

Vibration Primer

Vibration consists of oscillatory waves that propagate from the source through the ground to adjacent buildings. Vibration from construction projects is caused by general equipment operations, and is usually highest during pile driving, soil compacting, jackhammering and construction related demolition activities. Although the vibration is sometimes noticeable outdoors, it is almost exclusively an indoor problem. Although it is conceivable for ground-borne vibration from construction projects to cause building damage, the vibration from construction activities is almost never of sufficient amplitude to cause even minor cosmetic damage to buildings. The primary concern is that the vibration can be intrusive and annoying to building occupants.

The frequency of a vibrating object describes how rapidly it is oscillating. The unit for frequency is Hertz, abbreviated Hz, and represents the number of cycles per second of oscillation. Construction vibration consists of a composite or “spectrum” of many frequencies and are generally classified as broadband or random vibrations. The normal frequency range of most ground-borne vibration that can be felt generally starts from a low frequency of less than 1 Hz to a high of about 200 Hz. Vibration levels are usually expressed as single-number measure of vibration magnitude, in terms of velocity or acceleration, which describes the severity of the vibration without the frequency variable.

Vibration energy spreads out as it travels through the ground, causing the vibration level to diminish with distance away from the source. High frequency vibrations reduce much more rapidly than low frequencies, so that low frequencies tend to dominate the spectrum at large distances from the source. Discontinuities in the soil strata can also cause diffractions or channeling effects that affect the propagation of vibration over long distances. When vibration encounters a building, a ground-to-foundation coupling loss will usually reduce the overall vibration level, however, under certain circumstances, the ground-to-foundation coupling may also amplify the vibration level due to structural resonances of the floors and walls.

While people have varying sensitivities to vibrations at different frequencies, in general they are most sensitive to low-frequency vibration. Vibration in buildings caused by construction activities may be perceived as motion of building surfaces or rattling of windows, items on shelves, and pictures hanging on walls. Vibration of building components can also take the form of an audible low-frequency rumbling noise, which is referred to as ground-borne noise. Ground-borne noise is usually only a problem when the originating vibration spectrum is dominated by frequencies in the upper end of the range (60 to 200 Hz), or when the structure and the construction activity are connected by foundations or utilities, such as sewer and water pipes.

Table 1 summarizes the levels of vibration and the usual effect on people and buildings. The U.S. Department of Transportation (U.S. DOT) has guidelines for vibration levels from construction related to their activities, and recommends that the maximum peak-particle-velocity levels remain below 0.05 inches per second at the nearest structures. Vibration levels above 0.5 inches per second have the potential to cause architectural damage to normal dwellings. The U.S. DOT also states that vibration levels above 0.015 inches per second are sometimes perceptible to people, and the level at which vibration becomes annoying to people is 0.64 inches per second.

Table 1. Effects of Construction Vibration

Peak Particle Velocity (in/sec)	Effects on Humans	Effects on Buildings
<0.005	Imperceptible	No effect on buildings
0.005 to 0.015	Barely perceptible	No effect on buildings
0.02 to 0.05	Level at which continuous vibrations begin to annoy in buildings	No effect on buildings
0.1 to 0.5	Vibrations considered unacceptable for people exposed to continuous or long-term vibration	Minimal potential for damage to weak or sensitive structures
0.5 to 1.0	Vibrations considered bothersome by most people, however tolerable if short-term in length	Threshold at which there is a risk of architectural damage to buildings with plastered ceilings and walls. Some risk to ancient monuments and ruins.
1.0 to 2.0	Vibrations considered unpleasant by most people	U.S. Bureau of Mines data indicates that blasting vibration in this range will not harm most buildings. Most construction vibration limits are in this range.
>3.0	Vibration is unpleasant	Potential for architectural damage and possible minor structural damage

Typical levels from vibration do not have the potential for any structural damage. Some construction activities, such as pile driving and blasting, can produce vibration level that may have the potential to damage some vibration sensitive structures if performed within 50 to 100 feet of the structure. The reason that normal construction vibration dose not result in structural damage has to do with several issues, including the frequency vibration and magnitude of construction related vibration. Unlike earthquakes, which produce vibration at very low frequencies and have a high potential for structural damage, most construction vibration is in the mid- to upper- frequency range, and therefore has a lower potential for structural damage.

Construction Vibration Levels Impacts:

Vibration associated with general construction activities can result in vibration impacts. Project related vibration sources include excavators, haul trucks, flat bed tractor-trailers, backhoes, cranes and jackhammers. The vibration sources associated with the project, even though are likely to be noticeable to residents when construction is nearby, are not expected to cause any structural damage.

Vibration levels for construction activities are projected to be the highest during demolition activities and soil compacting. Demolition activities include breaking and removing sidewalks, asphalt and curbs. Major construction equipment that would be used during demolition includes excavators, haul trucks, backhoes, and jackhammers. Vibration levels are projected to remain

below 0.5 in/sec at residents along the project corridor and there is only a minimal potential for any structural damage.

Other vibration producing activities, such as soil compacting, are only expected to occur in the center of roadway for the track base, and therefore would be at a sufficient distance not to result in any vibration impacts. Vibration levels from other general construction activities will also be well below the 0.5 in/sec criteria.

Vibration Mitigation:

Because the mitigation of construction vibration is very difficult, and in most cases can only be performed through limiting the times the activities can occur, the following general vibration mitigation measures and information are provided.

The construction contract specifications would contain a section specific to vibration, and include, at a minimum, vibration monitoring of all activities that may produce vibration levels near the U.S. DOT maximum recommended vibration level whenever there are structures located near the construction activity. This would include pile driving, vibratory sheet installation, soil compacting, and other construction activities that have the potential to cause high levels of vibration.

Vibration mitigation could include limiting the hours when the vibration-producing equipment can be used near sensitive receivers. Reduction of vibration related to pile driving is not feasible; however, the use of an auger to install piles instead of a pile driver would greatly reduce the noise and vibration levels. By restricting and monitoring vibration-producing activities, vibration impacts from construction could be kept to a minimum.

During high vibration-producing activities such as pile driving and shoring installation, there is a potential for settlement and small movements of nearby structures. Design and installation of suitable shoring systems and other mitigations would reduce the potential of settlement-related damage. Other mitigation includes underpinning adjacent structures, installing recharge wells to reduce dewatering induced settlement, and/or re-leveling and repairing impacted areas following construction. In addition, pre-construction condition surveys and during-construction monitoring programs for neighboring structures would be conducted and repairs made as necessary.