthquake was so strong that it also awaken people in cities as distant as Pittsburgh, Pennsylvania, Norfolk, Virginia. The two severe earthquakes that followed the December 16 earthquake occurred on January 23, 1812 and February 7, 1812. Based on newspaper accounts of damage to structures, the February 7 earthquake was the biggest of the three.

In the Mississippi and Ohio River valleys the earthquakes devastated an area which is now the southeast part of Missouri, the northeast part of Arkansas, the southwest part of Kentucky, and the northwest part of Tennessee. . Damage was reported in an area as large as 230,000 square miles. The earthquakes were felt over an area of 1,900,000 square miles.

Uplift of over 9 feet (3 m) was reported at one locality where a lake formed by the St. Francis River had its water replaced by sand. Large fissures were formed in the soft alluvial ground. The earthquakes made previously rich prairie land unfit for farming, because of deep fissures, land subsidence which converted good fields to swamps, and numerous sand blows which covered the ground with sand and mud.

Some of the most dramatic effects of the earthquakes occurred along rivers. Entire islands disappeared, banks caved into the rivers, and fissures opened and closed in the river beds. Water spouting from these fissures produced large waves in the river. Many boats were capsized.

The Charleston, South Carolina Earthquake

The Charleston earthquake is the most damaging earthquake to occur in the Eastern United States. It started with a barely perceptible tremor at 9:51 p.m., local time, on Sunday, August 31, 1886 and then a sound like a heavy metal body rolling along. The sound became a roar and then all movable objects began to shake and rattle for 35 to 40 seconds. A strong aftershock occurred 8 minutes later. Six additional shocks followed during the next 24 hours. Very few buildings in the city of Charleston escaped damage from the strong shaking of the earthquakes with the initial shock estimated at a magnitude of 7.0. Many buildings were totally destroyed. Chimneys of at least 14,000 houses were destroyed in Charleston.

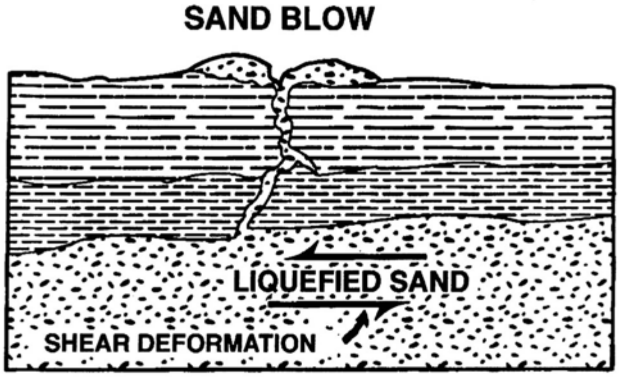

Figure 4 Sand Blow

An estimated 60 persons were killed by falling buildings and many more were injured. Many lost their lives from falling chimneys or walls, when they rushed out of the houses in panic. Property damage was estimated at $23 million. Structural damage was reported hundreds of miles from Charleston, including central Alabama, central Ohio, eastern Kentucky, southern Virginia, and western West Virginia. The long-period effects were observed at distances exceeding 600 miles (966 km). The total area affected by this earthquake covered more than 2,000,000 square miles and included distant points such as New York City, Boston, Milwaukee in the United States, and Havana, Cuba, and Bermuda. All or parts of 30 states and Ontario, Canada, felt the principal earthquake.

Sand blows are formed during strong ground shaking, when the pore water pressure in saturated, loose sand increases until the sand loses its shear strength and acts like liquid, finally erupting to the ground surface through fissures. (See Fig. 4)

Railroad tracks were damaged, including lateral and vertical displacement of tracks, formation of S-shaped curves and longitudinal movement. The formation of sand craterlets and the ejection of sand (sand blows) were widespread. Many acres of ground were overflowed with sand, and craterlets as much as 20 feet (7 m) across were formed. Water from the craterlets spouted to heights of about 15 to 20 feet (5 to 7 m). Fissures over 3 feet wide extended parallel to canal and stream banks. Large trees were uprooted.

