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VIA E-MAIL: **trogers@davidjpowers.com**

SUBJECT: **3585 El Camino Real, Palo Alto, CA –**
Construction Noise and Vibration Assessment

Dear Tyler:

The 3585 El Camino Real project is located in Palo Alto north of the intersection of El Camino Real and Matadero Avenue. The approximately 0.14-acre project site is currently vacant, except for an approximately 800 square-foot metal shed located along the northeast property line and a commercial sign on the southeast corner of the site. The proposed project involves the demolition of the existing shed and redevelopment of the site with a three-story, mixed-use building with up to 2,500 square feet of office space and three residential units. The first floor would contain approximately 1,250 square feet of office space and a separate, common entryway for the upper residential units. Additional office space and one residential unit would be located on the second floor, with the remaining two residential units located on the third floor. The building would be a maximum of 35 feet high.

This study evaluates the potential for construction-related noise and vibration impacts on adjacent land uses. This report includes a brief description of the fundamentals of environmental noise and vibration, summarizes applicable regulatory criteria, and discusses construction noise and vibration levels expected at receptors near the project site. Based on a review of construction information provided by the applicant, recommendations are made to mitigate construction noise and vibration impacts to less-than-significant levels.

Fundamentals of Environmental Noise

Noise may be defined as unwanted sound. Noise is usually objectionable because it is disturbing or annoying. The objectionable nature of sound could be caused by its *pitch* or its *loudness*. *Pitch* is the height or depth of a tone or sound, depending on the relative rapidity *(frequency)* of the vibrations by which it is produced. Higher pitched signals sound louder to humans than sounds with a lower pitch. *Loudness* is intensity of sound waves combined with the reception characteristics of the ear. Intensity may be compared with the height of an ocean wave in that it is a measure of the amplitude of the sound wave.

In addition to the concepts of pitch and loudness, there are several noise measurement scales which are used to describe noise in a particular location. A *decibel (dB)* is a unit of measurement which indicates the relative amplitude of a sound. The zero on the decibel scale is based on the lowest sound level that the healthy, unimpaired human ear can detect. Sound levels in decibels are calculated on a logarithmic basis. An increase of 10 decibels represents a ten-fold increase in acoustic energy, while 20 decibels is 100 times more intense, 30 decibels is 1,000 times more intense, etc. There is a relationship between the subjective noisiness or loudness of a sound and its intensity. Each 10 decibel increase in sound level is perceived as approximately a doubling of loudness over a fairly wide range of intensities. Technical terms are defined in Table 1.

There are several methods of characterizing sound. The most common in California is the *A-weighted sound level (dBA).* This scale gives greater weight to the frequencies of sound to which the human ear is most sensitive. Representative outdoor and indoor noise levels in units of dBA are shown in Table 2. Because sound levels can vary markedly over a short period of time, a method for describing either the average character of the sound or the statistical behavior of the variations must be utilized. Most commonly, environmental sounds are described in terms of an average level that has the same acoustical energy as the summation of all the time-varying events. This *energy-equivalent sound/noise descriptor* is called L_{eq}. The most common averaging period is hourly, but L_{eq} can describe any series of noise events of arbitrary duration.

The scientific instrument used to measure noise is the *sound level meter*. Sound level meters can accurately measure environmental noise levels to within about plus or minus 1 dBA. Various computer models are used to predict environmental noise levels from sources, such as roadways and airports. The accuracy of the predicted models depends upon the distance the receptor is from the noise source. Close to the noise source, the models are accurate to within about plus or minus 1 to 2 dBA.

Since the sensitivity to noise increases during the evening and at night -- because excessive noise interferes with the ability to sleep -- 24-hour descriptors have been developed that incorporate artificial noise penalties added to quiet-time noise events. The *Community Noise Equivalent Level* (*CNEL*) is a measure of the cumulative noise exposure in a community, with a 5 dB penalty added to evening (7:00 p.m. - 10:00 p.m.) and a 10 dB addition to nocturnal (10:00 p.m. - 7:00 a.m.) noise levels. The *Day/Night Average Sound Level* (L_{dn}) is essentially the same as CNEL, with the exception that the evening time period is dropped and all occurrences during this three-hour period are grouped into the daytime period.

