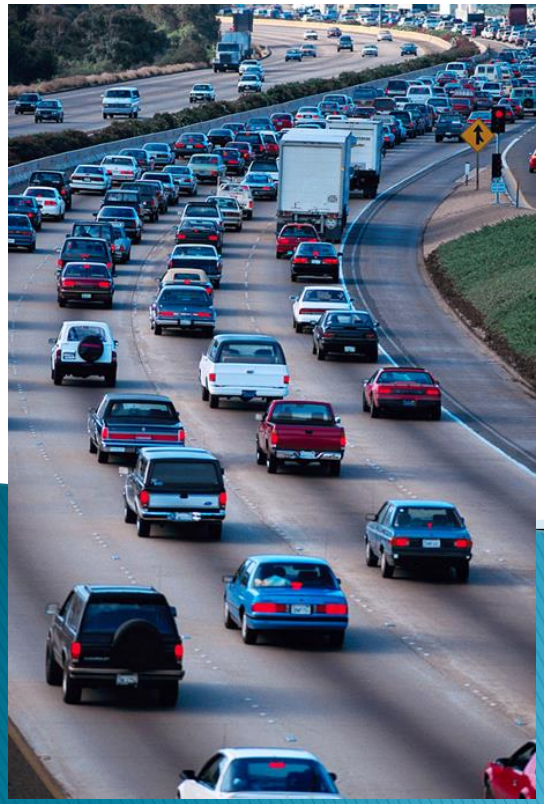
Acoustical Engineering Solutions

Transportation Noise Control in Residential Buildings

(Pssst: It's all about the windows)



Scott Harvey, PE

Thank you for attending!

Copyright Materials

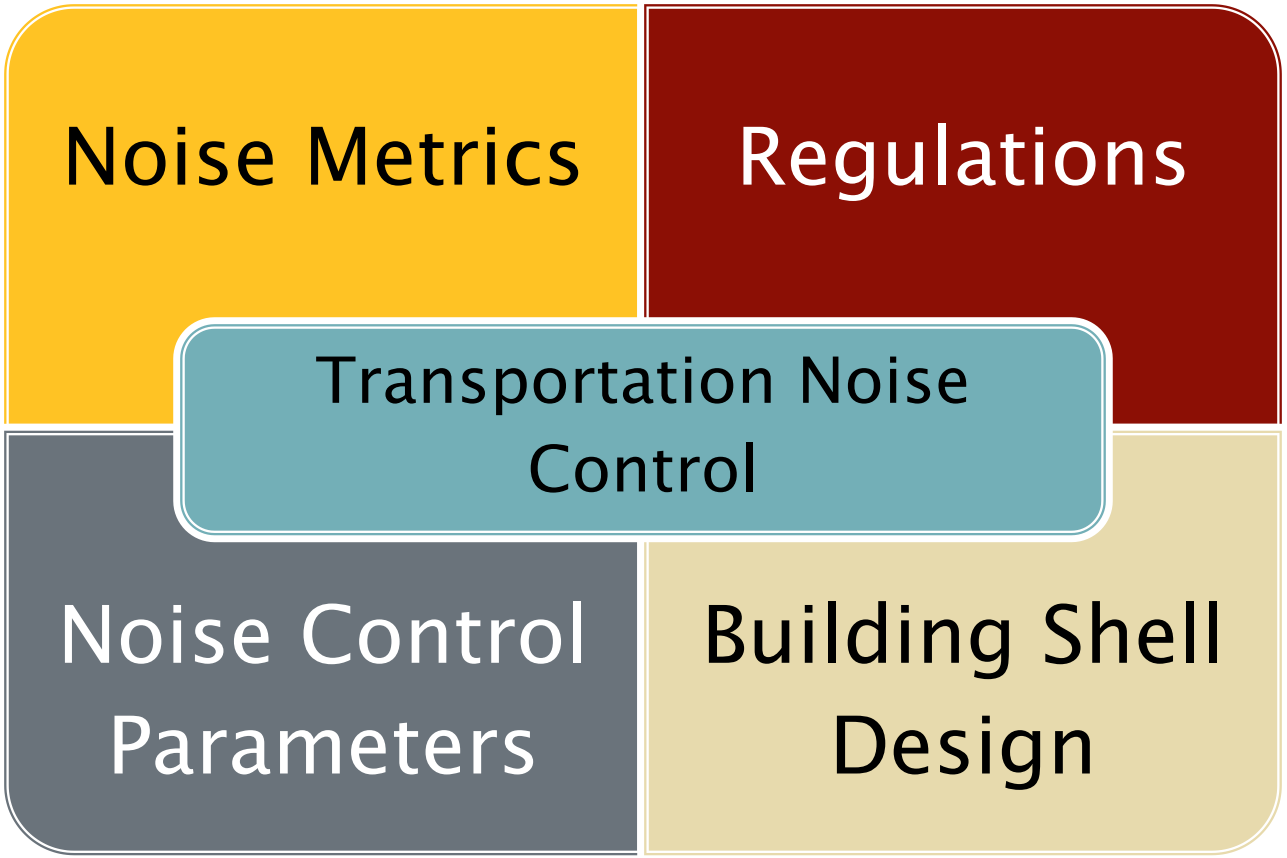
- This presentation is protected by US and International Copyright laws. Reproduction, distribution, display and use of the presentation without written permission of the speaker is prohibited.

PHOENIX
noise & vibration

Learning Objectives

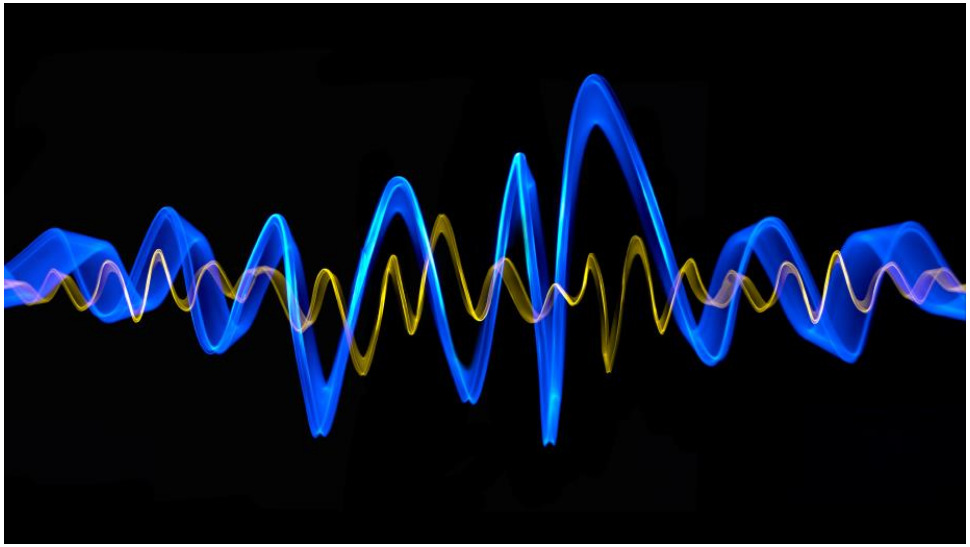
- At the end of this program, participants will be able to:

1. Define basic noise metrics
2. Understand local transportation noise regulations
3. Identify primary building shell noise control parameters
4. Incorporate fundamental noise control techniques in building design


Noise Metrics
Regulations
Transportation Noise Control
Noise Control Parameters
Building Shell Design

Basic Acoustics

- What is sound?
  - “Any pressure variation (in air, water or other medium) that the human ear can detect.” B&K



Basic Acoustics

- What is Noise?
  - Noise is Unwanted Sound (aka my neighbor's home theater)

Basic Acoustics

- How is noise quantified
  - Amplitude or loudness
    - Variation in the air pressure around us
    - The bigger the variation, the louder the sound
  - Frequency or pitch/tone
    - How quickly we vary the pressure
    - The quicker the variation, the higher the tone

