

Retrofit structural insulated panels (SIPs) increase sound transmission loss of existing single family houses impacted by highway noise

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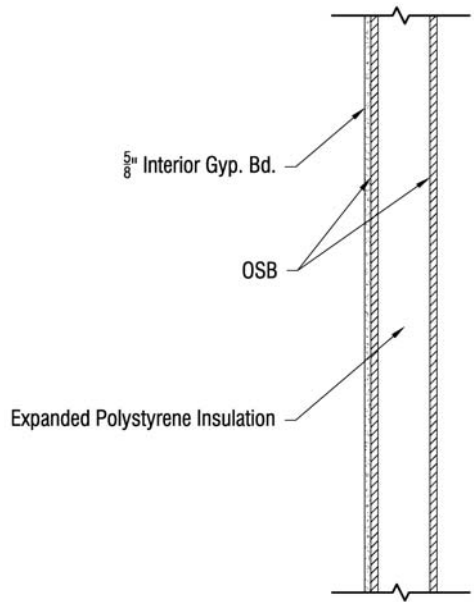
ABSTRACT

Owners of newly constructed houses complained of interior noise from a nearby interstate highway. The houses were constructed using Structural Insulated Panels (SIPs) as opposed to conventional 2x4 wood studs. The SIPs are composed of 3.5 inches of expanded polystyrene insulation sandwiched between two layers of oriented strand board (OSB) and exhibit higher thermal efficiency than conventional construction. Sound transmission loss testing of the standard SIPs, however reveals relatively low acoustical performance especially in the 630 Hz range. This characteristic acted as a band pass filter allowing only a portion of the broadband traffic noise to enter the house. The observed traffic noise inside the house had a clear tonal quality adding to the annoyance of the traffic noise impact. After consideration of several remedial options the builder decided to retrofit the exterior of the impacted houses using a combination of standard resilient channel, insulation, and additional OSB. Some window replacements were also required. These treatments resulted in reduced interior noise levels especially in the 630 Hz range.

1. INTRODUCTION

Occupants of a newly constructed residential development complained of excessive traffic noise within their single family units. Instead of conventional 2x4 wood stud construction, the houses were constructed using Structural Insulated Panels (SIP). The SIPs are composed of 3.5 inches of expanded polystyrene insulation sandwiched between two layers of oriented strand board (OSB) and exhibit higher thermal efficiency than conventional construction. Figure 1 shows a cross section of a typical SIP. SIPs are shipped to a site as a unit and reduce construction time of exterior walls. While beneficial for thermal insulation and ease of construction, the SIP panel system does not perform as well acoustically as conventional 2x4 wood construction. When compared to conventional construction, sound transmission testing of the raw SIP panel reveals an overall reduction at most frequencies with a significant reduction in the 600 Hz range.¹ A comparison between the two transmission loss curves is shown in Figure 2.^{2,3} Windows and doors used in the construction were also deficient in transmission loss characteristics.

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STC-29

Figure 1: Typical Structural Insulated Panel (SIP) section.