TABLE 1 Definition of Acoustical Terms Used in this Report

Term	Definition
Decibel, dB	A unit describing, the amplitude of sound, equal to 20 times the logarithm to the base 10 of the ratio of the pressure of the sound measured to the reference pressure. The reference pressure for air is 20 micro Pascals.
Sound Pressure Level	Sound pressure is the sound force per unit area, usually expressed in micro Pascals (or 20 micro Newtons per square meter), where 1 Pascal is the pressure resulting from a force of 1 Newton exerted over an area of 1 square meter. The sound pressure level is expressed in decibels as 20 times the logarithm to the base 10 of the ratio between the pressures exerted by the sound to a reference sound pressure (e. g., 20 micro Pascals). Sound pressure level is the quantity that is directly measured by a sound level meter.
Frequency, Hz	The number of complete pressure fluctuations per second above and below atmospheric pressure. Normal human hearing is between 20 Hz and 20,000 Hz. Infrasonic sounds are below 20 Hz and Ultrasonic sounds are above 20,000 Hz.
A-Weighted Sound Level, dBA	The sound pressure level in decibels as measured on a sound level meter using the A-weighting filter network. The A-weighting filter de-emphasizes the very low and very high frequency components of the sound in a manner similar to the frequency response of the human ear and correlates well with subjective reactions to noise.
Equivalent Noise Level, L_{eq}	The average A-weighted noise level during the measurement period.
L_{max}, L_{min}	The maximum and minimum A-weighted noise level during the measurement period.
L_{01}, L_{10}, L_{50}, L_{90}	The A-weighted noise levels that are exceeded 1%, 10%, 50%, and 90% of the time during the measurement period.
Day/Night Noise Level, L_{dn} or DNL	The average A-weighted noise level during a 24-hour day, obtained after addition of 10 decibels to levels measured in the night between 10:00 p.m. and 7:00 a.m.
Community Noise Equivalent Level, CNEL	The average A-weighted noise level during a 24-hour day, obtained after addition of 5 decibels in the evening from 7:00 p.m.to 10:00 p.m. and after addition of 10 decibels to sound levels measured in the night between 10:00 p.m. and 7:00 a.m.
Ambient Noise Level	The composite of noise from all sources near and far. The normal or existing level of environmental noise at a given location.
Intrusive	That noise which intrudes over and above the existing ambient noise at a given location. The relative intrusiveness of a sound depends upon its amplitude, duration, frequency, and time of occurrence and tonal or informational content as well as the prevailing ambient noise level.

Source: Handbook of Acoustical Measurements and Noise Control, Harris, 1998.

TABLE 2 Typical Noise Levels in the Environment

Common Outdoor Activities	Noise Level (dBA)	Common Indoor Activities
	110 dBA	Rock band
Jet fly-over at 1,000 feet		
	100 dBA	
Gas lawn mower at 3 feet		
	90 dBA	
Diesel truck at 50 feet at 50 mph		Food blender at 3 feet
	80 dBA	Garbage disposal at 3 feet
Noisy urban area, daytime		
Gas lawn mower, 100 feet	70 dBA	Vacuum cleaner at 10 feet
Commercial area		Normal speech at 3 feet
Heavy traffic at 300 feet	60 dBA	
		Large business office
Quiet urban daytime	50 dBA	Dishwasher in next room
Quiet urban nighttime	40 dBA	Theater, large conference room
Quiet suburban nighttime		
	30 dBA	Library
Quiet rural nighttime		Bedroom at night, concert hall (background)
	20 dBA	
		Broadcast/recording studio
	10 dBA	
	0 dBA	

Source: Technical Noise Supplement (TeNS), California Department of Transportation, September 2013.

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Fundamentals of Groundborne Vibration

Ground vibration consists of rapidly fluctuating motions or waves with an average motion of zero. Several different methods are typically used to quantify vibration amplitude. One method is the Peak Particle Velocity (PPV). The PPV is defined as the maximum instantaneous positive or negative peak of the vibration wave. In this report, a PPV descriptor with units of mm/sec or in/sec is used to evaluate construction generated vibration for building damage and human complaints. Table 3 displays the reactions of people and the effects on buildings that continuous vibration levels produce. The guidelines in Table 3 represent syntheses of vibration criteria for human response and potential damage to buildings resulting from construction vibration.

Construction activities can cause vibration that varies in intensity depending on several factors. The use of pile driving and vibratory compaction equipment typically generates the highest construction related groundborne vibration levels. Because of the impulsive nature of such activities, the use of the PPV descriptor has been routinely used to measure and assess groundborne vibration and almost exclusively to assess the potential of vibration to cause damage and the degree of annoyance for humans.

