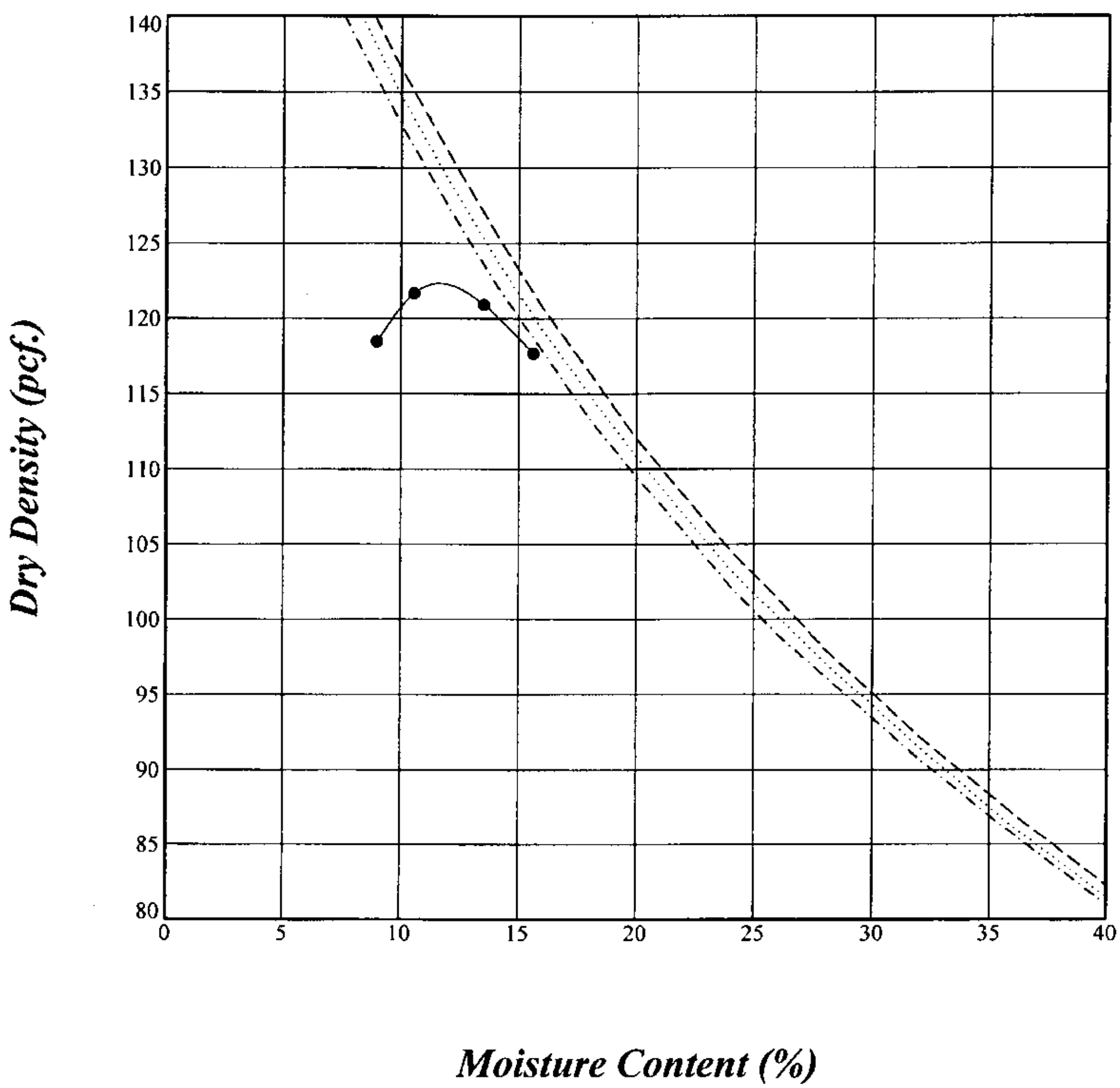
MOISTURE CONTENT - DRY DENSITY CURVE (ASTM D1557)

PROJECT NAME: *This Old House, LLC / San Rafael Ave.*	SAMPLE ID: *TP 01 @ 2.50'*
PROJECT NUMBER: *PIN 7387*	MATERIAL DESCRIPTION: *Alluvium (Qa)*



Maximum Dry Density (pcf.) :	*123.0*
Optimum Moisture Content (%) :	*12.0*

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GEOTECHNICAL ENGINEERS & ENGINEERING GEOLOGISTS

Figure M.1

APPENDIX III

CALCULATIONS

Bearing Value

Temporary Stability Calculations

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BEARING CAPACITY ANALYSIS

PIN # **7387**
CLIENT: **This Old House**

CALCULATE THE ULTIMATE AND ALLOWABLE BEARING CAPACITIES OF THE BEARING MATERIAL LISTED BELOW USING HANSEN'S METHOD. (REFERENCE: J. BOWLES, *FOUNDATION ANALYSIS AND DESIGN*, 1988, p. 188-194).

