TECHNICAL BULLETIN NO. 9

VIBRATION AND NOISE LEVELS

Construction vibration and noise levels are important when considering the effect of construction activities on adjacent buildings, building additions and neighbors. This technical bulletin describes the results of vibration and noise monitoring performed adjacent to Rammed Aggregate Pier® (RAP) activities using the Geopier®, Impact®, Rampact®, and Densipact systems. This information should be used when evaluating the feasibility of a RAP solution at a particular site. For sites with increased vibration and noise sensitivity, a site-specific monitoring program should be considered.

1.CONSTRUCTION VIBRATIONS

Many construction activities result in the transmission of vibrations across the construction site. Vibration levels depend on the types of construction activities as well as the soil conditions at the site. The effect of vibrations on adjacent buildings depends on the building's construction (wood, masonry, steel, concrete), building age, distance of the adjacent building from the source of vibration, duration of vibration, vibration frequency, vibration amplitude and soil conditions. In general, low frequency (long period) motions result in a greater likelihood of building damage compared to high frequency (short period) motions. This is because of the significant damping effect that occurs in soils subjected to high frequency (short period) motions. In contrast, soils subjected to low frequency (long period) motions may amplify the vibrations.

In the United States, high frequency vibrations levels less than two in/sec at the building location are generally considered to be acceptable (Wiss 1981). These levels of vibrations are unlikely to lead to building damage. Vibration levels between 0.5 in/sec and 2 in/sec, are generally considered to be an annoyance but not structurally damaging. Vibration levels of less than 0.5 in/sec are often not noticeable.

GEOPIER®

2. RAMMED AGGREGATE PIER CONSTRUCTION

Rammed Aggregate Pier installation using the Geopier system is constructed by drilling out a volume of compressible soil to create a cavity and then ramming select aggregate into the cavity in thin lifts using the patented beveled tamper. The Impact system and Rampact system are each installed in caving soils through the use of a hollow mandrel driven to the design depth. Aggregate placed down the center of the hollow mandrel fills the cavity and is compacted in thin lifts as the mandrel is raised up and rammed down to achieve compaction. The Densipact system creates Rammed Compaction® points in granular soils by repeatedly driving a multi-tined tool into the ground. After the initial drive and between re-drives, the cavities and depressions formed by the multi-tined tool are filled with sand or other suitable aggregates. The ramming action during RAP construction causes the aggregate to compact vertically and to push laterally against the matrix soil, thereby increasing the horizontal stress in the matrix soil. Rammed Aggregate Pier construction results in a very dense aggregate pier or compaction point with superior strength and stiffness. During installation, the hammers that produce the ramming action operate at ranges of 400 to 600 cycles per minute (7 to 10 cycles per second) for the Geopier system and 2,000 to 2,400 cycles per minute for Impact, Rampact, and Densipact systems. These high frequency vibration levels are higher than most other construction activities resulting in a large amount of damping within the reinforced soils at the project site. Conversely, pile driving typically produces vibrations associated with low frequencies on the order of 60 cycles per minute (one cycle per second) and an associated period of one second. The RAP vibration levels are thus both lower in amplitude and higher in frequency than pile driving activities, resulting in lower vibrations measured at adjacent sites.

