SEISMIC OPTIONS REPORT
A PLAN FOR SEISMIC RETROFIT OF OREGON BRIDGES

Bruce V. Johnson, P.E.[1]
Craig Shike, P.E.
Albert Nako, P.E.
Jan Six, P.E.

Abstract

The seismic risk in Oregon is significant. However, Oregon has performed very little seismic retrofit. This paper will discuss the seismic risk in Oregon and a proposal for addressing the risk with strategic seismic retrofit projects. This paper describes Oregon Department of Transportation (ODOT) efforts to develop a bridge and landslide seismic retrofitting program

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Introduction

The Oregon coast is vulnerable to large seismic events from the Cascadia Subduction Zone (CSZ) which shares common seismic characteristics with those at Sumatra that generated large tsunamis in the Indian Ocean in December 2004, the recent Chile earthquake and the Japan Tohoku earthquake in 2011. Studies of tsunami deposits and evidences of coastal subsidence indicate that a large seismic event in CSZ occurs once every 300-500 years (Goldfinger et al. 2003). The most recent large seismic event in the CSZ occurred in 1700; therefore, there is a relatively high probability that a large seismic event will occur in the near future that could damage structures along the coastal area in the Pacific Northwest.

The bridges in Western Oregon are an important part of the transportation system. Any major damage to these bridges would result in traffic disruption and impede post-event emergency response. Since these bridges, mostly built in the 1950-70's, were not designed to resist large seismic loads, they are at the risk of being severely damaged during large seismic events. Consequently, the Oregon Department of Transportation (ODOT) initiated a research program and study to develop a plan for seismic retrofit of bridges in Western Oregon.

Oregon has experienced forty large damaging earthquakes over Magnitude 8.0 during the last 10,000 years, even though we have not had a major seismic event during our recorded history. Scientists currently estimate there is a 37% conditional probability that a Cascadia subduction zone earthquake will strike Oregon within the next 50 years. It is prudent to understand and take steps to mitigate this risk to our economy and to our businesses, homes, and communities. When a large earthquake is triggered within the Cascadia Subduction Zone, there will be widespread disruption to the transportation system that will make rescue operations difficult, if not impossible, and there will be an immediate, disruptive impact to the economy. The majority of bridges in western Oregon are susceptible to serious damage in a major seismic event because they were built before modern seismic codes were in place. Dozens of unstable slopes and pre-

[1] State Bridge Engineer, Oregon Department of Transportation

existing deep slides are expected to fail under the extended three minutes or more of shaking that will accompany a large Cascadia event.

The extended period of strong shaking that occurs with a subduction zone event will damage bridges, retaining walls, unstable slopes, landslides and structures built prior to modern seismic codes, which were developed in the late 1980's and early 1990's. Homes, hospitals, businesses, schools and other critical structures that have not been seismically retrofitted may collapse or be severely damaged; killing or injuring many people. The injured will need immediate attention, but may be stranded due to the lack of mobility.

Seismic retrofitting is a well developed and well understood practice. It has been extensively accomplished in California and Washington. These states have had dedicated funding for seismic retrofit programs. This is due in part to their relatively higher level of known seismicity or the more frequent occurrence of earthquakes. The Washington and California DOT's have been directed to allocate a significant portion of their transportation and infrastructure funding to undertake retrofits so that rescue and recovery operations can move forward rapidly after an event. Knowledge of the locations of faults and the geological history of major events in Oregon is very recent. Though Oregon has low seismicity in comparison, there is potential for a much larger and more damaging earthquake than the other two states, but on a much less frequent basis. Oregon has not yet seen the effect of a large damaging earthquake and ODOT has so far expended minimal resources on retrofitting. As a result, we are unprepared for use of the highway system immediately after a major seismic event.

