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®, and Rampact® 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.

2. RAMMED AGGREGATE PIER® CONSTRUCTION

Rammed Aggregate Pier construction is described in detail in the Geopier Reference Manual (Fox and Cowell 1998). RAP 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 ramming action during Rammed Aggregate Pier 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 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 and Rampact 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. The following table contains a sample of the collected data. The table includes a description of the soil conditions, installation technique, distance ranges from source, as well as the field vibration data for each of the project sites.

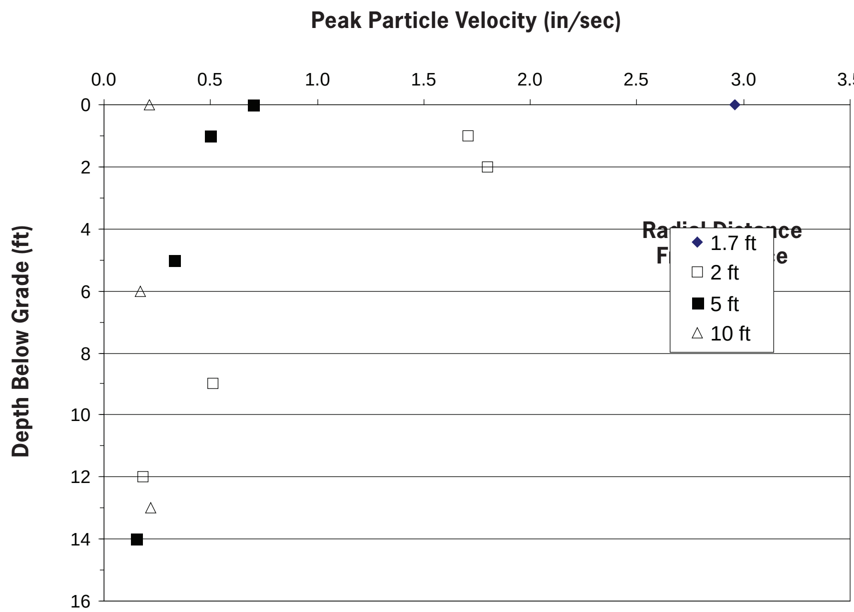
Table 1.
*Vibration Monitoring Results**

LOCATION	SOIL DESCRIPTION	REINFORCEMENT SOLUTION	DISTANCE FROM SOURCE (ft)	PEAK PARTICLE VELOCITY (ips)	FREQUENCY (Hz)
MEMPHIS, TN	MED. STIFF CLAY	GEOPIER	1.7 - 2	.18 - 2.96	43 - 57
		GEOPIER	5 - 10	.12 - .70	43 - 73
SOMERVILLE, MA	MED. DENSE GRANULAR FILL	GEOPIER	1.5 - 10	.50 - .65	30 - 85
SAN LUIS OBISPO, CA	STIFF CLAY	GEOPIER	7 - 15	.04 - .55	15 - 60
MINNEAPOLIS, MN	LOOSE SAND	GEOPIER	3 - 50	.07 - .90	27 - 57
MINNEAPOLIS, MN	LOOSE SAND	IMPACT	3 - 20	.56 - .99	21 - 47
		IMPACT	30 - 100	.02 - .48	21 - 47
MANALAPAN, NJ	MED. DENSE SILTY SAND	IMPACT	5 - 10	.57 - 3.19	37 - 64
		IMPACT	25 - 50	.10 - .62	34 - 73

**Monitoring results are also plotted in Figures 2 and 3.*

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 both accelerations and 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. The results of the accelerometer testing are shown graphically in Figure 1.

Figure 1.
Peak Particle Velocity With Depth
For Different Energy Source Distances



4. DISCUSSION OF VIBRATION RESULTS

The results of the vibration monitoring data (Figure 1) indicate that RAP construction vibration amplitudes decrease with increasing depth below the ground surface. The highest vibration amplitudes are observed when the tamper is at the ground surface. Table 1 and Figures 2 to 4 show the ranges of peak particle velocity with distance from the source. The data indicates 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 two in/sec at distances of two feet from the installation location and less than 0.75 in/sec at distances of five feet from the installation location. For Impact and Rampact elements, the peak particle velocities are less than two in/sec at distances on the order of 10 to 15 feet from the pier installation location and less than 0.75 in/sec at distances of 20 to 25 feet from the installation location. The higher amplitudes observed for the Impact and Rampact 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 4 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 2.
Peak Particle Velocities For Geopier System
With Distance From Energy Source

