



Perforated Metal Panel Parking Garage Façade Noise, Part 2

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ABSTRACT

Perforated metal panel facades can generate screeching or shrieking due to wind excitation. This phenomenon was previously observed, replicated, measured, tested, and silenced for non-corrugated panels of specific perforation size and spacings. More recent observations show that varying factors such as the size of the perforations, wind impact angle, and panel corrugation during testing produce more unique acoustic results. Work towards developing design parameters to prevent this common phenomenon is ongoing and will continue to require further testing.

1. INTRODUCTION

Perforated metal panels are a common architectural element used on parking facilities to create a visually-aesthetic screen that can also allow airflow. Specific windy conditions interacting with the panels can produce high-pitched, shrieking sounds that can have a negative impact on nearby residences and businesses. MD Acoustics, LLC (MD) was previously assigned to investigate and solve this problem as observed at parking facilities in Tempe, Arizona and in Norman, Oklahoma. Previous research relating to wind-induced panel noise was studied [1, 2, 3]. Perforated metal panels of varying dimensions and perforation patterns were tested and silenced. The results from those tests were published as a conference proceedings article titled *Ghouls Begone: Acoustics of Shrieking Perforated Panels* [4].

Most recently, MD observed this problem again at parking facilities in Tulsa, Oklahoma and Fort Worth, Texas; the circumstances found at these facilities encouraged more testing to determine the correlation between this acoustics problem and variables such as perforation size, wind angle, and panel corrugation. The damping effects of a viscoelastic damping coating on the panels were also tested. This paper

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describes the process used to further investigate and solve this acoustic phenomenon and presents MD's additional findings from recent observations and tests.

2. THE PROBLEM

Perforated metal panels are becoming a more common architectural element to parking facilities around the U.S. Windy conditions interacting with the panels have shown to produce a high-pitched, shrieking sound dominated by a tone in the 3-5 kHz frequency bands, to which the human hearing mechanism is particularly sensitive. Based on previous and recent findings, factors such as panel perforation size, panel corrugation, wind speed, and wind impact angle can affect the tone, and there appears to be a steady state feedback mechanism.

There are many ways to conceptualize this problem in terms of acoustical systems. In terms of a simple musical instrument model, the system includes a generator or oscillator (the wind), a resonator (standing waves in the panel surface), and a radiator (the panel surface itself). One way to silence a musical instrument is to decouple the oscillator from the resonator. For example, a cello string with the same tension and no connection to the wooden body of the instrument would radiate far less energy than its counterpart coupled to a wooden body. Unfortunately, in the case of the perforated panels, the generator cannot be decoupled from the resonator or the radiator in the system because the wind is in direct contact with the metal panel. There are different theories as to what constitutes the resonator in the system. In many applications, the perforated panels are attached to hollow tubes that could support standing waves; however, testing indicates that the panels exhibit the same behavior whether mounted to hollow tubes or to Unistrut or similar structural elements. The panel is essentially a vibrating plate that has its own modes and characteristic frequencies.

Another way to model the problem is as a simple mechanical system. In terms of a simple mechanical system, the perforated panel system consists of a mass (the surface mass of the panel), spring (determined by the material properties of the panel), and the damping (which is very low for galvanized aluminum). The mass of the system is determined by the material (typically aluminum), the panel thickness, and the size and quantity of perforations. Changing the mass by adjusting any of these parameters is nearly impossible once the panels are installed on the building. The restorative force of the panel is determined by the modulus of elasticity of the material, and likewise, is unable to be adjusted once the panels are installed. The damping properties of perforated architectural panels are the easiest physical properties of the panel to change once the panels have been installed. Damping coatings can often be applied in situ without having to remove panels from the building.

This paper presents additional experimental results when testing panels of varying perforation sizes and corrugation and testing varying wind impact angles. Although damping coatings are still an effective method to reduce the radiation of sound from architectural panels, the results show that the combination of certain panel design parameters and wind conditions can worsen the acoustic phenomenon, even with the application of a damping coating.

3. EXPERIMENTAL OVERVIEW

3.1. Beamforming Using Acoustical Cameras

MD utilized acoustical beamforming techniques using an acoustic camera to demonstrate the source of the noise while the noise phenomenon was reproduced. The camera utilizes arrays of digital MEMS microphones to map the location of noise sources in real time.

