CLOSING THE GAP
IN THE RACE TO SEISMIC SAFETY

Submitted to the Director
California Department of Transportation

by the
Caltrans Seismic Advisory Board

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EXECUTIVE SUMMARY

Following the 1989 Loma Prieta Earthquake, the California Department of Transportation (Caltrans) established the Caltrans Seismic Advisory Board (Board) to provide advice on seismic safety policy as it applies to the design of transportation structures in California. The Board published two landmark reports on the seismic performance of transportation structures in California during the 1989 Loma Prieta and the 1994 Northridge Earthquakes [1,2], and included recommendations on steps to be taken to improve their future performance and safety. In 2003, the Board released a third report titled *The Race to Seismic Safety* [3] that documented the accomplishments and advances made by Caltrans since 1989. It also provided guidance for resolving outstanding performance and safety issues in order to achieve acceptable levels of seismic response in future earthquake events. This report made seven recommendations to help Caltrans achieve this goal.

In 2008 the Board asked Caltrans to conduct a self-assessment on progress towards completing these seven recommendations. The results of this self-assessment are contained in a report titled "*Progress on the Race to Seismic Safety in California"* [Appendix I], published in August 2009. The Board's response to this self-assessment is presented in this report.

It is the opinion of the Board that Caltrans has made significant progress towards completing these recommendations, and the State and its transportation structures are better prepared today to face a major earthquake than seven years ago, when *The Race to Seismic Safety* [3] was published. However, the race continues and Caltrans must remain committed to the improvement of the seismic safety of California's highway transportation system.

This report presents an overall assessment and comments on progress in each of the seven areas, and concludes with a number of specific recommendations that are intended to further Caltrans' expertise and effectiveness in the race to seismic safety.

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INTRODUCTION

In 2003, after extensive review of current and past Caltrans bridge seismic design practices and accomplishments, the Seismic Advisory Board made seven recommendations to help California achieve a seismically safe transportation system. The seven recommendations were published in "*The Race to Seismic Safety"* [3] and are related to the following topics:

1. Seismic safety policy
2. Non-state-owned bridge retrofits
3. Design standards
4. Regular safety reassessment
5. Toll bridge seismic safety program
6. Problem-focused investigations
7. Emergency response

In 2008 the Board asked Caltrans to conduct a self-assessment on progress towards completing these seven recommendations. The results of this self-assessment are contained in *Progress on the Race to Seismic Safety in California*, which is reproduced in Appendix I to this Report. The Board's response to this self-assessment is given in the following sections.

Section 1

SEISMIC SAFETY POLICY

The California Legislature should establish as State policy the current Caltrans practice - to the maximum extent feasible by present earthquake engineering practice - to build, maintain, and rehabilitate highway and transportation structures so that they provide an acceptable level of earthquake safety for users of these structures.

Figure 1-1. *Traffic management and safety during the seismic retrofit and reconstruction of the West Approach to the Bay Bridge that required un-interrupted traffic operations for the ~ 280,000 daily Bay Bridge crossings.*

1. SEISMIC SAFETY POLICY

1.1 General

Ever since the 1989 Loma Prieta and 1994 Northridge Earthquakes, Caltrans has vigorously pursued the implementation of Governor Deukmejian's Executive Order D-86-90. Under this order Caltrans has improved the performance and life-safety of the State's transportation structures and the Board commends Caltrans for its proactive project delivery in seismic safety. While the State-owned bridge inventory (about one-half of all bridges in California) has been screened, reviewed, and where necessary retrofitted to date (with a few exceptions that are close to completion) in response to the Executive Order, the other half, namely Local Agency-owned bridges are in various stages of completion (See Section 2) and require a continued commitment to attain full project delivery.

Despite the fact that the State's transportation system is now better prepared than ever to perform well during the next earthquake, it is not clear how the general public is informed about the expected performance of the system during and after the next major seismic event. Caltrans needs to communicate to the general public what the retrofit program to date entailed and what can be expected from the State's transportation structures in future earthquakes, in particular in urban areas with dense population.

Caltrans provides oversight and assistance to the Local Agency Program and the Board believes that this assistance could be strengthened by appropriate policy aimed at reaching the stated seismic performance and safety goals as expeditiously as possible. While the Board understands that Caltrans should not set or influence policy but rather implement it, the Board stands ready to work with the Executive and Legislative State leadership to see if this policy could not be strengthened to emphasize the importance of the State's transportation infrastructure during and after the next major earthquake to protect lives and property and to facilitate post earthquake recovery (See Section 7). Furthermore, the Board does not see any clear policy in place that deals with the safety and functionality of transportation structures owned by other government agencies and private entities, even though these structures have a major impact on public safety and post-earthquake recovery.

1.2 Recommendations

- That Caltrans, in collaboration with the Board, continue to actively engage in a dialogue with Executive and Legislature leaders to stress the importance of a State seismic policy. The Board would like to continue to explore ways to strengthen Executive Order D-86-90 by incorporating it into State law or by equivalent legislative action that would provide the highest priority to seismic safety projects.

- That Caltrans clarifies the existence and extent of the Department's mandated oversight over non-state-owned transportation structures (such as railroad bridges, bridges that

do not cross a Caltrans' right-of-way, the planned High Speed Rail and other transportation structures) that could impact recovery after a major seismic event.

- That Caltrans maintains on its staff highly trained and experienced professionals that can interact with the State Government and continue to provide leadership, oversight, and expertise to translate policy into effective guidelines, criteria, and procedures for seismic safety project delivery to the highest technical standards.

- That Caltrans embarks on an informational campaign to educate the general public as to its guiding policies, what their implementation entails, and what the general public can expect from the performance of the State's transportation infrastructure during and following the next seismic event in California.

- That Caltrans maintains a stable funding source for pro-active problem-focused seismic performance research for all transportation structures and systems (See Section 6).

Section 2

NON-STATE-OWNED BRIDGE SEISMIC RETROFITS

The Legislature should provide timetables for the seismic retrofit of non-state-owned bridges so that those bridges requiring retrofit are completed within the next five years. The standards for non-state-owned bridges should be the same as for state-owned bridges.

Figure 2-1. *The Foresthill Bridge, spanning the American River in Placer County near Auburn, is to be retrofitted as part of the Local Seismic Safety Retrofit Program.*

2. NON-STATE-OWNED BRIDGE SEISMIC RETROFITS

2.1 General

Caltrans has been diligent in providing oversight and guidance to the Local Bridge Seismic Retrofit Program (LBSRP), and is working closely with the local agencies on program completion. The Board still has questions as to the extent of the LBSRP with respect to private bridge owners such as railroads, and with respect to other public transportation agencies, such as the California High Speed Rail Authority. There seem to be other transportation structures in the California transportation system that should undergo the same rigorous seismic design, assessment, evaluation and where necessary, retrofit, as Caltrans-owned structures to ensure their functionality and safety following the next earthquake and enable a fast recovery with minimal economic disruption.

2.2 Recommendations

- That Caltrans continues its oversight and assistance with the LBSRP and to work with the Business, Transportation, and Housing Agency, the California Transportation Commission, and local agency partners to ensure that the LBSRP is completed in a timely manner, and to advocate for adequate and stable funding for all remaining projects that are ready for construction.

- That Caltrans works with the local agencies and the general public on performance expectations for the local bridge inventory in moderate and safety-evaluation earthquakes, and on strategies to repair expected damage expeditiously.

- That Caltrans, with the assistance of the Board, continues to seek clarification from the State Government as to the extent of the Department's oversight for the seismic safety of local, private, and other agency-owned transportation structures (See Section 1).

Section 3

DESIGN STANDARDS

Caltrans should maintain its standards for construction and retrofit of bridges and other transportation structures to provide life safety for all structures and functionality for lifeline and other important structures following an earthquake. Further, Caltrans should maintain its current policy that seismic-related design and construction issues be independently reviewed to ensure compliance with these standards. Selective seismic peer reviews should be conducted under policies and procedures reviewed by the Seismic Advisory Board (Board).

Figure 3-1. *Before and after the 1994 Northridge Earthquake. Changes in design standards and details for flared columns were developed and implemented by decoupling the flares to increase the column height between plastic hinges.*

3. DESIGN STANDARDS

3.1 General

Caltrans has long been recognized as a leader in the seismic design, performance assessment, and retrofit of bridge structures. It has successfully maintained this leadership role nationally and internationally through continued problem-focused research, independent design and construction reviews, selected seismic peer review of important projects, as well as oversight by the Board. While it is recognized that new findings, tools, and design concepts are continuously evolving in seismology and earthquake engineering and that insight into structural seismic performance improves with each major earthquake around the world, Caltrans needs to continue to adopt a flexible and streamlined approach that allows new knowledge to be translated into design practice. While seemingly a plethora of new findings are supported in their development by Caltrans and implemented in the form of Memo to Designers (MTD), Seismic Design Criteria (SDC), and Bridge Design Criteria (BDC), all reviewed by numerous designers, experts, and oversight committees and boards, it is important that a clear and transparent system is adopted that allows designers and engineers to determine the current state-of-the-practice, and that updated design criteria are readily available on-line.

3.2 Recommendations

- That Caltrans continues an aggressive seismic research program to ensure that the seismic design standards used by the Department are up-to-date and based on the latest research findings (See Section 6).

- That Caltrans strives to ensure that the results of research are implemented in practice in the shortest possible time in the form of design guidelines and standards.

- That Caltrans remains committed to interaction, involvement, and collaboration with designers, researchers and practitioners at both the national and international levels and supports participation of their seismic design professionals in national and international meetings and conferences.

- That Caltrans develops and updates, on a regular basis, the best practice for the seismic design and assessment of transportation structures in a comprehensive and transparent fashion using state-of-the-art information technology (IT) tools and infrastructure. This should also include a clear statement on the review process to allow assessment of rigor and quality.

- That Caltrans extends its position as one of the foremost seismic design leaders of transportation structures to include not only bridges but also tunnels, retaining structures, geotechnical structures, and elevated rail structures. This is necessary in order to address the seismic performance and safety of not only

individual structures but also entire transportation routes or sectors, and the statewide transportation system.

- That Caltrans continues to develop and implement expedited seismic design and construction techniques that allow for a faster recovery from a major seismic event.

Section 4

REGULAR SAFETY ASSESSMENT

Caltrans should regularly reassess the seismic hazard and engineering performance of bridges, including existing, retrofitted, and new structures. Caltrans should determine, as measured by the then-current state of knowledge, whether bridges and transportation structures can be expected to perform in an acceptable manner under earthquake shaking.

Figure 4-1. *The Dumbarton Bridge, on State Route 84 between San Mateo and Alameda Counties, is to be retrofitted to improve its seismic performance following a peer reviewed assessment by BATA and Caltrans.*

4. REGULAR SAFETY ASSESSMENT

4.1 General

Prompted by the 1971 San Fernando Earthquake and reinforced by lessons learned in subsequent major seismic events, Caltrans implemented a comprehensive multi-phase bridge assessment and retrofit program to ensure that all bridges in California meet a life-safety (no-collapse) performance level. Furthermore, important bridges are required to meet a higher performance level, such as post-earthquake functionality for emergency or even normal traffic. While this multi-phase assessment and retrofit program is nearing completion and the Local Agency and the Toll Bridge programs are in their final stages, new findings in seismology, geotechnical and earthquake engineering need to be continuously reassessed and applied, if appropriate, to transportation structures and systems to ensure their adequate performance.

