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Trolling for better Acoustics under a Highway Overpass

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AECOM

But first. . . .
A Cheesy Nursery Rhyme

There was an old troll who lived under a bridge
Scaring children and eating goats was what he mostly did.

Not a bad way to live, if that's your kind of thing

It's not for me to say what things doth happiness bring.

But as the years wore on and the traffic noise grew

He developed a hearing threshold shift, poor shrew.

Now the children and goats have no more fears,

For the ugly old creep is now deaf in both ears.

Introduction

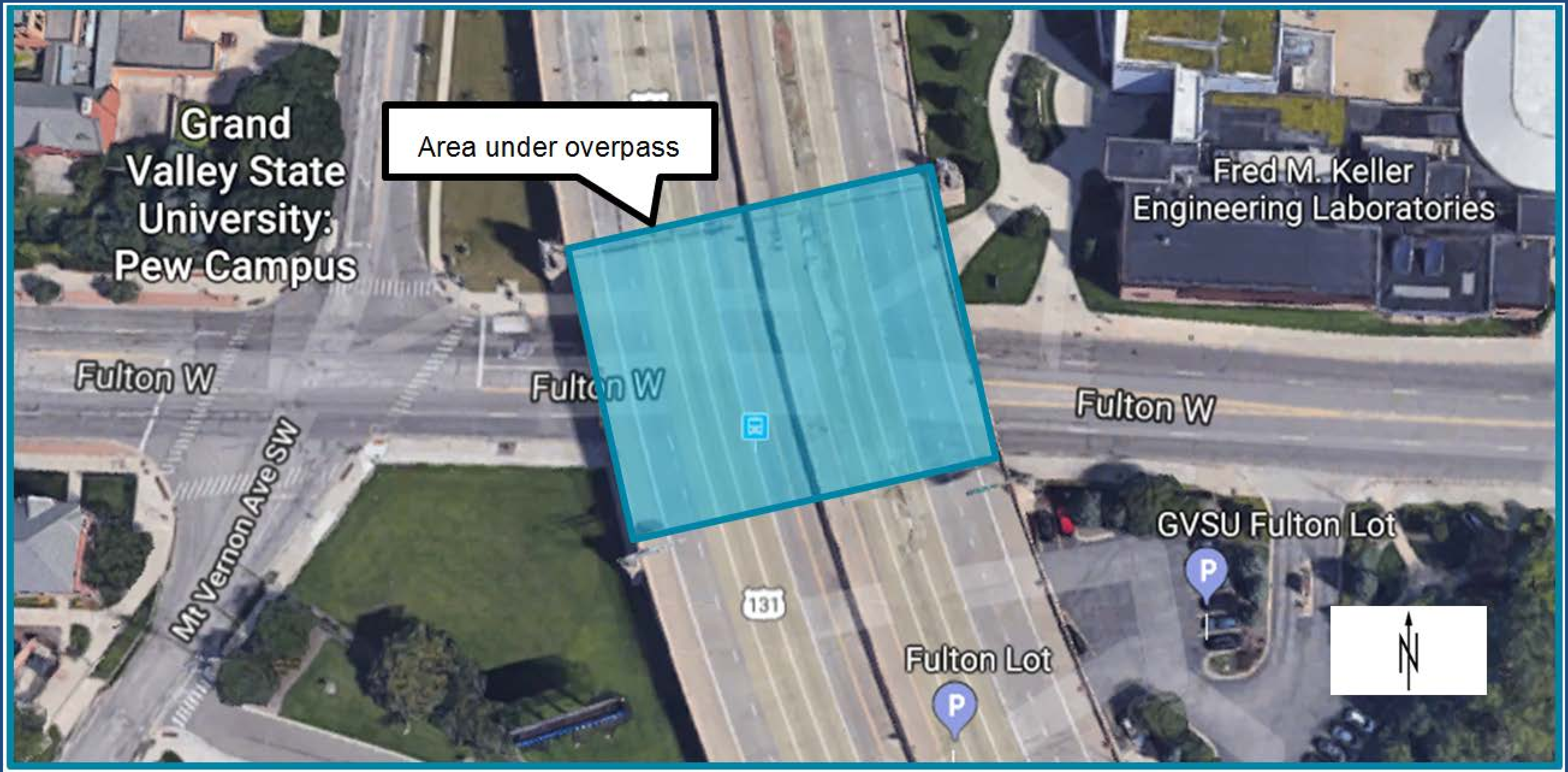
So what’s the problem here?

