Research Project Work Plan

for

SEISMIC PERFORMANCE DESIGN CRITERIA
FOR
EXISTING BRIDGE BENT PLASTIC HINGE REGIONS

SPR-802

Submitted by

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for

Oregon Department of Transportation
Research Unit
555 13th St. NE, Ste 2
Salem, OR 97301-6867

December 2016
Research Project Work Plan
for
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FOR
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1.0 Identification

1.1 Organizations Sponsoring Research

Oregon Department of Transportation (ODOT)
Research Section
555 13th Street NE
Salem, OR 97301

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

1.2 Principal Investigator (PI)

Peter Dusicka, Ph.D., P.E.
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Phone: (503) 986-2700

1.3 Associate Investigator

Thomas Schumacher, Ph.D., P.E.
Portland State University
Department of Civil and Environmental Engineering

1.2 Technical Advisory Committee (TAC) Members

Matthew Mabey, ODOT Research (Chair)
Albert Nako, ODOT Bridge Section
Bruce Johnson, ODOT Bridge Section
Craig Shike, ODOT Bridge Section
Tanarat Potisuk, ODOT Bridge Section
Tim Rogers, FHWA

1.3 Research Coordinator

Matthew Mabey, Ph.D., P.E.

Phone: 503-986-2847
2.0 Problem Statement

Seismic design of new bridges and assessment of existing bridges in Oregon needs to consider two levels of performance criteria; life-safety and operational. The life-safety performance criteria are intended to ensure that the bridge does not collapse under the design earthquake; however, the bridge is expected to sustain significant damage. The operational performance criteria are intended to limit the seismic damage resulting from a specific demand level so that functionality of the bridge is minimally impacted. Within the Western parts of the state, the structural design of the substructure is often governed by the operational performance criteria and not the life safety criteria. The current design methodology for the operational performance criteria has two main components: use of a specific seismic hazard that has traditionally been lower than that used for life safety performance, and limit of the material strains to stricter levels than those used for life safety.

The operational criteria often govern bridge bent design, but limited confidence exists in the selection of the appropriate material limits for achieving rapid return to operational condition. This lack of knowledge has cascading effects on the direct cost and on construction schedule of bridges, especially when considering the retrofit of existing bridges. This has recently been highlighted in retrofit assessment projects conducted on a select number of bridges where the designers found that the operational performance under the Cascadia Subduction Zone (CSZ) event governed the extent of retrofit required.

2.1 Background and Significance of Work

Current material strain limits are based on experimental data generated for reinforced concrete columns that are either based on 1) modern detailing requirements, 2) exhibit excessively poor detailing relative to those used in existing bridges in Oregon, or 3) do not consider the cumulative damage effects from the long duration CSZ event. Recently completed tests of a bent representative of ODOT detailing were completed as part of a project on earthquake duration effects (Dusicka et al 20151). One of the tangent results provided limited, but tantalizing, data that pointed to seismic performance that was better than anticipated, given the lack of modern detailing. The possible contributing factors of this surprising result may be the intermediate lap-splice lengths (between excessively short and modern long splice details) utilized in vulnerable ODOT bridges prior to the 1980s and the nearly constant axial load considered. More focused research is therefore needed to assess the influence of these variables; specifically on the types of detailing used in Oregon due to the potentially positive outcome on the overall seismic bridge design.

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3.0 Objectives of the Study

The main objective of this research is to quantify the steel and concrete strain limits to be used for the seismic assessment of bridge bents considering the operational performance design criteria of existing reinforced concrete bridge bents. Multi-column bents are typical for bridges in Oregon and are therefore more representative of the need to gather performance related data. The proposed research is for experimentally evaluating large-scale reinforced concrete subassemblies representing critical parts of the bents. These primarily represent column-to-crossbeam and column-to-foundation aspects of the bent. Of key interest from the experiments are the monitoring of material strains and deformations as the bent reaches target performance levels.

3.1 Benefits

The benefit to ODOT relates directly to cost and mobility. Recent bridge designs, especially for retrofit, have highlighted the need to better understand performance criteria because those bridge designs had been governed by the operational performance limits; driving the cost of the retrofit. The hypothesis, based on limited data points collected in past research at PSU and those sampled from laboratory assessment of building columns, is that the current strain limits may be conservative for the type of detailing encountered in Oregon. Hence, experimentally validated strain limits obtained from this research can directly influence the retrofit costs.

The mobility aspect is especially important as ODOT aims to maintain dedicated lifeline routes following CSZ earthquake (ODOT 2014). While the operational criteria currently uses a lower hazard, the design is potentially moving to explicitly consider CSZ as an operational performance level this year. As such, the seismic demand considerations for operational criterial in certain parts of the state are likely to increase, making the need to better understand the underlying assumptions even more vital.

