September 23, 2020

Christopher Enright, NCARB
248.258.6485 Office
cenright@enrightarchitects.com

Enright Architects
628 E. Parent Avenue
Suite 106
Royal Oak, MI 48067

Subject: Belle Tire – Naperville, Illinois
Sound Propagation Report – concise version for City Council meeting

Dear Chris:

Soundscape Engineering has completed the sound study for the future Belle Tire Naperville site. We measured the ambient sound level at the Naperville site for comparison to the sound impact. The sound source levels were recorded at a Belle Tire location in New Hudson, Michigan. The results of the New Hudson measurements were superimposed on the Naperville site plan, and various sound mitigation measures were incorporated until the predicted levels met the Naperville Noise Ordinance. The sound mitigation recommendations are presented along with the analysis.

<u>**Executive Summary**</u>

- The recommended mitigation measures are listed below.
    - Build an interior partition to close off the alignment bays from the tire changing bays, where the louder tools are used.
    - Extend the exterior wall at the northeast corner of the building to further reduce the sound level at the east property line.
    - Install a 6’ high fence at the east and north property lines.
    - Install 2” thick acoustical panels on 60% of the garage ceiling.
- Based on the average level measured at the New Hudson store, **we predict the Naperville Noise Ordinance is met for the daytime level along all property lines**.
- **The nighttime ordinance level is met with procedural changes**, namely the restriction of grinder use from 7:00 pm to 8:00 pm.

Background

Belle Tire is proposing to construct a new store at a location at 1126 Ogden Ave, Naperville, Illinois. A special use permit is required to operate at this location. To the east and southeast is a single-family residential neighborhood as shown in Figure 1. Commercial properties are in the other directions.
In an effort to reduce sound emanating from the store wherever possible, the Naperville location will be Belle Tire's first new store with quieter electric and battery operated equipment. It is using a new quieter electric tire mounting machine at 30567 Milford Road, New Hudson, Michigan location, and proposes the same machine for Naperville. Additionally, quieter battery-operated air wrenches will be used in Naperville.

The maximum allowable sound levels per the Naperville ordinance are given in Figure 2. The Land Use category refers to the property generating the sound, in this case categorized as Commercial. The Belle Tire hours of operation will fall entirely within the ordinance daytime category of 7:00 a.m. to 7:00 p.m. except for the 7:00 p.m. to 8:00 p.m. hour on Mondays and Thursdays when the store is open late. Per the ordinance, the emanating sound level from Belle Tire cannot exceed 62 dBA during daytime hours and 55 dBA during the nighttime hour. These levels must be met at the property line of the parcel from which the sound is generated.

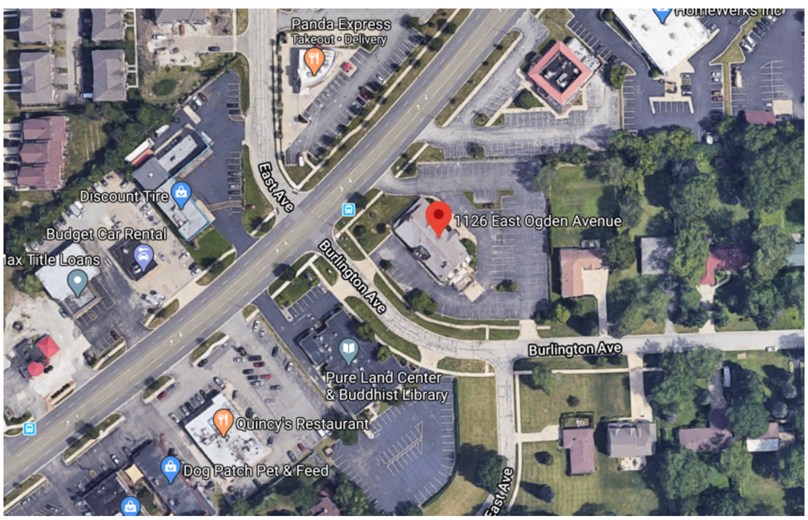


Figure 1: Proposed Naperville Belle Tire Location

Land Use	7:00 a.m. To 7:00 p.m.	7:00 p.m. To 7:00 a.m.
Residential	55 dBA	50 dBA
Commercial	62 dBA	55 dBA
Light industrial	70 dBA	70 dBA
Industrial	80 dBA	80 dBA

Figure 2: Naperville Noise Ordinance Limits

Acoustics Terminology

A glossary of acoustical terminology is appended to this report in case you wish to refer to it while reading the report.

Instrumentation

An NTi Audio model XL2-TA acoustic analyzer with model MC230 microphone and model MA220 preamp was used for all measurements reported here. This system is Class 1 Type Approved, meeting the requirements of IEC 61672 and ANSI S1.4. The system was field checked to verify its calibration.

Measurement Procedure

Soundscape visited the proposed Naperville Belle Tire location and an existing Belle Tire location in New Hudson, Michigan to establish typical sound levels.

Naperville Measurements

Soundscape measured the existing ambient sound level in Naperville, Illinois. Measurements took place on June 16th, 2020 starting at 7:00 pm. A ten-minute measurement was taken at each of the locations shown in Figure 3. This is the minimum sample time for ambient levels per the Illinois Pollution Control Board. The "SLM" (i.e., sound level meter) labels correspond to the data record and are used for reference internally at our company.

Figure 3: Proposed Naperville Belle Tire Layout

New Hudson Measurements

Soundscape visited the New Hudson, Michigan Belle Tire location on June 17th and July 13th to measure the sound level during operation. Measurements began at 3:00 pm on Wednesday, June 17th. During this visit, the technicians used pneumatic air wrenches. The second visit occurred on Monday, July 13th at 9:00 am and the technicians used battery-powered wrenches. Measurements were taken at five points for a minimum of 10 minutes. Measurement locations are shown in Figure 4. The distance away from the building at the New Hudson store are the same distance as the distance between the building and property lines in Naperville. The measurement locations relative to the building are numbered the same for both properties so that they can be directly compared.

In addition to the property line measurements, comparison measurements at close range were taken of the traditional pneumatic socket wrench and a battery-powered socket wrench.

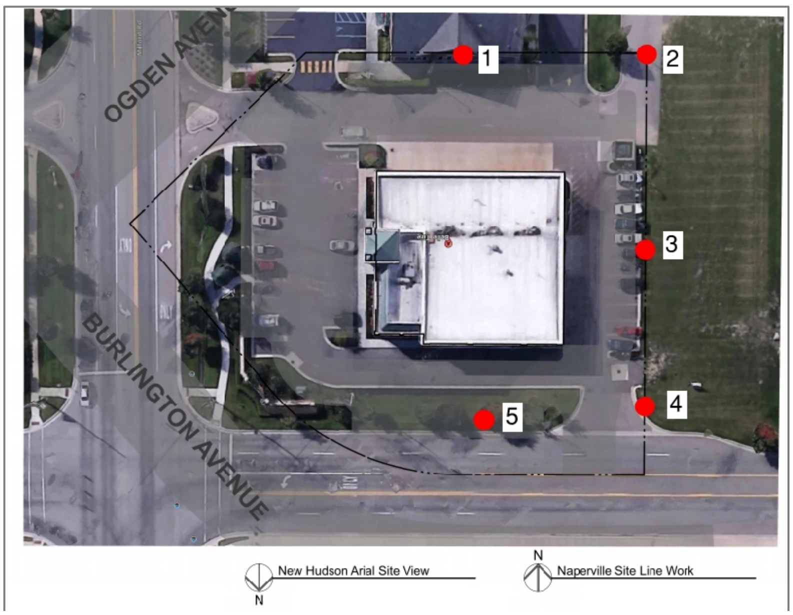


Figure 4: New Hudson Measurement Locations Overlayed on the Naperville Locations

Figure 5: View from Location 1

Measurement Results

Various sound sources were recorded during the measurements including, but not limited to, grinders, air compressors, mechanical wrenches, and banging on metal. The results of the 10-minute A-weighted average sound level (designated as LAeq) for all measurement locations are presented in Table 1. The LAeq is the average level over the duration of the measurement period. As expected, Location 1 (outside the eight tire changing garage bays), is the loudest measurement point. The garage sound influenced Locations 2 and 3 also because the entire garage and storage area were open to each other. This allowed the sound generated in the tire changing area to radiate into the alignment area and out the open doors on that side of the building.