This provides a visual representation of the areas of the panel that produce the most noise. In addition, the systems provide the acoustic spectrum and sound pressure level of the resonant phenomenon.

The phenomenon was replicated by towing the perforated architectural panels on a trailer at 30-60 mph. The sound cameras were used from the bed of the truck pulling the trailer at a distance of approximately 10-15 ft. The output of the sound cameras is a video showing a color map of the loudest noise sources, the acoustic spectrum measured, and a spectrogram recorded during the measurement.

4. TESTING RESULTS

4.1 Varying Perforation Size

Four (4) metal architectural panels with the same thicknesses, but different perforation sizes were tested: Panels A, B, C, and D. Perforation size increased from Panel A to Panel C. Panel D had a mixture of the perforation sizes found in Panels A, B, and C. Figure 1 shows a close-up photo of Panels A, B, C, and D.

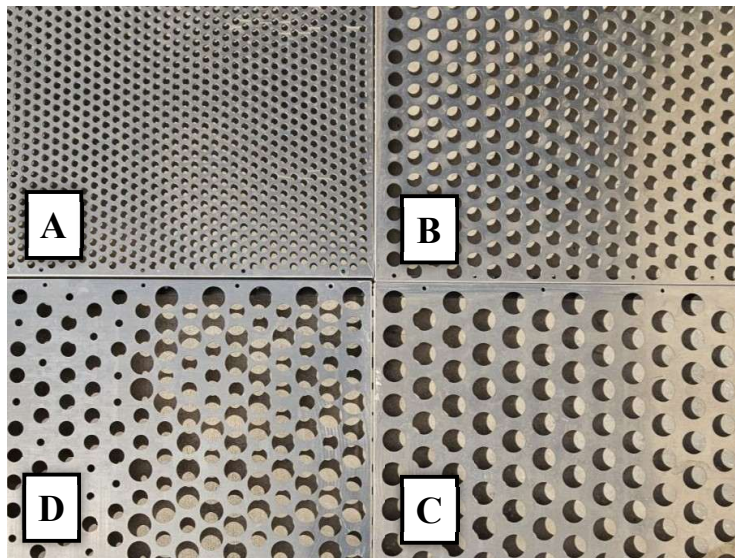


Figure 1: Panels A, B, C, & D

MD observed some wind-generated noise from Panel A and little to no wind-generated noise from Panels B, C, and D at speeds up to 57-60 mph. The wind-induced noise started around 35-45 mph.

In an effort to reduce the panel noise, MD applied a viscoelastic coating to Panel A. The damped panels resulted in reduced amplitude of the noise and an increase in the wind speed required to induce the noise. Panel A with no coating begins to whistle at speeds of 35-42 mph. Panel A with coating begins to whistle at approximately 44-48 mph. Although some whistling was still observed, the impact was reduced by the application of the viscoelastic damping material. Figure 2 shows the progression of the spectrogram for Panel A with and without coating applied.

