National Center for Asphalt Technology
NCAT
AUBURN UNIVERSITY

Tire/Pavement Noise

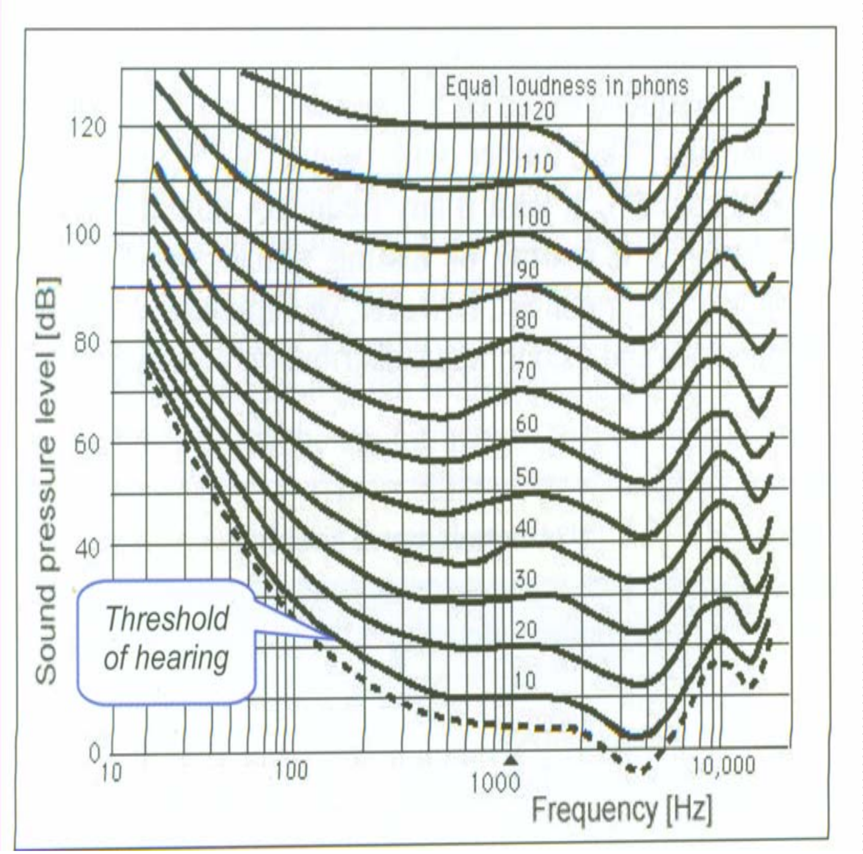
Effects:	Sound intensity ratio: (rel. hearing threshold)	A-weighted SPL in dB:	Typical sound source at this level:
Serious hearing damage	100 000 000 000 000	**140 dB**	Space rocket launch, in vicinity of launch pad
Hearing damage and pain	10 000 000 000 000	**130**	Jet engine (25 m distance)
			THRESHOLD OF PAIN
Hearing damage after short exposure	1 000 000 000 000	**120**	Air-raid alarm (5 m distance)
Serious hearing damage hazard	100 000 000 000	**110**	Rock music concert, close to stage
Hearing hazard	10 000 000 000	**100**	Jet plane take-off (300 m)
Some hearing hazard	1 000 000 000	**90**	Noisy industrial hall
Health effects	100 000 000	**80**	Heavy truck, 70 km/h (10 m distance)
Some health effects Severe annoyance	10 000 000	**70**	Car, 60 km/h (10 m distance)
Annoyance	1 000 000	**60**	Normal conversation (1 m distance)
Some annoyance	100 000	**50**	Quiet conversation (1 m distance)
Good environment	10 000	**40**	Subdued radio music
	1 000	**30**	Whispering (1 m distance)
	100	**20**	Quiet bedroom
	10	**10**	Rustling leave
Uncomfortably "quiet"	(reference)	**0**	Anechoic room for sound measurements
			HEARING THRESHOLD

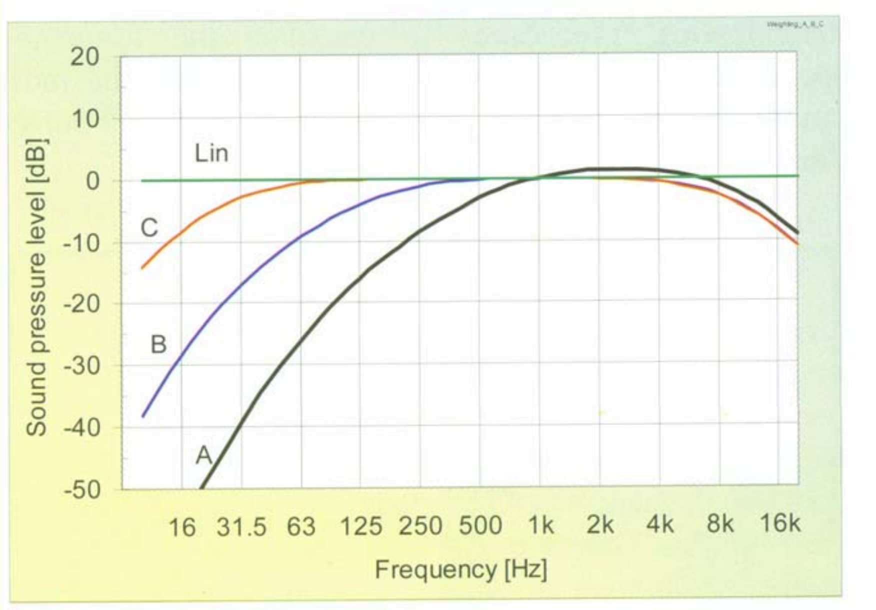
FHWA Guideline
– 67 dB(A) -

Noise terminology - dB

- Acousticians use a logarithmic scale when measuring Sound Pressure Levels (SPL)
- The unit for SPL is the dB
  - 0 dB is the threshold of hearing
  - 120 dB is the threshold of pain
  - 1 dB is the smallest difference in sound pressure level that our hearing is capable of perceiving under ideal circumstances

Noise Terminology – dB(A)