CALCULATION PARAMETERS

EARTH MATERIAL:	ALLUVIUM	EMBEDMENT DEPTH:	1 feet
SHEAR DIAGRAM:	0	FOOTING LENGTH:	100 feet
COHESION:	210 psf	FOOTING WIDTH:	1 feet
PHI ANGLE:	31 degrees	SLOPE ANGLE:	0 degrees
DENSITY:	125 pcf	FOOTING INCLINATION:	0 degrees
SAFETY FACTOR:	3		
FOOTING TYPE:	S Strip		

CALCULATED RESULTS

HANSEN'S SHAPE, DEPTH, AND INCLINATION FACTORS

Nq =	20.63	Dq =	1.28	Sy =	1.00
Nc =	32.67	Gc =	1.00	Dy =	1.00
Ny =	17.69	Bc =	1.00	Iy =	1.00
Sc =	1.01	Iq =	1.00	Gy =	1.00
Sq =	1.01	Ic =	1.00	Gq =	1.00
Dc =	1.40	Bq =	1.00	By =	1.00

CALCULATED ULTIMATE BEARING CAPACITY (Qult)	14,094.9 pounds
ALLOWABLE BEARING CAPACITY (Qa = Qult / fs)	4,698.3 pounds
PERCENT INCREASE FOR EMBEDMENT DEPTH	26.8%

CONCLUSIONS:

THE ULTIMATE AND ALLOWABLE BEARING CAPACITIES OF THE BEARING MATERIAL WERE CALCULATED USING HANSEN'S METHOD. THE RECOMMENDED DESIGN BEARING PRESSURE IS 1500 POUNDS PER SQUARE FOOT.

SubSurface Designs Inc.

BEARING CAPACITY ANALYSIS

PIN # 7387
CLIENT: This Old House

CALCULATE THE ULTIMATE AND ALLOWABLE BEARING CAPACITIES OF THE BEARING MATERIAL LISTED BELOW USING HANSEN'S METHOD. (REFERENCE: J. BOWLES, *FOUNDATION ANALYSIS AND DESIGN*, 1988, p. 188-194).

CALCULATION PARAMETERS

EARTH MATERIAL:	ALLUVIUM	EMBEDMENT DEPTH:	1 feet
SHEAR DIAGRAM:	0	PAD LENGTH:	2 feet
COHESION:	210 psf	PAD WIDTH:	1 feet
PHI ANGLE:	31 degrees	SLOPE ANGLE:	0 degrees
DENSITY:	125 pcf	PAD INCLINATION:	0 degrees
SAFETY FACTOR:	3		
FOOTING TYPE:	P Pad		

CALCULATED RESULTS

HANSEN'S SHAPE, DEPTH, AND INCLINATION FACTORS

Nq =	20.63	Dq =	1.28	Sy =	0.80
Nc =	32.67	Gc =	1.00	Dy =	1.00
Ny =	17.69	Bc =	1.00	Iy =	1.00
Sc =	1.32	Iq =	1.00	Gy =	1.00
Sq =	1.30	Ic =	1.00	Gq =	1.00
Dc =	1.40	Bq =	1.00	By =	1.00

CALCULATED ULTIMATE BEARING CAPACITY (Qult)	17,824.1 pounds
ALLOWABLE BEARING CAPACITY (Qa = Qult / fs)	5,941.4 pounds
PERCENT INCREASE FOR EMBEDMENT DEPTH	27.4%

CONCLUSIONS:

THE ULTIMATE AND ALLOWABLE BEARING CAPACITIES OF THE BEARING MATERIAL WERE CALCULATED USING HANSEN'S METHOD. THE RECOMMENDED DESIGN BEARING PRESSURE IS 1800 POUNDS PER SQUARE FOOT.

SubSurface Designs Inc.

BEARING CAPACITY ANALYSIS

PIN # **7387**
CLIENT: **This Old House**

CALCULATE THE ULTIMATE AND ALLOWABLE BEARING CAPACITIES OF THE BEARING MATERIAL LISTED BELOW USING HANSEN'S METHOD. (REFERENCE: J. BOWLES, *FOUNDATION ANALYSIS AND DESIGN*, 1988, p. 188-194).

CALCULATION PARAMETERS

EARTH MATERIAL:	COMPACTED FILL	EMBEDMENT DEPTH:	1 feet
SHEAR DIAGRAM:	0	PAD LENGTH:	2 feet
COHESION:	245 psf	PAD WIDTH:	1 feet
PHI ANGLE:	31 degrees	SLOPE ANGLE:	0 degrees
DENSITY:	125 pcf	PAD INCLINATION:	0 degrees
SAFETY FACTOR:	3		
FOOTING TYPE:	P Pad		

CALCULATED RESULTS

HANSEN'S SHAPE, DEPTH, AND INCLINATION FACTORS

Nq =	20.63	Dq =	1.28	Sy =	0.80
Nc =	32.67	Gc =	1.00	Dy =	1.00
Ny =	17.69	Bc =	1.00	Iy =	1.00
Sc =	1.32	Iq =	1.00	Gy =	1.00
Sq =	1.30	Ic =	1.00	Gq =	1.00
Dc =	1.40	Bq =	1.00	By =	1.00

CALCULATED ULTIMATE BEARING CAPACITY (Qult)	19,930.5 pounds
ALLOWABLE BEARING CAPACITY (Qa = Qult / fs)	6,643.5 pounds
PERCENT INCREASE FOR EMBEDMENT DEPTH	24.9%

CONCLUSIONS:

THE ULTIMATE AND ALLOWABLE BEARING CAPACITIES OF THE BEARING MATERIAL WERE CALCULATED USING HANSEN'S METHOD. THE RECOMMENDED DESIGN BEARING PRESSURE IS 1800 POUNDS PER SQUARE FOOT.