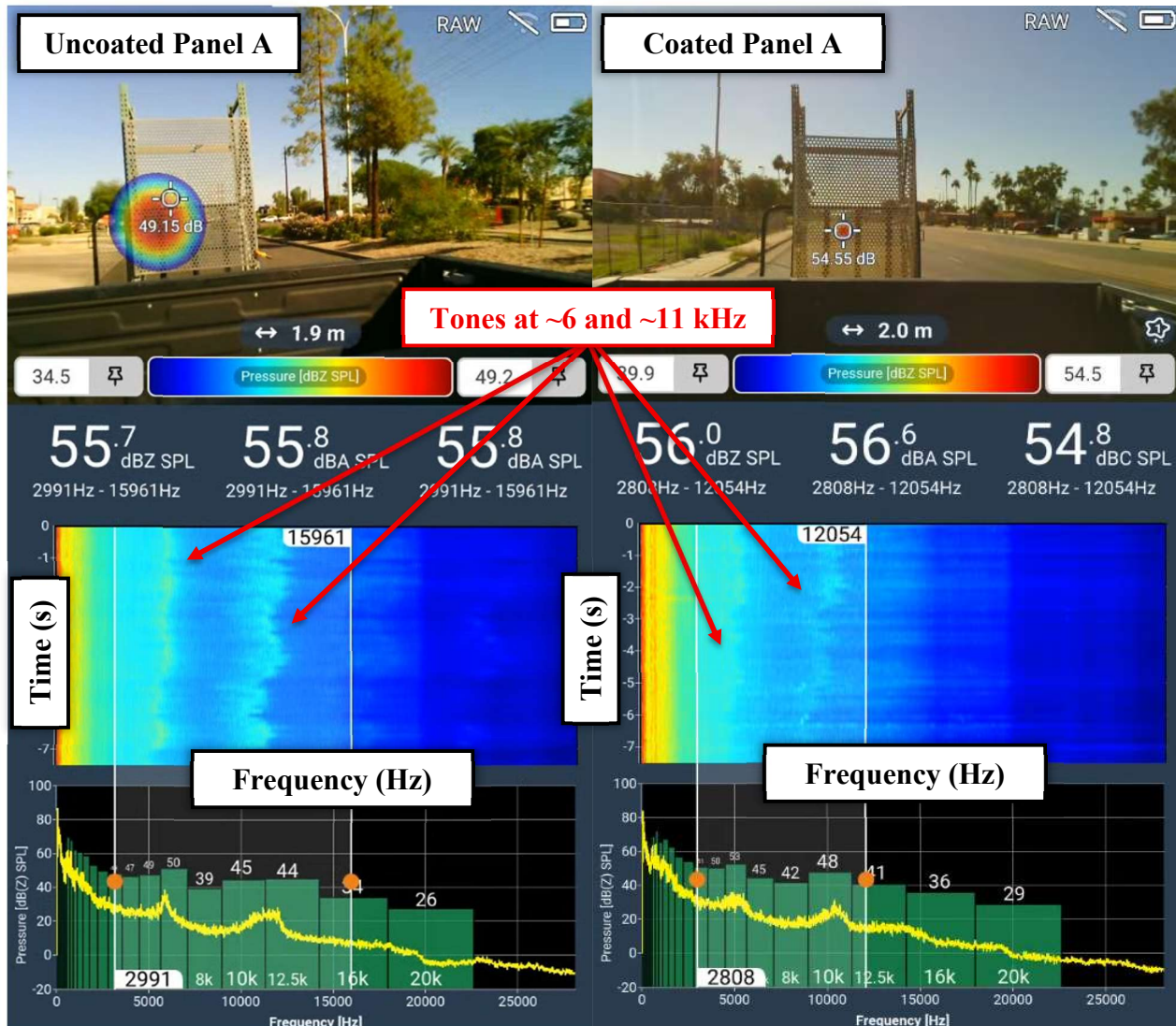


Figure 2: Panel A With (*right*) and Without (*left*) Coating

As shown in Figure 2, applying coating reduced the amplitude of the panel tones at around 6 and 11 kHz. Although the tones could still be observed at wind speeds above 45 mph, there was an audible difference between what could be heard before and after coating was applied (and allowed to cure).

4.2 Varying Wind Angle on Corrugated Panels

From previous tests on non-corrugated panels, MD observed the high-pitched, shrieking phenomenon when wind hit the panels at different angles. For flat panels, different wind angles simply required faster speeds to reproduce the same acoustic effect. Recent observations in the field and lab testing on corrugated panels introduced the same phenomenon exacerbated at similar wind speeds, but at different wind impact angles.

MD initially tested three (3) corrugated, metal architectural panels with and without perforations and different corrugations. Panels X and Y had the same sized perforations and Panel Z had no perforations. Each panel had a different corrugation type. Figure 3 shows a photo of Panels X, Y, and Z side-by-side.