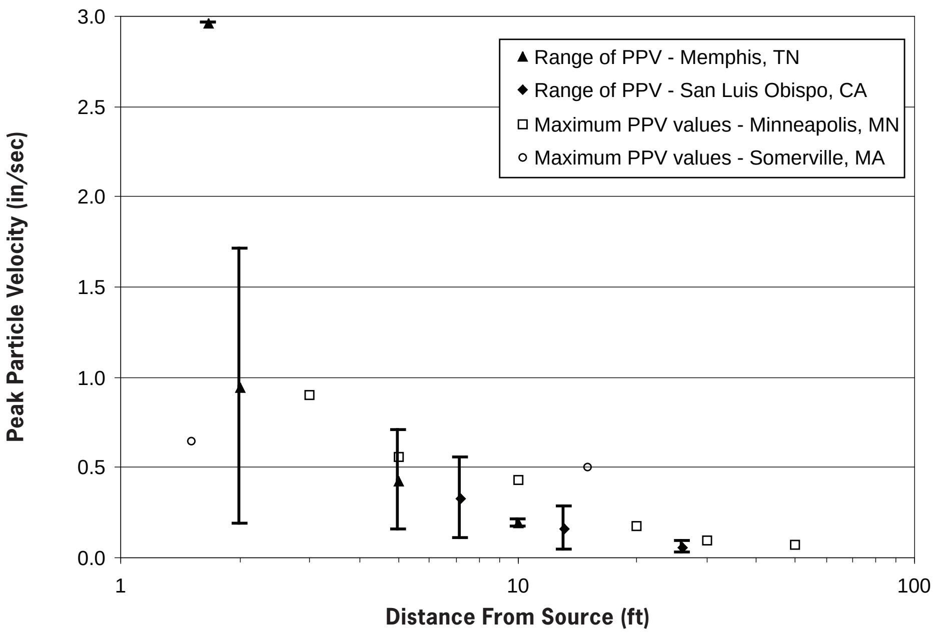


Figure 3.
Peak Particle Velocities For Impact and Rampact Systems
With Distance From Energy Source

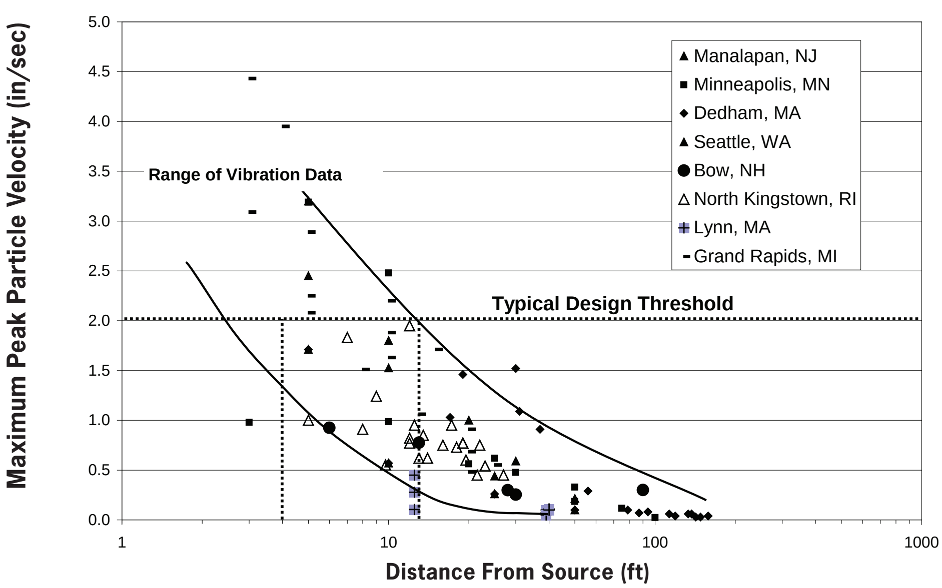


Figure 4.
Peak Particle Velocity With Distance
From Geopier Installation (Fiegel 2005)