4.2 Recommendations

- That Caltrans develops a roadmap for a comprehensive, continuous performance review and re-assessment of the State's inventory of transportation structures in light of new findings and research results in earthquake engineering. This requires not only a dedicated and highly trained staff of qualified professionals, but also a firm funding commitment to perform this re-assessment and to implement practical outcomes.

- That Caltrans develops a similar seismic performance re-assessment strategy for local, private and other public agency-owned bridges, and work with these agencies to develop funding mechanisms for this continuous review and upgrade.

- That Caltrans extends this re-assessment review to transportation structures other than bridges, such as tunnels, retaining structures, geotechnical structures, and rail structures.

- That Caltrans investigates new funding opportunities for the above seismic re-assessment and upgrade program. Current funding through the State Highway Operation and Protection Plan (SHOPP) is inadequate since this Plan is seriously underfunded at only 19% of identified needs and is over-committed. It is preferable not to place seismic safety issues in competition with maintenance issues, but rather have separate designated funding. If this is not possible, seismic issues should have clear priority over maintenance.

Section 5

TOLL BRIDGE SEISMIC SAFETY PROGRAM

The Toll Bridge Seismic Safety Program needs to be completed efficiently and without further delay.

Figure 5-1. *Construction of the East Spans of the San Francisco-Oakland Bay Bridge near Yerba Buena Island.*

5. TOLL BRIDGE SEISMIC SAFETY PROGRAM

5.1 General

Caltrans, the California Transportation Commission (CTC), and the Bay Area Toll Authority (BATA), should be commended for their strong support and commitment to completing the Toll Bridge Retrofit Program. The Board fully supports the decision to add the Dumbarton and Antioch bridges into the Toll Bridge Retrofit Program despite their more recent vintage. The Board also supports the performance-based design approach for the retrofit of these structures.

5.2 Recommendations

- That Caltrans completes the Toll Bridge Retrofit Program as a matter of urgency, including the construction of the new East Bay Spans of the San Francisco-Oakland Bay Bridge (SFOBB) and the retrofit of the Dumbarton and Antioch Bridges.

- That Caltrans documents and evaluates the performance-based seismic retrofit approach taken for the Dumbarton and Antioch bridges and its economic impact. Such a report will serve as a useful reference for future seismic assessments and retrofit projects of other major bridge structures.

Section 6

PROBLEM-FOCUSED INVESTIGATIONS

Caltrans should continue its commitment to problem-focused seismic investigations at or above its current level.

Figure 6-1. *Results from large scale testing of precast girder system seismic performance will be used to update Caltrans seismic design criteria.*

6. PROBLEM-FOCUSED INVESTIGATIONS

6.1 General

Caltrans has maintained its leadership in seismic research for transportation structures through its continuous commitment and financial support of a vigorous problem-focused research program. The Board supports the extension of this program to earthquake-related issues beyond bridge performance, and in particular to the improved assessment of complete transportation routes and corridors. Despite cuts in the California State budget, Caltrans is to be commended for maintaining the funding level for problem-focused seismic research. The Board urges Caltrans to continue this practice in light of the fact that there is already a significant lead time between the identification of a problem and implementation of a solution. Decreased funding will only lengthen this delay, which must be strenuously avoided if implementation is to occur before the next big earthquake.

6.2 Recommendations

- That Caltrans remains committed to advance and fund problem-focused seismic investigations.

- That Caltrans continues to encourage interaction between practitioners and the research community to facilitate dissemination of research findings and development of a focused research program.

- That Caltrans re-evaluates and prioritizes its problem-focused research program, on a regular basis.

- That Caltrans re-evaluates the entire seismic research program to ensure that the program is outcome-focused and not process-focused.

- That Caltrans formally integrate a performance-based design approach into the Seismic Design Criteria manual within the next several years.

Section 7

EMERGENCY RESPONSE

Caltrans should maintain its rapid response capability to evaluate, repair, and restore damaged bridges, regardless of the cause - whether natural or terrorist.

Figure 7-1. *A section of the eastbound I-80 to I-580 MacArthur Maze connector collapsed following a tanker fire on the roadway below. The lower deck was reopened in eight days and the upper deck was rebuilt and reopened less than a month following the incident. [Fire Photo from Associated Press]*

7. EMERGENCY RESPONSE

7.1 General

Caltrans has demonstrated over the years its improved rapid response capability to moderate earthquakes and localized events and emergencies. While Caltrans has a well-defined rapid response infrastructure (teams and equipment), it is not clear to the Board if this infrastructure is sufficient to cope with a major earthquake in a metropolitan area in California sometime in the future. Furthermore, most bridges in the State are designated as "ordinary" bridges and designed to meet the no-collapse criterion. Caltrans should determine the likely damage state of these bridges for various earthquake scenarios (small, moderate, and large), identify what repairs are likely needed, and prepare typical repair details in order to expedite response and recovery.

7.2 Recommendations

- That Caltrans continues to develop and implement procedures to expedite bridge construction for pre-planned delivery projects and expedited emergency response and recovery.

- That Caltrans join forces with other local planning groups and state and federal agencies, in particular the California Emergency Management Agency (CalEMA), to evaluate entire transportation routes for emergency response and access/ evacuation potential following a major seismic event. Caltrans should also coordinate with the U.S. Department of Defense (DOD) to identify major supply/evacuation routes, and to discuss evacuation plans with utilities in case of reactor accidents. The goal is a coordinated approach to the designation of important transportation corridors, which Caltrans cannot do on its own. However, once these important transportation routes/corridors have been agreed upon, Caltrans should formulate respective performance standards, review and where necessary upgrade procedures, and develop appropriate implementation plans.

- That Caltrans outlines and communicates a clear plan/strategy how Operational Area Satellite Information Systems (OASIS) are deployed, how they interact with the Standardized Equipment Management System (SEMS), and how Caltrans' rapid response infrastructure interacts with CalEMA.

- Since both new and existing bridges, as well as bridges designated "ordinary" and "important", will experience some level of damage following a major earthquake, Caltrans should anticipate the type of damage that may occur and develop repair solutions before the damage occurs. In this way the time to repair a damaged bridge may be reduced and opened to traffic in the shortest possible time. Being proactive in this regard is important because there may be limited resources to design and repair a multitude of structures damaged in a major earthquake.

CONCLUSION

It has been more than fifteen years since the last catastrophic earthquake caused considerable damage to the State's transportation infrastructure. There is a high probability that a major earthquake will shake California in the future. The only questions are when and where. Therefore, winning the race to achieve seismic safety for transportation structures must continue to be a top priority for Caltrans.

Following the above assessment, the Board is of the opinion that Caltrans has made significant progress towards protecting the State's transportation infrastructure against the continued seismic threat. It is also of the opinion that this infrastructure is better prepared today to face a major seismic event than it was seven years ago when *The Race to Seismic Safety* was published. However, the race continues and Caltrans must remain committed to the improvement of the seismic performance of the State's transportation system.

In summary, the Board urges Caltrans to complete the Toll Bridge Retrofit Program as expeditiously as possible, to work with local agencies to complete the local agency bridge retrofit program, to work with the Board and the State Government to keep seismic funding a priority, to take an active role in the seismic assessment of all transportation structures and systems in California, and to continue a vigorous problem-focused seismic research program.

In view of the extreme seismic risk and the high value of California's economy, Caltrans must remain a leader in the seismic design and assessment of transportation structures and continue to advance these issues. This is particularly true today when it is more than a decade since decision makers were reminded of the dire consequences of strong ground shaking by a major earthquake. Caltrans will be held responsible for the performance of the transportation system in the next earthquake and must therefore continue to be at the forefront in the fight against complacency and the advancement of seismic performance and safety.

REFERENCES

[1] Caltrans Seismic Advisory Board, *Competing Against Time*, Report submitted to the Director, California Department of Transportation, May 1990.

[2] Caltrans Seismic Advisory Board, *The Continuing Challenge - The Northridge Earthquake of January 17, 1994*, Report submitted to the Director, California Department of Transportation, October 1994.

[3] Caltrans Seismic Advisory Board, *The Race to Seismic Safety - Protecting California's Transportation System*, Report submitted to the Director, California Department of Transportation, December 2003.

APPENDIX I

PROGRESS ON

THE RACE TO SEISMIC SAFETY IN CALIFORNIA

California Department of Transportation

August 30, 2009

1. INTRODUCTION

Following the 1989 Loma Prieta Earthquake, the California Department of Transportation (Caltrans) established the Caltrans Seismic Advisory Board (SAB) to provide advice on seismic safety policy as it applies to the design of transportation structures in California. In 2003, the SAB released the report "*The Race to Seismic Safety*" [1] that documented the accomplishments and advances made by Caltrans since 1989, and provided guidance for resolving the outstanding safety issues so that the highway bridges could perform at an acceptable seismic performance level in future earthquake events. The SAB report also proposed seven recommendations to help California achieve a seismically safe transportation system. Since the release of the SAB report, Caltrans has made concerted efforts to meet the SAB's recommendations. This progress report documents the current status and progress of Caltrans' efforts towards implementation of the seven recommendations.

2. PROGRESS ON THE RACE TO SEISMIC SAFETY

Based on extensive reviews of current and past Caltrans bridge seismic design practices and accomplishments, the SAB made seven recommendations to help California achieve a seismically safe transportation system. The seven recommendations covered the following topics:

- Seismic safety policy
- Non-state-owned bridge retrofits
- Design standards
- Regular safety reassessment
- Toll bridge seismic safety program
- Problem-focused investigations
- Emergency response

Over the last six years, Caltrans has made concerted efforts in "*The Race to Seismic Safety*" to meet the challenges in future seismic safety performance. Progress has been made in ensuring that the State's bridges are seismically safe. This section presents the summaries of Caltrans' actions on the seven priority recommendations that will lead to an acceptable seismic performance of California's transportation structures.

2.1 Seismic Safety Policy

The SAB recommended that *"The California Legislature should establish Caltrans seismic practice as a state policy, to the maximum extent feasible by present earthquake engineering practice - to build, maintain, and rehabilitate highway and transportation structures so that they provide an acceptable level of earthquake safety for users of these structures."*

The State and Caltrans have implemented actions on the policy level to assure that highway bridges would achieve adequate seismic performance in future earthquake events. Current State laws [2, 3, and 4] provide Caltrans with clear responsibilities for developing and maintaining seismic design standards to ensure the safety of California's highways and bridges. The law requires Caltrans to update these standards periodically to reflect Caltrans' research and experience in seismic design. In addition, it requires Caltrans to utilize the lessons learned from past earthquakes, and to use the latest technology, including those from other engineering and scientific disciplines in developing our seismic design standards.

State laws [2, 3, and 4] also require Caltrans to maintain communication, and exchange information with persons and organizations concerned with seismic engineering issues. Upon completing the development of revised seismic standards, Caltrans has actively distributed the seismic standards, (including the supporting data), to all other public agencies in this state engaged in the design, construction, or inspection of transportation structures. Second, Federal rules and Caltrans policy require that all bridges under the State's review should be

designed in accordance with Caltrans standards. Caltrans is continuously and actively engaged in communication and information exchange with parties and organizations that are concerned with seismic engineering issues.

Current State policy, given by the Governor's Executive Order D-86-90 [5], ensures that "seismic safety… [is given]… priority consideration ... in the design and construction of all state structures, including transportation structures." The declared policy will continue to be in effect unless specifically rescinded by the Governor. The SAB expressed concern that this policy could be overturned with a change in administration and thus potentially risk seismic safety efforts to protect state transportation structures. Therefore, the SAB advocates incorporating the Executive Order D-86-90 into state law so that the seismic safety considerations remain a top priority indefinitely.