The two primary concerns with construction-induced vibration, the potential to damage a structure and the potential to interfere with the enjoyment of life, are evaluated against different vibration limits. Human perception to vibration varies with the individual and is a function of physical setting and the type of vibration. Persons exposed to elevated ambient vibration levels, such as people in an urban environment, may tolerate a higher vibration level.

Structural damage can be classified as cosmetic only, such as paint flaking or minimal extension of cracks in building surfaces; minor, including limited surface cracking; or major, that may threaten the structural integrity of the building. Safe vibration limits that can be applied to assess the potential for damaging a structure vary by researcher. The damage criteria presented in Table 3 include several categories for ancient, fragile, and historic structures, the types of structures most at risk to damage. Most buildings are included within the categories ranging from “Historic and some old buildings” to “Modern industrial/commercial buildings”. Construction-induced vibration that can be detrimental to the building is very rare and has only been observed in instances where the structure is at a high state of disrepair and the construction activity occurs immediately adjacent to the structure.

The annoyance levels shown in Table 3 should be interpreted with care since vibration may be found to be annoying at much lower levels than those shown, depending on the level of activity or the sensitivity of the individual. To sensitive individuals, vibrations approaching the threshold of perception can be annoying. Low-level vibrations frequently cause irritating secondary vibration, such as a slight rattling of windows, doors, or stacked dishes. The rattling sound can give rise to exaggerated vibration complaints, even though there is very little risk of actual structural damage.

TABLE 3 Reactions of People and Damage to Buildings from Continuous or Frequent Intermittent Vibration Levels

Velocity Level, PPV (in/sec)	Human Reaction	Effect on Buildings
0.01	Barely perceptible	No effect
0.04	Distinctly perceptible	Vibration unlikely to cause damage of any type to any structure
0.08	Distinctly perceptible to strongly perceptible	Recommended upper level of the vibration to which ruins and ancient monuments should be subjected
0.1	Strongly perceptible	Threshold at which there is a risk of damage to fragile buildings with no risk of damage to most buildings
0.25	Strongly perceptible to severe	Threshold at which there is a risk of damage to historic and some old buildings.
0.3	Strongly perceptible to severe	Threshold at which there is a risk of damage to older residential structures
0.5	Severe - Vibrations considered unpleasant	Threshold at which there is a risk of damage to new residential and modern commercial/industrial structures

Source: Transportation and Construction Vibration Guidance Manual, California Department of Transportation, September 2013.

Regulatory Background

The California Department of Transportation (Caltrans) and City of Palo Alto have established regulatory criteria that are applicable in this assessment. A summary of the applicable regulatory criteria is provided below.

California Department of Transportation

Caltrans recommends a vibration limit of 0.5 in/sec PPV for buildings structurally sound and designed to modern engineering standards, 0.3 in/sec PPV for buildings that are found to be structurally sound but where structural damage is a major concern, and a conservative limit of 0.25 in/sec PPV for historic and some old buildings (see Table 3).

City of Palo Alto

Policy N-6.11 of the City of Palo Alto Comprehensive Plan addresses construction noise. Policy N-6.11 states that the City will, "Continue to prioritize construction noise limits around sensitive receptors, including through limiting construction hours and individual and cumulative noise from construction equipment".

Program N6.11.1 requires, "For larger development projects that demand intensive construction periods and/or use equipment that could create vibration impacts, such as the Stanford University Medical Center or major grade separation projects, require a vibration impact analysis, as well as formal, ongoing monitoring and reporting of noise levels throughout the entire construction process pertinent to industry standards. The monitoring plan should identify hours of operation and could include information on the monitoring locations, durations and regularity, the instrumentation to be used and appropriate noise control measures to ensure compliance with the noise ordinance".

City of Palo Alto Municipal Code. The City of Palo Alto Municipal Code limits noise levels caused by construction on adjacent residential properties. The applicable portions of the noise code are as follows:

9.10.060 Special Provisions. The special exceptions listed in this section shall apply, notwithstanding the provisions of Sections 9.10.030 through 9.10.050. Said exceptions shall apply only to the extent and during the hours specified in each of the following enumerated exceptions.

