Appendix H

BRIDGE STRUCTURE-BORNE NOISE

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Vibration is caused within a bridge structure when vehicles travel over the bridge. These vibrations can result from can be caused by normal vehicle movement but can also be the result of tire interaction and impact at bridge expansion joints. The noise generated from these movements is often at low-frequencies and can vary depending on bridge design and construction. When predicting noise resulting from vehicles traveling on the bridge, consideration should be given to the contribution of structure-borne noise as it has the potential to alter the acoustic effectiveness of noise walls and feasibility of abatement.

Methodology

FHWA's Traffic Noise Model used in the IBR traffic noise analysis does not have the capability to calculate structure-borne noise directly. To calculate and analyze the potential effect of structure-borne noise for this project, structure-borne noise was analyzed following the procedures documented in the NCHRP Report 791 (NCHRP 2014). Information is included in Chapter 2 and Appendix A of NCHRP Report 791 and a description of the procedures applied to this part of the IBR noise study is described in detail in Section 2.2.2: Best Modeling Practice #2. This is summarized below:

- Model direct highway noise contributions from all roadways using FHWA TNM.
- Conduct multiple (minimum of three) sets of noise measurements at the drip edge ground level location and at a minimum of two setback distances to validate the FHWA TNM runs and determine the contribution of structure-borne noise.
- Apply the adjustments from the provided worksheet to levels at setback locations to determine total modeled noise levels at each setback location.
- If expansion-joint noise is the predominant source of structure-related noise, assume that the noise emanates from the joint above the measurement point rather than at the midpoint of the structure.
- Apply the values from the Table 2 worksheet to FHWA TNM predicted levels for the proposed project using the drop-off rates that best correlate with the measured levels.

Field Measurements

Noise level measurements were conducted at three locations on the eastern and western side of the southern section of the North Portland Harbor Bridge along N Center Ave. This location was chosen as a proxy of the project design due to its concrete construction, but also to provide a conservative assessment of structure borne noise. The bridge's low height and its proximity to an expansion joint was expected to increase structure borne noise at this location.

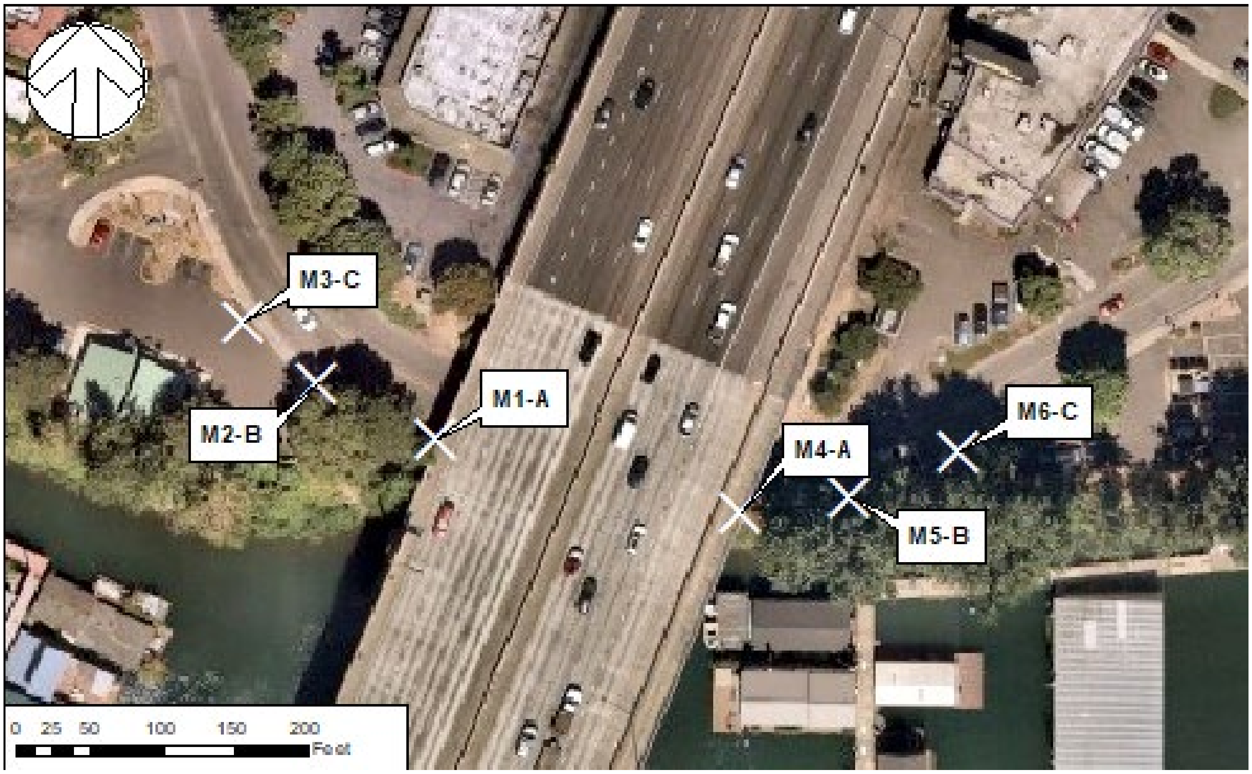
Measurements for each set (either side of the bridge) were conducted simultaneously at the drip edge and at two setback distances. The measurements on the western side of the bridge were completed on April 6 and the eastern side on April 7 2022. The measurement locations were within 200ft of the expansion joint on the bridge and approximately 50-100ft to the north of noise sensitive receptors (houseboats located east and west of the bridge). The locations of the measurements are shown on Figure H-1.

