Reducing targeted low frequency railway noise with precast modular sound absorbers
NC_2024_0078

EKHO Infrastructure Solutions and nexcem

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agenda

- Introduction
- Noise Sources of Trains
- Acoustic Properties of The Guideway
- Noise Mitigation Measures
- Rail Silencer Acoustical Properties
- Installation Examples
- Insitu Performance on a Concrete Slab Track

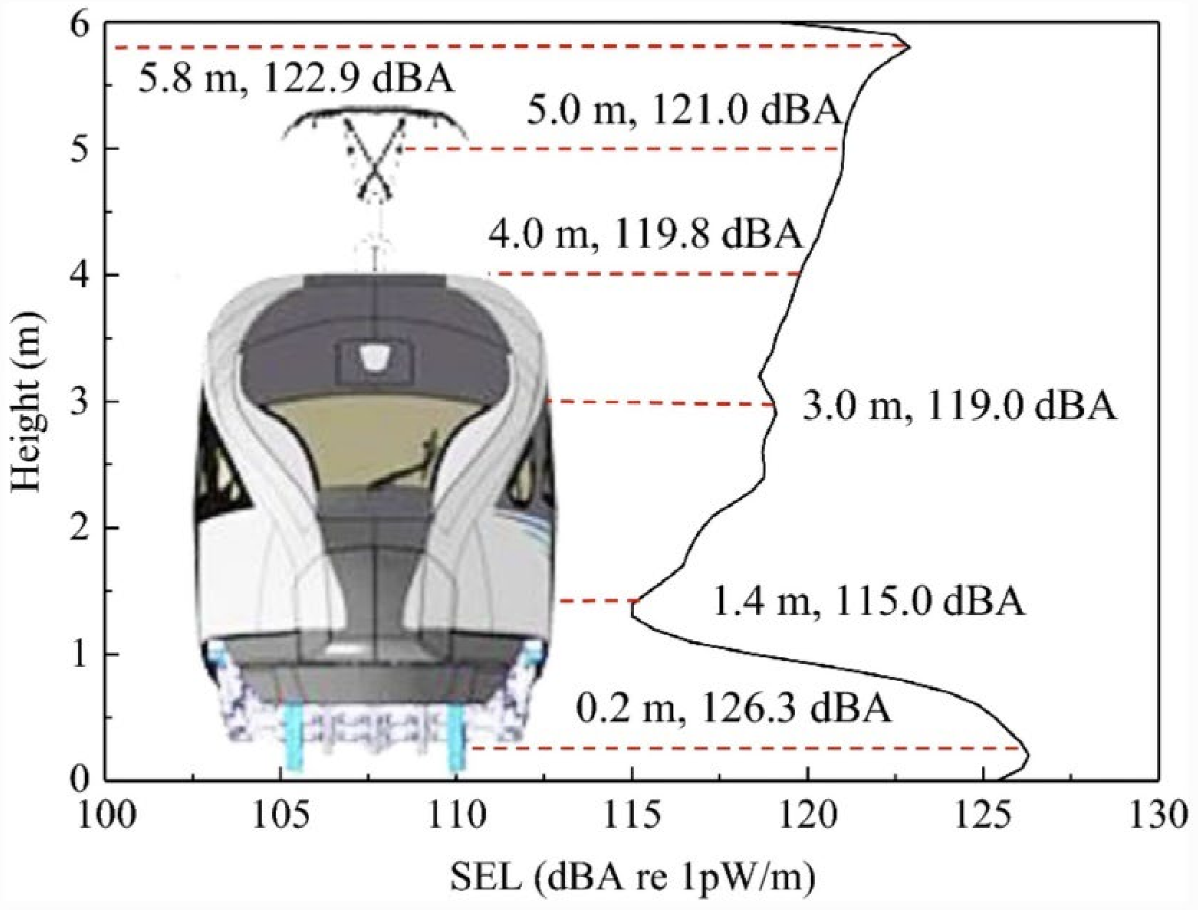
Noise Sources of Trains

Best practices in design and maintenance of train systems are necessary for control of train system noise

- **Wheel truing and rail grinding** – Provide control of high frequency sources at the wheel rail interface.
- **Train Speed** – Noise increases as train speed increases, creating low frequency aerodynamic noise, varies with speed and type of train
- **Turbulence** – Airflow around the bogie area creates noise close to the trackbed
- **Selection of the guideway** – Ballasted tie and rail track or concrete slab track affect the propagation of noise.
- **Tunnels are naturally reverberant spaces** – Benefitting from installation of sound absorptive materials.

Noise Sources of Trains

Vertical distribution of the exterior noise sources of the high-speed train running at 310 km/hr, 192 mph



Vertical distribution of the exterior noise sources of the high-speed train running at 310 km/h (frequency range: 500–5000 Hz)

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Federal Railway guidance manual for High-Speed Ground Transportation Noise and Vibration Assessment

Table 5-2 Noise Source Reference Levels for High-Speed Trains (SELs at 50 ft)

System Category and Features [a]	Example Systems		Subsource Component	Subsource Parameters		Reference Quantities			
				Length Definition, *len*	Height above rails (ft)	SEL_{ref} (dBA)	len_{ref} (ft)	S_{ref} (mph)	*K*
HS and VHS ELECTRIC LOCOMOTIVE-HAULED TRAINS	Amtrak Acela TGV Eurostar X2000 KTX-I /KTX-II ETR 500		Propulsion	len_{power}	12	86	73	[b]	[b]
			Wheel-rail	len_{train}	1	91	634	90	20
		AERO	Train Nose	len_{power}	10	89	73	180	60
			Wheel Region	len_{train}	5	89	634	180	60
			Pantograph	[c]	15	86	[c]	180	60
			(Only include aerodynamic subsources for very high-speed trains above 150 mph.)						
HS and VHS EMU TRAINS	IC T ICE 3 AVE S103 ETR450 KTX-III		Propulsion	len_{power}	2	86	634	[b]	[b]
			Wheel-rail	len_{train}	1	91	634	90	20
		AERO	Train Nose	len_{power}	10	89	73	180	60
			Wheel Region	len_{train}	5	89	634	180	60
			Pantograph	[c]	15	86	[c]	180	60
			(Only include aerodynamic subsources for very high-speed trains above 150 mph.)						
HS GAS-TURBINE LOCOMOTIVE-HAULED TRAINS	Rohr RTL-2 Bombardier Jet-Train		Propulsion	len_{power}	10	83	73	20	10
			Wheel-rail	len_{train}	1	91	634	90	20
MAGLEV	TR08		Propulsion	len_{train}	1.5	68	165	90	8
			Guideway/Structural	len_{train}	-5	80	295	90	30
		AERO	Train Nose	[c]	0	61	[c]	90	50
			TBL [d]	len_{train}	10	78	295	120	50