> *(b) Construction.* Except for construction on residential property, construction, alteration and repair activities which are authorized by valid city building permit shall be prohibited on Sundays and holidays and shall be prohibited except between the hours of eight a.m. and six p.m. Monday through Friday, nine a.m. and six p.m. on Saturday provided that the construction, demolition or repair activities during those hours meet the following standards:
>
> > (1) No individual piece of equipment shall produce a noise level exceeding one hundred ten (110) dBA at a distance of twenty-five (25) feet. If the device is housed within a structure on the property, the measurement shall be made out-side the structure at a distance as close to twenty-five feet from the equipment as possible.
> >
> > (2) The noise level at any point outside of the property plane of the project shall not exceed one hundred ten (110) dBA.
> >
> > (3) The holder of a valid construction permit for a construction project in a non-residential zone shall post a sign at all entrances to the construction site upon commencement of construction, for the purpose of informing all contractors and subcontractors, their employees, agents, materialmen and all other persons at the construction site, of the basic requirements of this chapter.
> >
> > > (A) Said sign(s) shall be posted no less than three feet and no more than five feet above ground level, shall be visible from the adjacent street, and shall be of a white background, with black lettering, which lettering shall be a minimum of one and one-half inches in height.
> > >
> > > (B) Said sign shall read as follows:
> > > CONSTRUCTION HOURS
> > > FOR RESIDENTIAL PROPERTIES
> > > (includes any and all deliveries)
> > > MONDAY-FRIDAY.......8:00 a.m. to 6:00 p.m.
> > > SATURDAY......9:00 a.m. to 6:00 p.m.
> > > SUNDAY/HOLIDAYS.......Construction Prohibited.

> Violation of this Ordinance is a misdemeanor punishable by a maximum of six months in jail, $1,000 fine, or both. Violators will be prosecuted. P.A.M.C. § 9.10.060(b).

Construction Noise Impacts

The City's Municipal Code limits construction between the hours of 8:00 a.m. and 6:00 p.m. Monday through Friday and between 9:00 a.m. and 6:00 p.m. on Saturday. Construction is prohibited on Sundays and holidays. The City requires that no individual piece of equipment produce a noise level exceeding 110 dBA at 25 feet or the noise level at any point outside of the property plane of the project not exceed 110 dBA.

Neither the City of Palo Alto nor the State of California specify quantitative thresholds to assess the impact related to temporary construction noise level increases above existing ambient noise levels. The threshold for speech interference indoors is 45 dBA. Assuming a 15 dBA exterior-to-interior reduction for standard residential construction and a 25 dBA exterior-to-interior reduction for standard commercial construction, this would correlate to an exterior threshold of 60 dBA L_{eq} at residential land uses and 70 dBA L_{eq} at commercial land uses. Additionally, temporary construction noise would be annoying to individuals at surrounding land uses if the ambient noise environment increased by at least 5 dBA L_{eq} for an extended period of time. Therefore, the temporary construction noise impact would be considered significant if project construction activities exceeded 60 dBA L_{eq} at nearby residences or exceeded 70 dBA L_{eq} at nearby commercial or open space land uses and exceeded the ambient noise environment by 5 dBA L_{eq} or more for a period longer than one year.

Noise impacts resulting from construction depend upon the noise generated by various pieces of construction equipment, the timing and duration of noise-generating activities, and the distance between construction noise sources and noise-sensitive areas. Construction noise impacts primarily result when construction activities occur during noise-sensitive times of the day (e.g., early morning, evening, or nighttime hours), the construction occurs in areas immediately adjoining noise-sensitive land uses, or when construction lasts over extended periods of time.

Construction noise levels would vary by phase and vary within phases based on the amount of equipment in operation and location where the equipment is operating. Typical construction noise levels at a distance of 50 feet are shown in Tables 4 and 5. Table 4 shows the average noise level range by construction phase and Table 5 shows the maximum noise level range for different construction equipment. Most construction noise ranges from 80 to 90 dBA at a distance of 50 feet from the source. Construction-generated noise levels drop off at a rate of about 6 dBA per doubling of the distance between the source and receptor. Shielding by buildings or terrain can provide an additional 5 to 10 dBA noise reduction at distant receptors.

TABLE 4 Typical Ranges of Construction Noise Levels at 50 Feet, L_{eq} (dBA)

	Domestic Housing		Office Building, Hotel, Hospital, School, Public Works		Industrial Parking Garage, Religious Amusement & Recreations, Store, Service Station		Public Works Roads & Highways, Sewers, and Trenches	
	I	II	I	II	I	II	I	II
Ground Clearing	83	83	84	84	84	83	84	84
Excavation	88	75	89	79	89	71	88	78
Foundations	81	81	78	78	77	77	88	88
Erection	81	65	87	75	84	72	79	78
Finishing	88	72	89	75	89	74	84	84

I - All pertinent equipment present at site.
II - Minimum required equipment present at site.

Source: U.S.E.P.A., Legal Compilation on Noise, Vol. 1, p. 2-104, 1973.

