

1 **EVALUATION OF LIGHTWEIGHT NOISE BARRIER ON BRIDGE STRUCTURE**

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ABSTRACT

The Texas Department of Transportation commissioned a study to analyze the feasibility and effectiveness of a lightweight noise barrier on Interstate Highway 30, near downtown Dallas. The highway segment in question, an elevated structure next to a creek, has presented noise problems for the adjacent neighborhood ever since its expansion in the early 2000s. The highway carries substantial commuter traffic as well as heavy trucks. The neighborhood is hilly and sits at a higher elevation relative to the highway, except for a few residences on the street adjacent to the creek. The material for the noise barrier needed to be lightweight in order to be supported by the existing bridge structures without having to retrofit them. A 10-ft. tall transparent acrylic noise barrier was designed to be installed on top of the existing 8-ft. concrete wall. Residential sound pressure level tests were performed at various locations for five months before the transparent wall installation, and continued for nine months after the wall was completed. A portable weather station was utilized to monitor the conditions at the time of the tests. Measurements were conducted three times a day –morning, afternoon and evening, and test days occurred once or twice a month. A statistical analysis of the various weather variables and their influence on the noise levels was performed. The results indicate that the wall is effective for certain receivers, although the acoustic benefits are small, and the neighbors are satisfied with its performance and with its aesthetic appearance.

Keywords: Traffic noise, noise barrier, lightweight material, transparent material, aesthetics, visual impact

INTRODUCTION

The Dallas District of the Texas Department of Transportation (TxDOT) asked researchers at The University of Texas at Austin Center for Transportation Research (UT-CTR) to develop a pilot project to investigate the feasibility of a lightweight noise barrier on Interstate Highway 30 (IH-30), just west of downtown Dallas. The highway segment in question, an elevated structure next to a creek, has presented noise problems for the adjacent neighborhood ever since its expansion in the early 2000s. The highway carries substantial commuter traffic as well as heavy trucks. The material for the noise barrier needed to be lightweight in order to be supported by the existing bridge structures without having to retrofit them. An existing 8-ft. tall concrete wall already provided some noise mitigation to the residences. However, the neighborhood is hilly and sits at a higher elevation relative to the highway, except for a few residences on the street adjacent to the creek, so TxDOT wanted to provide a taller barrier to increase the noise abatement, without entirely blocking the views of the residences towards downtown. Therefore, an aesthetic solution was also sought. A 10-ft. tall transparent acrylic noise barrier was designed to be installed on top of the existing 8-ft. concrete wall. Noise barriers are normally not effective for receivers on a hillside overlooking the highway or for receivers at heights above the top of a noise barrier, thus, it was not expected that the residences at the higher elevations would be substantially benefited.

The transparent noise barrier that was recommended, designed and installed as the outcome of this project was the first one of its kind in Texas. TxDOT's intent for this project, besides the benefit to Kessler Park –the adjacent neighborhood on the south side of IH-30, is to provide cost and performance information for future project comparisons and, if successful, to develop this type of projects on other highways facing similar problems.

Objective and Tasks

The main objective of this study is to assess the feasibility and effectiveness of a lightweight noise barrier on IH-30 in Dallas, and to serve as a pilot project for TxDOT. The tasks are as follows:

- Conduct a feasibility study for a lightweight traffic noise wall
- Selection of material types and vendors
- Design
- Inspection
- Sound measurements
- Evaluate performance

Review of Materials and Vendors

As part of the investigation, a review of various lightweight noise barrier materials considered as candidates for the noise wall installation was conducted. The review was not limited to documents available in the literature. Interviews, meetings, and electronic mail and telephone conversations with material vendors and suppliers, as well as representatives from State DOTs and other entities, where such materials have been used, were also part of this review. The experiences from other States with such materials were a valuable source of information that cannot necessarily be found in publications. The organizations consulted included:

- FHWA
- Various DOTs (Kentucky, Washington, Ohio, California)
- Three noise barrier lightweight material manufacturers in the U.S. (Acrylite, Plaskolite, and AIL Soundwalls, the first two of which manufacture transparent barriers)

The findings are summarized in the following paragraphs:

Materials

The information provided by these organizations indicate that lightweight noise barrier projects are not the most common among the existing noise walls installed throughout the country. In regards to transparent barriers, the state that has the highest number is Ohio, followed by California, and then by other states such as New Jersey, Tennessee, Florida, Minnesota, Wisconsin, and Virginia.

Noise barriers reduce the sound which enters a community from a highway by absorbing the sound, transmitting it, reflecting it back across the highway, or forcing it to take a longer path over and around the barrier (1). Therefore, noise barriers work by reflecting some of the acoustic energy, while part of the energy is transmitted through the barrier, part of it is diffracted, and some of it reaches the receiver directly, for those receivers with line of sight from the source.