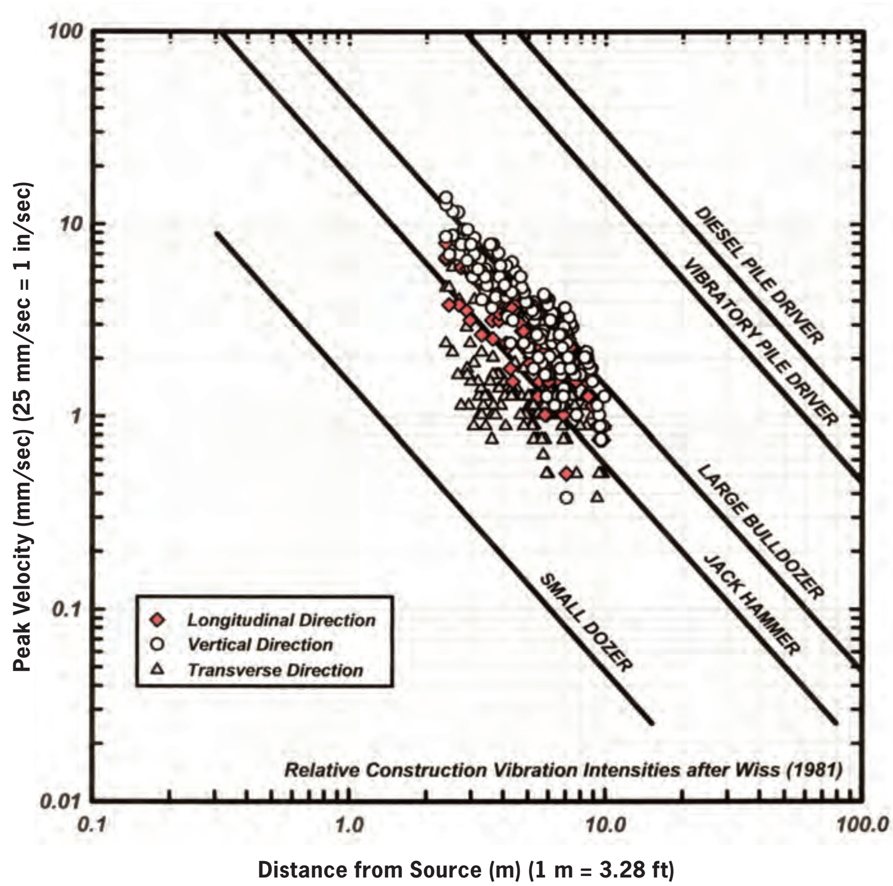
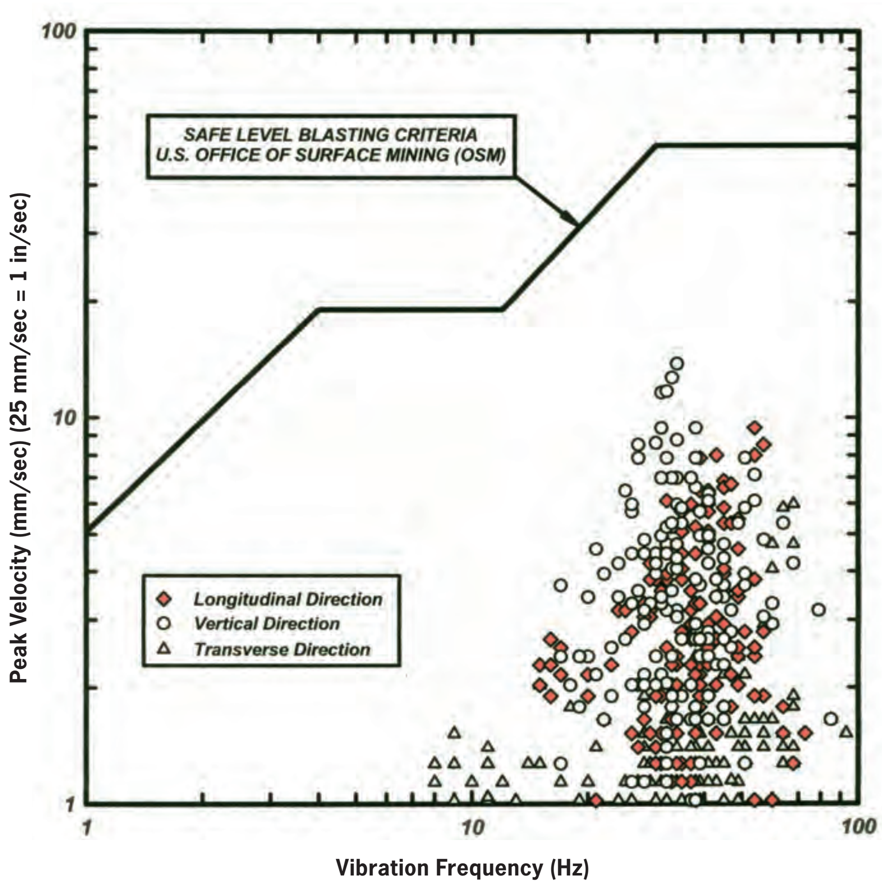