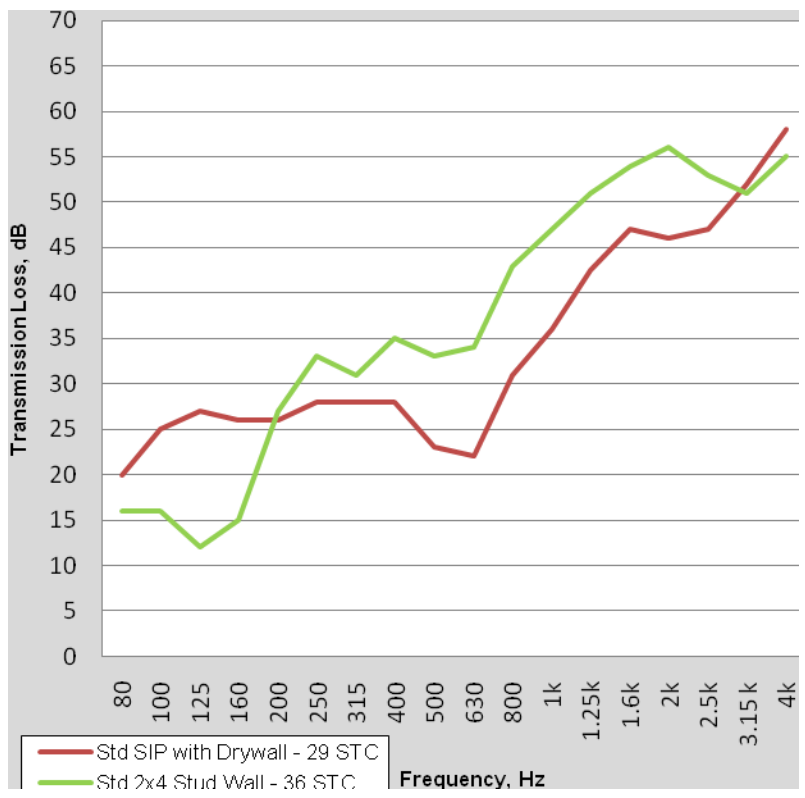


Figure 2: Transmission loss comparison of SIP and standard 2x4 construction.

A standard SIP panel with one layer of 1/2 inch drywall attached to the interior face achieves a 29 STC rating. Conventional 2x4 wood stud construction achieves a 36 STC rating.

Subjectively, the noise level in the house had a clear tonal quality which added an annoyance factor to the noticeable traffic noise. Normally traffic noise has a fairly broadband characteristic; however with a notable dip at the 630 Hz band the SIP transmission loss spectrum acts as a band pass filter to the broad band noise producing the tonal character of the interior noise.

2. BACKGROUND

The residential development is located south of Washington, D.C. along Interstate 95, a major interstate highway with heavy commuter and commercial traffic volumes. The nearest house to the roadway lies approximately 575 feet from the centerline. The roadway in the vicinity of the development is composed of 3 northbound lanes, 3 southbound lanes, and 2 center express lanes which change direction depending upon traffic volume requirements. The 2005 average daily traffic count for the roadway was 207,000 vehicles per day; forecasted volume for the year 2020 is 255,000 vehicles per day. Posted speed is 65 mph. With such volumes, traffic along the roadway is fairly constant throughout a typical 24 hour period.

Phoenix Noise & Vibration was contracted by the builder to develop a methodology for reducing the interior noise level within the impacted houses. Several traditional methods of noise control were investigated, including window/door replacement and barrier construction. Based upon an acoustical building shell analysis it was determined that, regardless of STC rating, simply replacing windows and/or doors would not overcome the SIP's poor acoustical performance.⁴

Barrier designs were prohibitive because of excessive height requirements, space limitations, cost, and aesthetics. All houses have two stories and 9 foot first floor ceilings while several have walk out basements. On the rear side of the houses, the ceiling of the top floor could easily be 30 feet above the surrounding grade. Construction of a 30 to 35 foot barrier to control noise impact at the upper levels was neither feasible nor attractive. Zoning limitations restricted construction of barriers to the lots of each house. Small lots sizes left approximately 40 feet between the rear of the house and the property line.

3. SOLUTION

In order to reduce the interior noise level, it was determined that both the exterior walls of the house must be modified and, when necessary, windows and doors upgraded with units with higher STC ratings. While window and door replacement was a part of the remedial action, this paper focuses primarily on resolving the poor acoustical performance of the SIP wall construction.

Modifications to the SIP wall from the inside and the outside was considered. After thorough analysis it was determined that attacking the issue from the outside was preferable given complications and cost of housing occupants during construction, removal of furniture, and dealing with details such as outlet penetrations, flooring, ceilings, drywall finishing, custom paints, etc. By approaching the wall from the outside there would be less impact to the owner and an easier construction process; therefore modifications to the wall from the outside became the chosen path. Challenges for the outside approach included aesthetics, waterproofing, and moisture control.

Two options of wall remediation were recommended and tested for performance. The first option involved removal of the exterior vinyl siding and attaching a layer of home slicker, house wrap, and loaded vinyl sheeting (2 lb/ft²) to the face of the SIP panel. The vinyl siding was then reinstalled. These additional layers were simply screwed to the SIP at 12 inches on center. This modification provided a "Level One" increase in the walls transmission loss. This option

increased the rating of the SIP from 29 STC to 32 STC.⁵ This option was used for houses which required less noise reduction than other houses impacted by higher noise levels. See Figure 3 for a cross section of the construction.