3. VIBRATION MONITORING

Vibration monitoring has been performed at a number of Rammed Aggregate Pier project sites to evaluate the amplitude and frequency of vibrations as a function of distance from the energy source. At one project site, the Baptist Memorial Hospital Addition in Memphis, Tennessee, Geopier elements were installed in close proximity to existing hospital facilities. An accelerometer was used at the site to measure peak particle velocities (PPV) during the installation of the Geopier system. The accelerometer was positioned at distances ranging from 1.7 feet to 10 feet away from the Geopier elements as the tamper head elevation ranged from the ground surface to greater than 13 feet below grade. The subsurface conditions consisted of medium-stiff clay with groundwater below the bottoms of the piers. At a second project site, the Metro Wastewater Reclamation District in Denver, Colorado, a similar study was performed where accelerometers were placed between 5 feet to 15 feet away from Impact RAP construction. During installation of the Impact RAP elements, peak particle velocities were also measured as a function of the mandrel depth. The profile here generally consisted of loose to medium dense silty sands with groundwater 1 feet below grade. The results of the accelerometer testing for both project sites are shown in Figures 1 and 2. The results indicate that RAP construction vibration amplitudes decrease with distance and with increasing depth below the ground surface. The highest vibration amplitudes are observed when the tamper/mandrel is at the ground surface.

Figure 1.
Peak Particle Velocity With Depth
and Radical Distance for Geopier RAPs

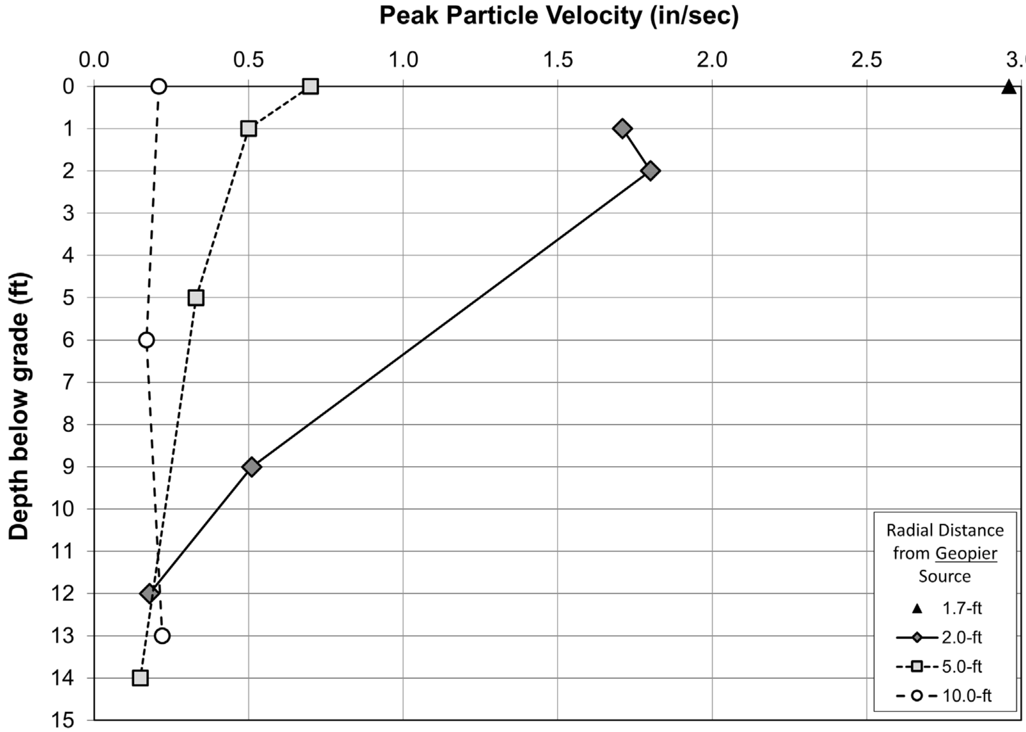
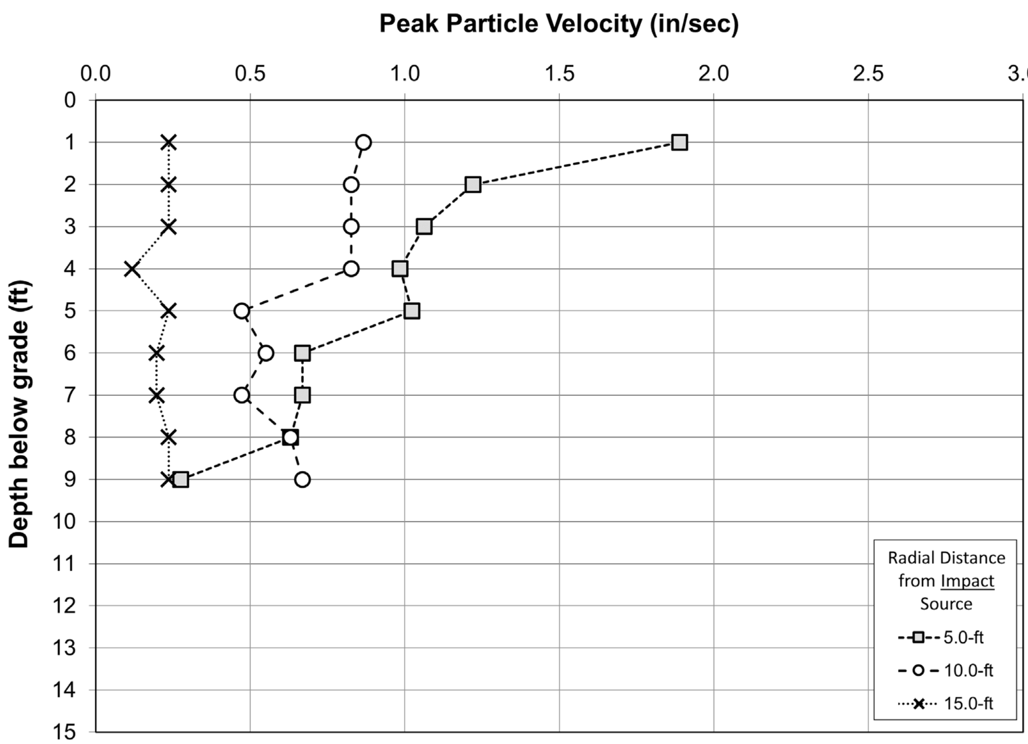