A Cascadia earthquake and tsunami have the potential to cause an unparalleled economic and human catastrophe for the State of Oregon because impacts will be wide spread. The issue is "when" not "if" the state will have a major damaging seismic event. The question is whether we will be effectively prepared to rescue our citizens and recover economically without the use of the highway system. This report discusses work done to assess the risks associated with a major seismic event, particularly the effect on highway facilities. It describes the necessary sizable investments needed to allow this fundamental public facility to be usable shortly after a major event. The total estimated cost to repair all seismically deficient bridges and unstable slopes is in the billions of dollars. However, this report outlines options for phased retrofitting that will provide the maximum degree of mobility with reasonable investments. The manner and timing of funding will influence how and where Oregon is prepared for rescue and recovery. ODOT has been working for about twenty years on solutions to this statewide problem in cooperation with a variety of stakeholders and decision-makers.

Portland State University under contract with ODOT conducted an economic assessment using the REDARS western Oregon model. The REDARS model is an analytical tool for evaluating the impact of a seismic event on a specific bridge population. This analysis suggests that the longer the State delays increasing investment in bridge strengthening, or otherwise mitigates for potential earthquake damage, the greater the cost and potential adverse effect on the state's economy. If risks related to bridges and slopes are left unaddressed, the odds grow every day that we will be unprepared for an increasingly likely major damaging earthquake.

Background

In November 2009, ODOT published a report that identified major mobility risks from earthquakes and recommended possible mitigation strategies. The report marked the culmination of two years of study jointly conducted by ODOT and Portland State University. It describes potential damage from six representative earthquake scenarios that are thought most likely to occur in Oregon.

The study found that highway mobility would be severely reduced after a major Cascadia Subduction Zone event, as well as after a significant crustal earthquake. US 101 would have dozens of failures and would be impassable due to bridge collapses. All of the existing highways that connect US 101 to I-5 would be impassable due to bridge collapse, landslides and other damage. Small segments of I-5 would be useable because a number of those bridges have been replaced since 1990, including many in the OTIA III Program, but many older, obsolete overpasses would collapse and block the through lanes and many older river crossings would be impassable. Some essential services that depend on the Willamette River crossings in Portland would also be affected. The report also considers possible mitigation, including bridge retrofit and strengthening to withstand seismic damage.

The report concludes with seven recommendations. Three are related to finding ways to include seismic retrofitting projects in the Statewide Transportation Improvement Program (STIP) in the face of current funding constraints. The remaining four are as follows:

- Refine the recommendations by working with stakeholders to define the highest priority and most cost effective mitigation strategies and routes.
- Communicate and educate stakeholders and highway users on potential damage and options for mitigation.
- Update the previous lifeline route designations.
- Work with stakeholders to define a long term comprehensive study of seismic vulnerability and risk for the entire transportation system

Vulnerabilities and Mitigation – Bridges

The following figures based on the 2009 Seismic Vulnerability Report summarize the history of seismic bridge design in Oregon and the bridge retrofitting status at the time of the report.