The research outcomes will have additional technical reach within ODOT. The experimental data will provide knowledge on existing bridge performance at varying levels of demand and as such could also inform post disaster inspection.

4.0 Implementation

The main product of the research will be the development of performance criteria recommendations for structural seismic bridge design in Oregon. The standards engineers could use these findings to guide their design and further the development of BDDM. Progress of the research will be shared with the design community by presenting at regional conferences, such as the Western Bridge Engineers and Northwest Transportation conferences. For all research activities, the PIs collaborate closely with ODOT personnel throughout the project to ensure the research is of practical relevance and knowledge gained is transferred effectively.
Given the unique data that will be generated, the findings will be of interest to the profession as the field of structural engineering in general moves toward performance based design. As such, technical papers will be presented in appropriate conferences and submitted to journal publications.

5.0 Research Tasks

Recently concluded research (Bazaez and Dusicka 2016) has shown that the long duration effects of subduction zone earthquakes result in a large total number of cycles, with majority being at low ductility levels and few at high ductility. Consequently, the number and amplitude of damaging cycles from subduction earthquakes is vastly different from crustal earthquakes. Laboratory performance data of bridge components from subduction type events is scarce and yet the impact on performance measures is expected to be significant. Furthermore, the simultaneously occurring axial load in the columns will need to be considered to vary with lateral demand to more closely replicate the seismic forces imposed on the columns in multi-column bents. This is in contrast to majority of past research that often considered a constant axial load. The research tasks to accomplish the above goals include:

Task 1: Initial TAC Meeting

Project kick off meeting.

**Time Frame:** December, 2016/January 2017.  
**Responsible Party:** PI, ODOT Research Coordinator, TAC  
**Cost:** $ (incorporated into Task 2)  
**Deliverable:** TAC meeting attendance, TAC meeting presentation, TAC Meeting Minutes  
**TAC Action:** Review and understand project research problem statement, research question, the limits of the research, and the project schedule. Advise ODOT Research Coordinator regarding any critical issues with the project’s scope or schedule. Advise PI’s regarding related professional practices, standards, methods and context for the project. Initial guidance regarding vintage of existing bridge details, column cross-section geometry will be a part of this advice.

**ODOT Action or Decision:** Review TAC advice, discuss with PI, and if necessary direct PI to make changes to project documents.

Task 2: Draft Literature Review

A literature review will be conducted to gather as much data as possible on past tests that resemble the bent component details that are representative to Oregon. The Transportation Research Board publication “Literature Searches and Literature Reviews for Transportation Research Projects” is a good resource for guiding this

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The literature review should be written so as to be readily incorporated into the final research project report.

**Time Frame:** December 2016 – April, 2017  
**Responsible Party:** Portland State University Investigators  
**Cost:** $14,135  
**Deliverable:** A review of pertinent literature on the subject of strain criteria for plastic hinges in bridge reinforced concrete members subjected to seismic loading.  
**TAC Action:** Read draft literature Review and advise ODOT Research Coordinator regarding any gaps in the literature.  
**ODOT Action or Decision:** Review TAC advice, discuss with PI, and if necessary direct PI to make changes to project documents. Research Coordinator will indicate acceptance of the task being complete.

**Task 3: Draft Research Methodology**

This task includes identification and description of required data, variables, and specification of analysis technique. The laboratory experiments will be designed as part of this task, consisting of the specimen details and the test setup. The specimen design is expected to consist of two different sub-components of a typical bridge bent; specifically the column-to-foundation and the column-to-beam connections. Previous analyses indicate that these areas are potential location of plastic strain and damage in existing bridge bends.

The associated test setup will be conceptually developed for both cases, followed by detailed design of the needed fixtures and instrumentation. The loading protocol will also be outlined as part of this task. Given the large scale of the specimens and the desire for imposing controlled deformations, the loading protocol is expected to consist of lateral deformations and of representative internal axial loads. The column in particular will experience variable axial load that is intended to be more representative of the loading conditions experience within a bent under lateral earthquake loads.

The Draft Research Methodology will document the proposed data collection including primarily communicated via an instrumentation plan. The Draft Research Methodology will determine the kinds of techniques will be used to analyze the collected data. The Draft Research Methodology will document approval for any work with human subjects, and protections of personnel private information related to any human subjects.

**Time Frame:** March – June, 2017  
**Responsible Party:** Portland State University Investigators  
**Cost:** $21,978  
**Deliverable:** Description of the proposed research methodology, written in anticipation of being incorporated into the final research project report.
**TAC Action:** Read draft of research methodology in preparation for Methodology TAC Meeting.