Basic Acoustics

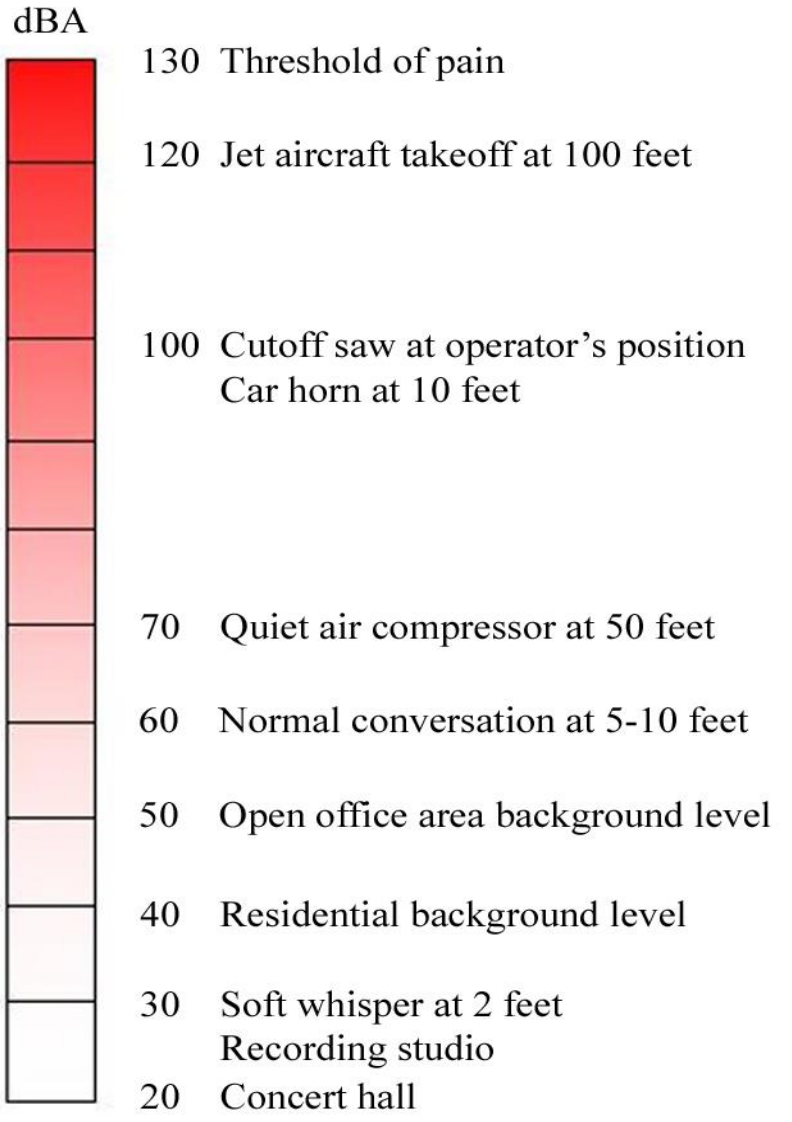
- Loudness measured in decibels (dB)
  - $dB = 10 \times \log(Pressure^2/refPressure^2)$
  - From this we observe:
    - logarithmic
    - simply a comparison between two numbers
- Human Range: 0 to 130 dB

Why the dB Scale?

- Reduces the broad range of numbers to a manageable range of numbers.
  - Humans hear from 20 to 20,000,000 micro-Pascals*…
  - In decibels, this is reduced to a range of 0 to 120 dB.

*1 Pascal = 0.000145 psi

Examples of Common Noise Levels



Source: "Environmental Noise: The Invisible Pollutant", William Cavanaugh and Gregory Tocci

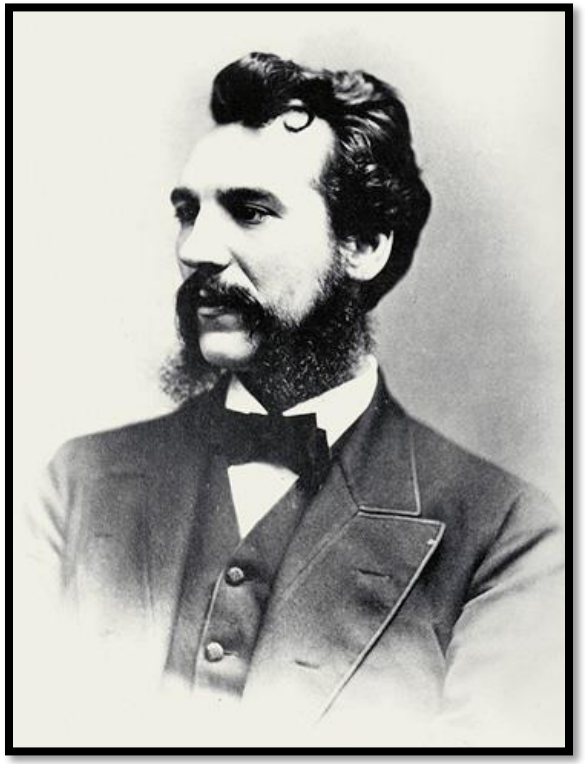
Why the dB Scale?

- Eases Comparisons
- Example of the logarithmic nature:

Change in dB	Subjective Response
3 dB	Barely Perceptible
5 dB	Clearly Perceptible
10 dB	Twice as Loud

Fun Fact

The decibel named after Alexander Graham…

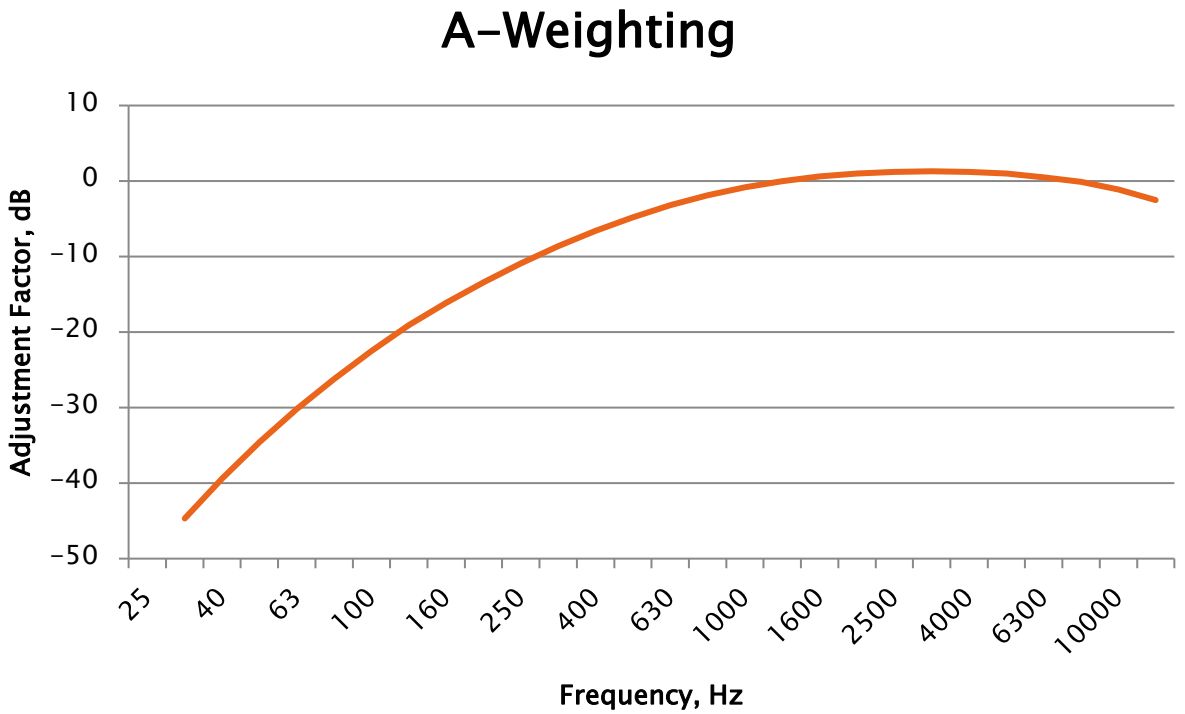


Humans aren't perfect….