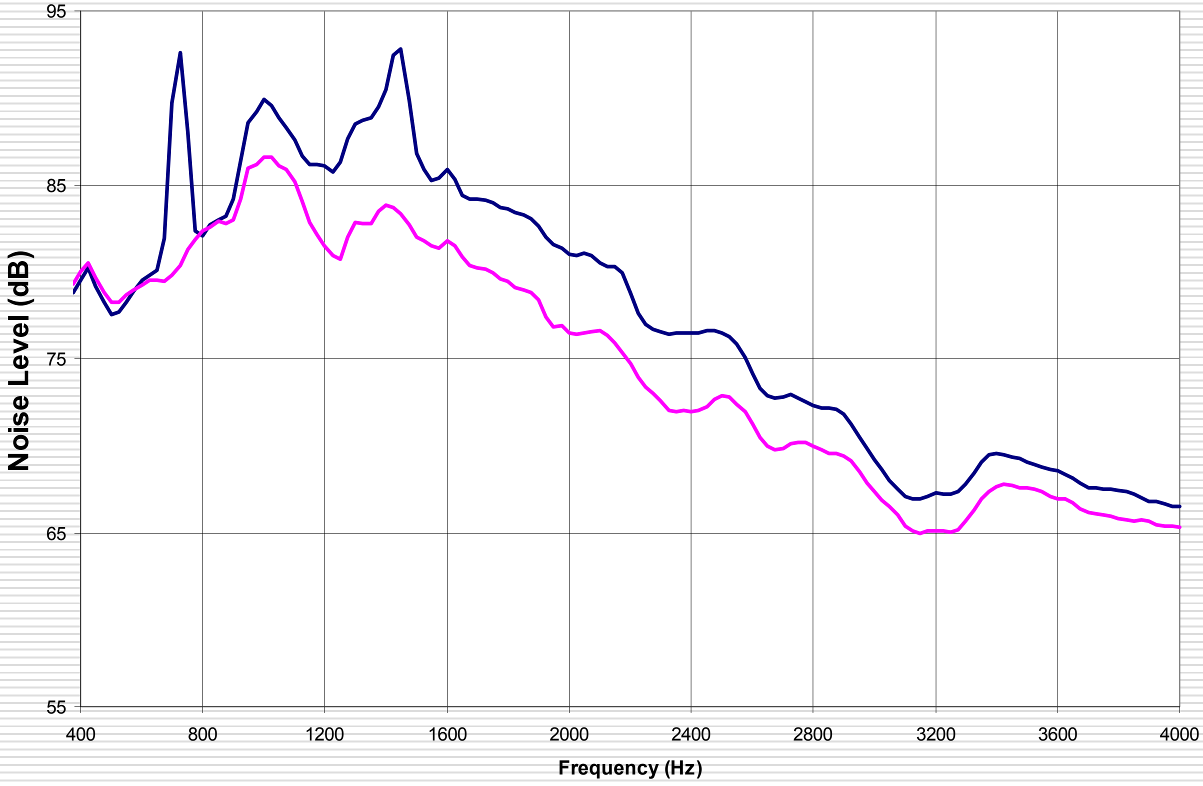




Noise Terminology - frequency

- Frequency spectrum – graphical representation of SPL (dB) as a function of frequency
- Hearing range – 20 to 20000 Hz
- 1000 Hz is considered the middle of the band
- Sound at low frequencies is less attenuated by distance than sound at high frequencies
- Thus low frequency sound will propagate further from the road

Frequency Spectrum for a Pavement



Nature of highway noise

Tire/pavement

- Generally the primary source at highway speeds (greater than 35 mph)
  - Level is dependent on vehicle type, vehicle speed and tire type
- Other sources include
  - Vehicle – engine, exhaust, etc.
  - Aerodynamic sources

Nature of highway noise

Sound absorption of pavement

- Greater absorption – less sound reflected off road and into communities
- Some quiet pavements absorb high frequency sound

Nature of Noise –

- **For speeds greater than 35 mph for cars and 45 mph for trucks pavement/tire noise dominates.** ***(Billera, et al., TRR 1601)***
- ***Sandburg – Cross-Over Speeds (the speed above which the tire/road noise is more important than the power train noise***
  - ***Cars***
    - ***Cruising – 25 Km/hr (16 mph)***
    - ***Accelerating – 45 km/hr (28 mph)***
  - ***Trucks***
    - ***Cruising – 35 km/hr (22 mph)***
    - ***Accelerating – 50 km/hr 32 mph)***

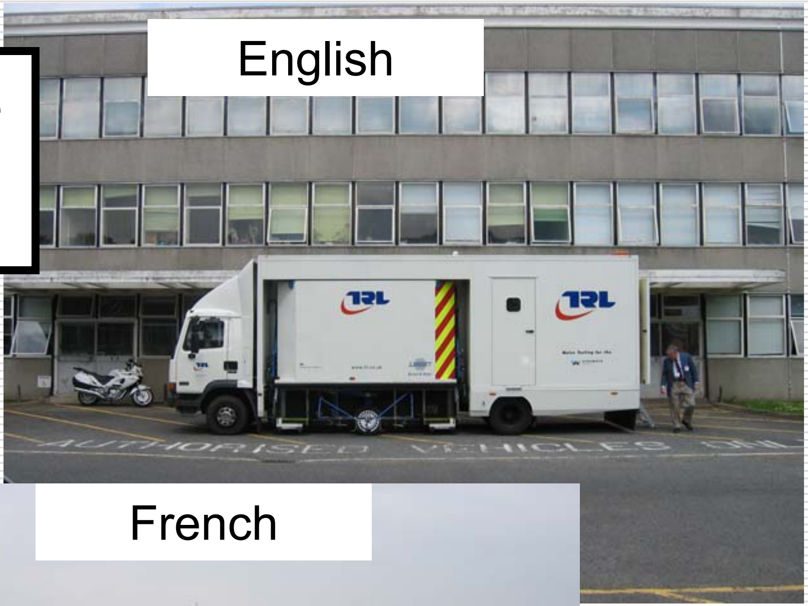
Measurement of Traffic Noise

- Source measurement – measures the effect of quiet pavement on the tire/pavement interaction at the source
- Wayside measurements – measures the effects of quiet pavements on communities