The FHWA in its noise barriers guidelines (2) recommends that, to effectively reduce sound transmission through the barrier, the material chosen must be rigid and sufficiently dense (at least 20 kg/m²).

A single-number rating used to compare the sound insulation properties of barriers is the Sound Transmission Class (STC). The STC rating is the transmission loss value for the reference contour at 500 Hz. Thus, the STC rating is not designed for lower frequencies of traffic noise, so it is typically 5 to 10 dB greater than the transmission loss provided (3). Approximate transmission loss values for common noise barrier materials are as follows: concrete barriers provide 34 to 40 dB; metal barriers, 18 to 27 dB; and transparent barriers, 22 dB (3).

The FHWA keeps an inventory of noise barriers throughout the country (4), which contains information of barriers constructed up to 2010. According to this inventory, Texas had 68.3 linear miles of noise barriers of any materials in 2010. Caltrans is the state agency with more linear miles of barriers with 526.4. Ohio, one of the states that is prominent for its use of transparent barriers, has 179.5 miles of noise barriers, and is second in the nation behind California. Arizona is third with 170.8 miles.

Of a total of 181,302,000 sq.ft. of barriers nationwide, only 35,000 sq.ft. correspond to transparent noise barriers (identified as “Clear/Paraglass” and “Transparent”), which accounts for 0.019% of the total. Concrete is, by far, the most common noise barrier material type, representing 84.2% of the total noise barrier construction by surface area in the country.

Aesthetics

The main advantage of transparent materials over traditional materials in noise barriers is aesthetics (5). Several communities have objected the installation of acoustic barriers because of fears over loss of views or other perceived visual impacts. Some of such objections are attributed to specific designs, heights or materials (6, 7). Therefore, transparent barriers, given the properties listed above, provided a feasible alternative for this project.

Transparent Barriers

Some of the most outstanding characteristics of transparent noise barriers are that the barriers:

- Are aesthetically pleasing
- Preserve views and sunlight for both residents and driving public
- Could relieve the feeling of enclosure
- Could attract graffiti, but the graffiti is easier to clean compared to other surfaces
- Are acoustically as effective as concrete walls
- Are lightweight

- Are expensive

In general, transparent noise barriers have a shorter service life than concrete barriers. The service life of a noise barrier can be defined as the period of trouble-free performance with no discernible change in barrier insertion loss or appearance (8). The normal estimated service life for transparent barriers is 25 years (9, 10), whereas, for instance for concrete, it is 50 years (9, 10, 11). The average cost for concrete noise barriers is about \$18 per sq. ft. (Mr. Bill Hale, TxDOT Dallas District, unpublished data), whereas the cost of the transparent noise barrier that was installed on the IH-30 project was \$32 per sq. ft. Cost is one of the most important factors for the low number of installations, relative to barriers made with other materials (9).

The following sections present some of the information provided by the various organizations that were contacted for this review:

Ohio DOT One of the most informative conversations was held with Ohio DOT. Ohio is the state with the highest amount of transparent noise barriers. They have 11 transparent noise barrier locations, and they are very satisfied with their performance, both from the structural and acoustical standpoints. The selection of transparent barriers is attributed mainly to the lighter weight and aesthetics. In many instances, it has been the public that has requested that ODOT use this type of barriers. The first transparent barriers in Ohio were constructed as pilot projects. The first one is from 2005. No major maintenance problems have occurred.

The tallest barrier that ODOT has constructed is 10-ft. high of clear area, not including the concrete barrier below it. The fact that the barriers let the sunlight go through is a feature that the public and the DOT consider very positively, as opposed to opaque materials.

The drawback of these barriers is their cost, which is approximately twice of an equivalent concrete wall.

Most of the ODOT barriers are within the cities of Columbus, Cincinnati, and Cleveland-Akron. The transparent walls are, for the most part, self-cleaning. ODOT has about 180 miles of noise barriers, of which only 4,000 ft. correspond to transparent barriers. (Mr. Noel Alcala, ODOT, unpublished data).

FHWA Only a handful of states have clear barriers; for instance, Alaska, Virginia, Ohio, New Jersey, New York and California. Acrylic barriers are the most common because some other plastics tend to turn yellow over time. Acrylite and Plaskolite are the only manufacturers that have been approved in the U.S., with Acrylite being the most common. FHWA does not know of any reports of maintenance issues post-installation.

The oldest barrier of this kind is in New Jersey, and it is about 20 years old. The material is by Cyro, which is now Acrylite. (Mr. Adam Alexander, FHWA, unpublished data).