In order to avoid the policy being overturned, Caltrans is fully committed to assist the SAB to "highlight the peril" and offered to seek opportunities for the SAB to interact with transportation policymakers, including the SAB Chair's January 14, 2009 appearance before the California Transportation Commission (CTC). In addition, Caltrans, in collaboration with the SAB, will continue to actively engage in communications with Executive and Legislature leaders to stress the importance of a state seismic policy.

2.2 Non-State-Owned Bridge Seismic Retrofits

Caltrans has made significant efforts in upgrading the seismic safety performance of state-owned bridges. However, non-state-owned bridges have not been addressed with the same timeliness. The SAB recommended the *"Legislature should provide timetables for the seismic retrofit of non-state-owned bridges so that those bridges requiring retrofit are completed within the next five years. The standards for non-state-owned bridges should be the same as for state-owned bridges."*

It is important that local agencies and other state agencies complete a seismic retrofit program for their structures to assure emergency response and mobility after a major earthquake. According to Caltrans 2009 estimates, there are 1,193 local bridges in the Local Bridge Seismic Retrofit Program (LBSRP), a part of the larger Federal Highway Bridge Program (HBP) [Appendix A]. Since the implementation of California Proposition 1B, which provides State matching funds to Federal HBP funds, considerable State and Federal funding for LBSRP is now available to complete the seismic retrofit of the remaining bridges within the program.

The local agencies' recent access to State and Federal LBSRP funding has reduced the backlog of bridges still requiring retrofit. According to the latest quarterly Seismic Retrofit Program Progress Report [6], 729 local bridges have been retrofitted, 154 bridges are under construction, 303 bridges are under design, and 7 bridges are in a pre-strategy phase [Attachment A].

Furthermore, based on the latest input from local agencies, the remaining bridges are expected to be in construction by 2014.

Caltrans is committed and will continue to work with the CTC and local agency partners to ensure that the LBSRP is completed and to advocate for adequate funding for projects that are ready for construction. Moreover, Caltrans will continue to monitor the situation to find opportunities for savings, additional funding, and strategies to speed completion of this important effort.

2.3 Design Standards

The SAB stated that *"Caltrans should maintain its standards for construction and retrofit of transportation structures to provide life safety for all structures and functionality for some selected structures following an earthquake. Also, the Department should maintain its current policy of independently reviewing seismic-related design and construction issues to ensure compliance with these standards. Selective seismic peer reviews should be conducted under policies and procedures reviewed by the SAB."*

Providing for life safety as a minimum for all structures and for functionality on a select group of important structures is one of Caltrans' main requirements for construction and retrofit of bridges in California. All ordinary bridges in California are required to be designed to meet the life safety performance level, encoded by the Caltrans Seismic Design Criteria (SDC) [7]. For selected "Important" bridges, post-earthquake functionality performance criteria is applied to seismic design and retrofit schemes to allow full access to normal traffic immediately following an earthquake. The seismic design criteria for this type of bridge are currently developed by project design teams on a case-by-case basis.

Caltrans continues to perform and sponsor seismic research to improve the seismic performance of the State's highway bridges. The seismic design standards for California are regularly updated by incorporating knowledge gained from research and analytical studies, the lessons learned from major seismic events and interactions with peers from around the world. The following briefly describes some of the actions that Caltrans has taken to maintain its seismic design standards:

- Caltrans actively participates in the AASHTO T-3 Seismic Design Committee and the Transportation Research Board's AFF50 Seismic Design and Performance Committee. These opportunities allow Caltrans to engage other DOTs, peers, researchers, industry, and public and private engineering practitioners from across the country on seismic issues.
- Caltrans' Office of Earthquake Engineering (OEE) is solely devoted to maintaining the seismic standards and managing and implementing results of the seismic research program.

APPENDIX I

- Caltrans is engaged with peers in Japan, Taiwan, China, Italy, Turkey, Korea, and other nations on seismic issues of common interest [8].
- OEE continues to collaborate and interact with academic research institutions such as the Pacific Earthquake Engineering Research Center (PEER), the Multidisciplinary Center for Earthquake Engineering Research (MCEER), and the Mid-America Earthquake Center (MAE) on seismic-related topics.
- Caltrans interacts regularly with the California Geological Survey, the United States Geological Survey, the Southern California Earthquake Center and others to stay current on the understanding of seismic hazards.
- Caltrans continues to seek advice from the SAB on seismic policy, practices, and standards to enhance the seismic safety of California's transportation structures (for roles and responsibilities of the SAB, see Appendix B).

The following lists the significant changes to the Caltrans' seismic design standards made since 2003:

A. Caltrans 2007 Seismic Fault Data and Map, and SDC Version 1.5

The map includes updates to fault location and fault characteristics, use of the Next Generation Attenuation (NGA) models developed by PEER and amplification factors to account for depth-dependent effects in basins. In addition, the Design Response Spectrum (DRS) now considers a deterministic and a probabilistic spectrum (see Appendix C for details). The new Fault Data and the associated DRS are included in the 2009 SDC Version 1.5. The new SDC and the Fault Data will be implemented on September 30, 2009.

B. Memo-to-Designers (MTD)

i. MTD 20-4 *Seismic Retrofit Guidelines for Bridges* [9]

The guideline was rewritten in its entirety to incorporate current Caltrans seismic retrofit practices utilizing displacement based design and analysis methods, and to make updates associated with the latest research results. This included modifications to the superstructure hinge retrofit guidelines, with an emphasis on the use of pipe seat extenders, and a revised methodology to determine hinge restrainer requirements. In addition, new Joint Shear Modeling Guidelines for existing bridges were published, which is expected to result in more cost effective and rational bent cap retrofit practices.

ii. MTD 20-16, *Seismic Safety Peer Review* [10]

External expertise is utilized through the use of Seismic Safety Peer Review Panels to consider seismic issues associated with specific projects. As recommended by the SAB, Caltrans requires that the construction and retrofit of complex structures be reviewed by an external and independent seismic safety peer review panel. The peer review panel is required to independently review and approve a project-specific Seismic Design Criteria to meet specified seismic performance goals. This new MTD 20-16 document identifies when Seismic Safety Peer Reviews should be held, who should be included, the scope of the Seismic Safety Peer Review Panel's responsibilities, and an outline of the process from initiation to final documentation.

C. Seismic Design Criteria (SDC)

Caltrans SDC was updated in February 2004 and in June 2006. A new SDC Version 1.6 is currently pending and is expected to be published in 2010. These new and updated standards incorporate the latest findings from experimental research and analytical studies. Design standards recently updated include:

i. Abutment soil structure interaction and shear key design and details,
ii. Isolation of column flares and pile cap detailing, and
iii. Modified details to improve constructability of Type II Pile shafts.

From 2003 to the present, Caltrans has actively employed research findings to update design standards to reflect the latest seismic design technologies. The following design standard topics are currently under development:

- Fault rupture guidelines,
- State of the practice for soil liquefaction and lateral spreading,
- Seismic displacement requirements for utilities on bridges,
- Updated seismic retrofit design procedures, and
- Seismic requirements for bridge widening and other modifications.

In addition, Caltrans has played an active leadership role in developing the American Association of State Highway and Transportation Officials (AASHTO) Guide Specifications for Load and Resistance Factor Design (LRFD) Seismic Bridge Design (Seismic Guide Specifications), and seismic updates to the AASHTO LRFD Bridge Design Specifications. The AASHTO Seismic Guide Specifications incorporated many of the principles and practices currently included in the Caltrans SDC (e.g. displacement-based analysis methods, capacity design principles, and minimum ductile detailing requirements). In 2008, Caltrans was involved in developing efforts

to update the AASHTO Seismic Guide Specifications for liquefaction and other geotechnical issues, which were approved at the 2008 AASHTO Annual Meeting.

2.4 Regular Safety Reassessments

The SAB believed that periodic seismic reassessments of existing structures should be initiated, and thus recommended that Caltrans "*should regularly reassess the seismic hazard and engineering performance of bridges, including existing, retrofitted, and new structures." Caltrans "should determine, as measured by the most current state of knowledge, whether bridges and transportation structures can be expected to perform in an acceptable manner under earthquake shaking."*

Since the substantial completion of the Highway Bridge Seismic Retrofit Program, Caltrans has implemented a focused program that reassesses bridges regularly based on the state-of-the-art knowledge in earthquake engineering to determine the seismic performance of the existing bridges. Conditions that could potentially affect seismic performance are identified, assessed and documented as part of the focused bridge evaluation. When seismic scanning and assessment suggest that a bridge needs to be seismically improved, the recommendation is incorporated into the Caltrans' ongoing bridge rehabilitation program. The following summarizes the major procedures in the current seismic safety scanning and assessment program:

2.4.1 Bridge Widening and Modifications

Bridges that are considered for widening, modifications, and other safety upgrades, are also seismically evaluated and analyzed. Engineers are required to perform comprehensive seismic evaluations for the existing and modified structures using current seismic design standards to identify their seismic deficiencies. These seismic evaluations ensure that the seismic details of the modified structure are upgraded to an acceptable performance level based on the latest site-specific seismic hazard information.

2.4.2 Structure Inspection and Vulnerability Evaluation

Caltrans structure maintenance engineers continue to inspect state bridges, typically every two years, providing the opportunity to identify field conditions that could potentially affect seismic performance. The conditions are assessed and documented as part of a comprehensive bridge evaluation to determine the type and scope of repair work needed, including potential seismic retrofit needs.

Based on the initial assessment, each bridge is given a "Vulnerability Score", assigned to one of four seismic retrofit priority categories, and submitted to be included in the Caltrans bridge rehabilitation program. Once the funds are programmed for a nominated bridge, a project

is initiated to identify the bridge's seismic retrofit needs through a comprehensive seismic analysis. Past and recent comprehensive seismic evaluations indicated that the seismic retrofit modifications are not required for many bridges preliminarily identified with potential seismic retrofit needs. This is because bridges with the greatest seismic retrofit needs were addressed by the Highway Bridge Seismic Retrofit Program in the 1990s.

As part of the on-going seismic assessment program, Caltrans earthquake engineers are currently screening bridges for several potential seismic vulnerabilities. Based on a review of bridge performance in past earthquakes and the results of seismic research, potential seismic vulnerabilities have been identified and discussed with the SAB. Currently identified vulnerabilities include superstructure response to vertical acceleration, flared columns, and bridges located in potential fault rupture zones, potentially liquefiable soils.

In addition, Caltrans reassessed the seismic retrofit needs for the Dumbarton and Antioch Bridges and the seismic vulnerability assessment studies identified various seismic vulnerabilities on both bridges. A seismic retrofit design and strategy for these bridges are currently under development.

Most recently, Office of Earthquake Engineering is performing a comprehensive seismic vulnerability parametric study on existing bridges with column flares. The studies would identify bridges that have realistic seismic vulnerabilities. In the parametric study, potential seismic vulnerabilities of each bridge and the potential risk associated with the identified vulnerability are assessed based on the potential seismic hazard at the bridge site.

Currently, over 1,000 state highway bridges are identified with rehabilitation needs. Three hundred bridges are identified with potential seismic vulnerabilities based on new knowledge gained since the inception of the Seismic Retrofit Program. These bridges are programmed through the State Highway Operation and Protection Plan (SHOPP), which is used to address deficiencies on the existing State Highway System. Current demands on the SHOPP program significantly exceed available funds. Allocated funds for seismic retrofitting and other bridge rehabilitation needs are determined based on a prioritization process using utility functions and cost-benefit analyses. Notwithstanding the growing imbalance between needs and available funds, about 19% of available bridge rehabilitation SHOPP funds are used to program projects to address potential seismic retrofit needs.