[a] *HS (High-Speed)* = maximum speed 150 mph
VHS (Very High-Speed) = maximum speed 250 mph
MAGLEV = maximum speed 300 mph
[b] Source level is not adjusted for train speed
[c] Source level is not adjusted for train length
[d] Turbulent Boundary Layer

Subsource component: Wheel-rail source

1 ft above top of rail

SEL 91 dBA**

** (for ballasted track, add 3 dB for concrete guideway at grade and 5 dB for concrete track on aerial guideway)

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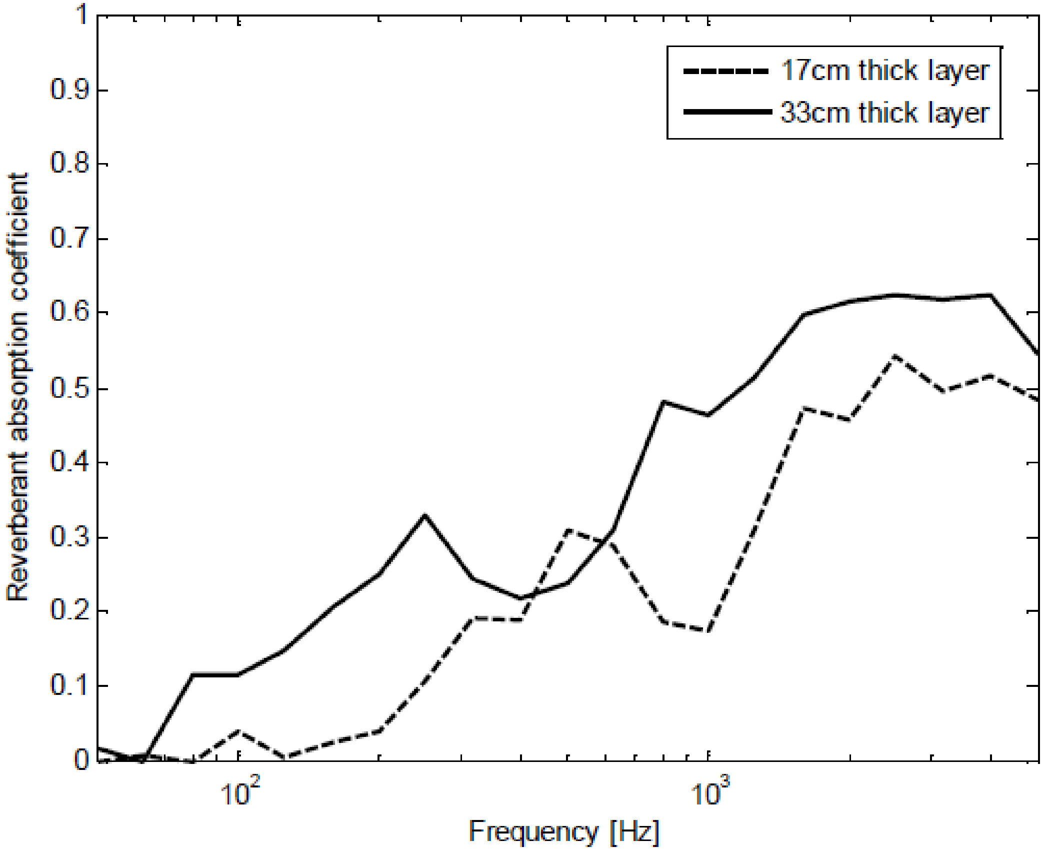
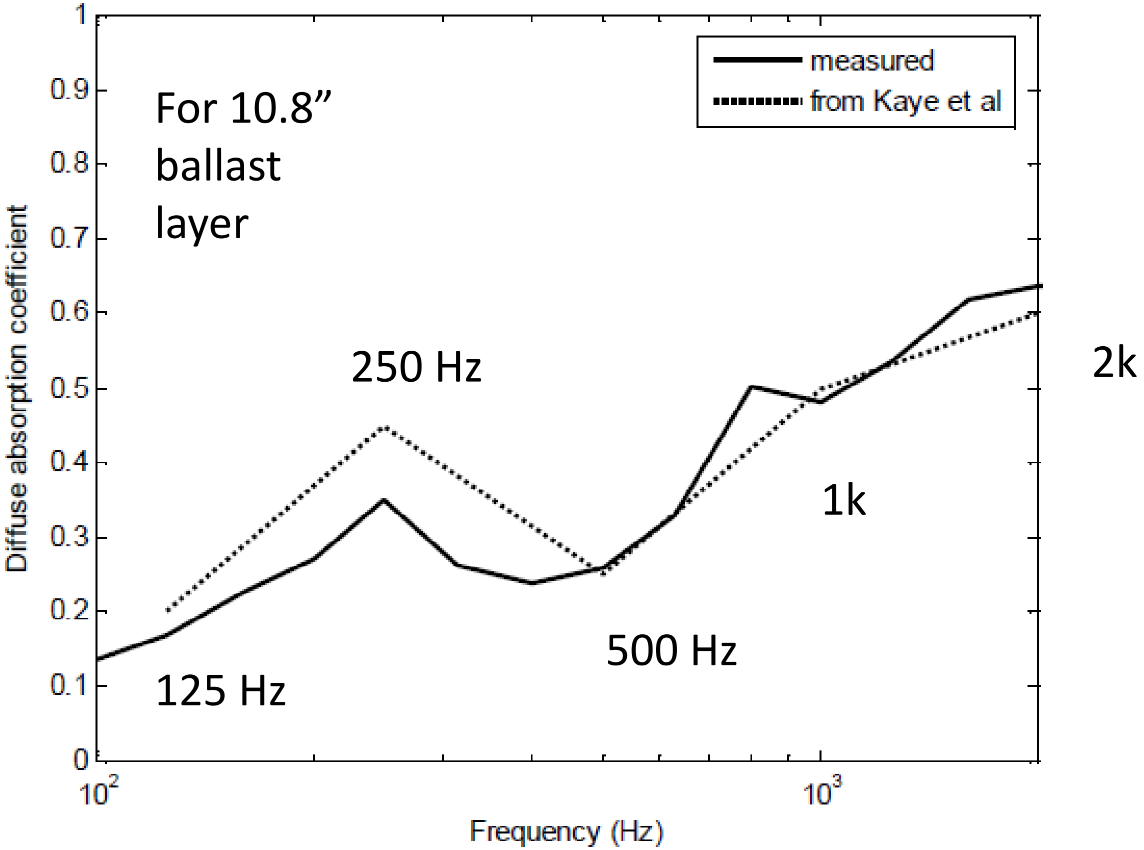
Acoustic Properties of Ballast





Trackside Acoustical Properties: the First Reflection

- The direct field will dominate the wayside noise
- Acoustically soft ground to the side of the track may reduce the intensity of the reflected noise
- Absorption for single refection is best measured in an impedance tube (E1050 or C384)
- Ballast has a low absorption coefficient at low frequency

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Federal Railway Guidance Manual: Mitigation Measures

What is missing from this table are modular sound absorptive rail silencers that could provide abatement on concrete guideways at grade, on aerial structures and in tunnels.