Table 1: Measurement Summary - LAeq

Location	Naperville Ambient	New Hudson - Visit 1	New Hudson - Visit 2
1	62	74	65
2	55	60	58
3	51	62	58
4	52	65	62
5	51	66	64

During the first visit, the level at Location 1 was significantly louder due to extended periods of grinding and banging sounds that did not occur during the second visit. During the second visit, the large grinder was used sporadically and less overall. Location 4 and 5 sound levels were driven significantly by traffic levels. If the grinder sound is excluded from the New Hudson - Location 1 Visit 1 measurement, the LAeq is reduced from 74 dBA to 67 dBA.

The measured average sound level at Location 1 exceeds the Naperville noise ordinance. Locations 2 and 3 are predicted to exceed 62 dBA with the use of a grinder (see analysis in following section). All locations exceed the nighttime noise ordinance of 55 dBA due to garage-generated sound. Hence, mitigation measures must be undertaken. Our recommendations for these are detailed in the next report section.

Measured Sound Source Levels

During the 10-minute measurements, different tools were used. We isolated these sound sources for each measurement and location. Not all tools were recorded at all locations due to the typical workflow at the store. Table 2 presents the average sound level (LAeq) of each type of sound source measured during the first and second visits. Descriptions of each isolated sound source is as follows:

- Powered Wrench – Tool to take tires on and off vehicles
  - Visit 1 – Pneumatic powered
  - Visit 2 – Battery powered
- Large Grinder – Loud full-spectrum sound, disc approximately 4-6” in diameter
- Small Grinder – Higher pitch sound source, disc approximately 2” in diameter
- Banging – Any instance of metal on metal impact sound
- Compressed air – Using the compressed air nozzle to spray clean an object

- Garage general sound – Unidentifiable tool sound from garage bays
- Self-service Air Station – Beep and alarm that emits from the tire fill station located on the north side of the New Hudson Bell Tire
- NC – Not Captured, the sound source was not captured during the measurement

Again, the levels in Table 2 are not 10-minute average levels but the instantaneous level measured for that tool. The average level over time will be lower since the tool was not in use continuously for ten minutes.

Table 2: Isolated Sound Source Levels of Individual Tools

		Visit 1	**Visit 2**
	Sound Source	**LAeq**	**LAeq**
Location 1	Large Grinder	85	70
	Wrench	68	67
	Banging	NC*	69
	Compressed Air	NC*	72
Location 2	Large Grinder	58	58
	Small Grinder	63	NC*
	Wrench	61	57
	Banging	63	66
Location 3	Large Grinder	NC*	58
	Small Grinder	65	NC*
	Wrench	62	58
	Banging	61	61
	Compressed Air	NC*	58
Location 4	Garage General	66	NC*
	Self-service Air Station	NC*	59
Location 5	Self Service Air Station	NC*	64

*NC - Not Captured

Pneumatic and Electric Wrench Sound Levels

Measurements of a pneumatic powered wrench and a battery power wrench taking on/off tire lug nuts were taken at 3 feet from the tools. The results are shown in octave bands in Figure 6. The battery-powered wrench is approximately 2 dBA quieter than the pneumatic wrench. While this difference is not generally considered a perceptible difference, it was subjectively observed that the battery-powered wrench was considered a less annoying sound than the standard “whorl sound” of a pneumatic tool. This is mainly due to the lower levels in the mid-frequency octave bands, which can be seen in the graph at 250, 500 and 1000 Hz.

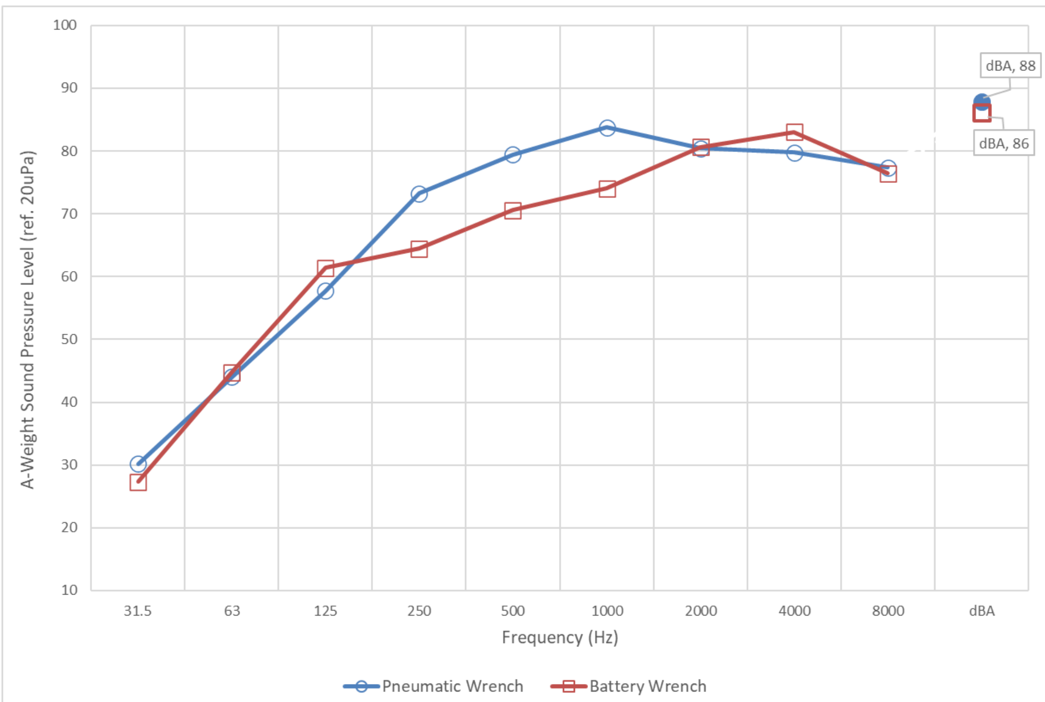


Figure 6: Measured Sound Pressure Level of Pneumatic and Battery Powered Wrenches

Sound Propagation Modeling and Recommendations

1. Interior Wall between Main Garage and Alignment Bays

We understand that there will be no grinding and banging activity in the alignment bays. Therefore, to prevent sound from passing from the main garage bays to the alignment bays, we recommend erecting a wall to separate the two areas. This wall should be full height on all three sides of the alignment area and sealed to the underside of the deck with acoustical caulk. Please refer to Appendix B for further construction details. The minimum sound isolation rating of the wall between bays should be STC 28. This rating can be accomplished by the following partition types:

- a single layer of 5/8" regular weight Type X or Type C gypsum board
- a stud wall with gypsum board on each side, no insulation in stud cavities
- CMU

The newly enclosed volume will need to be assessed by a mechanical engineer for HVAC requirements. The supply duct to the alignment bays should be its own branch and serve only these bays. A return transfer duct should have 1-inch thick internal acoustical duct liner, two elbows without turning vanes, and a minimum of 4 feet of straight duct between the elbows. Locate the transfer duct on the storage side of the alignment bays farthest from the tire changing bays.

Additionally, the louver in the exterior wall on the alignment side of the building should ideally be relocated from the east side of the building or have a similar amount of acoustically lined ductwork associated with it as described for the transfer duct. Figure 7 has images of this louver from the outside and inside of the building.

Self-closing doors with seals at the jamb and head should be installed for access between the main garage area and the alignment bays. Rubber bulb seals are preferred, but brush seals can be used if necessary. Automatic door bottoms are not required.

