# CALTRANS BRIDGE SEISMIC SCREENING PROGRAM

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## Abstract

California's high seismicity makes bridges susceptible to earthquake damage that may lead to disrupted service or possible bridge failure. After the 1989 Loma Prieta Earthquake, Caltrans initiated an ambitious seismic retrofit program to address seismically deficient bridges identified from a screening and prioritization of the California bridge inventory. Although the initial screening was based on the best information available at the time, not all seismically vulnerable bridges were identified. This paper summarizes past Caltrans seismic screening efforts and summarizes the effort underway to identify vulnerable bridges that may not have been captured by earlier screening efforts.

## Introduction

Caltrans' external advisory board has urged the department to periodically re-screen its bridge inventory for potential seismic vulnerabilities. There are several reasons why this is necessary. As we learn more about bridge behavior, we recognize vulnerabilities that were not addressed in earlier screening efforts and retrofit programs. For instance, it is now understood that bridges with both tall and short columns are vulnerable because the unbalanced column stiffness leads to concentrated damage in the shorter columns. The importance of balanced stiffness wasn't fully appreciated until the 1994 Northridge Earthquake where several bridges with a mix of short and tall columns performed poorly. Earlier bridge screenings did not take unbalanced stiffness into account.

Knowledge of seismic hazard also evolves with time and may impact the vulnerability assessment of existing bridges. New earthquakes provide critical data leading to periodic updates of ground motion prediction equations (GMPE's). New faults are identified and the properties of existing faults are refined. Additionally, in recent years there has been a trend toward increased use of probabilistically assessed seismic demand. In regions near active faulting, this has resulted in a sharp increase in design ground motion levels. However, this was only recognized after the 1994 Northridge Earthquake toward the end of the legislated seismic retrofit program.

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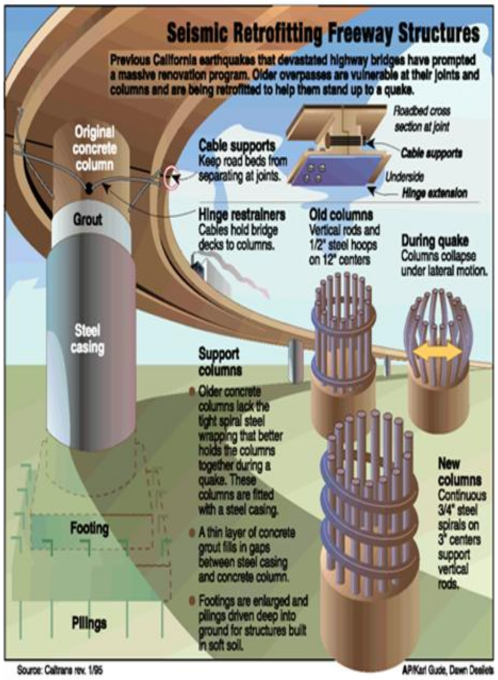
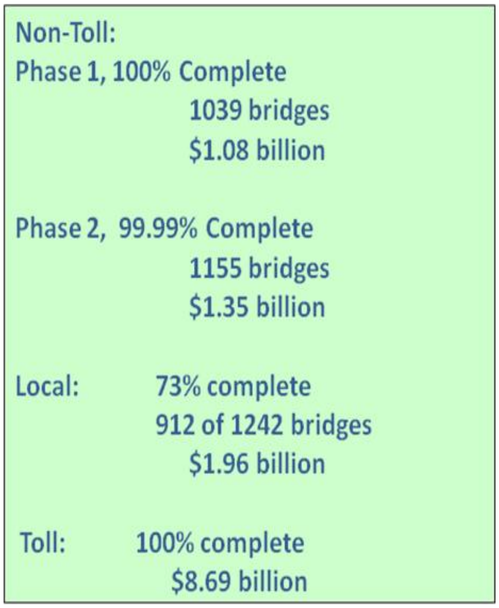
## **Caltrans Bridge Seismic Retrofit Programs**

The first bridge retrofit program began after the 1971 San Fernando earthquake. Approximately 1300 state bridges were identified as vulnerable to large displacements and retrofitted with cable restrainers at a cost of $54 million. The Phase 1 seismic retrofit program began in 1987 (after the Whittier Narrows Earthquake) due to the realization that restrainers were not as effective at preventing column damage as was previously believed.