2.5 Toll Bridge Seismic Safety Program

The Toll Bridges provide several metropolitan regions with vital transportation links to the rest of the State. Should an earthquake impart damage and cause closure of one of the Toll Bridges, the neighboring regions and the State would experience significant economic hardship. Thus, Caltrans, following the 1989 Loma Prieta Earthquake, initiated the Toll Bridge Seismic Safety Program to upgrade and improve seismic performance of all Toll Bridges. Realizing the

importance of the Toll Bridges, the SAB recommended that *"The Toll Bridge Seismic Safety Program needs to be completed efficiently and without further delay."*

The seismic retrofit of all bridges included in the original Toll Bridge Seismic Safety Program has made significant progress [11]. The seismic retrofits of the Vincent Thomas, San Diego Coronado, San Francisco-Oakland Bay Bridge (SFOBB) West Span and approach, the Carquinez, the Benicia-Martinez, the San Mateo-Hayward, and the Richmond-San Rafael bridges have been completed. For the seismic upgrade to the SFOBB East Span, the Skyway segment was completed in late 2008 and the West Tie-in structure was successfully replaced and rolled-into place during an accelerated 3-day Labor Day weekend in 2007. The East Tie-in to the South-South-Detour structure was also successfully rolled-into place during an accelerated 4-day Labor Day weekend in 2009. As of August 30, 2009, the Self-Anchored-Suspension span and the transition structure are scheduled to be completed in 2014.

A recently proposed Assembly Bill 1175 (Torlakson) would add the Dumbarton and Antioch Bridges to the Toll Bridge Seismic Retrofit Program. As of August 30, 2009, the Bill is pending approval from the State Legislature. Caltrans has conducted a reassessment of the seismic retrofit needs of the Dumbarton and Antioch Bridges. A seismic vulnerability assessment study has identified various seismic vulnerabilities at both bridges. The seismic retrofit design and strategy for these bridges is currently being finalized under the oversight of the Toll Bridge Program Oversight Committee with input by the external Toll Bridge Seismic Safety Program Peer Review Panel.

2.6 Problem-Focused Investigation

A cornerstone of the significant improvements in bridge design during the past decade has been the commitment of Caltrans to a vigorous seismic research program. For this matter, the SAB recommended that the *"Department should continue its commitment to problem-focused seismic investigations at or above its current level*."

Within available funding, Caltrans continues to identify seismic design and performance issues that are then addressed through problem-focused studies. Recent research program restructuring clarifies how issues to be studied are identified, prioritized and addressed with an increased emphasis placed on rapid implementation of research results. The typical annual allocation for seismic-related research is $4.2 million.

Caltrans manages a multi-million dollar problem-focused research program to investigate issues and develop results that can be deployed to meet Project Delivery needs. Caltrans has developed a research process guided by the Research and Deployment Steering Committee (RDSC), consisting of Deputy Directors and District Directors. The RDSC, in turn, created Program Steering Committees (PSCs) to assist in developing the research agenda and deploying

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research products. The PSCs consist of Division Chiefs in Headquarters and Deputy District Directors and they advise the RDSC on which proposals should become research projects.

Caltrans utilizes experts to identify research needs and to provide technical support to research projects to ensure they can be deployed into practice. A Technical Advisory Panel (TAP) is comprised of members with expertise in the structural, construction, maintenance, geotechnical, materials, earthquake engineering, and other technical disciplines. The TAP is responsible for coordinating the research program, developing strategic research plans, evaluating and prioritizing seismic research problem statements and proposals, and providing technical support to the research projects. The TAP provides recommendations to the PSCs on research proposals that should be funded. With this system, Caltrans hopes to provide more customer participation throughout the research process, and ownership of research products.

A Strategic Research Roadmap and Plan (Attachment B) have been developed to help guide, manage, and operate the research program and to ensure a focus on developing results that can be deployed into practice. The program focuses research on the following topics [see Appendix D for details]:

1. Advanced numerical modeling and analysis techniques
2. Non-destructive damage evaluation and condition assessment following extreme events
3. Design guidelines for structural connections and components
4. Seismic performance of Accelerated Bridge Construction (ABC) structures
5. Hazards and ground motion studies
6. Strong motion instrumentation
7. Health monitoring of bridge structures and components
8. Seismic Response Modification Devices (SRMDs)
9. Geotechnical effects (liquefactions and lateral spreading)
10. Foundation analysis and design
11. Earth retaining systems-seismic loading and design

At the recommendation of the SAB, Caltrans has initiated a research synthesis study on liquefaction and lateral spreading hazards. Furthermore, significant attention has been given to investigate the seismic performance of structures for ABC. ABC is becoming more important throughout the nation because the practice can reduce the traffic, environmental, and economic impact to the public, thus yielding tremendous economic savings for the states. Research results are disseminated to practitioners through updates to Caltrans' seismic design and construction standards. Topics of broad interest are documented on-line that summarize the purpose and results of Caltrans-funded research [Attachment C].

Caltrans encourages interaction between practitioners and the research community. Researchers are regularly invited to interact with engineers at the monthly Earthquake Committee meetings

to discuss ongoing or recently completed research projects of interest. In addition, Caltrans has been involved in technical conferences such as the Caltrans Bridge Research Conference in October 2005, FHWA's Fifth and Sixth National Seismic Conferences in 2006 and 2008 respectively, Seismic ABC/Next Generation Bridge Workshop in 2009, and the Caltrans/PEER seismic research workshop in 2009.

The current program of problem-focused investigations has been a catalyst in improving the Caltrans' seismic design and retrofit practices. This translates to improving the earthquake performance of California's transportation structures. Caltrans remains committed to advance and fund these problem-focused seismic investigations.

2.7 Emergency Response

Caltrans maintains rapid response to emergency events. The SAB further emphasized in their report that the *"Department should maintain its rapid response capability to evaluate, repair, and restore damaged bridges, regardless of the cause - whether natural or terrorist."*

On a continual basis, Caltrans has been reviewing and updating emergency procedures to ensure efficiency and effectiveness in responding to and recovering from catastrophic man-made or natural events. Continuing preparedness efforts have progressed in the following fields:

A. Response Infrastructure

Caltrans has made significant investments in office facilities necessary to properly manage an emergency response situation. Each district has established an Emergency Operation Center (EOC) that acts as the central hub for coordinated response activities. Structure Maintenance has also established a command center to facilitate the collection and dissemination of post-earthquake bridge damage assessment information.

B. Communications

Effective communication is vital for effective response activities. Recognizing the need for redundant communication methods for emergency response, Caltrans has acquired several Operational Area Satellite Information Systems (OASIS) vehicles. The OASIS trailers provide mobile (radio, video, satellite) communication facilities that can be directed to damaged areas.

C. Response Tools

Caltrans continues to enhance the Shakecast software systems used for emergency response. Shakecast clearly defines the location, magnitude and extent of seismic

events and provides rapid distribution of information around the state via e-mail and mobile devices. Bridge fragilities are incorporated within Shakecast to provide an initial projection of damage within minutes of a seismic event.

Post-earthquake response teams have access to web-based software tools that provide remote access for damage assessment data entry and access to all bridge plans and past inspection records. The post event damage assessment software can be operated over cellular data networks. Caltrans also uses the Standardized Emergency Management System (SEMS) that helps Caltrans better coordinate activities with external agencies and the California Emergency Management Agency (CalEMA) who can provide Caltrans additional resources as needed for emergency response.

D. Response Training and Drills

Caltrans continues to provide manuals, training, and practice drills designed to keep its employees in a state of readiness. Caltrans has continued to maintain a Post-Earthquake Investigation Team (PEQIT) to ensure earthquake damage is thoroughly documented following each major event. PEQIT members receive training annually and the PEQIT manual is periodically updated to ensure our readiness to investigate the performance of bridges and other highway structures after a large earthquake.

In 2008, Caltrans participated in the California Golden Guardian exercise to test our preparedness and to correct identified areas of improvement [Appendix E]. Analysis of potential bridge damage due to ground shaking was based on the REDARS™ 2 default bridge models and Caltrans input data [12]. This analysis showed over 90% of the recently designed bridges and bridges that had undergone a Phase 2 seismic retrofit generally responded within the prescribed ductility capacity [13].

Caltrans has rapid response mechanisms in place that have proved very effective in past events. This was particularly illustrated during Caltrans' accelerated responses to the 1994 Northridge Earthquake, the 2007 MacArthur Maze Interchange fire, and the 2007 Santa Clarita I-5 Tunnel fire. In all three events, segments of bridge structures were damaged beyond repair, shutting down the freeway link. The segments constituted a vital transportation artery to the region and the closure yielded major economical impact to the state. Caltrans employed Accelerated Bridge Construction (ABC) practice to expedite bridge replacements. In both 2007 events in Oakland and in Los Angeles, Caltrans, in partnership with contractors, replaced the damaged segments and restored the freeway operation in 30 calendar days [14].

Capitalizing on these recent successes, Caltrans has developed and is currently implementing ABC alternative considerations to expedite bridge construction for pre-planned and emergency response structure delivery projects [15].

3. CONCLUSIONS

It has been more than fifteen years since the last catastrophic earthquake caused considerable damage to the State's transportation infrastructure. It is a high probability that a major earthquake will shake California in the future. The only questions are when and where. Therefore, racing to achieve seismic safety for transportation structures is and will continue to be a top priority for Caltrans.

In this race to seismic safety, Caltrans has made considerable progress and the State is better prepared today than fifteen years ago to face future seismic events. However, the race continues on and Caltrans is committed to improve the highway transportation structures so that they can withstand the next major earthquake.

4. REFERENCES

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5. APPENDICES

A. LBSRP - Background and Status

The LBSRP is a part of the larger federal Highway Bridge Program (HBP) and is subject to the limitations of federal appropriations and obligation authority. On August 10, 2005, then President Bush signed into law the "Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users" (SAFETEA-LU). This act renamed the Highway Bridge Replacement and Rehabilitation Program (HBRR) to the Highway Bridge Program (HBP), and changed federal participation from 80 percent to 88.47 percent.

Since the LBSRP guidelines were developed, additional investigations by Caltrans revealed that eleven bridges were either: a) not owned by local agencies, b) the seismic retrofit had already been completed, or c) the bridge had been demolished/removed. In addition, 42 Bay Area Rapid Transit (BART) bridges within the LBSRP will be de-federalized, as requested by BART, and will become a part of a new project undertaken solely by BART, as no local assistance federal or state funds will be needed. Caltrans and the CTC are and will continue to monitor the delivery of the LBSRP projects.

The voters of California passed Proposition 1B, "The Highway Safety, Traffic Reduction, Air Quality, and Port Security Bond Act of 2006," which provides state matching funds to Federal HBP funds for the Local Bridge Seismic Retrofit Program. The Bond program budget of $125 million is to be allocated to provide the 11.47 percent required local match for right of way and construction phases of remaining seismic retrofit work on local bridges, ramps, and overpasses and includes $2.5 million set aside for bond administrative costs.

