Memorandum 1.11

I-5 MEDFORD VIADUCT PLANNING & ENVIRONMENTAL STUDY

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Subject:	**Task 1.11 Existing Structure Baseline Seismic Performance Memo**

The purpose of this memorandum and the other early anchoring activity memorandums in Phase 1A of the project is to inform the Draft Problem Statement and guide further development of the project.

Introduction

OBEC created a three-dimensional spline model ("seismic model") to determine the baseline seismic performance of the existing Medford Viaduct structure. Two seismicity levels were evaluated in the model: 1) "Operational" Criteria Cascadia Subduction Zone Event and 2) "Life Safety" Criteria 1,000-year Seismic Event. **Figure 1** at the end of the memorandum provides a diagram that visually identifies the terms, “bent”, “crossbeam”, and “column”.

Baseline Seismic Performance Methodology Summary

We subjected the seismic model to cyclical bi-directional horizontal accelerations at various cycle periods in response-spectra analyses for both seismicity levels. From the model output, we extracted the lateral displacements at the column tops relative to those at the column bases. These displacements are the 'demands'. We screened these demands to isolate samples of the various bent frame configurations with the highest displacement demands relative to their flexibility. We created individual models of each of these bent frames and subjected each to a 'pushover' analysis. The frames are incrementally 'pushed' up to the displacement demands determined from the model, and each of the frame component vulnerabilities is identified. These analyses identify which components in the bent frame yield, and at what displacements. Our evaluation of these vulnerabilities generally indicates that retrofit a feasible and practical alternative to address the bridge vulnerabilities at the two seismicity levels.

The baseline performance modeling indicates that the majority of the bridge substructure components are vulnerable to damage at the seismicities evaluated and seismic retrofit of most substructure components is required. In particular the crossbeams and spread footings do not provide adequate elastic structural capacity to allow the columns to develop the required partial plastic moments to achieve the required column seismic displacement demands; and in most cases even if the crossbeam and/or spread footings did not fail, the columns would still be insufficient to meet the displacement demands.

The full extent of component retrofits will be based on criteria yet to be established in collaboration with ODOT under Task 1.12. These criteria may require a margin of ductile behavior above the displacement demands associated with the seismicity levels that were evaluated in the baseline performance modeling. We did not generate any retrofit concepts or associated costs. This will be completed as part of Task 1.12.

Methodology Details

Seismic modeling generally followed the steps and recommendations presented in the Task 1.6 Memo. Two seismic response spectra were modeled according to ODOT Bridge Design and Drafting Manual (BDDM) protocols:

1) "Operational" Criteria: Full rupture Cascadia Subduction Zone seismicity.
2) "Life Safety" Criteria: 1,000-year return period earthquake (Seven percent probability of exceedance in 75 years) seismicity

Displacement demands were output from a multi-modal response spectrum seismic analysis of the existing structure using MIDAS structural modeling software. Net displacement demands at the column tops for each seismic load case were combined according to the AASHTO Guide Specification for LRFD Seismic Bridge Design to account for directional uncertainty of the modeled design seismicity.

We completed a pushover analysis of 13 representative bent frames by grouping them together according to similar displacement demands and geometric configurations to provide a performance sampling of the entire structure. Displacement capacities were derived from pushover analyses. By comparing the bent frames' longitudinal and transverse stiffnesses relative to the displacement demands, we determined that transverse response of the existing bent frames would control over the longitudinal response. Therefore, pushover analyses were only conducted for the predominantly transverse (parallel to the bent axis) load case combination. We established maximum column top displacement capacities for each bent frame associated with the column concrete non-confined compressive strain limit of 0.003.

In addition to evaluating the displacement capacity of the existing structure using pushover analyses, we solved for the plastic shear demand of the confined column at the seismic displacement demand determined from the entire bridge model. The columns do not currently have detailing consistent with confined concrete, so these plastic shears are the shear demands that would need to be achieved with confinement retrofit.

See **Appendix A** for Baseline Performance Tables.

Observations and Conclusions

We have identified baseline seismic performance vulnerabilities at specific seismicities and offered a judgement that practical retrofit strategies can feasibly address those vulnerabilities. One facet of Task 1.12 is to collaborate with ODOT engineers on the applicability of seismic codes, and the results of those discussions could potentially require margins of ductility above those to address the ductility demands identified by the baseline performance modeling. Such ductility margins will affect retrofit details.