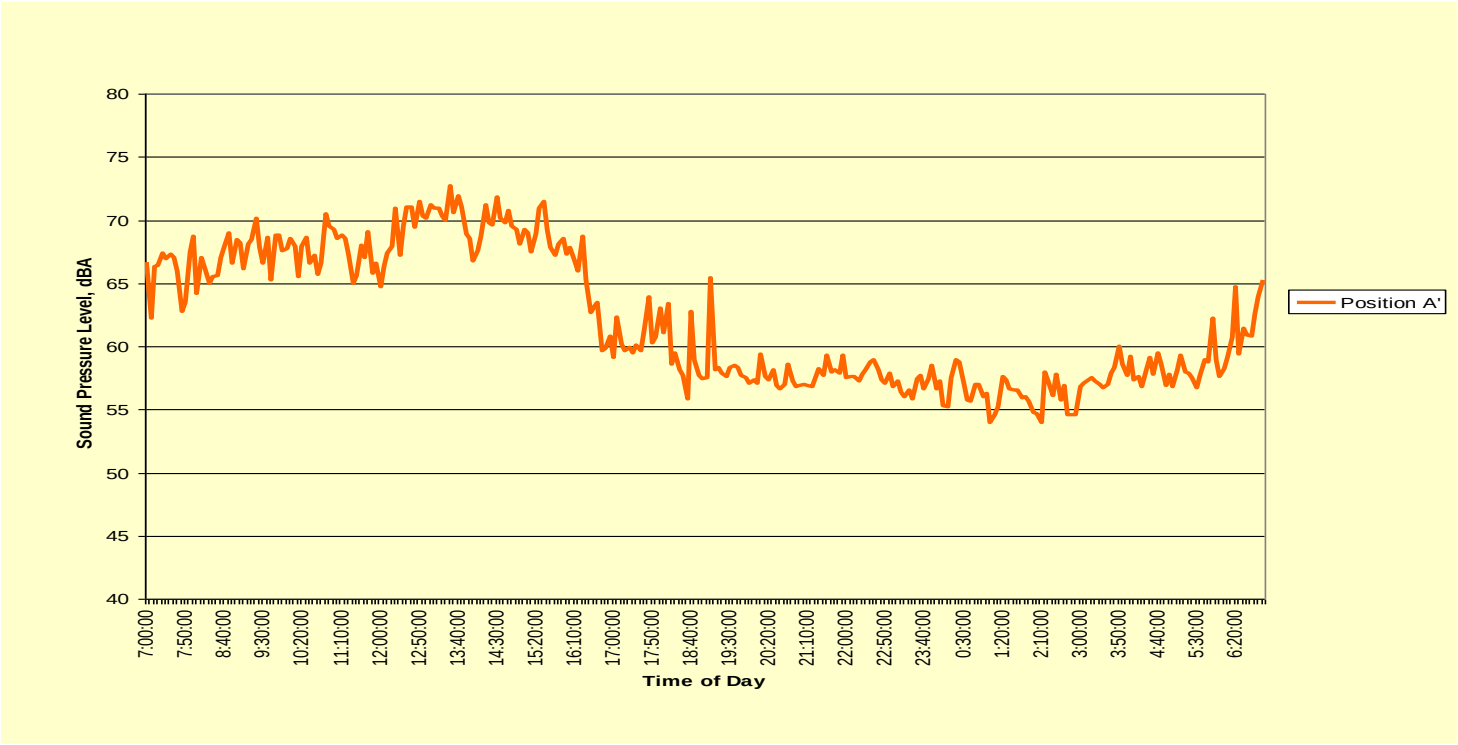
- To compensate for our inability to hear perfectly we:
  - Adjust measurements to simulate human hearing
  - This is referred to as "A-weighting"
  - Nomenclature: dBA

Measuring Units

- Typically measured using the “A-weighted” dB scale or “dBA”
- The A-weighting simulates human hearing and is generally used for overall, environmental noise measurements.



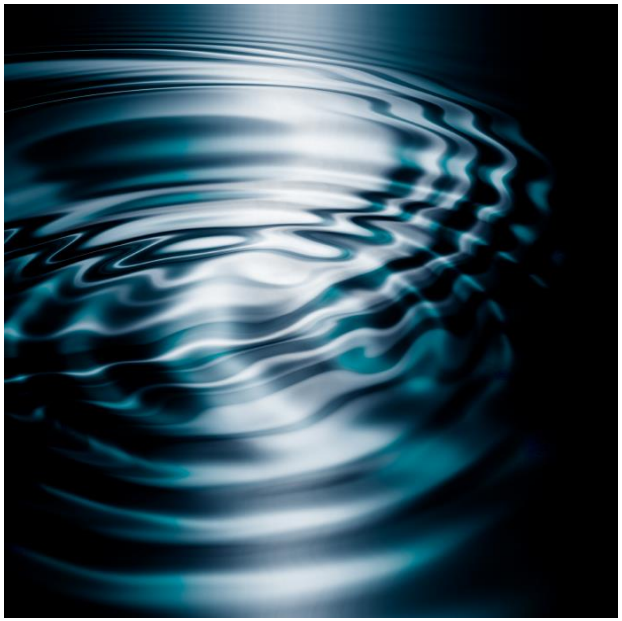
Noise Levels Vary with Time



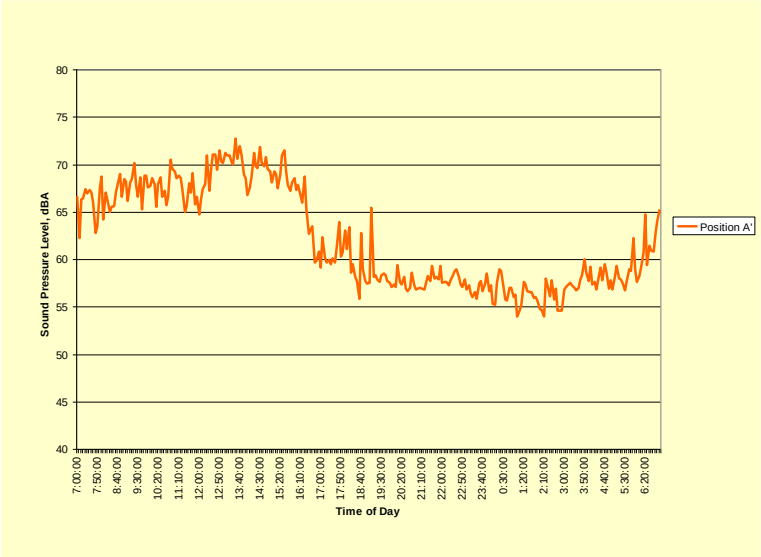
- Traffic noise varies throughout the day
- Can be difficult to analyze

So we measure, but we also average

- Since noise levels from transportation sources vary with time we generally average the level over a fixed period and in some cases adjust the average further.



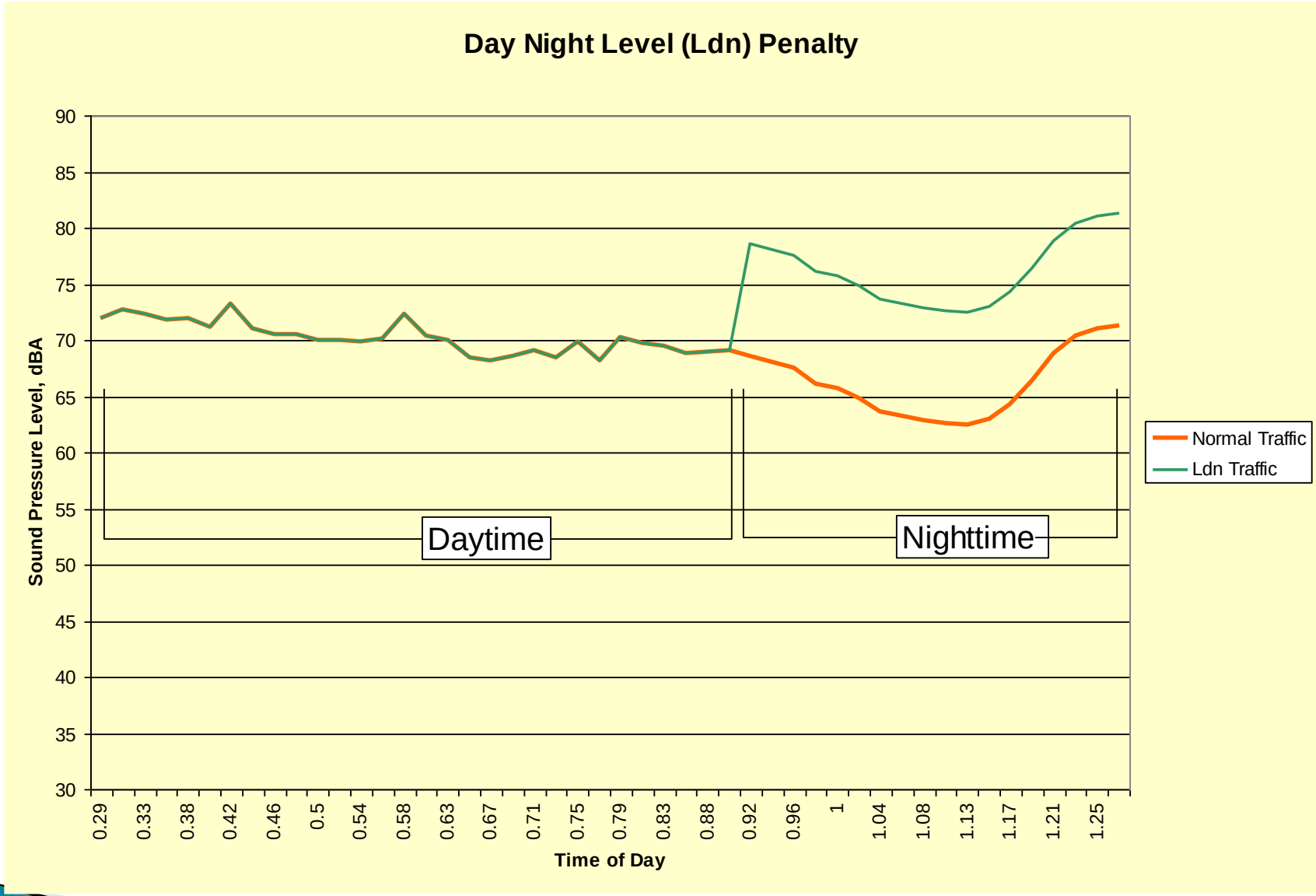
Average to Simplify



= 65.4 dBA

But Wait…..