Figure 2.
Peak Particle Velocity with Depth
and Radical Distance for Impact RAPs



Figures 3 to 5 show the ranges of peak particle velocity with distance from the source for Geopier, Impact/Rampact, and Densipact systems respectively. The data further validates that vibration amplitudes reduce with radial distance from the energy source. This rapid dissipation of vibration amplitudes is attributed to the high frequency (low period) vibrations resulting from the hammers used during RAP construction. For Geopier elements, the peak particle velocities are generally less than 2.0 in/sec at distances of 5 feet from the installation location. For Impact, Rampact, and Densipact elements, the peak particle velocities are less than 2.0 in/sec at distances of 10 to 15 feet from the pier installation location. The Densipact data points generally fall within the same range as the Impact/Rampact except at distances of less than 10 feet. At 4 feet away from the pier installation, the maximum peak particle velocity doubles for the Densipact system (8.0 in/sec vs 4.0 in/sec). The higher amplitudes observed for the Impact, Rampact, and Densipact installations are likely attributed to the displacement installation procedure and the densification of the granular soils during installation. As shown, predrilling and other construction methods are effective at reducing vibrations of displacement installations.

Figure 3.
Peak Particle Velocity with
Distance from Geopier RAPs

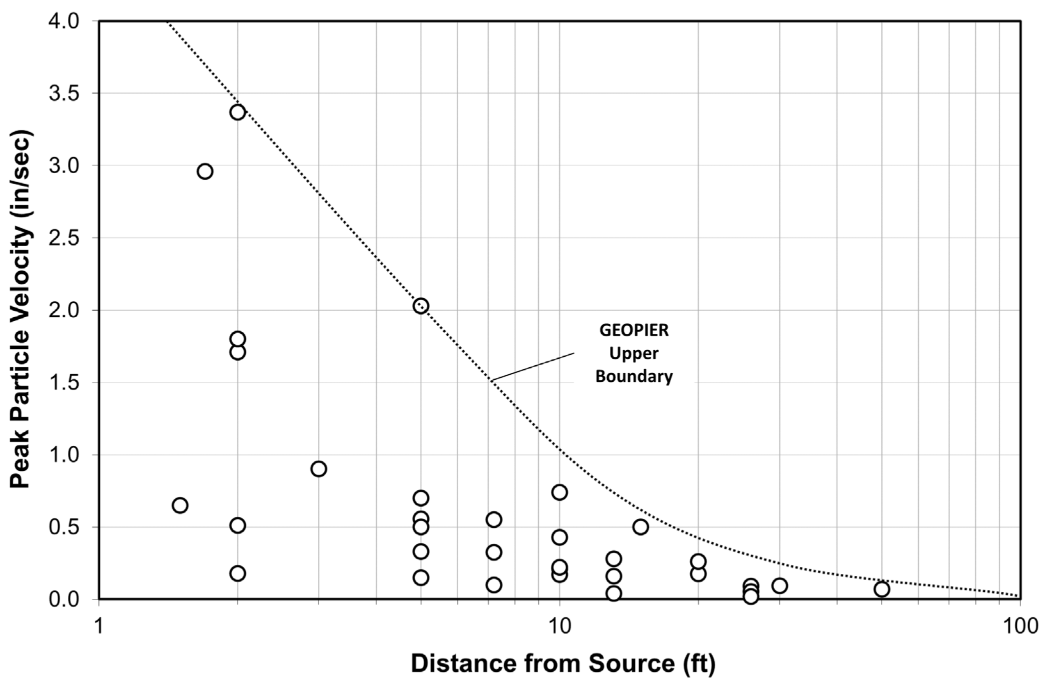


Figure 4.
Peak Particle Velocity with
Distance from Impact/Rampact RAPs

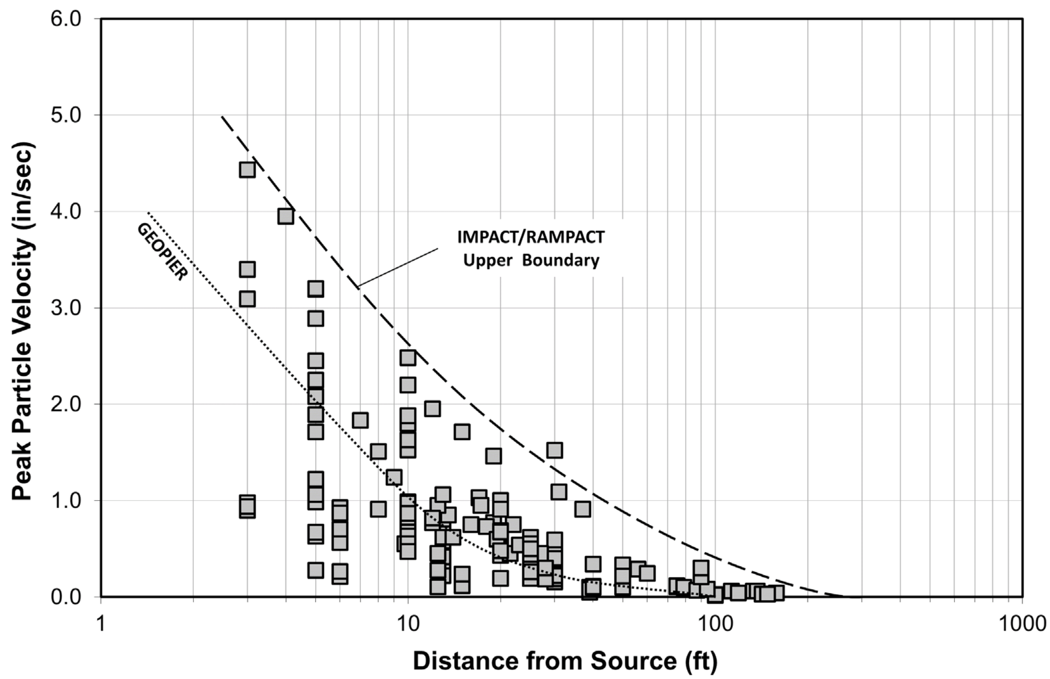


Figure 5.
Peak Particle Velocity with
Distance from Densipact RAPs

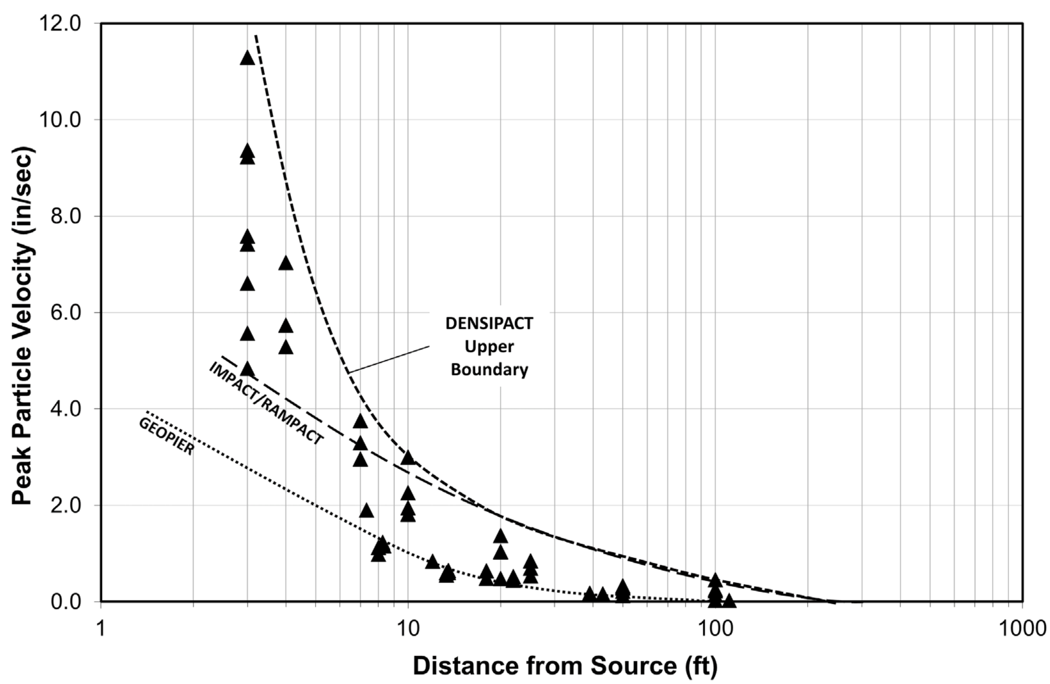


Figure 6 shows a comparison of Geopier vibration levels from the site in San Luis Obispo, California compared with other construction equipment. As indicated, the measured vibration levels are comparable to those induced by a jack hammer or a large bulldozer and are considerably lower than pile driving operations.

Figure 6.
Peak Particle Velocity with Distance from Geopier RAP (Fiegel 2005)

