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SEISMIC RETROFIT OF MAJOR STEEL BRIDGES IN CALIFORNIA TECHNICAL, SOCIAL, AND ECONOMIC CONSIDERATIONS

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ABSTRACT

Four years have passed since the disastrous Loma Prieta earthquake and over three years have passed since the Governor's Board of Inquiry into the cause of highway structure failures during that earthquake issued its final report with the warning title "Competing Against Time". It is the purpose of this paper to discuss the Seismic Evaluation and Retrofit of Steel Bridges in California with special emphasis on the large Toll Crossings of the San Francisco Bay and Southern California waterways; to bring readers up to date on the unprecedented research program that has brought us to the implementation of major construction projects to seismically retrofit seven of the nine Toll Bridges throughout the state; and to discuss the social and economical issues that affect the retrofit strategies. Caltrans staff engineers, consulting firms, independent Peer Review Teams, and university researchers have cooperated in this program of Bridge Seismic Retrofit Strengthening to meet the challenge presented in the Board of Inquiry report. The State Legislature, the California Transportation Commission, and the Department of Transportation management designated this program the number one priority for budget allocation. The six year old Seismic Advisory Board has been an invaluable asset in reviewing our performance criteria, design specifications, and design procedures. In many instances the Advisory Board has positively influenced management decisions to continue financial support of a strong research program to support seismic design and retrofit, through its recommendations to the Director of Transportation.

The success of the Bridge Seismic Retrofit program and the success of future seismic design for California bridges is based, to a large degree, on the accelerated and "problem-focused" seismic research program. That program has been supported at a level more than ten times the pre Loma Prieta level of financial support for all bridge research. The Department has been able to sustain the necessary high level of research support over the past six years, and has adopted a commitment for that level of funding for the forseeable future.

The Hazard Analyses, Vulnerability Analyses and initial Seismic Retrofit Strategies have been completed for seven of the eight Toll Bridges, and final design has been started on those bridges. The San Francisco-Oakland Bay Bridge, because of its size and complexity will be the last Toll Bridge to be completed. Many large scale tests must be completed to confirm retrofit strategies and to reduce the initial estimated retrofit costs for this bridge. On two of the Toll Bridges replacement, rather than retrofit, appears to be the logical strategy and is being pursued.

KEY WORDS

Seismic Retrofit, Hazard Analysis, Vulnerability Assessment, Ductility, Displacements, Soil-Structure Interaction, Retrofit Strategy, Base Isolation, Energy Dissipation.

CALTRANS RESPONSE TO GOVERNOR'S BOARD OF INQUIRY RECOMMENDATIONS AND EXECUTIVE ORDER OF JUNE, 1990

The Governor's Board of Inquiry, in its report to then Governor George Deukmejian, made several recommendations specifically for the Department of Transportation. In the 1993 Annual Report of progress in accomplishing those recommendations the Department of Transportation responded positively to each of the eleven recommendations of the Governor's Board of Inquiry, presented in their report "Competing Against Time" dated June 1, 1990; to Governor George Deukmejian's Executive Order D-86-90, dated June 2, 1990; to the requirements of Senate Bill 36X, Signed into law by Governor Deukmejian on November 6, 1989; and to Senate Bill 2104 (Kopp), passed into law in 1991. Each of these four documents recommended and mandated specific aspects of a continuing and aggressive Seismic Safety Program for Transportation Structures. This paper will address only those of the recommendations which affect the steel bridges, with emphasis on the Toll Bridges.

STATUS OF COMPLIANCE WITH RECOMMENDATIONS/ORDERS

The progress report on the current status of the Department's Bridge Seismic Safety Retrofit Program is addressed in the "Seismic Safety Retrofit Program-Annual Report" which was presented to the California Transportation Commission on February 24, 1996, and will be updated and presented again in February, 1997. There are nine Toll Bridges on the state highway system, exclusive of the Golden Gate Bridge. Eight Toll Bridges, including the Golden Gate Bridge, are in various stages of analysis and design and will be under construction beginning in the spring of 1996. Because of the need to balance this work with other transportation safety needs the California Legislature has determined that the Toll Bridge program will be spread over the next three years. The San Francisco-Oakland Bay Bridge has been the subject of various stages of seismic retrofitting since the Loma Prieta earthquake but, because of its size and complexity, will be the last to be completed, in the late fall of 1998.