TABLE 5 Construction Equipment 50-foot Noise Emission Limits

Equipment Category	L_{max} Level (dBA)[1,2]	Impact/Continuous
Arc Welder	73	Continuous
Auger Drill Rig	85	Continuous
Backhoe	80	Continuous
Bar Bender	80	Continuous
Boring Jack Power Unit	80	Continuous
Chain Saw	85	Continuous
Compressor[3]	70	Continuous
Compressor (other)	80	Continuous
Concrete Mixer	85	Continuous
Concrete Pump	82	Continuous
Concrete Saw	90	Continuous
Concrete Vibrator	80	Continuous
Crane	85	Continuous
Dozer	85	Continuous
Excavator	85	Continuous
Front End Loader	80	Continuous
Generator	82	Continuous
Generator (25 KVA or less)	70	Continuous
Gradall	85	Continuous
Grader	85	Continuous
Grinder Saw	85	Continuous
Horizontal Boring Hydro Jack	80	Continuous
Hydra Break Ram	90	Impact
Impact Pile Driver	105	Impact
Insitu Soil Sampling Rig	84	Continuous
Jackhammer	85	Impact
Mounted Impact Hammer (hoe ram)	90	Impact

Equipment Category	L_{max} Level (dBA)[1,2]	Impact/Continuous
Paver	85	Continuous
Pneumatic Tools	85	Continuous
Pumps	77	Continuous
Rock Drill	85	Continuous
Scraper	85	Continuous
Slurry Trenching Machine	82	Continuous
Soil Mix Drill Rig	80	Continuous
Street Sweeper	80	Continuous
Tractor	84	Continuous
Truck (dump, delivery)	84	Continuous
Vacuum Excavator Truck (vac-truck)	85	Continuous
Vibratory Compactor	80	Continuous
Vibratory Pile Driver	95	Continuous
All other equipment with engines larger than 5 HP	85	Continuous

Notes:
1 Measured at 50 feet from the construction equipment, with a "slow" (1 sec.) time constant.
2 Noise limits apply to total noise emitted from equipment and associated components operating at full power while engaged in its intended operation.
3 Portable Air Compressor rated at 75 cfm or greater and that operates at greater than 50 psi.

Project construction is expected to last 18 months and begin in Spring 2020. Construction equipment would be staged on the project site. Specific quantities of equipment to be used for project construction were not provided. Based on the typical ranges of construction noise provided in Table 4, potential construction noise levels would be anticipated to reach 75 to 89 dBA L_{eq} at 50 feet during periods of construction. Demolition activities are expected to be minor, and the project will not involve impact or vibratory pile driving, which can produce substantial noise and vibration levels. Construction activity is proposed to take place between the hours of 8:00 a.m. and 6:00 p.m. Monday through Friday and between 9:00 a.m. and 6:00 p.m. on Saturday, within the City's allowable hours of construction. Further, the project would limit noise levels produced by any individual piece of equipment to less than 110 dBA at 25 feet or the noise level at any point outside of the property plane of the project to not exceed 110 dBA.

A two-story commercial building located at 3567 El Camino Real which shares the property line to the northwest. A gas station is located to the southeast across Matadero Avenue, and commercial buildings are located to the southwest across El Camino Real. The nearest noise sensitive land uses are multifamily residential buildings located northeast of the site across an alley, and approximately 75 feet from the center of the project site.

Typical noise levels during construction would range between 71 and 85 dBA L_{eq} at 75 feet from the center of the site. Noise levels could intermittently reach 95 dBA L_{max} at the building façade along the southwest and northeast sides of 3567 El Camino Real. Prolonged heavy construction near this building would expose the receptors to noise levels between 81 and 95 dBA L_{eq}. The southeast facade of 3567 El Camino Real has no windows or doors. Interior levels along the southeast facade would be at least 40 dBA lower than exterior levels due to building construction. Noise levels at the gas station 90 feet southeast of the site would range between 70 and 84 dBA L_{eq} during heavy construction. The commercial land uses located 160 feet southwest would experience noise levels between 65 and 79 dBA L_{eq}.

Construction noise would exceed 60 dBA L_{eq} at residences and 70 dBA L_{eq} at commercial uses. However, this is a **less-than-significant** temporary noise impact given that the following best construction management practices are followed.