- A regional transit agency has an existing bus stop located under a wide (10 lane) freeway overpass.
- The bus stop primarily serves a busy urban college campus.
- Positives: shade in summer, protection from snow and rain in winter.
- Negatives: really loud and reverberant all the time!
- Agency wanted to explore aesthetic and acoustical upgrades for area under overpass, if practical and cost effective.

Approach for Acoustical Analysis

- It was anticipated that sound under the overpass would have contributions from both the street level traffic and overhead highway traffic sources, and may need to address both.
- Conduct noise measurements to assess existing noise environment and attempt to quantify contributions from overhead and street level traffic.
- Assess potential treatments to reduce sound levels and reverberation time.

Project area

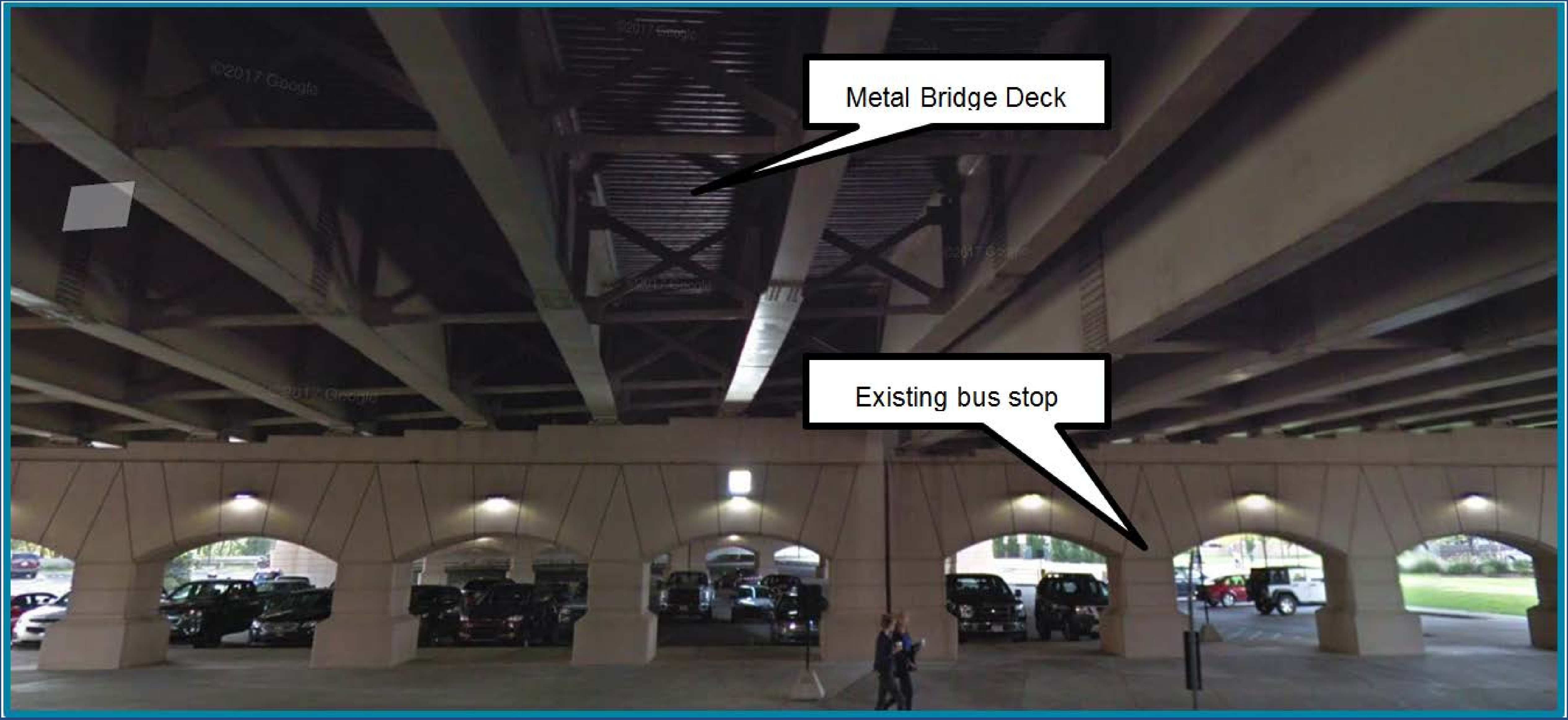


Overhead view of project area

Project area

Surface street, looking East

Project area



Under overpass, looking South

Noise Measurements

The objectives of the noise measurements were to:

- Quantify the existing sound level in the areas under the overpass,
- Attempt to determine relative contributions from street level and overhead sound sources, and
- Estimate the reverberation time in the space under the overpass

Noise Measurements Conducted

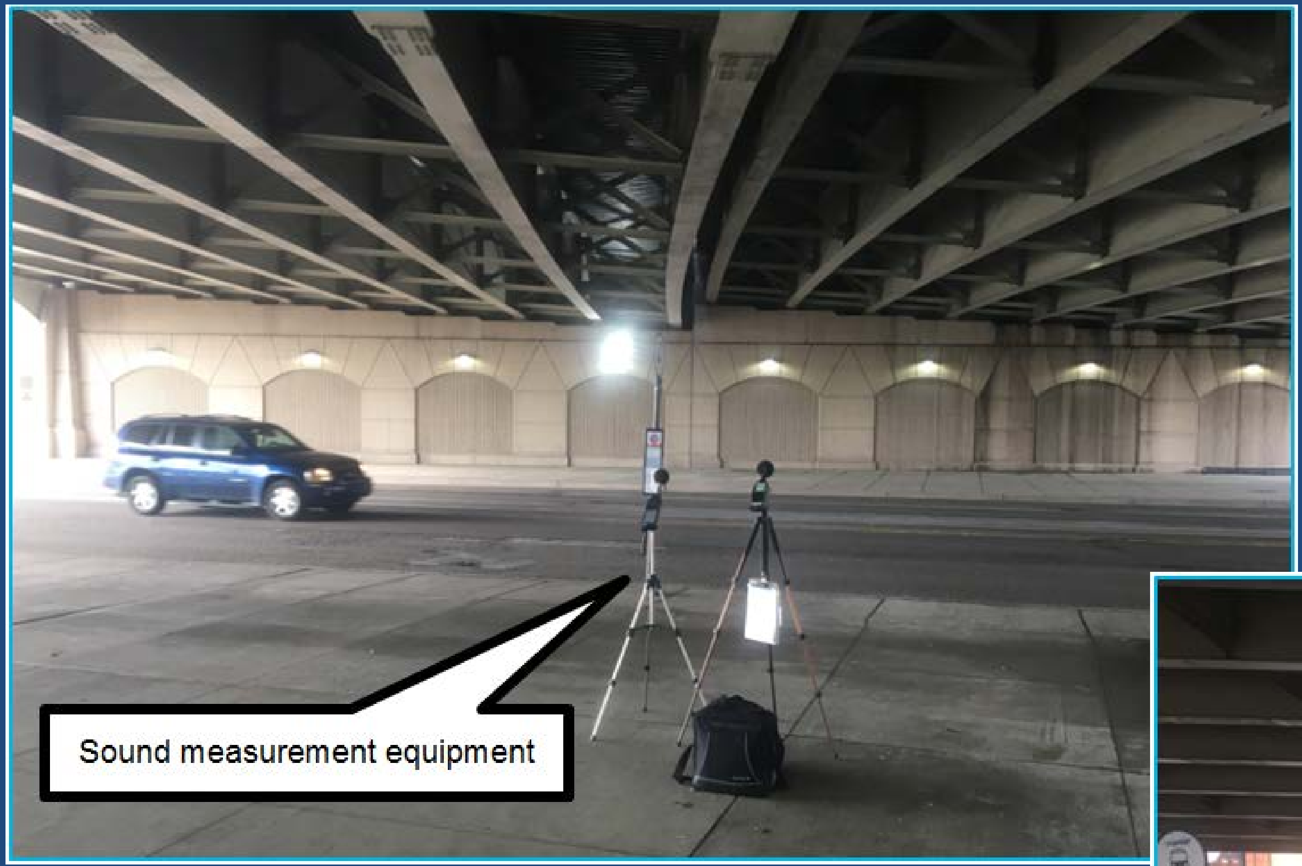
- Overall existing sound pressure level, one minute intervals, peak and off-peak periods (LD 820)

- Frequency spectrum (1/3 octave band) sound level, one second intervals, peak and off-peak periods (B&K 2250)

- Reverberation time measurements, five samples, off-peak period (B&K 2250)

Note: “Peak” period measurements were conducted between about 5:30 and 7:00 pm when traffic was fairly heavy but still free flowing, and “off-peak” measurements were conducted between 9:30 and 10:45 at night when traffic was noticeably lighter.