By July, 1990 Caltrans engineering staff had completed an initial "Vulnerability Analysis" of the 24,000 state, county and city bridges and produced a prioritized list from which to complete the seismic safety retrofit program. The logical strategy was to retrofit or replace the most vulnerable bridges on the list first, when this approach is possible. That initial screening list contained approximately 7000 state and 4500 city and county bridges which required further analysis and evaluation before a determination could be made as to seismic retrofit needs. The current program includes 2218 State and approximately 500 City and County bridges which need seismic retrofit strengthening to meet current seismic safety criteria. Unfortunately, the highly important Toll Bridges are so complex and large that they are some of the last to be designed and put under construction.

SEISMIC DESIGN PHILOSOPHY

Performance Criteria-An agency or designer must have a performance criteria established. How do you want the structure to perform in an earthquake? How much damage can you accept? What are the reasonable alternate routes? A bridge seismic performance criteria was developed by Caltrans' Engineering staff for state owned bridges and was approved by the Seismic Advisory Board in September, 1992. That current Performance Criteria is **"No Collapse", "No Major Damage", "No Secondary Injuries or Fatalities Because Emergency Equipment Cannot Get Through", "Major Important Structures and Lifeline Routes Must Remain Operational".** This criteria is generally attainable but the last one can be expensive if structures are expected to withstand severe earthquakes such as a 45 second duration shake due to large earthquakes on a major fault. That is what is expected of major important structures in California and the 45 second duration shake is what the experts predict when the "Big One" comes.

Seismic Design Principles-Continuity is extremely important and is the easiest and cheapest insurance to obtain. If structures are not continuous and monolithic, they must be tied together at deck joints, supports and abutments. This will prevent them from pulling apart and collapsing during an earthquake. Ductility in the substructure elements is the second key design consideration. It is important that when you design for ductility you accept some damage during an earthquake. The secret to good seismic design is to balance acceptable damage levels with the economics of preventing or limiting the damage. Properly designed ductile structures will perform well during an earthquake as long as the design has accounted for the displacements and controlled them at abutments and hinges.

Steel versus Concrete-While it can be argued that steel is inherently more ductile than concrete, it must also be remembered that the materials must be designed to resist the current anticipated seismic forces. Most damage in California during the Loma Prieta earthquake occured on structures that had been designed 30 to 60 years ago to comply with codes that required seismic design forces of only 0.06g to 0.08 g. Today most of those structures would be designed for 8 to 10 times these seismic forces. The forces are derived from the acceleration coefficients multiplied by the weight of the contributing mass at any supporting member or joint. A quick survey of most bridges in this country will confirm that almost all have reinforced concrete substructures, regardless of the type of superstructure. And the substructures are where most of the earthquake damage occurs. Since we rely on internal strain energy to dissipate the external work (energy), concrete substructure elements are preferrable, as long as they are properly confined and will remain intact. Internal damage can be repaired after a seismic event.

RETROFIT PHILOSOPHY

It was and still is Caltrans philosophy to first retrofit those structures which pose the greatest risk to the public and are the most vital to the transportation system. The ultimate goal is to insure that all the bridges in the state will be capable of surviving maximum credible earthquakes without collapse. Some damage is inevitable but, with proper retrofitting, it is believed that collapse is preventable and, further, it is believed that damage can be held to a minimum, to the extent that the critical elements of the transportation system can remain open and functioning during a civil disaster and during repair. As we implement the actual analysis and design it is becoming apparent that retrofitting many older structures to this standard may not be cost effective. It is highly probable that we may have to accept some period of closure on many structures to effect repairs. It is also apparent that some structures will be replaced rather than retrofitted simply as an economic decision. Time and further analysis will bring this problem to the decision makers. As a direct result of the one month loss of the San Francisco-Oakland Bay Bridge during the Loma Prieta earthquake, it has been recommended that major transportation structures be designed for essentially elastic performance, while subjected to higher seismic force levels and longer shaking periods, in order to reduce the damage to non structural type. To accomplish this goal a new "importance factor" was introduced into the design and retrofit performance criteria. This represents a major change in the seismic design criteria for bridges and also represents introduction of a subjective factor which will be based on judgement more than engineering principles.