Acrylite This noise barrier material manufacturer has many installations throughout the US; the first one of them was built in 1995 in East Brunswick, New Jersey. This project was a predecessor for several other New Jersey projects, including a rather large one in New Brunswick in 2008. They have many installations in Ohio, but also in California, and some smaller but multiple barriers in states such as Tennessee, Florida, Minnesota, Wisconsin, and Virginia (the Woodrow Wilson Bridge), plus Ontario, and British Columbia, in Canada (Mr. Nathan Binnette, Acrylite, unpublished data).

The Acrylite material has an STC rating, when tested in accordance with ASTM E-90, of 32 dB for a 15-mm thick panel, 34 dB for the 20-mm thick panel, and 36 dB for the 25-mm thick panel (12).

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2 **Plaskolite** The transparent noise barrier product manufactured by this company is called OPTIX
3 NB (noise barrier acrylic sheet). This material is lightweight, ranging from under 3 lbs. per sq. ft. at
4 0.5-in. thick, up to about 6 lbs. per square foot at 1.0-in. thick. It is UV stable, meaning it will not
5 degrade with exposure to outdoor elements. The first noise barrier project using this material was
6 installed in Columbus, Ohio in 2009. (Mr. Justin Bradford, Plaskolite, unpublished data).

7 Optix NB has an STC rating of 32 for the 0.5 -in. thick sheet and 34 for the 0.75-in. thick
8 sheet (13).

9 10 **PROJECT DESCRIPTION**

11 The project consists of a 2,500-ft. long section, between Edgefield Ave. and Sylvan Ave., west of
12 downtown Dallas, on IH-30. The facility has an average daily traffic of 167,500 vehicles, of which
13 7.7 percent are trucks. The highway segment is comprised of elevated sections (bridges) above a
14 creek (Coombs Creek), and it is next to a residential neighborhood (Kessler Park). A lightweight
15 noise barrier was considered to avoid having to retrofit the bridges to accommodate a heavier
16 structure. The neighborhood is just south of the highway and it is separated from it by a linear park
17 surrounding the creek. Kessler Parkway, a busy street that carries local traffic, runs along the park
18 approximately parallel to IH-30; on the south of this street are the first-row residences that are
19 affected by the highway noise because of their proximity to it. These residences are below or
20 slightly above the highway level, but further south, the topography of the Kessler Park area is hilly,
21 with many homes sitting at higher elevation relative to IH-30. An 8-ft. tall concrete wall already
22 existed on the south side of the highway; therefore, a new wall would be placed on top of the
23 existing barrier to provide additional benefit to the residences. A foremost concern of the residents,
24 as well as of TxDOT, was to preserve the views from some of the homes towards the city, and to
25 minimize the visual impact of the highway; since the barrier would add height to the existing wall,
26 in all likelihood, this would not be possible with an opaque barrier.

27 Four residential locations, and an additional location representative of the park, were
28 identified for the purpose of noise level monitoring. Figure 1 shows a map of the area, indicating
29 the location of the five test sites (three of which are along Kessler Parkway), as well as the project
30 limits (Edgefield Ave. on the west side, and Sylvan Ave. on the east side).



FIGURE 1 Project location, showing noise monitoring sites.

DESIGN AND RECOMMENDATION

The design of the noise barrier was performed using the FHWA Traffic Noise Model (TNM) program; noise levels were evaluated for existing and future traffic conditions (for the year 2035). Twenty-six receivers, located between Fort Worth Ave. and Beckley Ave., were included in the model. Some of these receivers are located further east of Sylvan Ave., in consideration of a possible future second noise barrier installation from Sylvan Ave. to Beckley Ave. Three receivers had noise impact (66 dBA or above), for both the current and future traffic. It should be noted that the decision about proceeding with the installation of this project was not dependent upon impacts, as it was known that the barrier would not be justified by the number of impacted receivers.

The barrier analysis was conducted for the existing 8-ft. high wall, with additional height increments of 2-ft. up to 20 ft. total, i.e., new barrier heights of 2, 4, 6, 8, 10, and 12 ft. on top of the existing wall.

A minimum height of 8-ft. was recommended (on top of the existing wall) to provide benefits to some residential receivers, and a 10-ft. wall was recommended to provide benefits for locations along the park. TxDOT agreed to install a 10-ft. barrier of transparent acrylic material. The Acrylite product was selected, with 15-mm thick panels. The installation of the barrier was completed in mid October 2013. Figure 2 shows a picture of the finished barrier, looking east towards downtown Dallas.



FIGURE 2 IH-30 transparent noise barrier.

TEST PROGRAM

Measurement Description

The noise testing consisted of Sound Pressure Level (SPL) measurements. Measurements were performed at the five locations shown in Figure 1, either once or twice per month, before and after the noise barrier installation. During each test day, measurements were conducted at all five locations on three different occasions: once in the morning, once in the early afternoon, and once in the evening, to cover a wide range of traffic conditions. Weather conditions at the time of each test were monitored by means of a portable weather station equipped with a data logger and software.

