Quieter Pavements

Caltrans Division of Environmental Analysis

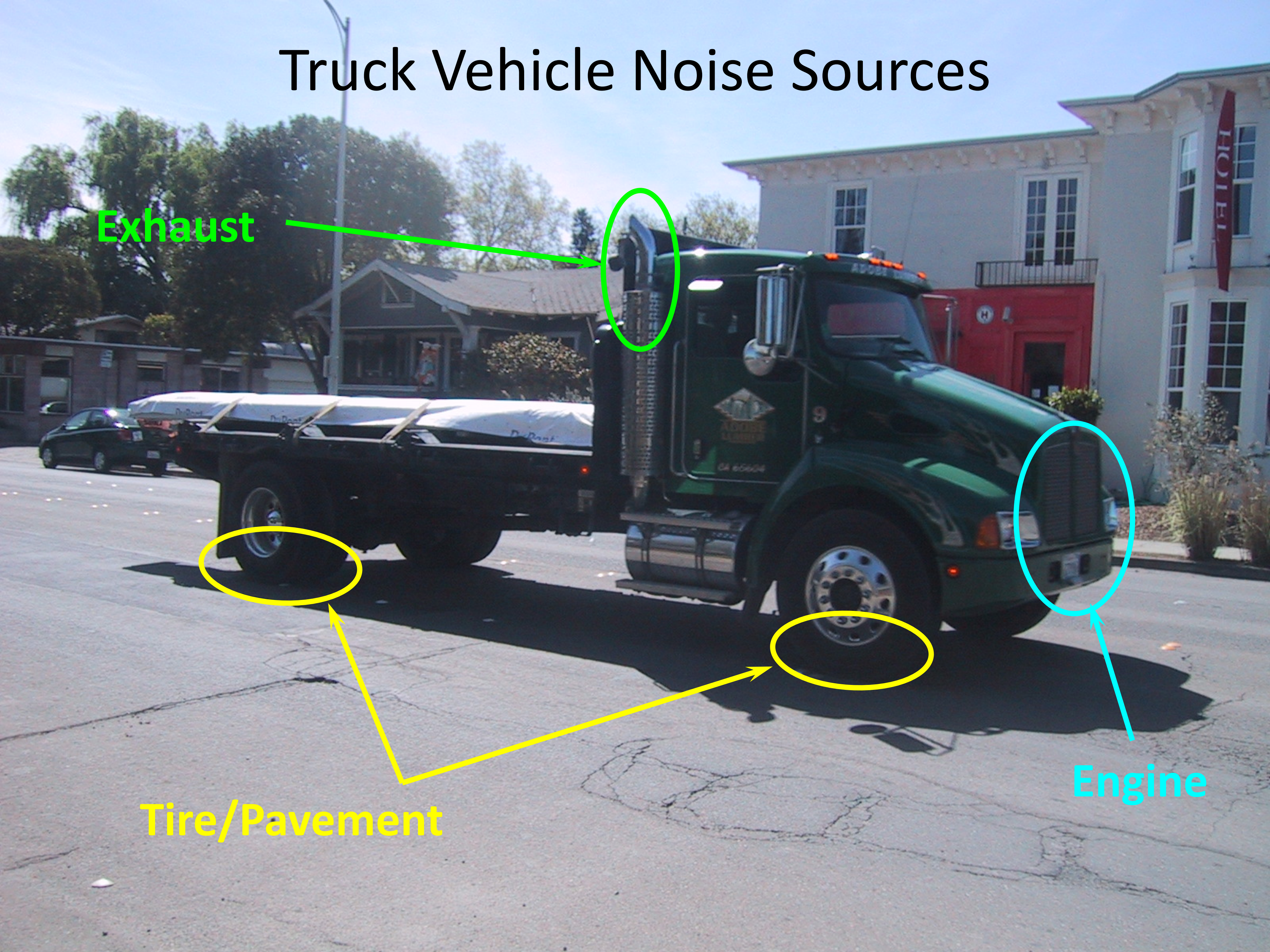
Traffic Noise

- Not the loudest, but the most pervasive environmental noise
- $$ to mitigate with sound walls
- Quality of life issue for people near major roadways
- Thoughtful design lowers noise impacts
- Pavement #1 Product of Caltrans

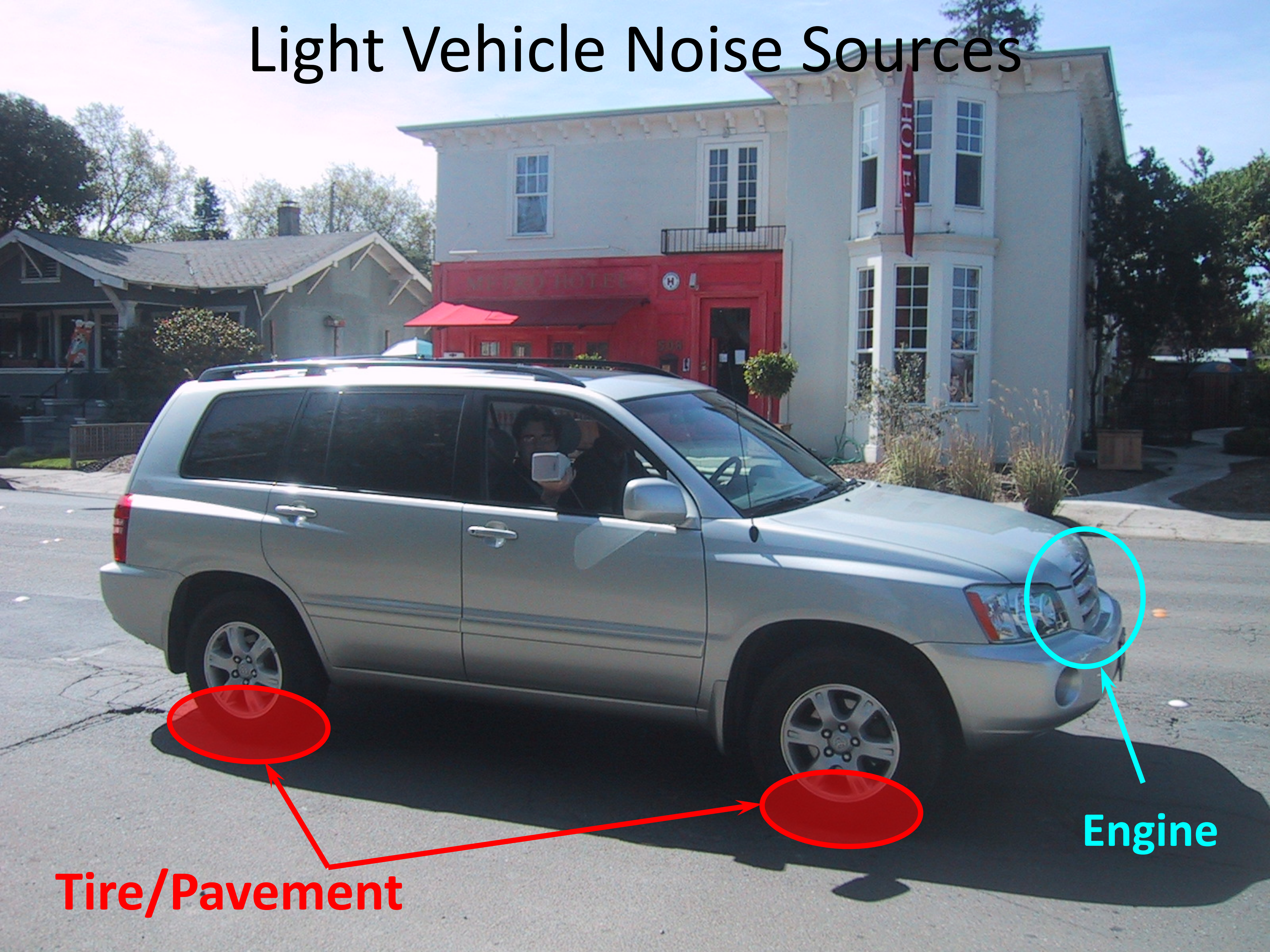
Quieter Pavement Studies

- Awareness
- Develop Measurement Methods
- Inventory various pavement acoustics
- Demonstration & Research Projects
- Longevity studies
- Noise abatement implementation

Truck Vehicle Noise Sources



Light Vehicle Noise Sources



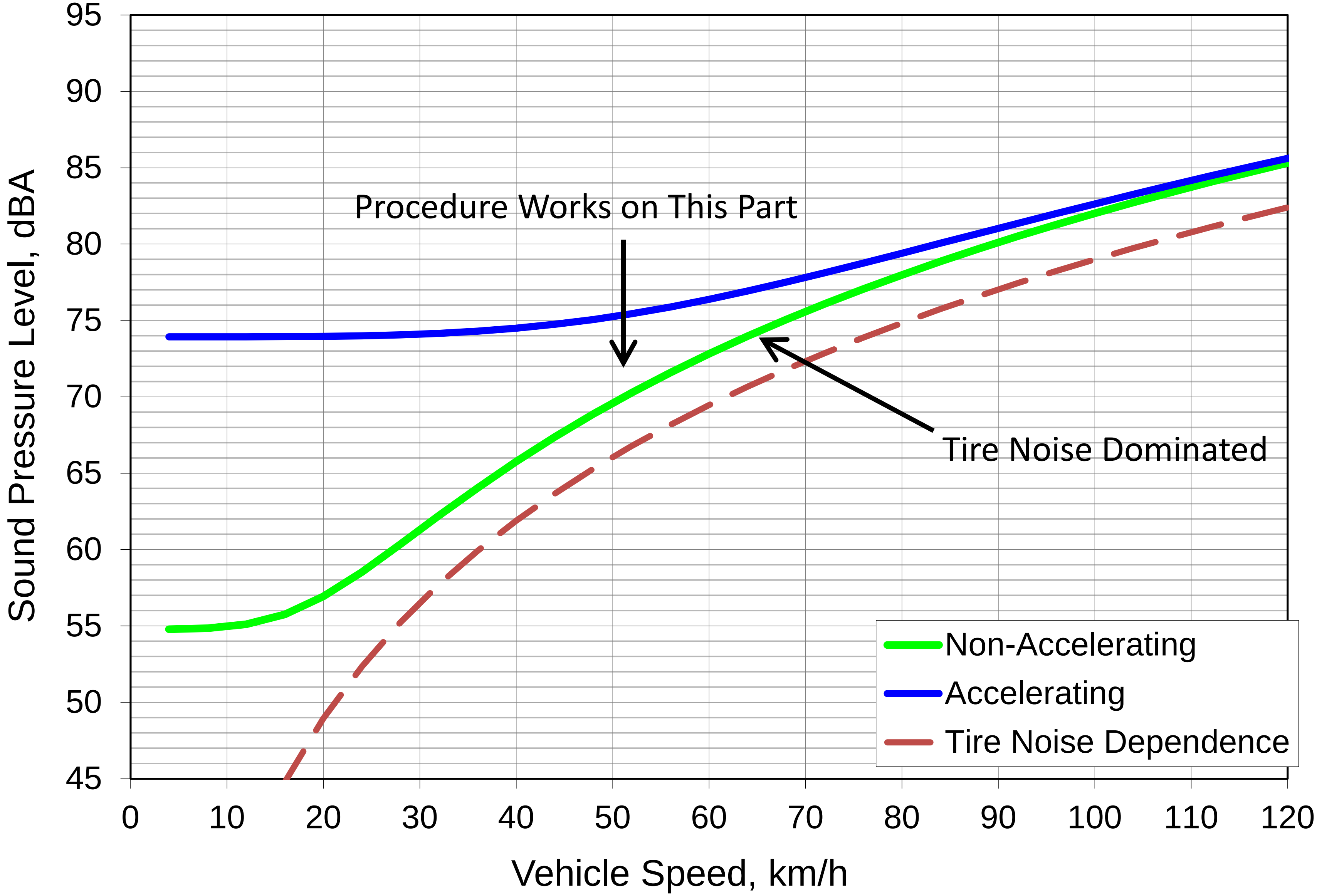
What does Caltrans have control over?

Can changing just pavement influence T/P subsource ?

Can T/P subsource change overall wayside noise levels?