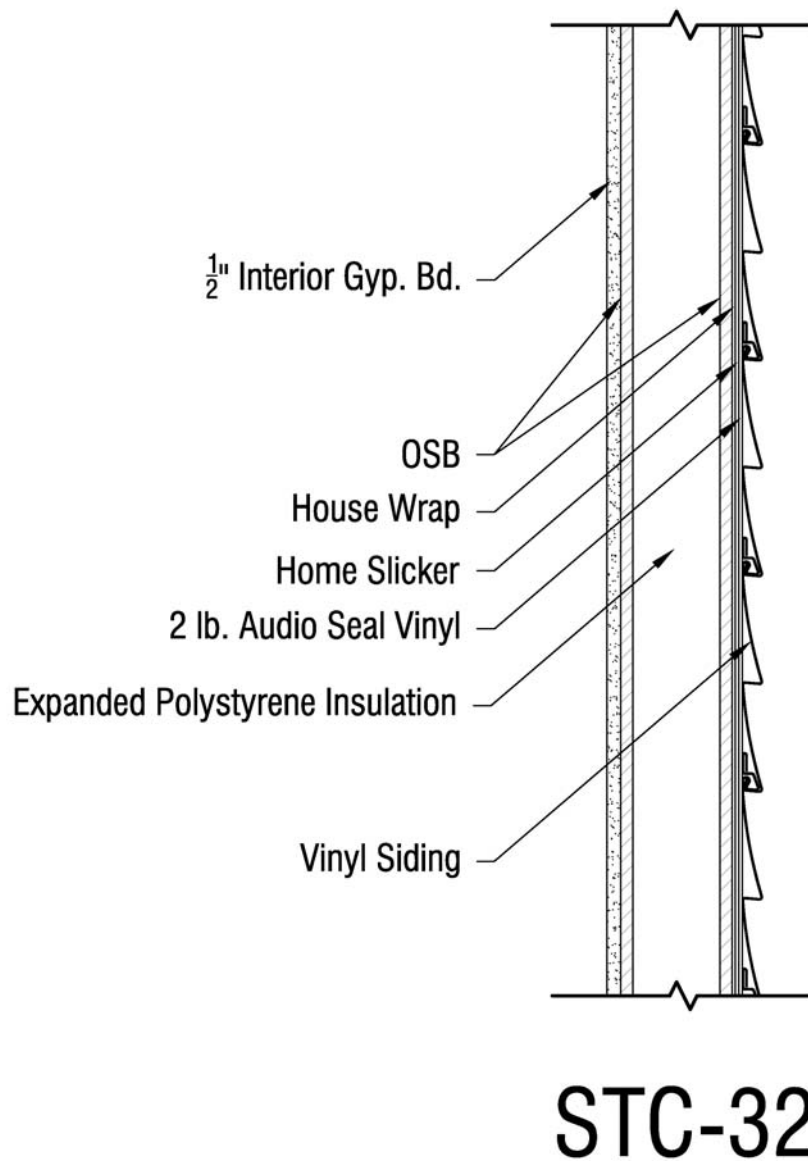
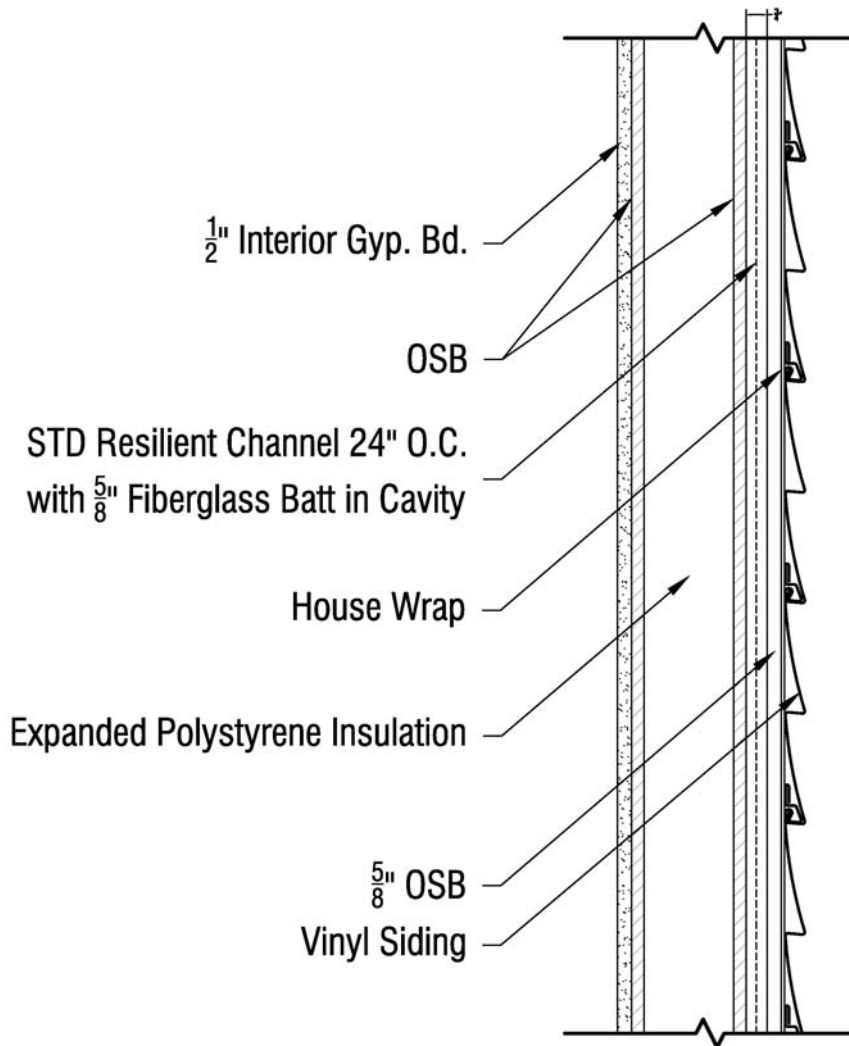