Figure 3 shows the equipment utilized for the tests consisting of the SPL meter mounted on a tripod, and the weather station on top of the vehicle.

The noise level monitoring program began in May 2013 and continued through June 2014. A total of 130 measurements were performed before the noise barrier was installed, and 125 measurements were conducted after the installation was completed.



FIGURE 3 Test equipment: SPL meter and weather station, in the proximity of the noise barrier.

Test Results

The average noise levels by location, for the tests both before and after the noise wall, are presented in Figure 4.

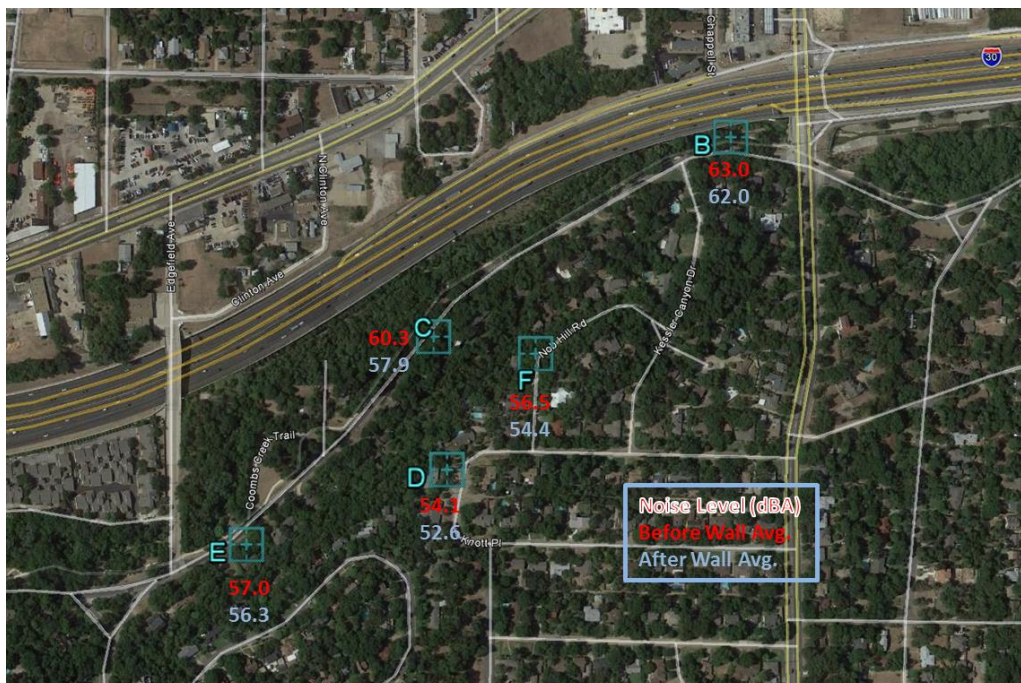


FIGURE 4 Average noise levels by location, before and after the barrier.

All the locations show some benefit from the noise wall. The location with the smallest benefit is location E (0.7 dBA), the westernmost residential location, which is very close to the west end of the noise wall, at Edgefield Ave. In all likelihood, highway noise coming from west of Edgefield Ave. still reaches this residence and this could be the reason for the marginal noise reduction. The location with the highest noise reduction after the wall was in place is residence C, the closest residence to the highway. This location shows a 2.5 dBA noise reduction with the noise wall. Besides its proximity to the highway, this location is at a lower elevation relative to the highway, which results in higher benefit from the barrier. Another location that is very close to the highway and at a lower elevation, is the park location, identified as B, and which benefit, on average is 1.0 dBA. It would be expected that this location would obtain a greater noise reduction from the wall, but some of that benefit might be negated by its proximity to the easternmost end of the wall, at Sylvan Ave., by which noise coming from the highway segment unprotected by the wall still reaches this site, similarly to location E, on the other end of the project.

Figure 5 presents the average measurements by date, to illustrate the seasonal variation of the noise before and after the barrier. It shows that the noise levels were fairly uniform before the barrier installation (coefficient of variation, $CV = 5.5\%$). After the barrier was installed, there is more variability ($CV = 6.9\%$), with the trend showing that during the warmer months, the noise levels decreased.