*Best Construction Management Practices***:** Modification, placement, and operation of construction equipment are possible means for minimizing the impact of construction noise on existing sensitive receptors. Construction equipment should be well-maintained and used judiciously to be as quiet as possible. Construction activities for the proposed project should include the following best management practices to reduce noise from construction activities near sensitive land uses:

- Construction activities shall be limited to the hours between 8:00 a.m. and 6:00 p.m. Monday through Friday, between 9:00 a.m. and 6:00 p.m. on Saturday, and prohibited on Sundays and holidays in accordance with the City's Municipal Code, unless permission is granted with a development permit or other planning approval.

- Equip all internal combustion engine-driven equipment with intake and exhaust mufflers that are in good condition and appropriate for the equipment.

- Unnecessary idling of internal combustion engines should be strictly prohibited.

- Locate stationary noise-generating equipment, such as air compressors or portable power generators, as far as possible from nearby receptors. If they must be located near receptors, adequate muffling (with enclosures where feasible and appropriate) shall be used reduce noise levels at nearby receptors. Any enclosure openings or venting shall face away from receptors.

- Utilize "quiet" air compressors and other stationary noise sources where technology exists.

- A temporary noise control blanket barrier could be erected, if necessary, along building facades facing construction sites. This mitigation would only be necessary if conflicts occurred which were irresolvable by proper scheduling. Noise control blanket barriers can be rented and quickly erected.

- Control noise from construction workers' radios to a point where they are not audible at existing structures bordering the project site.

- The contractor shall prepare a detailed construction plan identifying the schedule for major noise-generating construction activities. The construction plan shall identify a procedure for coordination with adjacent land uses so that construction activities can be scheduled to minimize noise disturbance.

- Neighbors located adjacent to the construction site shall be notified of the construction schedule in writing.

- Designate a "disturbance coordinator" who would be responsible for responding to any complaints about construction noise. The disturbance coordinator will determine the cause of the noise complaint (e.g., bad muffler, etc.) and will require that reasonable measures be implemented to correct the problem. Conspicuously post a telephone number for the disturbance coordinator at the construction site and include in it the notice sent to neighbors regarding the construction schedule.

Implementation of the above best management practices would reduce construction noise levels emanating from the site, limit construction hours, and minimize disruption and annoyance. With the implementation of these measures and recognizing that noise generated by construction activities would occur over a temporary period, the impact would be **less-than-significant**.

Construction Vibration Impacts

The City of Palo Alto does not specify a construction vibration limit. For structural damage, Caltrans recommends a vibration limit of 0.5 in/sec PPV for buildings structurally sound and designed to modern engineering standards, 0.3 in/sec PPV for buildings that are found to be structurally sound but where structural damage is a major concern, and a conservative limit of 0.25 in/sec PPV for historic and some old buildings (see Table 3). There are no historic buildings within the site vicinity[1]. The 0.3 in/sec PPV vibration limit would be applicable to properties in the vicinity of the project site.

The operation of the project would not be expected to produce perceptible vibration levels at the property line of the site; however, construction of the project may temporarily generate perceptible vibration when heavy equipment or impact tools (e.g. jackhammers, hoe rams) are used. Construction activities would include site preparation work, foundation work, and new building framing and finishing. The proposed project would not require impact or vibratory pile, avoiding the excessive vibration levels associated with such construction techniques.

Table 6 presents typical vibration levels that could be expected from construction equipment at a distance of 25 feet and at a variety of distances representative of the nearest structures. Construction activities, such as use of saws, excavators, scrapers and other high-power or vibratory tools, and rolling stock equipment (tracked vehicles, compactors, etc.) may generate substantial vibration in the immediate vicinity. Vibration levels would vary depending on soil conditions, construction methods, and equipment used.

1 City of Palo Alto Master List of Structures on the Historic Inventory, https://www.cityofpaloalto.org/civicax/filebank/documents/3504, accessed September 12, 2019.

TABLE 6 Vibration Source Levels for Construction Equipment

Equipment		Reference PPV at 25 ft. (in/sec)	PPV at 5 ft. (in/sec)	PPV at 20 ft. (in/sec)	PPV at 50 ft. (in/sec)
Clam shovel drop		0.202	1.186	0.258	0.094
Hydromill (slurry wall)	in soil	0.008	0.047	0.010	0.004
	in rock	0.017	0.100	0.022	0.008
Vibratory Roller		0.210	1.233	0.268	0.098
Hoe Ram		0.089	0.523	0.114	0.042
Large bulldozer		0.089	0.523	0.114	0.042
Caisson drilling		0.089	0.523	0.114	0.042
Loaded trucks		0.076	0.446	0.097	0.035
Jackhammer		0.035	0.206	0.045	0.016
Small bulldozer		0.003	0.018	0.004	0.001

Source: Transit Noise and Vibration Impact Assessment Manual, United States Department of Transportation, Federal Transit Administration, September 2018, as modified by Illingworth & Rodkin, Inc., September 2019.