With the addition of the interior wall, a significant sound reduction is predicted at the east property line.

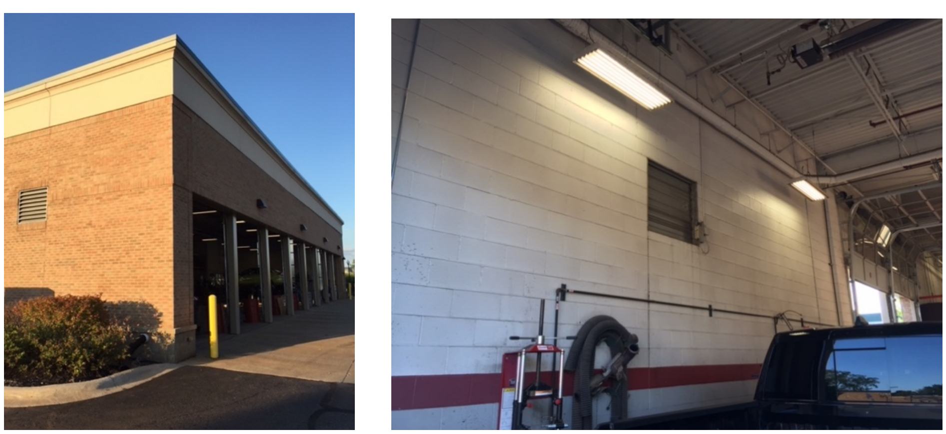


Figure 7: Garage Louver in Exterior Wall

2. Exterior Wall Extension

We recommend extending the east exterior wall on the northeast corner of the building to act as a barrier to sound propagating eastward. The wall should extend approximately 2 feet above the top elevation of the garage doors. We understand that this wall can only extend 8 feet from the building to allow proper clearance for firefighting and delivery trucks. Figure 8 shows the 3D acoustics model of the future building with the extended wall (in cyan) at the northeast corner.

The minimum sound isolation performance of the exterior wall extension at the northeast corner should be STC 33.

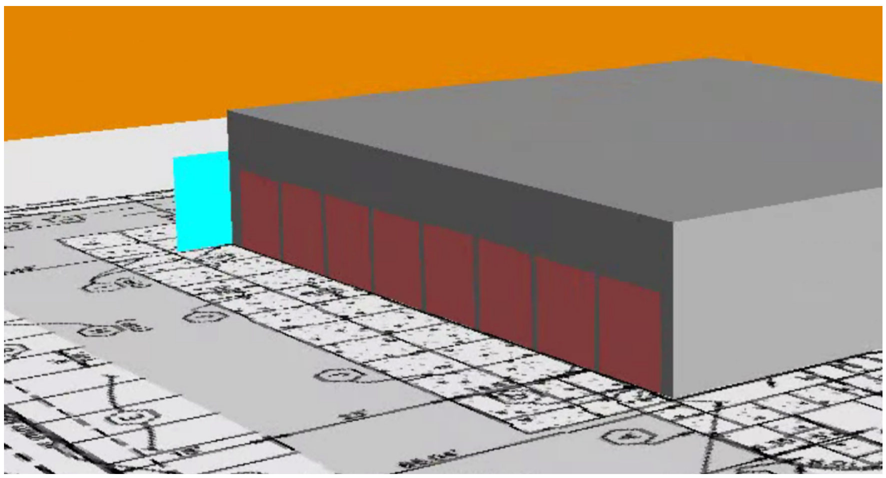


Figure 8: SoundPlan 3D View - Wall at Northeast Corner

3. Property Line Acoustical Barrier

An acoustical barrier in the form of a solid fence is recommended along the east and north property lines. Our recommendations for the acoustical barrier are as follows.

- We recommend a 6 foot high wooden fence or masonry wall. Both will perform the same as long as the STC rating of the material is STC 33 or higher. This is because the sound going over the barrier will be greater than the sound going through the barrier for a material with this performance.
- For wood fencing, it is imperative that no gaps exist between the slats. We recommend high quality kiln dried tongue and groove wood slats or panels. The preferred board thickness is 1-1/2" inches, but a ¾" thick board can be used if the ceiling acoustical panel coverage area is increased from 50% to 80%. This increase reduces the sound level by 1 dBA at the property line, and compensates for the thinner boards. See next section for discussion on the acoustical panels.

- For ease and expediency of installation, manufacturers make purpose-built acoustical barrier panel systems that meet these requirements. Two manufacturers are listed below.
    - Noise Barriers LLC
      https://www.noisebarriers.com
    - Sound Fighter Systems
      https://www.soundfighter.com

The effectiveness of an acoustical barrier depends mainly on its height, but another parameter is the ability of the material to prevent sound from penetrating through. In general, the sound blocking performance of the material needs to be STC 33 or higher. This is easily accomplished by masonry. Wood, metals and plastics need to be evaluated to verify that their thicknesses will perform well. For example, slats in a wood fence may be ¾" thick typically, but to obtain the STC performance, a thickness of 1-½" is recommended. However, the reduction in performance for the thinner boards is only a slight 1 dB when going from a nominal 2x to a 1x board. A discussion of barrier design and materials can be found in Appendix B.

Note that a narrow row of screening vegetation does not provide a measurable amount of sound reduction like popularly believed. However, it could psychologically provide a perceived reduction for the residents by blocking the line of sight.

An overview of the model with the exterior wall and the property line acoustical barrier is shown in Figure 9.

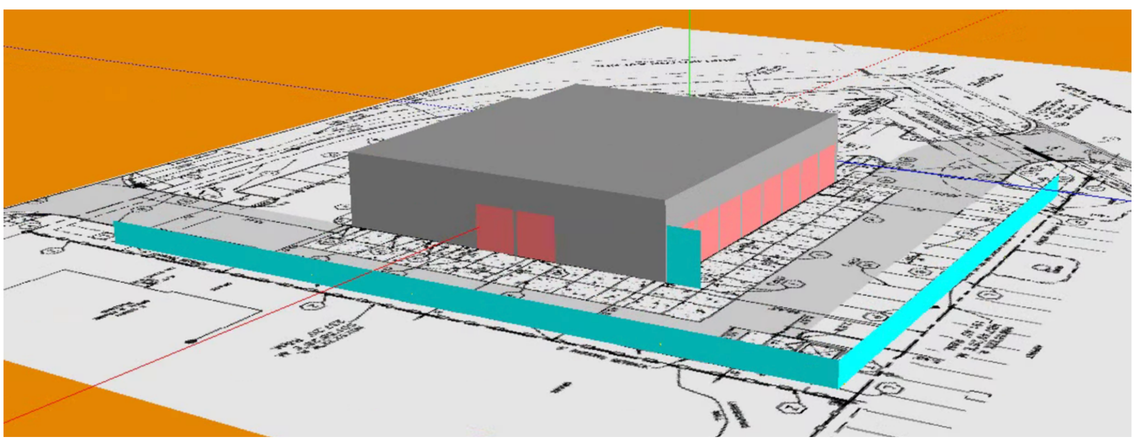


Figure 9: SoundPlan 3D View – External Wall and Property Line Fence/Wall

4. **Main Garage Deck Acoustical Panels**

   Reducing the reverberant sound energy in the main garage will decrease the sound radiating from the garage. To accomplish this, we recommend installing acoustically absorptive panels to the underside of the deck.

   Two inexpensive materials that can be used are theater board and duct liner (3 psf). Note that these panels are dark colored. Light colored materials are also available but may be more expensive. Please contact us for alternates or submit a product for our review.

   The panels sound should cover a minimum of 60% of the main garage deck area. None are needed in the alignment bays. The panel thickness needs to be 2-inches, and the minimum Noise Reduction Coefficient of the panels should be NRC 0.80. We have attached further details about these panel types in Appendix D.