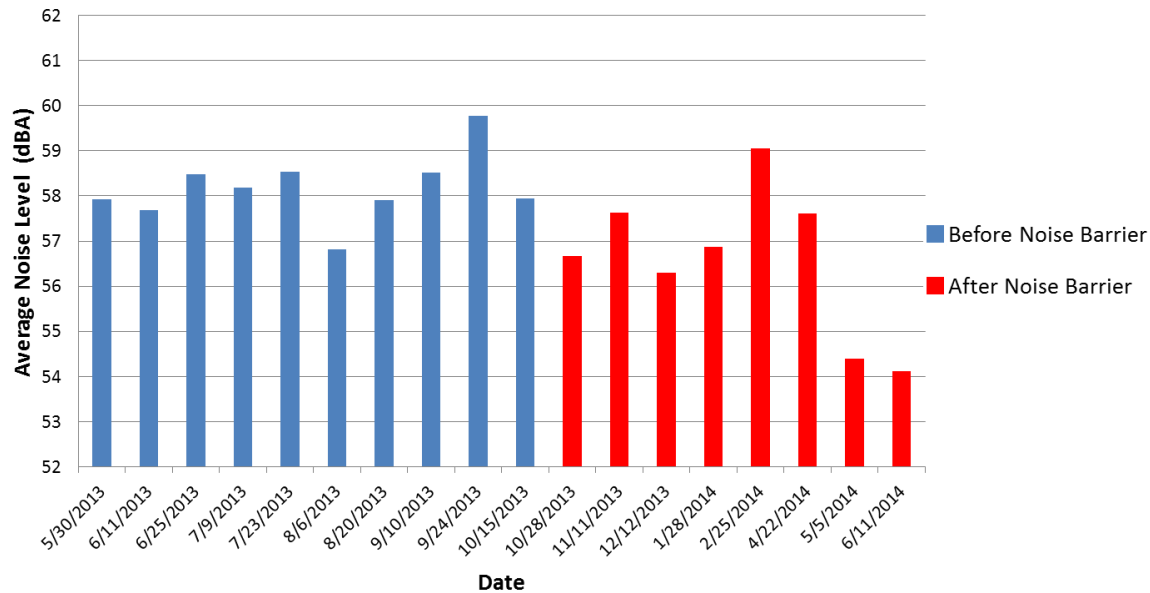


FIGURE 5 Average noise levels by test date, before and after the barrier.

Temperature effects have an important influence on the noise generation and propagation. Cold temperatures are normally correlated to higher tire-pavement noise generation (1 dBA per 10°C) (14). Therefore, for instance, a change from a temperature of 95°F , typical for the summer in Dallas, to a temperature of 40°F , also very common in the winter time, represents an increase of 3 dBA in tire-pavement noise generation alone, with all the other conditions staying constant. Such difference in noise levels represents a significant increase. In general, under colder conditions, the pavement materials as well as the rubber from the tires are stiffer and produce higher noise levels than those produced under warmer conditions. To further analyze the seasonal variations of noise that occurred after the wall was installed, the plot shown in Figure 6 was prepared. In it, the noise levels before the wall was installed are averaged, given that they were fairly uniform, due to the

fact that all of the measurements were conducted during very warm months in Texas (May through October), and then compared to the variations in levels by date after the wall was completed, for each test location. This graph confirms that the February 2014 measurements were slightly louder for all locations, and that the May and June 2014 are the quietest measurements recorded in this project.

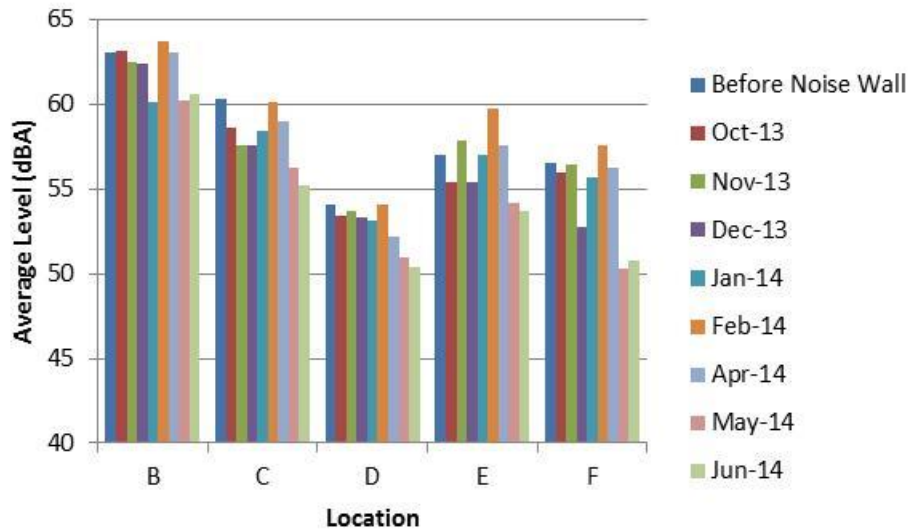


FIGURE 6 Average noise levels by test date and location, before and after the barrier.

In general, Location D, the farthest from the highway, was the quietest, and Location B, the closest to the highway, was the loudest, before and after the barrier.

The relation between temperature and noise levels is illustrated in Figure 7. The chart shows weak correlations, and the fact that all of the measurements before the barrier was installed were conducted in warm temperatures, which is not the case for the tests after the barrier was in place.