SubSurface Designs Inc.

BEARING CAPACITY ANALYSIS

PIN # **7387**
CLIENT: **This Old House**

CALCULATE THE ULTIMATE AND ALLOWABLE BEARING CAPACITIES OF THE BEARING MATERIAL LISTED BELOW USING HANSEN'S METHOD. (REFERENCE: J. BOWLES, *FOUNDATION ANALYSIS AND DESIGN*, 1988, p. 188-194).

CALCULATION PARAMETERS

EARTH MATERIAL:	COMPACTED FILL	EMBEDMENT DEPTH:	1 feet
SHEAR DIAGRAM:	0	FOOTING LENGTH:	100 feet
COHESION:	245 psf	FOOTING WIDTH:	1 feet
PHI ANGLE:	31 degrees	SLOPE ANGLE:	0 degrees
DENSITY:	125 pcf	FOOTING INCLINATION:	0 degrees
SAFETY FACTOR:	3		
FOOTING TYPE:	S Strip		

CALCULATED RESULTS

HANSEN'S SHAPE, DEPTH, AND INCLINATION FACTORS

Nq =	20.63	Dq =	1.28	Sy =	1.00
Nc =	32.67	Gc =	1.00	Dy =	1.00
Ny =	17.69	Bc =	1.00	Iy =	1.00
Sc =	1.01	Iq =	1.00	Gy =	1.00
Sq =	1.01	Ic =	1.00	Gq =	1.00
Dc =	1.40	Bq =	1.00	By =	1.00

CALCULATED ULTIMATE BEARING CAPACITY (Qult)	15,705.9 pounds
ALLOWABLE BEARING CAPACITY (Qa = Qult / fs)	5,235.3 pounds
PERCENT INCREASE FOR EMBEDMENT DEPTH	24.4%

CONCLUSIONS:

THE ULTIMATE AND ALLOWABLE BEARING CAPACITIES OF THE BEARING MATERIAL WERE CALCULATED USING HANSEN'S METHOD. THE RECOMMENDED DESIGN BEARING PRESSURE IS 1500 POUNDS PER SQUARE FOOT.

SubSurface Designs Inc.

TEMPORARY EXCAVATION HEIGHT

PIN # **7387**
CLIENT: **This Old House**

CALCULATE THE HEIGHT TO WHICH TEMPORARY EXCAVATIONS ARE STABLE (NEGATIVE THRUST). THE EXCAVATION HEIGHT AND BACKSLOPE AND SURCHARGE CONDITIONS ARE LISTED BELOW. ASSUME THE EARTH MATERIAL IS SATURATED WITH NO EXCESS HYDROSTATIC PRESSURE.

CALCULATION PARAMETERS

EARTH MATERIAL:	ALLUVIUM	HEIGHT:	5 feet
SHEAR DIAGRAM:	0	BACKSLOPE ANGLE:	45 degrees
COHESION:	210 psf	SURCHARGE:	0 pounds
PHI ANGLE:	31 degrees	SURCHARGE TYPE:	U Uniform
DENSITY:	125 pcf	INITIAL FAILURE ANGLE:	5 degrees
SAFETY FACTOR:	1.25	FINAL FAILURE ANGLE:	85 degrees
WALL FRICTION:	0 degrees	INITIAL TENSION CRACK:	1 feet
CD (C/FS):	168.0 psf	FINAL TENSION CRACK:	20 feet
PHID = ATAN(TAN(PHI)/FS) =	25.7 degrees		

CALCULATED RESULTS

CRITICAL FAILURE ANGLE	53 degrees
AREA OF TRIAL FAILURE WEDGE	3.8 square feet
TOTAL EXTERNAL SURCHARGE	0.0 pounds
WEIGHT OF TRIAL FAILURE WEDGE	479.6 pounds
NUMBER OF TRIAL WEDGES ANALYZED	3240 trials
LENGTH OF FAILURE PLANE	1.7 feet
DEPTH OF TENSION CRACK	3.7 feet
HORIZONTAL DISTANCE TO UPSLOPE TENSION CRACK	1.0 feet
CALCULATED HORIZONTAL THRUST	**-35.4 pounds**
CALCULATED EQUIVALENT FLUID PRESSURE	**-4.4 pcf**
MAXIMUM HEIGHT OF TEMPORARY EXCAVATION	**5.0 feet**

CONCLUSIONS:

THE CALCULATION INDICATES THAT THE TEMPORARY EXCAVATIONS UP TO 5 FEET HIGH WITH A 1:1 BACKSLOPE HAVE A NEGATIVE THRUST AND ARE TEMPORARILY STABLE.

APPENDIX IV

REFERENCES

Site References

Geotechnical References

REFERENCES

Site References

Soils reports were not on file for the subject site at the time research was conducted.

Geotechnical References

1. Bowles, Joseph, E., Foundation Analysis and Design (McGraw-Hill, New York : 1968)

2. California Geological Survey, Special Publication 117A - Guidelines for Evaluation and Mitigating Seismic Hazards in California, 2008.