After the 1989 Loma Prieta EQ, Executive Order D-86-90 set policy that all state owned and operated structures are to be seismically safe and that important structures are to maintain their function after earthquakes. Caltrans screened the state bridge inventory using an algorithm that considered the size of the ground shaking hazard, the frequency of strong shaking, the vulnerability of the bridge, and the bridge's importance. Out of the 11,895 state bridges that were screened, evaluated and prioritized, 6,892 bridges were identified as needing potential retrofit. 1,544 bridges were eliminated by main span type and an additional, 3,049 bridges were eliminated through a General Plan review. 1039 bridges were retrofitted during Phase 1 of the program. An additional 1155 bridges were retrofitted during Phase 2 of the program to address bridges with multi-column bents. The replacement of the Schuyler Heim Bridge in Los Angeles, the last seismic retrofit project from the legislated program, is projected to be completed by May of 2017.




Non-Toll:
Phase 1, 100% Complete
1039 bridges
$1.08 billion

Phase 2, 99.99% Complete
1155 bridges
$1.35 billion

Local: 73% complete
912 of 1242 bridges
$1.96 billion

Toll: 100% complete
$8.69 billion

FIGURE 1. CALIFORNIA BRIDGE RETROFIT PROGRAM

## Original Caltrans Screening Criteria

The initial screening algorithm was developed to identify and prioritize the bridges most vulnerable to collapse or heavy damage due to large earthquakes. The algorithm consisted of a summation of a series of pre-weighted attributes that included year of construction, soil type, acceleration value, detour length and structural attributes such as framing configuration, skew angle, and column height (Maroney 1990).

The original algorithm used to screen the inventory after the Loma Prieta EQ was the sum of pre-weighted factors resulting in a bridge score between 0.0 and 1.0. The weighted factors are shown below the equation.

$$R = \sum [(wt) \times (pre - wt)]$$

*Year Built*
*# of Hinges*
*Traffic Exposure*
*Length of Detour*
*Peak Ground Acceleration*
*Columns per Bent*
*Skew Angle*
*Abutment Type*
*Soil Type*
*Column Height*
*Route Type*

After screening and prioritization, an initial filtering was done based on main span type. Bridges that were thought to be less vulnerable such as timber bridges, continuous slabs, and culverts were removed. A general plan review of the remaining bridges was done and additional bridges were removed based on bridge length (less than 300 ft.), continuity, and modern details (post 1980). The screening algorithm continued to evolve during the 1990's.

## Post Retrofit Program Screening Efforts

Between 2002-2004, the Office of Earthquake Engineering (OEE) revamped the screening algorithm and rescreened the state bridge inventory for seismic vulnerabilities observed during the Northridge Earthquake that were not addressed in the initial screening effort.

The changes to the screening algorithm were based on knowledge gained from advancements in retrofit technology, proof testing, and improved dynamic analysis procedures. The algorithm was updated and an emphasis placed on vulnerable bridge components. Over twenty vulnerabilities were added to the newly modified screening algorithm. The vulnerabilities were divided into four weighted categories; vulnerabilities that are brittle in nature and could result in nearly immediate failure in a minor or moderate event; vulnerabilities associated with non-ductile behavior and could result in failure after several cycles of shaking during a moderate or major event; structure systems/components that could induce other vulnerabilities during a major event; and poor details/conditions. The

2004 algorithm multiplied the summation of vulnerabilities by a hazard score.

$$Initial\ Score = [Hazard\ Score] \times \left[\sum (Vulnerability\ Factors)\right]$$
$$Hazard\ Score = [Soil\ Type\ Factor] \times [Moment\ Magnitude\ Factor] \times [PRA]$$

Where:
*Soil Type Factor = 2.5 for soil soils and 1.0 for other types of soil*
*Moment Magnitude Factor = 1.0 for* $M_w$ *6.5, 1.1 for* $M_w$ *7.25 & 1.25 for* $M_w$ *8.0*

The results of the 2004 screening were mixed. The approach was conservative and in some categories such as liquefaction and bridges near newly discovered fault, half of the bridge inventory was scored as potentially vulnerable. However, three populations of bridges emerged that needed to be addressed: bridges with unrestrained short in-span seat hinges without restrainers; slab bridges with unrestrained hinges; and bridges with grouted hinge restrainers. In 2007 these populations of bridges were added to the Structure Replacement and Improvement Needs (STRAIN) list. STRAIN is the mechanism used by Caltrans to address outstanding bridge maintenance needs. The deficiencies are addressed when either funding becomes available or when a capital project is initiated for the bridge the STRAIN needs must be addressed. By 2007, over 300 bridges were identified as needing further seismic evaluation.

## Need For More Screening Emerges

In 2004 Caltrans developed a funding mechanism to address the bridges listed in STRAIN as potentially seismically vulnerable. Projects were created by bundling these bridges by geographical proximity and initiating projects to retrofit them. It became apparent that the screening criteria and programming process did not adequately scope the need and/or breadth of retrofit work required. An improvement to the methodology was needed.