Table 5-6 High-Speed Train Noise Mitigation Measures

Application	Mitigation Measure		Effectiveness
SOURCE	Stringent vehicle & equipment noise specifications		Varied
	Placement of HVAC systems		Varied
	Sound-absorptive duct lining for air intake/exhaust		Varied
	Operational restrictions		Varied
	Resilient or damped wheels	For rolling noise on tangent track:	2 dB
		For wheel squeal on curved track:	10–20 dB
	Vehicle skirts		6–10 dB
	Under-car absorption		5 dB
	Spin-slide control (prevents flats)		*
	Wheel truing (removes wheel flats)		*
	Rail Grinding (removes corrugations)		*
	Turn radii greater than 1,000 ft		(Avoids squeal)
	Rail lubrication on sharp curves		(Reduces squeal)
	Movable-point frogs (reduce rail gaps at crossovers)		(Reduces impact noise)
	Elimination of all surface discontinuities/edges on vehicle		3–6 dB
	Pantograph cover or shroud		5 dB
PATH	Sound barriers close to vehicles		6–10 dB
	Sound barriers at right-of-way line		5–8 dB
	Alteration of horizontal & vertical alignments		Varied
	Acquisition of buffer zones		Varied
	Ballast on at-grade guideway		3 dB**
	Ballast on aerial guideway		5 dB**
	Resilient track support on aerial guideway		Varied
RECEIVER	Acquisition of property rights for construction of sound barriers		5–10 dB
	Building noise insulation		5–15 dB

* These mitigation measures work to maintain a high-speed rail system in its as-new condition. Without incorporating them into the system, noise levels could increase by up to 10 dB.

** The General and Detailed noise models are based on high-speed trains operating on ballast and tie track. For systems which use slab track (i.e., with direct fixation), noise levels would be approximately 3 dB higher at-grade and 5 dB higher on an aerial guideway.

5 dB for under-car absorption

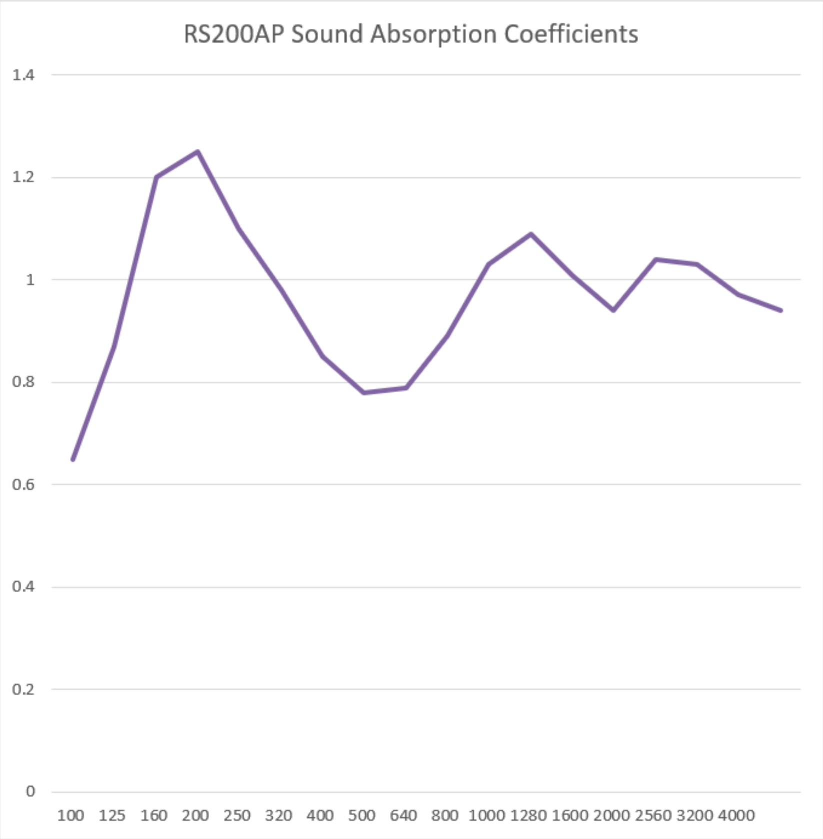
** for slab track with direct fixation, add ~ 3dB at-grade and ~5dB on aerial guideway

Rail Silencer Acoustical Properties

Nexcem RS200AP modular rail silencer absorption coefficients per ISO 354 (similar to C-423)

Applicable to reverberant noise environments, e.g., under car and in tunnels

1/3 FRQ	1/1 FRQ	1 6" Nexcem Coefficient 1/3 Octave 1	2 8" Nexcem RS200AP Coefficient 1/3 Octave 2	3 10" Nexcem RS250AP Coefficient 1/3 Octave 3
25			0.00	
32	31.5		0.00	
40			0.00	
50			0.00	
63	63		0.00	
80			0.00	
100			0.65	
125	125		0.87	
160			1.20	
200			1.25	
250	250		1.10	
320			0.98	
400			0.85	
500	500		0.78	
640			0.79	
800			0.89	
1000	1000		1.03	
1280			1.09	
1600			1.01	
2000	2000		0.94	
2560			1.04	
3200			1.03	
4000	4000		0.97	
5120			0.94	
6400			0.00	
8000	8000		0.00	
10240			0.00	
12800			0.00	
16000	16000		0.00	
20480			0.00	
	SAA	0.91	0.98	0.89
	SUM/4		0.96	
	NRC	0.95	0.95	0.95