5. **Procedural Modification**

   To meet the nighttime noise ordinance limit, procedural modifications, such as not using grinding tools after 7 pm, will need to be introduced.

Sound Propagation Predictions

The Naperville daytime sound level requirement of 62 dBA is met with the adoption of mitigation Steps 1 through 4 listed in the previous section. Figure 10 (sound levels at selected property line locations) and Figure 11 (sound mapping over the entire property and onto neighboring properties) present the computer model predictions. These predictions are based on the measured average sound level (LAeq) from the first site visit to the New Hudson location.

The Naperville nighttime sound level requirement of 55 dBA is met with the adoption of Steps 1 through 5 listed in the previous section. Figure 12 and Figure 13 present the predictions for this condition, which is essentially the elimination of grinder sound from the analysis. The level of 64 dBA used in this model is confirmed as applicable by the measurements from our second New Hudson visit, which are 62 dBA.

Note that the predicted nighttime levels are well under the ambient levels that were measured at the Naperville site. We purposely made the measurements between 7:00 PM and 8:00 PM to capture the quietest time of day during the Belle Tire operating hours. The measurements were also made shortly after the pandemic lockdown, so it is uncertain how this affected the traffic noise.

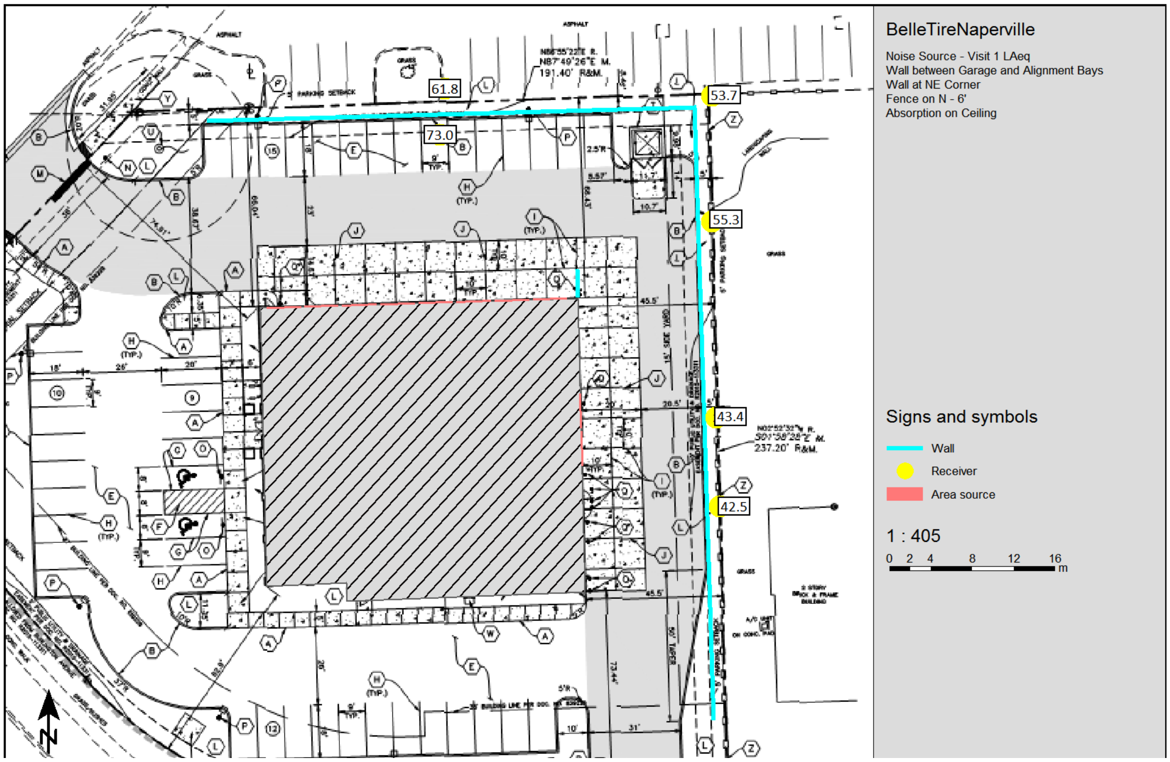


Figure 10: Predicted Daytime Sound Levels at Property Line Locations

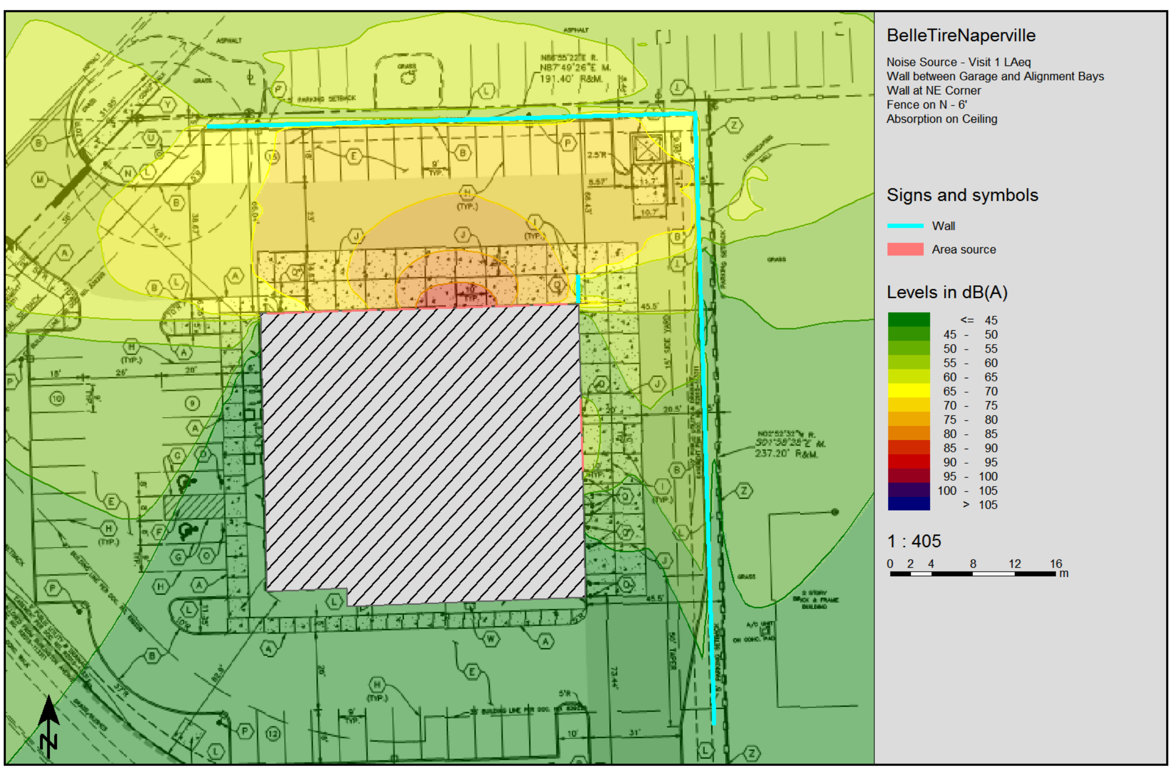


Figure 11: Predicted Daytime Sound Level Propagation

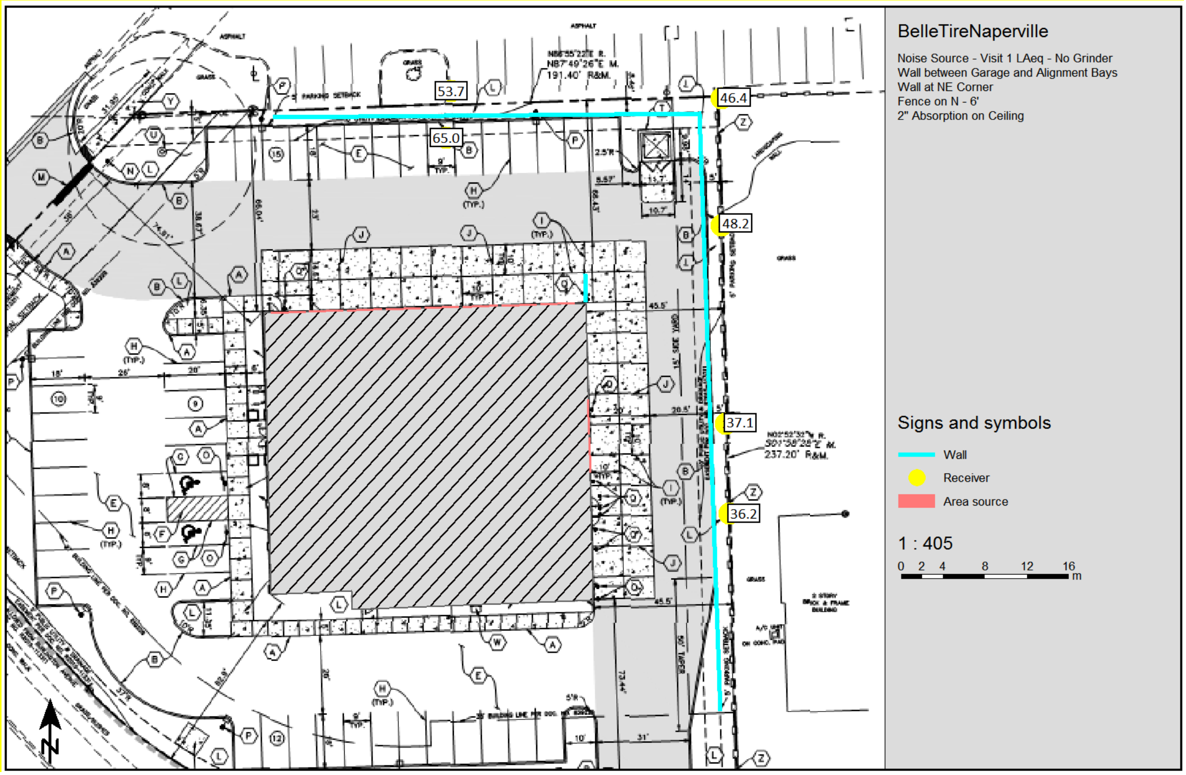


Figure 12: Predicted Nighttime Sound Levels at Property Line Locations

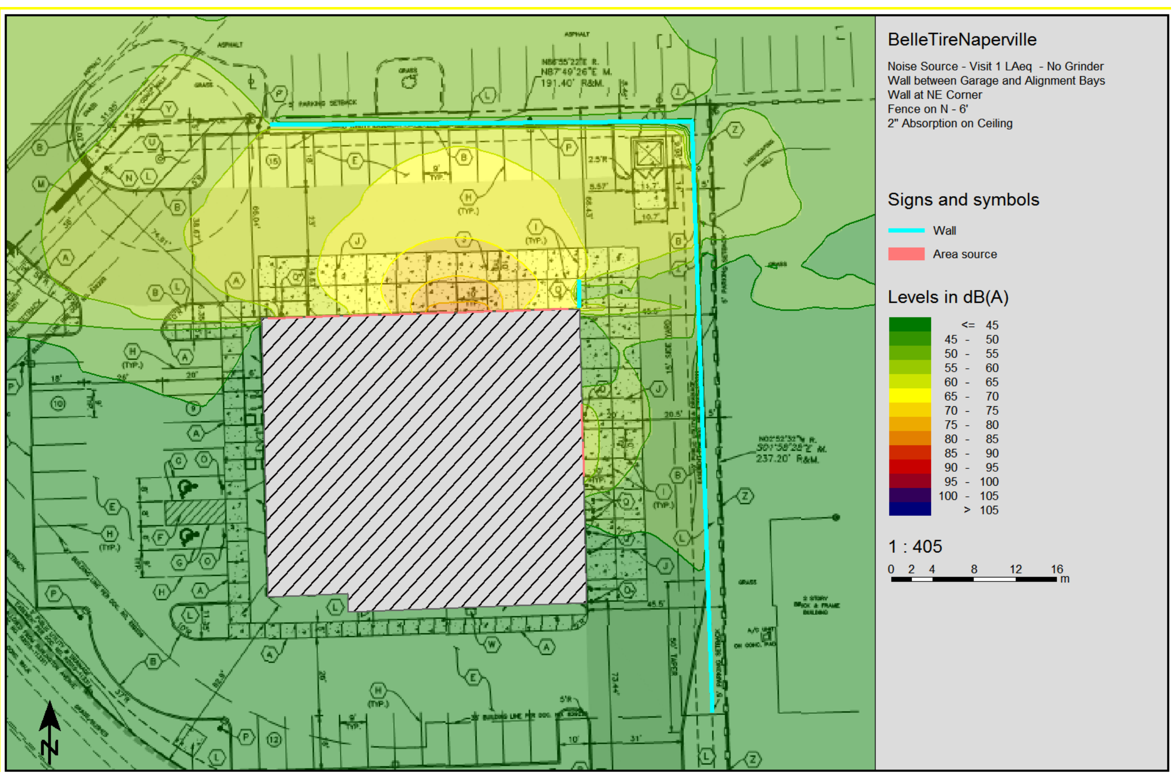


Figure 13: Predicted Nighttime Sound Level Propagation

Final Note

Please note that our recommendations and comments are exclusive to acoustics. We cannot comment on such things as local codes, life-safety requirements, or any other non-acoustic issues.

This concludes our measurement report. We will be happy to elaborate on anything contained within this report.

Sincerely,

Soundscape Engineering
Per:

Mandy Kachur, PE, INCE.Bd.Cert.
Principal Consultant
mkachur@SoundscapeEngineering.com
direct: (734) 494-0322

Anna Catton, Consultant
MSAE
acatton@SoundscapeEngineering.com
(734) 418-8663 x106

Appendix A: Acoustic Terminology
Appendix B: Gypsum Board Partition Details