- The vulnerabilities added during the 2004 rescreening effort need to be refined.
- The scoring system employed in 2004 did not adequately address risk and hazard.
- The 2004 results did not adequately delineate clearly which bridges were most vulnerable. This is illustrated by the large number of bridge with low scores shown in Figure 2.
- A lower threshold score was needed so bridges below this point would not need to be evaluated.

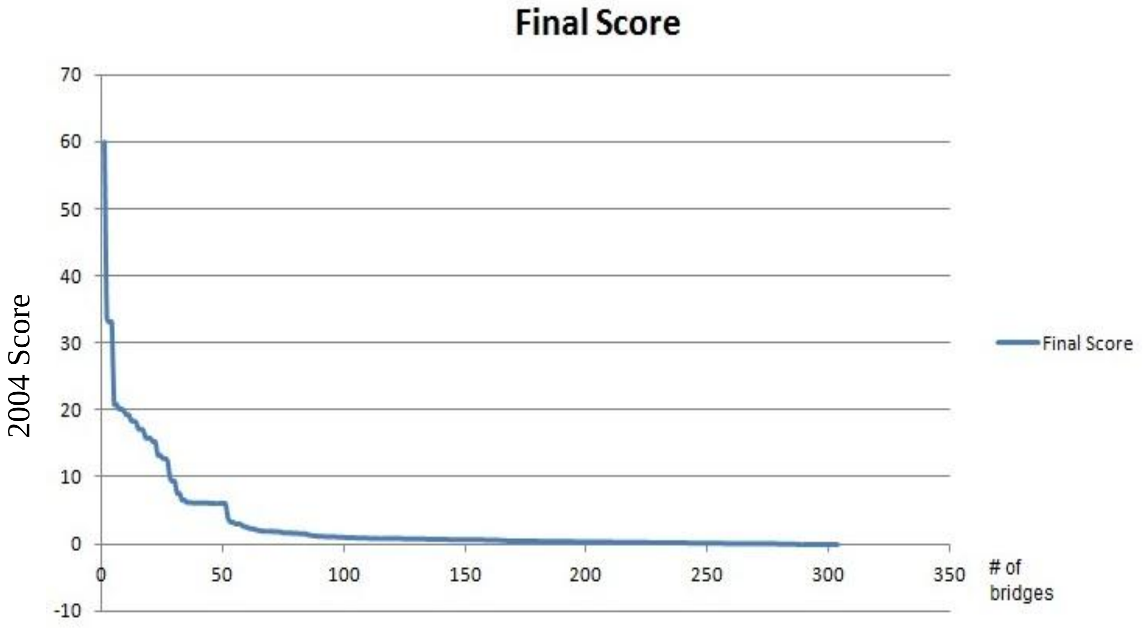


FIGURE 2. DISTRIBUTION OF BRIDGE SCORES
USING THE 2004 ALGORITHM

In 2010 Caltrans adopted a new seismic hazard policy that enveloped the deterministic and probabilistic spectra. The probabilistic spectra are based on the United States Geologic Survey (USGS) seismic hazard maps. The USGS maps identified previously unknown faults or changed the expected ground acceleration of existing faults.

A comparison of ground accelerations between the 1996 Caltrans deterministic map and 2010 USGS acceleration maps identified over 1000 bridges with ground acceleration ($S_{a\ 1sec}$) increases of more than 40%. Some locations saw increase of 100% in expected acceleration. Bridges that were deemed safe from the initial seismic screening or were retrofitted to the older accelerations levels may be vulnerable.

Previous screening did not consider the proximity of bridges to active faults because the data was not available at the time. The structural behavior of near fault bridges during seismic events was also not well understood in the past. Caltrans began to suspect vulnerabilities existed for these bridges even if previously retrofitted in the Phase 1 or Phase 2 program.

Caltrans is finishing a study on bridges susceptible to fault rupture where horizontal offsets are anticipated from faulting that may extend under bridges. Previous seismic screening did not account for liquefaction and lateral spreading. Liquefaction potential is a significant vulnerability that can affect many bridges near water or in areas with shallow ground water tables.

In 2013 the work team was formed to develop a proposal for rescreening the State bridge inventory. The following five step work plan was developed and subsequently approved.

1. Update the algorithm used to rank bridges for seismic risk.
2. Identify bridges using the new algorithm that are at significant risk for seismic hazards such as ground shaking, liquefaction, and fault rupture.
3. Quantify the hazard for each of the bridges identified in step 2.
4. Combine the populations of bridges for each hazard into a single list, review the plans, and rank each bridge using the updated algorithm.
5. After all the bridges have been ranked, identify those bridges at high and low priority for additional seismic evaluation.

