

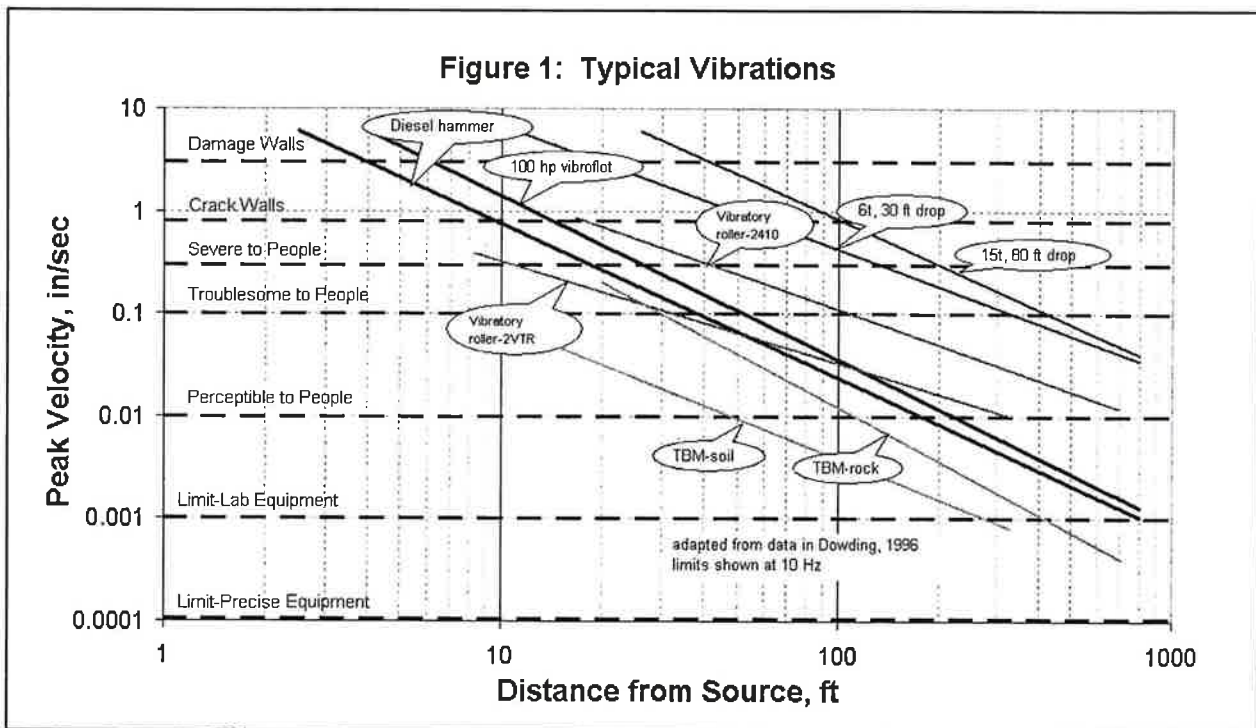
Dealing with Vibration and Noise from Pile Driving¹

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Pile driving produces vibrations and noise that may extend thousands of feet away from the driving activity. People have become increasingly intolerant of these effects. They complain to government agencies and oppose developments that use pile elements. Their opposition is beginning to seriously affect the pile driving industry in the developed countries. Governmental agencies and owners are choosing alternatives to pile driving to avoid the vibrations and noise. This is an unfortunate and uninformed reaction for three reasons: (1) the alternatives may be considerably more expensive than driving piles, (2) the alternatives may produce comparable levels of noise and vibrations, and (3) the perceptions of people about the possible damage from vibrations and noise are generally wrong. This paper addresses the third issue.

The pile driving hammer produces vibrations and noise with each blow delivered to the pile. The vibrations of consequence are caused by waves of energy traveling away from the pile. Each blow to the pile transfers energy from the pile to the surrounding soil. As much as 70% of the energy transferred to the soil by pile driving travels away from the pile in the form of surface waves (Woods, 1997). The particle velocity of the ground surface caused by these traveling waves of energy decreases with distance from the source due to geometric effects, much like the height of a ripple created by dropping a stone into a pond decreases with distance away from the drop point.