Source measurement

Common Procedure in Europe

Standard is ISO 11819-2

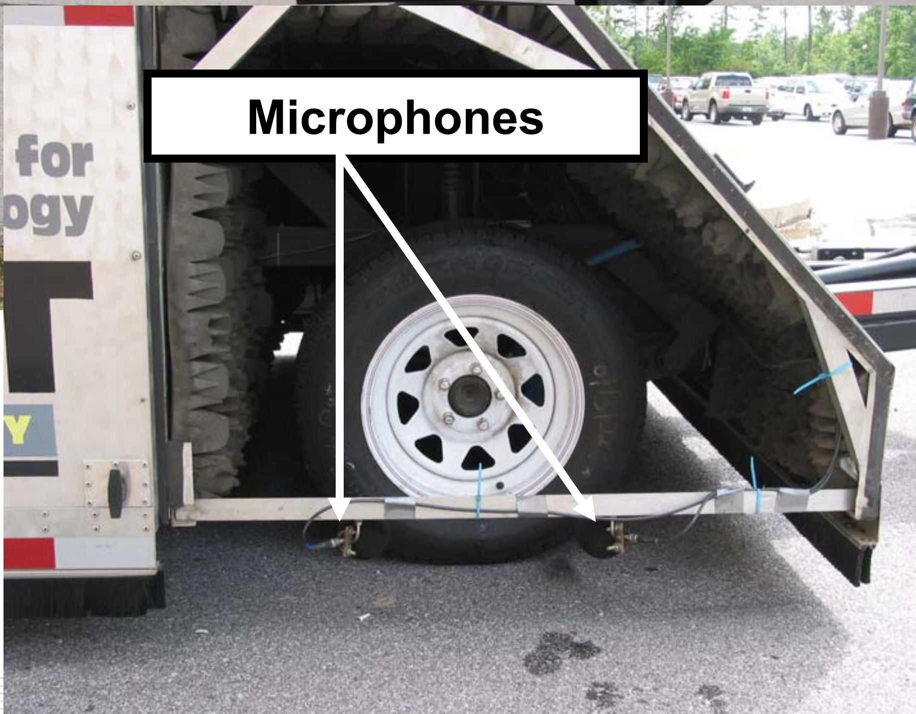


English

Finnish

French

Meets ISO 11819-2

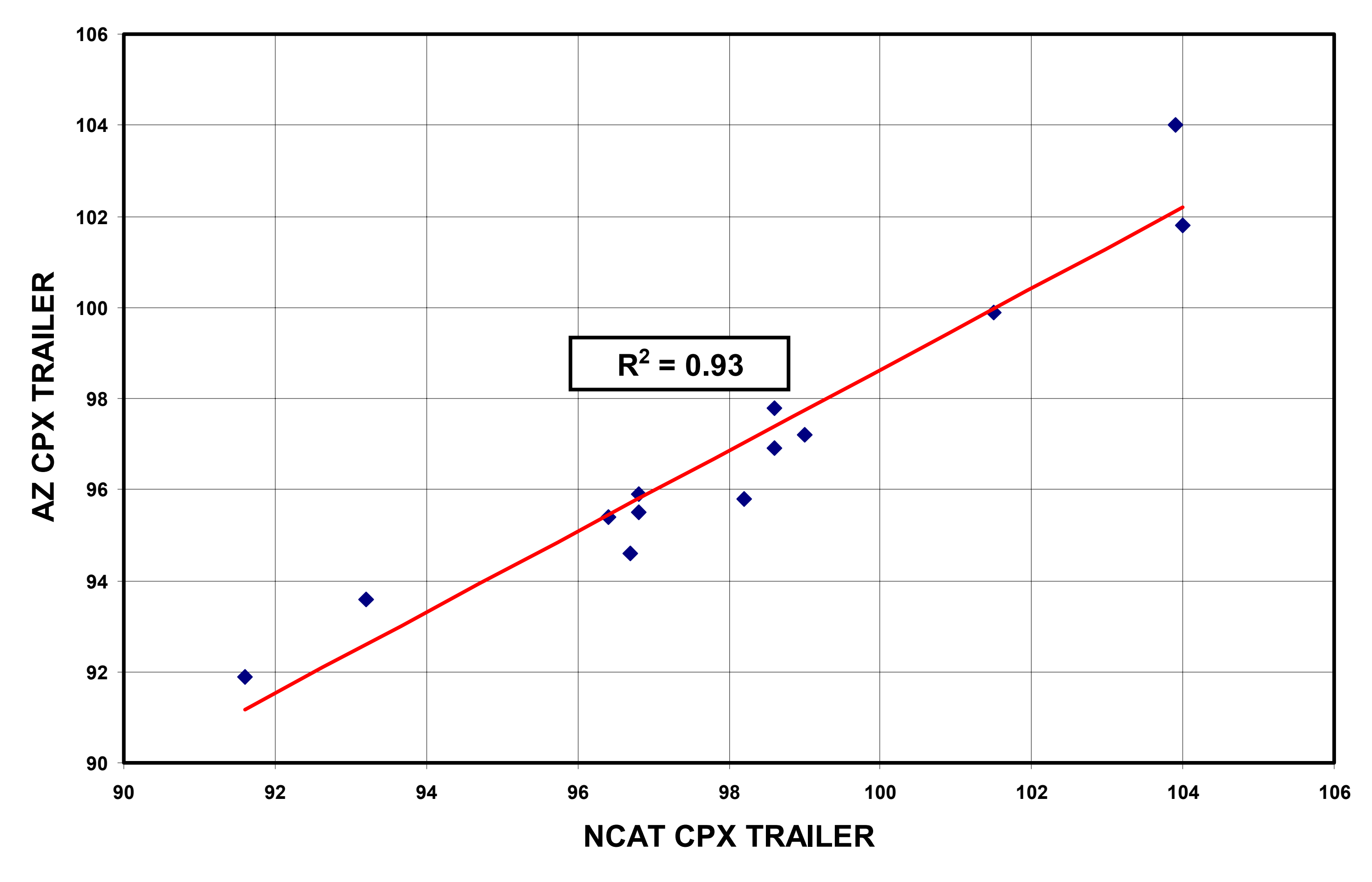


NCAT Close Proximity Noise Trailer

NCAT Trailer

- Advantages
  - Isolates tire/pavement noise
    - Great for comparing road surfaces
  - Efficient and inexpensive
  - Measures the road properties along extended length of road surface
- Disadvantages
  - Isolates tire/pavement noise
    - Cannot determine the quiet pavement benefits in communities – correlation with wayside measurements is being investigated
    - Single vehicle/tire type is represented

NCAT CPX Trailer

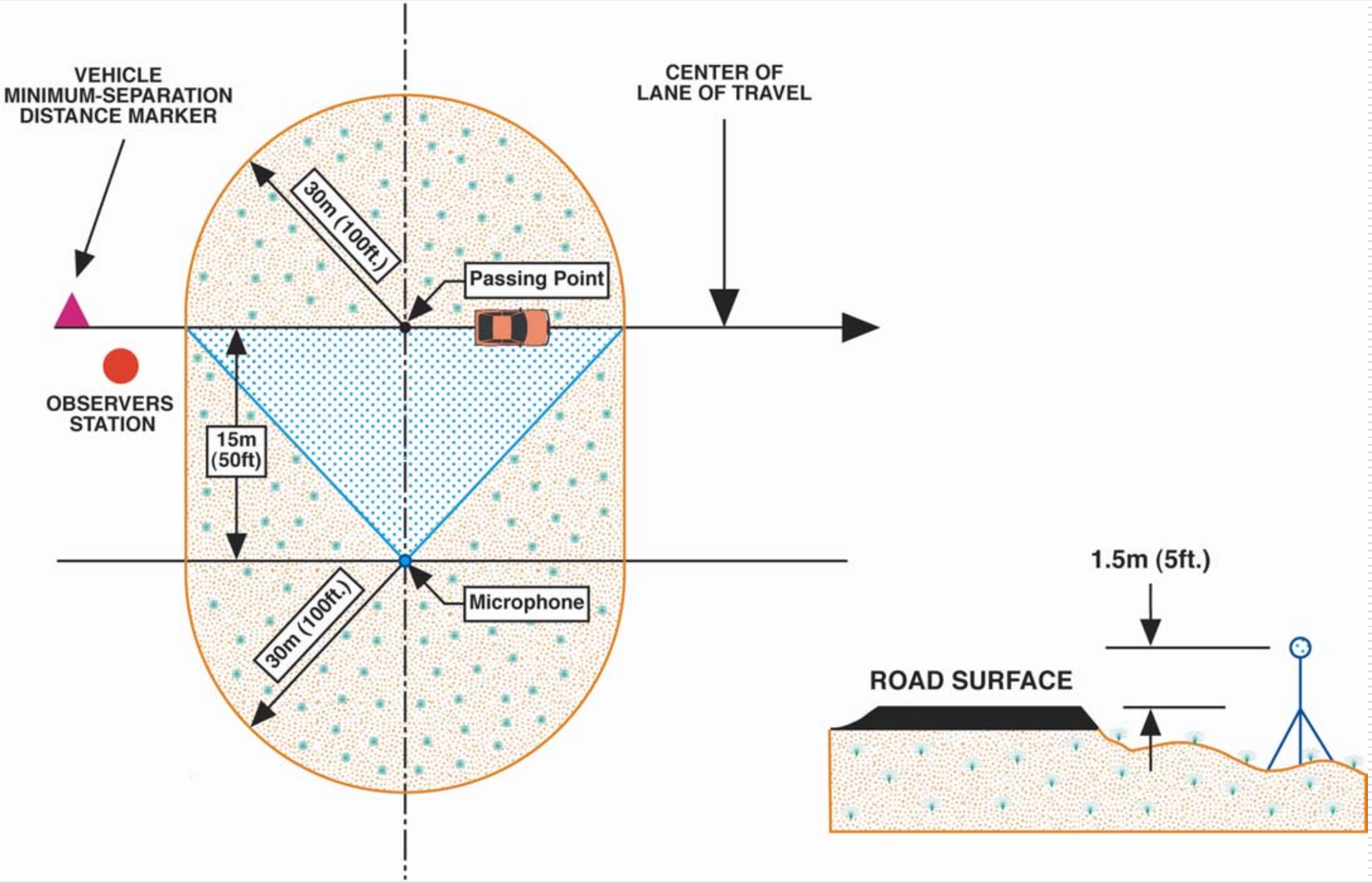


AZ CPX Trailer

Wayside measurements

- Statistical pass-by method
  - Based on measuring the noise level from a minimum of 180 single-vehicle passbys
  - Can compare pavements at different locations
  - Microphones generally set at 50 ft from roadway
- Controlled pass-by
  - Same as statistical pass-by but with limited number of vehicles
- Time-averaged method
  - Noise-level is measured continuously over a time period
  - Traffic counts & metrological data is needed

Wayside Measurements – Site Layout



Wayside measurements

- Advantages
  - Results account for mix of traffic
  - Results account for noise from all sources (tire, engine, exhaust)
  - Helps to determine enviromental effects & noise abatement policy

- Disadvantages
  - Time consuming and costly
  - Examines road properties at only one location
  - Strict measurement conditions (site geometry, traffic density, etc.)