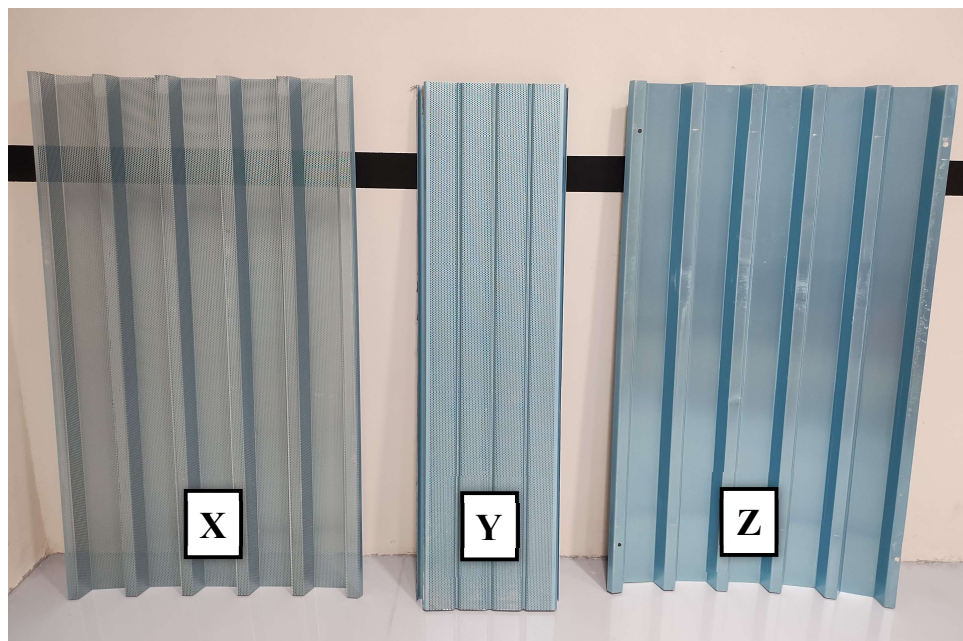


Figure 3: Panels X, Y, & Z

MD observed little to no wind-generated noise from Panel Z at speeds up to 57-60 mph and some wind-generated noise from Panels X and Y. The wind-induced noise started around 33-42 mph for both panels X and Y. To reduce the wind-generated noise from Panels X and Y the viscoelastic coating was applied to the panels. Figures 4 and 5 show the progression of the acoustic spectra of Panels X and Y, respectively, with and without coating applied.