Figure 5 shows the peak particle velocities caused by Geopier installation plotted with vibration frequency as measured at the San Luis Obispo, California project site. The figure indicates that the high frequency energy used during installations results in peak particle velocities lower than the recognized standard threshold for building damage.

Figure 5.
Peak Particle Velocity With
Vibration Frequency (Fiegel 2005)



Although the data from Table 1 and Figures 1 through 5 may be used for most project sites, settlement-sensitive sites should include a site-specific monitoring program to evaluate vibration levels.

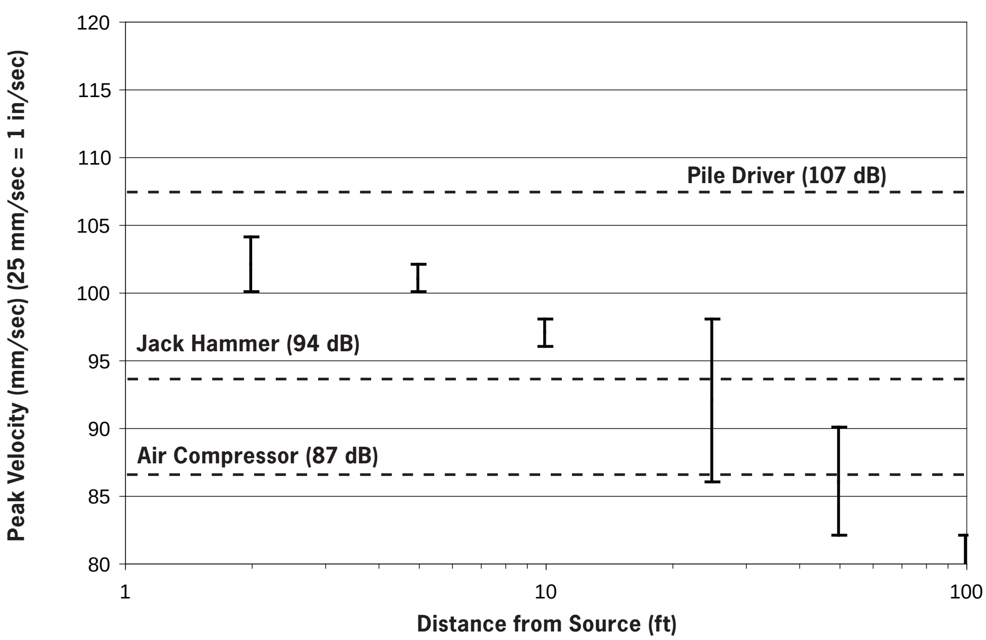
5. NOISE LEVELS

Construction noise decibel levels were recorded during the installation of the Geopier system at the Baptist Memorial Hospital project. Using a decibel meter, the noise levels were recorded with increasing distance from the Geopier 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 results of the measurements are summarized in Table 2 and shown in Figure 6.

Table 2.
Summary Of Noise Levels

DISTANCE FROM RAMMING ASSEMBLY (ft)	DECIBEL LEVEL WITH TAMPER AT TOP (dB)	DECIBEL LEVEL WITH TAMPER AT BOTTOM (dB)
2	100	104
5	100	102
10	96	98
25	86	98
50	82	90
100	75	82

Figure 6.
Range Of Geopier System Noise
Levels With Distance From Source



The decibel level for the Geopier installation process 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. For comparison purposes, it should be noted that interpersonal communication is on the order of 60 dB, heavy truck traffic is on the order of 85 dB and pile driving operations are on the order of 105 dB.

5. NOISE LEVELS

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 between 2 and 5 feet from the installation location, while vibration levels for displacement Impact and Rampact systems are within tolerable levels at distances between 10 and 20 feet from installation locations. Alternative construction approaches such as predrilling helps reduce the vibration levels in close proximity to Impact and Rampact piers. Noise levels for all Rammed Aggregate Pier systems are consistent with construction-type activities.

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