Knowledge Gap

- Can the source measurements be correlated to the wayside measurements?
- Two preliminary studies have been done – they showed it could be done and the difference is about 23 dB(A)
- Thus, if the trailer measures 95 dB(A) – at 25 feet from the source the noise level would be 72 dB(A)
- More work is needed!!

Noise Characteristics of Pavement Surfaces

Pavements tested

- Locations
  - NCAT test track, Michigan, Alabama, New Jersey, Maryland, Colorado, Nevada, California, Arizona, Texas, Florida, Virginia
- Numbers of surfaces tested
  - Total – 244 surfaces
  - HMA – 201 surfaces
  - PCCP – 43 surfaces
- Currently conducting testing in –
  - Minnesota and Colorado

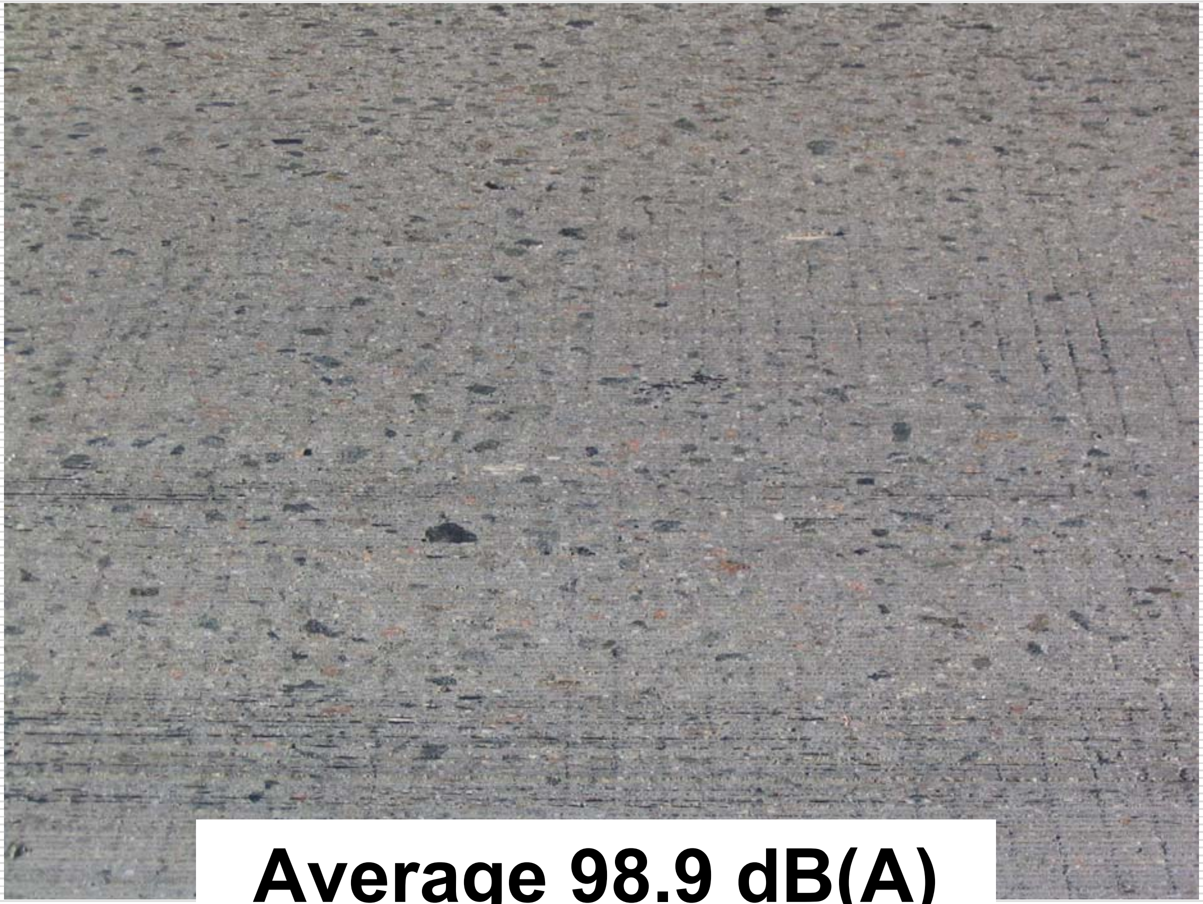
Transverse Tining

Average 103.6 dB(A)