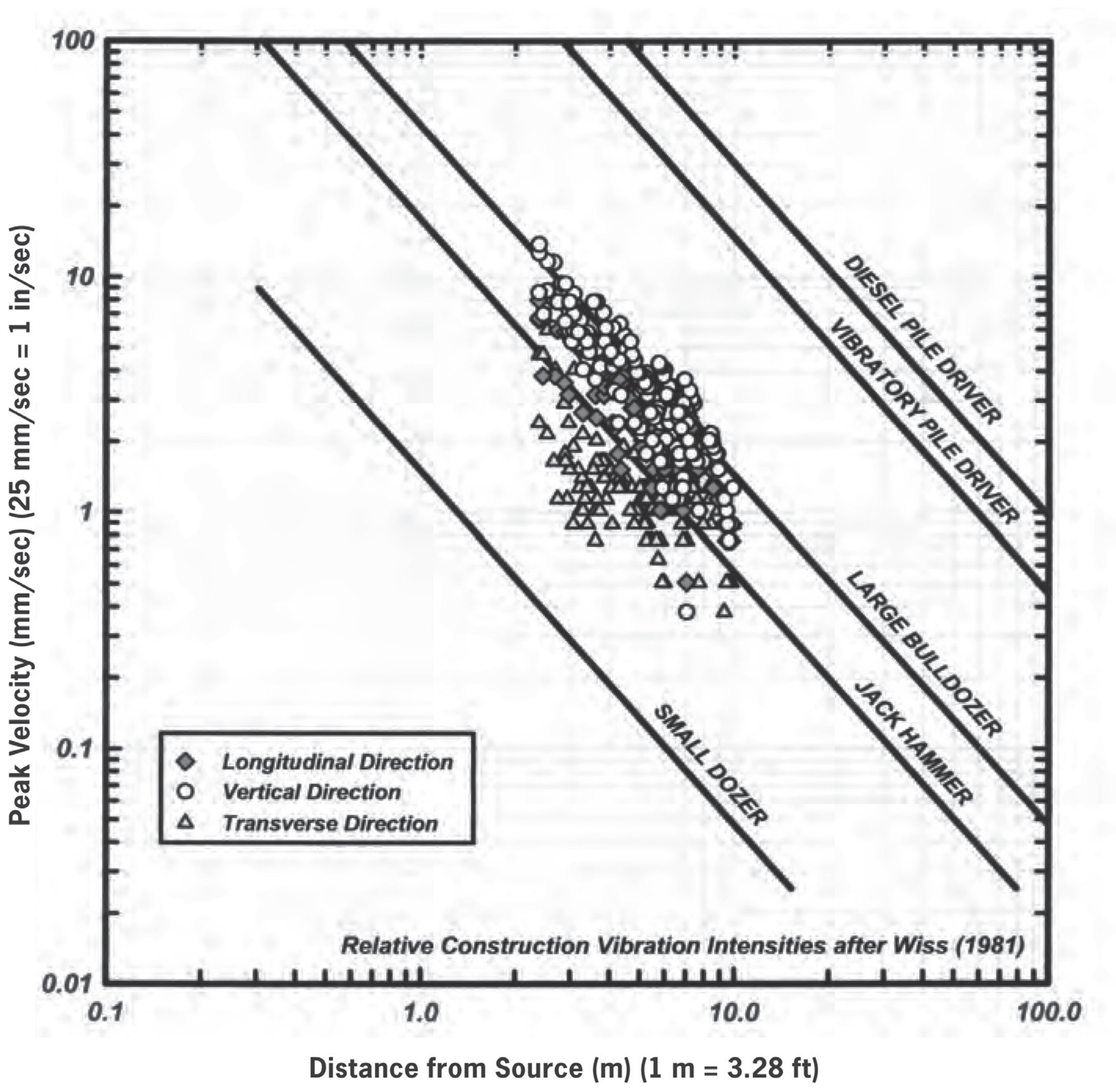