- More than just straight average
- DNL accounts for higher sensitivity at night by penalizing nighttime hours.


Day Night Level (Ldn) Penalty
Sound Pressure Level, dBA
90
85
80
75
70
65
60
55
50
45
40
35
30
Daytime
Nighttime
0.29
0.33
0.38
0.42
0.46
0.5
0.54
0.58
0.63
0.67
0.71
0.75
0.79
0.83
0.88
0.92
0.96
1
1.04
1.08
1.13
1.17
1.21
1.25
Time of Day
Normal Traffic
Ldn Traffic

24 Hour Terminology

- "Day Night Average Noise Level"
  - DNL or Ldn
  - Measured in dBA

Example: 72 dBA, Ldn
or
"a DNL of 72 dBA"

24 Hour Average

- Considers full 24 hour time period
- SENSITIVE TO NOISE AT NIGHT AND EARLY MORNING
- Typically Used for evaluation of Transportation Noise

Regulations

Transportation Noise Control

Two basic ways to evaluate transportation noise…

…

1. Peak hour Leq – the average noise level during the peak noise hour. (Leq(h))

2. Day/Night Average – the average over a 24-hour period with 10 dB penalty during nighttime hours. (Ldn or DNL)

Who Does What?

Peak Hour

- FHWA
- MDSHA
- VDOT
- Howard Co
- Loudoun Co
- Anne Arundel Co

24 Hour

- All Airport Noise
- Fed. Railway Admin.
- HUD
- City of Alexandria
- Fairfax Co
- Montgomery Co
- Prince George's Co

What's "Too Loud?"

Most Say Outdoor Levels…	
<65 dBA	Acceptable
65 – 75	Normally Unacceptable (requires mitigation)
>75 dBA	Unacceptable (no build condition)

Funny, these apply to both Leq(h) and Ldn standards

Recommended Indoor Levels

- Indoor noise <= 45 dBA
  - Accepted by most jurisdictions

Outdoor to Indoor Reduction

- Typical residential construction in today's market reduces outdoor noise levels by approximately 20 dBA.

- So….

$$65 - 20 = 45 \text{ dBA}$$

More on this later…

Transportation Noise Control

Noise Control Parameters

Sound Transmission Class (STC):

- A single number rating used to compare the sound insulation properties of walls, floor, ceiling, windows, or doors.

- In other words,

"How well does a building element block out the sound."

STC

- Higher STC rating indicates it blocks out more noise
- Calculated based upon sophisticated noise measurements
- Based upon the decibel (dB) scale
- So yes, its logarithmic too.

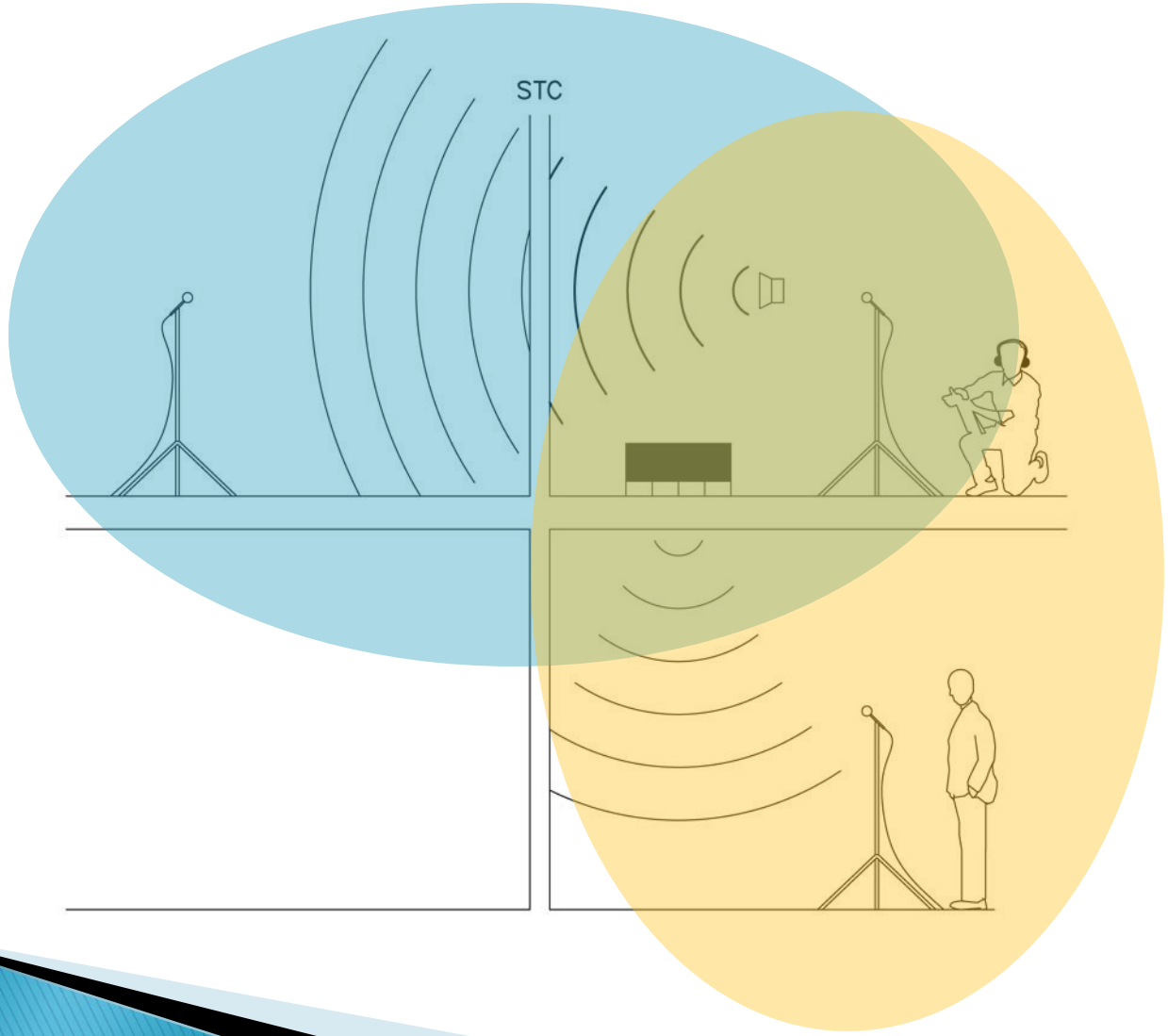
Confusing Because….

- STC developed for speech BUT applied to many other noise sources such as:
  - Mechanical
  - Transportation
  - Music

The weird thing is…

- STC works pretty well for transportation noise, especially traffic noise.

How it's measured



Barrier vs. Absorbers

- There are noise barriers and there are noise absorbers.
  - Barriers are not absorbers.
  - Absorbers are not barriers.
  - Many times the absorber is somewhat transparent.

- Good barriers are generally composed of dense, heavy material layers or lighter layers separated by an air space.

Good building shell materials

- Brick or other masonry
- Fiber Cement Panels (Hardie planks)
- Laminated glass panels

- Note: Heavy & dense

Not so good building shell materials

- Vinyl siding
- EFIS
- Thermo-ply
- Structural Insulated Panels (SIP)
- Single paned windows (historical buildings)

- Note: lightweight

STC

STC		Subjective Description
30		Most sentences clearly understood
40		Speech can be heard with some effort
50		Loud speech can be heard with some effort
60		Loud speech essentially inaudible
70		Loud music heard faintly
75+		Most noises effectively blocked