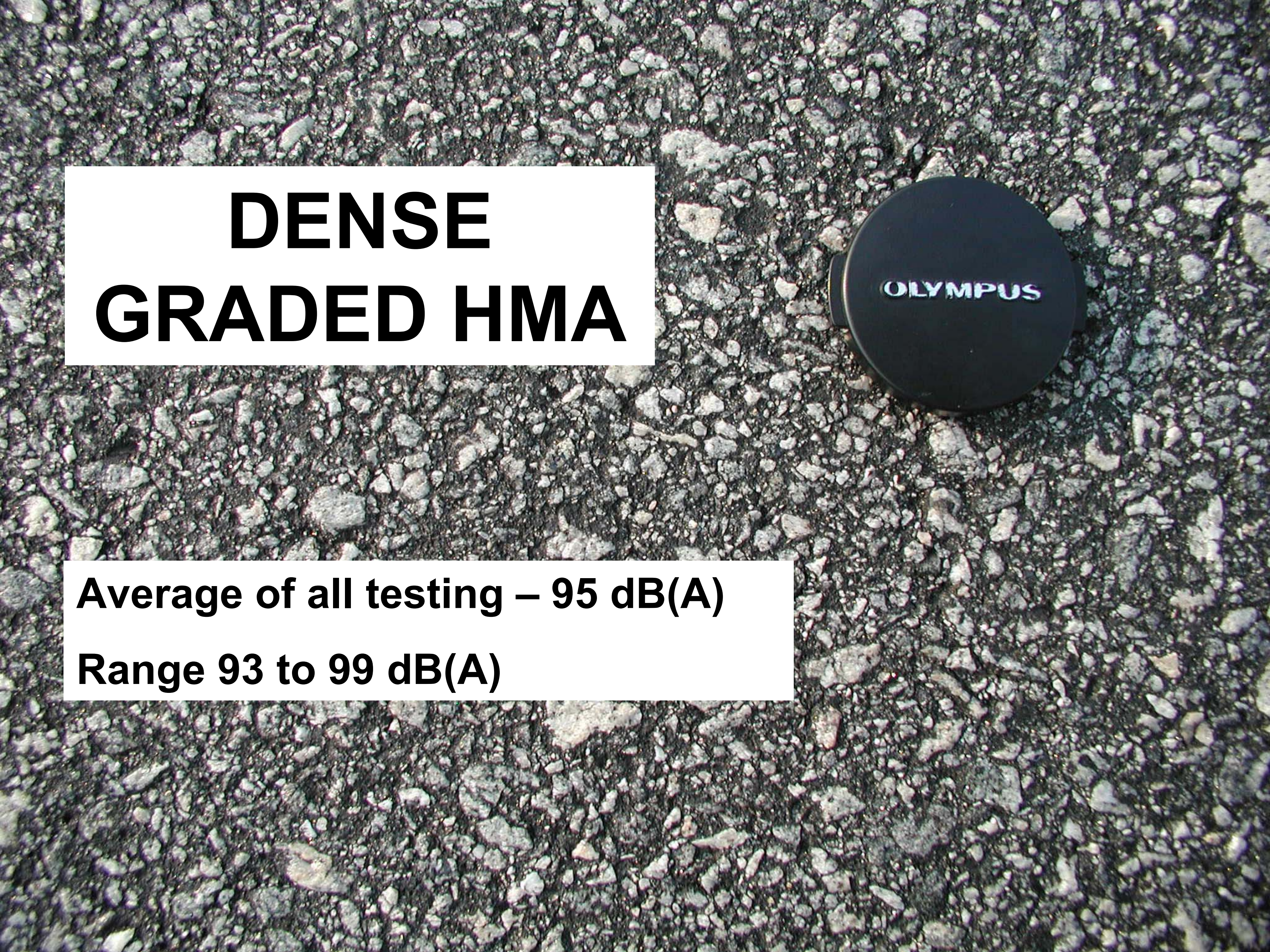
Longitundinal tining

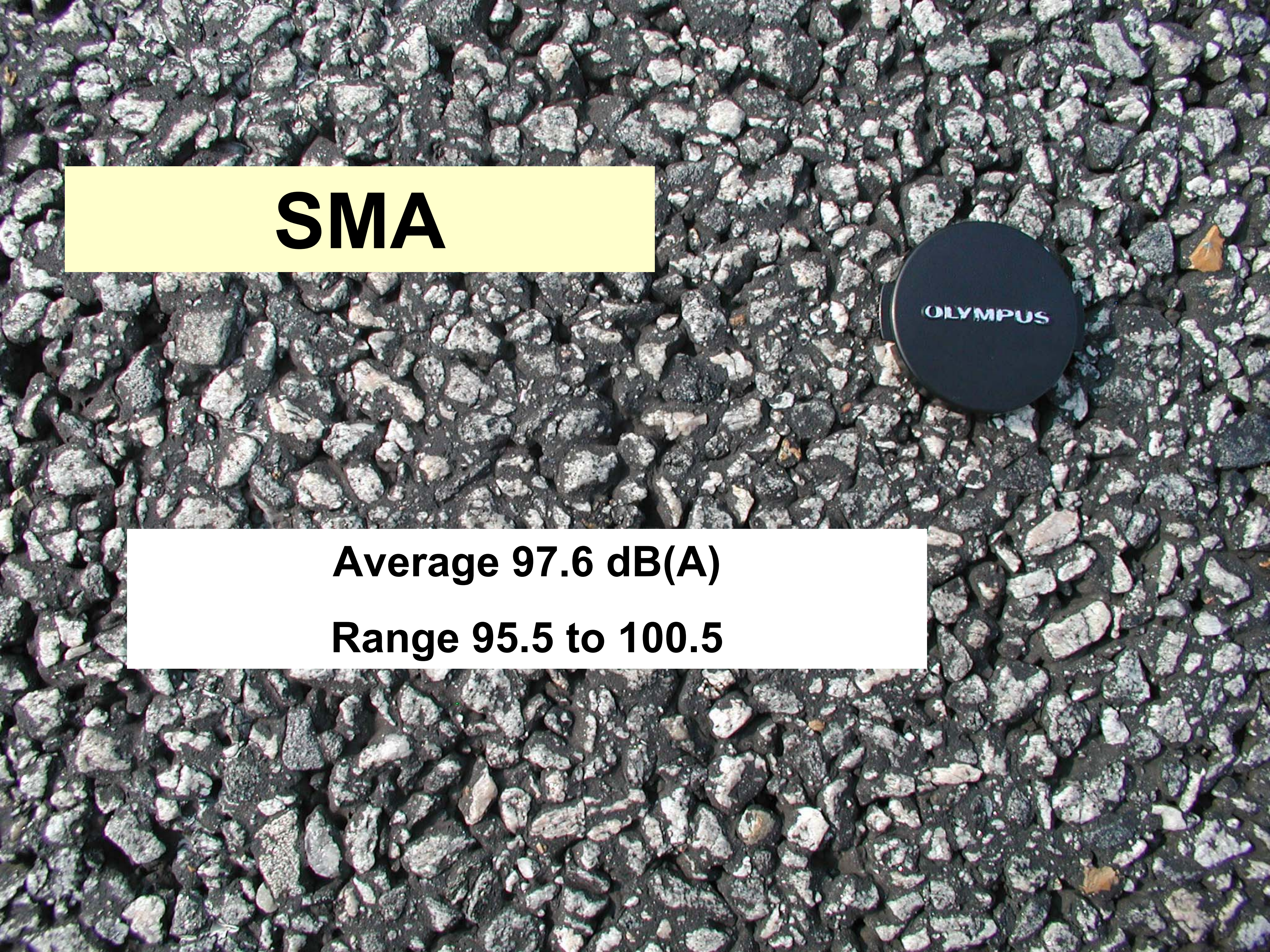
Average 99.6 dB(A)

Diamond Ground



Average 98.9 dB(A)


DENSE
GRADED HMA
OLYMPUS
Average of all testing – 95 dB(A)
Range 93 to 99 dB(A)


SMA
OLYMPUS
Average 97.6 dB(A)
Range 95.5 to 100.5

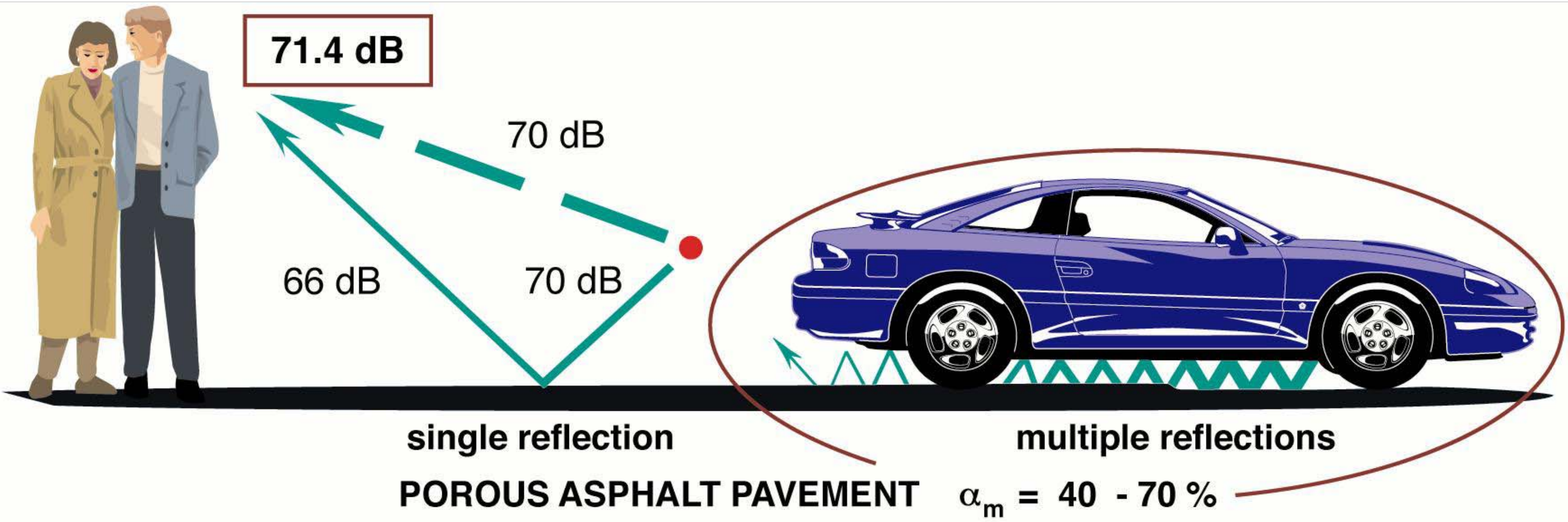
SMA

Route	State	Noise Level	Mix	Date Placed
MD 50	MD	95.5 dB(A)	9.5 mm	2002
I – 270	MD	97.7 dB(A)	12.5 mm	2003
I - 495	MD	98.9 dB(A)	12.5 mm	2003
I - 83	MD	99.0 dB(A)	19 mm	1994
US 50	CO	96.2 dB(A)	12.5 mm	2002
I – 70 W	CO	96.3 dB(A)	19 mm	2003
I – 225 N	CO	96.9 dB(A)	19 mm	2002
US 1	NJ	100.5 dB(A)	19 mm	-

The smaller the nominal maximum size of the aggregate the lower the noise level.