Caltrans

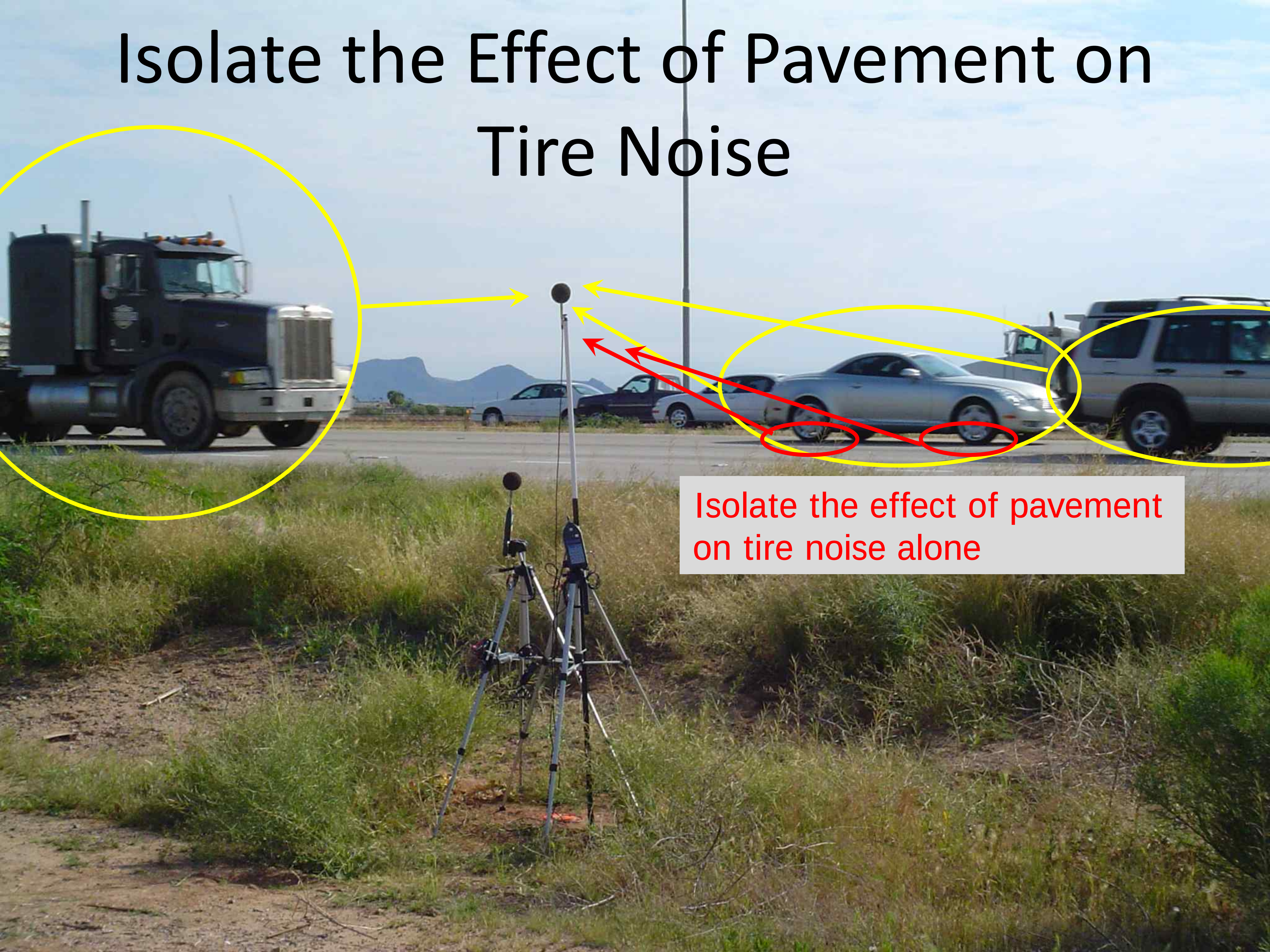
Light Vehicle Pass-by Level



Source: FHWA REMELs Data Base

Isolate Affect of Pavement on Each Vehicle Type in Traffic

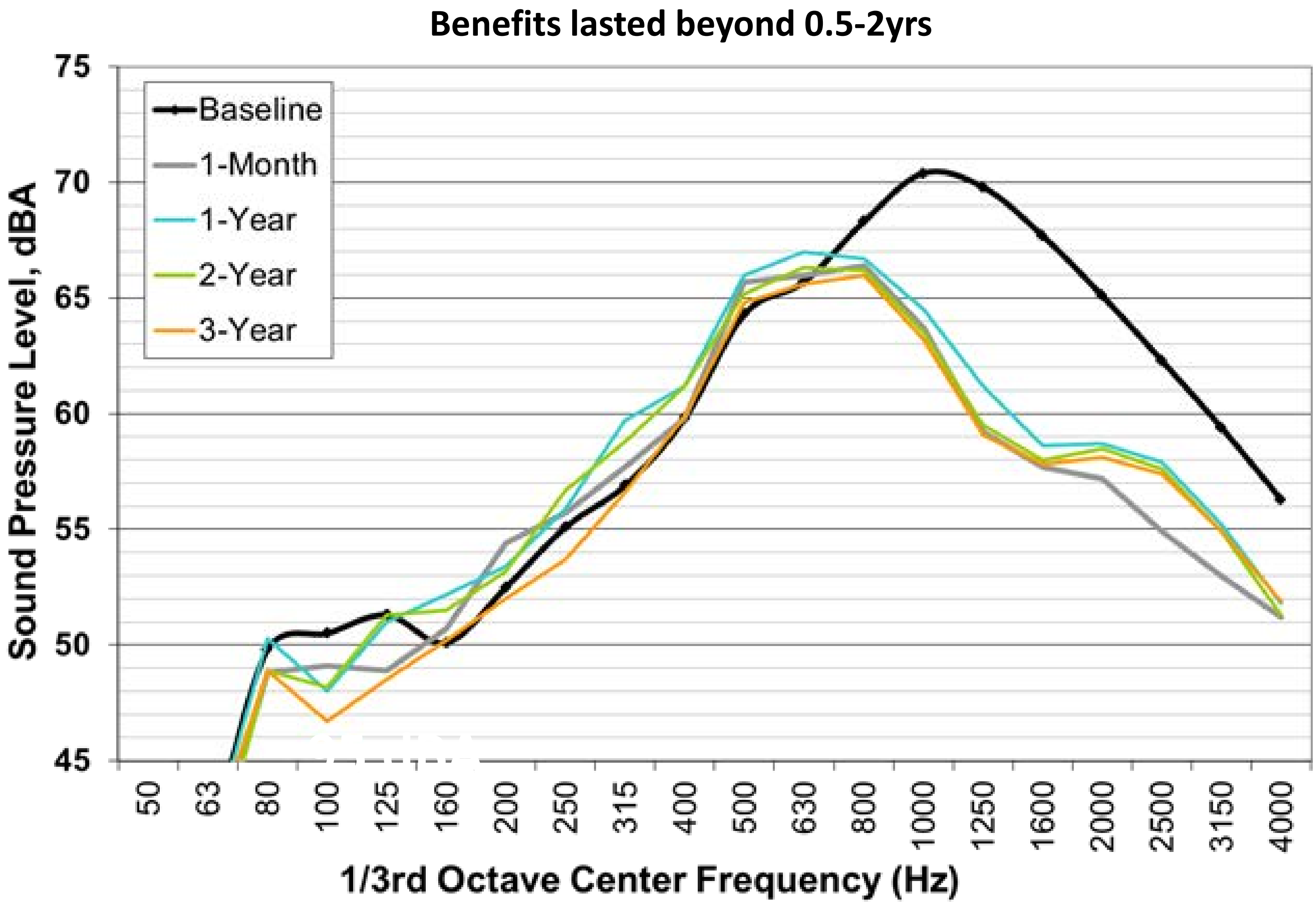
Isolate the Effect of Pavement on Tire Noise



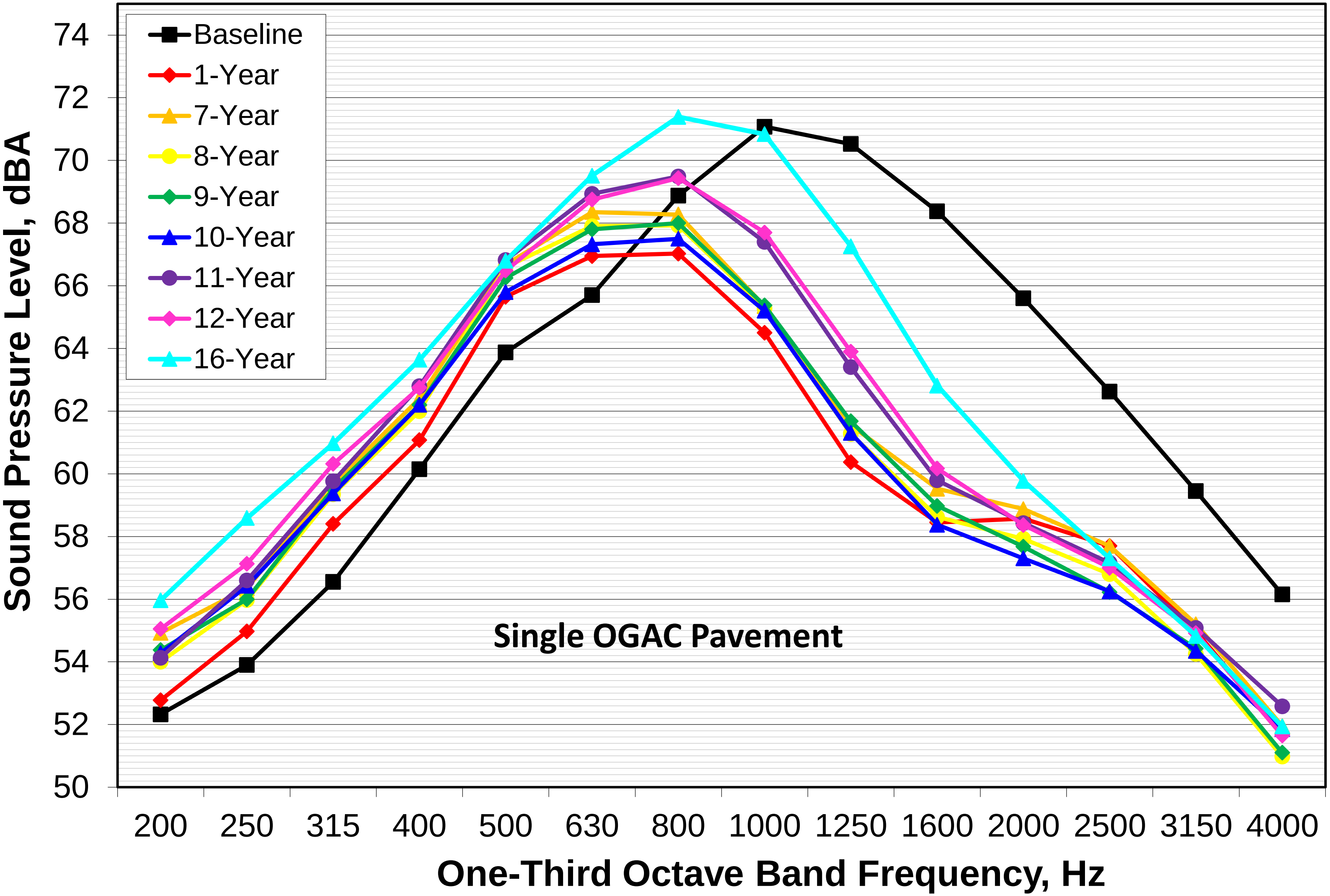
I-80 at Davis, CA

Longest Running QP Study in nation

I-80 Davis Wayside Noise Reduction



I-80 Davis Wayside Noise for 16 Years



LA-138 QP Study

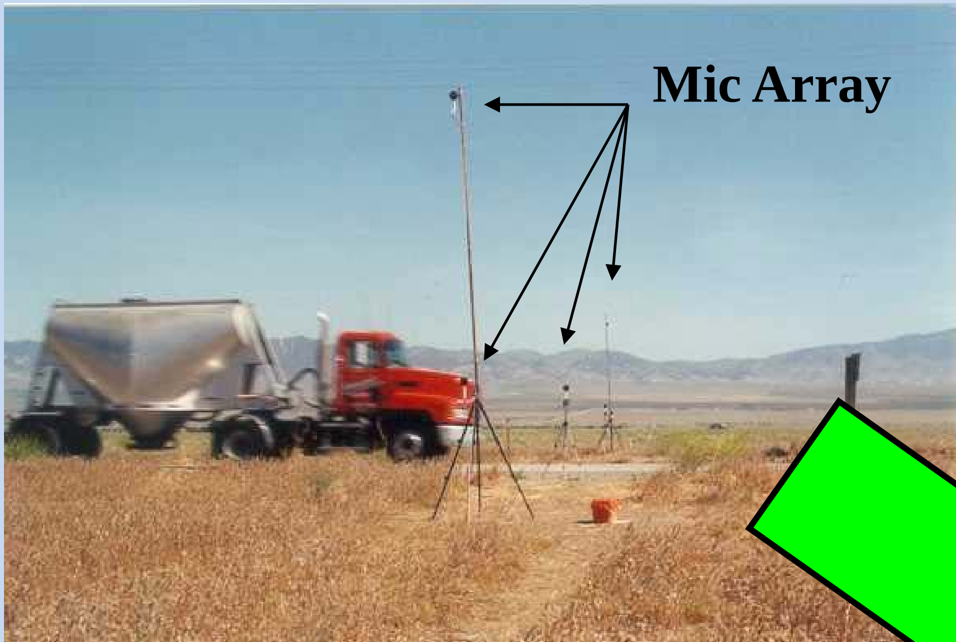
5 Typical Flexible Pavements
End-to-End

Low ADT
Clean Single Vehicle Pass-Bys
Vs I-80 Davis Continuous Traffic Stream

2000

Problem: Blowing Wind

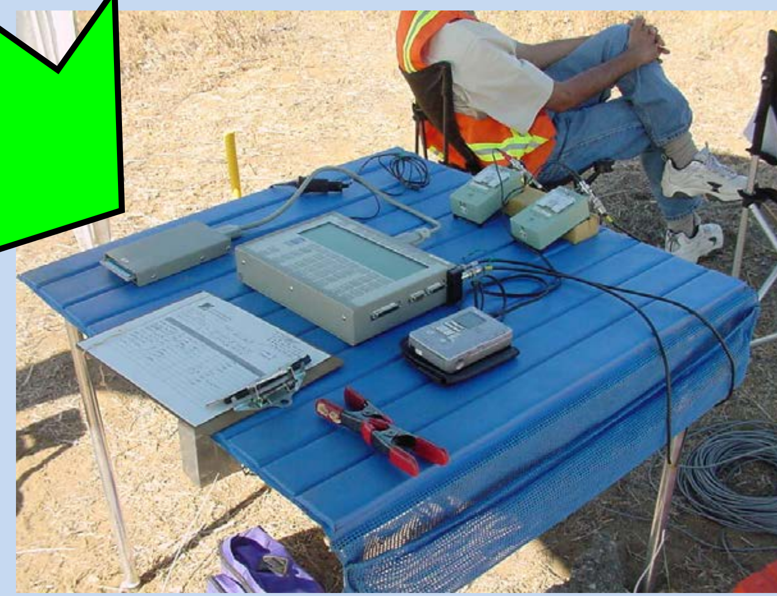
Roadside (Wayside) Pass By Method



Met data

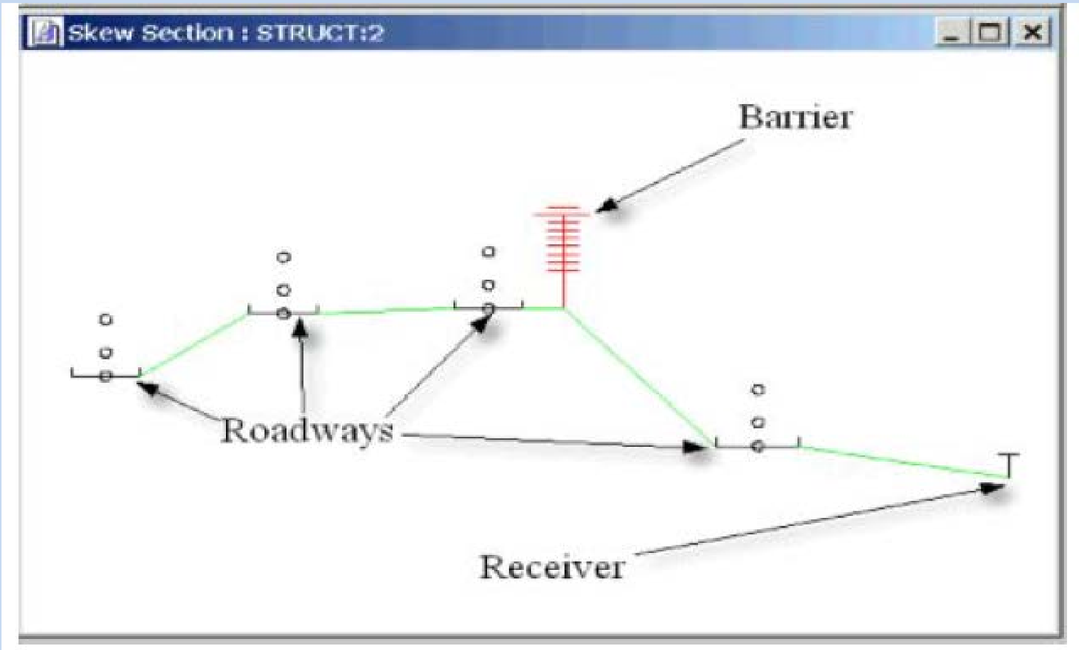
Vehicle Classification

Speed



Statistical Pass By (SPB)   ISO 11819-1

TNM 2.5 Sub Source Heights Sound Energy Distribution



Examples of Percentage Split Between Upper and Lower Source Heights (Cruise)