Appendix C: Acoustical Barrier Screen Walls
Appendix D: Acoustical Duct Liner and Theater Blanket/Board

Appendix A: Acoustics Terminology

Sound level is measured in units called decibels (abbreviated dB). Decibels are logarithmic rather than linear quantities and thus a doubling of the sound level does not translate to a mathematical doubling of decibels. Also, the human ear does not interpret a doubling of sound energy (two sources instead of one) as a doubling of loudness. The logarithmic nature of dB and the human subjective perception of relative sound levels result in the following approximate rules for judging increases in sound.

- 3 dB sound level increase or decrease - just noticeable
  (the addition of one identical sound source to an existing source)
- 5 dB sound level increase or decrease - clearly perceptible and is often considered significant
  (the addition of two identical sound sources to an existing source)
- 10 dB sound level increase or decrease - perceived as twice as loud/half as loud
  (the addition of nine identical sound sources to an existing source)

These perceived changes in the sound level are mostly independent of the absolute sound level. That is, a 35 dB sound will be perceived as twice as loud as a 25 dB sound, and a 60 dB sound will be perceived as twice as loud as a 50 dB sound.

Audible sound occurs over a wide frequency range, from low pitched sounds at approximately 20 hertz (Hz) to high pitched sounds at 20,000 Hz. These frequencies are commonly grouped into octave bands or 1/3 octave bands. Building mechanical systems generally produce noise in the 63 Hz to 1000 Hz octave bands, with the lower frequency noise generated by large fans. Human speech is predominantly contained in the 250 Hz to 2000 Hz octave bands.

A-weighted sound level - Humans do not hear equally well at all frequencies. We are especially poor at hearing low frequency sound and are best at hearing sound in the frequency range of speech. A microphone does not have these same characteristics. Therefore, when sound is being measured to determine how well people will be able to hear it, a "weighting" or microphone-to-human correction factor is applied to the sound level measured using a microphone. The most common weighting is the "A-weighting" and the resulting sound level is expressed in A-weighted decibels (dBA). This weighting reduces the low frequency sound, slightly increases the sound at the dominant frequencies of speech, and slightly lowers the sound level at high frequencies.