OGFC
OLYMPUS

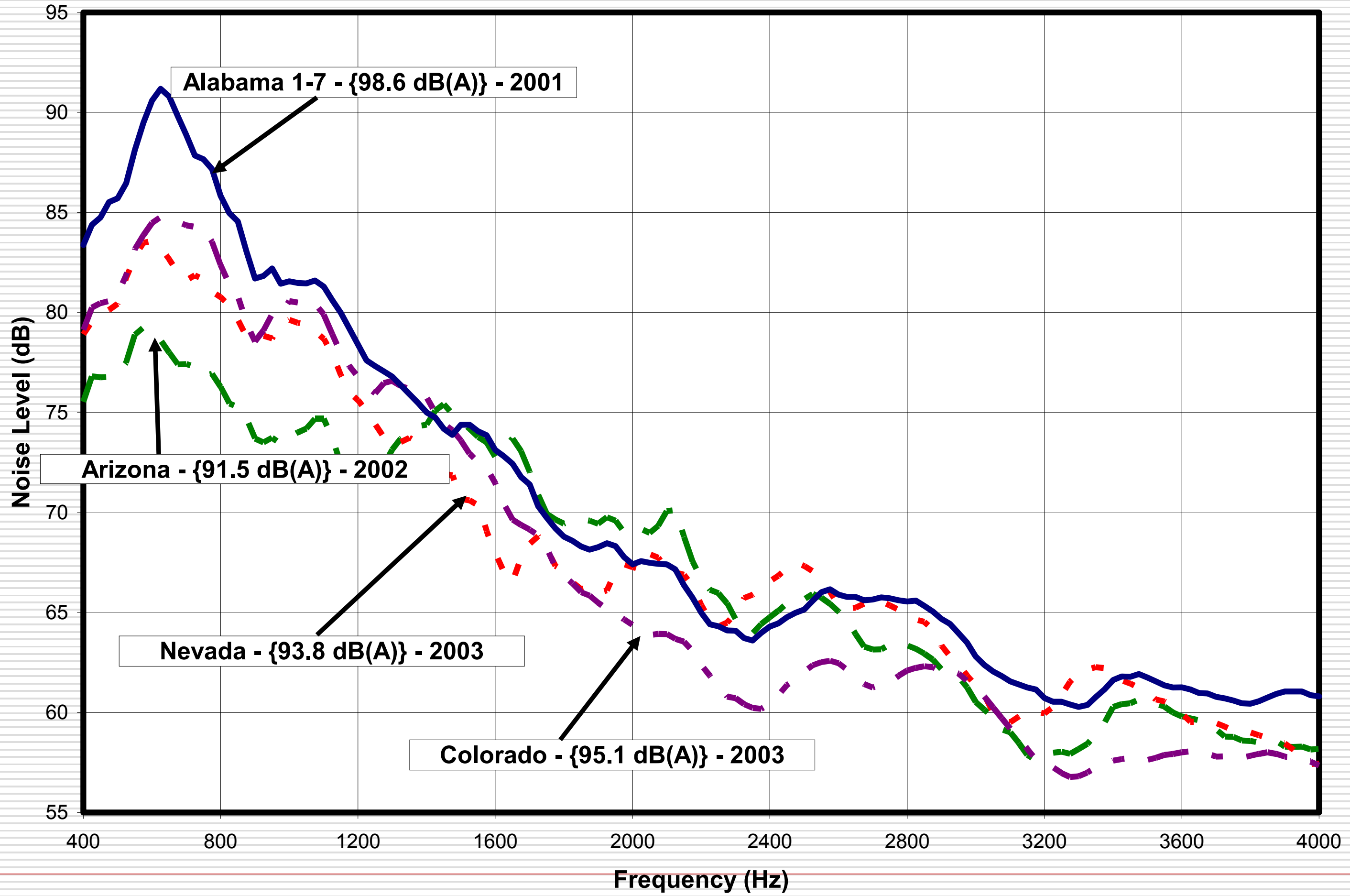
The OGFC Absorbs Part of the Sound Energy



Open Graded Mixes

- Alabama OFGC
  - Average: 97.2
  - Range: 95 to 98
- Nevada – No rubber
  - 1 yr – 93.7, 6 yr – 93.6, 8 yr – 93.8
  - 11 yr – 98.8
- Arizona – Rubber modified
  - Average: 92.0