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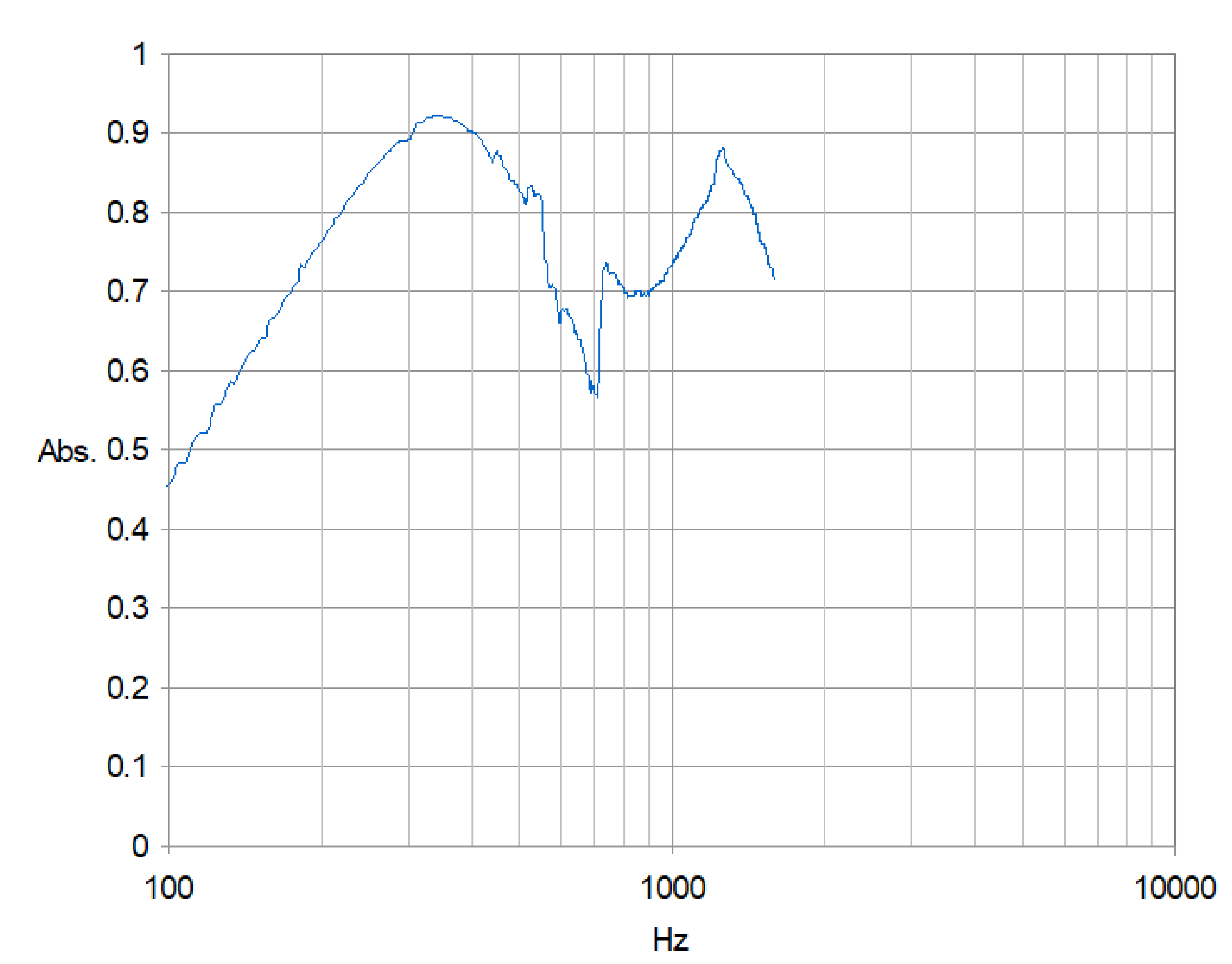
Nexcem RS 200 AP Rail Silencer Impedance Absorption Coefficients per ASTM E-1050

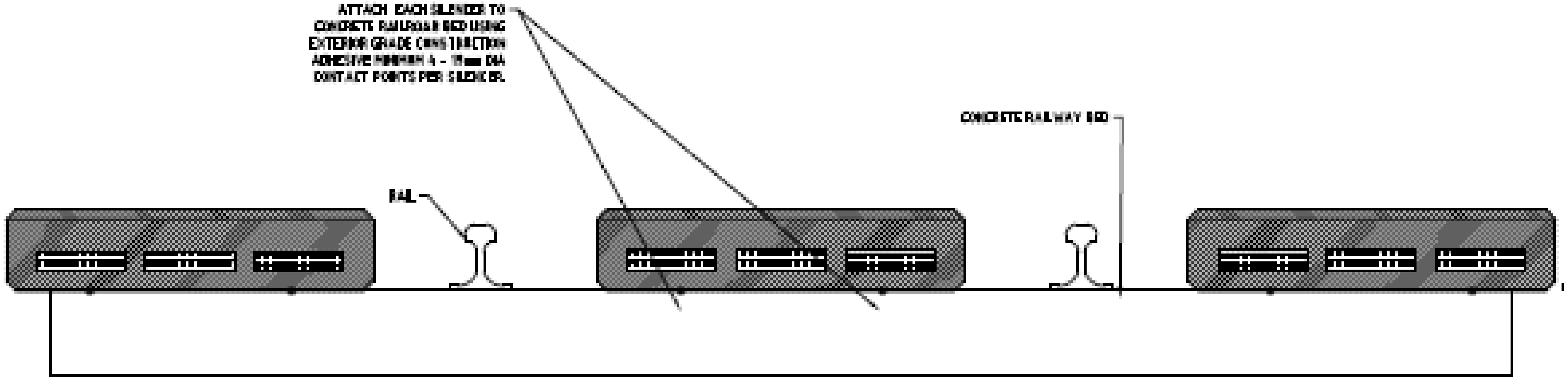
Acoustical impedance per E-1050 (or C-384) provides information on the first reflection of train noise on the path to the community, applicable when silencers are placed alongside the track.

Test result of each frequency:

Freq.	Abs.
125	0.56
160	0.66
200	0.76
250	0.85
315	0.91
400	0.9
500	0.83
630	0.65
800	0.7
1000	0.74
1250	0.84



Rail Silencer Installation example



Rail silencers placed on a concrete trackbed are glued in place. Units weigh ~75 lb each. Modules afford a stable walking surface, do not present a trip hazard and can be removed if necessary.