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4. California Division of Mines and Geology, Seismic Hazard Zone Report of the Pasadena 7.5 Minute Quadrangle, Los Angeles County, California.

5. Huang, Yang H., Stability Analysis of Earth Slopes (Van Nostrand Reinhold, New York : 1983)

6. Monahan, Edward J., PE, Construction of and on Compacted Fills (Wiley & Sons, New York : 1986)

7. Naval Facilities Engineering Command Foundations and Earth Structures - Design Manual 7.02 (Naval Publications and Forms Center, Philadelphia : 1986)

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10. Terzaghi, Karl and Peck, Ralph B., Soil Mechanics in Engineering Practice (Wiley & Sons, New York : 1948)

11. Tschebotarioff, Gregory P., Foundations, Retaining and Earth Structures - 2nd (McGraw Hill, New York : 1979)

Exhibit E

Conditions to HDP Approval

1. Conventional footings rather than compacted bed of fill: Conventional footings, hand excavated, with concrete pumped from street are accepted by the projects' soils engineer. These eliminate vibration from tamping vibration rammers or other pounding compaction methods. (It also minimizes migrant dust).
2. "Hand wrecking"—no impact tools: Demolition of an existing building can be achieved without impact tools—without sledgehammers, jackhammers, long crowbars, etc. Impact tools are customarily banned when damage to the other parts of a structure that are not being demolished must be minimized. Those customary procedures can be used here.
3. "Hand wrecking"- disassembly: We are finding more and more demolition contractors specialize in disassembly, so that building parts can be lawfully recycled. Disassembly can be used in your instance to minimize potential vibration and damage.
4. "Diamond sawing": Concrete and paving can be removed in 2x2 feet pieces and wheelbarrowed away, using a diamond saw with water…. Concrete should not be sledgehammered, and after sawing can be taken in smaller pieces to a low boy at the street.
5. Deliveries farther away from 815 San Rafael: Lumber dropping, rebar delivery, and other deliveries can be limited to the west side of the property furthest away from 815 San Rafael.
6. Tires on equipment: No metal wheeled equipment or dumpsters should be on site. If they go over bumps there will be vibration. Normal tires on backhoes etc. can be damped as they move on pavement.
7. Take structural and hardscape pieces away in large sections and demolish elsewhere. This may sound unusual, but it is actually practiced and may be preferable."

Additional conditions to control migratory dust.

1. Don't stockpile dirt on the site.
2. Cover stake beds, trucks, wheelbarrows, lowboys, etc. carrying dirt with a tarp.
3. Spray down excavation and demolition areas with water.
4. No sandblasting.
5. Erect barriers to shield spraying operations.

Summary of Expert
Reports, Letters

The collective advice of the attached experts is that vibration controls are needed to prevent vibration that will be expected to damage my client's property, especially an irreplaceable train collection which is contained in a room only 14 feet from the project site. The fact that our client already experienced damage and unacceptable vibration in the train room, as demonstrated to the BZA, further proves the need for additional conditions or else the required findings cannot be made.

Fred Hill, an expert on model trains, describes how fragile the trains are and how easily and irreversibly they can be damaged by shaking.

Vibration engineer Hugh Saurenman inspected the train room and surrounding area, and advised that "[W]ithout controls, vibration from construction activities at the residence next to the train room would be likely to cause sufficient jostling of the model train exhibit to cause damage to some of the displayed trains." Mr. Saurenman, stated on page 6 of his dated March 8, 2021, a copy of which was submitted to the BZA:

> "To ensure that the construction does not affect the train collection and that appropriate vibration limits are defined, I recommend ... Avoid using equipment within proximity of the train room that, based on the information available to us, is reasonably likely to cause PPV of 0.015 in/sec in the train room. This includes but is not limited to, vibratory compactors within 400 feet, pavement breakers within 230 feet, heavy trucks such as cement delivery trucks within 75 feet, jack hammers within 75 feet, or small dozers or pickup trucks within 7 feet."

Fran Offenhauser, a founder of Hollywood Heritage and long-time architect with extensive experience in construction practices affecting sensitive structures recommended a list of construction practices that, in her experience, are reasonable and appropriate to the situation, stating, "I have seen the following methods implemented, and I recommend them here as project conditions that the city imposes:

1. Conventional footings rather than compacted bed of fill: Conventional footings, hand excavated, with concrete pumped from street are accepted by the projects' soils engineer. These eliminate vibration from tamping vibration rammers or other pounding compaction methods. (It also minimizes migrant dust).
2. "Hand wrecking"—no impact tools: Demolition of an existing building can be achieved without impact tools—without sledgehammers, jackhammers, long crowbars, etc. Impact tools are customarily banned when damage to the other parts of a structure that are not being demolished must be minimized. Those customary procedures can be used here.
3. "Hand wrecking"- disassembly: We are finding more and more demolition contractors specialize in disassembly, so that building parts can be lawfully recycled. Disassembly can be used in your instance to minimize potential vibration and damage.