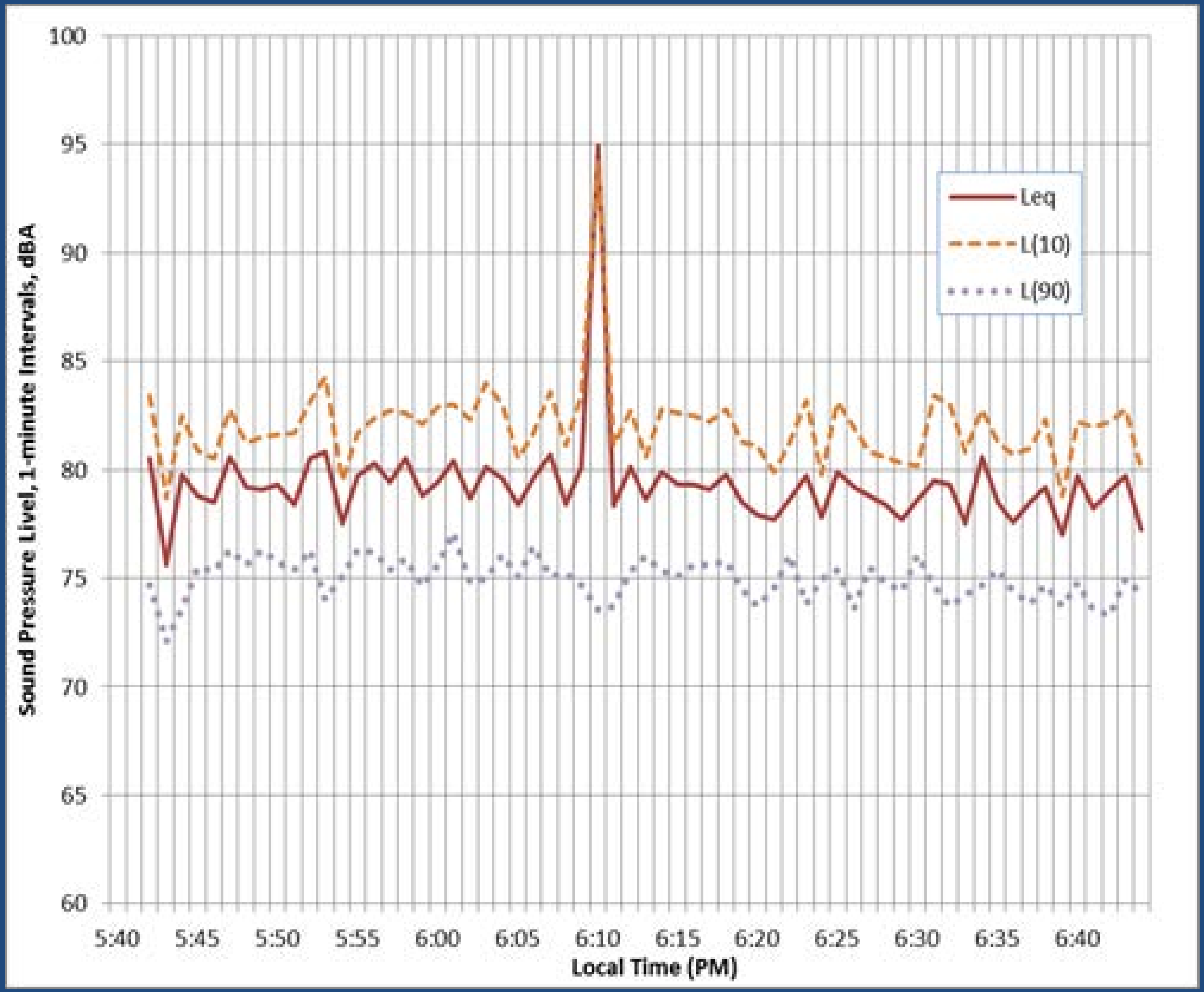
Noise Measurement Set-up



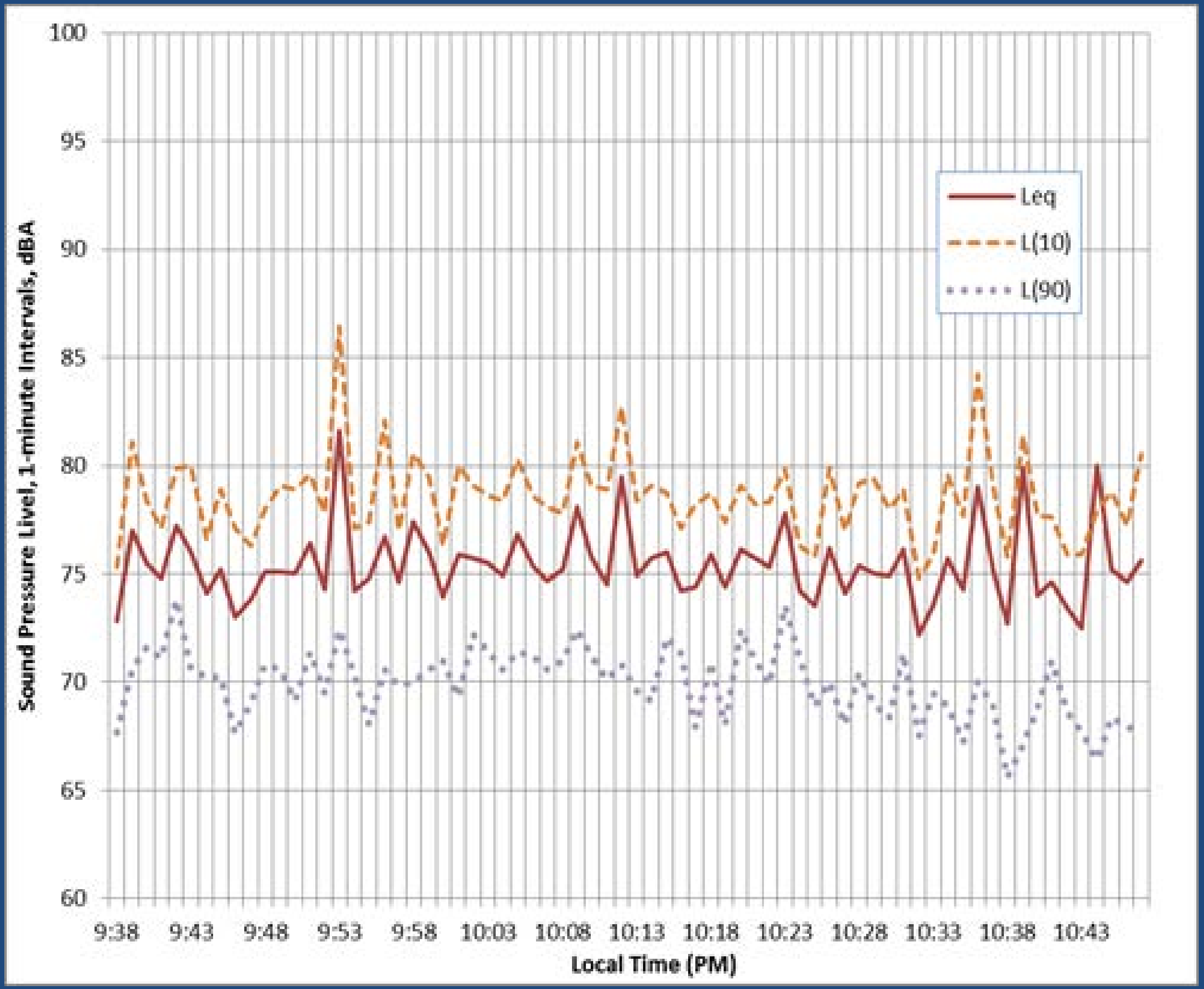
Looking North

Looking East

Overall SPL Measurement Results



Peak Traffic



Off-Peak Traffic

Crafty Observations and Assumptions

- It was observed during the sound level measurements that the overhead sound (from the bridge deck) was fairly constant, but the noise from the local street was more sporadic due to traffic lights on either side of underpass.