With a relative low design seismicity compared with sites located closer to the coast, and the favorable bridge geometry of relatively short spans paired with column lengths approximately equal to half the span length, the results indicate manageable seismic displacements that are conducive to practical retrofit strategies. However, the existing bridge was designed and detailed consistent with design practices of an era when design practices did not address seismic loading. Pushover analysis revealed two general conditions that represent the existing structure's seismic resiliency and deficiencies:

- Existing crossbeams and spread footings do not provide adequate strength to allow these substructure elements to remain elastic during the evaluated seismicities and allow the columns to develop the required partial plastic moments to achieve the required column seismic displacement demands. Potential seismic retrofitting to address these deficiencies could include crossbeam and spread footing strengthening, top of column and crossbeam connection strengthening and bottom of column and spread footing connection strengthening.

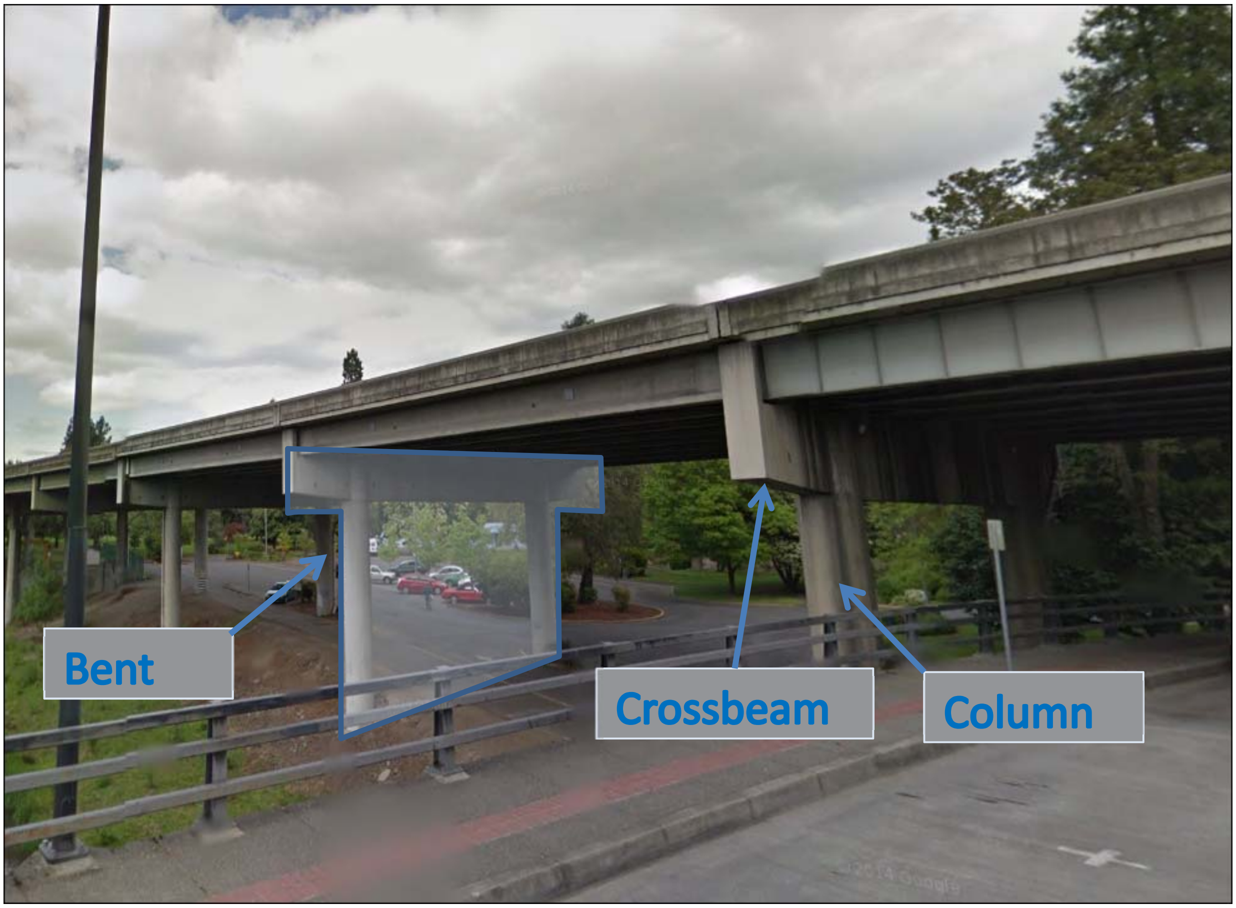
  Pushover analysis revealed that most bridge bents utilizing crossbeams supported by columns and spread footings are susceptible to these vulnerabilities.