Figure 3: SIP modified with 2 lb/ft² loaded vinyl.

The second option, “Level Two”, was more complex but provided a substantially greater increase in the transmission loss of the system. This involved removing the vinyl siding and installing resilient channel, fiberglass batt insulation, a single layer of 5/8 inch oriented strand board, house wrap and reinstallation of the vinyl siding. This option increased the rating of the SIP from 29 STC to 43 STC and was used for houses exposed to higher noise levels.² See Figure 4 for a cross section of the construction.



STC-43

Figure 4: SIP modified with OSB and resilient channel.

A comparison of the transmission loss values of the three wall systems is shown in Figure 5. While the mass loaded vinyl (Option 1) modification provides significant high frequency improvement and slight improvement at the 600 Hz range there is actually reduction in some frequencies below 400 Hz. The transition from frequency to frequency is smoother and without dips, providing a less tonal character to the interior noise, and an overall increase from 29 to 32 STC. On the other hand, the resilient channel/OSB modification provides significant increase in at all frequencies except those below 200 Hz. Most notable is the increase in the 630 Hz band. Again, there is a fairly smooth transmission from frequency to frequency. Overall the STC rating increases from 29 to 43.

The resilient channel solution is quite unique from traditional acoustical construction. First, for moisture control, the resilient channel was mounted vertically as opposed to horizontally. This allowed moisture to drip down the wall and weep out as opposed to collecting in the joint between the resilient channel and the base layer OSB. Secondly, with this configuration, the

resilient channel is “sandwiched” between two layers of OSB. With more traditional gypsum board applications, “sandwiching” resilient channel is strongly discouraged. This configuration restricts the resilient channel, negating its effectiveness may produce unfavorable resonances in the system. In instances where resilient channel is “sandwiched”, the installation of fiberglass batt between the channels is also uncommon.