	Source height	Low Frequencies (500 Hz and below)	High Frequencies (2000 Hz and above)
AUTO	5 ft	27%	2%
	0 ft	73%	98%
HEAVY TRUCK	12 ft	57%	46%
	0 ft	43%	54%

Source: Bowlby and Assoc., TNM 2.5 Caltrans Training Course Oct 2016

Measurement "Roll-Down"

<u>Traffic Noise</u>
CTIM TP 99

<u>Vehicle Noise</u>
SIP TP 98
SPB ISO 1189-1

<u>Tire Noise</u>
OBSI AASHTO T360
CPX ISO 11819-2

Measurement "Roll-Down"

Traffic Noise
CTIM TP 99

Vehicle Noise
SIP AASHTO TP 98
SPB ISO 1189-1

Tire Noise
OBSI AASHTO T 360
CPX ISO 11819-2

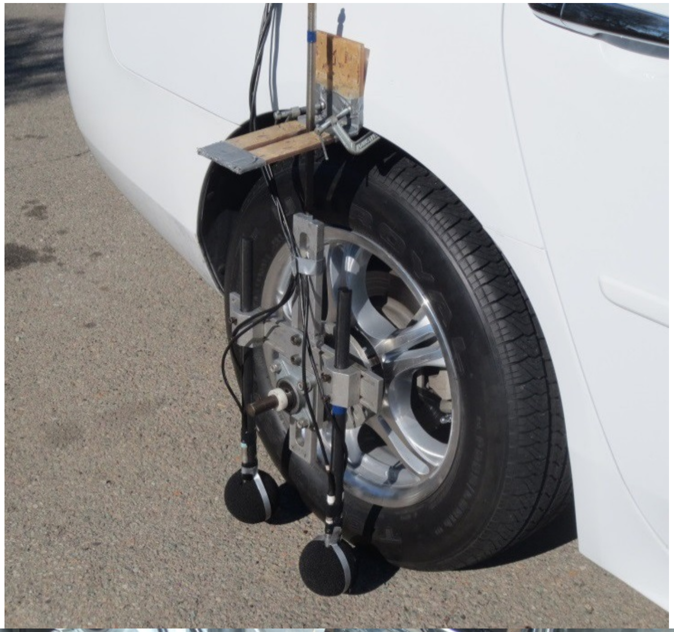
Roll-up for wayside prediction

Tire-Pavement Source Measurements

CPX

Sound Pressure

OBSI

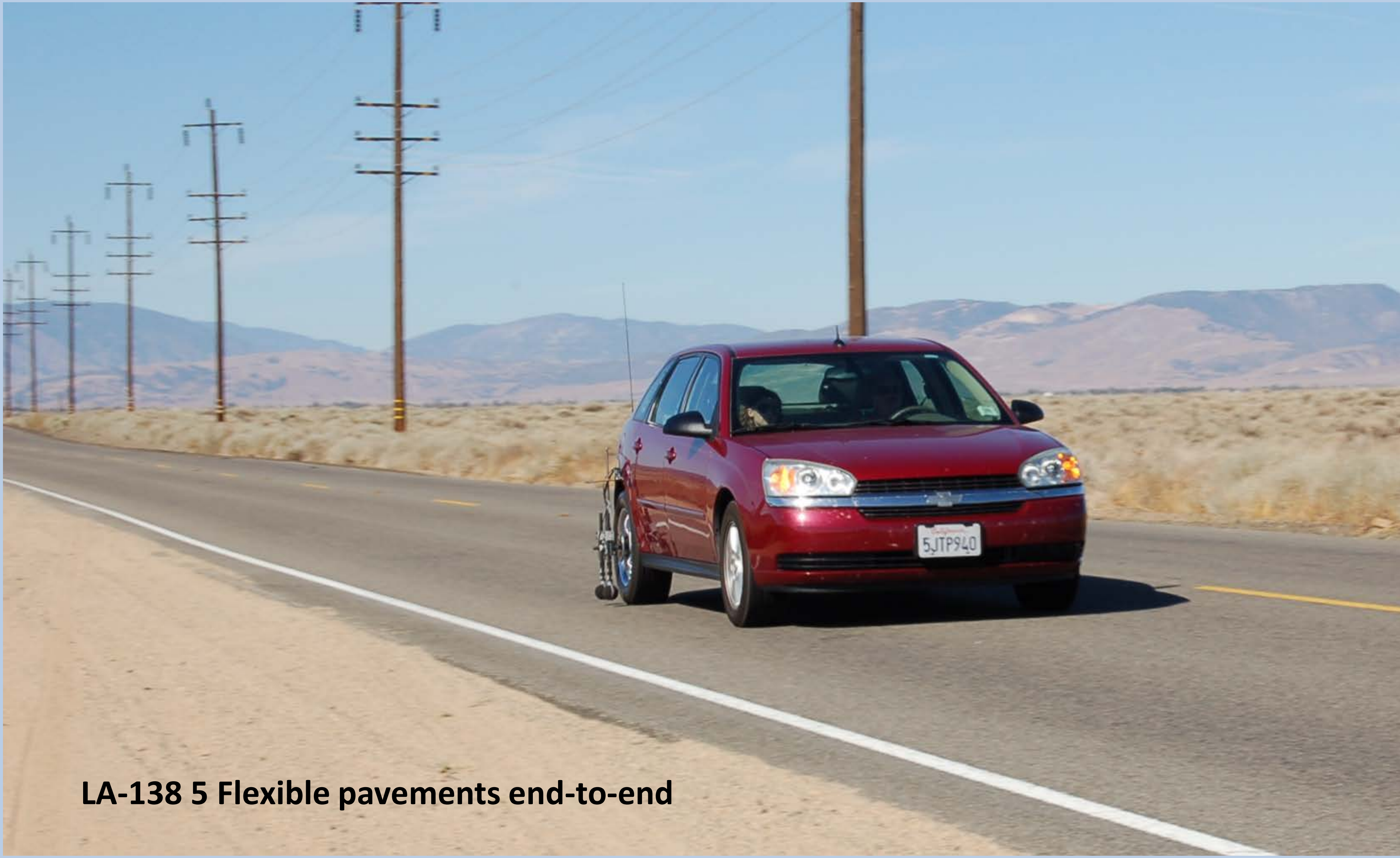


Sound Intensity

Close Proximity Method (CPX) or Trailer Method at NCAT Test Track

European ISO 11819-2 DRAFT

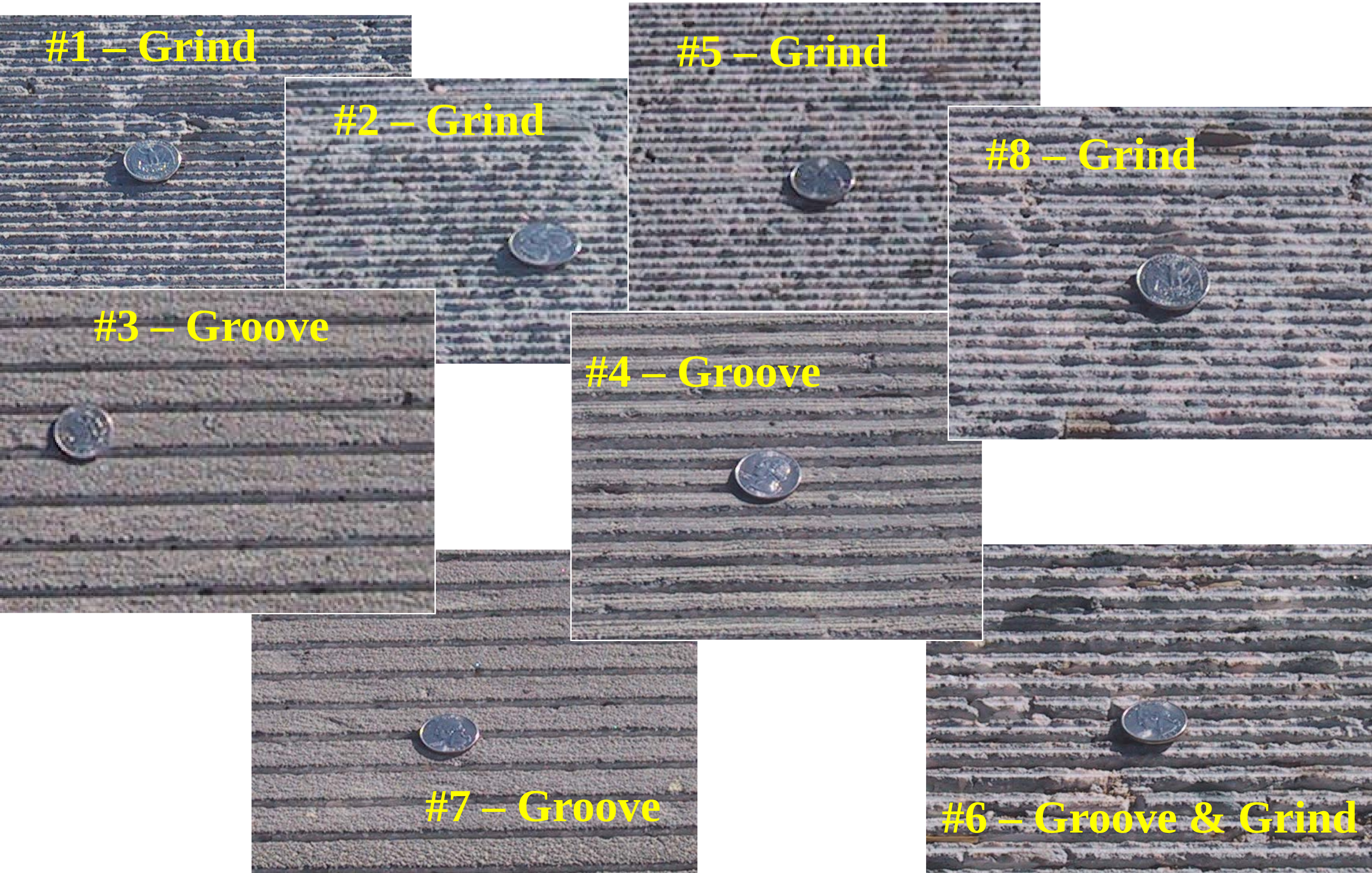
Tire-Pavement Noise Surveys



LA-138 5 Flexible pavements end-to-end

Mojave 58 By Pass Rigid Pavement w Various Textures

Applied Textures to Baseline Surfaces



GM invented Sound Intensity Measurements

Standard Method of Test for Measurement of Tire/Pavement Noise Using the On-Board Sound Intensity (OBSI) Method

AASHTO Designation: T 360-16[1]

Technical Section: 5a, Pavement Measurement

Release: Group 1 (April 2016)

AASHTO

1. SCOPE

1.1. This test method describes the procedures for measuring tire/pavement noise using the on-board sound intensity (OBSI) method and the procedures for verification of the measurement system. The test method provides an objective measure of the acoustic power per unit area at points near the tire/pavement interface.

1.2. The OBSI measurement method described herein permits tire/pavement noise to be measured in isolation of other noise sources allowing the noise performance of pavements to be compared.

1.3. *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety concerns associated with its use. It is the responsibility of the user of this standard to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. REFERENCED DOCUMENTS

2.1. *AASHTO Standards*:

- TP 98, Determining the Influence of Road Surfaces on Vehicle Noise Using the Statistical Isolated Pass-By (SIP) Method
- TP 99, Determining the Influence of Road Surfaces on Traffic Noise Using the Continuous-Flow Traffic Time-Integrated Method (CTIM)

2.2. *ASTM Standards*:

- D2240, Standard Test Method for Rubber Property—Durometer Hardness
- F2493, Standard Specification for P225/60R16 97S Radial Standard Reference Test Tire

2.3. *ANSI Standards*:

- S1.1, Acoustical Terminology
- S1.9, Instruments for the Measurement of Sound Intensity
- S1.11, Specification for Octave-Band and Fractional-Octave-Band Analog and Digital Filters
- S1.40, American National Standard Specifications and Verification Procedures for Sound Calibrators
- S1.42, American National Standard Design Response of Weighting Networks for Acoustical Measurements