Based on the levels shown in Table 6, heavy construction located within 20 feet of structures would have the potential to exceed the 0.3 in/sec PPV threshold for buildings that are found to be structurally sound but where structural damage is a major concern. The nearest existing structure, the commercial building at 3567 El Camino Real, borders the construction boundary to the northwest. Periods of heavy vibration-generating construction within 5 feet of the shared boundary would result in vibration levels calculated to be as high as 1.233 in/sec PPV, exceeding the 0.3 in/sec PPV threshold. Vibration levels at the nearest residences and other commercial land uses in the project vicinity, located at least 20 feet from the site property lines were calculated to be 0.268 in/sec PPV or less. Vibration levels at the nearest residences and other commercial land uses in the project vicinity are calculated to be below the 0.3 in/sec PPV threshold and would not be anticipated to be impacted by project construction generated vibration.

The US Bureau of Mines has analyzed the effects of blast-induced vibration on buildings in USBM RI 8507[2], and these findings have been applied to vibrations emanating from construction equipment on buildings[3]. As shown on Figure 1, these studies indicate an approximate 20% probability of "threshold damage" (referred to as cosmetic damage elsewhere in this report) at vibration levels of 1.2 in/sec PPV or less and no observations of "minor damage" or "major damage" at vibration levels of 1.2 in/sec PPV or less. Figure 1 presents the damage probability as reported in USBM RI 8507 and reproduced by Dowding assuming a maximum vibration level of 1.2 in/sec PPV. Based on these data, cosmetic or threshold damage would be manifested in the form of hairline cracking in plaster, the opening of old cracks, the loosening of paint or the dislodging of loose objects. However, minor damage (e.g., hairline cracking in masonry or the loosening of plaster) or major structural damage (e.g., wide cracking or shifting of foundation or bearing walls) to the adjacent residential structure would not be anticipated to occur assuming a maximum vibration level of 1.2 in/sec PPV.

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2 Siskind, D.E., M.S. Stagg, J.W. Kopp, and C.H. Dowding, Structure Response and Damage Produced by Ground Vibration form Surface Mine Blasting, RI 8507, Bureau of Mines Report of Investigations, U.S. Department of the Interior Bureau of Mines, Washington, D.C., 1980.

3 Dowding, C.H., Construction Vibrations, Prentice Hall, Upper Saddle River, 1996.

Due to the close proximity of the commercial building located at 3567 El Camino Real, vibration levels associated with construction activities are expected to intermittently exceed 0.3 in/sec PPV when heavy construction is occurring within 20 feet of the building. Cosmetic or threshold damage to structures would be possible at this distance. Occupants would intermittently experience vibration levels which, as shown in Table 3, could be perceived as severe and unpleasant. Vibration levels from the project's construction would exceed the vibration threshold. This would be a **potentially significant** impact.

Mitigation Measure 2: Implementation of the following measures would reduce the vibration impact to a less-than-significant level at the nearest commercial building at 3567 El Camino Real, which borders the construction boundary to the northwest:

- Place operating equipment on the construction site as far as possible from vibration sensitive receptors.
- Avoid using vibratory rollers and tampers near sensitive areas.
- Avoid dropping heavy objects or materials near shared property lines.
- Occupants of 3567 El Camino Real shall be notified of the construction schedule in writing. This schedule shall indicate when heavy vibration-generating construction will be taking place within 25 feet of the building.
- A construction vibration-monitoring plan shall be implemented to document conditions at 3567 El Camino Real, prior to, during, and after vibration generating construction activities within 20 feet of the building. All plan tasks shall be performed in accordance with industry accepted standard methods. The construction vibration monitoring plan should be implemented to include the following tasks:
    - Performance of a photo survey, elevation survey, and crack monitoring survey for the building at 3567 El Camino Real. Surveys shall be performed prior to, in regular intervals during, and after completion of vibration generating construction activities within 20 feet of the building, and shall include internal and external crack monitoring in the structure, settlement, and distress, and shall document the condition of the foundation, walls, and other structural elements in the interior and exterior of said structure to the extent that access is provided by the owner of the building.
    - Conduct a post-survey on the structure where monitoring has indicated high levels or complaints of damage. Make appropriate repairs or provide compensation where damage has occurred as a result of construction activities.
    - Designate a person responsible for registering and investigating claims of excessive vibration. The contact information of such person shall be clearly posted on the construction site.