At Summerville, a small town 15 miles (24 km) northwest of Charleston, many houses settled in an inclined position or were displaced as much as a couple of inches. Many chimneys were crushed at their bases, allowing the whole chimney to sink down through the floors. The absence of overturning in piered structures and the nature of the damage to chimneys led to the interpretation that the predominant motion was vertical.

There was no written report on the damage of bridges.

Lessons From Earthquakes

The engineering community learned some very valuable lessons from the 1971 San Fernando Earthquake in California. Over 60 bridges on the Golden State Freeway suffered major damages with some collapsed spans. The spans collapsed because of inadequate support widths at the in-span hinges and at supports over the piers. Many columns with inadequate capacity and confinement reinforcement suffered severe cracking, spalling and loss in axial capacity, resulting in excessive deformation or collapse. Soon after this earthquake, California initiated a program to upgrade seismic design and retrofit. California also started new research to develop procedures and specifications for seismic design, analysis and retrofit. Several other State DOT's with high seismicity also began to change their seismic design practices to make bridges more earthquake resistant. A national effort was also launched to perform research and study to develop a national seismic code.

The October 1989 Loma Prieta earthquake, the January 1994 Northridge earthquake, the January 1995 Kobe earthquake, the August 1999 Turkey earthquake, and the September 1999 Taiwan earthquake confirmed that bridges with in-span hinges, with narrow support widths over the piers and with inadequate confinement reinforcement and shear capacity in the columns are highly susceptible to major damage and collapse. These earthquakes also showed that bridges designed in accordance with the current criteria generally performed well with relatively minor damage, and bridges retrofitted to meet current retrofit philosophy and techniques performed well.

AASHTO Seismic Design Specifications

Prior to the 1971 San Fernando Earthquake, the American Association of State Highway and Transportation Officials (AASHTO) specifications for the seismic design of highway bridges were based on the lateral force requirements for buildings developed by the Structural Engineers Association of California. In 1972, California Department of Transportation (CALTRANS) introduced the Acceleration Response Spectra (ARS) for stiff soils and alluvium. ARS establish the attenuation relationships between peak bedrock accelerations and peak ground accelerations (PGA). PGA are the accelerations that translate into forces on the bridge foundations. In 1973, CALTRANS introduced new seismic design criteria and Phase 1 of the Bridge Seismic Retrofit Program. The new seismic design criteria included the relationship of the site to active faults, the seismic response of the soils at the site and the dynamic response characteristics of bridges.

In 1975, AASHTO adopted Interim Specifications, which were a slightly modified version of the 1973 CALTRANS Seismic Design Specifications, and made them applicable to all regions of the United States. In the same year, FHWA engaged Applied Technology Council to develop nationally applicable guidelines for the seismic design of bridges. These guidelines were completed in 1981 under Project ATC-6.

AASHTO subsequently adopted the ATC-6 guidelines and published a set of Guide Specifications in 1983. These guidelines lay the groundwork for a modern, comprehensive bridge seismic design specifications. These guidelines gave the bridge designers better analysis tools for determining earthquake forces necessary to properly design and detail seismic resistant bridges. Highway bridges designed, analyzed and detailed in accordance with these guidelines are expected to withstand design earthquakes of up to magnitude 7.5 for Zone 3 without collapse or major damage while maintaining function of essential bridges. In 1991, AASHTO made and incorporated the guidelines as a part of the Standard Specifications for Highway Bridges, subsequently known as the Division I-A, Seismic Design of the AASHTO Standard Specifications for Highway Bridges. The same general seismic provisions were included in the AASHTO LRFD Bridge Design Specifications.

In 1998, AASHTO initiated NCHRP Project 12-49 Comprehensive Specification for the Seismic Design of Bridges to update the LRFD seismic provisions, which are based on seismic hazard, design criteria and detailing practices that are 10 to 20 years old. The main objective of NCHRP Project 12-49 was to develop a nationally applicable seismic design specification addressing design philosophy and performance criteria, seismic loads and site effects, analysis and modeling, and design requirements. The research was performed and completed by a joint venture of the Applied Technology Council (ATC) and the Multidisciplinary Center for Earthquake Engineering Research (MCEER). At the end of this study, AASHTO further engaged ATC/MCEER to develop an AASHTO document titled “Recommended LRFD Guidelines for the Seismic Design of Highway Bridges” based on the findings and recommendations of NCHRP Project 12-49.