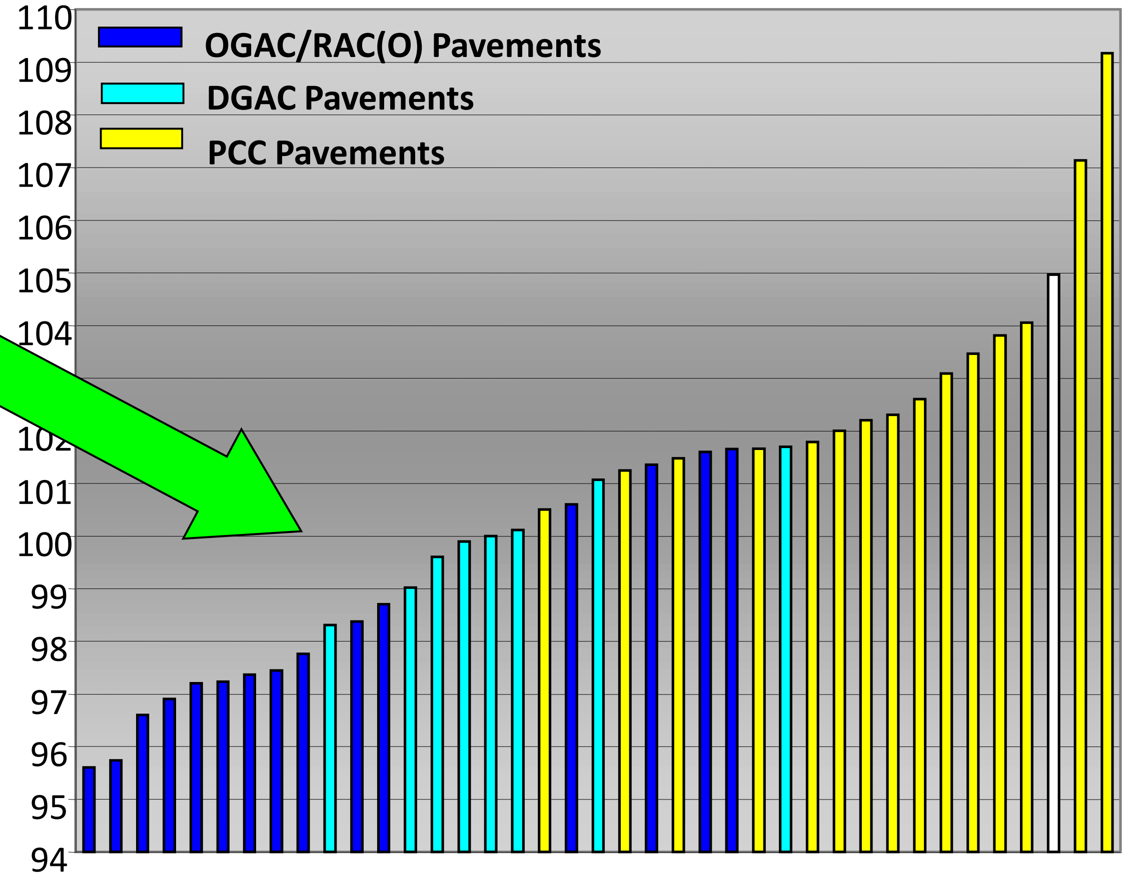
2.4. *International Electrotechnical Commission (IEC) Standard*:

- IEC 61260, Electroacoustics—Octave-Band and Fractional-Octave-Band Filters

2.5. *Other Document*:

- Donavan, P. R. and D. M. Lodico, *Measuring Tire-Pavement Noise at the Source*, NCHRP Report, Project 1-44(1), National Cooperative Highway Research Program, Transportation Research Board, Washington, 2011. Available at http://onlinepubs.trb.org/onlinepubs/nchrp/docs/nchrp01-44(01)_FR.pdf.

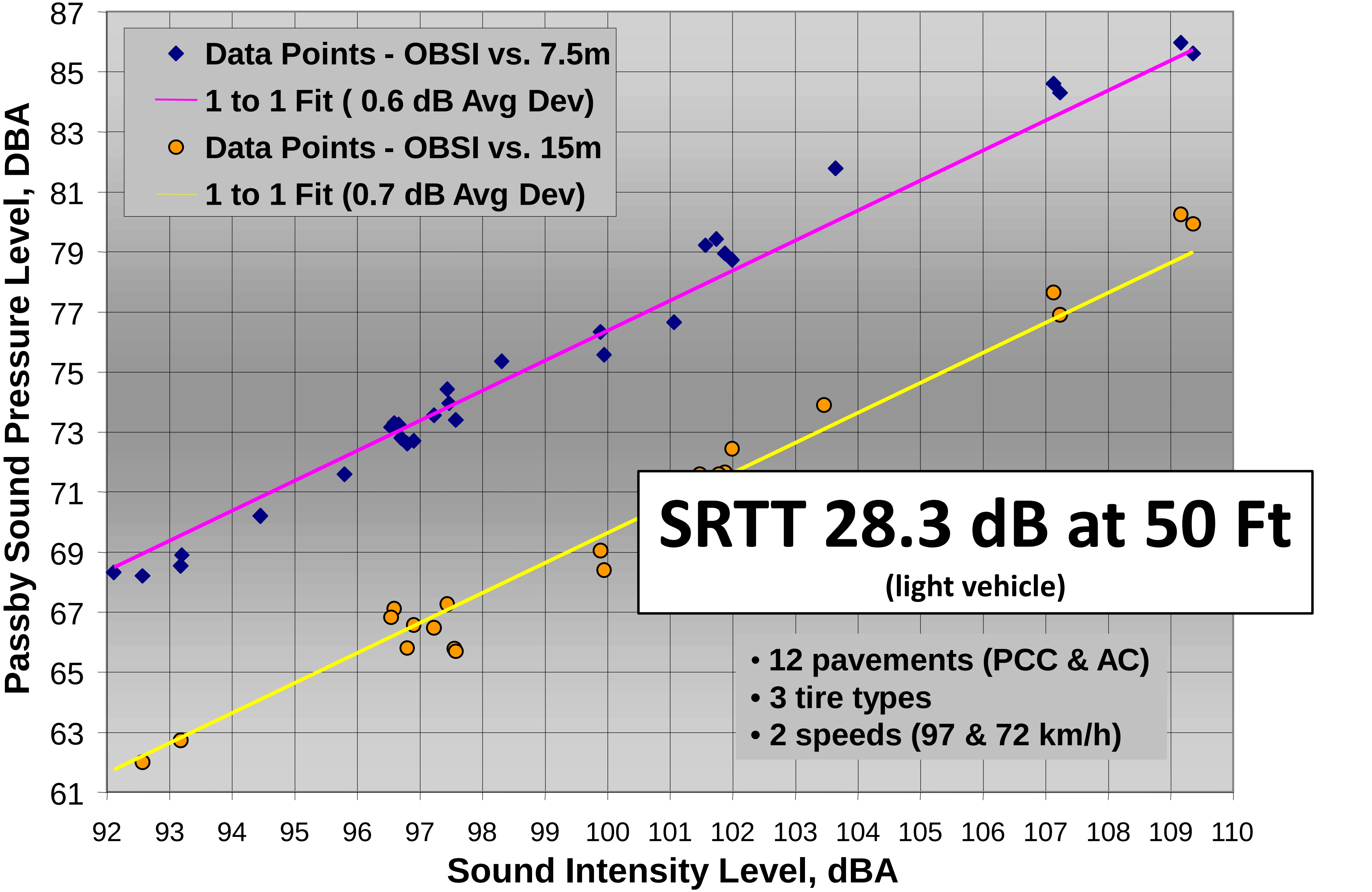
OBSI Quantifies Pavement Acoustics



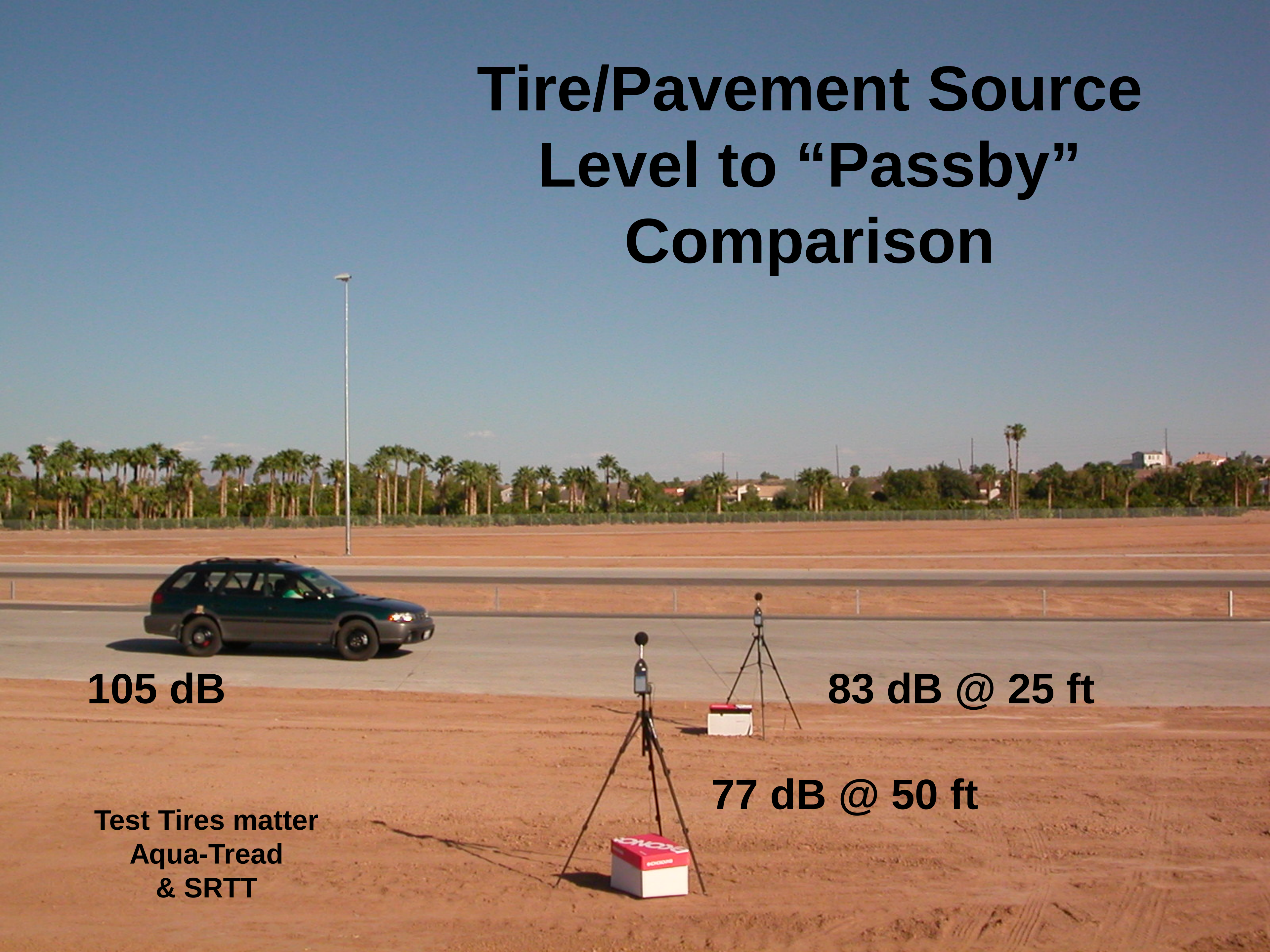
Overlap btw Pavement Types
Many pavement acronyms

Collect Database of Pavement Acoustics

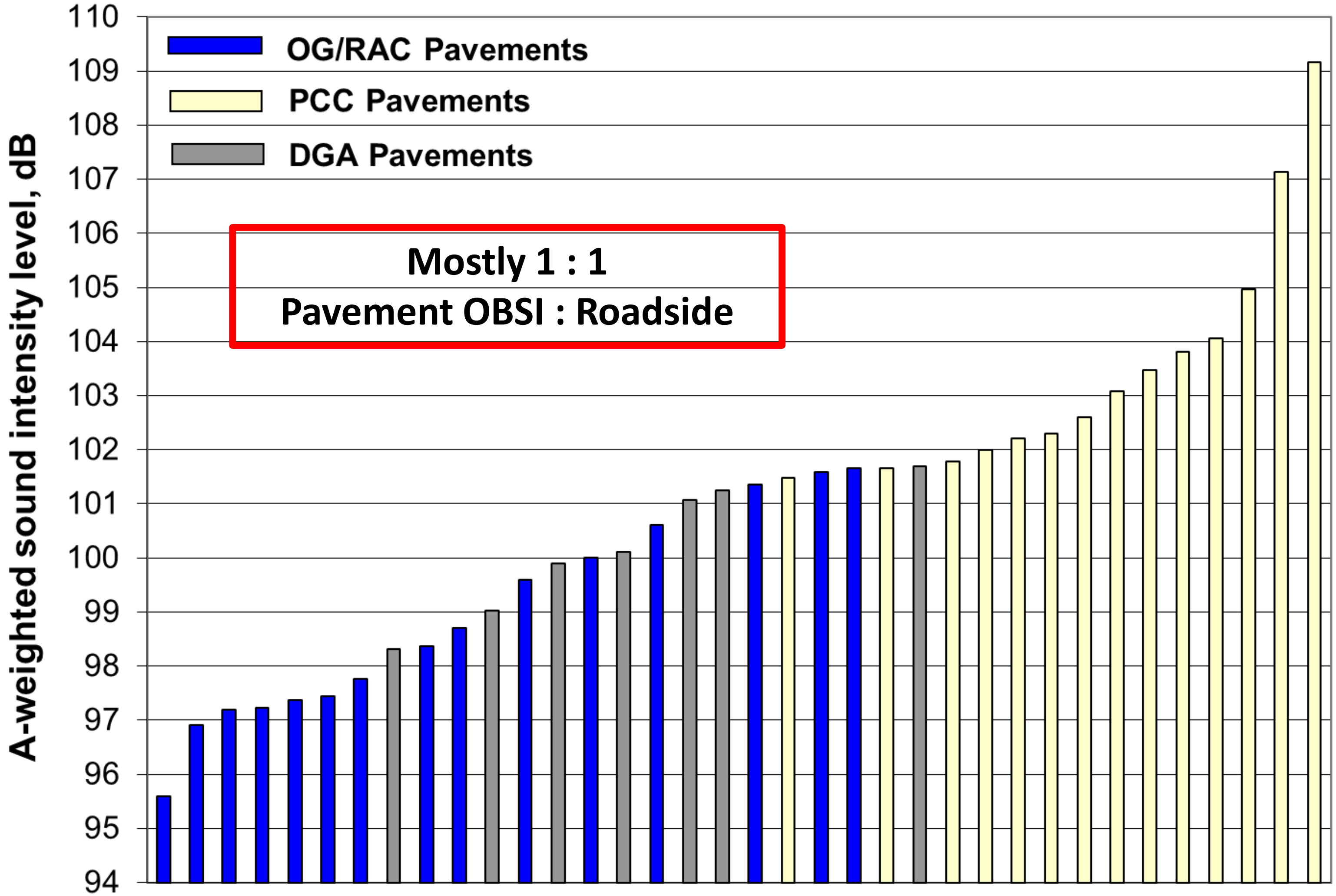
OBSI vs. PB Levels



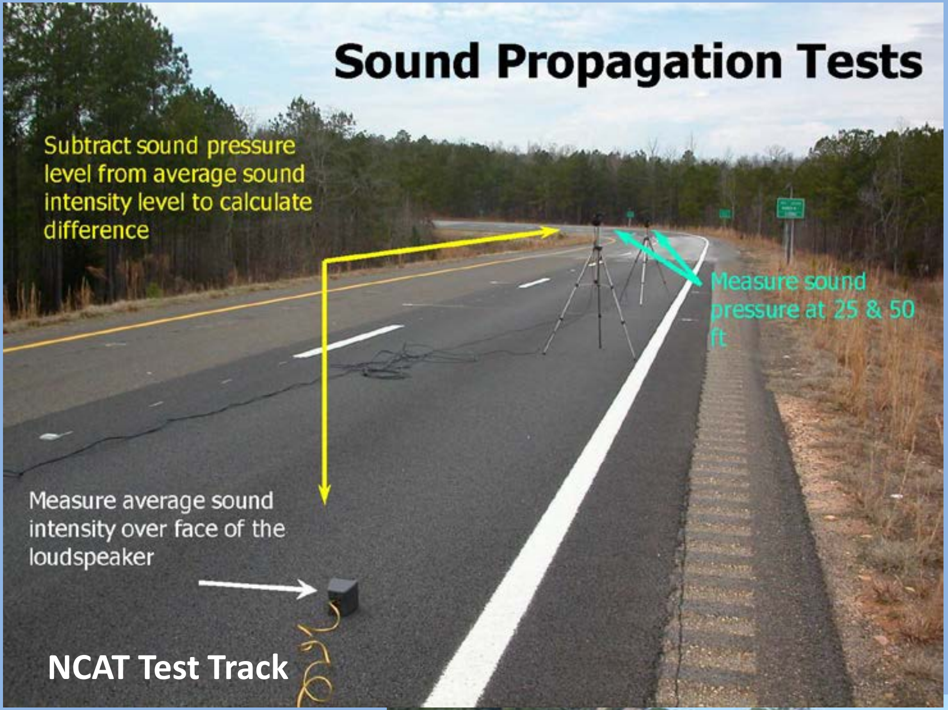
Tire/Pavement Source Level to "Passby" Comparison