Credit: *Architectural Acoustics: Principles and Design* 1999

OITC

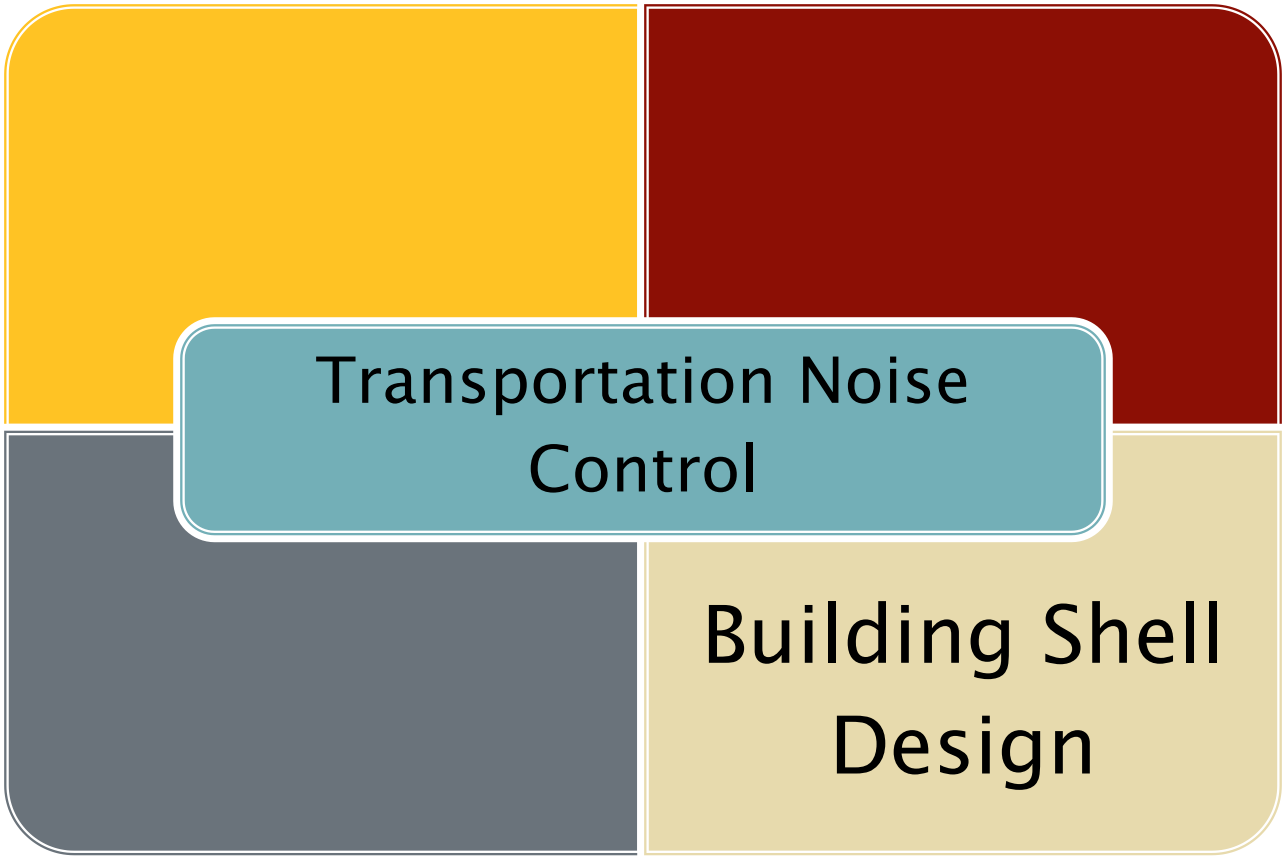
- Outdoor-Indoor Transmission Class: an A-weighted single number rating of the **transportation** sound reduction effectiveness of a partition that separates an indoor space from the outside.
- STC – Speech Frequencies
- OITC – Transportation Frequencies

Window	STC Rating	OITC Rating
½" Insulated	28	26
5/8" Laminated, Insulated	35	31

Note!

$$STC \neq OITC$$

The weird thing is, STC actually works better than OITC for transportation noise because of some flaws in the OITC method.


Transportation Noise Control
Building Shell Design

Building Shell Analysis

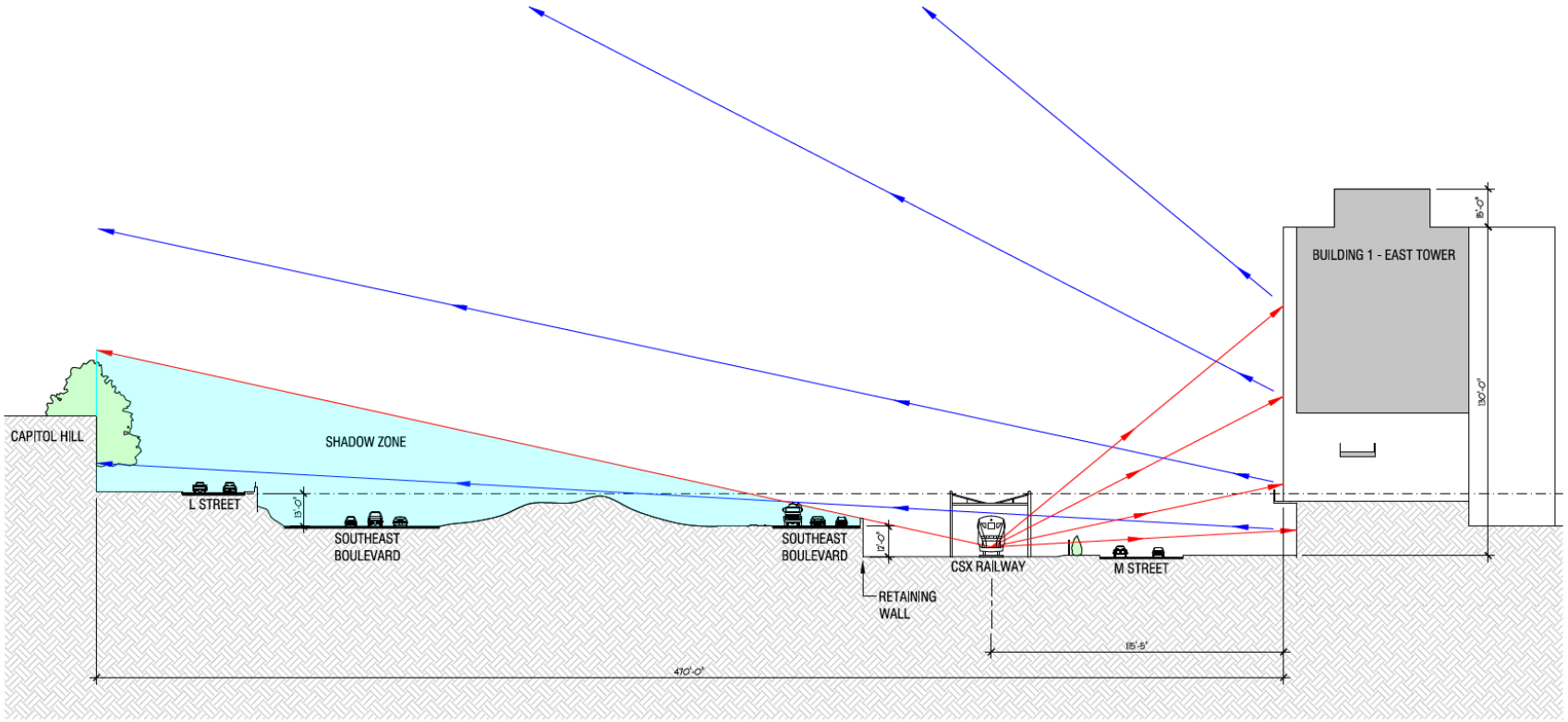
- Buildings can be designed to meet a certain interior noise level based upon expected outdoor noise level

Steps to Building Shell Analysis

1. Determine level of impact…how loud is it?
2. Analyze proposed structure.
3. Determine interior noise level.
4. Modify as necessary.

Determine level of impact

Measure and/or Model


CAPITOL HILL
SHADOW ZONE
L STREET
15'-0"
SOUTHEAST
BOULEVARD
SOUTHEAST
BOULEVARD
12'-0"
RETAINING
WALL
CSX RAILWAY
M STREET
BUILDING 1 - EAST TOWER
15'-0"
130'-0"
115'-5"
470'-0"

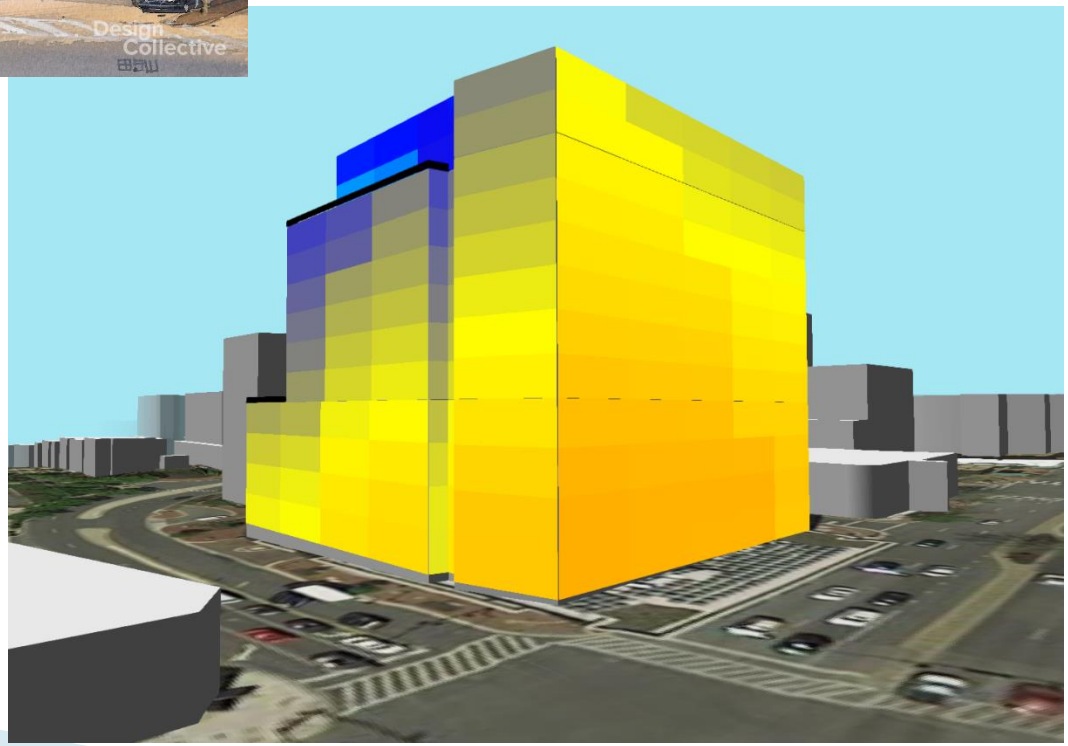
Noise Level Measurements

- Noise levels measured in decibels or “dBA”
- Measure using Sound Level Meter
- Only determines impact in one location