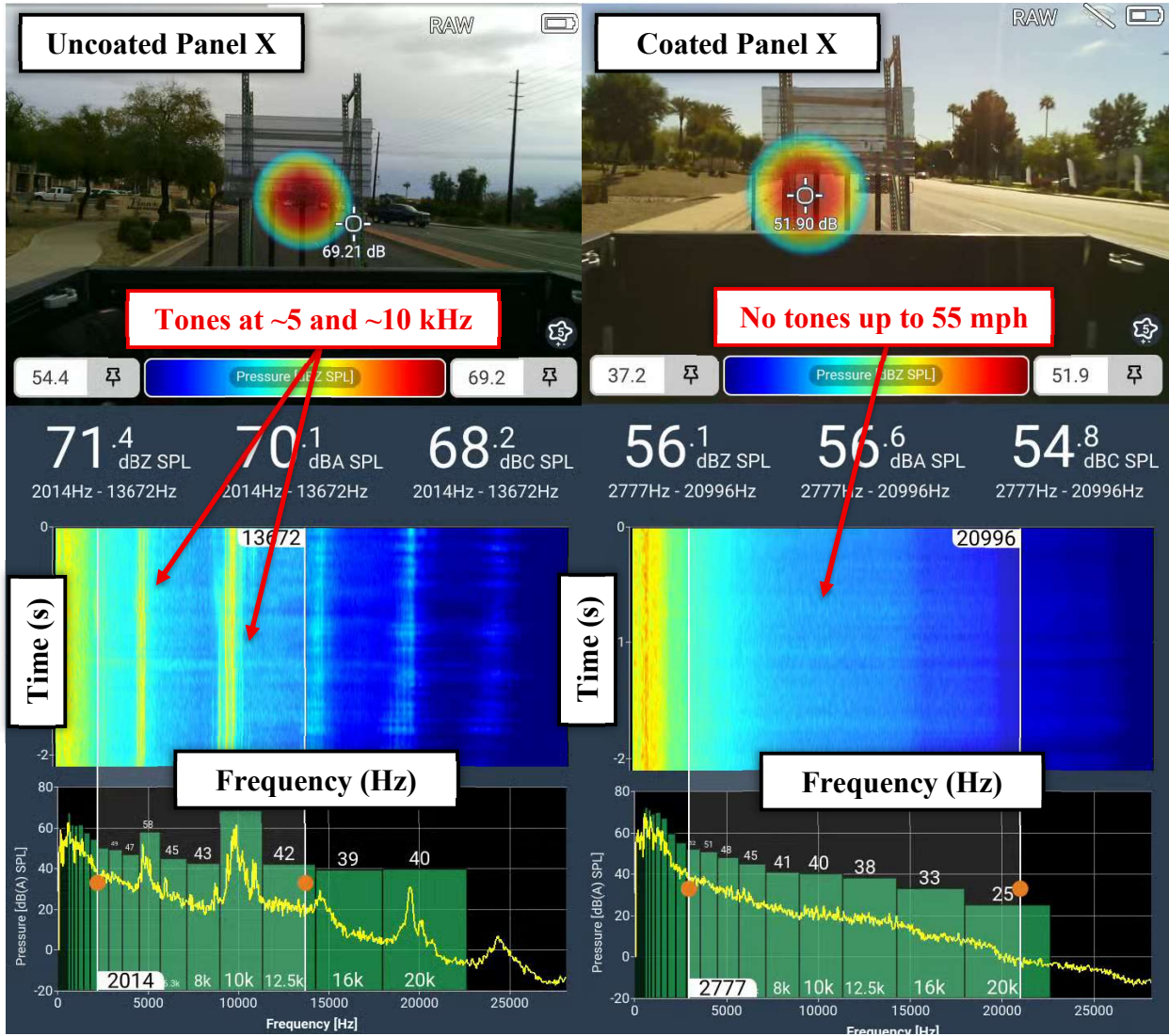


Figure 4: Panel X With (*right*) and Without (*left*) Coating

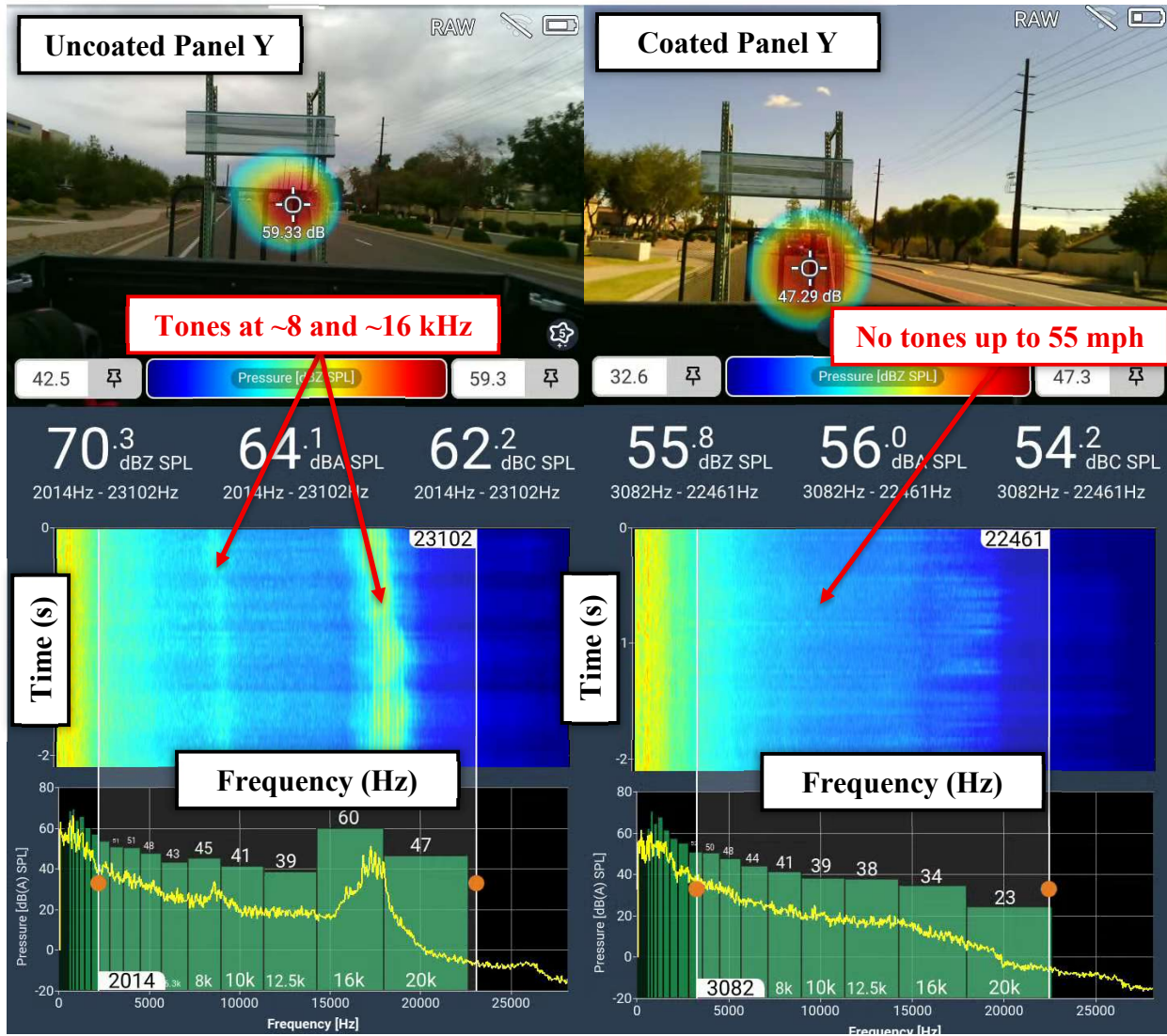


Figure 5: Panel Y With (*right*) and Without (*left*) Coating

As shown in Figures 4 and 5, the wind-generated noise was exacerbated by the corrugations on Panels X and Y. Applying coating to both panels fully quieted the tones when testing up to 55 mph.

Upon observations at a project site in Fort Worth, TX, the panels were retested at different incident angles to mimic the observed on-site noise. Table 1 summarizes what was observed at different wind speeds and wind impact angles (where 90 degrees is perpendicular to the panels).

Table 1: Angled Wind Observations

Wind Impact Angle (degrees)	Summary of Observation
90	Noise starts at 35 mph, is steady at 40 mph, & shifts in frequency at 50 mph.
75	Noise starts at 40 mph and is steady at 50 mph.
60	No noise until 55 mph, which was infrequent.
45	Different noise profile than at 90 degrees and 35 mph. Higher pitch occurs at 40 mph.
0	Swishing sound (like a moving jump rope) observed at 45 mph. Noise profile unlike typical observations.

MD used computational fluid dynamics (CFD) to further analyze the interaction of wind, at different wind impact angles and speeds, with corrugated panels. The CFD models illustrate the change in wind flow and speed through a corrugated panel; wind flows from right to left in all models. Figures 6 and 7 show CFD models for wind at 45 degrees and 90 degrees, respectively.