California & Arizona Data Base



Caltrans

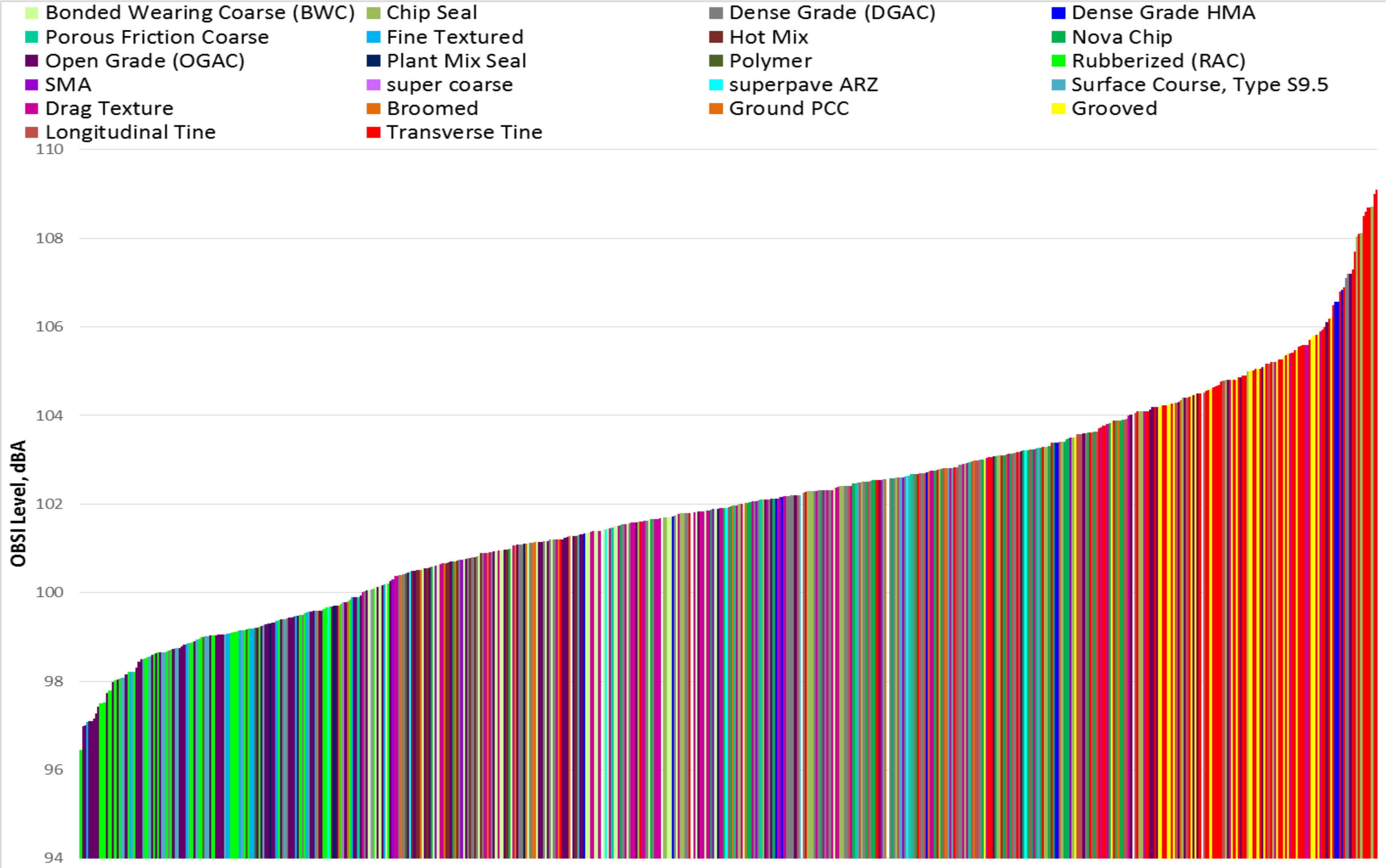


Exception : Super Absorptive Flexible Pavement

Flexible Pavements – Texture & Porosity

Dual Layer Porous Asphalt - $$$

Current OBSI/SRTT Data Base



Examples & Case Studies

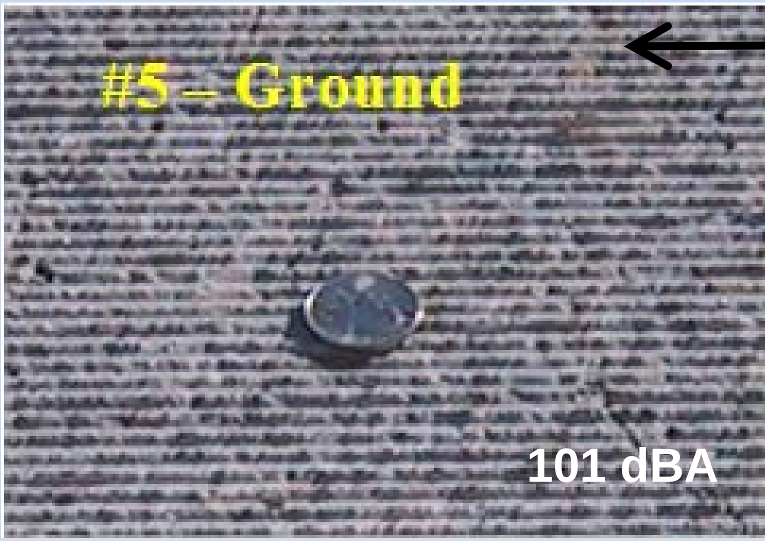
Quieter Rigid Pavements – Direction of Texture

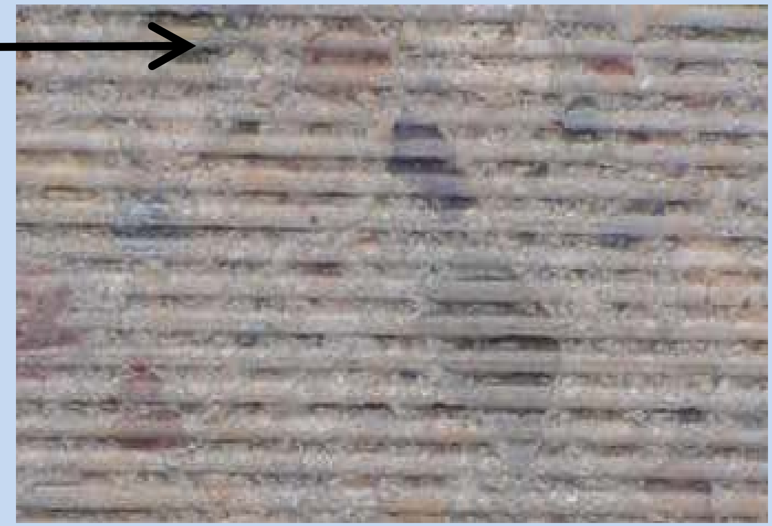
Direction of Travel

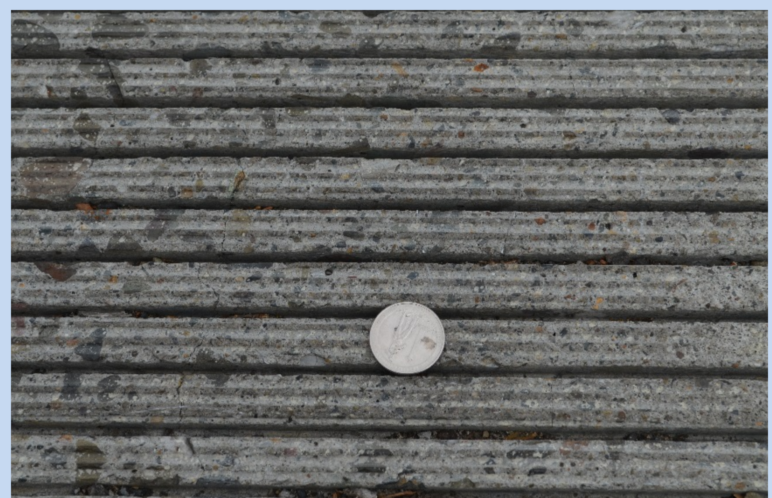
Caltrans history: Only SDOT to do LT for 30 years – off Structures