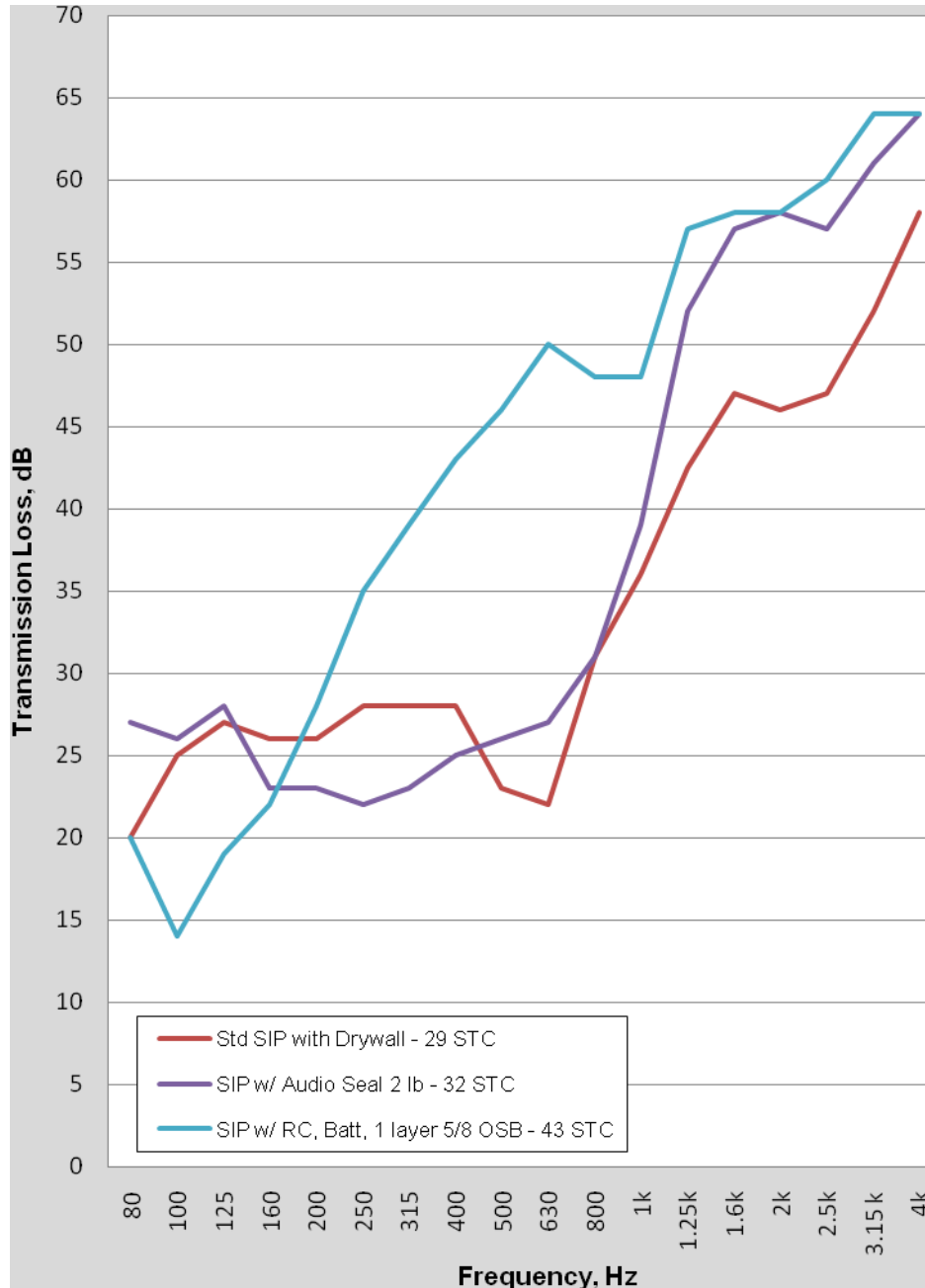


Figure 5: Transmission loss comparison of 3 SIP constructions.

4. CONSTRUCTION

A conceptual layout of the resilient channel option (Option 2) is shown in Figure 6. Photographs are also provided showing actual field construction of both the loaded vinyl (Option 1) and the resilient channel options in Figures 7 –10.