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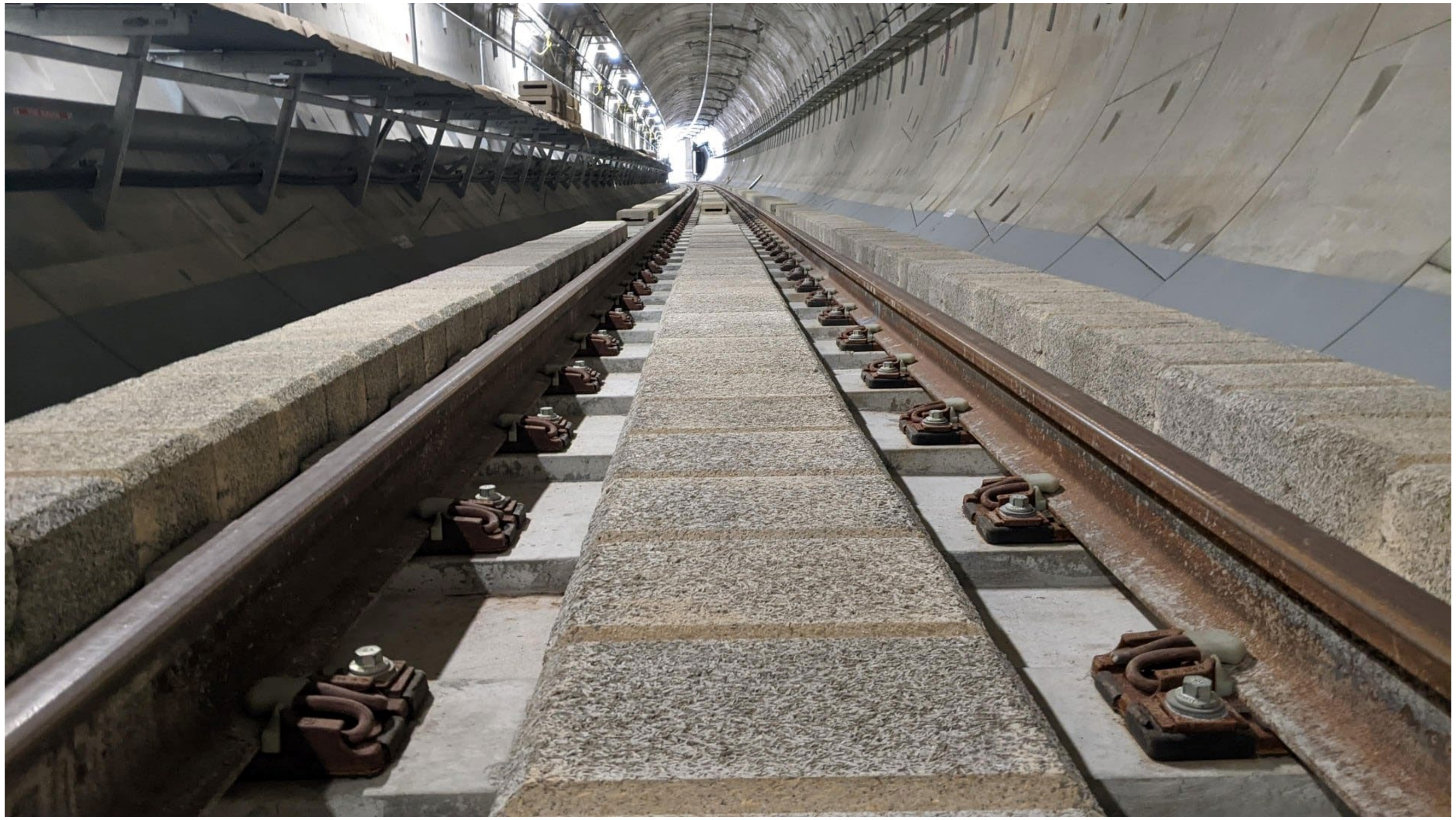
Rail Silencer Installation example

Rail silencers on elevated concrete viaduct between Rouse Hill and Kellyville Station in Sydney, Australia running Alston fully automated metropolis trains at 150 km/hr (90 mph). Resilient fasteners, rail dampers, and sound absorptive parapet walls enhance the noise abatement of the project, installed in 2017 comprising 8,114 sm of modules.

Rail Silencer Installation example

Rail silencers in the Bayswater tunnel in the 7.5 km Forrestfield Airport Link running Bombardier B Series train at 130 km/hr (80 mph). Silencers placed between the tracks and on the shoulders absorb noise in the tunnel and station. Installed in 2021 comprising 13, 915 sm of modules.



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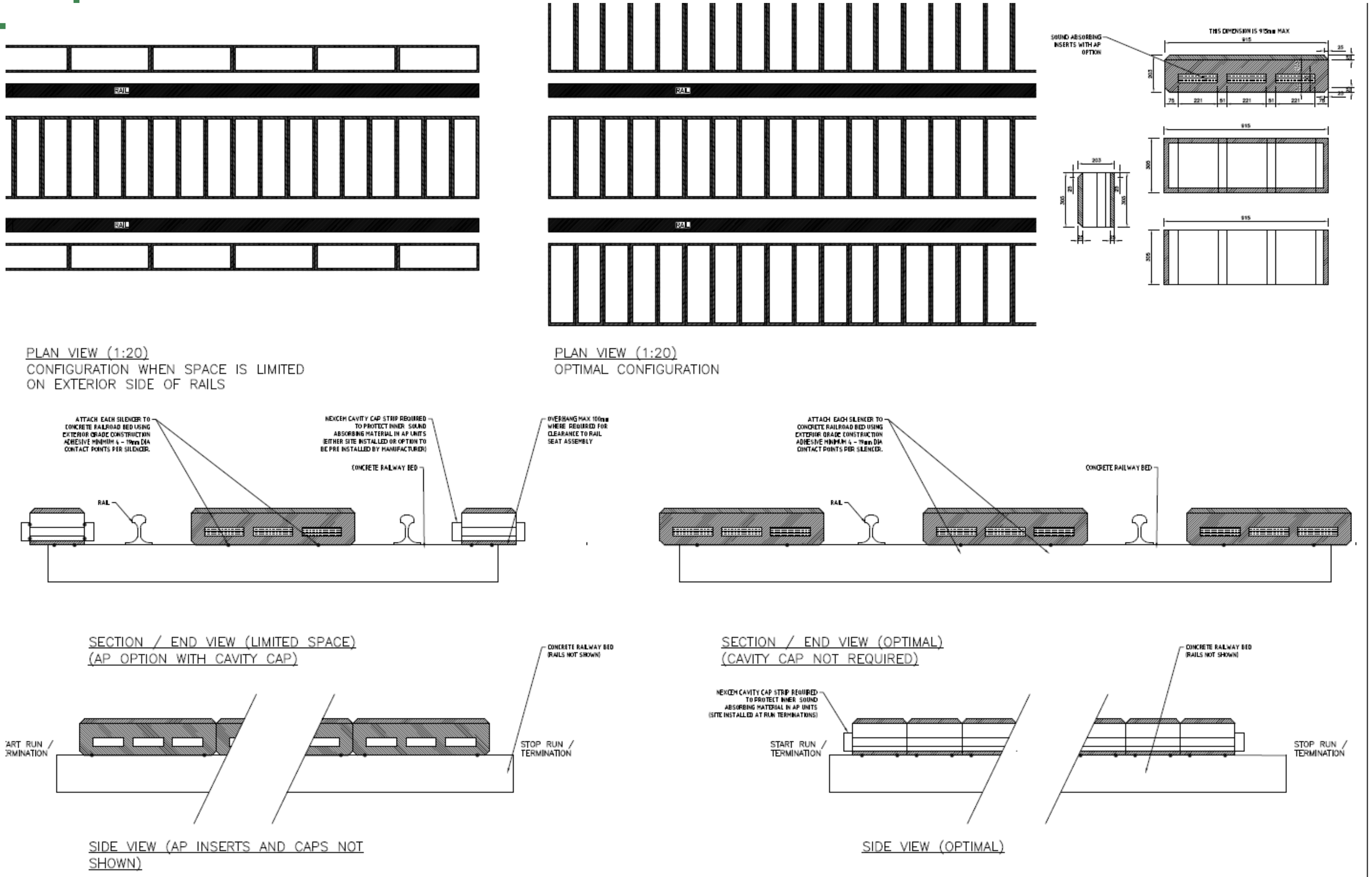
Rail Silencer Installation example