B. Seismic Advisory Board - Vision, Mission, and Responsibilities

In order to ensure Caltrans' policies and practices are reviewed and audited by external perspective and expertise, as recommended by the Governor's Board of Inquiry, the Seismic Advisory Board (SAB) was created following the Loma Prieta Earthquake. The SAB is an independent body whose role is to advise the Department on seismic policy and technical practices to enhance the seismic safety and functionality of California's transportation structures. With experts in Structural Engineering, Structural Mechanics, Seismic and Structural Research, Seismology, Geotechnical Engineering, Bridge Engineering, Transportation Engineering, and Construction Engineering, the mission of the SAB is to assist Caltrans in its role and obligation to provide seismic safety of California's transportation structures through:

1. Continued review of earthquake engineering and seismic design as practiced by Caltrans.
2. Formulation of recommendations for improvements in Caltrans earthquake engineering and seismic design practices.
3. Policy review of seismic hazard definition and mitigation directives.
4. Technical review of seismic design guidelines and standards for transportation structures.
5. Review and comment on Caltrans seismic research agenda and priorities.
6. Provide the general public with explanations regarding Caltrans' seismic safety policies and procedures for maintaining safety and functionality of California's transportation structures.

C. Background on the Design Response Spectrum

The Design Response Spectrum now considers both a deterministic and a probabilistic spectrum. The deterministic spectrum is calculated as the arithmetic average of the median response spectra using the Campbell-Bozorgnia and Chiou-Youngs ground motion prediction equations. These equations are applied to all faults in or near California considered to be active in the last 700,000 years and capable of producing a maximum moment magnitude (Mmax) earthquake of 6.0 or greater as defined by the California Geological Survey (CGS). The probabilistic spectrum is obtained from the U.S. Geological Survey (USGS) 975 Year Return Period Seismic Hazard Map, which uses the average of the Boore-Atkinson, Campbell-Bozorgnia, and Chiou-Youngs ground motion prediction models. The Design Response Spectrum is an envelope of the deterministic and probabilistic spectra.

D. Research Topics currently being studied

1. *Advanced Numerical Modeling and Analytical Techniques*
   - Abutment-Soil Interaction and Modeling
   - Effective System Damping
   - Suspension Bridge Modeling
   - Live Load Effects on Seismic Response
   - Skew Effects
   - Archiving Toll-Bridge ADINA Models for Post-Earthquake Assessment
   - Multi-Support Response Spectrum/Near Fault Response Spectrum Analysis
   - Nonlinear Seismic Analysis
   - Long Span Bridge Analysis

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2. *Non-Destructive Damage Evaluation and Post-Event Condition Assessment*
   a. Post-Earthquake Live Load Capacity
   b. Post-Earthquake Emergency Repair with Fiber Reinforced Polymer (FRP) Composites
   c. Rapid Post-Earthquake Damage Assessment of Long Span Toll Bridges
   d. Post-Earthquake Assessment
   e. Accessible Hinges for Bearing Replacement and Inspection

3. *Structural Connections and Components*
   a. Seismic Performance of Fiber-Reinforced Concrete Columns
   b. Abutment Shear Key Design
   c. Pipe Pin
   d. Slab Bridge Superstructure/Pile Extension Connections
   e. Epoxy Bonded Couplers
   f. Adhesive Anchors
   g. Low Cycle Fatigue Characteristics of Large Diameter Rebar

4. *Seismic Performance of Accelerated Bridge Construction Structures*
   a. Seismic Performance of Concrete-Filled-Tube Connections
   b. Precast Piers with Energy Dissipating Joints
   c. Precast I-girder on Inverted T Bent Cap Seismic Performance
   d. Segmental Construction Seismic Performance and Design Guidelines
   e. Next Generation Bridges with Improved Serviceability and Utilizing Accelerated Bridge Construction (ABC) Methods
   f. Joint-sponsored Transportation Research Board (TRB)/AASHTO research on the seismic performance of connections for ABC

5. *Hazards and Ground Motion Studies*
   a. Tsunami
   b. Vertical Acceleration
   c. Near Fault Ground Motion and Fault Rupture/Crossing
   d. Next Generation Attenuation Models
   e. Ground Motion Library

6. *Strong Motion Instrumentation*
   a. Caltrans Strong Motion Instrumentation Program

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7. *Health Monitoring*
   a. Long-Term Structural Performance Monitoring of Highway Bridges
   b. Health Monitoring to Determine the Performance of Prestressing Steel in Segmental Box Girders

8. *Seismic Response Modification Devices (SRMDs)*
   a. Vincent Thomas Bridge Viscous Damper Forensic Investigation
   b. In-Service Evaluation and Inspection of SRMDs
   c. Seismic Isolation Bearing Design Guidelines
   d. Seismic Performance of Service-Level Bearings
   e. Assessment of the Performance of Dampers and Bearings In Service

9. *Geotechnical Effects*
   a. Liquefaction Screening in Collaboration with the California Geological Survey
   b. Developing Liquefaction Fragility Relationships
   c. Synthesis of Comprehensive Design Recommendations

10. *Foundation Analysis and Design*
   a. Type II pile shaft - Analytical Study of Reinforcing Details at the Column/ Shaft Interface
   b. Type II pile shaft - Field Study of the Seismic Performance for Alternative Reinforcing Details
   c. Type II pile shaft - Anomaly Identification, Repair and Quality Assurance
   d. Battered Piles and Sloping Ground Analysis

11. *Retaining Wall Seismic Loading and Design*

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E. Background of the 2008 Golden Guardian and the ShakeOut Scenario

The *Golden Guardian Statewide Exercise Series* is California's state-sponsored emergency preparedness exercise endeavor. Golden Guardian is an ongoing annual event, comprised of a series of seminars, discussion based tabletop exercise and drills, culminating in a full scale exercise designed to test the emergency capabilities of the State of California to deter, prevent, respond and recover from a potential terrorist attack or catastrophic natural disaster.

The 2008 Golden Guardian (GG08) exercise was partnered with the ShakeOut Scenario to focus on a simulated catastrophic 7.8 magnitude earthquake on the southern portion of the San Andreas Fault, ranging from the Salton Sea in Riverside County to Northern Los Angeles County. The ShakeOut Scenario described what would happen during and after a large fault rupture along the southernmost 300 km of the San Andreas Fault. The scenario simulated a plausible event on the fault most likely to produce a major earthquake that is large enough to cause strong shaking over much of Southern California. The ShakeOut Scenario considered a range of effects from the direct physical impacts to the long-term, social, cultural, and economic consequences. The ShakeOut Scenario also identified factors that will determine whether the event would be a disaster or a catastrophe, that is, whether the event would disrupt Southern California for a few years, or for decades.

Seven Southern California counties participated in this main event, as well as the State Operations Center in Sacramento. A catastrophic natural disaster exercise involving the multi-state Lake Tahoe region was also planned. Thousands of participants representing dozens of local, state and federal agencies including the U.S. Military participated in the GG08. This unprecedented exercise endeavor brought together a diverse collaboration of more than 300 scientists, academics, engineers, industry professionals, emergency managers, and public servants.

6. ATTACHMENTS

A. Non-Toll Seismic Retrofit Program Report - Second Quarter 2009

B. DES Structure, Seismic, and Geotechnical Research Program Strategic Plan and Research Roadmap

C. DES Research Notes, March 2008

Attachment - A

Non-Toll Seismic Retrofit Program Report - Second Quarter 2009

Local Bridge Seismic Retrofit Program Status

The purpose of this report is to provide information on program delivery status of the Local Bridge Seismic Retrofit Program (LBSRP) for the1,235 bridges which includes the 479 bridges adopted by the California Transportation Commission (Commission) on May 28, 2008.

The 479 bridges adopted by the Commission were identified to receive bond funds to match federal Highway Bridge Program (HBP) funds for their right of way and construction phases. Additional investigation by the Department revealed that eleven bridges either were not owned by local agencies, the seismic retrofit had already been completed, or the bridge had been demolished/removed. In addition, 42 Bay Area Rapid Transit (BART) bridges in this program will be de-federalized as requested by BART and will be a new project undertaken by BART alone. No local assistance federal or state funds will be needed for that work. Therefore this report will reflect the program delivery of 1,193 bridges under LBSRP which includes 426 bond bridges from here on.

The Highway Safety, Traffic Reduction, Air Quality and Port Security Bond Act of 2006 provides $125 million of State matching funds to complete the LBSRP with bond funds. The Bond program budget of $125 million is to be allocated to provide the 11.47 percent required local match for right of way and construction phases of remaining seismic retrofit work on local bridges, ramps, and overpasses and includes $2.5 million set aside for bond administrative costs. An additional $32.9 million state match through annual exchange of a portion of local share of funds received from federal HBP fund is also available to accommodate the current remaining required local match needs. The Commission has allocated $13.5 million bond funds for FY 2007/08 and $21 million bond funds for FY 2008/09. Consistent with the Local Bridge Seismic Retrofit Guidelines, the Department has exchanged $24.3 million of local share of funds received through the federal HBP for state funds to accommodate local match needs for BART bridges. To date, $11.3 million of seismic bond funds have been sub-allocated.

This report fulfills the Department's statutory reporting requirement outlined in Assembly Bill (AB) 144 (Chapter 71, Statutes of 2005), which amended Section 188.5 (g) of the Streets and Highways Code as follows:

"(1) Commencing on January 1, 2004, and quarterly thereafter until completion of all applicable projects, the Department shall provide quarterly seismic reports to the transportation committees of both houses of the Legislature and to the commission for other seismic retrofit programs."

Attachment - A

Non-Toll Seismic Retrofit Program Report - Second Quarter 2009

Local Bridge Seismic Retrofit Program Progress Report

The LBSRP is currently 61 percent complete. To date, 729 local bridges, out of total of 1,193 planned bridges, have been retrofitted under the LBSRP. Currently, there are 154 bridges under construction, 303 bridges under design, and 7 bridges in a pre-strategy phase.

LBSRP Milestones Achieved This Quarter

The status as of June 30, 2009 of local bridges by phases is as follows:

	2005	2006	2007	2008	2009
Complete	692	699	709	724	729
Construction	46	45	66	124	154
Design	291	295	333	349	303
Pre-Strategy	206	196	127	38	7
Total	1,235	1,235	1,235	1,235	*1,193

**42 BART bridges were removed from the retrofit list in 2009.*

Milestones Achieved This Quarter for Bond Funded Bridges

The status as of June 30, 2009 of local bridges by phases is as follows:

	2005	2006	2007	2008	2009
Complete	0	0	0	4	7
Construction	0	0	15	99	107
Design	0	0	271	327	305
Pre-Strategy	0	0	193	38	7
Total	0	0	479	*468	**426

Investigation by the Department removed eleven bridges.42 BART bridges were removed from the retrofit list in 2009*

LBSRP Program Budget and Expenditures

The estimated budget for the overall LBSRP is $1,992.8 millions. A total of $792 millions have been encumbered (spent) to date.

Between April 1 and June 30, 2009, there has been a total of $45.9 millions of federal, $4.6 millions of state and $1.3 millions of Bond funds de-obligated due to low bids in the last quarter. A project with $3.8 millions of bond funds was incorrectly coded for the wrong type of funds so it was not encumbered.

Funds (millions)	Spent	Plan	Total
State	$67.1	$25.8	$92.9
Bond	$11.3	$111.2	$122.5
Federal	$713.6	$1,063.8	$1,777.4
Total	$792.0	$1,200.8	$1,992.8

Funds Committed to Bond Projects (millions)

Component	Available	Allocated	Percent
LBSRP Bond	$122.5	$34.5	28%
State Funds	$32.9	$24.3	74%
LBSRP Bond Support	$2.5		
Total	$157.9	$58.8	37%

Attachment - A

Non-Toll Seismic Retrofit Program Report - Second Quarter 2009

Overall Program Delivery by Agency Group (Includes all the bridges in the LBSRP)

Bridges By Agency Group	Number Of Agencies	Pre Strategy	In Design	In Construction		Complete or No Retrofit		Total # Bridges	Percent Program
		Bond	Bond	Bond	Non-Bond	Bond	Non-Bond		
All Other Agencies	59	7	123	18	33	4	612	797	67%
Los Angeles Region (City and County)	2	0	26	38	13	0	109	186	16%
Department of Water Resources	1	0	24	0	0	1	0	25	2%
BART	1	0	130	52	0	3	0	185	15%
Total	63	7	303	108	46	8	721	1,193	100%

Projects in the pre-strategy and design phase will qualify for bond match when they advance to right of way and construction phase.