This north side of the North Portland Harbor Bridge was selected to conduct noise measurements for this analysis because of the following factors:

- the replacement bridge at North Portland Harbor is planned to have similar structural characteristics and height (approximately 10 feet taller than the current North Portland Harbor Bridge);
- presence of bridge joint nearby;
- presence of noise-sensitive receptors in the area;
- and noise walls are evaluated as part of the project in this location; thus this analysis serves to confirm any planned noise mitigation. At this time, noise walls do not meet Oregon DOT Feasibility and Reasonableness Criteria for inclusion in the project).

Other areas were considered for inclusion in this analysis including the south landing of the North Portland Harbor Bridge and both the north and south landings of the Interstate Bridge. The south landing of the North Portland Harbor Bridge wasn't selected due to the greater distance to future noise sensitive-land uses, site restrictions, and more contributing noise from local streets. The Interstate Bridge (two bridges than span the main channel of the Columbia River) was not included in this analysis because the steel vertical-lift through-truss bridges are structurally different and noticeably lower in elevation than the replacement bridge planned in this area; therefore, the resulting structure-borne noise would not apply to the future replacement bridge. As described in the Results Section, identification and analysis of existing bridges similar in structure and height to the replacement bridge planned over the main channel over the Columbia River could provide additional insight into the vibro-acoustic properties of the replacement bridge.

Figure H-1. Structure-borne Noise Measurement Locations



Measurements M1-A and M4-A were conducted underneath the drip edge either side of the structure. The measurements on the west side of the I-5 were approximately 65ft (M2-B) and 110ft (M3-C) from the drip edge. Measurements on the east side of the I-5 were approximately 50ft (M5-B) and 90ft (M6-C) from the drip edge. The traffic volumes were collected on the I-5 and N Center Ave during each set of measurements and the position of each measurement was captured using GPS. A TNM model was then created using this information to validate predictions at these locations. Site photographs taken during the measurements and field data sheets are included in Appendix D of the IBR Noise and Vibration Report.

Results

The difference between the measured and modelled sound levels were tabulated to determine the extent of structure-related noise contributions. Table H-1 shows the measured and modelled noise level and the estimated effect of the structure-borne noise.

Table H-1. Structure-borne Noise Validation

Measurement Location	Location of Measurement in Relation to Drip Edge (Feet)	Measured $_{Leq, 1hr}$ Noise Level (dBA)	FHWA TNM Modeled $_{Leq, 1hr}$ Noise Level due to Highway Traffic	Estimated Effect of Structure-borne Noise
M1-A	0	73.0	/	/
M2-B	65	71.5	72.2	-0.7
M3-C	110	70.1	70.9	-0.8
M4-A	0	74.1	/	/
M5-B	50	72.7	72.9	-0.2
M6-C	90	70.9	71.5	-0.6

Notes
Traffic Noise Modeling files were included in the TNM files for the IBR Traffic Noise Analysis and available electronically.

Discussion and Analysis

The results show that in all modeled locations the TNM model validates well with measurement results and are within 1 dBA of the predicted values. This indicates that structure-borne noise is not influencing noise levels at these modeled locations. For example, at location M3-C, the measured noise level is 70.1 dBA while the TNM prediction (which represents highway traffic only) is 70.9 dBA. The TNM calculated levels are considered “valid” for prediction purposes and show good agreement with the measured values. In line with the NCHRP guidance following the validation of the model, further analysis has not been conducted and there is no requirement to apply corrections for structure-borne noise to predicted results.

This study assumes that the structure-radiated noise from the project will be similar to the southern portion of the existing North Portland Harbor Bridge, and has endeavored to provide a conservative assessment for the prediction of nearby impacts. This approach is recommended by the NCHRP guidance; however, it should be noted that changes to the detailed design have the potential to alter the radiated sound from the structure. Consideration should be given to analyzing the vibro-acoustic properties of the replacement bridges during the design process and the potential for abatement of structure-borne noise near to noise sensitive locations.

Conducting measurements and analysis similar to those taken for this effort near existing bridges that include similar structural characteristics as the replacement bridges will help further analyze the potential effect of structure-borne noise.

Detailed information on potential abatement strategies for expansion joints is provided in the ‘Modular Expansion Joint Noise Mitigation Study’ (University of Washington 2022).