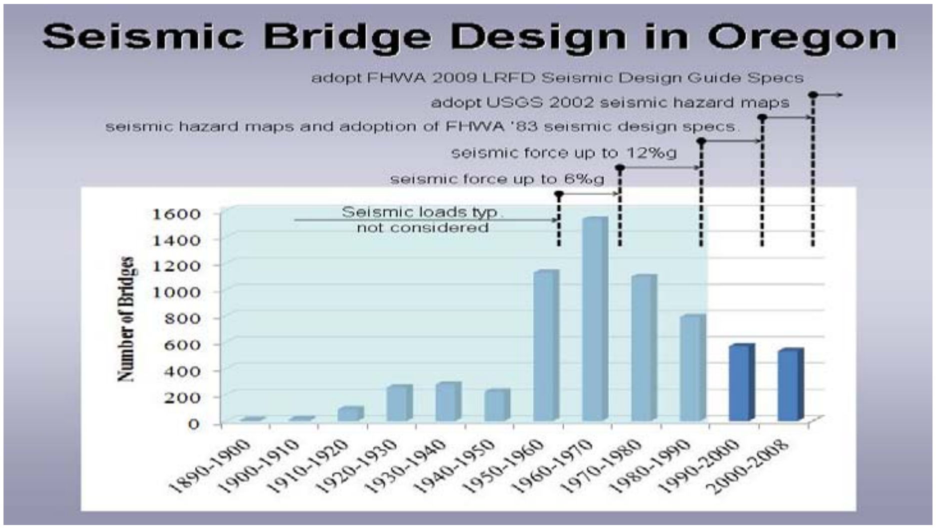

FIGURE 1: BRIDGE SEISMIC DESIGN HISTORY

Retrofitting Progress *First 16 years Since Vulnerability was Identified*		
Years	**Actions**	**Number of Bridges**
1994, 1997	Ch2M Hill Prioritization Studies Identify Vulnerable Bridge – State bridges only included in total shown	***1155***
1994 Thru 2010	Phase 1 retrofit added to repair contracts in STIP In the OTIA III Program Bridge Replacements, current seismic design in STIP In the OTIA III Program Total number of Bridges Addressed	***72*** ***6*** ***40*** ***<u>150</u>*** ***268***
Future	Bridge Still Needing Retrofitting About 200 years at average 4.5 bridges retrofitted per year in the STIP, much longer for Phase 2 and much longer due to OTIA III bond payback	***887***

FIGURE 2**:** BRIDGE TRETROFIT AND REPLACEMENT ACCOMPLISHMENTS

The post-earthquake reconnaissance reports of some of most significant earthquakes worldwide have indentified various bridge failure modes. Each failure mode can impact traffic and life safety differently, depending on the damage level of various bridge components. Minor structural damage, such as concrete spalling or minor approach settlement, can be easy repaired and do not pose any significant threat to traffic. However, the situation can become overwhelming when bridge columns experience significant damage, the bridge superstructure falls off, or when the entire bridge collapses.

Minor structural damage is either the result of an earthquake smaller than the design earthquake, or the bridge was intentionally designed for a higher damage level, based on cost considerations. Heavier damage than expected can occur on bridges that were either designed for smaller earthquakes or have not been designed for seismic loads at all (most Oregon bridges).

Acknowledging the fact that many bridges across our nation were built well before the seismic design specifications were available, the bridge design community has developed retrofit details to make these bridges seismically resilient. Having a good understanding on how a bridge will behave under a given earthquake motion, bridge engineers are now able to identify the vulnerable bridge elements and retrofit those accordingly. FHWA has been working intensively with many DOTs to identify the appropriate retrofit details and methods for vulnerable bridges. The recommended details and bridge seismic retrofit guidelines were published in the 2006 Seismic Retrofit Manual for Highway Structures.

A preliminary assessment has identified Oregon bridges to have seismic vulnerabilities similar to the bridges damaged in previous earthquakes, such as insufficient column reinforcement, insufficient foundation capacity, non-stable bearings, inadequate superstructure seat width, presence of liquefiable soils, etc. ODOT adopted the 2006 FHWA Retrofit Manual in April 2010. After an evaluation process, some of the details included in this manual have been selected as a good solution for retrofitting Oregon bridges. Because of the unique seismic situation of our state, ODOT is currently evaluating the performance of these retrofit details under a very strong and very long shaking event such as the M9.0 CSZ Earthquake. This evaluation process is not expected to reinvent new retrofit details, but it would identify any needs for refinement of the existing details.

The vulnerabilities of Oregon bridges are complex and different from bridge to bridge and from site to site. Some bridges are prone to more than one type of seismic deficiency, and a few may need to be replaced. ODOT has already conducted research and investigation to develop the best approach for mitigating the problem. Worldwide experience has shown that while we are not knowledgeable enough to predict the exact time that an earthquake would strike, we can be proactive to save lives and speed up the recovery process.