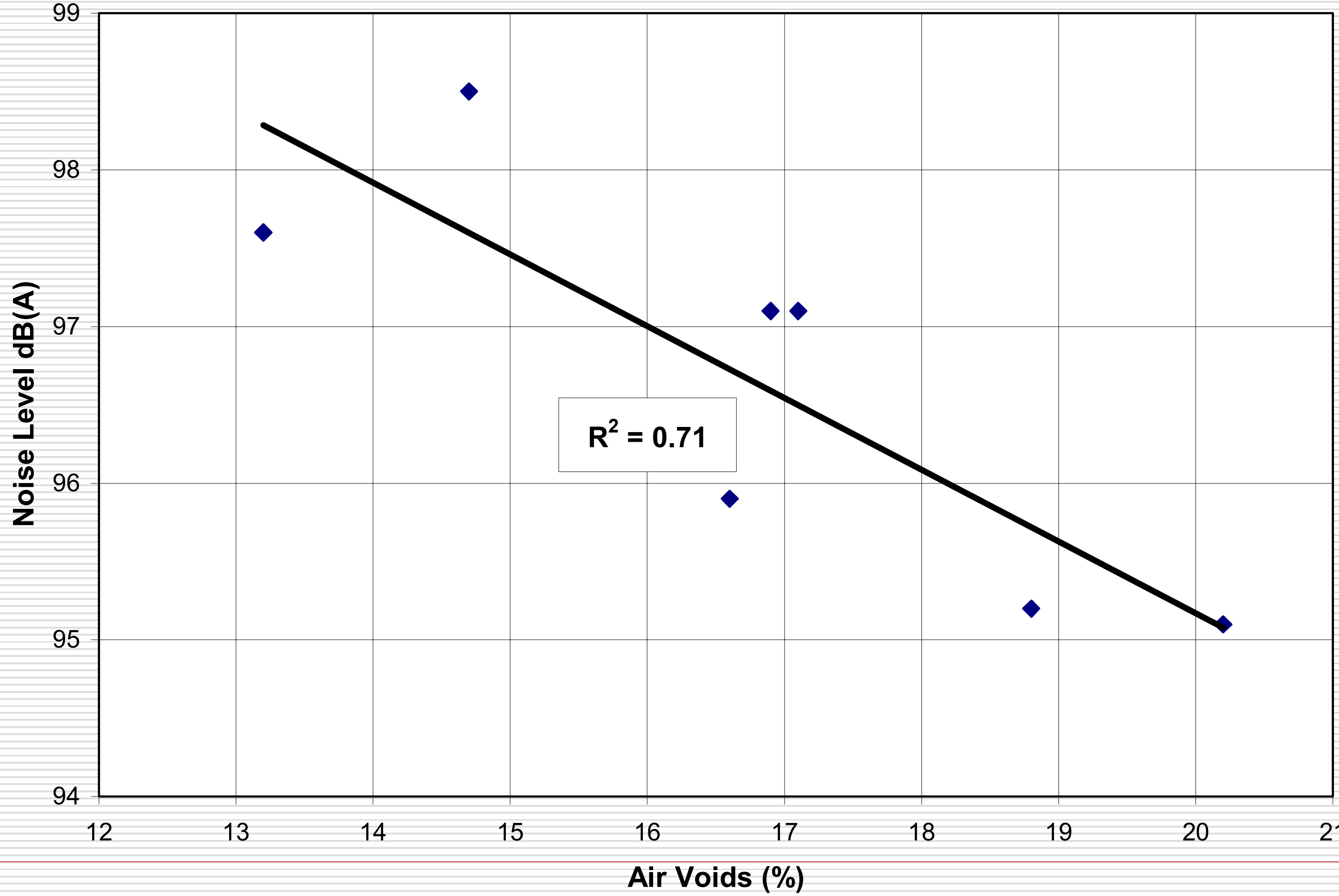
OGFC Comparisons



GRADATIONS

Gradation	Arizona[1]	Nevada[1]	Colorado[2]	AL 1 – 7[2]
¾ inch	-	-	100	100
½ inch	-	100	98	89
3/8 inch	100	95	64	56
No. 4	38	45	11	14
No. 8	6	-	8	9
No. 16	-	11	6	-
No. 200	1.2	2	3.3	3.2
Fineness Modulus	5.42	5.00	6.00	6.14
Air Voids	-	-	21 %	17 %
Noise Level	91.5	93.8	95.1	98.6

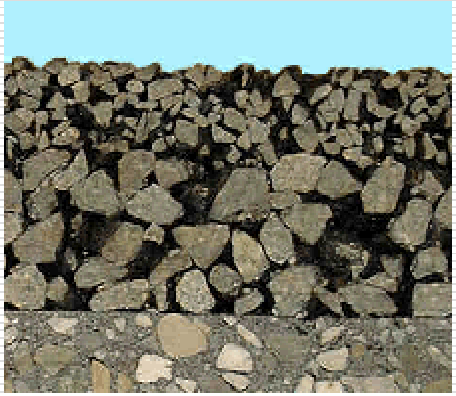
Effect of Air Voids on Noise (OGFC)



QUIET PAVEMENT - Europe

Two Layer Porous Asphalt

- 2.5 cm fine grade (top) 2/6 or 4/8 mm aggregate
- 4/5 cm course grade 11/16 mm aggregate (lower layer)
- 8-9 dBA quieter than conventional mixes
- 4 dBA quieter than single layer (high speed)
- Higher cost than single layer mix (25-35 %)



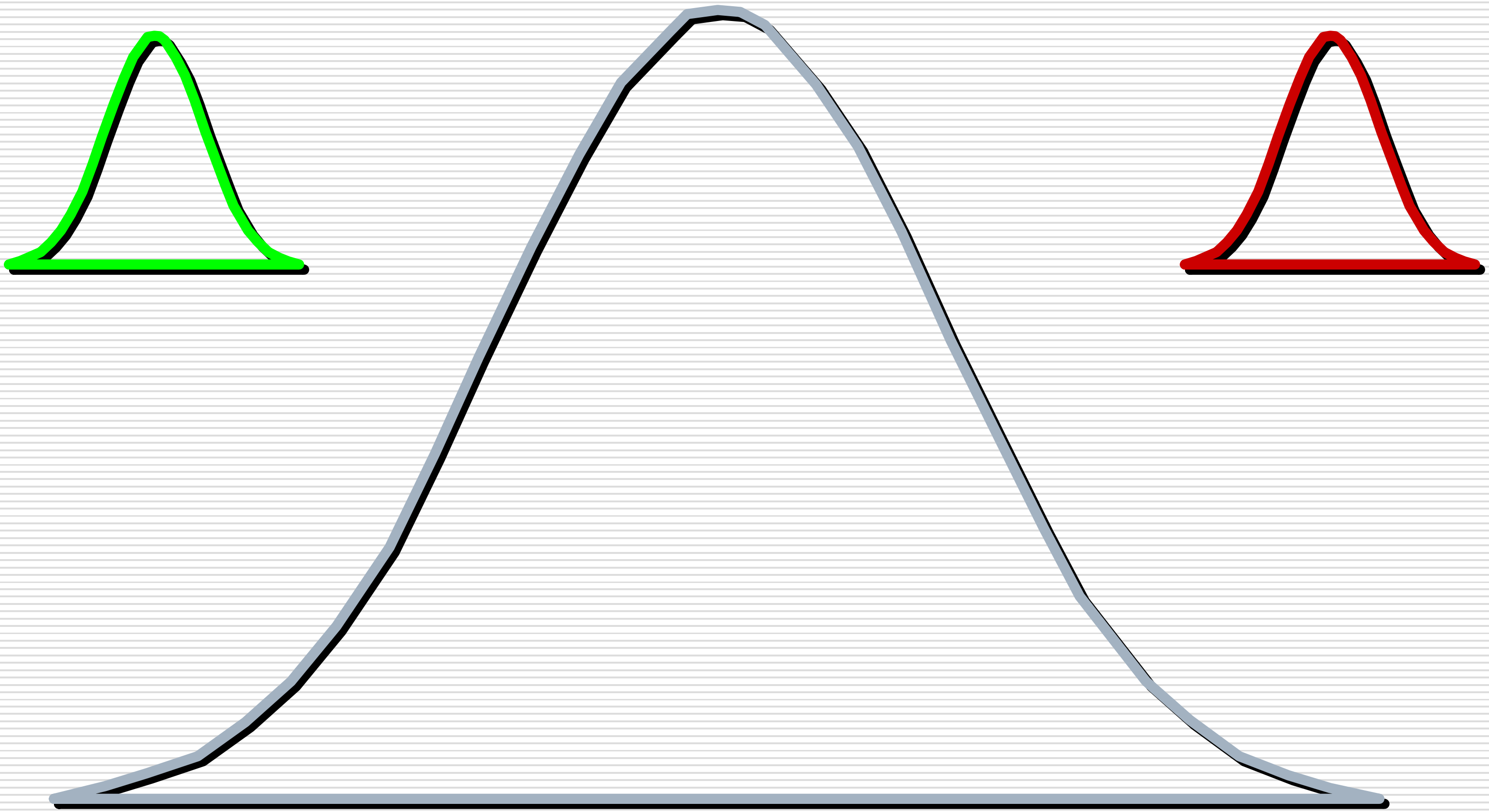
2.5 cm fine grade

4.5 cm coarse grade

Conclusions

- OGFC mixes reduce the high frequency noise
- The gradation of an OGFC affects the low frequency noise – the coarser the mix the higher the low frequency noise
- Based on European testing – thickness may also reduce low frequency noise