Step 1, 2 and 3 have been completed. The plan review portion of Step 4 is nearly 50% complete. Step 5 will be considered after the plan review is completed and the results are analyzed. At that point Caltrans will decide how to proceed with the addressing the bridges that emerge at risk for potential failure during the 975 year seismic event.

## 1. Updated Algorithm to Rank Bridges for Seismic Risk

The 2014 risk algorithm is based on the sum of the three variables normalized to give risk values between 0 and 100.

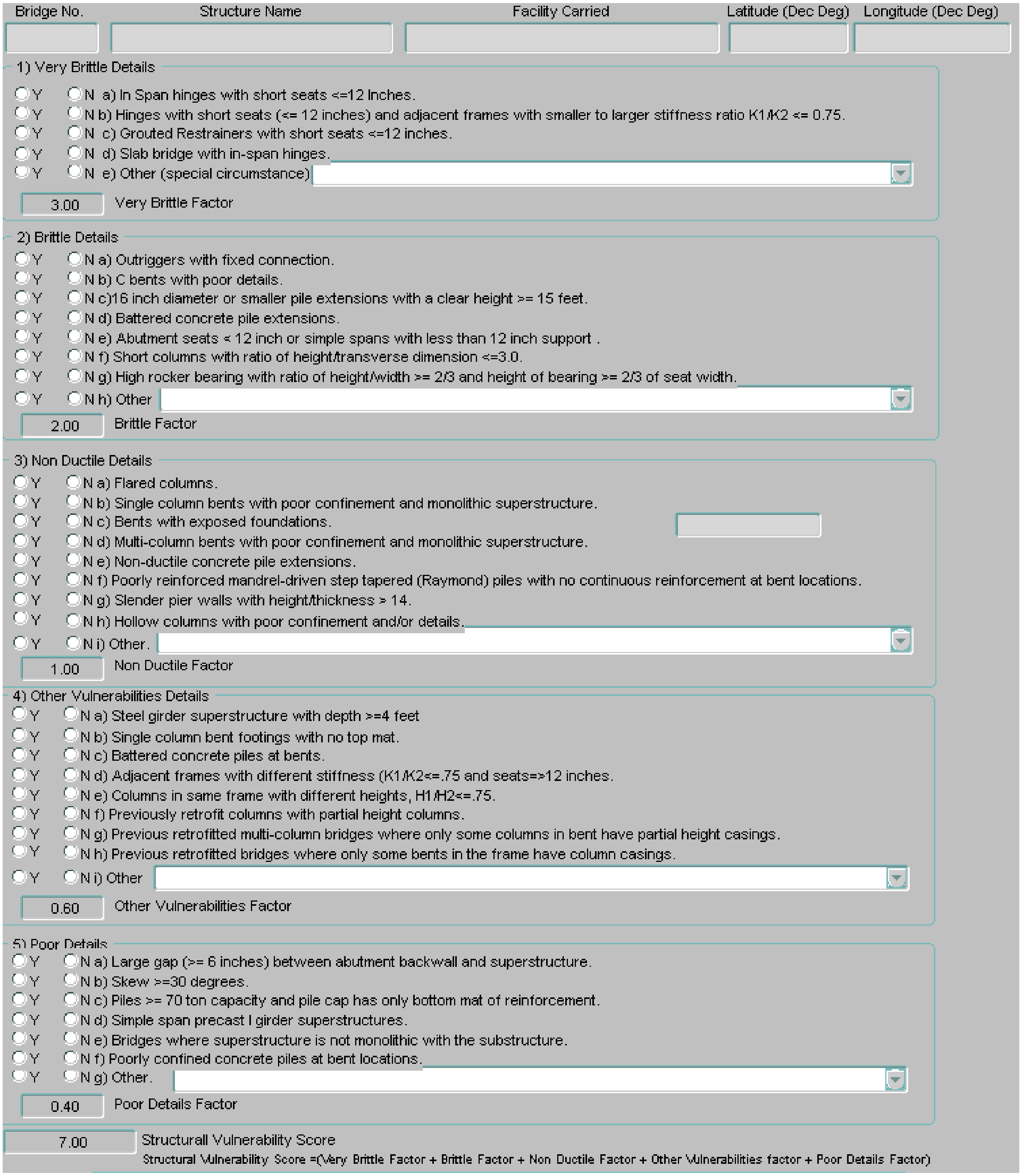
$$V = f(\mathit{Very\ Brittle\ Details}, \mathit{Brittle\ Details}, \mathit{NonDuctile\ Details}, \mathit{Other}, \mathit{Poor\ Details})$$

$$H = f(1\ \mathit{Second\ Spectral\ Acceleration}, \mathit{Soil\ Factor}, \mathit{Surface\ Offset})$$

$$I = f(\mathit{Average\ Daily\ Traffic}, \mathit{Detour\ Length})$$

$$\text{SCORE} = (\mathit{Vulnerability})\ \text{x}\ (\mathit{Hazard})\ \text{x}\ (\mathit{Importance})$$