4. "Diamond sawing": Concrete and paving can be removed in 2x2 feet pieces and wheelbarrowed away, using a diamond saw with water.... Concrete should not be sledgehammered, and after sawing can be taken in smaller pieces to a low boy at the street.
5. Deliveries farther away from 815 San Rafael: Lumber dropping, rebar delivery, and other deliveries can be limited to the west side of the property furthest away from 815 San Rafael.
6. Tires on equipment: No metal wheeled equipment or dumpsters should be on site. If they go over bumps there will be vibration. Normal tires on backhoes etc. can be damped as they move on pavement.
7. Take structural and hardscape pieces away in large sections and demolish elsewhere. This may sound unusual, but it is actually practiced and may be preferable."

At the BZA hearing, the developer agreed that these conditions are reasonable and acceptable. She represented that these practices "have been employed on the prior project and if this project is permitted and will go forward they would also be employed".

Mr. Saurenman and Ms. Offenhauser also recommend that vibration levels inside the train room be monitored using an electronic monitoring system, which my client has installed. Mr. Saurenman recommends that vibration levels in the room not be allowed to exceed 0.0.15 peak particle velocity (PPV) inches per second. Our requested conditions are intended to achieve this.

We have also asked for conditions to control migratory dust. They are, as taken from Ms. Offenhauser's letter:

1. Don't stockpile dirt on the site.
2. Cover stake beds, trucks, wheelbarrows, lowboys, etc. carrying dirt with a tarp.
3. Spray down excavation and demolition areas with water.
4. No sandblasting.
5. Erect barriers to shield spraying operations.

With the exception of not stockpiling dirt on site, the developer also agreed that these conditions are acceptable, as reflected in the following exchange with Commissioner Nanney during the BZA hearing:

Commissioner Nanney:	OK. So it looks like of all of the conditions that that your neighbor wanted, [--the don't stock pile dirt condition--] that's the only one that you've really rejected for the reasons you stated. Is that right?

Ms. Rachlin:	I'm not objecting. It's just it's a part of the process and will be reused on site, so it's not all it's not all being removed.
Commissioner Nanney:	OK. So if we are we as the Board of Zoning Appeals were wanting to add to the conditions, this list of things, we wouldn't be able to adopt them all. This one [dirt stockpiling] would have to be .... It couldn't be modified as stated by the appellant her on Item #1. I mean it would have to be with the understanding of what you stated that in order to be acceptable to you, right?
Ms. Rachlin:	Yeah. I guess I'm not following. As part of the process, dirt is set aside and then is reused. So I don't know how you avoid stockpiling it, as there's a few days to a week's time frame that the footings are dug then backfilled. So it's not like I can take it off site and then bring it back. That would be more harmful.
Commissioner Nanney:	I know, I know, I understand. I'm just trying to, I'm just trying to understand, you know, how what we need to modify on these requests that were made by our neighbor and that you're otherwise seemed to be completely accepting.

The developer explained that she wishes to stockpile the dirt needed to backfill foundation trenches. The other conditions were acceptable.

The BZA ultimately determined that the matter needed to go back to the staff for CEQA review. However, a majority of the commissioners made clear that the conditions we requested would need to be imposed in order to make the findings. Commissioner Nanney stated, "I think that these should be added as conditions to the permit." Commissioner Lyon stated, "I think the facts and findings are there particularly given that the applicant is willing to accept the appellant's conditions." Commissioner Wendler stated, "I'm inclined to support it with some appropriate conditions to kind of document these commitments by the applicant." Commissioner Coher appeared to oppose the permit entirely, but approved the motion to send the matter back to the staff for CEQA review.

Had the Board of Zoning Appeals reached the findings, they would have done so only with our requested conditions added to the permit. Without these conditions, the findings cannot be made and the HDP permit must be denied. Therefore, *if* the City Council reaches the HDP findings, which it should not since the threshold issue, then the City Council should require that the conditions be added to the HDP or else deny the HDP.

The City Council has broad discretion to condition (or deny) an HDP to ensure that our client's property is protected. Because this is an application for an HDP under Section 17.29.080, the City Council has the discretion to require heightened conditions of approval tailored to my particular situation. Section 17.29.080 (J) states, "In approving a Hillside Development Permit, the review authority may impose any conditions it deems reasonable and necessary to ensure that the approval will comply with the findings required by Subsection F. above."

Consulting
acoustics, transportation + strategy

MEMORANDUM

To: Ms. Roxanne Christ
815 S. San Rafael Avenue, Pasadena, CA 91105

From: Hugh Saurenman, Ph.D., P.E.
ATS Consulting

Date: March 8, 2021

Subject: **DRAFT** Model Train Collection Sensitivity to Construction Vibration

On January 23, 2021, I visited Ms. Christ's collection of HO gauge model trains. It is a remarkable collection and I understand that the individual pieces are easily damaged even by even minor jostling that may cause them to come off the rails. Figure 1 is a photograph of a small segment of Ms. Christ's collection. The remainder of this memorandum provides some background on commonly used construction vibration limits; provides recommended vibration limits to protect Ms. Christ's model train collection and provides projected vibration levels for various construction activities and equipment.