Conclusions

This report documents the processes used to evaluate risks and identify strategies to mitigate the seismic vulnerabilities of the highway system. The investigations and studies conducted to support this report resulted in substantial information that was used to develop the following recommendations and Seismic Investments Options.

Recommendation 1

Put an investment package into place immediately to begin a strategic retrofitting and replacement program for Oregon bridges and unstable slopes. Securing the Interstate and key lifeline routes is a priority, followed by critical city and county connector routes.

Recommendation 2

Implement the strategic investment plan in three tiers that build on each other. The Tier 1 routes listed in Table 1, Phase 1 and then Phase 2, are considered top priority for ensuring the greatest return on investment to support rescue and recovery operations. Tiers 2 and 3 are listed in the Oregon Highways Seismic Options Report will follow as funding becomes available. This strategy anticipates that ODOT will continue bridge retrofits and slope strengthening in combination with other projects, even as it shifts to a more strategic, corridor-based approach to maximize potential future investments in seismic retrofit.

Recommendation 3

Strategic and operational changes may be needed within ODOT to meet the challenge of maintaining the transportation infrastructure. This will include assigning staff to manage and implement this program, pursuing additional funding for future stages, and investing in technology and data storage/retrieval systems to increase efficiency and effectiveness.

Seismic Investment Options

Option 1 – Bonding program of $750 M to fund bridge retrofit and slope stabilization of Tier 1, Routes over 20 years.

Option 2 – Bonding and reallocation of Federal funding to seismic for a total of $1.0 B for bridge retrofit and slope stabilization of Tier 1 and the highest priority Tier 2 routes over 30 years.

Option 3 – Bonding and reallocation of Federal funding to seismic for a total of $1.25B for bridge retrofit and slope stabilization of Tier 1, Tier 2, and highest priority Tier 3 routes over 40 years.

Corridor No.	Highway	Description (Point to Point)	Bridges		Landslides/Rockfalls	
			Total No. of Bridges	Estimated Seismic Retrofit Cost ($1000)	Total No. of Slides	Estimated Slide Stabilization Cost ($1000)
Phase 1						
1	US 97	I-84 to CA Border	61	$7,275.00	41	$36,231.00
2	I-84	I-205 to US 97	81	$13,350.00	54	$58,748.00
3	I-205	WA Border to I-5	58	$127,925.00	4	$2,000.00
4	I-5 & OR 22	I-405 to OR 58	145	$33,940.00	7	$8,747.00
5	OR 58	I-5 to US 97	19	$2,635.00	67	$24,864.00
		Subtotal	***364***	***$185,125.00***	***173***	***$130,590.00***
Phase 2						
6	I-405	US 30 to I-5	24	$18,885.00	0	$0.00
7	US 30	US 101 to I-405	27	$22,650.00	77	$28,623.00
8	OR 99W & OR	I-5 to US 101	35	$13,825.00	7	$6,500.00
9	I-5	OR 58 to CA	183	$49,820.00	41	$51.821.00
10	OR 38	US 101 to I-5	19	$3,315.00	68	$25,049.00
11	US 101	OR 18 to US 20	9	$12,085.00	24	$17,842.00
12	US 101	OR 18 to	17	$5,640.00	55	$14,586.00
13	US 101	OR 38 to OR 42	10	$26,160.00	13	$5,663.00
14	US 101	OR 38 to OR 126	6	$14,235.00	14	$4,317.00
15	I-5 & I-405	WA Border to	21	$70,900.00	0	$0.00
		Subtotal	***351***	***$237,515.00***	***299***	***$154,401.00***
		TOTAL	***715***	***$422,640.00***	***472***	***$284,991.00***

TABLE 1: TIER 1 PROJECT LIST[2]

[2] Bridge seismic retrofit costs and landslide/rockfall mitigation costs provided in this report are estimated in 2012 dollars.