**ODOT Action or Decision:** Schedule Methodology TAC Meeting.

**Task 4: Methodology TAC Meeting**

The objective of this meeting is to review the research methodology along with the testing and budgetary constraints.

**Time Frame:** May/June, 2017  
**Responsible Party:** Portland State University Investigators, ODOT Research Coordinator, TAC  
**Cost:** $ (incorporated into Task 3)  
**Deliverable:** TAC meeting attendance, TAC meeting presentation and/or handouts, TAC Meeting Minutes.

**TAC Action:** Review of Draft Research Methodology and Draft Literature Review. Advise ODOT Research Coordinator regarding any critical issues with the project’s research design. If possible reach consensus regarding the content and methods contained in the draft research design. Advise ODOT Research Coordinator regarding recommended project next steps.

**ODOT Action or Decision:** Review TAC advice. Assess project potential for successful completion. If necessary direct PI to make changes to project documents. Provide formal acceptance of Draft Research Methodology. Authorize PI to proceed with subsequent steps, notify by memo or email.

**Task 5: Large-scale Destructive Testing**

Large scale destructive experiments will be conducted on bent sub-assemblies. Reinforcing details will consider the presence and absence of splices within hinge zones as appropriate for the sub-assembly. For the column-to-foundation, the foundation reinforcing details will also be included as no experimental data to date currently exists that considers the existing spread foundation reinforcing. For the column-to-beam, representative transverse reinforcing details of both the beam and the column will be considered.

Lateral deformations representative of subduction zone earthquake demands will be utilized and imposed on the test specimen. The specimen loading protocol will draw on past research results with regard to the number and amplitude of inelastic cycles. The tests will be conducted to target performance levels, which are expected to be inelastic and which will be determined as part of the predetermined Research Methodology.

**Time Frame:** June, 2017 - January, 2018  
**Responsible Party:** Portland State University Investigators  
**Cost:** $81,220
**Task 6: Evaluation of Testing Results**

Data from the experiments will be analyzed. The behavior and performance of the test specimens will be evaluated in order to assess the bent subassembly overall behavior. Specifically, the data will be analyzed for material limits corresponding to predetermined operational performance levels while taking into account the test setup, test observations and related analyses.

*Time Frame:* September, 2017 – April, 2018  
*Responsible Party:* Portland State University Investigators  
*Cost:* $51,790  
*Deliverable:* Analyses of the results of the destructive testing to be incorporated into the final research project report. Noteworthy or unusual results may be shared with the TAC during evaluation or upon completion.  
*TAC Action:* Respond to any inquiries from the investigators regarding the results.  
*ODOT Action or Decision:* None.

**Task 7: Numerical Analysis of Tested Configurations**

The tested configurations will be numerically analyzed using current techniques, such as moment curvature based on pushover that is often used for design (FHWA 2006, 2011). The results will be contrasted to the experimentally obtained capacities such that recommendations for design can be made.

*Time Frame:* January – September 2018  
*Responsible Party:* Portland State University Investigators  
*Cost:* $55,878  
*Deliverable:* Results of the analyses will be incorporated into the final research project report.  
*TAC Action:* Respond to any inquiries from the investigators regarding the results.  
*ODOT Action or Decision:* None.

**Task 8: Draft Final Report**

Content Complete Draft Final Report in the prescribed ODOT report format.  
(Formating includes correct fonts, spacing, citations and graphics) 
Contents include: an updated abstract, acknowledgement, disclaimer, introduction, literature review

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(Task 2), research methodology (Task 3), data and analysis section (Tasks 5, 6, and 7), discussion of results, conclusions, and potential for future research, application, or technology transfer, and other sections as appropriate.

**Time Frame:** July – September, 2018  
**Responsible Party:** Portland State University Investigators  
**Cost:** $ (incorporated into tasks 2, 3, 5-7)  
**Deliverable:** Draft Final Report using ODOT’s report template  
**TAC Action:** TAC review and feedback to the ODOT Research Coordinator  
**ODOT Action or Decision:** Review and counsel prior to TAC meeting

### Task 9: Draft ODOT Research Note

Write 1000 to 1500 word summary of the research project. The summary will concisely document the research findings, value of the research to the agency, science and society, and any limitations on the use of the findings. The target audience is the general public and transportation professionals outside the specialty area of the research project.

**Time Frame:** September/October, 2018  
**Responsible Party:** Portland State University Investigators  
**Cost:** $ (incorporated into tasks 2, 3, 5-7)  
**Deliverable:** Draft ODOT Research Note using ODOT’s Research Note template  
**TAC Action:** None  
**ODOT Action or Decision:** Review and advise.

### Task 10: Final TAC Meeting

This TAC meeting will include a review of the Draft Final Report, and Draft Research Note prior to the TAC meeting. The TAC will offer advice on the content and clarity of these work products. The TAC will also advise on post research implementation.