- It was also observed that the overhead noise was much less noticeable when there was active traffic on the local street.

- Therefore, it was attempted to quantify the overhead noise as the L_{90} value and the combined level as the L_{eq} value and the street traffic level as the L_{eq} minus L_{90} level.

Estimating Overhead and Local Traffic Level

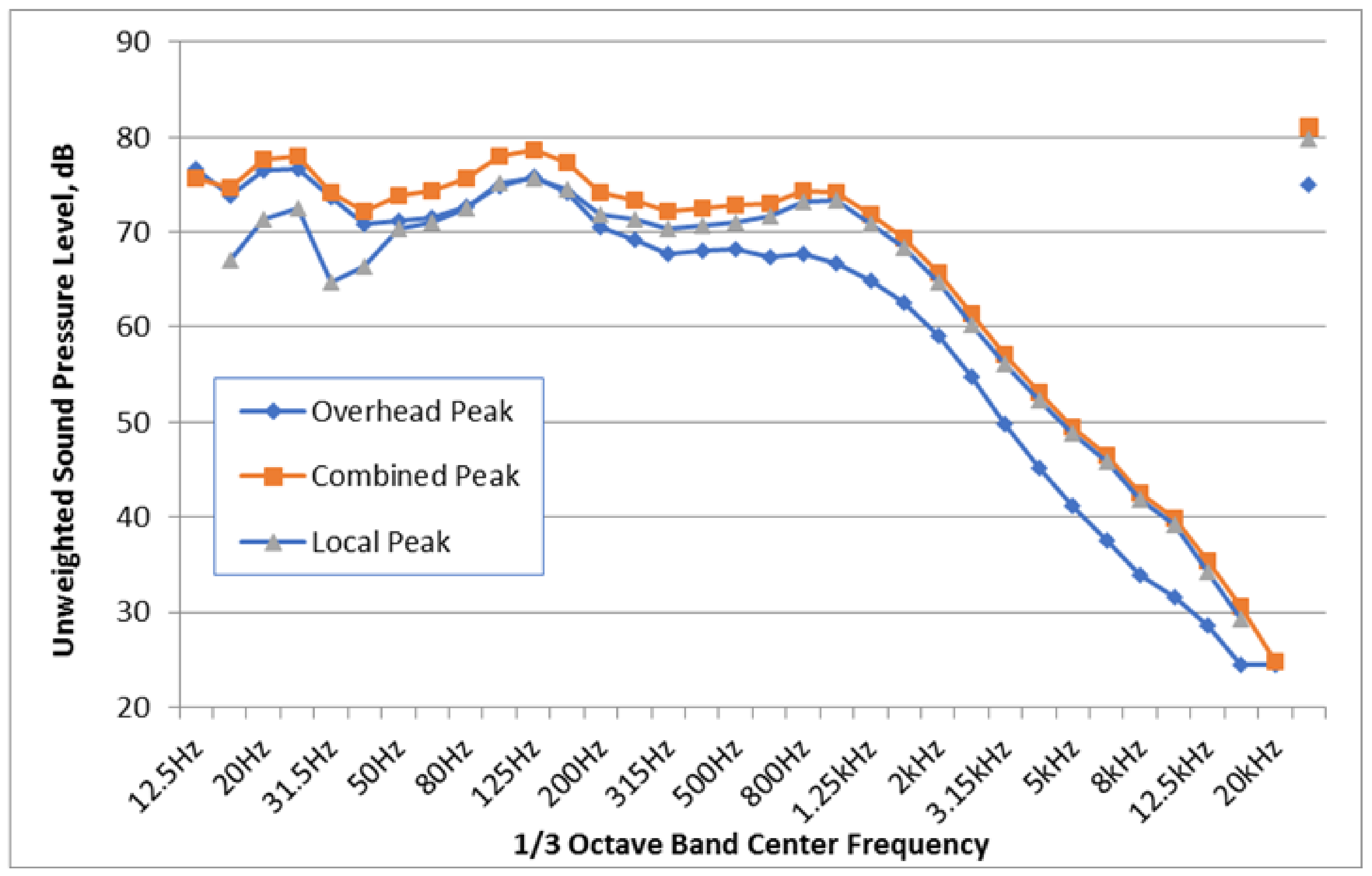
Event	*Peak Traffic (5:30 to 6:30 PM)*	*Off-Peak Traffic (9:30 to 10:30 PM)*
Noise from overhead traffic (measured L_{90})	75	70
Combined noise level (measured L_{eq})	81	76
Noise from local traffic (calculated $L_{eq} - L_{90}$)*	80	75

*Note, the calculated difference between decibel levels is performed on an energy basis, where $L1 - L2 = 10*\log[10^{(L1/10)}-10^{(L2/10)}]$

Using this method, it looks like the overhead bridge deck noise was about 5 dBA down from the local street noise (which “sounds” about right).