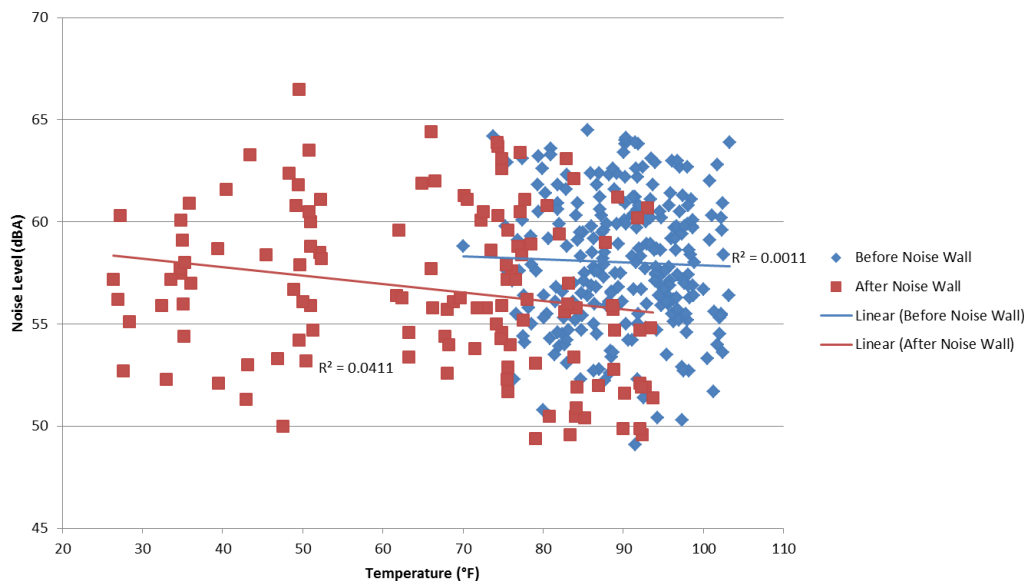


FIGURE 7 Noise levels and temperature, before and after the barrier.

It was expected that the wind and its direction would be an important factor on the noise levels. One of the main reasons for monitoring the wind was that according to some residents' accounts, the noise problem was exacerbated by winds blowing from the north and carrying the noise from the highway towards the residential area. However, the large amount of data collected does not confirm such hypothesis. Neither the wind speed nor its direction provide a strong correlation with noise levels. Figure 8 shows a plot of noise levels and wind speed, in which each data point corresponds to a noise measurement and the average wind speed that was obtained by the weather station during the noise measurement. The two weak correlations do not indicate that higher noise levels occurred with higher winds, but rather, the opposite.

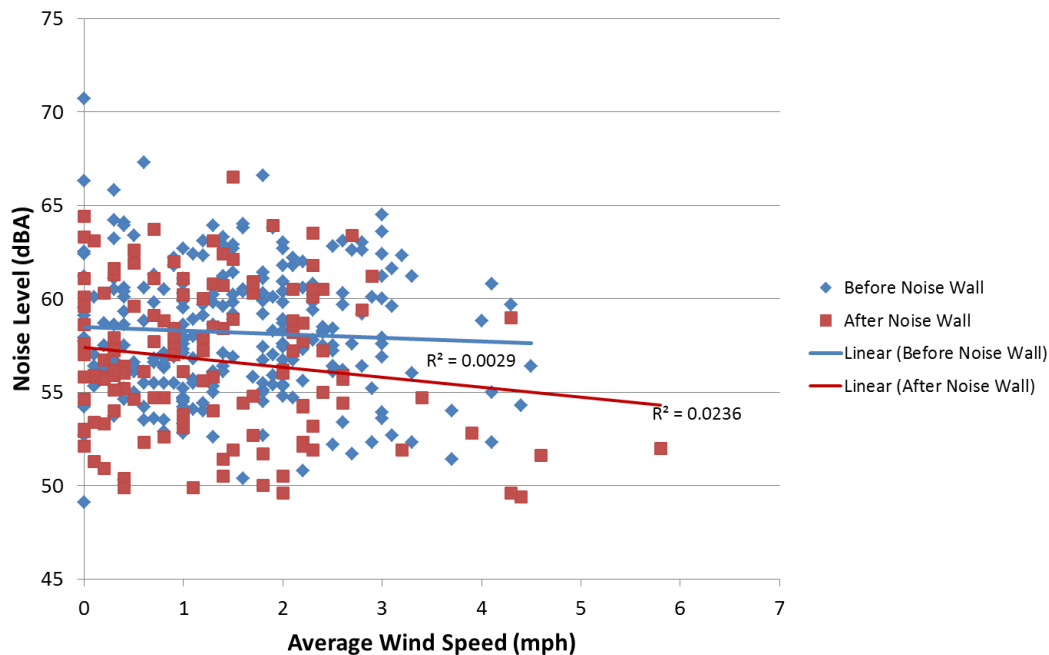


FIGURE 8 Noise levels and average wind speed, before and after the barrier.