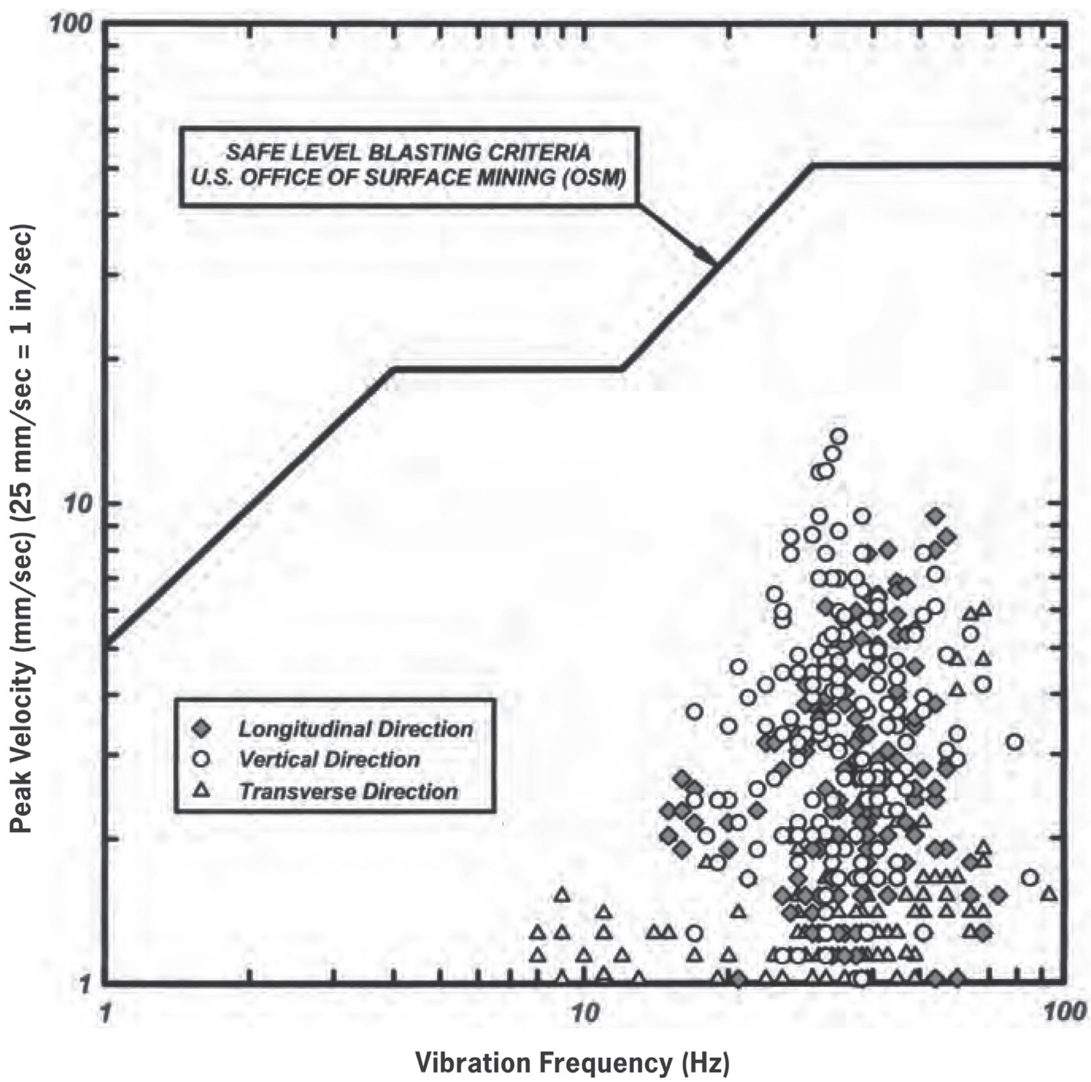