Key observations and conclusions are:

1. This is a unique collection and normal construction vibration criteria are not applicable. The most commonly used criteria apply to structural damage and human annoyance.
2. Vibration limits used to avoid damage to one of a kind museum collection are the most appropriate for protecting this collection.
3. Ensuring that the collection is not damaged will require careful selection of construction processes and monitoring of the vibration.
4. We recommend use of a vibration monitor that provides an alert whenever the vibration exceeds a predefined limit. A primary goal of this report is to provide a preliminary definition of this limit. Experience during the construction process may indicate modifications to the limit may be necessary if it appears that the vibration is excessive.
5. This report provides a preliminary list of acceptable and unacceptable construction methods. The lists have been derived from literature on vibration amplitudes created by different construction processes. Of course, the actual amplitudes of vibration depend on a number of factors including the soil conditions, how the building structure affects transmission of vibration from outdoors to indoors, etc. If feasible, the uncertainty about the vibration amplitude caused by different

construction processes may be reduced with measurements. It is possible that testing will refine the limits on the types of construction activities that are acceptable and demonstrate that fewer restrictions are needed.

6. My recommended vibration limit to ensure that construction vibration does not jostle the model trains sufficiently to cause damage is a PPV of 0.015 in/sec. This is well below vibration amplitude limits used to avoid damage to buildings and generally about at the threshold for human perception. Similar limits have been used for museum construction to avoid damage to sensitive artwork. Avoiding exceeding this limit is expected to require the separation distances shown in Table 1.:

Table 1. Approximate Separation Distance to Reduce Construction Vibration to 0.015 in/sec

Equipment Type	Closest Distance
Vibratory compactor	400 ft
Pavement breaker	230 ft
Heavy trucks and large dozer	75 ft
Jack hammer	75 ft
Small dozer and pickup truck	7 ft

The values in Table 1 illustrate that considerable attention must be given during construction to avoid disturbing the model train collection.

We recommend the following steps to minimize the potential for the construction vibration damaging any portion of Ms. Christ's extensive model train collection:

1. Preconstruction vibration monitoring outdoors and in the train room.
2. Continuous monitoring of vibration during construction. At a minimum one monitor should be placed outside the train room and a second monitor should be placed inside the train room. These monitors should send an alert if the vibration approaches or exceeds a PPV of 0.015 in/sec. A warning level alert of 0.012 (85% of the maximum), would be appropriate.
3. Testing before the use of any high vibration construction processes, such as using vibratory compaction, to verify the vibration levels that will be generated. Determine alternative, lower vibration construction process to replace any processes that are likely to cause vibration that exceeds the 0.015 in/sec limit.

Figure 1. Photograph of a Small Section of Collection

The analysis presented in this report is based on data and recommendations from a number of sources. The key resources used are:

1. *Transit Noise and Vibration Impact Assessment Manual,* FTA Report No. 0123, September 2018. Often referred to as the "FTA Guidance Manual," It was first issued in 1995 and the most recent update was in 2018. It is oriented to human annoyance from noise and vibration created by rail transit systems such as the Gold Line. In also covers noise and vibration from construction projects. The guidelines for human annoyance are applied to most rail transit projects in North America.

2. *Construction Vibration,* Charles H. Dowding, 1996.
   This is a well respected book on a wide array of construction vibration issues. The main focus is building damage by vibration and it touches briefly on human response to vibration. It does not provide information on vibration limits that could be used to protect Ms. Christ's model train collection.

3. "Managing Construction-Induced Vibration in the Museum Environment," Anna Serotta, Andrew Smyth, Source: "Objects Specialty Group Postprints," Volume Twenty-One, Pages: 263-279, 2014.
   This paper covers the efforts to protect ancient, fragile Egyptian Art during reconstruction of the museum. The approach taken included monitoring vibration before and during the construction and installing a resilient material (Sorbothane pads under some of the larger pieces. "Typical alert thresholds were in the 1 or 3 mm/s range." These were not thresholds that would cause work

stoppage, but thresholds that would trigger alert messages that would be reviewed and would lead to actions ranging from stopping construction to modification of the construction activity.

Definitions of Technical Terms

Vibration Velocity: Vibration is oscillation of a solid around the equilibrium point. The amplitude of a vibration can be defined in terms of the displacement, the velocity of the movement, or the acceleration of the movement. The common approach is do define ground vibration and vibration within a building using the velocity of the movement.

Peak Particle Velocity (PPV): Peak Particle Velocity (PPV) is a most common approach for defining the amplitude of vibration. It is widely used when investigating the potential for building vibration to cause damage to the building. Over a period of time, PPV is the peak amplitude of the vibration.

Root Mean Square (RMS) Velocity: All the numbers in this report are in terms of PPV. RMS vibration is widely used when investigating human annoyance with the vibration. RMS is basically the average vibration over a time, commonly a 1-second time period.

Crest Factor: Crest factor defines the relationship between RMS and PPV. For typical environmental vibration, the crest factor varies between 1.4 and 6. For all the data presented in this memorandum, a crest factor of 4 has been assumed.

Vibration Event: The annoyance to humans caused by vibration events is related to how frequently and for how long the vibration occurs. A vibration event is defined as every time the vibration occurs.

Vibration limits on construction activities are typically specified in terms of Peak Particle Velocity (PPV). The limits are usually based on potential for damage to buildings. The RMS average time is commonly 1 second. Table 2 shows the construction vibration limits recommended by the FTA Guidance Manual.

Table 2. Construction Vibration Damage Criteria
Table 7-5 from Reference 1.