Implementation of the above measures would reduce this impact to a **less-than-significant** level.

♦ ♦ ♦

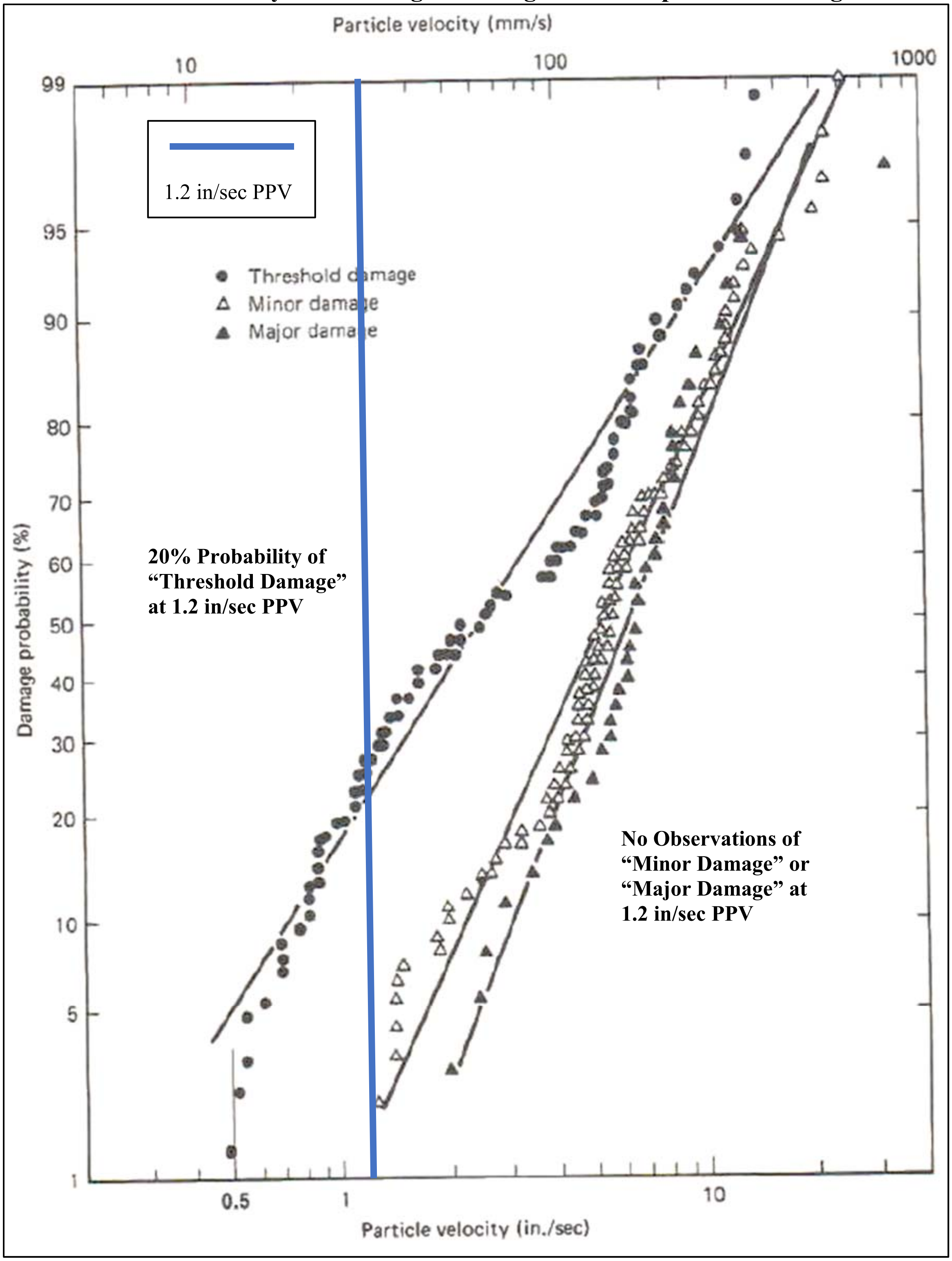
Please feel free to contact us with any questions on the analysis or if we can be of further assistance.

Sincerely,

Michael S. Thill
Principal Consultant
***Illingworth & Rodkin, Inc*.**

I&R Job: 19-174

FIGURE 1 Probability of Cracking and Fatigue from Repetitive Loading



Source: Dowding, C.H., Construction Vibrations, Prentice Hall, Upper Saddle River, 1996 as modified by Illingworth & Rodkin, Inc., September 2019.