Quieter Rigid Pavements

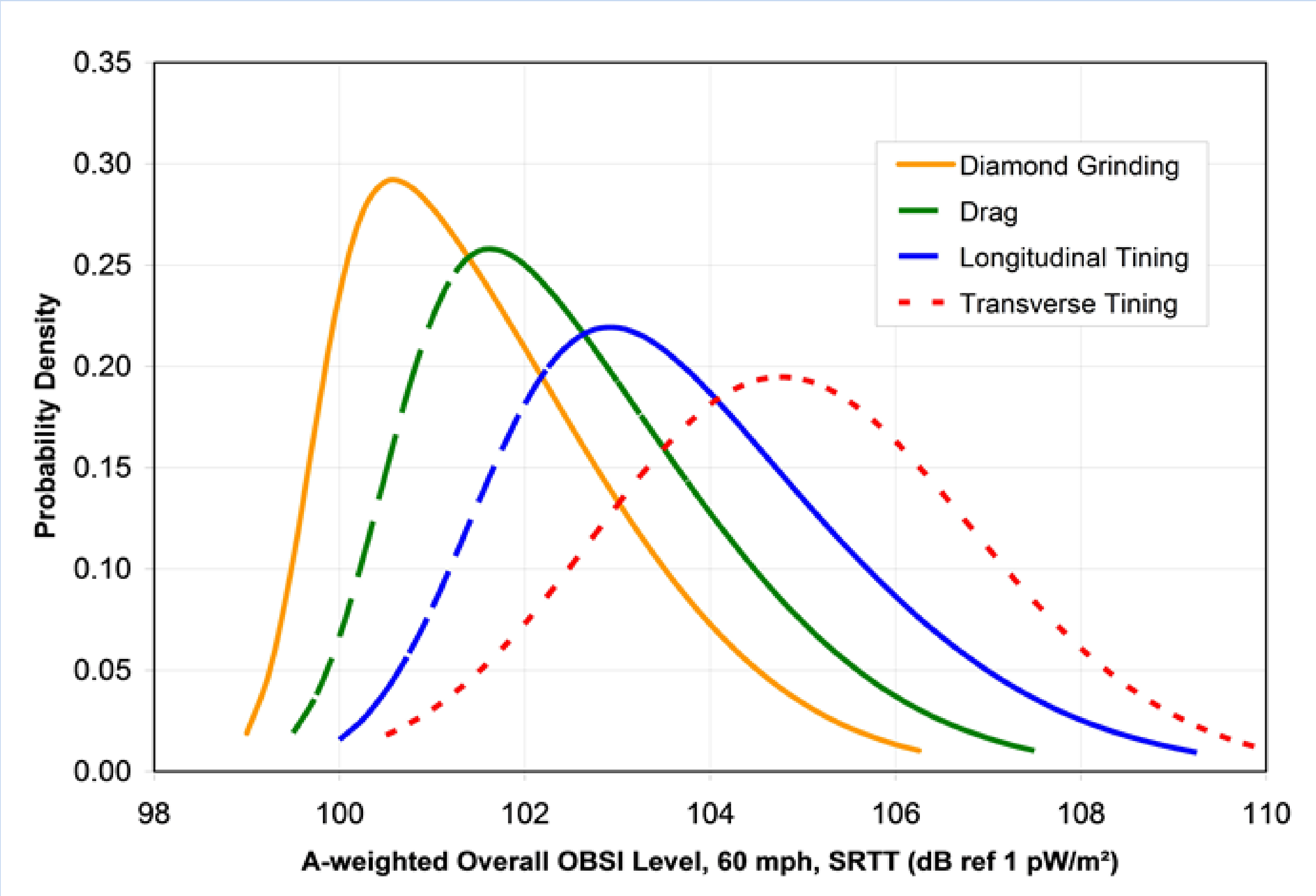
Direction of Travel







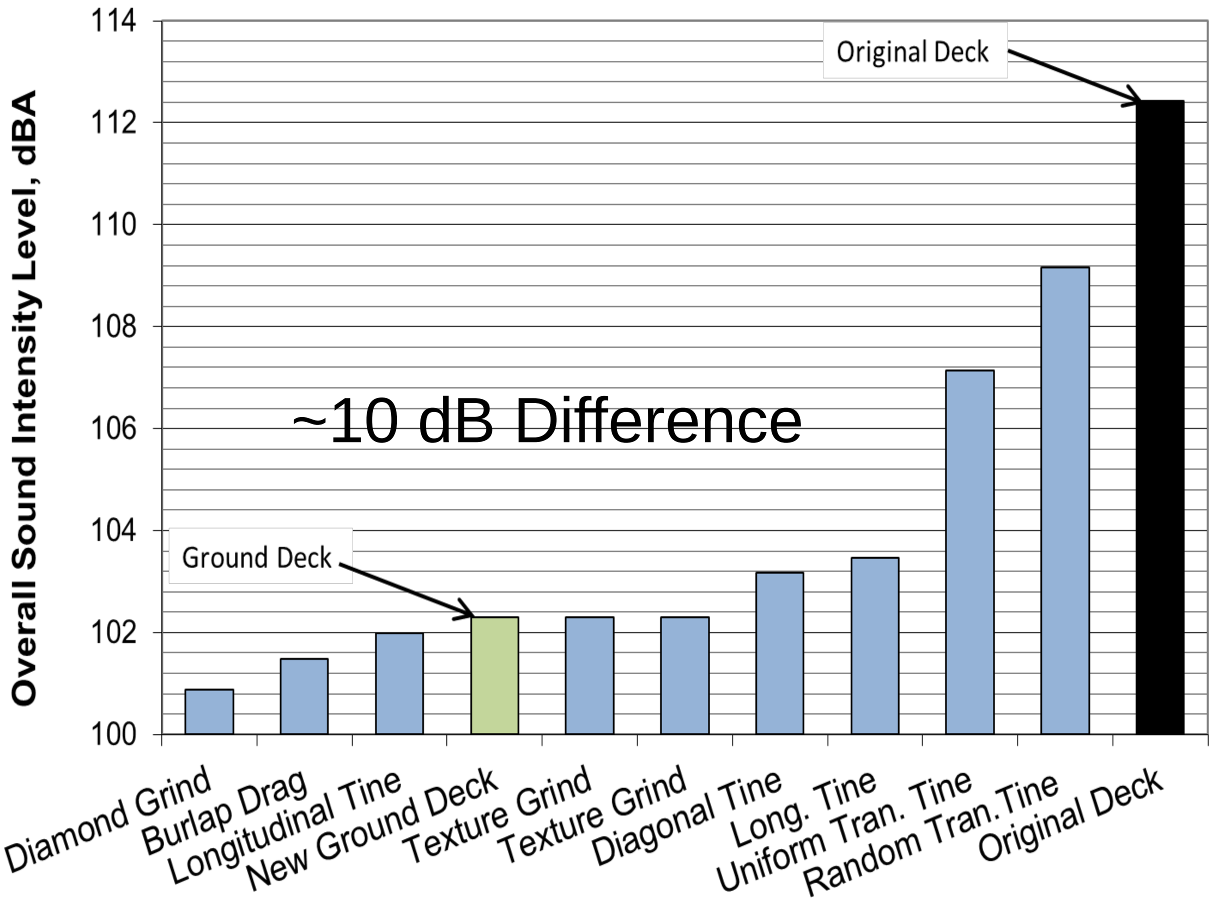
Portland Cement Concrete Data Base

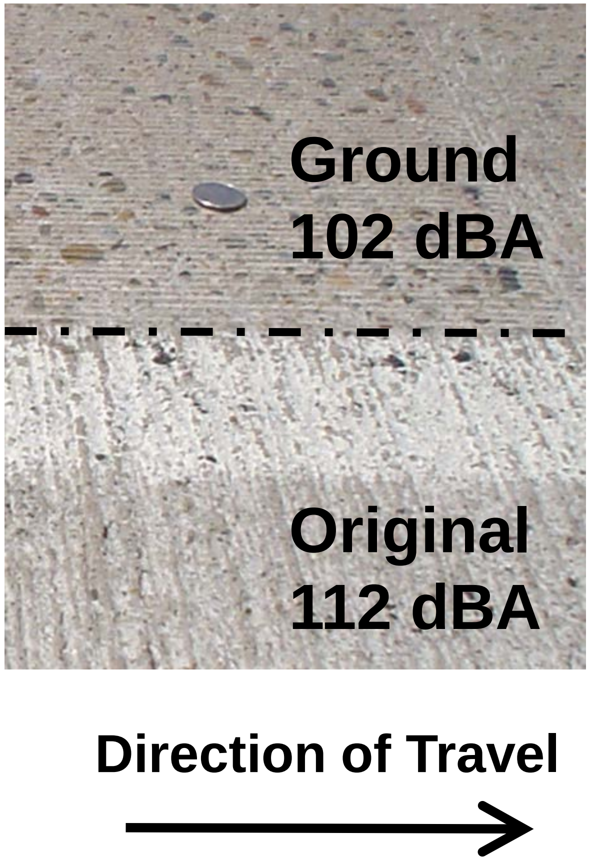


Source : Transtec

Long-term Sound Measurement
OBSI Levels decreased 10 dB(A)
At 500 ft. peak hour Leq dropped 7-8 dB(A) 48,000 AADT in 2002 w/ 14 % Trucks

Quieter Rigid Pavements – Grinding





TT Texture done to elevate friction; construction process
SE's don't like to grind; removes protective 'skin', and reduces rebar cover
Safety not an issue - LT off Structures since 1970's

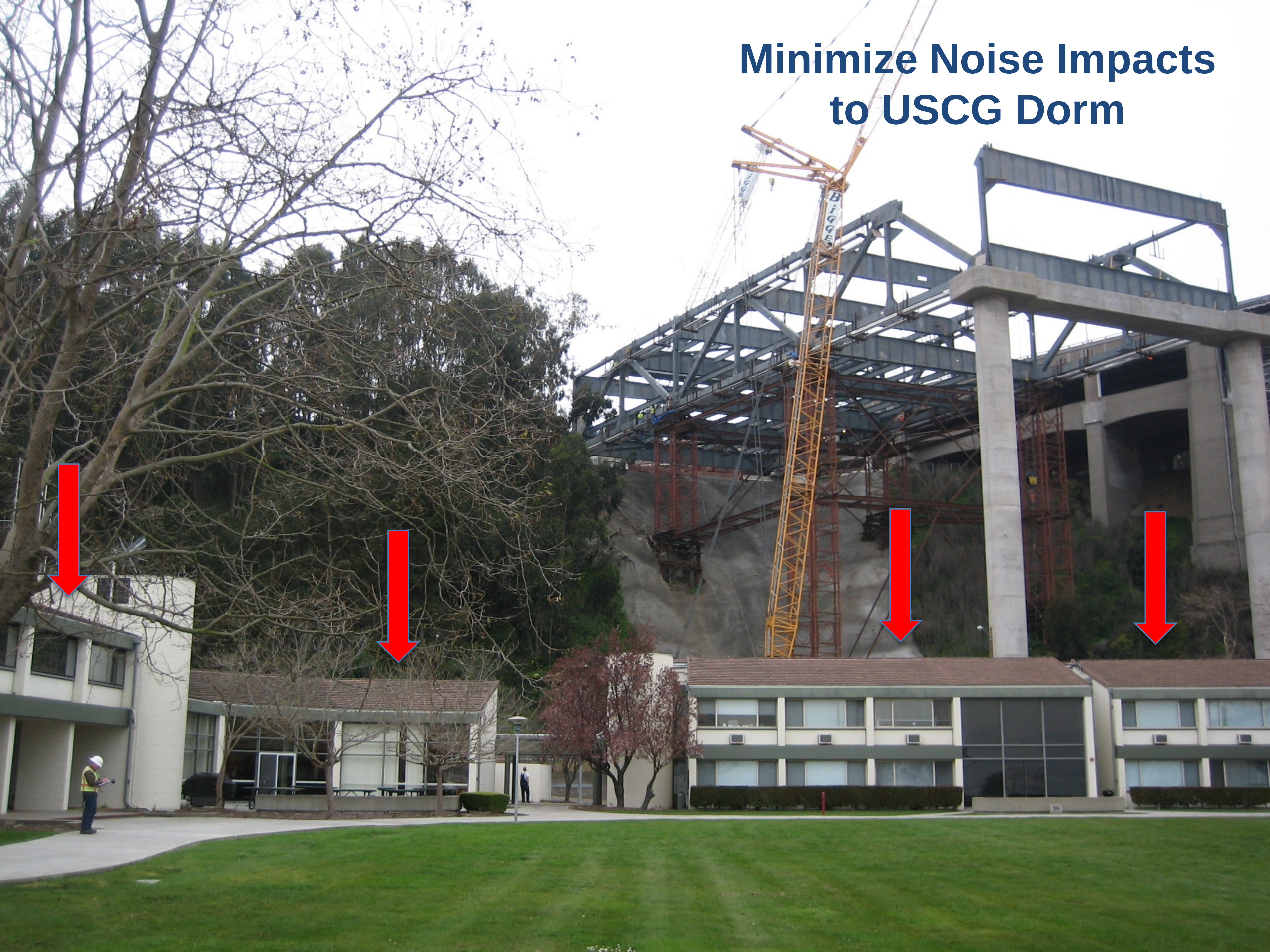
San Francisco Oakland Bay Bridge

Two Tales of the ‘Bridge Whisperer’


Oakland
Treasure Island
Yerba Buena Island
OBSI Tire/Pavement Measurements on the SFOBB
San Francisco


USCG Dorm
SFOBB Temp Viaduct

Minimize Noise Impacts to USCG Dorm



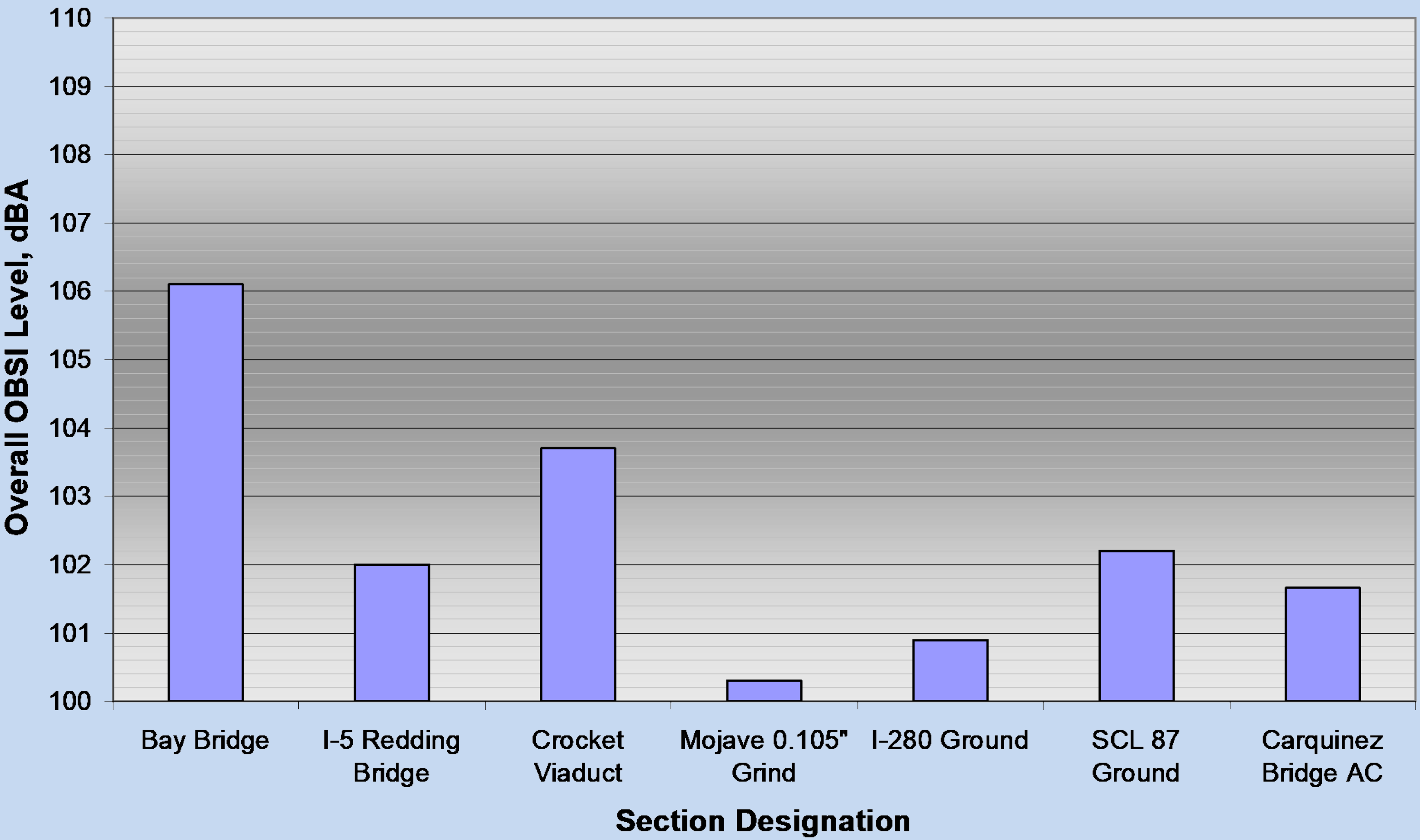
Completed Temporary Viaduct Structure

Eastbound Lower Deck Average Overall Levels

106.1 dBA

Westbound Upper Deck Average Overall Levels
106.2 dBA

Comparison of Bay Bridge Average Level to other Structures and Ground PCC Surfaces