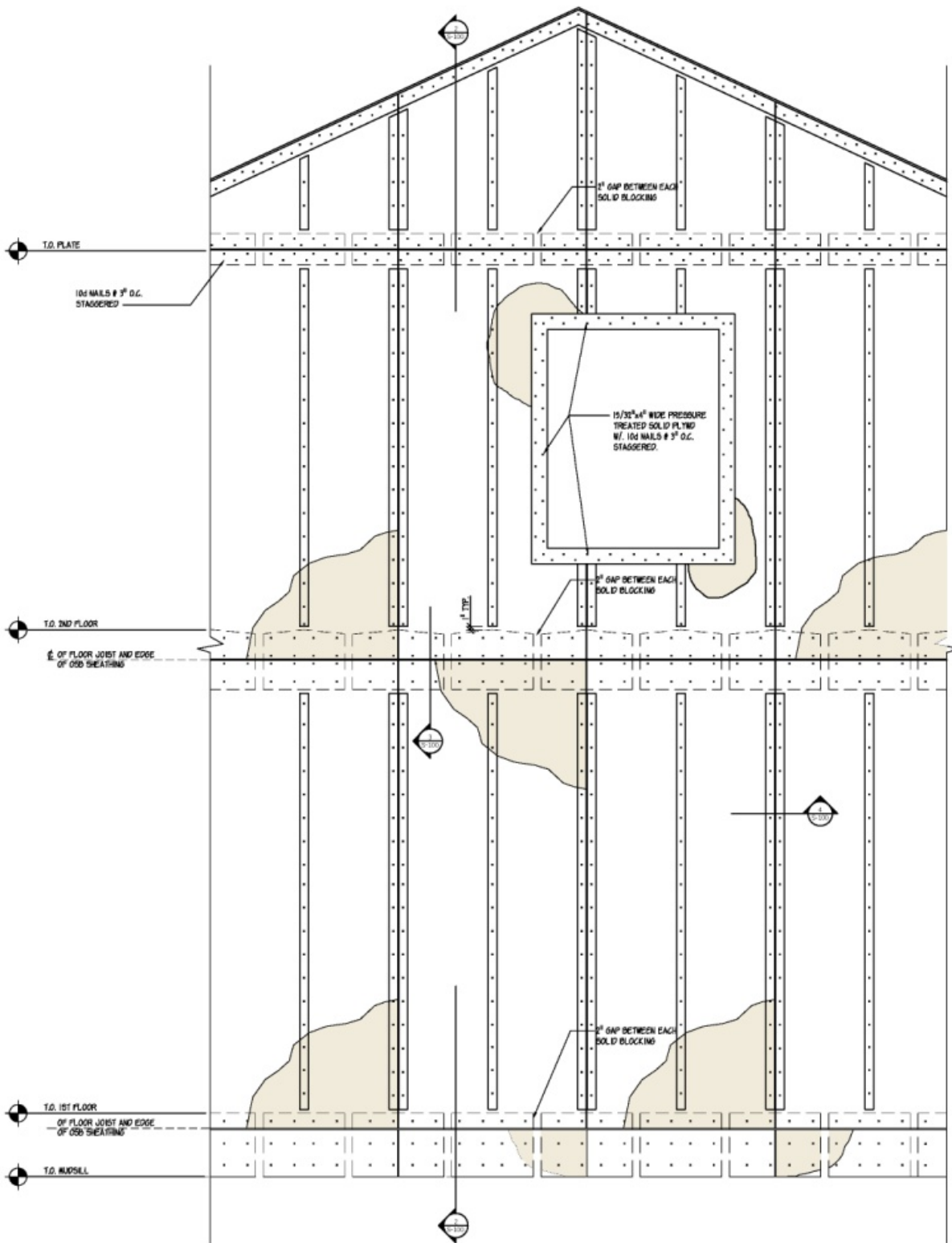


Figure 6: Conceptual resilient channel layout.



Figure 7: Construction of loaded vinyl option.



Figure 8: Construction of resilient channel option.



Figure 9: Resilient channel option.



Figure 10: Resilient option showing final OSB and caulking.

5. POST CONSTRUCTION MEASUREMENTS

In one of the impacted single family units, on site measurements were conducted both before and after the remedial construction. A measuring microphone was placed outside the house on a 25 foot tall pole, 15 feet from the façade on the roadway side of the house. Output from the microphone was sent to an integrating sound level meter with 1/3 octave capabilities, sequentially recording 5 minute Leqs. A second instrument was placed inside the house in various rooms to record simultaneous noise levels of traffic noise. The internal clocks on each

instrument were synchronized to permit direct comparison of measured data after analysis. Care was taken to reduce ambient noise levels from within the house to a minimum. The house was unoccupied except for the field engineer, and HVAC, televisions, computers, etc. were turned off.

The results were post-processed to produce an Outdoor Indoor Level Reduction (OILR) at each frequency which was applied to a common outdoor noise level for direct comparison of the before and after noise conditions measured in each room.

A single room will be used as an example in this paper. This upper level bedroom was located in the front corner of the house with the side fully exposed to roadway noise. The front of the building faced away from the roadway and received less impact than the side due to shielding from the house. A floor plan of the house is shown in Figure 11. The front wall of the room was faced in brick and has two windows, while the side wall is SIP construction and has no windows. In the pre-construction condition it was very evident to the listener that the traffic noise in the room came through the SIP wall. The tonality of the noise was also present.

Results of the before and after conditions within the subject bedroom are presented in Figure 12. To show how the human ear responds to the noise level, the A-weighted frequency values are plotted. The common outdoor noise level is also plotted, also A-weighted, from which the interior noise levels were determined based upon the calculated OILR.