Decibel addition is not on an arithmetic basis but on a logarithmic basis. This means that the level produced from two sound sources of 60 dBA is 63 dBA and not 120 dBA. While acoustics consultants use the mathematical formulas for this calculation, this table provides a shorthand method of calculation. To add up a spectrum of multiple bands, the logarithmic process has to be repeated multiple times.

When two dB values differ by…	…add the following dB to the higher value.
0 or 1	3
2 or 3	2
4 to 8	1
9 or more	0

Examples:

43 dB + 44 dB = 47 dB
43 dB + 48 dB = 49 dB
43 dB + 53 dB = 53 dB (sounds that are 10 dB or more less do not affect the final level)

Equivalent Sound Level (L_{eq}) is essentially the average sound level in an environment. However, the L_{eq} is not a simple arithmetic average of the sound level over time, but is a logarithmic average of the sound energy level over a period of time. L_{eq} can be measured for any time period, but is typically measured for some increment or fraction of an hour such as 15 minutes, 1 hour, or 24 hours. Steady sounds, such as fan noise, can be accurately measured for much shorter periods of time, such as 30 to 60 seconds.

Sound Transmission Class (STC) is a single number rating of the amount of sound blocked by a partition (a window glazing unit, door, wall, floor-ceiling assembly) measured in a laboratory under ideal conditions. STC is a single number reduction calculated from the measured one-third octave band spectrum. This metric is mathematically normalized and can be compared other partitions or test data. STC is most appropriately used to assess the ability of a partition to block sound in the frequency range of speech. The original sound transmission test reports should be consulted when the sound source contains low frequencies, such as music or mechanical noise. A higher number indicates better performance.

Sound absorption coefficient (α) is a measure of the amount of sound absorbed by a material. It is measured in a reverberation chamber and is specified at octave band center frequencies. In theory, it ranges from 0.00 (perfect reflector) to 1.00 (perfect absorber). In reality, for highly absorptive materials, the test method can result in absorption coefficients higher than 1.00, occasionally as high as 1.20. The absorption coefficient can be used to compare the acoustical performance of sound absorbing materials. It is also used in calculations to estimate sound reverberation time and reverberant sound level in enclosed spaces.

Noise Reduction Coefficient (NRC) is basically the average percentage of incident sound that is absorbed by a material in the speech frequencies. It is a single number rating derived by averaging the measured absorption coefficients for the 250 Hz, 500 Hz, 1000 Hz, and 2000 Hz octave bands. Theoretically, NRC 1.0 (100% of sound absorbed) is the best performance achievable, but NRC's higher than 1.0 are sometimes encountered as a result of the testing and calculation procedure. Most manufacturers of sound absorbing acoustical products provide the NRC for their products. NRC is mostly used as a convenient means of comparing the acoustical performance of products. If low frequency absorption (125 Hz) is required, then NRC cannot be used and the octave band absorption coefficient at 125 Hz must be evaluated.

Insertion Loss (IL) is the reduction in decibels with and without a barrier or attenuator being placed between the sound source and the measurement location. For example, if the sound level at the measurement location is 55 dBA with no barrier and 48 dBA with the barrier, then the insertion loss is 7 dBA. Larger numbers indicate more sound being blocked.

Appendix B: Gypsum Board Partitions Details

Gypsum board partitions must adhere to the following conditions:

a. When the wall is parallel to metal deck flutes, sheet metal or treated plywood panels must be attached to the underside of metal deck to span a minimum one deck flute beyond the thickness of the wall. Stuff cavity with fiberglass batt insulation between metal deck and flute closure pane. See Figure 14 on the next page.

b. When the wall is perpendicular to the metal deck flutes, all layers of gypsum board called for in the detail must be coped to follow metal deck profile. Seal joint between metal deck and gypsum board with acoustical sealant to create an airtight seal. See Figure 15 on the next page.

c. Provide a continuous bead of acoustic caulk along the top and bottom of the wall between gypsum board and metal deck on each side of the partition. Use U.S. Gypsum Sheetrock Brand Acoustical Sealant or equivalent acoustical sealant. Non-acoustical sealants are not acceptable substitutes.

d. The gypsum board must be regular weight Type X or Type C with a density of 2.2 lb/ft^2 or greater. Do not use USG Ultralight panels or other brand of lightweight panels, because they do not have the necessary density for the acoustic partitions described in this report.

e. All gaps around wall or ceiling perimeters, and around wall/ceiling penetrations should be ¼” to ½” wide and sealed airtight with acoustical sealant.