The bridge vulnerability categorization is based on the five categories that were defined in 2004: 1) Very Brittle 2) Brittle 3) Non-ductile 4) Other Vulnerabilities 5) Poor Details. See Figure 3 for the detailed list of the bridge vulnerabilities.



| Bridge No. | Structure Name | Facility Carried | Latitude (Dec Deg) | Longitude (Dec Deg) |
|---|---|---|---|---|
| | | | | |

1) Very Brittle Details

○ Y ○ N a) In Span hinges with short seats <=12 Inches.
○ Y ○ N b) Hinges with short seats (<= 12 inches) and adjacent frames with smaller to larger stiffness ratio K1/K2 <= 0.75.
○ Y ○ N c) Grouted Restrainers with short seats <=12 inches.
○ Y ○ N d) Slab bridge with in-span hinges.
○ Y ○ N e) Other (special circumstance)

3.00 Very Brittle Factor

2) Brittle Details

○ Y ○ N a) Outriggers with fixed connection.
○ Y ○ N b) C bents with poor details.
○ Y ○ N c)16 inch diameter or smaller pile extensions with a clear height >= 15 feet.
○ Y ○ N d) Battered concrete pile extensions.
○ Y ○ N e) Abutment seats < 12 inch or simple spans with less than 12 inch support .
○ Y ○ N f) Short columns with ratio of height/transverse dimension <=3.0.
○ Y ○ N g) High rocker bearing with ratio of height/width >= 2/3 and height of bearing >= 2/3 of seat width.
○ Y ○ N h) Other

2.00 Brittle Factor

3) Non Ductile Details

○ Y ○ N a) Flared columns.
○ Y ○ N b) Single column bents with poor confinement and monolithic superstructure.
○ Y ○ N c) Bents with exposed foundations.
○ Y ○ N d) Multi-column bents with poor confinement and monolithic superstructure.
○ Y ○ N e) Non-ductile concrete pile extensions.
○ Y ○ N f) Poorly reinforced mandrel-driven step tapered (Raymond) piles with no continuous reinforcement at bent locations.
○ Y ○ N g) Slender pier walls with height/thickness > 14.
○ Y ○ N h) Hollow columns with poor confinement and/or details.
○ Y ○ N i) Other.

1.00 Non Ductile Factor

4) Other Vulnerabilities Details

○ Y ○ N a) Steel girder superstructure with depth >=4 feet
○ Y ○ N b) Single column bent footings with no top mat.
○ Y ○ N c) Battered concrete piles at bents.
○ Y ○ N d) Adjacent frames with different stiffness (K1/K2<=.75 and seats=>12 inches.
○ Y ○ N e) Columns in same frame with different heights, H1/H2<=.75.
○ Y ○ N f) Previously retrofit columns with partial height columns.
○ Y ○ N g) Previous retrofitted multi-column bridges where only some columns in bent have partial height casings.
○ Y ○ N h) Previous retrofitted bridges where only some bents in the frame have column casings.
○ Y ○ N i) Other

0.60 Other Vulnerabilities Factor

5) Poor Details

○ Y ○ N a) Large gap (>= 6 inches) between abutment backwall and superstructure.
○ Y ○ N b) Skew >=30 degrees.
○ Y ○ N c) Piles >= 70 ton capacity and pile cap has only bottom mat of reinforcement.
○ Y ○ N d) Simple span precast I girder superstructures.
○ Y ○ N e) Bridges where superstructure is not monolithic with the substructure.
○ Y ○ N f) Poorly confined concrete piles at bent locations.
○ Y ○ N g) Other.