- One agency, Bay Area Rapid Transit (BART) is responsible for 185 bridges (15 percent of the entire program). The remaining 130 BART bridges in design phase are programmed to go to construction this federal fiscal year.

- Construction of nine Department of Water Resources (DWR) bridges that were planned to go to construction this year has been delayed due to DWR's concerns regarding the federal Disadvantaged Business Enterprise requirements.

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Attachment - B

DES Structure, Seismic, and Geotechnical Research Program Strategic Plan and Research Roadmap

DES Structure, Seismic and Geotechnical Research Program Strategic Plan:

The DES Structure, Seismic and Geotechnical Research Program has developed a Strategic Plan to help guide its management and operation and to ensure a focus on developing results that are deployed into practice.

GOALS	OBJECTIVES
Ensure structure and seismic research effectively supports the goals of the Department and meets the needs of practicing bridge engineers.	• Involve practicing bridge engineers in multidisciplinary Work Teams to provide technical support throughout the research process from identifying problems to implementing results. • Utilize the Structure/Geotechnical Technical Advisory Panels (TAP) to advise and provide recommendations to the Structure & Geotechnical Research Program Steering Committee (PSC) on structure, seismic and geotechnical research needs. • Utilize Management level oversight committees to develop strategic research objectives and allocate funds.
Develop overarching research thrust areas to create a framework for the development and evaluation of structure, seismic and geotechnical research proposals.	• Obtain input from DES Technical Committees and Offices, other Divisions, research institutions, and the Seismic Advisory Board. • Hold regular workshops with participants from academia, industry, and internal and external practicing bridge engineers to develop Structure and Geotechnical Research Roadmaps. • Develop Problem Statements focused on the needs identified in the Roadmaps. • Evaluate research proposals based on their relevance in supporting Roadmap priorities.
Ensure the highest priority research is being investigated by the most qualified research institution.	• Develop a process to request research proposals that ensures responses from a large pool of capable research institutions. • Utilize the Structure and Geotechnical TAPs and PSC to review and prioritize research problem statements, and evaluate and approve research proposals. • Develop a comprehensive, objective procedure to evaluate research proposals. • Ensure a comprehensive literature search is conducted prior to beginning new research projects.
Ensure the successful evaluation and implementation of structure, seismic and geotechnical research results.	• Evaluate proposals based on the likelihood of the research resulting in recommendations that can be implemented into practice. • Require that research reports provide implementation recommendations. • Assign a multi-disciplinary Work Team to negotiate the final scope of work, provide technical support during the research project, evaluate final research reports, develop implementation recommendations, and assist with implementation through Caltrans Technical Committees or Technical Specialists. • Utilize Work Team members to assist other practicing bridge engineers in the implementation of final recommendations. • Effectively communicate research results which would include distributing and posting a database of completed, ongoing, and pending research online, inviting principal investigators to address technical committees and other user groups, and holding workshops and conferences.
Develop and document an effective, efficient Structure, Seismic and Geotechnical research program process.	• Maintain a database tracking the status of structure, seismic and geotechnical research projects. • Perform regular progress reviews of ongoing research projects and verify their ongoing viability. • Use Project Management processes to ensure project costs are reasonable, and projects are completed in a timely manner. • Provide training to the Structure, Seismic and Geotechnical Research contract management team. • Define clear roles and responsibilities of contract managers, technical support team members, and research TAP and Steering Committee members. • Define deliverables for each research project. • Develop an abbreviated research process, which can quickly address urgent research needs. • Allocate personnel and travel resources to manage approved research projects.
Maintain strong internal and external lines of communication and forge strategic partnerships to support the Structure Research program.	• Develop and maintain a strong communication network with structure and seismic experts in academia, industry and practitioners to broaden the perspective of the program. • Sponsor structure research workshops or conferences to present results from recently completed or ongoing research. • Leverage research funds in collaborative efforts with other states, agencies, associations, organizations, and research institutions. • Participate and make presentations at technical conferences, workshops and symposiums. • Coordinate activities with other Divisions, Technical Advisory Panels and others that can help to advance the Structure, Seismic and Geotechnical Research program.

Attachment - B

DES Structure, Seismic, and Geotechnical Research Program Strategic Plan and Research Roadmap

Research Roadmap:

In the Fall of 2005, the Division of Engineering Services held a one-day workshop with participation by DES practitioners, consultants and academia. This initial Roadmap has been updated and presented in multiple formats, but remains focused on these primary research areas.

Structure TAP Roadmap Focus Areas:

STAP1	Improved Methods to Monitor and Assess the Performance of Existing Transportation Structures
STAP2	Extended Service Life of Highway Structures
STAP3	Reduced Impact of Structure Construction and Maintenance Activities on the Traveling Public (Accelerated Construction)
STAP4	Optimized and Validated New and/or Existing Materials, Systems and Components for Bridges and Highway Structures
STAP5	Improved Soil-Foundation-Structure-Interaction Analysis Tools, Techniques, and Methods
STAP6	Improved Seismic Analysis and Design Tools, Techniques, and Methods
STAP7	Improved Understanding of Seismic Hazards
STAP8	Improved Performance of Highway Structures to Earthquake and Other Man-made and Natural Extreme Events, and Improved Ability to Quickly Restore Facilities to Full Functionality
STAP9	Nationally Accepted Specifications Advanced for Implementation in California

Geotechnical TAP Roadmap Focus Areas:

GTAP1	Improved Methods for Collecting, Storing and Disseminating Geotechnical Data
GTAP2	Improved Reliability and Consistency of Geotechnical Recommendations and Designs through the Development of Standardized Best Practices.
GTAP3	Development of a Comprehensive Risk Management Strategy for Geotechnical Hazards
GTAP4	Development of More Cost-Effective Foundations
GTAP5	Reduced Impact of Foundation Construction on the Environment

Current Research Projects:

Currently the DES Research Program has over 60 research projects under contract. Topics currently under investigation include the following:

- Analytical Modeling
  - Effective System Damping
  - Suspension Bridge Modeling
  - Live Load Effects on Seismic Response
  - Skew Effects
  - Archive Toll-Bridge ADINA Models for Post-Earthquake Assessment
  - Caltrans Strong Motion Instrumentation Program
  - Multi-Support Response Spectrum/Near Fault Response Spectrum Analysis
  - Nonlinear Analysis
  - Battered Piles and Sloping Ground Analysis
- Post-Earthquake Capacity
  - Post-Earthquake Live Load Capacity
  - Post-Earthquake Emergency Repair with Fiber Reinforced Polymer (FRP) Composites
  - Next Generation Bridges with Improved Serviceability and Accelerated Bridge Construction (ABC)
  - Post-Earthquake Assessment
  - Accessible Hinges for Bearing Replacement and Inspection
  - Innovative Foundations for Improved Performance
- Column Connections
  - Pipe Pin
  - Slab Bridge Superstructure/Pile Extension Connections
  - Epoxy Bonded Couplers
  - Adhesive Anchors
  - Low Cycle Fatigue Characteristics of Large Diameter Rebar
- Near Fault Effects
  - Vertical Acceleration
  - Fault Crossing
  - Near Fault Ground Motion and Fault Rupture

APPENDIX I

Attachment - B

DES Structure, Seismic, and Geotechnical Research Program Strategic Plan and Research Roadmap

- Seismic Response Modification Devices (SRMDs)
  - Vincent Thomas Bridge Viscous Damper Forensic Investigation
  - In Service Evaluation and Inspection of SRMDs
  - Seismic Isolation Bearing Design Guidelines
  - Seismic Performance of Service Bearings
- Accelerated Bridge Construction
  - Concrete-Filled-Tube connections
  - Precast Piers with Energy Dissipating Joints
  - Precast I-girder on Inverted T Bent Cap Seismic Performance
  - Segmental Construction Seismic Performance and Design Guidelines
  - Post-Grouting to Improve Seismic Performance in Pileshafts
- Liquefaction
  - California Geological Survey Liquefaction Screening
  - Liquefaction Fragility
  - Comprehensive Design Recommendations
- Ductile Steel Cross-Frames
- Retaining Wall Seismic Loading and Design
- Type II Pileshafts
  - Analytical Study
  - Field Study
- Tsunami
- Fiber Reinforced Polymer (FRP) Composites
  - Long-Term Durability of FRP Composites
  - Non-Destructive Evaluation of FRP Bridge Decks
  - Pultruded FRP Sign Structures
- Condition Assessment
  - Long-Term Structural Performance Monitoring of Highway Bridges
  - Health Monitoring to Determine the Performance of Prestressing Steel in Segmental Box Girders
- Construction
  - Falsework Cap and Sill Beam
  - Sand Jacks
  - Closure Pour Waiting Time
  - Pre-weld Distortion Control Measures for Orthotropic Steel Bridge Decks
  - Column Cage Stability
- Structural Response to Blast Loading
- Concrete Materials
  - Controlling the Effects of Heat of Hydration
  - Corrosion Resistant Mineral Admixture Concrete
  - Creep and Shrinkage of Lightweight Concrete
  - Fiber Reinforced Concrete
- Soil-Structure Interaction
  - Battered Piles in Layered and Sloping Soils
  - Post-Grouting Methods to Increase the Load Capacity of Deep Foundations
- LRFD Specifications
  - LRFD Specification Strength Reduction Factors for FRP Composites
  - Prestress Losses in Long Span Post-Tensioned Bridges
- Replacement Alternatives for Concrete Approach Slabs

Attachment - B

DES Structure, Seismic, and Geotechnical Research Program Strategic Plan and Research Roadmap

New Research Projects:

The Structure and Geotechnical Technical Advisory Panels (TAPs), with concurrence from the Structure and Geotechnical Research Program Steering Committee (PSC) and the Research and Deployment Steering Committee (RDSC), approved the following projects during the FY7/8 research project development cycle.

Seismic:

- Live Load Effects on Seismic Response of Bridges
- Abutment Soil-Structure Interaction and Modeling
- Assessment of the Performance of Dampers and Bearings In Service
- LRFD Specifications for Bearings and Isolators
- The Effects of Vertical Ground Motion on Column Shear Capacity
- The Effects of Seismic Ground Motion on Retaining Walls and Soundwalls
- Rapid Remote Post-Earthquake Damage Assessment
- Seismic Performance of Fiber-Reinforced Concrete Columns

Non-Seismic:

- Skew Effects on Concrete Box Girder Superstructures
- Validation of Bridge Deck Rehabilitation Strategies
- Use of Near Surface Mounted Rebar for Bridge Deck Rehabilitation
- Embedded Downhole Foundation Investigation Methods

Additional Information:

Additional information on the DES Structure, Seismic and Geotechnical Research Program is available at http://www.dot.ca.gov/hq/esc/earthquake_engineering/Research/techreps.html, http://onramp.dot.ca.gov/hq/esc/sdsee/earthquake_eng/documents/funded_research_program2.xls and http://onramp.dot.ca.gov/newtech/ . These websites include a listing of past research projects, electronic copies of recent research reports, and information on the Caltrans research program. Hard copies of research reports can be found through the DES Technical Reference Center located on the 2nd Floor of Farmers Market I Building. For additional information on the DES Structure, Seismic and Geotechnical Research Program please contact Mike Keever, Chair of the Structure TAP at 916-227-8806 (mike.keever@dot.ca.gov) or Mark Willian, Chair of the Geotechnical TAP at 916-227-7014 (mark.willian@dot.ca.gov).