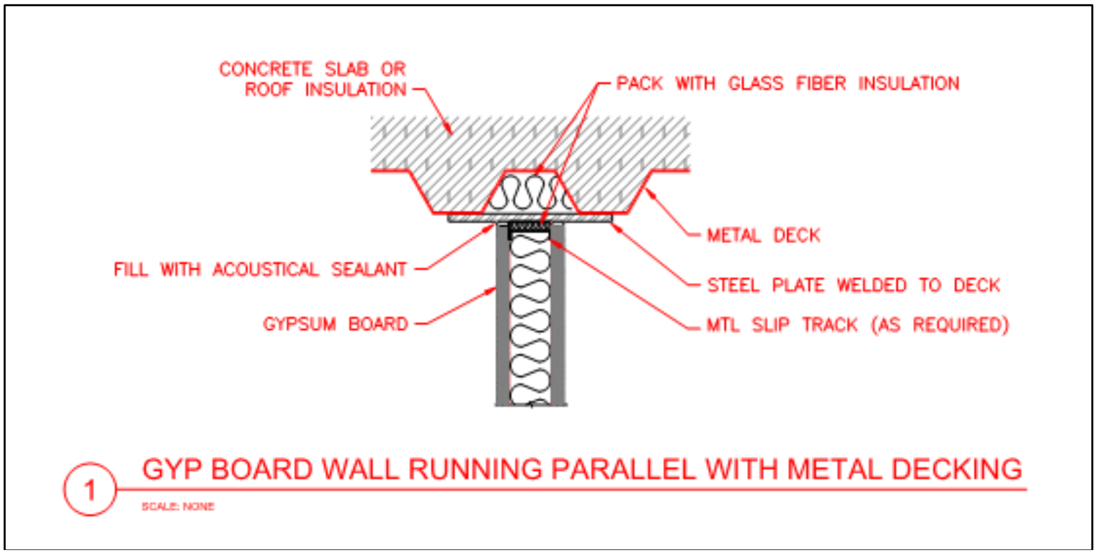


Figure 14: Wall Parallel to Deck

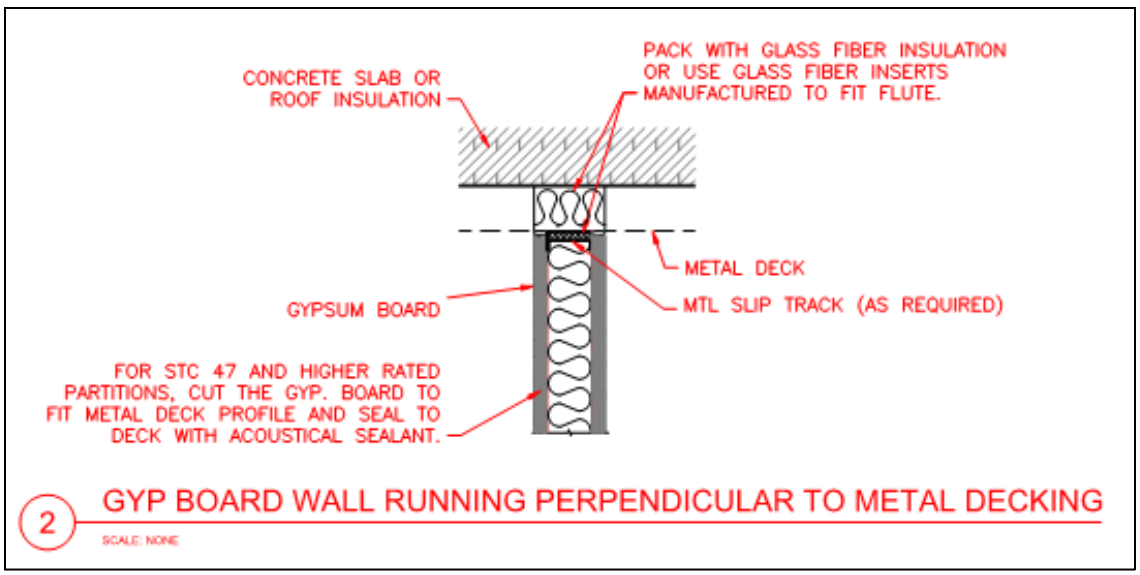


Figure 15: Wall Perpendicular to Deck

Appendix C: Acoustical Barrier Screen Walls

Acoustical barrier screen walls and berms are often used to reduce the sound level at a listener's location. The sound is referred to as the source and the listener as the receiver.

In order for a screen wall or berm to have acoustical value, it must break the line of sight between the source and receiver. Otherwise, the sound traveling along the direct path without the barrier (i.e., in the direct line of sight of the source) is not attenuated by the barrier, but by distance and atmospheric absorption only.

The taller the wall is with respect to the source and receiver, the more effective it is acoustically. The acoustical performance of a screen wall or berm is referred to as the insertion loss, measured in dB. This is the difference in sound level at a receiver location with and without the barrier in place. The barrier performance is frequency dependent, with higher frequency sounds being more easily blocked than low frequency sounds.

Figure 16 provides an illustration of an acoustical barrier and how it blocks sound. The sound source is shown as a person and the receiver can be assumed for our purposes to be halfway between the house and barrier.

An acoustical barrier blocks sound in an area called the shadow zone of the barrier. This is depicted in Figure 16 as the shaded area on the house side of the barrier wall. The sound level in this shaded area depends on the sound level of the source and the amount of sound diffracted (or bent downward) over the top of the wall. The amount of diffraction depends on the frequency of the sound (shown as "angle of diffraction"). This amount is calculated by an equation.

Acoustical barrier walls have a practical upper performance limit of approximately 24 dB of reduction in the higher frequencies. The performance is less in the lower frequencies because the diffraction phenomenon over the top and ends of the wall is more prevalent at lower frequencies. Also, the performance is dependent on how close the source and receiver are to the barrier and the distance that the barrier breaks the line of sight.

Different materials can be used for the acoustical barrier as long as the following conditions are met:

1. The amount of sound going through the barrier material is much less than the sound going (diffracting) over the barrier. For practical purposes, this means that the barrier material must be at least STC 33.

2. The material has no gaps or acoustically weak points that allow sound to pass through.

3. The selected material is appropriate for the amount of maintenance that it will receive.

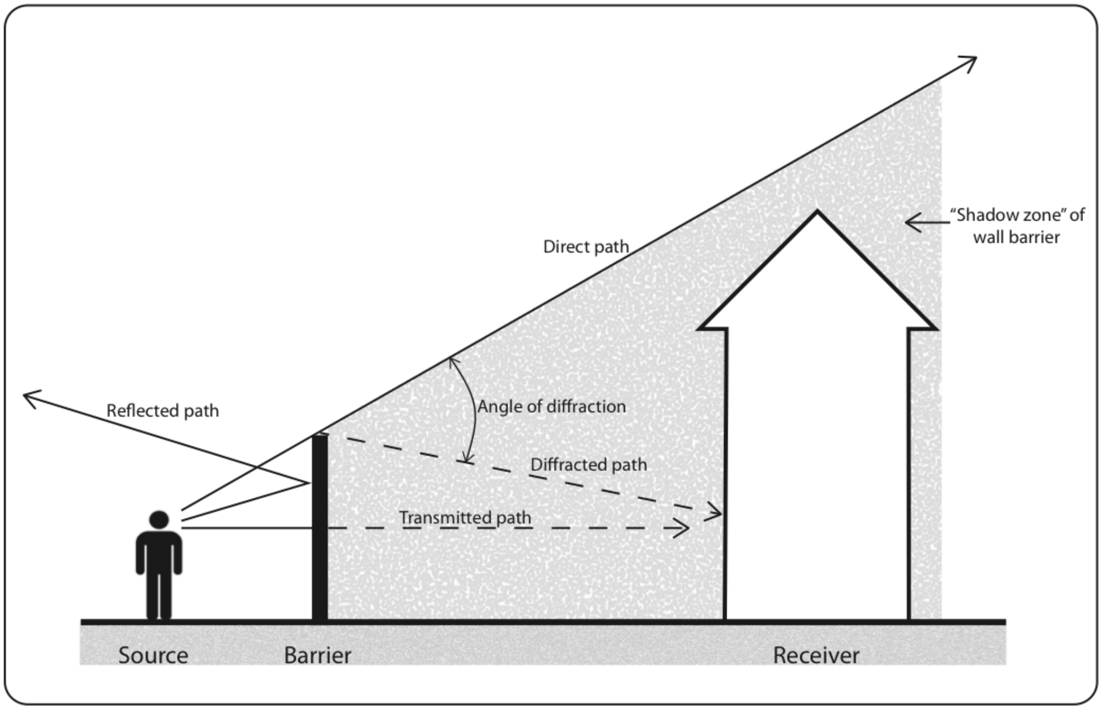


Figure 16: Acoustical barrier wall sound paths

A description of various acoustical barrier materials is provided for your consideration. Further details can be found in the Noise Barrier Design Handbook at the US Department of Transportation - Federal Highway Administration website at the link below.

https://www.fhwa.dot.gov/environment/noise/noise_barriers/design_construction/design/design00.cfm

- ***Concrete:*** Cast-in-place or precast panels can form the barrier. Concrete is a durable material that easily meets the STC requirement of a barrier wall. Precast panels can be erected quickly.

- ***Brick and Masonry Block:*** Hand-laid or preassembled panels are options with this material. A continuous concrete foundation is required. Both materials meet the STC requirements for an acoustical barrier wall. This type of material may not be as durable as concrete should it come into contact with deicing salts.

- ***Metal:*** These panels are lighter than concrete or masonry. Typical materials are steel, aluminum or stainless steel. The STC of these panels may not meet the minimum requirement, but corrugations or ribs will improve the performance. The manufacturer should submit test data to demonstrate the STC performance. Also, the typical 18 to 22 gauge thickness may not be structurally strong enough to withstand impact or other types of damage.

- ***Wood:*** Pressure preservative treated lumber, plywoods and glue laminated products are common materials used for wood barrier walls. This material may be aesthetically more desirable near residential areas. The main issues with wood are warping and shrinkage, which can open up cracks and gaps. This can be partially solved by specifying deeper than standard tongue and groove construction or screwing multiple sheet layers together. The STC rating of the material should be verified so that it meets the required performance.

- ***Transparent Panels:*** These panels block sound while allowing scenic views and reducing the visual impact of the barrier. They can cost up to twenty times that of concrete or steel panels.

- ***Plastics:*** These engineered panels of polyethylene, PVC and fiberglass are lightweight and potentially recyclable. Some materials or products may not be dimensionally stable and over time and could deform, opening cracks in the wall.

- ***Recycled Rubber:*** This material should be tested for its STC rating prior to selection. Some products may be too porous to meet the required performance.

- ***Composites:*** Combinations of the above materials may be available. Again, the STC rating of the assembly should be verified prior to specification.