Similarly, it was found that there was no significant correlation between noise levels and the high wind speed, i.e., the gusts, recorded during the measurement periods (Figure 9).

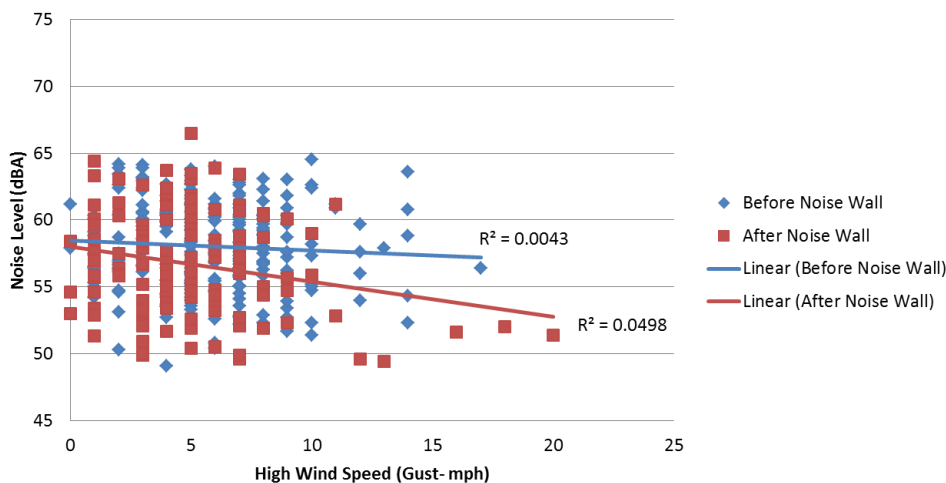


FIGURE 9 Noise levels and gusts, before and after the barrier.

In regards to wind direction, the results indicate that for most of the testing periods before the barrier was in place, the wind blew from the WNW and SSW directions (8% of the time for each direction), whereas for the post-barrier measurements, the prevailing directions were NNE (6%), S (5%) and SW (5%), so there was not a clear dominant wind direction that could be related to the higher occurrences of noise levels in the neighborhood.

Another noteworthy aspect of the results are the spectral differences among the various locations; one-third octave band spectra averaged throughout the pre- and post-barrier testing periods for each site are shown in Figure 10. These data show that Location C, the site with the greatest acoustic benefit from the barrier, but also the loudest one with and without barrier, has higher noise levels at the lower frequencies, much more than any other location, by a wide margin, and with the barrier, this location gets reduction in the frequencies between 400 and 1250 Hz. Locations D and F, the more distant sites from the highway, have flatter spectra and lower levels.