The oscillating ground can induce stresses in a structure that cause damage. Plaster and weak mortar are among the first elements to experience damage. The repeated stressing from the hundreds of blows necessary to drive a single pile potentially exacerbates damage due to fatigue effects. Figure 1 shows a typical plot of the levels of particle velocity required to produce structural damage at a frequency



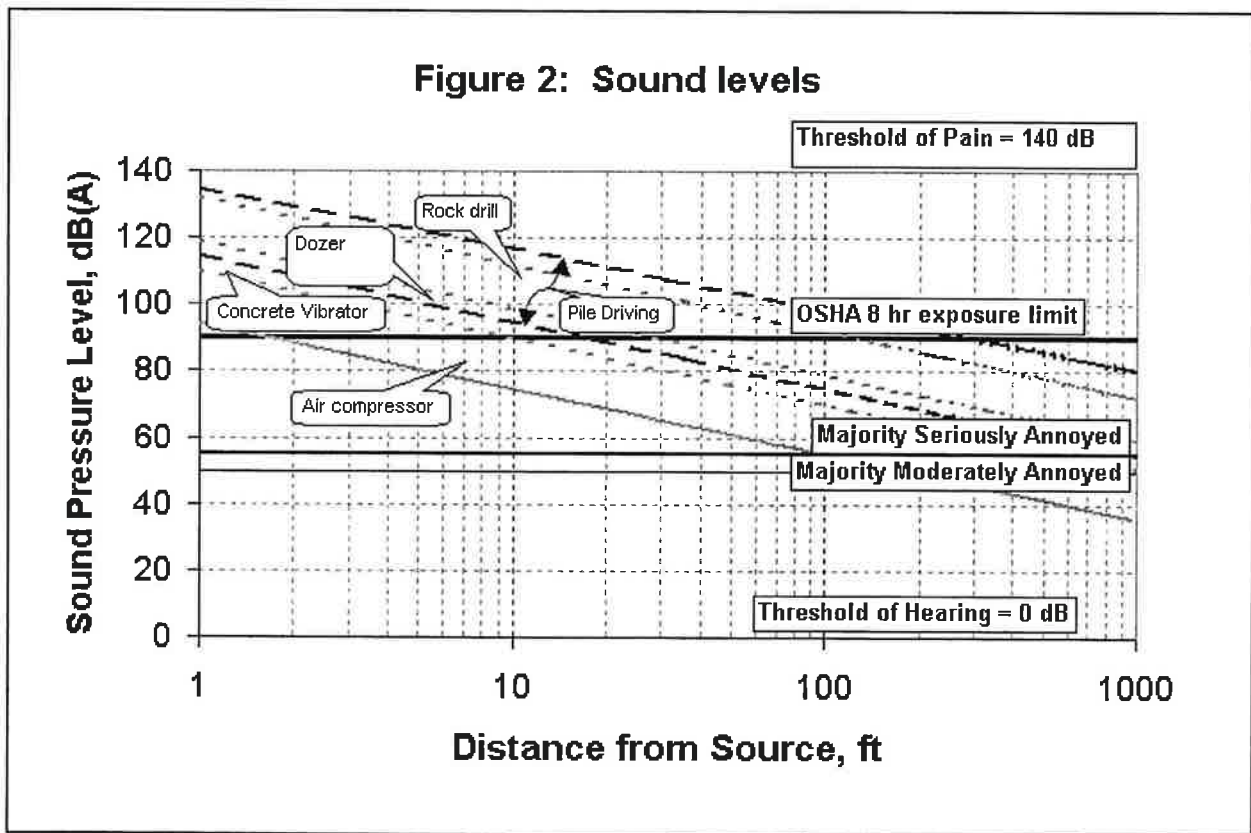
¹ Adapted from paper in Piledrivers.org, Pile Driving Contractors Association, Vol. 2, No. 1, 2001, pp 17-20.

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of 10 Hz. Also shown are the measured peak vibration levels from various construction activities as a function of distance away from the vibration source. The measured data show how the particle velocity decreases rapidly with distance from the source. Figure 1 shows that if one is more than 15 feet away from the vibration source for typical pile driving, the vibration level is below that which may damage a structure. The available data and experience show that unless pile driving is occurring within a few feet of a structure, it does not cause damage to the structure from vibrations. (There may be other undesirable effects such as vibration induced ground settlement or disruptions to very sensitive equipment, but these are special cases.) The contents of Figure 1 are well known to the geotechnical engineering profession and many pile driving contractors.

So why do people complain about pile diving and resist its use? Figure 1 holds a significant part of the answer. Figure 1 also shows criteria on the sensitivity of people to vibrations. People can typically perceive vibrations above 0.01 in/sec - one-hundredth the level at which structural damage might occur. Vibrations above 0.1 in/sec can become troublesome to people. People can feel and become concerned about vibrations that are only 1/100th of those that might begin to cause damage to structures. They can feel and become concerned about vibrations that are 1/10th of the levels that become troublesome to most people. People complain about pile driving effects because they are much more sensitive to vibrations than are buildings. They tend to extrapolate their personal sensitivity to vibrations to a concern about the safety of their building.