The tonality of the before condition is clearly evident in the 500 and 630 Hz bands. Also notable is the significant reduction at these frequencies in the after condition. Significant reduction was also experienced in the high frequency range. A 10 dBA reduction in the overall noise level was experienced in this bedroom.

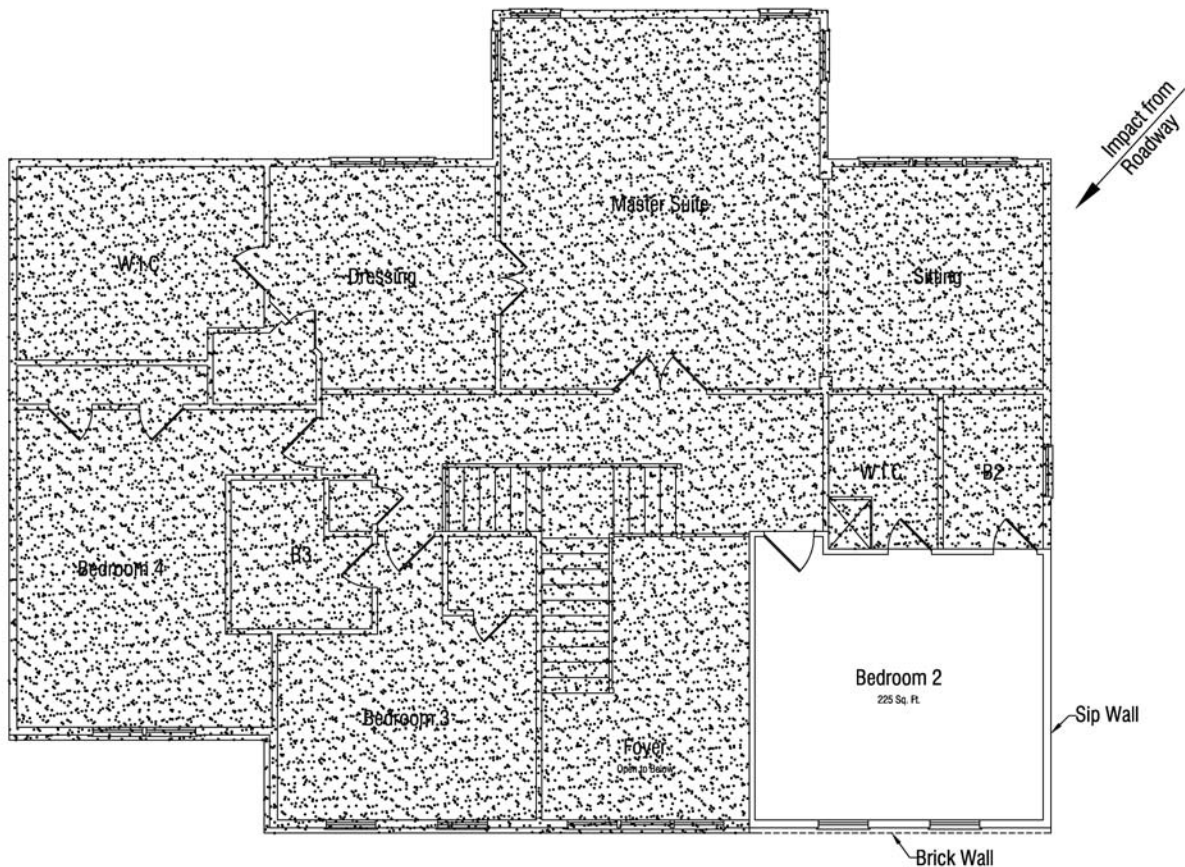


Figure 11: Floor plan showing subject bedroom relative to roadway impact.