PERFORMANCE AND DAMAGE

Over the years structural steel bridges have performed reasonably well during moderate earthquakes in California. Most structural steel bridges in California were designed prior to the development of the modern seismic design code and structural details in 1972. They were designed to withstand seismic forces of 0.06g or 6 percent of the contributing dead load acting laterally at the deck level. That seismic design force compares to current seismic forces which are typically 8 to 10 times as great at locations in the most severe aeismic zones. Despite such low seismic design forces most damage has been limited to the substructure, which in most cases is of reinforced concrete, and to connection details. Examination of damage to structural steel bridges after recent earthquakes has confirmed the need for continuous bridges or seismic retrofit details to tie superstructure joints together. It is equally important to tie superstructures to the supporting substructures. The most severe damage to a structural steel bridge in the 1971 San Fernando earthquake occurred when the girders came off their supports and fell because they were not tied down. Performance of the same type of bridge in the 1989 Loma Prieta earthquake was improved significantly by the addition of cable restraining systems to tie the girders to the substructure. Similar systems have been installed on all the older steel girder bridges throughout the state during the 17 year superstructure seismic retrofit program. Performance of retrofitted steel bridges was again improved in the 1994 Northridge earthquake. However, girder bearing damage was a problem, resulting in a strategy to replace most older bearings with base isolation systems.

San Francisco-Oakland Bay Bridge (SFOBB)-While structural steel is inherently a ductile material, it must be designed to resist the highest expected seismic forces or retrofitted to resist those forces. Additionally, the large relative displacements resulting from ductile columns going plastic during a seismic event must be considered in the initial design or retrofit scheme. The San Francisco-Oakland Bay Bridge is a good example of a long steel structure which performed well in the moderate Loma Prieta earthquake with little damage. To withstand a maximum credible seismic event, however, it must be analyzed and retrofitted for those higher forces , larger displacements and for longer shaking periods. The analysis of this bridge and eight other major bay and river crossings is now underway, retrofit designs were initiated in 1995, and contract work will begin in 1996.

The SFOBB was designed in the early 1930's for a seismic force of 0.075g to 0.10g. It is a tall column structure providing navigation clearance for capital ships. This height is both a benefit because the steel towers are flexible and a problem because they are all of different heights, causing non-uniform lateral displacements. It has been concluded that the damage at Pier E-9 of the East Bay truss spans was caused by the differential movement of these varying height towers that exceeded seven inches.

STATUS OF RETROFIT RESEARCH PROGRAM

Governor's Board of Inquiry Recommendation. "Fund a continuing program of basic and problem-focused research on earthquake engineering issues pertinent to Caltrans responsibilities."

Status-The initial Legislative investment in bridge seismic research was $8 million. Subsequently, the Department management has agreed to a problem-focused seismic research program at an annual expenditure level of $5 million (approximately 1% of the Caltrans annual bridge capital expenditure program). It is this last recommendation that gave impetus to the major seismic research work being supported by the Department today and for which we are supporting the annual seismic research workshops. The workshops serve a major goal of technology transfer to the user community.

The author was requested to present a Keynote Address and Commissioned Paper for the Bridge Session at the Earthquake Engineering Research Institute/National Academy of Science symposium on the "Practical Lessons Learned from the Loma Prieta Earthquake" in San Francisco on March 22-23, 1993. Each Keynote Speaker was asked to review all the pertinent research that resulted from the Loma Prieta event, discuss the research, and draw some practical lessons from the total. A summary of the conclusions from that paper follows.

PRACTICAL LESSONS FROM LOMA PRIETA APPLICABLE TO OTHER AREAS AND STATES

A great deal of the published research that resulted from the Loma Prieta earthquake served the useful purpose of validating many of the conclusions that the bridge engineering community had derived empirically. There were too many researchers and too much money spent on analysis of the failures at the San Francisco-Oakland Bay Bridge and the Cypress Street Viaduct. Both these structures were designed many years prior to the development of the modern bridge seismic design specifications. Both were designed for lateral force requirements of 0.06g to 0.10g and could not be expected to withstand the seismic forces that even a moderate earthquake such as Loma Prieta produced. It is a tribute to uncalculated redundancy and better than specified material strengths that these structures and other older highway structures performed as well as they did during the Loma Prieta event. This reasonable performance of older bridges in a moderate earthquake is significant for the rest of the United States because that knowledge can assist their engineers in designing an appropriate seismic retrofit program for their structures. While there is a necessary concern for the "Big One" in California, especially for the performance of important structures, it must be noted that many structures which can be bypassed need not be designed or retrofitted to the highest standards. It is also important to note that there will be many moderate earthquakes that will not produce the damage associated with a maximum event. These are the earthquake levels that should be addressed first in a multi phased retrofit strengthening program, based on the limited resources that will be available. Cost benefit analysis of proposed retrofit details is essential to measure and insure the effectiveness of a program.