Figure 7 shows the peak particle velocities caused by Geopier installation plotted with vibration frequency as measured at the San Luis Obispo, California project site. The figure indicates that the high frequency energy used during installations results in peak particle velocities lower than the recognized standard threshold for building damage. Although the data from Figures 1 through 7 may be used for most project sites, settlement-sensitive sites should include a site-specific monitoring program to evaluate vibration levels.

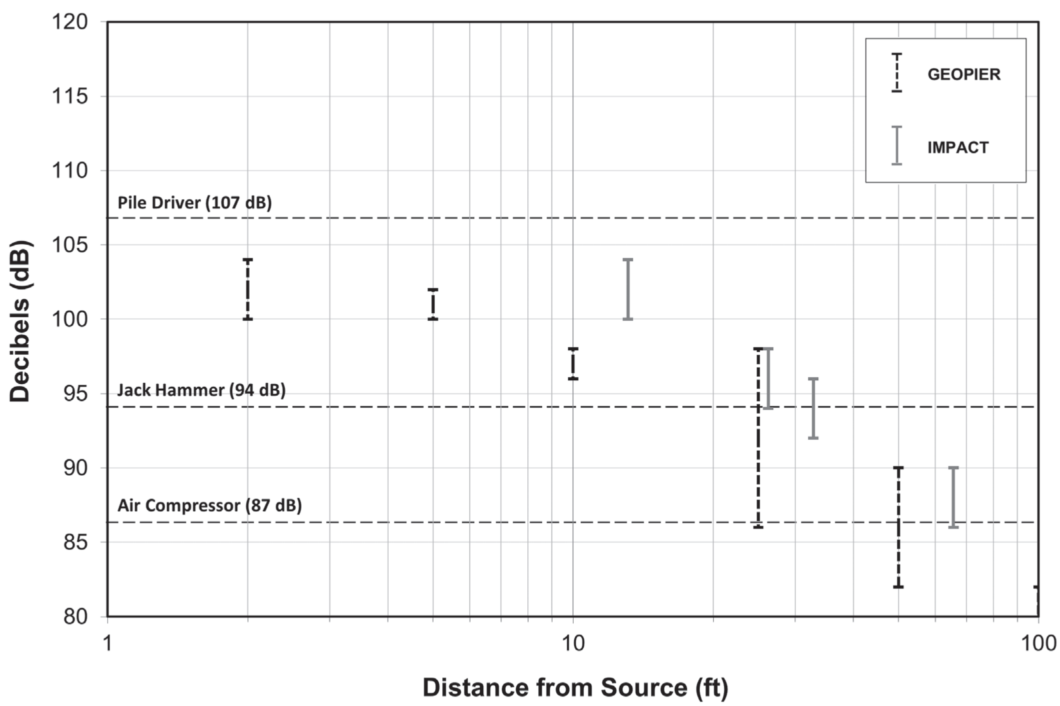
Figure 7.
Peak Particle Velocity with
Vibration Frequency
(Fiegel 2005)



4. NOISE LEVELS

Construction noise decibel levels were recorded during the installation of the both replacement (Geopier) and displacement (Impact) systems. Using a decibel meter, the noise levels were recorded with increasing distance from the RAP installation. At each distance, readings were recorded for the noise level while the ramming assembly was positioned at both the top and the bottom of the cavity. The ranges of measurements for both, replacement and displacement methods are shown in Figure 8.

Figure 8.
Range of Noise Levels with
Distance from Geopier and Impact RAPs



The decibel level for both Geopier and Impact processes reduces significantly with distance from the ramming assembly. The decibel levels drop from approximately 100 dB adjacent to the Geopier installation equipment to approximately 75 to 80 dB at a distance of 50 to 100 feet. At distances greater than 20 feet, noise levels are roughly the same for Geopier and Impact systems. At close distances, the Impact system produces slightly higher noise levels. For comparison purposes, it should be noted that interpersonal communication is on the order of 60dB, heavy truck traffic is on the order of 85 dB and pile driving operations are on the order of 105 dB.

5. CONCLUSION

Rammed Aggregate Pier installations induce high frequency (low period) vibrations during the construction process. Vibration levels for the Geopier system are typically within acceptable levels at distances greater than 5 feet from the installation location, while vibration levels for displacement Impact, Rampact, and Densipact systems are within tolerable levels at distances greater than 10 to 15 feet from installation locations. Alternative construction approaches such as predrilling helps reduce the vibration levels in close proximity to displacement piers. Noise levels for all Rammed Aggregate Pier systems are consistent with construction-type activities.

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NOTES

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