Variability on the Road

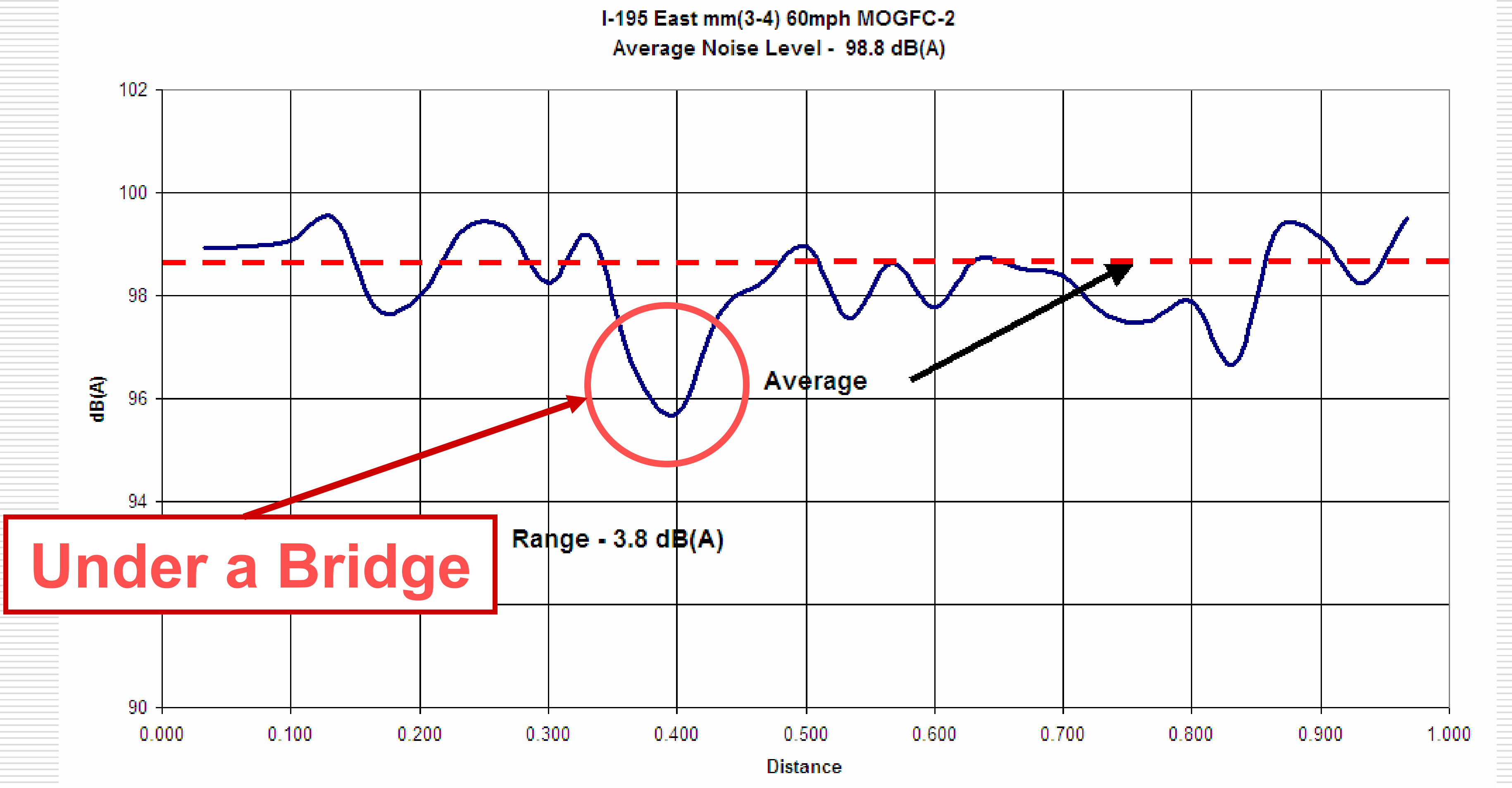


Typical variability

- HMA – Average variability over a one–mile section of roadway – 3.6 dB(A)

- PCCP – Average variability over a one-mile section of roadway – 4.4 dB(A)

MOGFC - 2



I-195 East mm(3-4) 60mph MOGFC-2
Average Noise Level - 98.8 dB(A)
102
100
98
96
94
90
dB(A)
0.000
0.100
0.200
0.300
0.400
0.500
0.600
0.700
0.800
0.900
1.000
Distance
Average
Range - 3.8 dB(A)
Under a Bridge

Pavement Under Bridge

Conclusions

- The noise level of a highway is a lot more variable that most folks doing noise testing understand it to be.
- This variability needs to be considered when doing side line measurements
- You can pick – low or high noise areas depending on what you want to prove

Effect of Age on Noise

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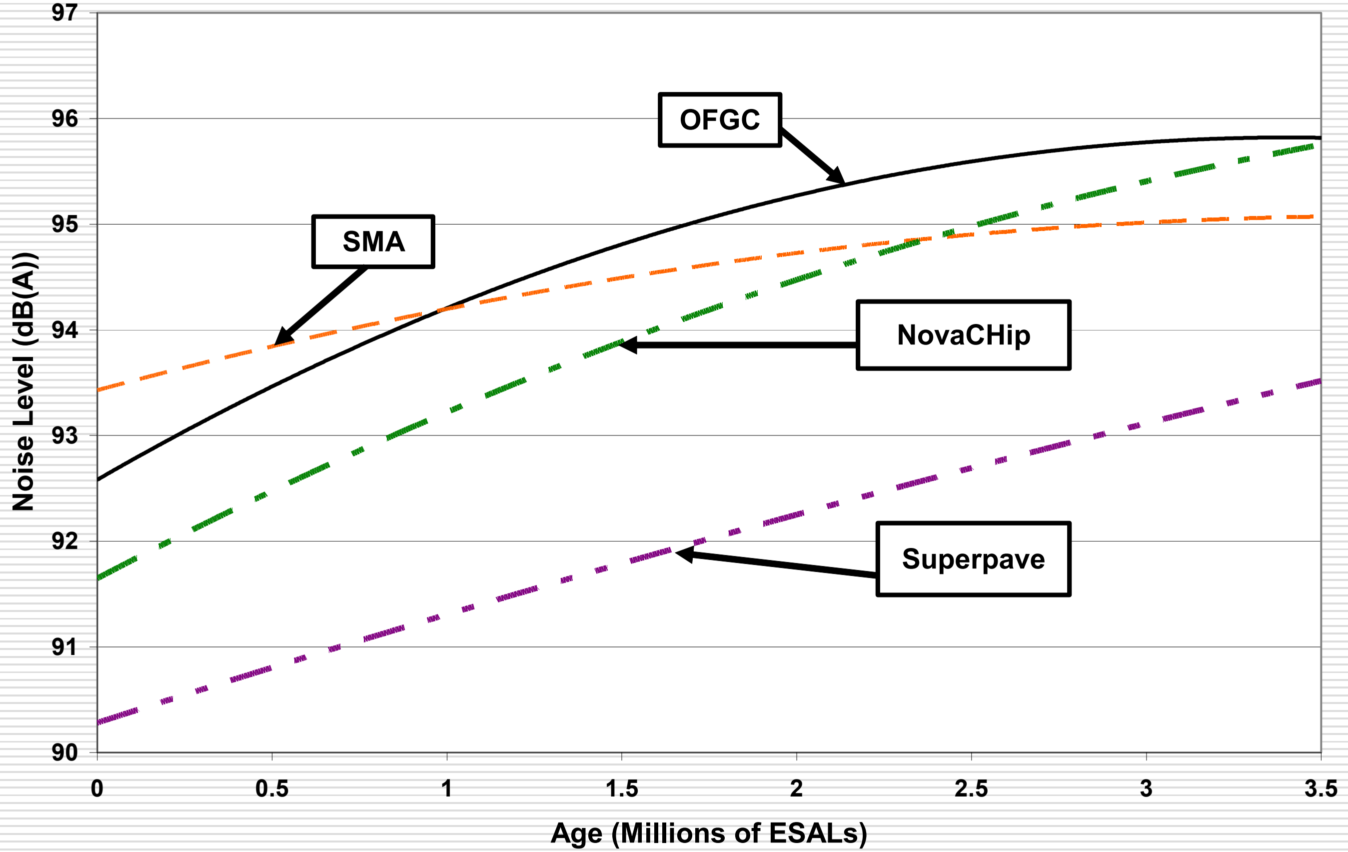
Test Track



97
96
95
94
93
92
91
90
Noise Level (dB(A))
0
0.5
1
1.5
2
2.5
3
3.5
Age (Millions of ESALs)
OFGC
SMA
NovaCHip
Superpave

What Makes a Difference?

Texture

- Maximum aggregate size
- Negative (rolled) surface

Voids

- More is better

Thickness

- Thicker is better


SR 101W ARFC
11/6/03 91 dB(A)
27th
Ave


27th
Ave
NCAT


NCAT

Questions ?