0.40 Poor Details Factor

7.00 Structurall Vulnerability Score

Structural Vulnerability Score =(Very Brittle Factor + Brittle Factor + Non Ductile Factor + Other Vulnerabilities factor + Poor Details Factor)

FIGURE 3. 2014 VULNERABILITY INPUT FORM

The vulnerability quantity in the SCORE equation is calculated as shown below:

$$Vulnerability = \sum(Score\ Very\ Brittle + Score\ Brittle + Score\ Non\text{-}ductile + Score\ Other + Score\ Poor\ Detail)$$

The score components listed above are computed as follows:

$$Score\ Very\ Brittle = \sqrt{\sum(3.0 \times Very\ Brittle)^2} \leq 3.0$$

$$Score\ Brittle = \sqrt{\Sigma(1.0 \times Brittle)^2} \leq 2.0$$

$$Score\ Nonductile = \sqrt{\Sigma(0.5 \times Non\ ductile)^2} \leq 1.0$$

$$Score\ Other\ Vulnerabilities = \sqrt{\Sigma(0.3 \times Other\ Vulnerabilities)^2} \leq 0.6$$

$$Score\ Poor\ Details = \sqrt{\Sigma(0.2 \times Poor\ Details)^2} \leq 0.4$$

The Square Root Sum of the Squares (SRSS) method is used on each score to reflect the decreasing net vulnerability magnitude effect when multiple vulnerabilities are combined in each category. All scores above are capped to a maximum value to reflect the saturation of the vulnerability magnitude when multiple vulnerabilities are present in one category.

The hazard portion of the SCORE was expanded to include bridges over active faults or bridges founded on potentially liquefiable soil. The fault crossing hazard may require additional modifications to the bridge vulnerabilities portion of the algorithm. Furthermore, these modifications are needed to address bridges that were previously retrofitted for dynamic shaking but not for the cross fault offset hazard. The hazard quantity in the SCORE equation is calculated as shown below:

$$Hazard=3[((Spectral\ Acc \times 10/12)(Soil\ Factor)(Remaining\ Life\ Factor)-0.4) + 2/3 \times 1/2\ Net\ Offset]$$

The first term of the hazard equation is the one second spectral acceleration coefficient expressed in terms of gravity acceleration “g” multiplied by a factor of 10/12 to give a resulting displacement magnitude expressed in a quantity of feet. The spectral acceleration is probabilistically-based on a 975 year return period as the purpose of the algorithm is a prioritization not a final design where the maximum of probabilistic and deterministic ground motions are considered. The Soil Factor is selected based on the soil profiles descriptions defined in the Caltrans Seismic Design Criteria v1.7.

$$Soil\ Factor\ = \begin{cases} 1.0\ non\ soft\ soil\ site \\ 1.4\ \ soil\ profile\ E \\ 1.7\ soil\ profile\ F \end{cases}$$

The Remaining Life Factor is meant to assign a variable priority for bridges that are programmed for replacement or temporary bridges with short duration exposures. This factor is currently muted until the appropriate weights are determined.

The objective of the prioritization is to separate a list of identified bridges from most vulnerable to least vulnerable. The displacement magnitude of 0.4 ft (12.2 cm) in the hazard equation is introduced to produce a negative score which is intended to easily identify the lowest risk bridges in the prioritization. The magnitude of 0.4 ft (12.2 cm) was selected as a value representing a nominal displacement for which bridges are considered to have an inherent capacity based on prior post earthquake investigations and observations.

The factor “3” in the hazard equation is introduced to tune in a “High Vulnerability” magnitude of 3 to a Bridge Score Value of 3. For example, for a Hazard Value of 1.0, considering no static offset, a Soil Factor of 1.0 and a Remaining Life Factor of 1.0, the One Second Spectral displacement is equal to (1/3 + 0.4) = 0.73 ft.( 22.3 cm). Considering a 12-inch (30.5 cm) seat with High Vulnerability value of 3.0, the seat displacement capacity is reduced from 12 inches (30.5 cm) to 9 inches (22.9 cm) due to concrete cover spall of 1.5 in. (3.8 cm) and median temperature movement of 1.5 in. (3.8 cm). As shown above, the spectral displacement of 0.73 ft (22.3 cm) compares favorably to the 0.75 ft (23 cm) seat displacement capacity for High Vulnerability Value of 3.0. Furthermore, it is expected to have results showing a high vulnerability corresponding to a score value close to 3.0.

In order to account for cross fault offset hazard, the Hazard Value includes a displacement magnitude for “Net Offset” computed as the SRSS of vertical and horizontal displacement offsets. The displacement offset is probabilistically-based on a 975 year return period as the purpose of the algorithm is a prioritization not a final design where the maximum of probabilistic and deterministic ground motions are considered. The displacement offset demand included in the Hazard Value is considered half of the magnitude determined by the geologist as the total offset demand is shared approximately at two bent locations. Furthermore, a reduction factor of 2/3 the displacement offset is applied to account for the combination of dynamic shaking demand in addition to static offset and the possibility of allowing a higher displacement capacity for this combination as opposed to capacity considered for dynamic shaking demand only.