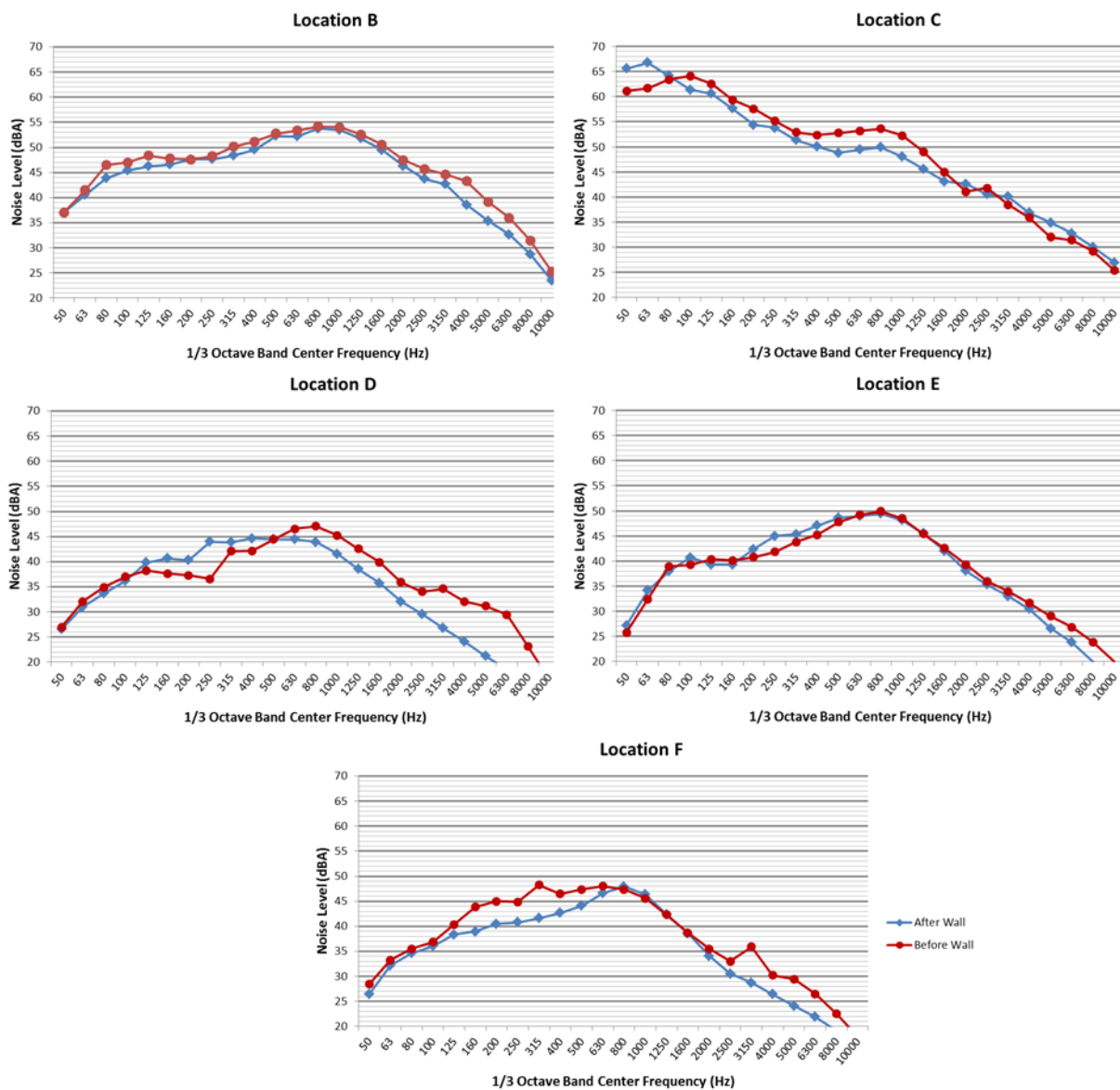


FIGURE 10 Noise spectra for the various locations.

DISCUSSION OF RESULTS

The marginal acoustic benefits of the new wall can be explained by the following facts:

- The presence of an existing 8-ft. barrier that already provided some noise mitigation to the neighborhood.

- The presence of many other sources of noise besides the IH-30 traffic noise, for which the noise barrier cannot provide any shielding. Among these, the following can be cited: airplane noise; traffic noise from Kessler Parkway, the residential street between IH-30 and the neighborhood; traffic noise from Sylvan Ave. on the easternmost end of the project, and especially from the underside of the IH-30 overpass above Sylvan Ave.; loud noises from birds and insects, especially in the warm months at dusk; and noise from airblowers and lawnmowers from residents. Every effort was made to eliminate such noises from being recorded during the measurements by using the “pause and delete the previous 5 s” feature provided by the SPL meters (back-erase), but frequently, these additional noises were prevalent in the background while performing the tests, and on many occasions surpassed the highway noise levels.

- For Locations E and B, their close proximity to the westernmost end and the easternmost end, respectively, of the new noise barrier. The highway noise coming from the sides of the barrier at either end reaches these locations. Location E is approximately 570 ft. from the west end of the barrier, while Location B is approximately 280 ft. away from the east end of the barrier.

- For Locations D and F, their distance to the highway, as well as their higher elevation, limit the effectiveness of the barrier.

Among the atmospheric factors, temperature is the most significant in regards to noise generation and propagation, while wind and relative humidity did not show influence on noise levels.

CONCLUSIONS

The noise benefits from the barrier were relatively small at all locations. The location with higher benefit is close to the highway and at a lower elevation. It was expected that the barrier would be most effective for sites of these characteristics. Other conclusions are:

- The sound barrier provided significant noise reduction in the few months following its completion, while the weather was still warm.

- Noise levels got higher in the colder months and decreased again significantly in the months of May and June 2014.

- Cold temperatures are correlated to higher tire-pavement noise generation.

- Other weather variables appear to have no significant influence.

- Foliage might have some influence on the noise levels (no foliage results in higher noise propagation). Foliage diffracts and absorbs sound. There is a considerable difference in the aspect of the foliage between the hot and cold seasons in this area, as illustrated in Figure 11.



FIGURE 11 Foliage differences between hot (left) and cold (right) seasons in the proximity of the barrier.

- Neighbors are very satisfied with the wall, as revealed by numerous conversations between the residents and the researcher. The public perception is very positive in regards to both acoustic benefits and aesthetics.

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The cooperation of the Kessler Park neighbors is acknowledged, especially those who kindly allowed the researcher to perform the measurements in their property at all times of the day.

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