Nevertheless, the screening processes and prioritization procedures that have been developed in California can have immediate application to other areas. Many excellent design details have been developed, through research and model testing, to guarantee ductile performance and these can be used elsewhere without "reinventing the wheel". The excellent work that has been accomplished in foundation response and soil-structure interaction during a seismic event represents significant improvement in the state-of-the-art and can be directly applicable in other parts of the country.

Response of Deep Soft Soils-One of the most important lessons gained from the Loma Prieta earthquake and the research that has followed is the importance of calculating the seismic response of soft mud foundation sites for use in design of a bridge. Geotechnical engineers and geologists have been sounding the warnings for some time, especially after the 1985 Mexico City earthquake. It required the loss of life in the Loma Prieta earthquake to spring the funding for research into foundation response in softer, cohesionless soils and bay muds. That funding has, generally, been made available and much valuable research has been completed with additional work to follow in the development of techniques to deal with soft and liquifiable soils. Much research has been and will continue to be completed in the area of foundations and soil-structure interaction. The bridge community is now equipped with the tools to design the appropriate structures in any foundation soil condition. Other areas of the country should learn from the foundation problems experienced in the Loma Prieta event, identify similar foundation problem areas in their jurisdictions, and build on the excellent research that has been completed since Loma Prieta to analyze the response of their structures to these varying foundation conditions.

Ductile Design Details-The research in ductile design details is second only to the amount of research that has been completed in foundation response. The continuation of research in this area will be aimed at reducing the conservatism that permeates ductile column and joint design in California today. Prior to the Loma Prieta earthquake there had been little or no research into the performance of very large column-cap joints and confinement details for large joints. Satisfactory performance of those bridges that had been designed for ductile performance during the earthquake gives the bridge design community reassurance that details can be developed to guarantee ductile column and joint performance in a major seismic event. Recent research results show that we can significantly reduce the amount of joint reinforcement that has been designed into these details since Loma Prieta. Additional research will be funded to corroborate those initial conclusions and design details will be modified accordingly.

Soil-Structure Interaction-There had been a significant amount of work in soil-structure interaction completed overseas before the Loma Prieta event and much additional research in this area has been completed or commissioned since the earthquake. This information is available and is important in the seismic retrofitting of older bridges because we know that very few of these older structures were designed with any consideration for the soil-structure interaction. Significant reduction in structural member forces can be achieved by considering the effects of the foundation resistance on the total structure response. The limited research in this area has given designers some analytical tools for modeling soil spring constants for both piling and pile caps/footings. For new design it is essential to consider the effects of foundation soil-structure interaction in modeling the system for an accurate dynamic response analysis.Typically, the abutments can be designed to resist a large percentage of the longitudinal earthquake forces in most bridges of shorter and moderate lengths. For any bridge a savings in column retrofitting, and reinforcing steel in new designs, can be achieved by proper consideration of the foundation-structure interaction.

Response and Retrofitting of Structural Steel Bridges-Despite the fact that structural steel is ductile, members that have been designed to meet the pre-1971 seismic design specifications must be evaluated for the seismic forces expected at the site based on earthquake magnitudes as we know them today. Typically, structural steel superstructures that had been tied to their substructures with joint and hinge restrainer systems performed well. However, we have identified many elevated viaducts and some smaller structures supported on structural steel columns which were designed prior to 1971 and which will require major retrofit strengthening for them to resist modern earthquake forces over a long period of shaking. One weak link is the older rocker bearings which will probably roll over during an earthquake. These can be replaced with modern neoprene, teflon, pot, and base isolation bearings to insure better performance in an earthquake. Structural steel columns can be strengthened easily to increase their toughness and ability to withstand a long period of dynamic input.

Nonlinear Analysis Procedures-Prior to the Loma Prieta event there was little use of nonlinear analysis in the design of bridges. In order to correctly analyze bridge performance in a major earthquake of long duration, the use of nonlinear analysis techniques is mandatory. Ample research has been completed in this area to give designers the necessary tools to conduct reasonable nonlinear analyses and design structures that will perform in a ductile manner during a major earthquake with long duration. Additional work in this area will continue to improve the expertise of and build confidence in the bridge designers.