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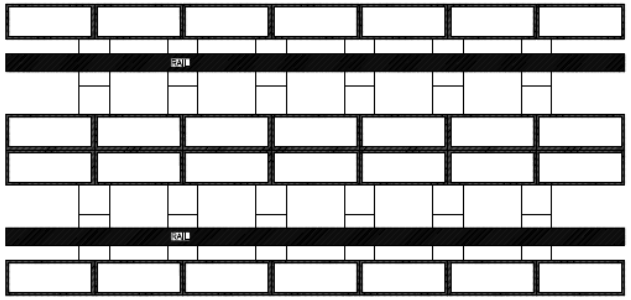
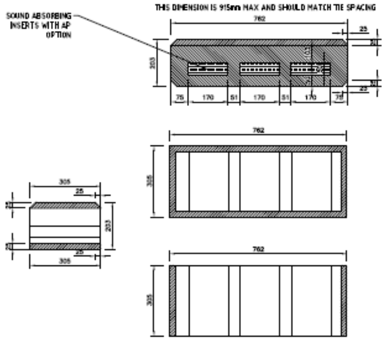
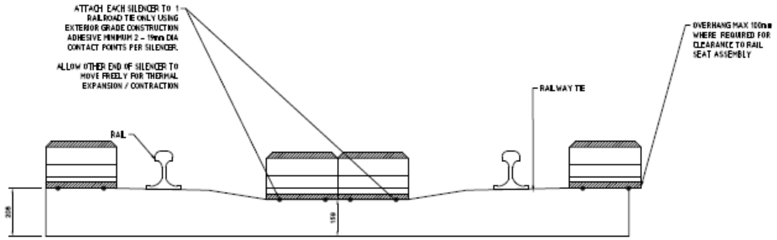
Rail Silencer Installation example

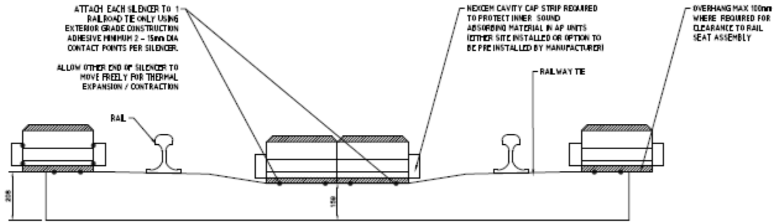


PLAN VIEW (1:20)

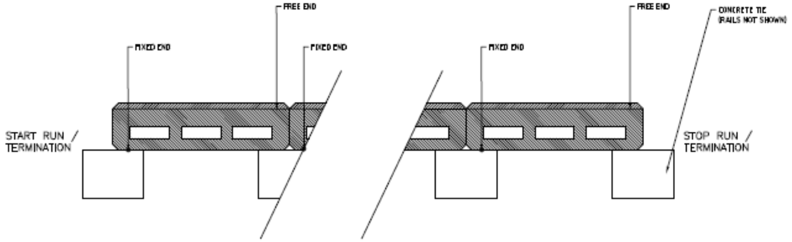




SECTION / END VIEW AT TIE



SECTION / END VIEW AT TIE
(AP OPTION WITH CAVITY CAP)



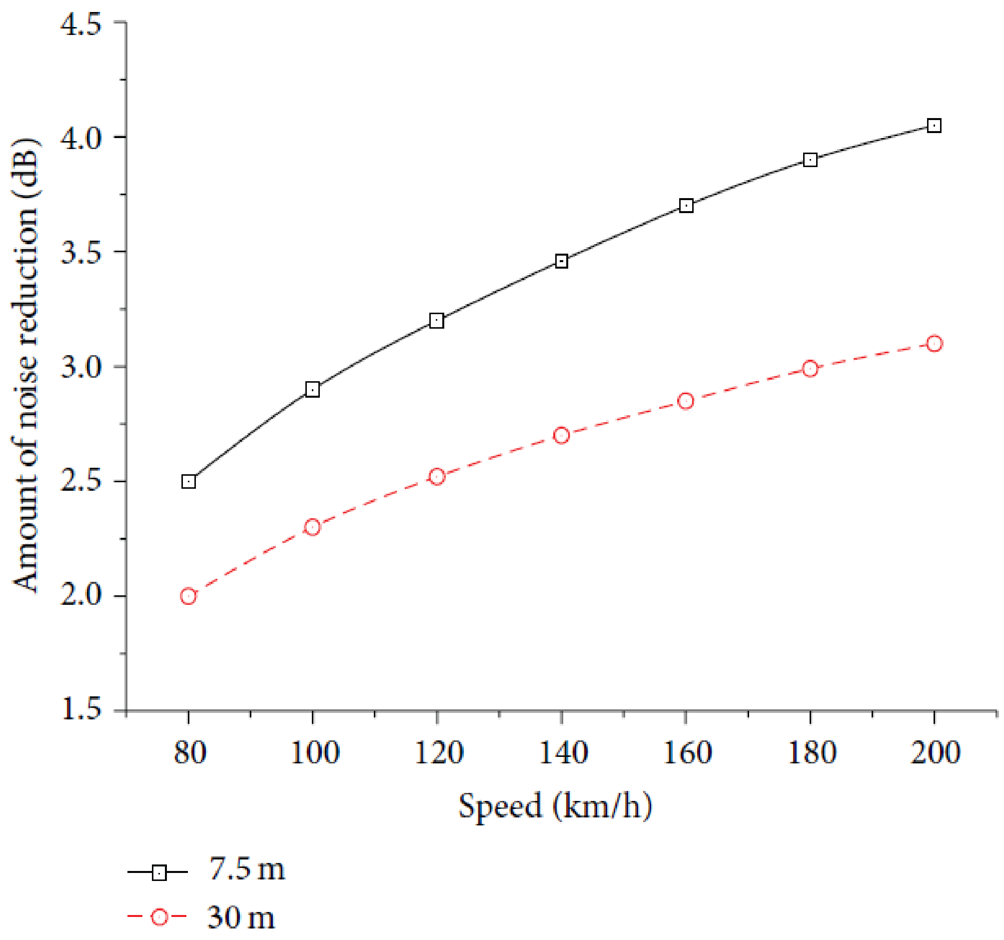
SIDE VIEW (AP INSERTS AND CAPS NOT SHOWN)

Insitu performance of a porous concrete rail silencer on a concrete slab track.

- Porous concrete silencer installed on an at-grade concrete guideway in China
- Impedance tube coefficients of 0.35 at 250 Hz, 0.75 at 500, 1k, and 2k Hz
- CRH@-300 train running at speeds from 80 to 200 km/hr (50 to 120 mph)
- Measurements taken at 7.5 and 37.5 m from centerline of track, elevation at top of rail

Insitu performance of a porous concrete rail silencer on a concrete slab track.