**Time Frame:** October/November, 2018  
**Responsible Party:** Portland State University Investigators, assisted by the ODOT Research Coordinator, TAC  
**Cost:** $ (incorporated into tasks 2, 3, 5-7)  
**Deliverable:** TAC meeting attendance, TAC meeting presentation and/or handouts, TAC Meeting Minutes.  
**TAC Action:** TAC review of Draft Final Report, and Draft Research Note. Advise ODOT Research Coordinator regarding any critical issues with the project’s research design, execution, or analysis. Advise ODOT Research Coordinator regarding any required final edits to the Draft Final Report, and Draft Research Note.  
**ODOT Action or Decision:** Review TAC advice. If necessary direct PI to make changes to project documents.

### Task 11: Finalize Report
Edit Draft Final Report to incorporate edits identified by the ODOT Research Coordinator following the last TAC meeting.

*Time Frame:* October – December, 2018  
*Responsible Party:* Portland State University Investigators  
*Cost:* $ (incorporated into tasks 2, 3, 5-7)  
*Deliverable:* A final, publication ready, research project report in the ODOT Research Section’s format. This should include consistent and accurate citations and corresponding bibliographic entries.  
*TAC Action:* None.  
*ODOT Action or Decision:* Provide formal acceptance of the completed research report. Publish the research report on ODOT’s research website.

**Task 12: Finalize Research Note**

Edit Draft Research Note to incorporate edits identified by the ODOT research Coordinator following the last TAC meeting.

*Time Frame:* November/December, 2018  
*Responsible Party:* Portland State University Investigators  
*Cost:* $ (incorporated into tasks 2, 3, 5-7)  
*Deliverable:* Final Research Note ODOT Research Section’s Research Note format.  
*TAC Action:* None  
*ODOT Action or Decision:* Provide formal acceptance of the completed Research Note. Publish Final Report on ODOT’s research website.

5.1 Reporting

All reports shall be produced in the standard ODOT Research Section report format provided to the Project Investigator by the Research Coordinator unless some other format is deemed to be more appropriate. The Project Investigator shall be responsible for submitting deliverables as professional-level written composition equivalent to the writing standards of peer-reviewed journals. These writing considerations include grammar, spelling, syntax, organization, and conciseness.

The Project Investigator, in consultation with the TAC and Research Coordinator, shall deliver to ODOT, in electronic format, the data produced during the project. The Project Investigator shall ensure the data is labeled and organized to facilitate future access. ODOT shall warehouse the data.

5.2 Safety and Related Training

Prior to accessing ODOT right-of-way (ROW), all personnel who will work on ODOT ROW shall complete safety training appropriate to the work to be performed within the ROW. The Project Investigator shall notify Project
Coordinator in writing (email accepted) prior to the first day of work within the ROW that all project personnel who will access ODOT ROW have been trained. Until all ROW work is completed, the Project Investigator shall notify Project Coordinator in writing (email accepted) annually that an active safety training appropriate to the work to be performed within the ROW has been completed by all personnel who will work on ODOT ROW.

6.0 Time Schedule

The anticipated schedule of tasks is summarized below.

<table>
<thead>
<tr>
<th>Task</th>
<th>2016</th>
<th>2017</th>
<th>2018</th>
<th>2019</th>
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<td>FY17</td>
<td>FY18</td>
<td>FY19</td>
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<td></td>
<td>Oct - Dec</td>
<td>Jan - Mar</td>
<td>Apr - Jun</td>
<td>Jul - Sep</td>
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<tr>
<td>1: Initial TAC Meeting</td>
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<td>2: Literature Review</td>
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<td>3: Draft Methodology</td>
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<td>4: Methodology TAC Meeting</td>
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<td>5: Destructive Testing</td>
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<tr>
<td>6: Evaluation of Results</td>
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<tr>
<td>7: Numerical Analysis</td>
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<tr>
<td>8: Draft Final Report</td>
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<td>9: Draft Research Note</td>
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<td>10: Final TAC Meeting</td>
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<tr>
<td>11: Finalize Report</td>
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<tr>
<td>12: Finalize Research Note</td>
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</table>

*Deliverables
R - Draft report submitted for ODOT review.
F - Revised report submitted to ODOT for publication. End of contract.

7.0 Budget Estimate

An itemized budget for the project is shown, inclusive of estimated expenditures for each task by fiscal year and in total.

<table>
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<th>Task</th>
<th>FY17</th>
<th>FY18</th>
<th>FY19</th>
<th>Total</th>
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<td>2: Literature Review</td>
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<td><strong>Total for ODOT (ODOT completes)</strong></td>
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