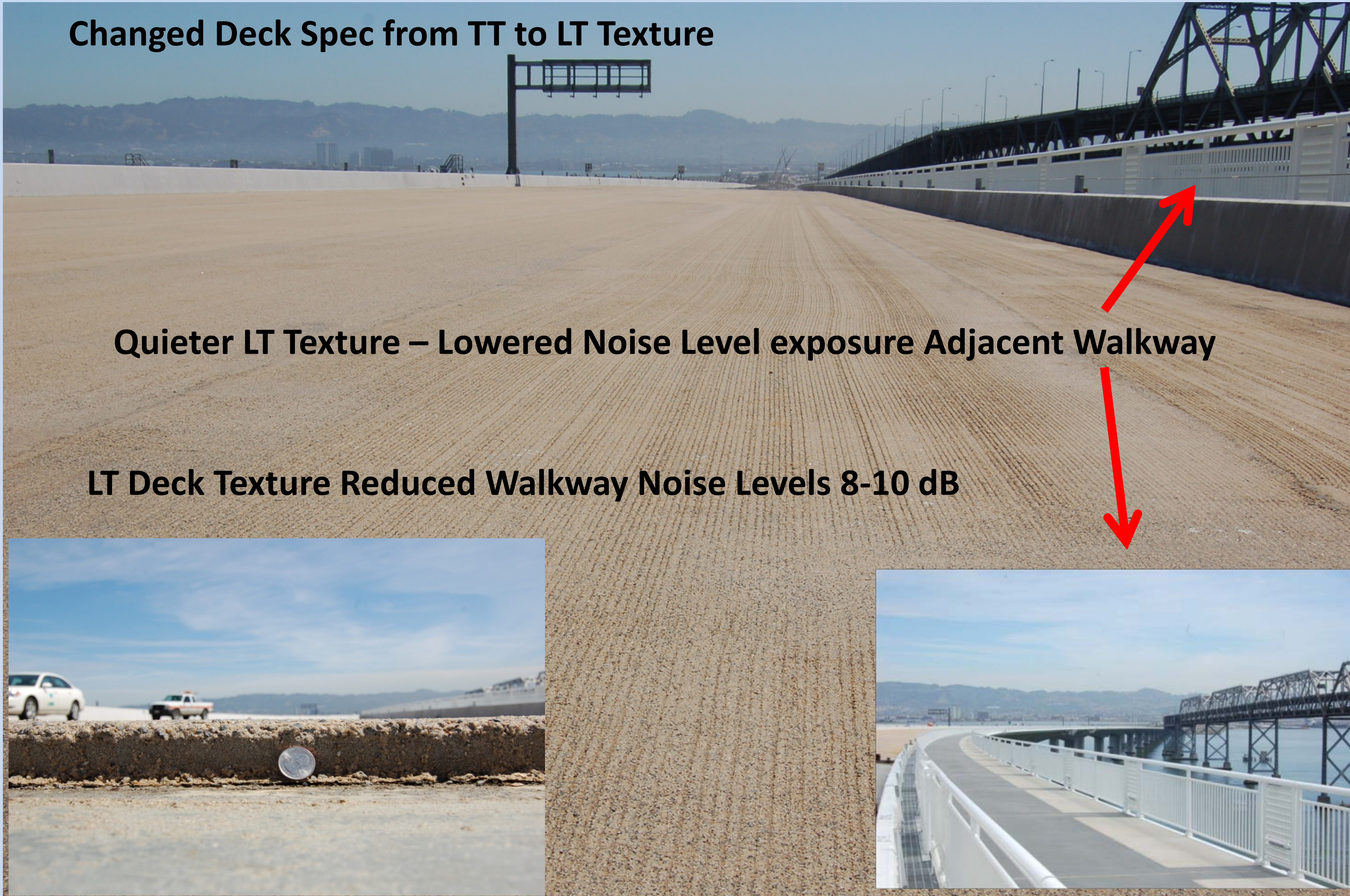
Advise Structures Division

Use LT Texture PCC – Avoid Additional Load of OGAC on Temp Viaduct Deck

Story 2 - Millions $$ Walkway with Million $ View

Public Access Walkway to Treasure Island – Cantilevered off EB Structure

OBSI Post Construction Measurements



Cautionary Tales of Pavement Promoters

(Rigid & Flexible)

ADOT Quiet Pavement Pilot Program (QP3)

AZ – Home to RPA

QP3 Project - Pre & Post Overlay

ARFC Overlay (25mm Thick)

Transverse Tined PCC

ADOT would have seen noticeable reduction just by changing rigid pavement specification from TT to LT

Quiet flexible RAC product marketed to WsDOT; could over come temperature construction issues & solve noise problem. …..SO much quieter than rigid pavement…..

IH-5 Seattle

WSJ Story - "Quiet Pavement Doesn't Work !"

(Doesn't mention heavily rutted WsDOT lanes due to snow tires and chains

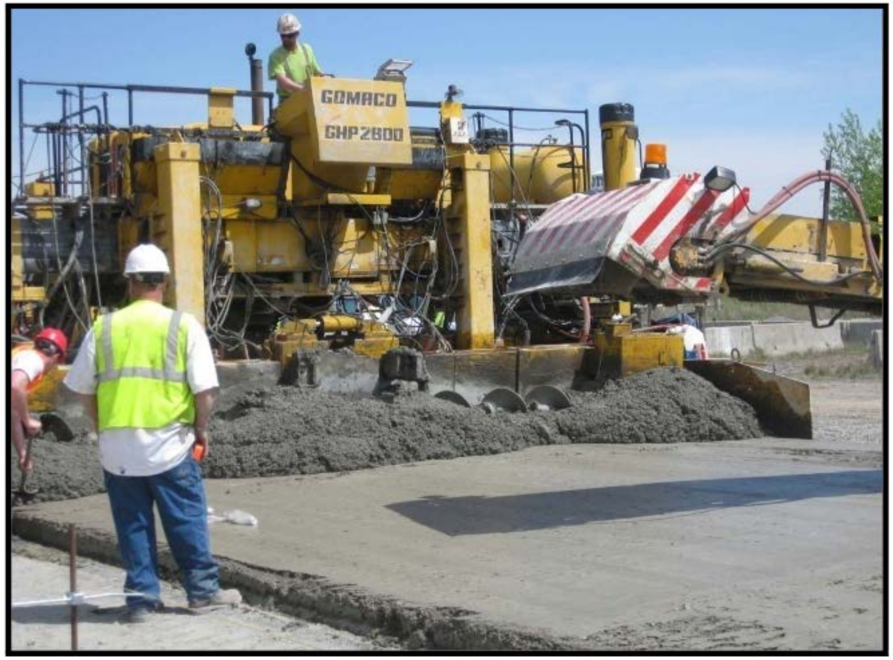


Figure 9: Demo Slab Construction

Figure 10: Demo Slab Finished Surface

European Exposed Aggregate – “is *SO* Quiet”

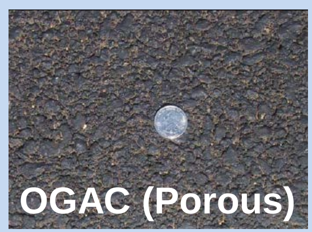
-- Mostly not; need ½ inch or less aggregate to be quiet

Acoustical Longevity – Long Term Research

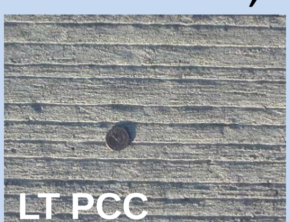
- Arizona DOT, QP3
  - 12-Year Study
  - AADT Varies over 330 miles of study area

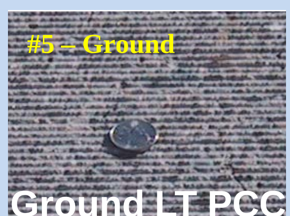
- Caltrans, Davis I-80
  - 16-Year Study
  - 146,000 AADT, 7.6 % trucks

- Caltrans, LA 138: Flexible Pavement (4,400 AADT, 14% trucks)



- Caltrans, Mohave SR 58: Concrete Texturing (17,000 AADT, 37% trucks)





Quieter Pavement and Heavy Vehicles

- Trucks ~10 dB louder than cars (wayside)
- Tire-noise major contributor
  - More aggressive tires and more of them
- Range in OBSI level for truck tires on a single pavement is 14 dB (similar to pavement range)

- Acoustical characteristics and pavements ranking consistent for car and truck tires
  - Aggressive treaded tires result in smaller ranges

Acoustic Longevity/Durability LA -138 AC

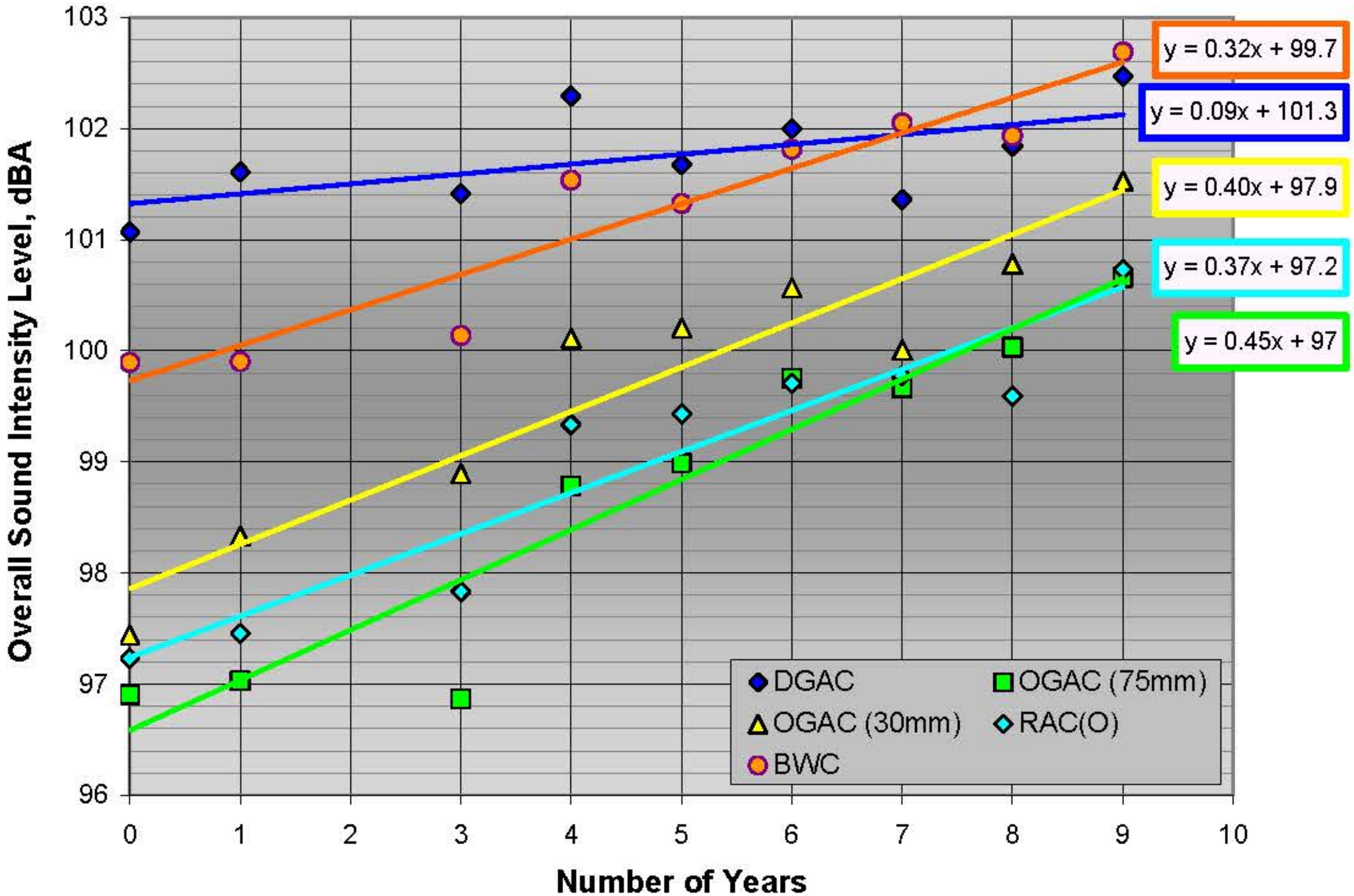


Figure D.12. Overall A-Weighted OBSI levels for each test pavement from October 2002 through October 2011 versus years since construction for Goodyear Aquatred test tire

Acoustic Longevity/Durability - Mojave PCC

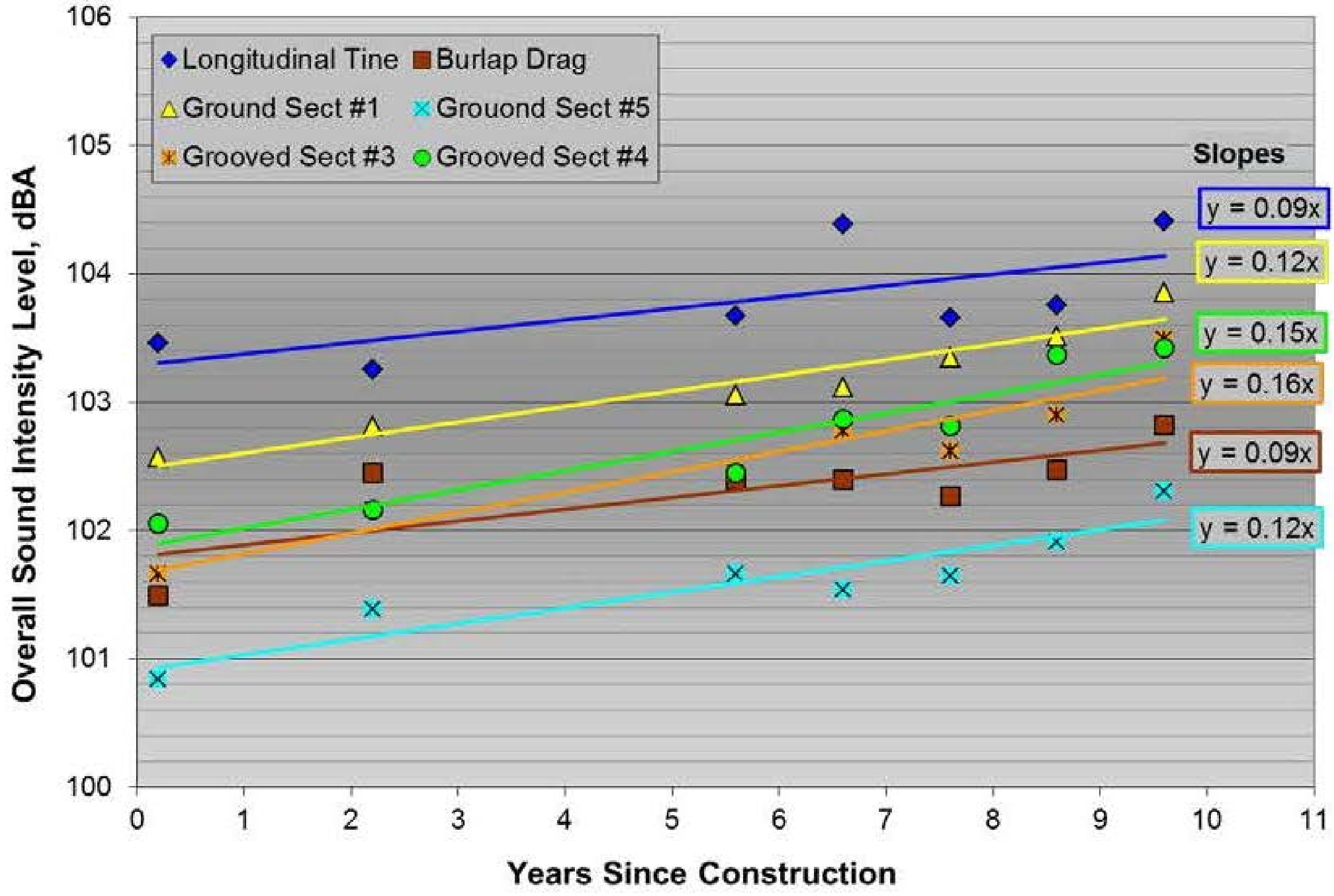


Figure D8. Overall A-Weighted OBSI levels for each test pavement from 2003 to 2012 with rate of increase per year shown for the Goodyear Aquatred test tire