- Noise reduction (dB) increases approximately linearly with vehicle speed



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Insitu performance of a nexcem rail silencer on a Light Rail Vehicle concrete slab track.

nexcem silencer installed on an at-grade concrete guideway in Canada.

- High rise building adjacent to urban light rail vehicle
- LRV operating speed up to 50 mph
- Reflections from the concrete slab track and reflective vertical walls.
- Improvement of 4 to 5 dB at upper floors.
- Average improvement for both East and Westbound 3 dB

Track Absorption Effect on LRV Noise

Confederation Line Stage 1

Ottawa

SLR Project No: 241.10042.00000

Prepared by
SLR Consulting (Canada) Ltd.
105-150 Research Lane
Guelph, ON N1G 4T2

for

City of Ottawa
Morrison Hershfield

August 2021

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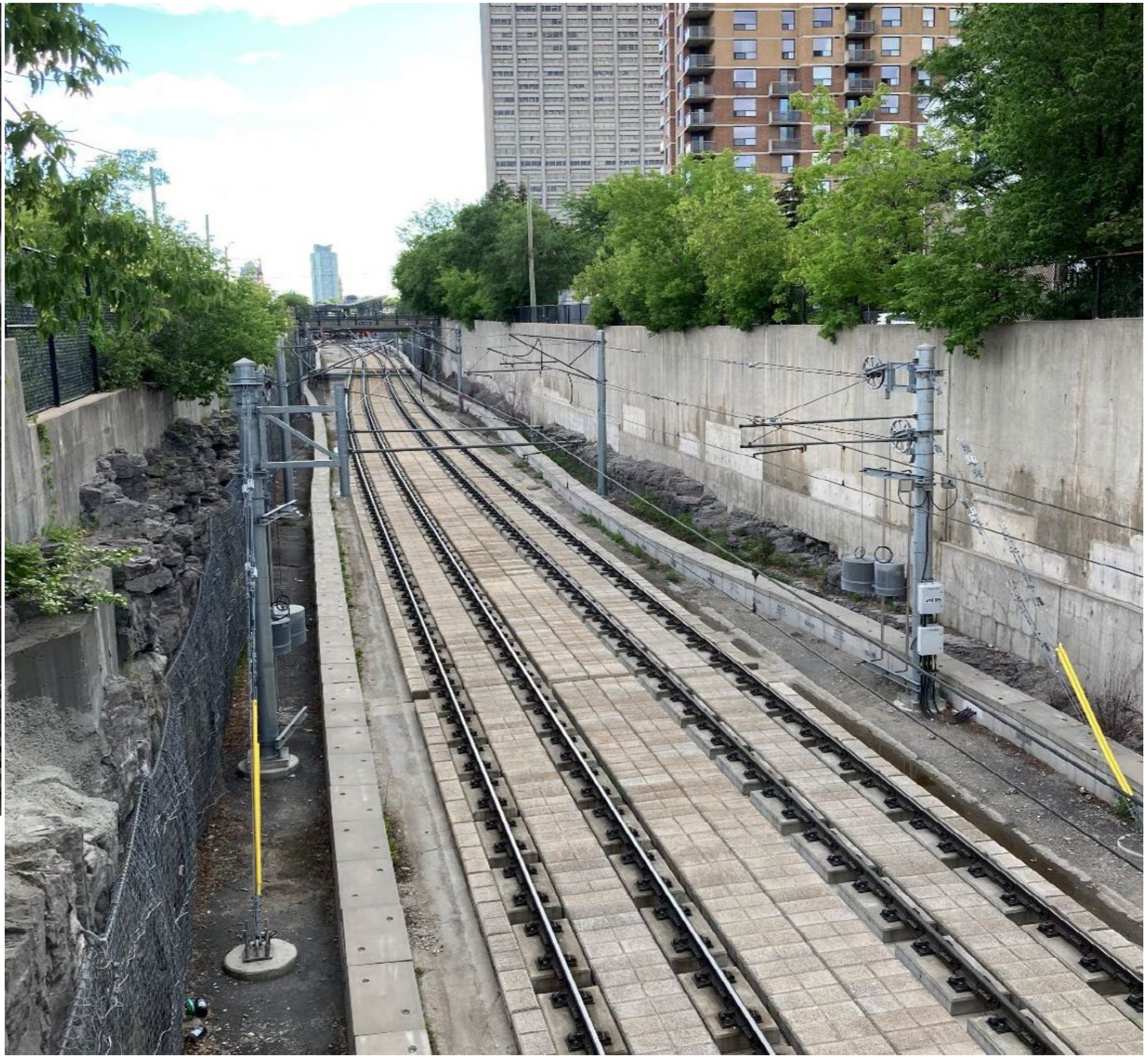
Insitu performance of a nexcem rail silencer on a Light Rail Vehicle concrete slab track.



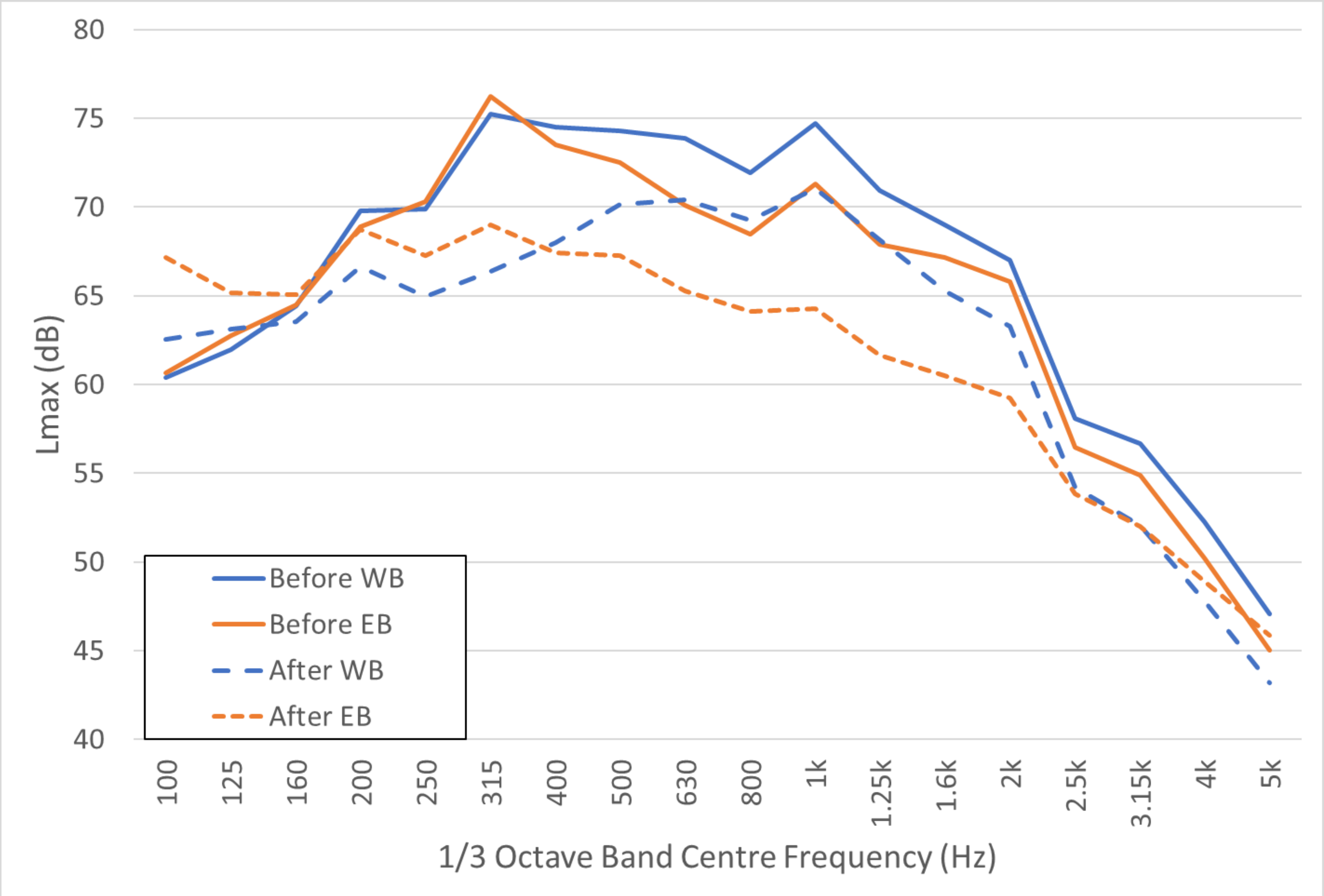
Formerly a rubber-tired transit busway converted to Light Rail Vehicle transitway on a concrete trackbed, with rail silencers placed to absorb and diminish reflected noise