In 2002, the AASHTO Technical Committee T-3 on Seismic Design submitted the “Recommended LRFD Guidelines for the Seismic Design of Highway Bridges” (Guidelines) to the AASHTO Highway Subcommittee on Bridges and Structures (SOBS) for adopted. However, some members of SOBS were concerned about the impact on the Mid-America States. As a result, AASHTO has initiated NCHRP 12-7/Task 193 to address the issues raised at the SOBS Committee Meeting and develop new guidelines for seismic design. The project is ongoing and the new guidelines are expected to be completed at the end of 2005 and submitted to SOBS for adoption in the 2006 Annual

FHWA Seismic Research Program

FHWA has been a very active partner in Seismic Research, Development, Deployment and Education. Some recent completed and on-going research projects are shown below:

- New Highway Construction Design Criteria – completed in 1999. This research consisted of impact assessment, which formed the basis for new design criteria and specifications, and synthesis studies, which reviewed seismic vulnerability and state-of-the-practice.
- Existing Highway Construction Retrofit Manuals:
  - Seismic Retrofitting Guidelines for Highway Bridges (FHWA Report 83/007)
  - Seismic Retrofitting Manual for Highway Bridges (FHWA Report 94-052)

    - Seismic Retrofitting Manual for Steel Truss Highway Bridges (work in progress). This manual follows the same assessment methodology presented in other published seismic retrofitting manuals. Every component of a truss will go through a staged assessment – screening, evaluation, and retrofit.
- Seismic Isolation Manual for Highway Bridges (Completed in 2004). This manual summarizes the state-of-the-practice of seismic isolation, and provides guidance and design examples to help the bridge designers.

Emergency Response Plan

The major earthquakes in California and around the world have raised the level of seismic awareness in the communities. The citizens are concerned about seismic risk. They deserve to have well prepared emergency response plan to reduce loss of lives and properties in earthquakes. The National Earthquake Hazard Reduction Program (NEHRP) has provided resources and leadership in understanding the components of earthquake risk and have yielded many useful tools for reducing the risk.

Many States in the U.S. have established Emergency Management Programs to respond to emergency quickly and effectively to reduce loss of lives, properties and commerce.

No one can predict the occurrence or nature of a disaster. It is important that personnel be familiar with emergency response procedures so that the disaster plans can be quickly implemented and updated to meet a specific situation.

Managing The Seismic Risks Of Highway Bridges and Structures

Data from seismic risk assessment through screening, evaluation and retrofit should be integrated into a bridge management system (BMS) to properly manage the seismic risks. The data can be used to make efficient and effective decisions in developing plans for seismic risk reduction, setting priority for seismic retrofit and setting aside resources for emergency preparedness. A BMS can help address questions like: What is the seismic hazard level? What are the seismic reduction needs? What type of seismic retrofit work should be performed? What is the impact of deferring work? Which bridges should be retrofitted first? What is the resource need?

Several bridge management systems (BMS) are used by the states. However, PONTIS is by far the most popular BMS software - being used by over 40 states, counties and cities, and a few international users. PONTIS was developed under the sponsorship of FHWA in the early 1990's. PONTIS is an AASHTOWare and can be licensed through AASHTO. Training for PONTIS may be arranged through the National Highway Institute (NHI)

Closing Remarks

The principal ways in which earthquakes cause damage are by strong ground shaking; and by the secondary effects of ground failures, such as surface rupture, ground cracking, landslides, liquefaction, uplift and subsidence. The focus of earthquake risk mitigation should be to develop seismic design criteria, retrofit plans, emergency response program and use bridge management systems to make sound decisions in reducing seismic risks.

It takes resources and the cooperative efforts of the citizens, city, county, state and federal governments to safeguard against major structural failures, loss of lives and property, and to maintain commerce. Regular review of emergency response plan, drills and exercises are important to keep the people in a state of earthquake preparedness. Nobody knows when and where the next BIG ONE will hit.

Modern seismic specifications and retrofits are effective. We must research, develop and implement seismic retrofit programs to reduce seismic vulnerability of older bridges and structures.