Appendix D: Acoustical Duct Liner and Theater Blanket/Board

Acoustical duct liner and theater blanket/board insulations may be used as a sound absorbing room finish or as a sound absorbing backing for a perforated room finish. They are frequently used in equipment rooms, in theater control rooms, on theater ceilings, on stage ceilings, on the walls of black box theaters, and locations where they will receive limited to no abuse and where a matte black finish is desired or acceptable.

Duct Liner

Duct liner is the least expensive of these insulations and the least abuse resistant. It should only be located where it will not receive any contact. Duct liner is available as a blanket or as a semi-rigid board. For most applications, we recommend the semi-rigid board because it will not sag as easily. If the duct liner is being use as a sound absorbing backing above a perforated metal suspended ceiling, then the less expensive blanket can be used.

It is usually attached with a combination of impaling pins with caps and adhesive.

Table 3: Typical sound absorption coefficients for different types of duct liner

Duct Liner Type	Sound Absorption Coefficients at Octave Band Center Frequencies						NRC
	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	
1" duct liner blanket (1.5 pcf)	0.09	0.25	0.47	0.66	0.82	0.85	0.55
2" duct liner blanket (1.5 pcf)	0.20	0.49	0.83	0.89	0.89	0.91	0.80
1" semi-rigid duct liner (3 pcf)	0.04	0.25	0.57	0.78	0.87	0.89	0.60
2" semi-rigid duct liner (3 pcf)	0.26	0.72	1.04	1.02	0.96	0.92	0.95

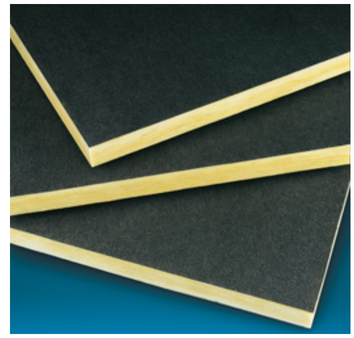
There are many manufacturers of duct liner. We suggest the following manufacturers and models:

CertainTeed ToughGard Rigid Liner Board
http://www.certainteed.com/products/insulation/hvac-mechanical/317385

Johns Manville Permacote Linacoustic R-300
http://www.jm.com/en/building-materials/hvac-insulation/duct-liner/linacoustic-r-300/

Theater Blanket and Theater Board

Theater board gives a small increase in durability but with slightly more expense. Theater board and theater blanket are black-faced glass semi-rigid glass fiber boards or blankets intended to be used as an interior finish in theaters, control rooms, and other locations where an inexpensive, black, sound absorbing finish is needed. The boards are more expensive than the blankets but are less prone to sagging and have slightly better acoustical performance. Sound absorption coefficients for theater blanket and theater board are similar to the absorption coefficients shown in Table 3 for 1.5 pcf and 3.0 pcf duct liner, respectively.



Certainteed model CertaPRO AcoustaBoard Black

Several manufacturers produce these products, including the following:

Owens Corning SelectSound Black Acoustic Board:
http://commercial.owenscorning.com/products/oem/selectsound-black-acoustic-board/

CertainTeed CertaPRO AcoustaBoard Black:
http://ab.certainteed.com/commercial/certapro-acoustaboard/

One difference between these two manufacturers' products is that the CertainTeed product is yellow insulation with a black face and the Owens Corning product is black insulation with a black face. It may be appropriate depending on the visibility to have the contractor spray paint the exposed yellow edges of the CertainTeed product.

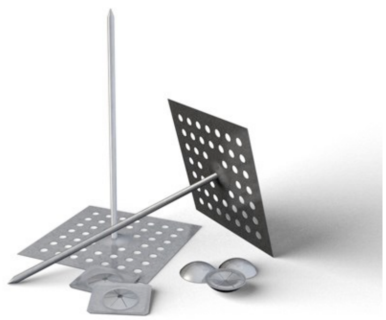
Installation

The above products are typically attached with adhesive or a combination of impaling pins (with caps) and adhesive. We recommend using impaling pins in combination with adhesive for horizontal applications such as on a ceiling or underneath a floor deck. Dome caps can also be placed over the exposed pins to provide a cleaner look.

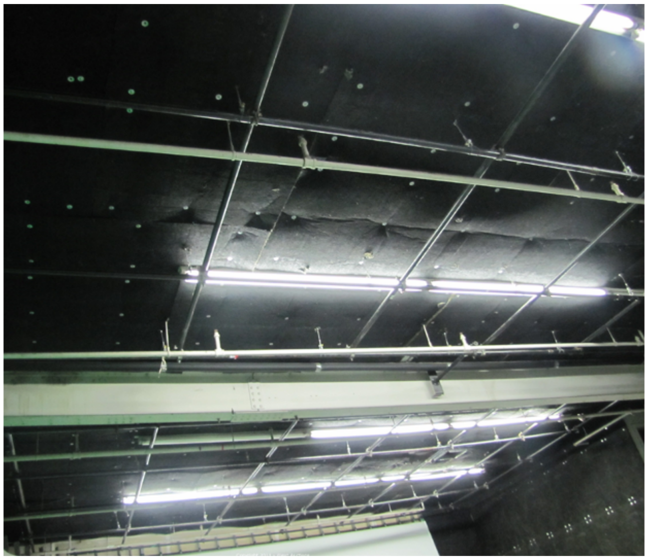
There are several manufacturers that produce insulation pins and dome caps, including the following:

Pyrotek Insulation Pins:
https://www.pyroteknc.com/products/accessories/install-pins/

Gemco Insulation:
http://gemcoinsulation.com/products



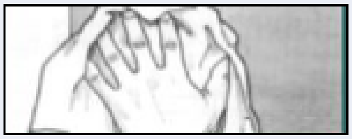
Insulation pins (left) and black dome caps (right)



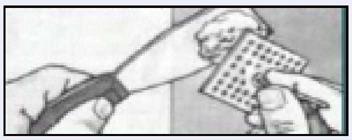
Typical installation of Owens Corning SoundSelect board (without dome caps over insulation pins)

The insulation pins can be installed with adhesive or welding, per the steps below. Pyrotek also provides a detailed installation guide online: https://www.pyroteknc.com/dmsdocument/146

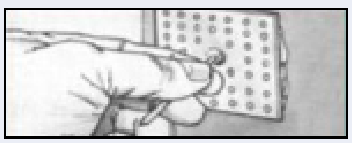
INSULATION PINS WITH ADHESIVE APPLICATION



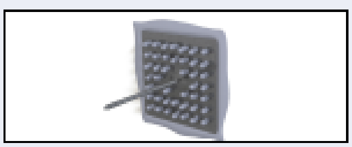
1. Wipe sureface clean. Perforated base must be applied to a clean dry surface.



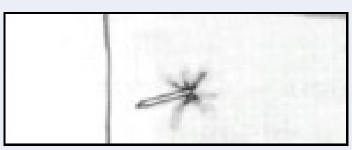
2. Apply adhesive to the base. Spread Mastic adhesive onto the preformed base with a putty knife.



3. Press into position with a twisting motion to allow even spread of the adhesive



4. The adhesive should protrude through the perforations and beyond the edges of the base. Allow adhesive to dry thoroughly before hanging insulation, usually 24 hours-72 hours. Drying time will vary.

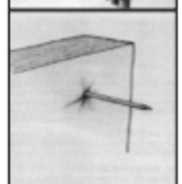


5. Install insulation after adhesive is dry.

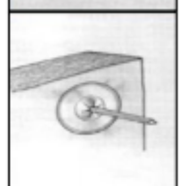
6. Secure the insulation with a self-locking washer. Bend over or snip off excess spindle length. For an aesthetic finish, use a washer-dome over the protruded spindle after snip-off.

INSTALLING WELDABLE INSULATION PINS

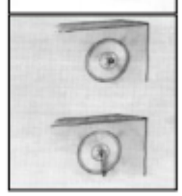
1. Weld pins in place



2. Install insulation over Pins



3. Slide self-locking washer over Pins to secure insulation



4. Either clip pin off or bend pin over at washer