Attachment - C

DES Research Notes, March 2008

RESEARCH NOTES

THE OFFICE OF EARTHQUAKE ENGINEERING

March 2008

Caltrans

Full Scale Cyclic Large Deflection Testing of Foundation Support Systems for Highway Bridges

***RESULTS:** Caltrans, in partnership with the University of California, Los Angeles investigated the seismic performance of several foundation components and systems by physical testing. Computer models were used to predict the behavior of these components and systems. The results of the testing were used to calibrate the computer models in order to more accurately analyze the soil-structure interaction of bridge foundations in a variety of conditions.*

Why We Pursued This Research

Understanding the effects of soil structure interaction is essential to understanding the seismic performance of bridge foundations. Current engineering practice requires the use of "soil springs" in computer models to simulate the effects of the soil on foundation behavior. However, the knowledge base for developing these soil springs is limited and has been based on small or scaled-down foundation components. One goal of this research was to test full-scale foundation systems and individual components in order to estimate effects such as shaft diameter and group efficiency when developing soil springs for computer models.

The seismic performance of abutment back-walls is not well understood. In addition to the foundation testing, a typical abutment back-wall was pushed against a standard Caltrans back-fill material in order to assess the back-wall's behavior. The results will be used to provide guidance to engineers when modeling bridge abutments.

Bridge foundations are typically very expensive to construct, and the results of this project will allow engineers to design foundations that are cost effective while meeting all design requirements.

What We Did

Full scale physical testing was performed on 5 bridge components. 1) A 6' diameter drilled shaft foundation and bridge column 2) A 2' diameter drilled shaft foundation and bridge column 3) a single 2' diameter fixed head pile 4) a 9 pile (2 ft. diameter) fixed head group 5) a 5' 6" high abutment back wall placed in a silty sand backfill that meets Caltrans standards. These components were designed according to Caltrans standards.

Test borings of the soil were performed and the soil properties were logged. The test specimens were cycled under increasing loads until failure occurred. During the testing, measurements of displacements, rotations, curvatures, and strains were made.

Placing Backfill for Abutment Test

In addition to physical testing, the researchers developed computer algorithms to estimate soil spring parameters and soil-structure interaction models that would predict the specimen's behavior during testing.

Prior to testing of the bridge components, the researchers performed a "blind" prediction for each specimen. The blind predictions were compared to the actual results and the computer models were recalibrated for the next test.

Attachment - C

DES Research Notes, March 2008

Excavation after Abutment Back-wall Test

Methodology

UCLA's approach was to test full-scale models of bridge foundation components. Each component was tested under cyclic loading until failure occurred. During the testing, researchers at UCLA were recording and analyzing data from instruments placed in the specimens. Soil and structural material properties were also recorded. Results from the physical testing were compared to results obtained from computer simulations of the test specimen.

Research Results

The results showed that the current method (American Petroleum Institute - API) of estimating p-y curves under-estimates their capacity and stiffness at shallow depths. The capacity may be increased by a factor from two to three at these depths. In addition, the end condition (fixed head or unrestrained head) did not result in a significant difference in p-y curves and no change in Caltrans' current practice is recommended.

The current practice of using group reduction factors for pile groups that are independent of displacement levels may underestimate the group's resistance particularly at large displacements. However, while the current practice is somewhat conservative, it is adequate in most cases.

The results of the abutment backwall test indicate that current techniques for estimating soil resistance are overly conservative. Additional abutment back-wall tests should be performed so that height and skew effects can be modeled.

A final report for this project will soon be available online at:

http://www.dot.ca.gov/hq/esc/earthquake_engineering/Research/techreps.html.

2 Ft. Flagpole Test

Conclusions

The modeling of bridge foundations and their behavior during seismic events is often a difficult procedure. The current practice for estimating abutment back-wall capacity and stiffness is overly conservative and the results of this research will be used to re-evaluate these parameters when modeling abutments.

Engineers often "envelope" bridge foundation parameters in order to ensure the foundations meet design requirements. This could result in foundations that are larger than necessary, thus increasing construction costs. The results from this project will allow engineers to design more efficient foundations by using group reduction factors more effectively and thus potentially reduce construction costs and impact on traffic.

The results from this project will be incorporated into the Seismic Design Criteria (SDC).

GOVERNOR'S EXECUTIVE ORDER D-86-90

The following is the text of Executive Department State of California Executive Order D-86-90 signed on June 2, 1990 in response to the Report of the Board of Inquiry on the Loma Prieta Earthquake of 1989 report and recommendations.

WHEREAS, on October 17, 1989 a major earthquake occurred in Northern California, causing deaths, injuries, and widespread damage to transportation facilities and other structures; and

WHEREAS, an independent Board of Inquiry was formed in November 1989 to investigate the reasons for the collapse of transportation structures and to recommend actions to reduce the danger of tragic structural failures in future earthquakes; and

WHEREAS, the Board of Inquiry found that there is a high probability that one or more major earthquakes will strike heavily populated areas in Northern and Southern California in the future; and

WHEREAS, California's state of earthquake readiness needs improvement to better protect the public safety and our economy from potentially serious impacts of future earthquakes;

NOW, THEREFORE, I, GEORGE DEUKMEJIAN, Governor of the State of California, by virtue of the power and authority vested in me by the Constitution and Statues of the State of California, do hereby issue this order, to become effective immediately:

1. It is the policy of the State of California that seismic safety shall be given priority consideration in the allocation of resources for transportation construction projects, and in the design and construction of all state structures, including transportation structures and public buildings.

2. The Director of the Department of Transportation shall prepare a detailed action plan to ensure that all transportation structures maintained by the State are safe from collapse in the event of an earthquake and that vital transportation links are designed to maintain their function following an earthquake. The plan should include a priority listing of transportation structures that will be scheduled for seismic retrofit. The Director shall transmit this action plan to the Governor by August 31, 1990.

3. The Director of the Department of Transportation shall establish a formal process whereby the Department seeks and obtains the advise of external experts in establishing seismic safety policies, standards, and technical practices; and for seismic safety reviews of plans for construction or retrofit of complex structures. The Director shall transmit a summary of this process to the Governor by August 31, 1990.

APPENDIX II

4. The Director of the Department of Transportation shall assign a high priority to development of a program of basic and problem-focused research on earthquake engineering issues, to include comprehensive earthquake vulnerability evaluations of important transportation structures and a program for placing seismic activity monitoring instruments on transportation structures. The Director shall transmit a description of the research program to the Governor by August 31, 1990.

5. Local transportation agencies and districts are encouraged to review the findings and recommendations of the Board of Inquiry on the 1989 Loma Prieta Earthquake and to adopt policies, goals, and actions similar to those proposed for Caltrans.

6. The Director of the Department of General Services shall prepare a detailed action plan to ensure that all facilities maintained or operated by the State are safe from significant failure in the event of an earthquake and that important structures are designed to maintain their function following an earthquake. The plan should include a priority listing of facilities that will be scheduled for seismic retrofit. The plan shall further propose measures by which the state agencies construction new facilities or retrofitting existing facilities would:

    a. be governed by the provisions of a generally accepted earthquake resistant code for new construction;

    b. secure structural safety review and approval from the Office of the State Architect;

    c. seek independent review of structural and engineering plans and details for those projects which employ new or unique construction technologies; and

    d. have independent inspections of construction to insure compliance with plans and specifications.

    The Director shall transmit the plan to the Governor by August 31, 1990.

7. The Department of General Services shall, when negotiating leases of facilities for use by state employees or the public, consider the seismic condition of the facilities and shall initiate leases only for those facilities that demonstrate adequate seismic safety.

8. The Seismic Safety Commission shall review state agencies' actions in response to this executive order and the recommendations of the final report of the Board of Inquiry and provide a report to the Governor on the adequacy and status of actions taken by December 1, 1990.

9. The University of California and the California State University shall give priority consideration to seismic safety in the allocation of resources available for construction projects. The University of California and the California State University shall prepare and transmit to the Governor by August 31, 1990 a description of their plans to increase seismic safety at facilities they maintain or operate.

IN WITNESS WHEREOF I have hereunto set my hand and caused the Great Seal of the State of California to be affixed this 2nd day of June 1990.

SEAL	George Deukmejian Governor of California
ATTEST:	March Fong Eu Secretary of State

Seismic Advisory Board

MISSION STATEMENT

PURPOSE: The Seismic Advisory Board is an independent body whose role is to advise Caltrans on seismic policy and technical practices to enhance the seismic safety and functionality of California's transportation structures.

MISSION: The mission of the Seismic Advisory Board is to assist Caltrans' in its role and obligation to provide seismic safety of California's transportation structures through:

1. Continued review of earthquake engineering and seismic design as practiced by Caltrans.

2. Formulation of recommendations for improvements in Caltrans' earthquake engineering and seismic design practices.

3. Policy review of seismic hazard definition and mitigation directives.

4. Technical review of seismic design guidelines and standards for transportation structures.

5. Review and comment on Caltrans' seismic research agenda and priorities.

6. Being available to provide the general public with explanations regarding Caltrans' seismic safety policies and procedures for maintaining safety and functionality of California's transportation structures.

APPENDIX IV

SEISMIC ADVISORY BOARD MEMBERS (MAY 2010)

Chair
Dr. Frieder Seible

Frieder Seible is the Dean of the Jacobs School of Engineering at the University of California, San Diego (UCSD). His responsibilities include strategic planning and operations, school-wide research and education initiatives, academic affairs, and UCSD-wide cooperative programs. He is a member of the National Academy of Engineering and is the Walter J. Zable Professor of Engineering and the Eric and Johanna Reissner Professor of Applied Mechanics and Structural Engineering.

Dr. Seible's research achievements include the development of large-scale structural testing techniques, seismic assessment and retrofit of bridges, and the application of Polymer Matrix Composites (PMC) in civil engineering structures. He was the founding director of the Charles Lee Powell Structural Research Laboratories, which serve as a worldwide resource for full-scale testing and analysis of structures. Dr. Seible is the chair of the California Department of Transportation (Caltrans) Seismic Advisory Board and has contributed to the Caltrans Bridge Seismic Safety Program through his large-scale testing and retrofit research. He has served on or led many national and international committees on bridge reconstruction and retrofit. Dr. Seible has received numerous awards for his research, including the 2006 Humboldt Research Award, and has published more than 600 papers and technical reports mainly related to seismic design of bridges and buildings, as well as blast resistant design of critical structures.

Dr. Seible joined the UCSD faculty in 1983, and served as the founding Chair of the Department of Structural Engineering from 1995 to 2001. As chair, he oversaw the development of the first nationally accredited program in structural engineering. Dr. Seible received the traditional engineering degree (Diplom-Ingenieur) from the University of Stuttgart, his M.S. degree from the University of Calgary, and Ph.D. from the University of California, Berkeley, all in civil engineering.

Vice - Chair
Dr. Ian Buckle

Ian Buckle is the Director of the Center for Civil Engineering Earthquake Research and Professor of Civil Engineering at the University of Nevada, Reno. Previously, he served as Deputy Vice-Chancellor of Research at the University of Auckland, New Zealand and as Deputy Director of the National Center for Earthquake Engineering Research, University at Buffalo, the State University at New York (now the Multidisciplinary Center). He earned his B.E. (Honours) and Ph.D. degrees from the University of Auckland, New Zealand.