Spectral Data

Extrapolating this method and applying to the data from the frequency spectrum measurement, sorting out spectral data with an overall level about 75 dBA, assumed to be overhead level, and 81 dBA, assumed to be the combined level, and calculating the energy difference as the Local street level. The spectral results (for peak traffic) are shown below:



Why Reverberation Time?

- Reverberation Time (Typically RT_{60}) is the time, in seconds, for the sound level in an enclosed space to drop by 60 dB after the noise source has stopped, and is primarily a function of the volume of the space and the total amount of acoustical absorption.
- For some musical performance spaces, a higher reverberation time may be desirable (perhaps 1.5 to 3.0 seconds).
- For non-musical spaces where excess reverberation may increase noise levels and hamper speech intelligibility, a reverberation time of less than one second is considered desirable.

Reverberation Time Measurements

- Five RT_{60} measurements were conducted during the “off-peak” period, during breaks in traffic.
- Balloon burst source was used.
- High background noise levels were a challenge.

Tests averaged	1/3-Octave Band Center Frequency (Hz)																
	100	**125**	**160**	**200**	**250**	**315**	**400**	**500**	**630**	**800**	**1kH**	**1.25k**	**1.6k**	**2k**	**2.5k**	**3.15k**	**Ave.**
All 5 test	1.1	0.2	2.9	2.0	1.4	7.7	1.8	1.2	1.7	0.9	3.3	3.7	3.1	1.8	1.4	1.4	2.2
Tests 3,4,5	1.1	0.2	2.9	2.0	1.5	2.6	1.5	1.3	1.4	1.1	1.6	1.9	1.5	1.9	1.7	1.5	1.6

- Throwing out two questionable tests (maybe just me getting better at blowing up bigger balloons), results looked reasonable.
- Results showed the values were not bad, but could be better.

Assessment of Acoustical Environment

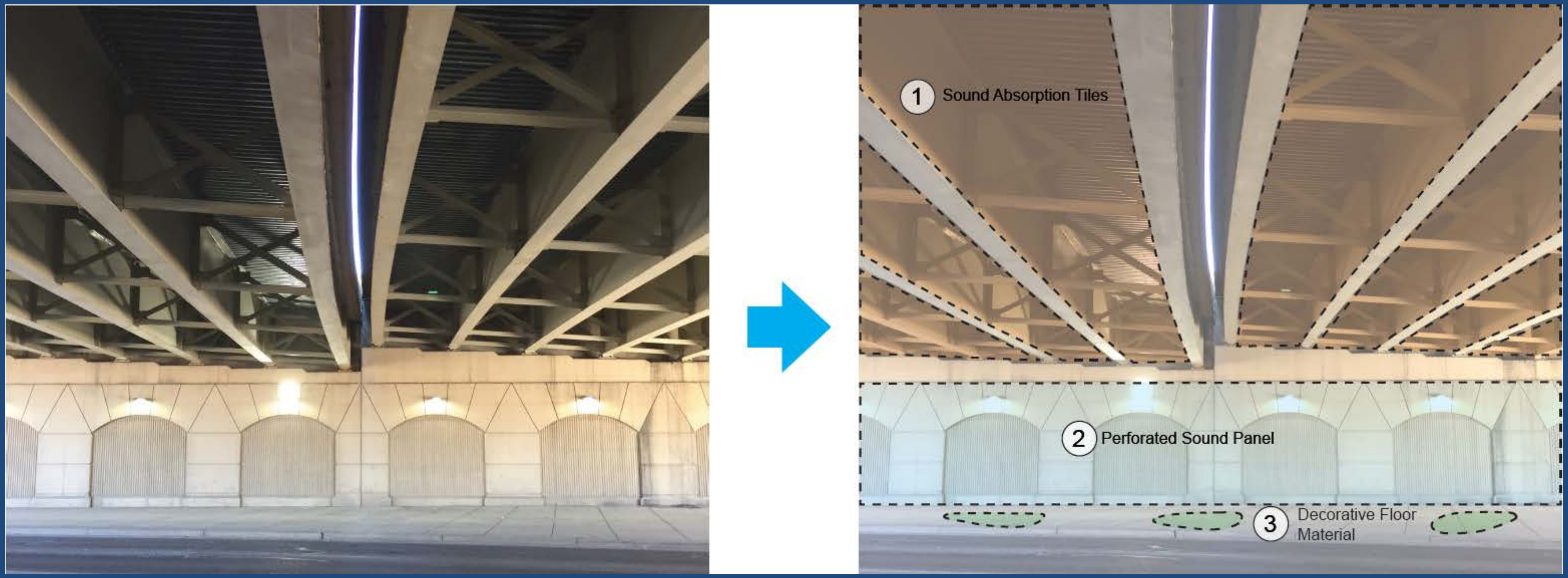
- Measured noise levels under the underpass were quite loud, with 1 minute L_{eq} values typically ranging between 75 and 80 dBA near the bus stop (approaching OSHA workplace limits) and occasionally as high as 95 dBA for some particularly noisy vehicles.