Computer Model

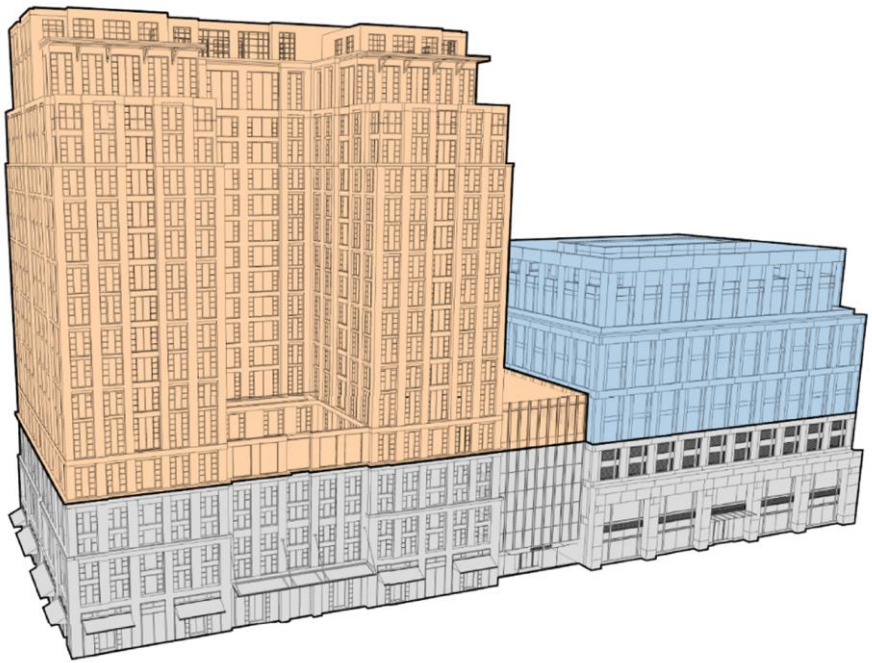
- Model determines noise levels in multiple locations
- Modeling accounts for future building shielding
- Measurements can be used to validate the model.


Design
Collective



Analyze Structure

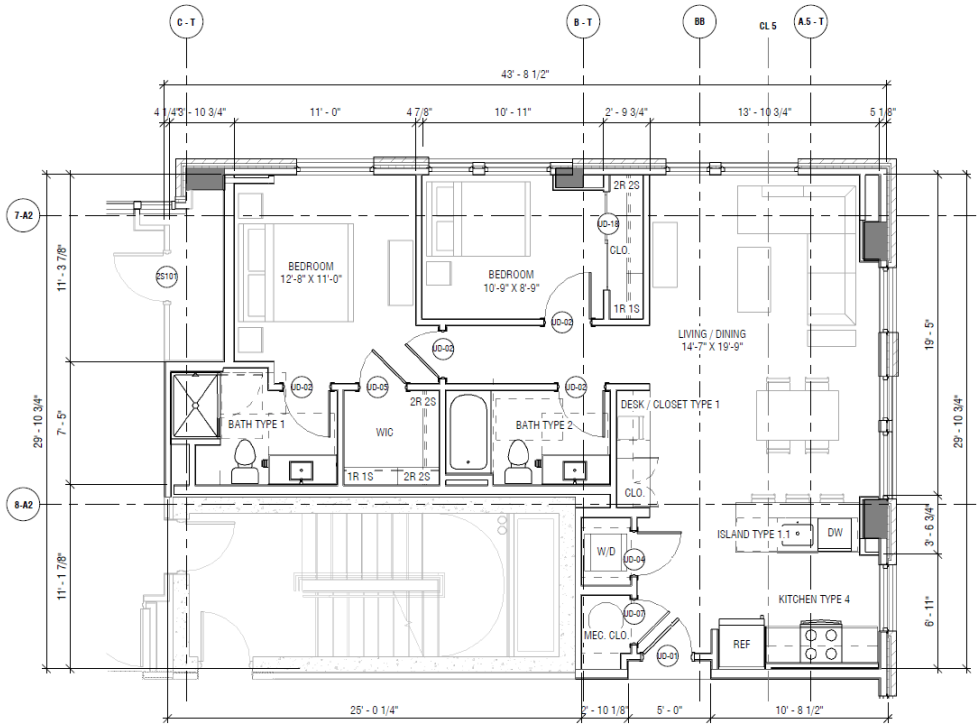
- Outdoor to indoor noise reduction is dependent upon
  - Exterior surface area
  - STC rating of exterior elements
  - Interior room volume
  - Room absorption

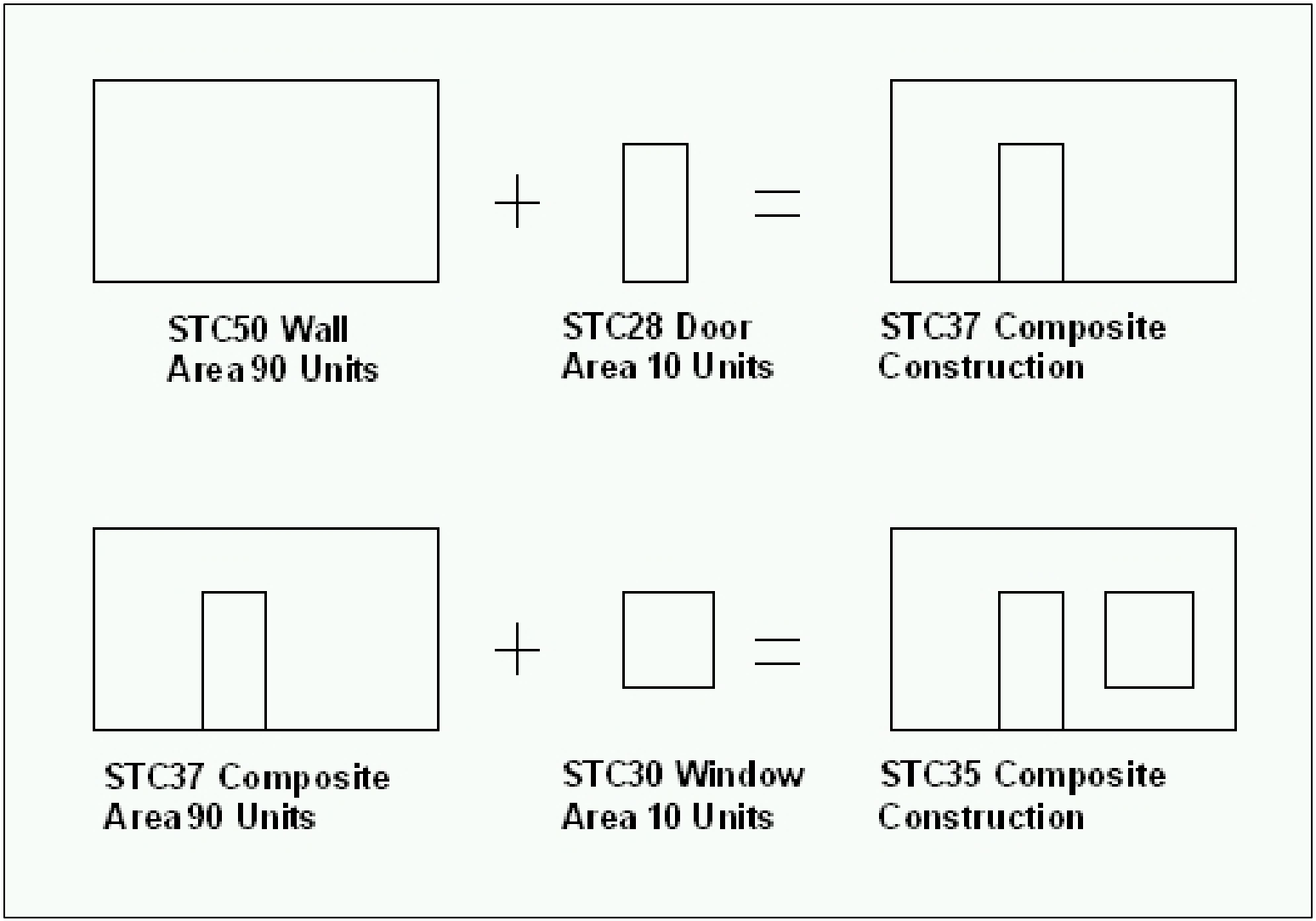


Exterior Surface Area

Room Parameters

- Gather STC of each element
- Determine exterior surface area of every element (walls, windows, doors)
- Calculate the composite STC of each room facade