STATUS OF TOLL BRIDGE RETROFIT PROGRAM

The toll bridges are the largest and most complicated bridges in the state. Nowhere in the world have any bridges as complex as these ever been seismically retrofitted. Variable soils and foundations, seismic forces nearly 10 times the original design forces, heavy traffic volumes, conflicts with utilities, air space concerns, handling of hazardous waste and care to protect sensitive resources all contribute to the difficulty in retrofitting these structures. Hazard and vulnerability studies have confirmed that seismic safety retrofit work is needed on seven of the State's nine toll bridges. There are many studies necessary prior to beginning actual retrofit design and construction on these major bridges.

Hazard Analysis-Determination of the Probabilistic Maximum Credible Design Earthquake Spectra at the Bed Rock for the specific site or region. This study is time consuming and expensive but absolutely necessary for long and important bridges.

Vulnerability Analysis-Bringing the Bed Rock Acceleration Spectra up through the materials overlying the Bed Rock, computer modeling the structure and foundation materials, and determining the seismic response of the structure to the design earthquake spectra. This study is conducted for each specific bridge.

Large Scale Confirmation Testing-Load tests of modeled or full size older bridge components to determine their capability to resist modern seismic forces.

Design PS&E-Taking the Structure response from the VulnerabilityAnalysis and designing details to resist both forces and movements, preparing contract plans and specifications and bid documents.

Generally the Hazard Analysis is performed for a region. The Carquinez Straits Hazard Analysis is good for both the Carquinez and Benicia-Martinez Bridge sites; the Hazard Analysis for all bridges in the San Francisco Bay was performed by one consultant and is good for Dumbarton through Richmond-San Rafael; the Southern California Hazard Analysis was completed by another consultant to provide input for the San Diego-Coronado Bridge and the three toll bridges around Terminal Island in Los Angeles. In a few cases the Vulnerability Analysis and PS&E can be combined into one consultant contract but on the longer bridges this is too large a package for one consultant. Often there will be several PS&E packages generated for a long bridge but based on the single vulnerability analysis.

The Hazard Analyses for all Toll Bridges were completed in 1993 and the final reports have been delivered. The Vulnerability Analyses on the Benicia-Martinez Bridge, the Carquinez Bridge, The Richmond-San Rafael Bridge, and the San Mateo-Hayward Bridge were completed by the consultants in 1995. The Lawrence Livermore National Laboratory of the UC System is conducting a confirmation analysis of the Dumbarton Bridge at no cost to the State. That bridge was designed for current seismic criteria but LLNL wanted to do some work for Caltrans to become familar with bridge modeling and to prove their capability. By working with them and having them work with the UC professors, we are developing a good team.

The San Francisco-Oakland Bay Bridge is obviously farther along in the retrofit process because the Hazard and Vulnerability analyses were assigned to the UC Berkeley team in 1990 and the work started immediately, and was completed in 1992. One repair project that upgraded the connections where the damage occured on Pier E-9 has been completed. Contractors have also completed a retrofit project on the concrete columns on Piers E-17 to E-23 since the Loma Prieta earthquake. The next retrofit project will go to contract this winter (1996) and all work will follow in parallel as plans are completed.

The greatest level of work is required on the San Francisco-Oakland Bay Bridge. More than 100 Caltrans engineers have been assigned during the 1995/96 fiscal year to work on the analysis and design of the anticipated 21 separate projects that will be required to retrofit this structure. An outside Peer Review Panel of independent (non-Caltrans) retrofit experts has been established to review and comment on design assumptions, findings and design proposals. Work on this retrofit has been intensified, and aggressive delivery goals set. The first project on the west approach to the bridge was awarded in May 1994, and construction was completed in October 1994. The second project was awarded in September 1995, to strengthen the east approach spans. While the strategy for the bridge has not been completed, these projects are common to all of the proposed strengthening options. However, a complete strategy for the entire bridge is needed before additional projects on the main spans can begin. Additional tests to determine performance capacity of the existing lattice members and piles are needed before the strategy can be completed. In addition, full scale tests are being contracted out on the proposed base isolation system, which if installed will be one of the largest in the world, and will potentially result in a significant reduction in the retrofit cost. Completion of strategy and updated estimates of cost are expected by mid-1996. Project clearances required by the U. S. Coast Guard, State Historic Preservation Office, and Bay Conservation Development Commission are proceeding pending completion of the bridge retrofit strategy.In addition to developing a retrofit strategy, the department is exploring the possibility of building a new replacement span for the eastern section of the Bay Bridge connecting Yerba Buena island and the Oakland shore as an alternative solution.