Pavement Acoustic Longevity Summary

Project	Pavement Details	Rate of Increase, dB/Year	Mid-Project Year Traffic Loading
ADOT QP3	ARFC[3]	0.50	Varies
Davis I-80 (6-lanes)	OGAC[2]	0.3 to 0.4	146,000 AADT, 7.6% Trucks (2006)
LA 138 (2-lanes)	DGAC	0.09	4,400 AADT, 14% Trucks (2007)
	OGAC 75 mm[2]	0.47	
	OGAC 30 mm[2]	0.41	
	RAC(O) [2,3]	0.38	
	BWC	0.33	
Mohave Bypass SR 58 (4-lanes)	LT PCC	0.09	17,000 AADT, 37% Trucks (2007)
	Ground PCC, S1	0.12	
	Ground PCC, S5	0.12	
	Burlap Drag PCC	0.09	
	Grooved PCC, S3	0.16	
	Grooved PCC, S4	0.15	

Pavement Acoustic Longevity Summary

Project	Pavement Details	Rate of Increase, dB/Year	Mid-Project Year Traffic Loading
SR 85, Saratoga, CA (6-lanes)	Ground and Grooved Long. Tined PCC	0.38	122,000 AADT, 0.57% Trucks (2007)
I-280, San Mateo County (6-lanes)	Diamond Ground PCC	0.28	105,000 AADT, 2.3% Trucks (2006)
	Texture Ground PCC	0.35	
	RAC(O)[3]	0.58	
	OGAC[2]	0.81	
I-10, Casa Grande, AZ (6-lanes)	AR-ACFC[3]	0.33	51,000 AADT (2007)
	ACFC	0.43	
	SMA	0.30	
	Porous-ACFC[2]	0.68	
	Porous Euro Mix[2]	negligible	

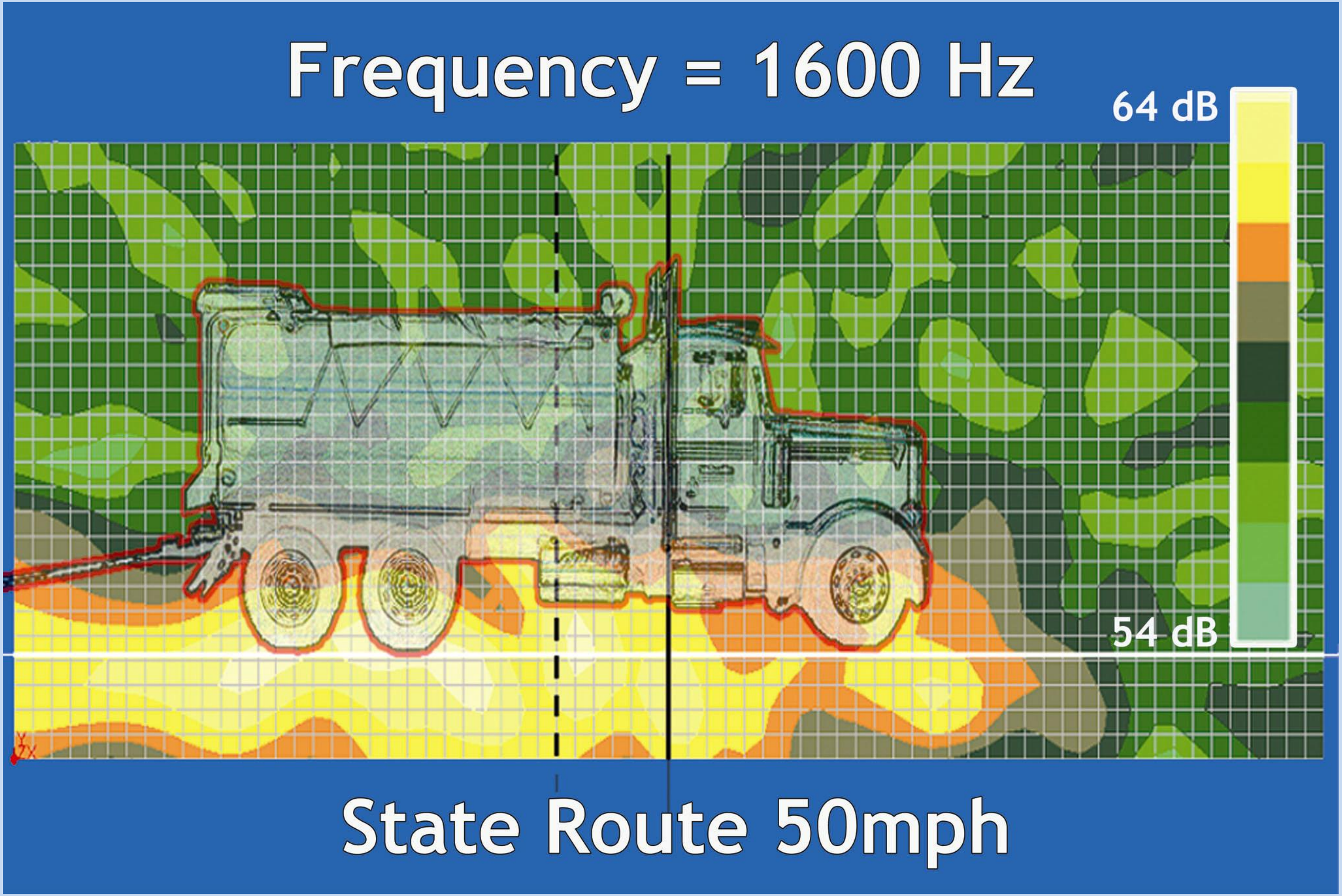
<u>Averages</u>

Asphalt – 0.46 dB/Yr

Concrete – 0.19 dB/Yr

Acoustic Beam Forming System

- Type WL9x6D2509 Foldable wheel Array
- Equal length arms
- 8.2ft in diameter
- 54 microphones
- Acquisition by B&K PULSE system
- Data processed by delay & sum method
- 315 to 4,000 Hz



At freeway speed for Autos and Heavy Trucks, ***majority of acoustic energy is at T/P interface*** and below 3.3 feet

Quieter Pavement Bulletin Design Guidance Oct 2009 (omitted Structures)

State of California
DEPARTMENT OF TRANSPORTATION

Business, Transportation and Housing Agency

Memorandum

Flex your power!
Be energy efficient!

To: DISTRICT DIRECTORS
CHIEF, DIVISION OF CONSTRUCTION
CHIEF, DIVISION OF TRAFFIC OPERATIONS
CHIEF, DIVISION OF ENVIRONMENTAL ANAYLSIS
CHIEF, DIVISION OF ENGINEERING SERVICES
CHIEF, DIVISION OF DESIGN
CHIEF, DIVISION OF MAINTENANCE
CHIEF, DIVISION OF PROJECT MANAGEMENT

Date: October 6, 2009

From: SHAKIR SHATNAWI
State Pavement Engineer
Chief
Division of Pavement Management

Subject: Quieter Pavement Bulletin

This transmittal memorandum provides notice that Quieter Pavement Bulletin is now available on the Pavement website at http://www.dot.ca.gov/hq/esc/Translab/ope/QuieterPavements.html. This bulletin is effective October 15, 2009 for use on all pavement construction or rehabilitation projects in noise sensitive areas of frequent human use where existing noise levels approach or exceed the Federal Noise Abatement Criteria as defined in Title 23, Code of Federal Regulations, Part 772 (23 CFR 772).

BACKGROUND:

Minimizing traffic noise impacts from State highways, while maintaining safe, smooth, and long lasting pavements, is a key goal for all pavement design, construction and maintenance strategies throughout the state. Research done to date has shown that traffic noise can be minimized by incorporating quieter pavement strategies in pavement mix designs and construction practices at little to no added cost. Quieter pavements help reduce the noise generated from the interaction between vehicle tires and pavement (i.e., at the source where the tire meets the road, thereby helping to reduce overall traffic noise impacts to the communities adjacent to the highways. This bulletin is provided as a part of the Department's Quieter Pavement Research (QPR) Program implementation plan to develop design guidance and specifications for quieter pavements in an ongoing effort to address traffic noise issues throughout the state.

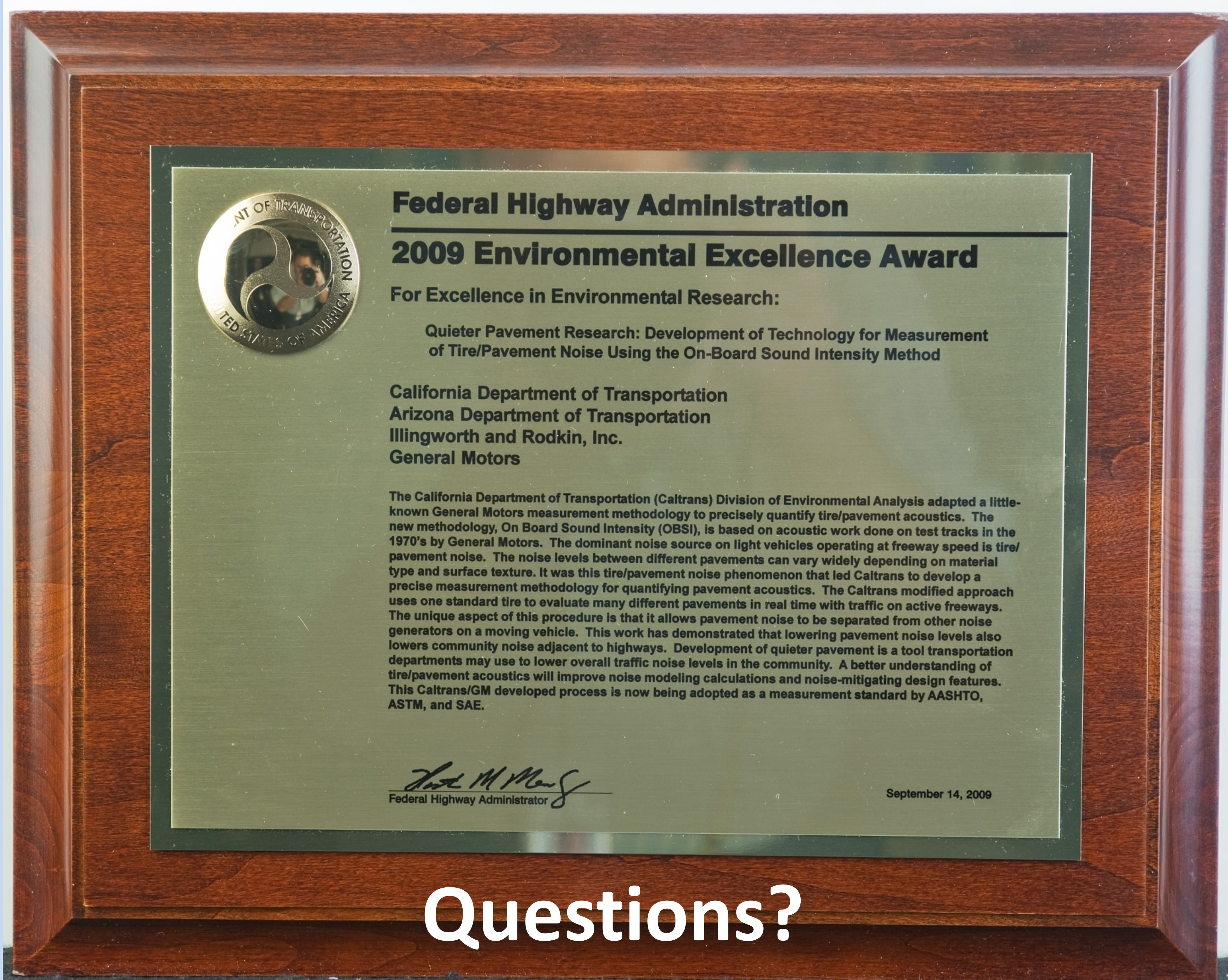
GOAL:

The goal of this bulletin and the overall QPR Program is not just to be able to build quieter pavements, but to build quieter pavements that will maintain noise reduction benefits over time without compromising on safety, ride quality, and sustainability of pavement surfaces. This quieter pavement policy bulletin is needed to facilitate this effort statewide and to provide the Districts with the latest information and direction for when and how to design, build, and maintain quieter pavements.

Quieter Pavement

- Lower initial cost than barriers
- Larger area of reduction
- Can be used anywhere
- Noise levels increase over time
- Maintaining performance requires periodic rehabilitation

Developing a Quiet Pavement Strategy is an important process for addressing traffic noise impacts – OBSI is an important tool



NT OF TRANSPORTATION
UNITED STATES OF AMERICA
Federal Highway Administration
2009 Environmental Excellence Award
For Excellence in Environmental Research:
Quieter Pavement Research: Development of Technology for Measurement of Tire/Pavement Noise Using the On-Board Sound Intensity Method
California Department of Transportation
Arizona Department of Transportation
Illingworth and Rodkin, Inc.
General Motors
The California Department of Transportation (Caltrans) Division of Environmental Analysis adapted a little-known General Motors measurement methodology to precisely quantify tire/pavement acoustics. The new methodology, On Board Sound Intensity (OBSI), is based on acoustic work done on test tracks in the 1970's by General Motors. The dominant noise source on light vehicles operating at freeway speed is tire/pavement noise. The noise levels between different pavements can vary widely depending on material type and surface texture. It was this tire/pavement noise phenomenon that led Caltrans to develop a precise measurement methodology for quantifying pavement acoustics. The Caltrans modified approach uses one standard tire to evaluate many different pavements in real time with traffic on active freeways. The unique aspect of this procedure is that it allows pavement noise to be separated from other noise generators on a moving vehicle. This work has demonstrated that lowering pavement noise levels also lowers community noise adjacent to highways. Development of quieter pavement is a tool transportation departments may use to lower overall traffic noise levels in the community. A better understanding of tire/pavement acoustics will improve noise modeling calculations and noise-mitigating design features. This Caltrans/GM developed process is now being adopted as a measurement standard by AASHTO, ASTM, and SAE.
Federal Highway Administrator
September 14, 2009

Questions?