- Existing column transverse reinforcement does not provide adequate confinement of column longitudinal steel to allow the column to develop the required partial plastic moment necessary to achieve the top of column seismic displacement demands. In addition, in some cases the column plastic shear demand exceeds the column's shear resistance capacity. Potential seismic retrofitting to address these deficiencies could include column wrapping to provide both confinement and shear strengthening.

  Pushover analysis revealed that bridge bents 2 thru 10 and 13 thru 47 are susceptible to this vulnerability.

In summary, bents 10 and 11 will require some level of crossbeam and spread footing strengthening and most of the remaining bridge bents will require retrofitting of crossbeams, columns and spread footings in order for the existing structure to become capable of resisting seismicity levels evaluated.

Figure 1. Diagram of Viaduct Showing a “Bent”, a “Crossbeam”, and a “Column”.



Appendix A

Baseline Performance Tables

We completed a pushover analysis of 13 representative bents by grouping bents together according to similar displacement demands and geometry configurations to provide a performance sampling of the entire structure. Displacement capacities were derived from pushover analyses.

Note that capacity-to-demand (C/D) ratios are only representative of the existing structure column's seismic resiliency and deficiencies. C/D ratios > 1.00 do not necessarily indicate that no retrofit is required. For example, columns with C/D > 1.00 may need crossbeam or spread footing connection strengthening. Further analysis and evaluation is required.

Table A1. "Operational" Cascadia Subduction Zone Seismic Event

					Capacity Demand Ratio (C/D)	
Bent	**Displacement Demand (in)**	**Column Displacement Capacity (in)**	**Plastic Shear Demand (kip)**	**Shear Capacity (kip)**	**Column Displacement**	**Column Shear**
11	1.01	2.01	198.97	220.79	1.99	1.11
14	1.61	2.23	161.54	219.97	1.39	1.36
16	1.78	2.33	182.87	218.44	1.31	1.19
21	1.46	1.73	279.16	259.54	1.19	**0.93**
22	1.02	1.47	392.33	307.42	1.44	**0.78**
26	1.49	1.78	214.18	217.70	1.19	1.02
29	1.75	1.84	208.90	218.09	1.05	1.04
39	1.49	2.16	205.10	327.29	1.60	1.06
40	1.92	1.86	339.35	306.50	**0.97**	**0.90**
41	1.93	2.25	185.07	218.05	1.17	1.18
44	1.57	1.33	281.60	216.53	**0.84**	**0.77**
45	1.10	0.89	340.46	217.14	**0.81**	**0.64**
46	0.42	0.66	580.07	260.44	1.57	**0.45**

Appendix A

Baseline Performance Tables

Table A2. "Life Safety" Criteria 1000 Year Seismic Event

					Capacity Demand Ratio (C/D)	
Bent	**Displacement Demand (in)**	**Column Displacement Capacity (in)**	**Plastic Shear Demand (kip)**	**Shear Capacity (kip)**	**Column Displacement**	**Column Shear**
11	1.64	2.01	198.97	217.96	1.23	1.10
14	2.51	2.23	186.14	218.01	**0.89**	1.17
16	2.77	2.33	182.87	217.22	**0.84**	1.19
21	2.35	1.73	279.89	258.06	**0.74**	**0.92**
22	1.59	1.47	394.18	305.59	**0.92**	**0.78**
26	2.38	1.78	214.18	216.53	**0.75**	1.01
29	2.78	1.84	209.78	217.36	**0.66**	1.04
39	2.46	2.16	308.87	327.29	**0.88**	1.06
40	3.14	1.86	341.67	306.13	**0.59**	**0.90**
41	3.12	2.25	185.85	217.05	**0.72**	1.17
44	2.38	1.33	282.47	216.53	**0.56**	**0.77**
45	1.66	0.89	341.35	216.62	**0.54**	**0.63**
46	0.65	0.66	584.26	257.76	1.02	**0.44**