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Research Project Work Plan for Impact of Cascadia Subduction Zone Earthquake on the Seismic Evaluation Criteria of Bridges

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Research Project Work Plan

for

IMPACT OF CASCADIA SUBDUCTION ZONE EARTHQUAKE ON THE SEISMIC EVALUATION CRITERIA OF BRIDGES

SPR 770

Submitted by

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for

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Research Unit
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1.0 Identification

1.1 Organizations Sponsoring Research

Oregon Department of Transportation (ODOT)
Planning and Research Unit
200 Hawthorne Ave. SE, Suite B-240
Salem, OR 97301-5192 Phone: 503-986-2700

Federal Highway Administration (FHWA)
Washington, D.C. 20590

1.2 Principal Investigator(s)

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1.3 Technical Advisory Committee (TAC) Members

Bruce Johnson, ODOT
Albert Nako, ODOT
Craig Shike, ODOT
Jan Six, ODOT
Tim Rogers, FHWA

1.4 Project Coordinator

Steve Soltesz Phone: 503-986-2851

1.5 Project Champions

Albert Nako, Jan Six

2.0 Problem Statement

The seismic risk used for bridge design and retrofit is defined by hazard maps of ground acceleration values. The maps combine multiple regional sources of ground shaking using a Probabilistic Seismic Hazard Analysis (PSHA). Each source has a different intensity, probability of occurrence, and distance to a specific location. One key source of ground shaking in PSHA in Oregon is from the Cascadia Subduction Zone (CSZ); however, a CSZ has several potential scenarios (M8.3 and M9.0) that can have significantly different ground motion estimates as a standalone event than what is captured in the values derived from PSHA.

For seismic evaluation of bridges in Oregon, two cases are considered: 'no collapse' for large earthquake shaking and 'serviceability' for more frequent smaller earthquake shaking. 'No collapse' is expected to result in severe damage without complete collapse; 'serviceability' requires little or no damage so the bridge remains functional. The ground acceleration used in design for the 'no collapse' and 'serviceability' cases at a specific location would have two different values derived from PSHA hazard maps.

For 'no collapse', the CSZ earthquake dominates calculated PSHA acceleration values along the coast, but has a diminishing contribution further inland. Consequently, actual ground acceleration inland from a CSZ event may exceed the PSHA values, which means designers, following current seismic design code, may be under-designing for collapse prevention in certain parts of the state. For 'serviceability', the less frequent CSZ would have little contribution when considering low level earthquakes. For this reason ODOT adopted higher hazard than recommended in the FHWA Seismic Retrofit Manual in an effort to recognize a more reasonable CSZ influence for serviceability. Doing this also raised the contributions from other earthquake sources across the state within the PSHA calculation. Consequently, designers following the current ODOT guidelines for serviceability could be over-designing to meet 'serviceability' performance.

For cases where acceleration values from a singular CSZ event are similar to those derived from the PSHA maps, the increased duration of a CSZ earthquake may result in more damage than expected. Numerical simulations using data from recent subduction earthquakes have shown that more damage occurs from the increased duration of shaking as compared to non-subduction earthquakes of the same peak acceleration. However, this result needs to be experimentally verified.

3.0 Objectives of the Study

The goal of this project is to provide ODOT with the best rational estimate of ground acceleration values for designing new and retrofitting existing bridges. The objectives are to:

- evaluate the hazard by contrasting the acceleration values from individual CSZ events to PSHA values
- provide experimental evidence of damage difference under longer duration shaking expected from CSZ event

3.1 Benefits

Provided that a CSZ earthquake is considered the most likely earthquake source in the next 50 years and that many of the important lifeline routes are most affected by a CSZ earthquake, the outcome of this project will assure that bridge safety, mobility, and retrofit decisions are made using the best estimate of seismic demand on our bridges.

4.0 Implementation

The project investigator will submit a report to ODOT that will include the design acceleration comparisons. The information gained will allow ODOT to make decisions regarding what seismic hazard basis to use for evaluating the "serviceability" performance level requirement. It is anticipated that conference or journal articles will be submitted for publication. The ODOT Seismic Committee will make up the technical advisory committee for this project, and that committee will be kept updated on the project results through quarterly reports, deliverables, meetings, and presentations.

5.0 Research Tasks

Task 1: Literature Review

Review of assumptions and calculations used by the United States Geological Survey (USGS) in developing the 2002 hazard maps for 500 and 1000 year return periods will be conducted so as to inform the subsequent process.