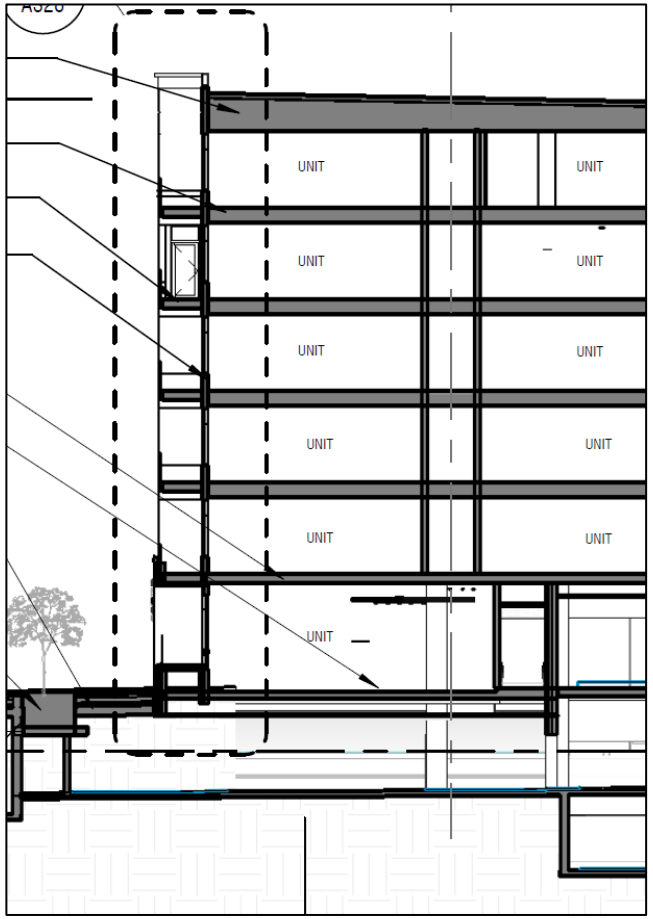

STC50 Wall
Area 90 Units
STC28 Door
Area 10 Units
STC37 Composite
Construction
STC37 Composite
Area 90 Units
STC30 Window
Area 10 Units
STC35 Composite
Construction

Common Building Elements

Building Element	STC Rating	Construction
Exterior Walls Brick Vinyl Siding Vinyl Siding w/RC	 56 39 45	2 x 4 wood studs, an exterior layer of ½" OSB or plywood, 3" of fiberglass batt insulation, 5/8" interior layer of drywall
½" Insulated Window	28	1/8" glass, ¼" air space, 1/8" glass
1" Insulated Window	35	¼" glass, ½" air space, ¼" glass
5/8" Laminated, Insulated Window	35	Two 1/8" panes laminated together, ¼" air space, 1/8" glass
Standard Patio Door	29	½" thick glass lite mounted in polystyrene frame
Upgraded Patio Door	36	1" dual glazed unit composed of 3/8" laminated glass, ½" air space, and 1/8" double strength glass

Room Parameters

- Determine room volume
- Estimate absorption
- Finally, calculate room's Outdoor to Indoor Noise Reduction or OINR.



Big Finish….

Outdoor noise level – OINR = Indoor Noise Level

For example:

75 – 25 = 50 dBA

But wait…

"How do I do that composite STC calculation?!?"

Sound Transmission Classification Assessment Tool (STraCAT)

Overview

The Sound Transmission Classification Assessment Tool (STraCAT) is an electronic version of Figures 17 and 19 in The HUD Noise Guidebook. The purpose of this tool is to document sound attenuation performance of wall systems. Based on wall, window, and door Sound Transmission Classification (STC) values, the STraCAT generates a composite STC value for the wall assembly as a whole. Users can enter the calculated noise level related to a specific Noise Assessment Location in front of a building façade and STraCAT will generate a target required attenuation value for the wall assembly in STC. Based on wall materials, the tool will state whether the composite wall assembly STC meets the required attenuation value.

How to Use This Tool

Location, Noise Level and Wall Configuration to Be Analyzed

STraCAT is designed to calculate the attenuation provided by the wall assembly for one wall of one unit. If unit exterior square footage and window/door configuration is identical around the structure, a single STraCAT may be sufficient. If units vary, at least one STraCAT should be completed for each different exterior unit wall configuration to document that all will achieve the required attenuation. Additionally, if attenuation is not based on a single worst-case NAL, but there are multiple NALs which require different levels of attenuation around the structure, a STraCAT should be completed for each differing exterior wall configuration associated with each NAL.

Exterior wall configurations associated with an NAL include those with parallel (facing) or near-parallel exposure as well as those with perpendicular exposure. When a façade has parallel or perpendicular exposure to two or more NALs, you should base the required attenuation on the NAL with the highest calculated noise level. For corner units where the unit interior receives exterior noise through two facades, the STraCAT calculation should incorporate the area of wall, window and door materials pertaining to the corner unit's total exterior wall area (i.e., from both walls).

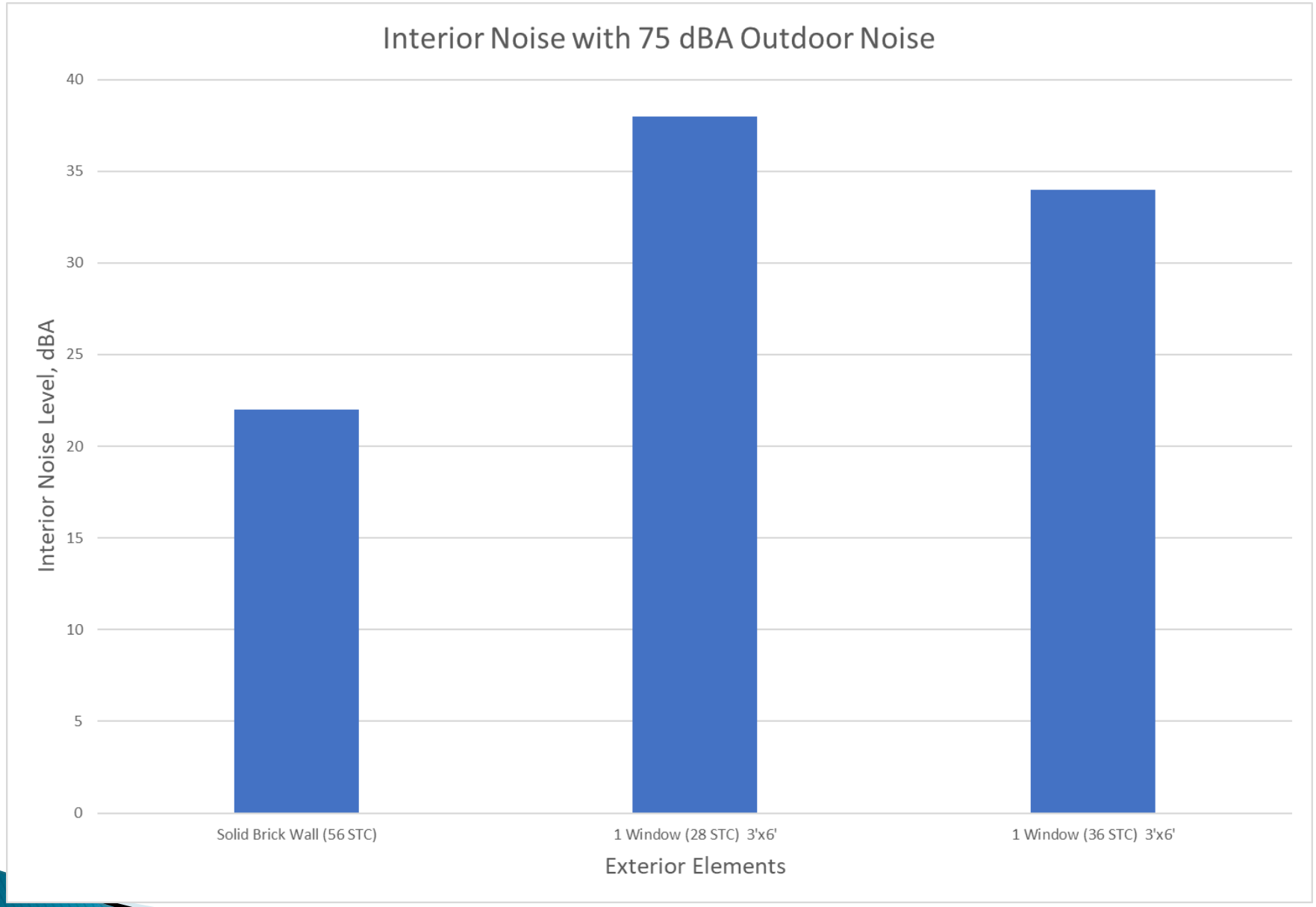
https://www.hudexchange.info/stracat/

Building Shell Analysis

- This all results in specification of…

… Sound Transmission Class (STC) ratings of windows, walls, and doors.