Noise from pile driving rarely if ever produces structural damage, but it causes annoyance that may reach a long distance. Figure 2 summarizes some typical data on noise levels for various construction activities. It also shows some of the criteria used to limit noise. The measurement of sound level used in Figure 2 is dB(A). Humans perceive a 10 dB increase in sound level as a doubling of



loudness. Sound level decreases approximately 6 dB(A) for every doubling of the distance from the source. Noise below 80 dB(A) is considered to not cause hearing loss. OSHA set the 8 hour exposure limit to noise at 90 dB(A). Studies by the World Health Organization have shown that the majority of people become moderately annoyed by steady, continuous sound levels above 50 dB(A) and seriously annoyed at continuous sound levels above 55 dB(A).

Pile driving is one of the noisiest construction operations. Figure 2 shows a range of sound levels reported for pile driving for a variety of hammer types and sizes. For the noisiest hammer, one would have to go approximately 300 ft away from the hammer to get below the OSHA 8 hour exposure limit. One would have to get several miles from the noisiest hammer for the sound level to drop below that causing moderate annoyance to most people. Clearly pile driving in urban areas has the potential to annoy a lot of people. When people become annoyed, they also become concerned. They start looking for evidence of damage to their property from the construction work and complaining to their elected officials. Some engage lawyers to pursue compensation for their grief. When people look for evidence to confirm their suspicions, they will usually find something. Politicians don't like receiving complaints. Lawyers love opportunity. Noise may be the most serious threat to the pile driving industry today - not because it is causing damage but because it creates a perceived problem to those impacted.

Vibration and noise from pile driving have some common elements. The intensity of both decreases with the log of distance away from the source. Both are unlikely to cause structural damage as long as the structure is several feet from the driving activity. For both, the real problem is the annoyance to people caused by the vibrations and the noise and not physical damage.

In today's urban world, people demand a secure environment free from annoyance. Contractors must develop means to manage the vibration and noise problems produced by pile driving. The following approaches are recommended for every project that involves pile driving:

1. Education - People that may be impacted by pile driving need to be informed in advance of the planned activities and what the impact to them may be. Informed people are less likely to suspect that the vibrations and noise are causing physical harm to themselves or their property. People potentially impacted should be provided with educational materials on the project schedule, the nature of the work, the importance of the work to the community and the potential impacts of the work on them. A special effort should be made to assure them that feeling vibrations and hearing noise does not equate to physical harm or damage. Be considerate and respectful of their expected right to a peaceful environment.
2. Abatement - Take steps to reduce vibration and noise levels to the extent that they are economically possible. Limit the time of driving to daylight hours when people are less affected by these nuisances. Try to reduce the time required for pile driving. Use noise shrouds or curtains to reduce noise levels by 15 to 30 dB(A). Figure 2 shows that a 30 dB(A) reduction to the noisiest hammer can limit the area within which most people are moderately annoyed to within 500 ft of the work!
3. Monitoring - Measure the vibration and noise levels at key locations. Use the measured data with the information in this paper to demonstrate that your work is well below the levels that cause harm. Actual measurements can become invaluable if you face a legal action over vibration or noise complaints. Should the measurements show unacceptable performance, adjust your work processes to correct the problem before someone else complains. Measurements should begin before pile driving starts to establish background levels of vibration and noise. Preconstruction damage surveys may be worthwhile where buildings are located within a few hundred feet of pile driving activities.
4. Involvement - Keep the affected parties engaged in the project and informed of progress. Use community representatives, community meetings, newsletters, or a project WEB

page to keep people informed of the work progress. Use the measurements from your monitoring program to show how well you are keeping vibrations and noise at safe levels.

5. Proactive - Stay proactive to manage vibrations and noise and minimize misinformation. After all, vibrations and noise from pile driving are more perceived problems than they are reality. But as the modern world acts, perception is reality, so you have to work to manage the perception.

We have been working on some technology to help contractors carry out these approaches. It involves the use of vibration and sound monitoring equipment connected to the Internet. We provide special seismographs to a contractor who places them at sensitive locations. The seismographs are coupled to the Internet via a cell phone. The system is programmed to call our server whenever a preset threshold of vibration or sound is recorded. Our server downloads the specific data from the seismograph and places it onto a WEB site. Our server may also send an email or a coded message by phone or pager to the contractor to alert them that threshold levels for vibration or noise are being exceeded. All of this happens automatically and within a few minutes.

This technology helps (1) educate the community on the real effects of pile driving rather than perceived effects, (2) give the Contractor measurements with which to establish and control abatement programs, (3) provide a data base of real facts to counter inflated claims, (4) keep significant parties involved by giving them access to the real facts on the project via the WEB and (5) provide a proactive way for contractors to work with the community by keeping its members informed. We look forward to using it to help contractors more effectively deal with vibrations and noise produced by pile driving.

References

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