Time Frame: 3 months
Responsible Party: PSU
Deliverable: A brief document of the findings from the literature review.
TAC Decision/Action: None

Task 2: Deaggregate PSHA data

At selected and geographically distributed sites along lifeline highway routes, the influence of individual earthquakes contributing to the overall hazard will be determined by mining the underlying USGS data. The site selection will consider the recently defined ODOT lifeline routes and the directionality of the subduction zone to consider at minimum 5 sites along the coast, 5 sites along the I-5 corridor and 5 sites on connecting routes between the two. The highest contributing hazard for PGA, 0.2 sec and 1.0 sec spectral will be identified for the 500 year and 1000 year return period spectra. The results will be presented in a spreadsheet.

Time Frame: 9 months
Responsible Party: PSU
Deliverable: Summary of deaggregated acceleration values.
TAC Decision/Action: Assist in selecting representative sites for analyses.

Task 3: Contrast CSZ with PSHA design values

At each site from Task 2, acceleration values for CSZ earthquakes will be compared to the acceleration values from the PSHA-based hazard maps. Based on the selection of the sites, geographical regions will be identified where CSZ accelerations vary from the PSHA design values for the two design criteria. A second phase of sites will be analyzed to refine the transition regions as needed.

Time Frame: 3 months
Responsible Party: PSU
Deliverable: Map(s) summarizing the results.
TAC Decision/Action: Review and comment on results.

Task 4: Contrast structural damage effect from long duration earthquakes

Duration effects are not captured by the single acceleration design value used by the code. Representative earthquake records will be selected from subduction and crustal earthquake sets and used to shake ductile columns on the shake table. The earthquake records will be selected from already completed single degree of freedom numerical analyses results. The five specimens will be scaled in size for cost considerations, but remain representative of typical ductile ODOT columns. Inertia mass will be selected and connected to the column to obtain a desired period of vibration for the test. The columns will have nominally the same properties and the input shaking motion will be the primary variable. The motion will be selected considering the numerically obtained cumulative plastic index and duration of the motion. One column will be subjected to a crustal earthquake, two columns to different subduction zone records. The input motion for the remaining two columns will be selected based on the preceding results. Each of the columns will be subjected to one earthquake scaled to peak accelerations in the valley and at the coast Relative measured displacement ductility and observed damage via crack formation and size between subduction and non-subduction earthquakes will be compared.

Specimen No.	**Earthquake Motion**
Column 1	Crustal
Column 2	Subduction A
Column 3	Subduction B
Column 4	TBA based on above results
Column 5	TBA based on above results

Time Frame: 12 months
Responsible Party: PSU
Deliverable: Data gathered and analyzed from the experiments.
TAC Decision/Action: Review and comment on results.

Task 5: Evaluate the impact on the dual design criteria

One of the reasons for ODOT selecting 500 year serviceability design event instead of the 100 year was to compensate for the unknown duration effects of the subduction zone. While the results of Task 4 would not be conclusive given the limited testing scope, the results will inform the significance of Task 3 results. For regions of relatively similar design accelerations between the CSZ and PSHA, the governing seismic risk used for design may be adjusted. No specific methodologies exist in combining acceleration amplitude and duration, nonetheless the results of Tasks 3 and 4 can be qualitatively evaluated for the ‘no collapse’ and ‘serviceability’ dual design criteria.

Time Frame: 3 months
Responsible Party: PSU
Deliverable: Document and/or presentation(s) summarizing the results.
TAC Decision/Action: Provide input regarding the damage threshold for the two performance levels.

Task 6: Final Report
Based on the recommendation of the TAC, the final report will either be written in the conventional format or in the form of individual papers prepared for peer review journals or conferences, with necessary appendices depicting the required data summarized in the papers. The report will contain the design acceleration comparisons and experimental results aimed to inform the CSZ design criteria for Oregon.

Time Frame: 3 months
Responsible Party: PSU
Deliverable: Final report.
TAC Decision/Action: Review draft report and provide comments and input to incorporate into the published report.

6.0 Time Schedule

	FY14		FY15				FY16	
	2014				2015			
Task	Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec	Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec
1. Literature Review								
2. Deaggregate PSHA data								
3. Contrast CSZ with PSHA								
4. Contrast Subd. EQ damage								
5. Evaluate impact on design								
6. Final Report								

7.0 Budget

Task	FY14	FY15	FY16	Total
1. Literature Review	$11,201			$11,201
2. Deaggregate PSHA	$9,062	$16,950		$26,012
3. Contrast CSZ with PSHA		$4,471		$4,471
4. Contrast Subd. EQ Damage		$102,764		$102,764
5. Evaluate Impact on Design			$26,319	$26,319
6. Final Report			$21,026	$21,026
Total for tasks (work order amount)	$20,263	$124,185	$47,345	$191,793
ODOT support/management	$3,000	$3,000	$4,000	$10,000
Total for ODOT	$23,263	$127,185	$51,345	$201,793