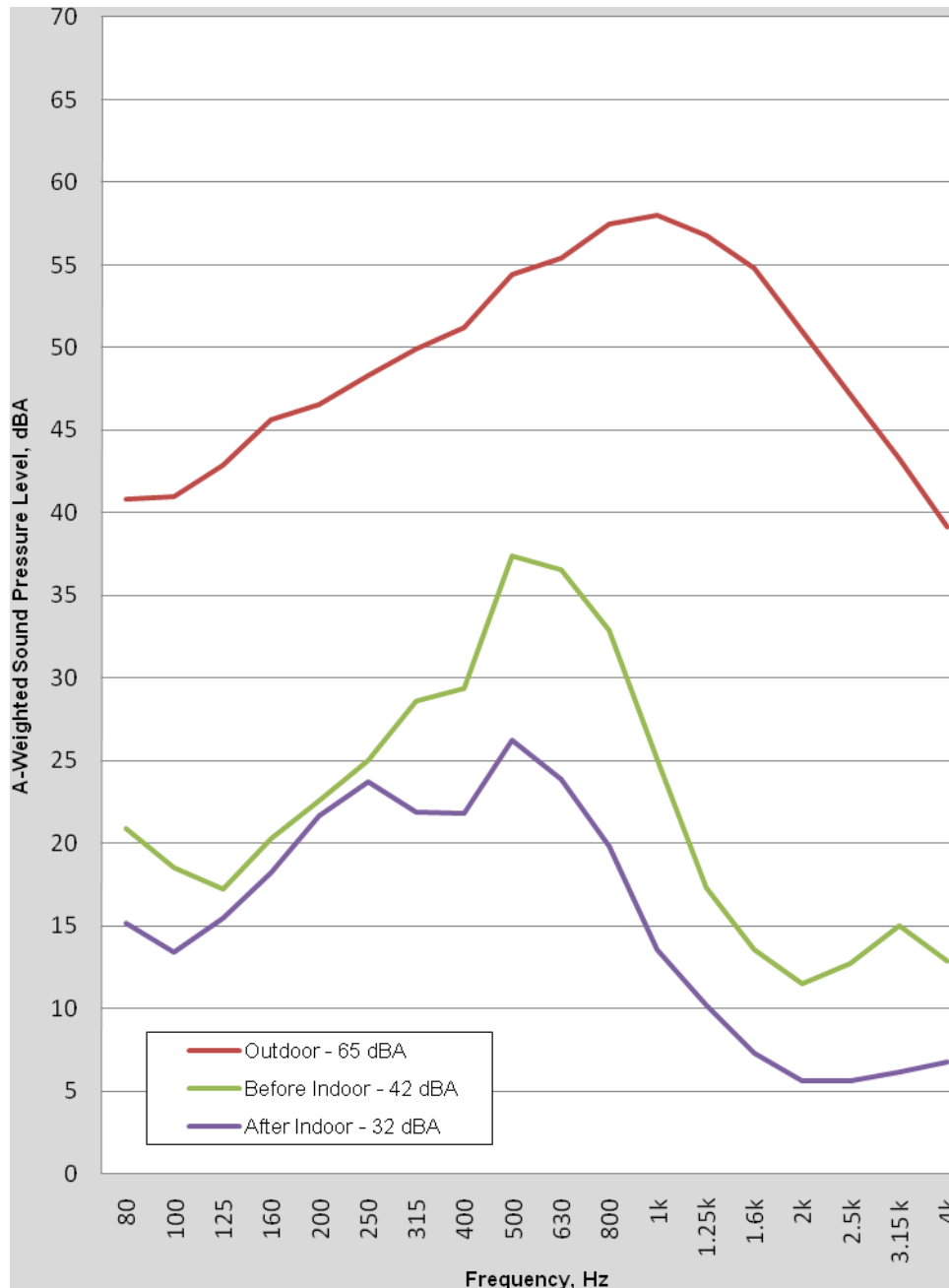


Figure 12: Comparison of Before and After interior, A-weighted noise levels.

6. CONCLUSIONS

By modifying the conventional SIP walls with resilient channel, OSB, and fiberglass batt insulation a significant increase the transmission loss is gained. This is evident not only in the overall noise level reduction inside the house but also in the elimination of the tonal quality of that noise. By approaching the remediation from the outside of the house, the project was greatly simplified and minimized impact upon the occupants.

7. REFERENCES

- ¹ Standard SIP Transmission Loss Values (n.d.)
- ² (13 October 2003). *ASTM E-90 – Laboratory Sound Transmission Class Test Report – Project Number: 30160-03-56829*. Stork Twin City Testing Corporation.
- ³ Birta, J.B. (October 2000). *IRC Internal Report, IRC IR818 – Laboratory Measurements of the Sound Insulation of Building Façade Elements*. Institute for Research in Construction – National Research Council of Canada.
- ⁴ Cyril M. Harris, P.E. (1998). *Handbook of Acoustical Measurements and Noise Control*. Melville, New York: Acoustical Society of America.
- ⁵ (28 July 2007). *ASTM E-90 – Sound Transmission Loss Test Report, Series Model: Audio Seal Sound Barrier/"SIP" Panel*. York, Pennsylvania: Architectural Testing Laboratories.