- Reverberation time, while not excessive, could be improved.

Potential Acoustical Treatments

A number of conceptual treatments were considered, including:

- A spray-on acoustically absorptive treatment on vertical surfaces and under the bridge deck
- Replacing roadway surface and sidewalk with something better
- Installing acoustical panels on vertical surfaces or underside of bridge.



Acoustical treatments considered

For further analysis, we considered a ridged acoustical panel that could provide both transmission loss and acoutical absorption that could be easily mounted on the underside of the bridge structure (and maybe also provide an aesthetic improvement).

Assessment off alternatives

Some quick analysis for the use of various types of acoustical panels (with low, medium, high values for acoustical absorption and transmission loss) on the underside of the bridge are presented below.

Expected Acoustical Results With Various Treatments (Peak Traffic at 1000 Hz)

				RT60, seconds			Overhead Noise, dB			Local St. Noise, dB			Combined Noise, dB		
Type of System	Acoustical Absorpt.	Trans. Loss	Room NR	Exist RT60	With Treat.	Delta	Exist. Level	With Treat.	Delta	Exist. Level	With Treat.	Delta	Exist. Level	With Treat.	Delta
High Absorption, Low Transmission Loss	0.9	5	2.8	1.3	0.7	0.6	66.7	61.7	5.0	73.4	70.6	2.8	74.2	71.1	3.1
Low Absorption, High Transmission Loss	0.5	20	0.8	1.3	1.1	0.2	66.7	46.7	20.0	73.4	72.6	0.8	74.2	72.6	1.6
Moderate Absorption, Moderate Trans. Loss	0.75	10	2.2	1.3	0.8	0.5	66.7	56.7	10.0	73.4	71.2	2.2	74.2	71.4	2.8
High Absorption, High Transmission Loss	0.9	20	2.8	1.3	0.7	0.6	66.7	46.7	20.0	73.4	70.6	2.8	74.2	70.6	3.6

Note: "Room NR" refers to room noise reduction due to an increase in total surface area acoustical absorption.

Unfortunately, it looks like, even using a panel with high values for both transmission loss and acoustical absorption, the acoustical results would be marginal at best, and also very expensive.

Results

- Only a sound panel under the bridge deck that could both absorb the sound generated below and block the noise generated above seemed like a realistic solution.
- Most critically, the amount of added acoustical absorption was limited by the fact that the underside of the bridge only make up about 30% of the “interior” surface area (so limited room for improvement).
- In reality, low frequency bridge noise would be hard to effectively reduce (even with good overall TL).
- After limited research, it is suspected that a high transmission loss, high absorption panel, would likely be quite expensive.

Conclusions

- The areas under highway overpasses can be noisy places (in case you were wondering).
- For many types of bridges, the noise from the traffic above (direct or radiated) may be a significant contributor to overall sound levels.
- At present, available retrofit noise treatments do not appear to be an effective and efficient solution.

Questions?