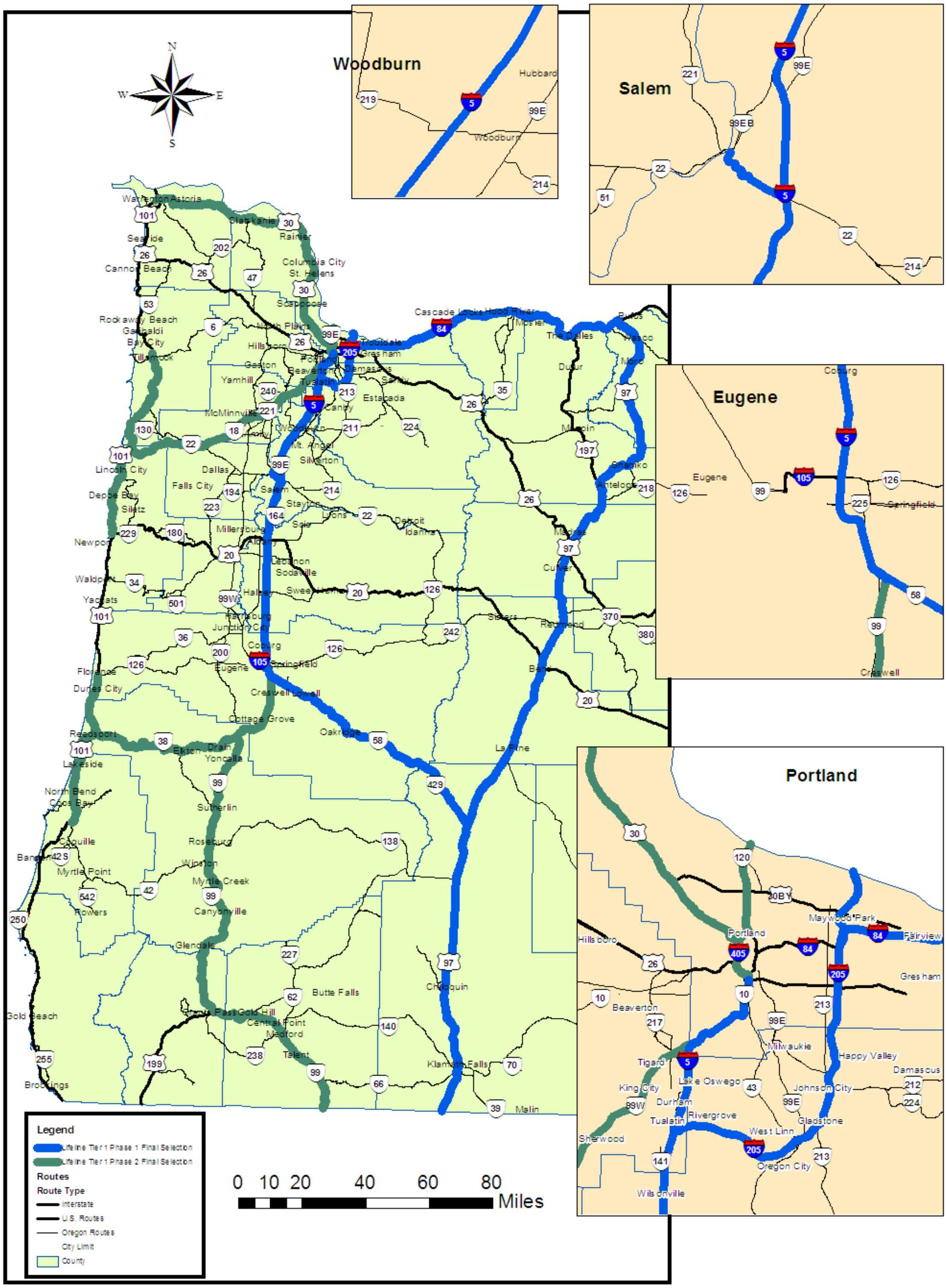

FIGURE 3: MAP OF SEISMIC OPTIONS PROGRAM: TIER 1 ROUTES

Acknowledgements

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