Building/ Structural Category	PPV, in/sec
I. Concrete, steel or timber (no plaster)	0.5
II. Engineered concrete and masonry (no plaster)	0.3
III. Non-engineered timber and masonry buildings	0.2
IV. Buildings Reinforced extremely susceptible to vibration damage	0.12

Table 3 provides the FTA Guidance Manual recommended vibration limits for typical residences. These criteria are based on the frequency of events as follows:

Frequent events: More than 70 events per day

Occasional events: 30–70 events per day

Infrequent Events Fewer than 30 events per day

As seen in Table 3, the vibration limits for human annoyance are substantially lower than those for potential damage to buildings. Where the concern for the model train display is jostling of the models, it is more appropriate to use the limits for human annoyance rather than the limits for building damage. I recommend using the information in Table 3 to help define an acceptable limit for the vibration that will be generated by the construction activities. A workable limit might be the frequent event PPV

(0.016 in/sec), which should be acceptable for occasional exceedances with construction activities stopped any time the construction vibration exceeds the frequent event limit of 0.016 in/sec.

Compliance with these limits could be insured through installation of a construction vibration monitor that sends an email or text message warning if the limit is exceeded.

Table 3. Vibration Limit for Human Annoyance

From Table 6-3 of the FTA Guidance Manual

Number of Events	PPV
Frequent Events	0.016 in/sec
Occasional Events	0.025 in/sec
Infrequent Events	0.040 in/sec

EXPECTED LEVELS OF CONSTRUCTION VIBRATION

The FTA Guidance Manual provides a list of typical vibration levels generated by a variety of construction equipment and equipment that has been extracted from Table 7-4 of the FTA Guidance Manual. The left three columns are from the Guidance Manual and the right two columns are the predicted distance from construction equipment to achieve the desired vibration level. For example, the lowest construction vibration level in Table 4 is a small bulldozer that caused a vibration level of 0.003 in/sec at 25 ft and is expected to be below the 0.015 in/sec at distances greater than 7 ft. At the other end of the spectrum is the upper vibration amplitude expected from pile driving. The vibration could exceed the lower limit of 0.016 in/sec at over 3,500 ft, which would be several houses away from the construction activity.

A pickup truck driving on a smooth roadway probably would have vibration levels similar to the small bulldozer in Table 4. A jack hammer probably would not cause a problem with the model train collection if it were at least 75 ft from the collection. Correspondingly, using a vibratory compactor if it is less than 400 ft from the collection could cause a problem.

Figure 2 shows another set of vibration data as a function of distance based on the work or Wiss in 1974. Also shown in Figure 2 is the recommended vibration limit of the ground outside the model train display of 0.015 in/sec. Based on this data, the 0.015 limit would occur at a distance of 7 ft from a small dozer, 75 ft from a jack hammer, 100 ft from large truck or dozer, and 300 ft from a pavement breaker.

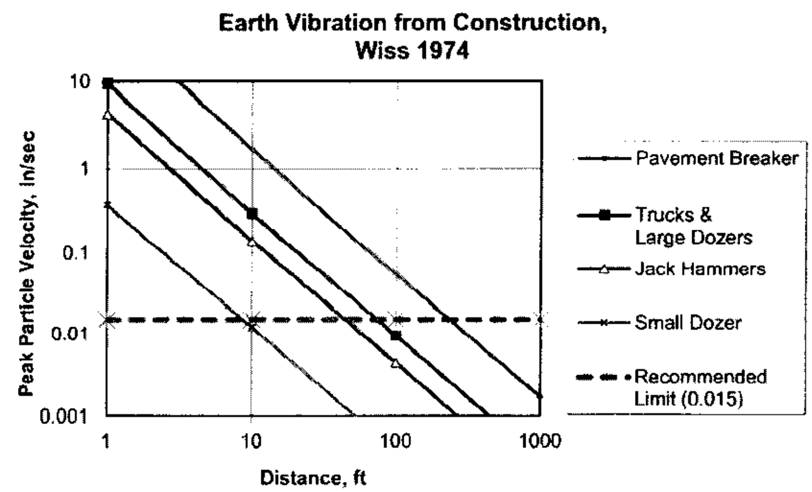

***Figure 2.* Data on construction vibration, Wiss 1974**

Table 4. Vibration Source Levels for Construction Equipment

Equipment	PPV at 25 ft, in/sec)	Dist. To PPV of 0.015
Vibratory Roller	0.21	492 ft
Caisson drilling	0.089	209 ft
Loaded trucks	0.076	178 ft
Jackhammer	0.035	79 ft
Small bulldozer and pickup tuck	0.003	7 ft

The initial conclusion is that, without controls, vibration from construction activities at the residence next to Ms. Christ's train room would be likely to cause sufficient jostling of the model train exhibit to cause damage to some of the displayed trains. To ensure that the construction does not affect the train collection and that appropriate vibration limits are defined, I recommend the following steps:

1. Avoid using equipment within proximity of the train room that, based on the information available to us, is reasonably likely to cause PPV of 0.015 in/sec in the train room. This includes but is not limited to, vibratory compactors within 400 feet, pavement breakers within 230 feet, heavy trucks such as cement delivery trucks within 75 feet, jack hammers within 75 feet, or small dozers or pickup trucks within 7 feet.
2. Monitor the existing vibration levels at the train room for several daytime hours. This will document vibration caused by local traffic and people walking in the train room and help define acceptable vibration levels.
3. Use the measured existing vibration levels and the data and predictions provided above to define acceptable vibration levels.