At this time the specifics of the importance factor have not been finalized.

The 2014 algorithm was applied to the 216 bridges remaining in STRAIN for seismic evaluation. The four bins illustrated in Figure 4 were selected corresponding to a change of slope in the curve produced by the resulting bridge scores. The fourth bin was considered for bridges with negative score as described above. The four bins cutoff score corresponded to the following:

- Bin 4 corresponds to a SCORE < 0, includes 88 bridges (41% of the total 216 bridges)
- Bin 3 corresponds to 0 < SCORE < 1.2, includes 69 bridges (32% of the 216 bridges)
- Bin 2 corresponds to 1.2 < SCORE < 2.7, includes 38 bridges (17% of 216 bridges)
- Bin 1 corresponds to a SCORE > 2.7, includes 21 bridges (10% of 216 bridges)

Based on the SCORE values shown above, it was deemed that bins 1 and 2 represent the portion of the 216 list of bridges pivoting around a target score of 3. These bins deserve the highest attention for seismic evaluation in terms of hazard intensity and structural vulnerabilities.

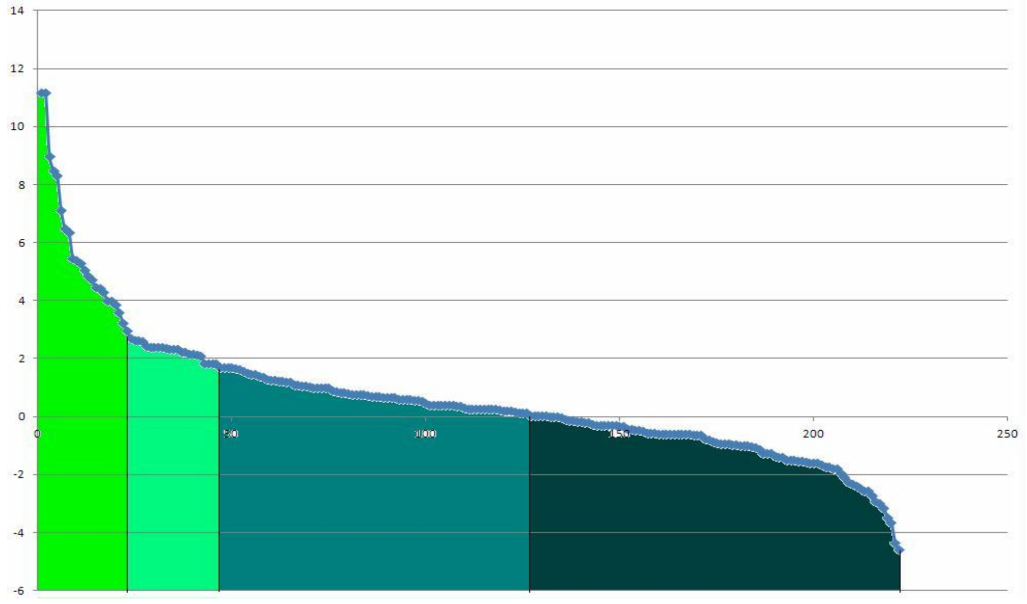


FIGURE 4. BRIDGES IN STRAIN RANKED BY
THE 2014 SCORE ALOGRITHM

## 2. Filtering Criteria

After the algorithm was tested, filtering criteria was necessary to determine which portion of the State bridge inventory needed to be re-screened. The filtering criteria are based on spectra acceleration and past dates when the Caltrans seismic design and retrofit policies changed. Over 6800 bridges were analyzed for seismic deficiencies as part of the previous Phase I and Phase II retrofit program. The filtering criteria were developed so as not to duplicate this effort. The filter eliminated all un-retrofitted bridges built after 1980. By 1980, Caltrans new bridges were generally designed with good seismic details. Furthermore, the retrofit program should have addressed bridges with vulnerabilities that could lead to failure in a minor or moderate earthquake so a minimum 1 second spectral acceleration level was set at 0.5g.

The filtering also addressed bridges that have been seismically retrofitted but may be susceptible to damage at the revised 2010 hazard levels. A series of filters were developed to capture combinations of spectral acceleration levels and early retrofit details that may not achieve the "no collapse" performance objective. Table 1 summarizes the populations of bridges identified for re-screening.