Dr. Buckle's research interests include seismic performance of bridges, lifelines and buildings; design and retrofit criteria for bridges; earthquake protective systems for structures including the theory, hardware, and engineering applications of seismic isolation; non-seismic bridge performance for extreme loads such as thermal effects and overloads; and linear and nonlinear analytical techniques for structures subject to dynamic loads. He has conducted short courses in bridge engineering, seismic retrofitting, and the seismic isolation of highway bridges; conducted full-scale field testing and large-scale laboratory testing of structures using static and dynamic loads; and has been a member of reconnaissance teams to earthquakes in California, Japan and Taiwan.

He is the lead author of the seismic provisions in the AASHTO LRFD Comprehensive Bridge Specifications, the AASHTO Standard Specifications Division I-A (Seismic Design), and the FHWA Seismic Retrofitting Manual for Highway Bridges.

Dr. Buckle is currently chair of the Transportation Research Board (TRB) Committee AFF50 on Seismic Design and Performance of Bridges, immediate past president Board of Directors NEES Consortium, and past chair ASCE Technical Council on Lifeline Earthquake Engineering. Current appointments also include being a member of the board of directors of the Consortium of Universities for Research in Earthquake Engineering, and the Nevada Earthquake Safety Council.

He is a member of the ASCE, the Earthquake Engineering Research Institute, and the New Zealand Society of Earthquake Engineering.

APPENDIX IV

SEISMIC ADVISORY BOARD MEMBERS (MAY 2010)

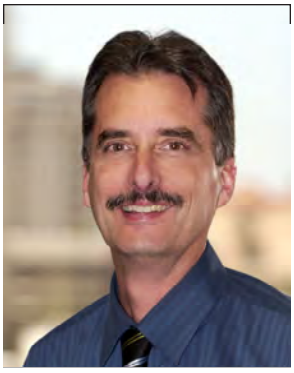
Dr. Norman Abrahamson

Norman Abrahamson is an internationally recognized expert in engineering seismology. Dr. Abrahamson has extensive experience in the practical application of seismology to the development of deterministic and probabilistic seismic criteria for engineering design and analyses. He has been involved in developing or reviewing design ground motions for hundreds of projects including dams, bridges, nuclear power plants, nuclear waste repositories, water and gas pipelines, rail lines, ports, landfills, hospitals, electric substations, and office buildings.

At PG&E, Dr. Abrahamson is responsible for developing ground motions for seismic evaluations of PG&E facilities including nuclear power plants, nuclear waste storage, dams, penstocks, electric substations, office buildings, and gas pipelines. He is also responsible for the technical management of the PG&E seismic research program funded through the Pacific Earthquake Engineering Research Center. He also directs the seismic studies in a cooperative agreement between PG&E and the U.S. Department of Energy.

As an adjunct professor at both the University of California, Berkeley and the University of California, Davis, Dr. Abrahamson teaches a graduate class on seismic hazard analysis and directs students in their Ph.D. research.

As a consultant, Dr. Abrahamson has been involved in the development and review of the ground motions for all of the major toll bridges in California. He also served as the leader of the ground motion characterization study for two major seismic hazard studies: the proposed nuclear waste repository at Yucca Mountain and a major update of the seismic hazard for Swiss nuclear power plants (PEGASOS project). He is currently leading a study by Electric Power Research Institute (EPRI) to update the models of the variability of ground motions in the eastern United States for application to new nuclear plants.



Jack Boda

Jack Boda, P.E. has over 30 years of transportation engineering experience including planning, design, construction, maintenance, and operations of the state highway transportation system within the public sector and more recently consulting in the private sector. He currently works for Kimley-Horn and Associates, Inc., as a team leader helping to advance transportation projects within California.

Before joining Kimley-Horn and Associates, Inc., Mr. Boda was in the public sector as the Director of Capital Projects and Mobility Management for the San Diego Association of Governments (SANDAG). His responsibilities involved working with Caltrans, in-house engineering staff, and consultants to design and construct major highway and transit projects using a 14-billion dollar local sales tax program. He also directed the SANDAG overall transportation program project office and the development and operation of the region's Intelligent Transportation System Network, including Managed Lanes (HOT) and Traveler Information system (511).

Before coming to SANDAG, Mr. Boda worked for the California Department of Transportation (Caltrans) and held several key management positions including State Traffic Engineer, Capital Project Program Manager, San Francisco Bay Area Chief Deputy Director, and served as the interim San Diego District 11 Director. Mr. Boda worked for James E. Roberts, the State Bridge Engineer as his executive assistant during the 1994 Northridge Earthquake and helped manage the seismic reconstruction effort. Mr. Boda holds multiple degrees in transportation and civil engineering from California Polytechnic State University, San Luis Obispo, is a registered civil engineer, and served as a member of the California Transportation Commission Statewide Project Delivery Council.

APPENDIX IV

SEISMIC ADVISORY BOARD MEMBERS (MAY 2010)

George Fotinos

George Fotinos is an experienced structural engineer. He has extensive experience in the design and construction of bridges, waterfront structures, tunnels, deep foundations and offshore structures.

He attended Santa Clara University where he obtained his B.S. in Civil Engineering. He started his career with the bridge department of Caltrans in Sacramento. He designed bridge structures for the new interstate highway system in Northern California. Following his assignment in Sacramento, he served two years in military service where he was assigned to administer the construction of radar bases in Iceland and Canada. Following discharge from the Army, he returned to school at the University of California, Berkeley, where he earned his M.S. in Civil Engineering.

Upon receiving his M.S., he was employed at the Ben C. Gerwick Company in San Francisco. The Gerwick Company specialized in waterfront structures and bridge foundations. He worked on several major bridges including the foundations of the Richmond-San Rafael Bridge, San Mateo-Hayward Bridge, Benicia-Martinez Bridge and waterfront structures throughout the San Francisco Bay.

The company was purchased by Santa Fe International Corporation and Mr. Fotinos served as the Chief Engineer of the engineering division of the corporation. He worked on many offshore and marine structures and bridges throughout the world, including the Northumberland Crossing in eastern Canada, Jamuna Bridge in Bangladesh, Bahrain Crossing in the Persian Gulf, and the Seven Mile Bridge in Florida.

Mr. Fotinos is a registered structural engineer in California, and a registered civil engineer in Washington, Nevada and Colorado. He has written many papers on the subject of marine foundations and bridges. He currently serves as a consultant to engineering and construction companies where he helps to solve difficult engineering and construction problems.

Dr. Geoffrey Martin

Geoffrey Martin has more than 40 years of experience in civil and geotechnical engineering. He is nationally and internationally recognized for his expertise in the field of geotechnical and earthquake engineering, particularly as related to the stability of earth structures, liquefaction, ground improvement, and the seismic design of foundations. He has authored or coauthored over 100 papers on these topics.

Dr. Martin received his M.S. in Civil Engineering from the University of Auckland, New Zealand in 1962 and his Ph.D. in Geotechnical Engineering from the University of California, Berkeley, in 1965. Following a 12-year career as a Professor of Civil Engineering at the University of Auckland, New Zealand, he joined the Earth Technology Corporation, Long Beach in 1977, as manager of Earthquake Engineering. Subsequently, as Vice President for Engineering, he was responsible for technical direction of major geotechnical projects particularly those related to earth dams, port facilities, offshore structures and bridges. He also directed the company's research activities in earthquake engineering.

In 1990, he returned to academia as a Professor in the Department of Civil Engineering at the University of Southern California where he is focusing his research interests on liquefaction-related ground stability studies and the seismic design of foundations and retaining structures. He is a contributing author to the "Recommended LRFD Guidelines for the Seismic Design of Highway Bridges" (2001), the "FEMA 273/274 Guidelines for the Seismic Rehabilitation of Buildings," and the Port of Los Angeles Seismic Code for Container Wharves.

He is active as an independent consultant and is currently a Technical Advisory Panel Member for the Los Angeles Metropolitan Transportation Agency Tunnel Projects, the Port of Los Angeles, the Los Angeles County Sanitation Districts Ocean Outfall Tunnel Project, and the Port of Long Beach Gerald Desmond Bridge.

APPENDIX IV

SEISMIC ADVISORY BOARD MEMBERS (MAY 2010)

Joseph Nicoletti

Joseph P. Nicoletti graduated from the University of California with a B.S. in Civil Engineering in 1943 with postgraduate studies in soil mechanics, coastal engineering, design of timber structures, and structural dynamics. In 1943-1946, his duties in the U.S. Navy included shipbuilding officer and deck division officer on submarine tender in Central and South Pacific.

After serving as Field Engineer for construction of the supersonic wind tunnel at Moffett Field, from 1946-1947, Mr. Nicoletti joined the staff of the structural engineering office of John A. Blume in 1947. He became a principal in the firm upon incorporation in 1957. The firm was known as URS/Blume - after acquisition by URS Corporation. In addition to the above administrative duties with URS/Blume, as Chief Engineer, Mr. Nicoletti was responsible and in charge of all firm design and consultation projects that included major commercial and public buildings, military facilities, and waterfront and coastal structures. He retired as president of URS/Blume in 1987, but returned as senior consultant after the Loma Prieta Earthquake in 1989 and retired completely in 2003.

For the Metropolitan Transportation Commission, Mr. Nicoletti chaired the Engineering and Design Advisory Panel for East Crossing of the Bay Bridge. For Caltrans, he co-chaired peer review panels for retrofit of the San Francisco double deck viaducts and was a member of the peer review panels for replacement of the Cypress viaduct and retrofit of the 24/580/980 interchange.

Mr. Nicoletti's Professional Affiliations include: The American Society of Civil Engineers, Fellow; Structural Engineers Association of Northern California, Past President and Honorary Member; Earthquake Engineering Research Institute, Honorary Member; Applied Technology Council, Past President; San Francisco Bay Conservation and Development Commission, Member and Past Chair of Engineering Criteria Review Board; and California Department of Transportation, member of the Seismic Advisory Board and Chair of Peer Review Panel for East Crossing of Bay Bridge.

Dr. Edward L. Wilson

Edward L. Wilson is a Professor Emeritus of Structural Engineering at the University of California, Berkeley, where he was a faculty member from 1965 to 1991. From 1973 to 1976, he served as Chairman of the Division of Structural Engineering and Structural Mechanics. From 1987 to 1990, he was Vice Chairman of the Department of Civil Engineering. At the present time he is a consultant on the structural analysis of complex structures and is engaged in the development of new nonlinear methods of analysis and computer programs in the general area of earthquake engineering. He is currently a member of the Seismic Review Committee for the University of California, Berkeley.

Dr. Wilson was responsible for the development of several computer programs extensively used by professionals in civil, mechanical and aerospace engineering. The general three-dimensional finite element Structural Analysis Program (SAP), is an example of a software application initially developed by Dr. Wilson.

In 1985, Dr. Wilson was elected to the National Academy of Engineering. He was appointed as the T. Y. and Margaret Lin Professor in Engineering in 1990. He received the Berkeley Citation at the time of his retirement from teaching in 1991. For his contributions to the profession he received the Huber (1974) and the Howard (1995) medals by ASCE. In 1998, he received the Lifetime Achievement Award from the Los Angeles Tall Buildings Structural Design Council. In 2003 he received the Von Neumann Medal from the United States Association of Computational Mechanics for the development of the SAP series of programs. In 2008, he received the Outstanding Contribution to Engineering Award from ASME and was made an Honorary Member of the Structural Engineering Association of Northern California.