4. Use vibration monitors during construction that sends an alert if the vibration levels exceed the defined threshold.

5. Before potentially high vibration construction activities start, use the monitor to determine if and when the activity may cause levels that will exceed the predefined limits.

Please note that we have not been provided with detailed information on the construction and demolition equipment and methods that the adjacent property's developer intends to use and how and exactly where they are proposed to be used. Nor have we, therefore, been able to test such proposed equipment and methods on your train collection. And, of course, performing testing without causing damage itself raises challenges. That said, if and when we are able to perform testing, it may be appropriate to revise our recommendations.

Consulting HOME SERVICES ONTRACK CONTACT LOGIN

The foundation of ATS Consulting is a wealth of experience with an active approach to problem solving. ATS combines technical know-how, an understanding of overall project needs, and practical solutions for tackling noise and vibration and other strategic project issues. Collectively, our team's experience provides a full range of noise and vibration consulting services for the environmental review, design, construction, and operation of surface transportation, infrastructure, and development projects.

The ATS Consulting team has detailed knowledge of acoustics, environmental regulations, and transit system design. In addition, each team member brings unique skills and insights, including expertise in vibration control, materials, and programming. Partnered with our clients, ATS is fully committed to minimizing the potential noise and vibration impacts from a project while meeting the project schedule and budget.

A particular strength of ATS Consulting is the ability to work with other experts to address problems that require a multi-disciplinary approach. Examples include a recently completed study of long-distance propagation of highway noise, TCRP Projects D-10 and D-12 which require studies of human response, and several evaluations of the acoustics and safety implications of audible warnings at light-rail grade crossings.

Dr. Hugh Saurenman, President

M.S., Ph.D., Mechanical Engineering, Tufts University, Boston, MA
B.S., Engineering, Harvey Mudd College, Claremont, CA
Professional Engineer in Mechanical Engineering

A nationally known expert in issues related to transportation noise and vibration control, Dr. Saurenman has over forty years experience in the field. He has played an integral role in the development of transit systems nationally and internationally, including light rail, subway, commuter rail, freight rail, bus rapid-transit projects, and railroad mergers and acquisitions. In addition, Dr. Saurenman has been responsible for the creation of many standard procedures used to predict rail noise and vibration and has both authored and been a key contributor to reference documents that are widely used by rail systems and their consultants to evaluate noise and vibration impacts.

With his experience in acoustical consulting, Dr. Saurenman has an unparalleled depth of understanding of transit and environmental noise and vibration, advanced measurement techniques and equipment, and methods to minimize impacts and improve operations.

John (Jack) Meighan, Associate

B.S. Mechanical Engineering, University of Southern California, Los Angeles, CA

Jack was an intern at ATS during the summer of 2014. As an intern, he used his skills in robotics to help streamline ATS's measurement procedures. Jack returned to ATS after completing his studies at USC in Mechanical Engineering. At ATS, Jack uses his experience in robotics along with his ability with MATLAB and Labview to help ATS provide our clients with the best, most efficient testing protocols. Jack participates in the full range of ATS projects, from designing and implementing field testing and analysis procedures to preparing technical reports that present project results and recommendations to clients.

Roberto Della Neve, Associate

B.S. Mechanical & Aerospace Engineering, Princeton University, Princeton, NJ

Roberto joined ATS Consulting in October of 2017. Before joining ATS, he worked as a researcher at Princeton University investigating the effects of digital audio filters on humans' perception of sound. This experience developed his ability to write scripts in MATLAB for data collection and processing.

At ATS, Roberto utilizes his research and programming skills, along with his data collection and processing experience, to streamline data processing in our measurements. Furthermore, he participates in field measurements,

analysis and preparing technical reports.

Jonathan Mabuni, Associate

B.S. Mechanical Engineering, Cornell University, Ithaca, NY
Engineer-In-Training (EIT), California

Jonathan joined ATS Consulting in August of 2018. Prior to joining ATS, he worked as a member of Cornell's Engineers without Borders chapter in Calcha, Bolivia where he and his team designed and built a 51-meter span hanging pedestrian bridge. In addition to his international experience in engineering, he comes from a mechanical and aerospace background, having worked on projects in robotics and mechanical design.

At ATS, Jonathan utilizes his comprehensive experience and technical skills to participate in field measurements and provide data analysis. He is an integral part of the team when it comes to preparing reports and supplying project results and client recommendations.

Amanda Troisi, Associate

BFA Tisch School of the Arts, New York University, New York, NY

Amanda joined ATS Consulting in May of 2018. Prior to joining ATS, she worked as an event planner, personal chef, business administrator, designer, sound engineer, and performer in the entertainment industry. Her varied and creative background is utilized at ATS to develop company outreach and design marketing materials.

Amanda is also an integral part of the ATS accounting team and focuses on developing new relationships to expand the company's partnerships and cultivate new opportunities.

ATS Consulting
P.O.Box 356
Sierra Madre, CA 91025

TEL: 626-710-4400
MAIL: ontrack@atsconsulting.com