TABLE 1. BRIDGES IDENTIFIED FOR 2014 SEISMIC SCREENING

| Filtering Criteria | Number of Bridges |
|---|---|
| Bridges built prior to 1980 with 1 second spectral acceleration (1secSA) ≥0.5g | 3415 |
| Retrofitted bridges with 1secSA ≥ 0.7g and (2013 1secSA)/(1996 1secSA) ≥ 1.4 | 177 |
| Retrofitted bridges with 1secSA ≥ 0.3g and the restrainers may be deficient | 342 |
| Retrofitted bridges with 1secSA ≥ 0.5g and only some columns are cased | 433 |
| Retrofitted bridges with 1secSA ≥ 0.5g and with partial height column casings | 34 |
| Bridges over active faults that need to be evaluated for fault offset | 200 |
| **Number of bridges identified for re-screening** | 4601 |

## Liquefaction Screening of Caltrans Bridges

A parallel effort was initiated by Geotechnical Services and the Division of Research and Innovation engineers to screen the State bridge inventory for liquefaction potential.

Liquefaction has been a major cause of damage in recent earthquakes worldwide, thus making it an important consideration in assessing the seismic vulnerability of bridges. The large number of bridges in Caltrans' inventory demanded an efficient assessment strategy whereby a rapid initial assessment is performed on the entire inventory and a more detailed and lengthy analysis is performed on a much smaller subset of bridges identified through the initial screening. An initial filtering removed single span bridges from consideration as well as those constructed or retrofitted after 1996. This initial filtering reduced the number of bridges requiring screening to about 6800.

The Level 1 screening procedure was developed with the goal that it could be performed, on average, in about 30 minutes. To meet this objective, the Level 1 screening focused solely on geotechnical issues and didn't consider details of the bridge structure. Consideration of bridge details was deferred to the Level 2 screening. Using a 975-year hazard level earthquake, the Level 1 screening assesses the potential for liquefaction occurrence using procedures by Idriss and Boulanger (2008). If determined liquefiable, a simple metric is applied to estimate the severity of corresponding ground displacement.

The vulnerability scoring metric uses three factors judged to be reasonably efficient predictors of ground displacement resulting from liquefaction: depth, continuity, and displacement potential. Generally, observations from past earthquakes suggest that shallow liquefaction is likely to result in more substantial ground failure than deeper liquefaction. Additionally, a liquefied stratum that is laterally continuous provides a more efficient failure plane and thus promotes larger ground displacement. Finally, loose deposits are able to undergo much larger strains while liquefied than soils that, while loose enough to achieve full liquefaction under strong shaking, are dense enough to regain strength under modest shear strain. These factors were combined to generate a vulnerability score that ranges from 0 to 18.

At the time of this writing Level 1 screening is approximately 50% complete. Following completion of this screening, bridges with high Level 1 vulnerability scores will graduate to Level 2 screening. Level 2 screening includes consideration of the structural system and its response to an imposed ground displacement profile using a static beam on nonlinear Winkler foundation (BNWF) analysis. This analysis is based on recommendations provided by Ashford et al. (2011) and further refined into a Caltrans guidance document (Shantz, 2013). Since the Level 2 screening typically requires 1 to 4 weeks of analysis time per bridge depending on the bridge size, site complexity, and need for additional field investigation, limiting this analysis to the most vulnerable locations will be necessary.

## **Next Steps**

To date, over 3000 bridges have been screened for seismic vulnerabilities and a similar number of bridges have been screened for liquefaction potential. OEE is currently finalizing the vulnerability list for previous retrofitted bridges. Vulnerabilities that are being considered include frames and bents with small percentages of columns jackets, partial height column jackets, and bent caps with inadequate moment and joint shear capacity.

The goal is to complete the plan review portion of the project by January 2015. At that time the results will be analyzed and the algorithm weightings evaluated and adjusted if necessary. Additionally the results from the seismic vulnerability screening, liquefaction screening and fault rupture study will be combined into one scoring system so the bridges can be prioritized.

## Conclusions

Caltrans has acted on the Seismic Advisory Board's recommendation to regularly reassess the seismic hazard and engineering performance of bridges, including existing, retrofitted and new structures (Seismic Advisory Board 2003).

The 2014 SCORE algorithm has been updated to include knowledge gained from the Northridge EQ and advancements in retrofit technology. The screening also includes updated strong motion models as well as potential liquefaction and fault rupture hazards.

The ongoing screening utilizes a database that allows for normalizing the risk score of any bridge against the screened population of bridges, allows for adjusting the weighting factors and the ability to continuously add additional bridges to the population. Furthermore, the database can be queried for various combinations of bridge attributes and vulnerabilities.

The improved algorithm and enhanced data collection will assist Caltrans in strategically deploying engineering and capital resources to efficiently and effectively improve the safety of California's highway bridges in the future.

## Acknowledgments

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