Insitu performance of a nexcem rail silencer on a Light Rail Vehicle concrete slab track.

WB = west bound (blue)

EB = east bound (orange)

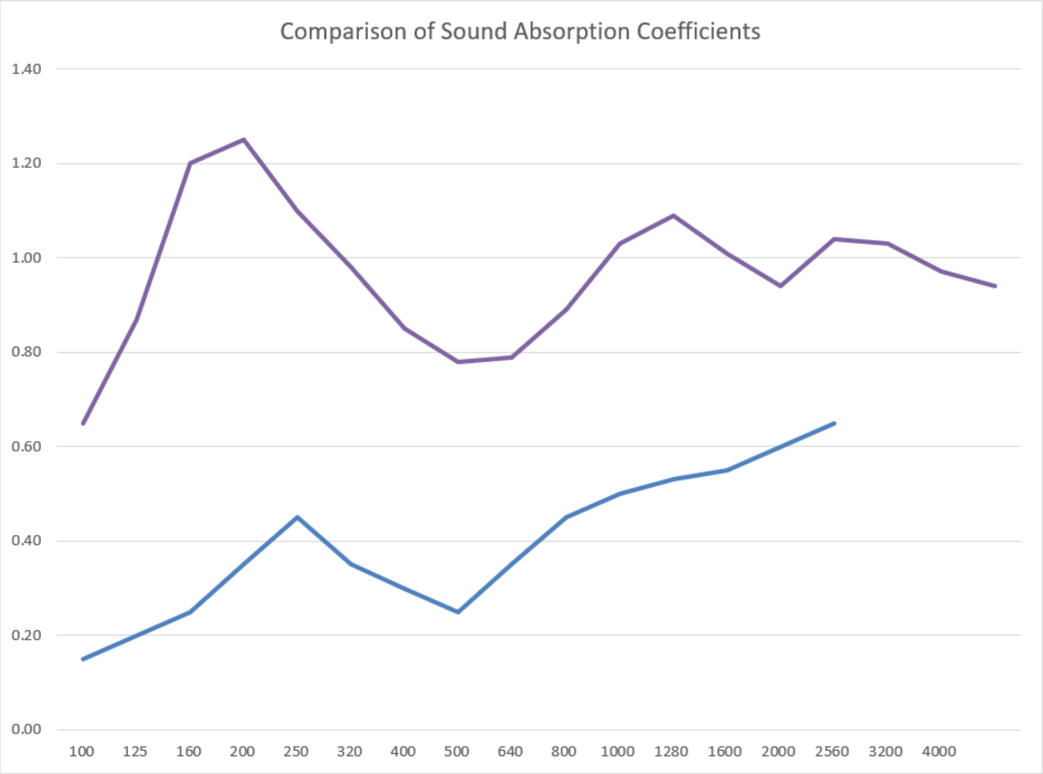
Average improvement for both is 3 dB reduction in noise from the train reaching upper floors of adjacent high rise apt building.



Comparison of Guideway Sound Absorption Options
10.8” Ballast , 8” Nexcem RS200 AP

High frequency noise is effectively managed by train systems but control of the lower frequency 200-600 Hz noise is where rail silencers can make a difference.

1/3 FRQ	1/1 FRQ	1 10.8" BALLAST Coefficient 1/3 Octave 1	5 8" Nexcem RS200AP Coefficient 1/3 Octave 5
25			
32	31.5		
40			
50			
63	63		
80			
100		0.15	0.65
125	125	0.20	0.87
160		0.25	1.20
200		0.35	1.25
250	250	0.45	1.10
320		0.35	0.98
400		0.30	0.85
500	500	0.25	0.78
640		0.35	0.79
800		0.45	0.89
1000	1000	0.50	1.03
1280		0.53	1.09
1600		0.55	1.01
2000	2000	0.60	0.94
2560		0.65	1.04
3200			1.03
4000	4000		0.97
5120			0.94
6400			
8000	8000		
10240			
12800			
16000	16000		
20480			
	SAA	0.44	0.98
	SUM/4	0.45	0.96
	NRC	0.80	0.95



Conclusions:

- **High-speed trains operating on concrete guideway propagate noise from the wheel/rail interface, low frequency aerodynamic noise from the wheel region including the bogie and reflections from the reverberant area underside of the vehicle.**

- **Abatement of these sources is enhanced by placement of broadband sound absorbers close to the rail, between the rails and adjacent to the track. High absorption coefficients of 0.80 to 1.00 from 160 Hz to 5,000 Hz span the most important frequencies of interest to reduce environmental wayside noise.**

- **It is particularly beneficial in a tunnel or in a station to have installed a product that has broadband absorption coefficients.**

- **In urban environments, LRV noise abatement can be achieved by reducing reflected noise from a concrete guideway.**

- **Selection of the patented nexcem product made in North America for use on projects in Australia after 4 years in service are testament to durability, economy, and satisfactory performance of the product.**

- **Nexcem is a cementitious wood concrete that has proven durability in harsh transportation related noise abatement applications since the mid 1970's in Canada and elsewhere around the world.**

Questions?

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