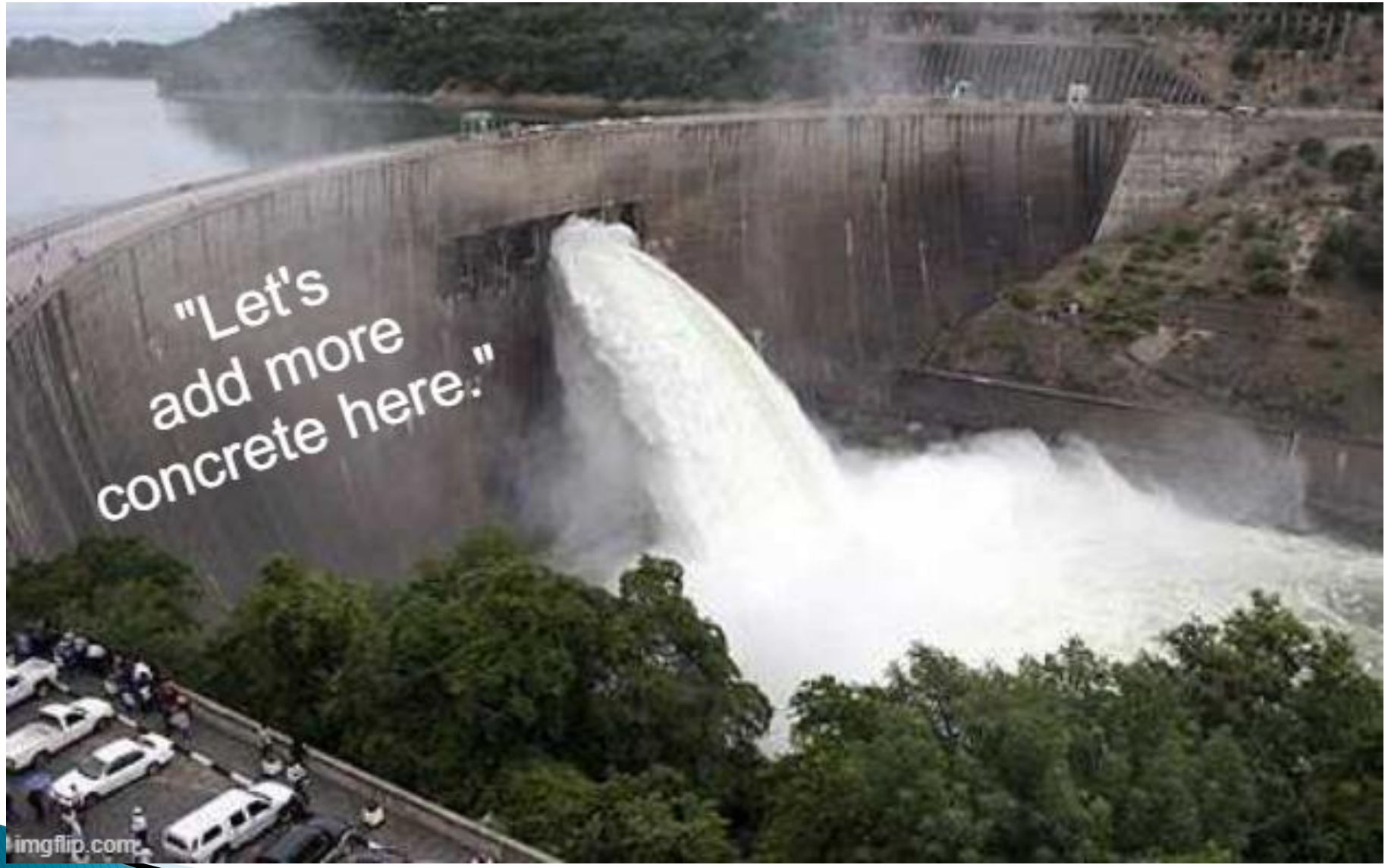
Windows & Doors are the Weak Links!


Interior Noise with 75 dBA Outdoor Noise
Interior Noise Level, dBA
40
35
30
25
20
15
10
5
0
Solid Brick Wall (56 STC)
1 Window (28 STC) 3'x6'
1 Window (36 STC) 3'x6'
Exterior Elements

We get the question all the time…

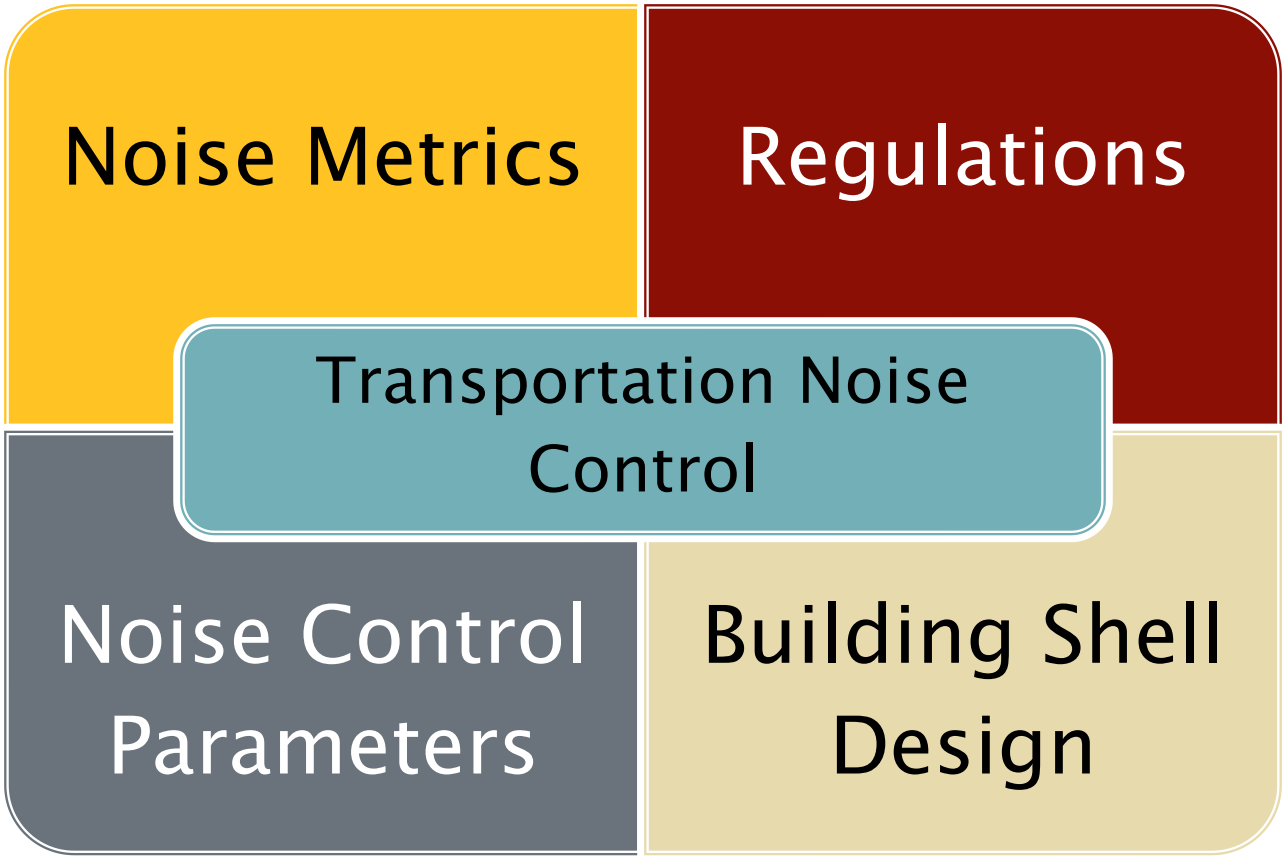
- Instead of better windows, can I just beef up the walls?

- Well, it's kind of like this….


"Let's
add more
concrete here."
imgflip.com

Outdoor to Indoor Design Challenges

- Restrictions on Exterior Façade Finishes
- Lots of Glass
- High STC Rated Windows and Doors = $$$
- Green Building Design
  - Bigger Windows
  - Fresh Air Openings


Noise Metrics
Regulations
Transportation Noise Control
Noise Control Parameters
Building Shell Design

This concludes The American Institute of Architects Continuing Education Systems Program.

Thank you.

Acoustical Engineering Solutions