On November 5, 1995, the Caltrans Seismic Advisory Board, which was appointed by the Department in September 1990, to provide continued focused evaluation of seismic policy and technical procedures, and members of Caltrans' Bridge Peer Review Panels informed the Department of their concern over the short period of time for the completion of plans and specifications for the retrofit of these complex bridges. Their concerns included the need for additional testing, time to develop with confidence the seismic retrofit solutions needed to protect both the bridges and the people that use them. The letter indicated their belief that it may be more prudent to stagger the toll retrofits over a longer time. The Department is evaluating the concerns on a bridge by bridge basis.

Caltrans has contracted out the structure design on the Coronado, Vincent Thomas, Benicia-Martinez, Carquinez, Richmond-San Rafael, and San Mateo-Hayward toll bridges. These contracts were awarded in May 1995. Analysis and design work is well underway. Additional tests are scheduled to determine pile lateral load capacity and performance for the Coronado, San Mateo, SFOBB, and Richmond-San Rafael Bridges. Structure design is projected to be complete on all 5 bridges late in 1996. Construction on some segments of these bridges will begin in 1996. Peer Review Panels have been identified for each of these bridges. Four separate contracts have been awarded to expedite special studies, required permit clearances and traffic handling on the Carquinez, Benicia-Martinez, San Mateo-Hayward, and Richmond-San Rafael Bridges. The Department is exploring the possibility of accelerating the replacement of the west bound Carquinez Bridge, approved by the voters in 1988 as part of Regional Measure One, as a way to significantly reduce the retrofit cost of the existing bridge.

Research contracts have been awarded to universities and private companies to determine how certain proposed toll retrofit elements will react to the maximum credible earthquake.

Significant progress has been made during the last year on the Toll Retrofit Program. With the continuing challenges, new concerns from the Seismic Advisory Board and Peer Review Panels, testing needs and construction options, it is becoming more obvious that the toll delivery strategies are segregating into three distinctly different elements. To allow a better focus on these different elements, the Department has divided the Toll Retrofit Program into the following three delivery elements.

• TOLL 1. The San Francisco Oakland bay Bridge, which needs more time and testing before the retrofit strategy can be completed and updated estimates of cost made.

• TOLL 2. Replacement of the west bound Carquinez Bridge, which will result in a significant economic savings. Studies are being made of work required on the existing bridge and time required to complete plans and clearances for the replacement. Cost of the replacement will be funded from Regional Measure One toll revenues.

• TOLL 3. The 5 bridge group, the Richmond-San Rafael, Benicia-Martinez, San Mateo-Hayward, Vincent-Thomas and the Coronado Bridges, with construction starting in 1996. Estimated capital and support cost for retrofit of these bridges is $650 million.

SUMMARY

The warning has been sounded and the challenge has been met with an ambitious and aggressive Bridge Seismic Retrofit Strengthening Program. That program is based on analysis backed up by problem-focused research and proof testing. The multitude of researchers working in this effort have assisted the design community by accelerating the research and producing implementable interim results. Those results are being put into practice even while additional research is conducted and new specifications are being developed.

Now is the time to reflect on the considerable research that has been conducted since the Loma Prieta earthquake and review our goals. The Caltrans External Research Advisory Panel and the Internal Research Committee will do just that during the Spring of 1996. Priorities will be placed on reducing the conservatism in joint confinement steel and on gathering more information on foundation response throughout the entire state, especially for liquifiable soils.

The sense of urgency has not remained with many people, those who have begun to forget the Loma Prieta earthquake as they face other social problems. The bridge design community and the bridge researchers cannot afford to reduce our sense of urgency, however. Conversely, we must maintain the pressure while the political interest is still there to support the retrofit program. The momentum was lost after the San Fernando earthquake and we cannot afford the same loss of momentum until the first phase of the current bridge seismic program is completed. We are still competing against time and will be competing for the next three years.