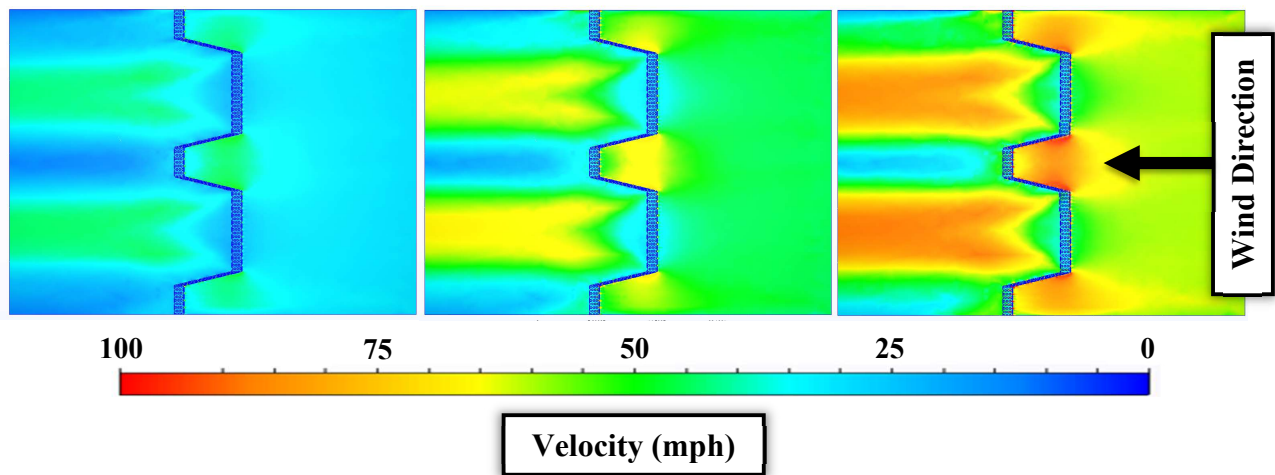


Figure 6: 45-Degree Wind at 30 (*left*), 45 (*middle*), and 60 (*right*) MPH

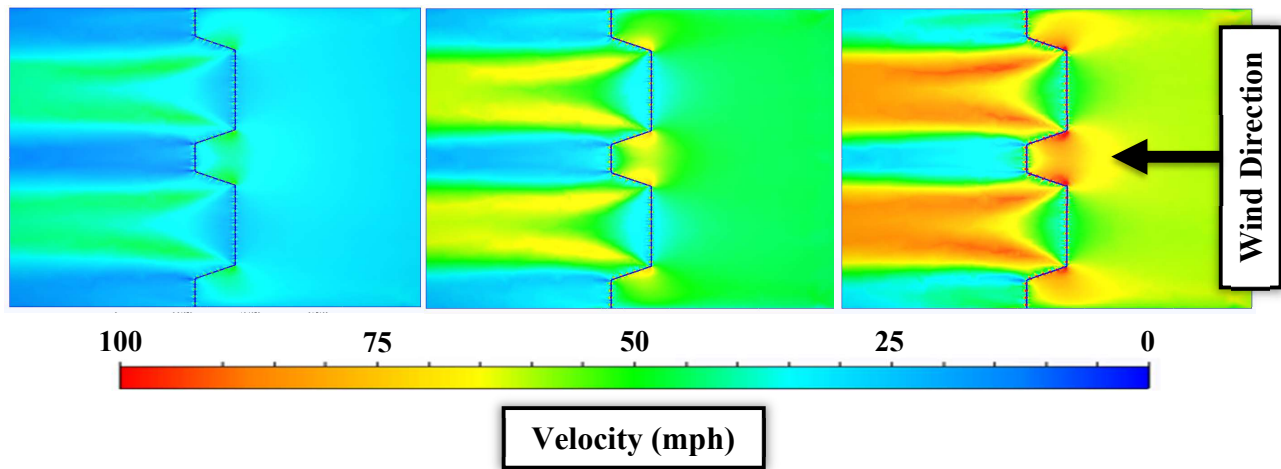


Figure 7: 90-Degree Wind at 30 (*left*), 45 (*middle*), and 60 (*right*) MPH

As shown in Figures 6 and 7, the corrugations cause the effective wind speed to increase after passing through the panels. Streams or channels of high wind speed form on the opposite side of the panels due to the angle of the corrugations. Although the wind speed may be faster through the narrower channels, the panel noise is caused and radiated by the panel as a whole. Therefore, only applying viscoelastic coating on the surfaces of the narrow channels would be ineffective in reducing radiated noise.

5. CONCLUSIONS

Previous observations and testing by MD determined that when wind interacts with perforated metal panels under specific conditions, a high-pitched, shrieking sound is produced. New observations and testing show that for a given metal panel thickness, there exists perforation sizes that do not induce audible noise. These results are general and the specific diameters that did not induce noise on the panels tested only apply to panels of identical material and thickness.

Furthermore, corrugations on perforated metal panels were shown to introduce additional phenomena not previously observed. When testing corrugated panels with wind impacting at 45 degrees, the high-pitched, shrieking sound occurs at similar speeds compared to wind impacting at 90 degrees. For non-corrugated panels, higher speeds are required to observe the noise phenomena at 45 degree incidence compared to 90 degree incidence. Regardless of the corrugations, the previously discovered damping solution (the viscoelastic coating) was effective at eliminating the noise altogether.

Overall, additional panel testing proved that even slight variations in panel design features (perforation size and pattern, corrugation pattern, panel orientation with respect to wind direction, etc.) caused differences in the radiated panel noise and the amount of damping needed to reduce the noise. As the demand for perforated metal panels on structures continues to grow, so will the variety of different panel designs. Therefore, MD will continue to encourage the need for acoustic testing on unique panels to avoid the radiation of disconcerting noises to sensitive uses.

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