

NCHRP 25-25/Task 72:



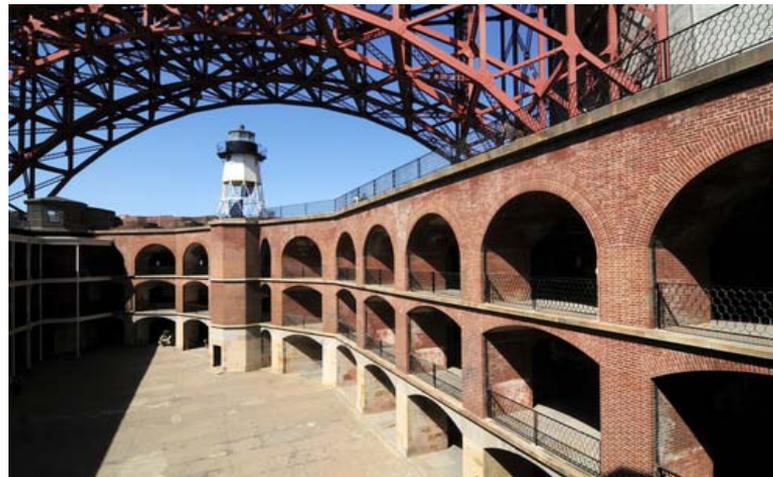
CURRENT PRACTICES TO ADDRESS CONSTRUCTION VIBRATION AND POTENTIAL EFFECTS TO HISTORIC BUILDINGS ADJACENT TO TRANSPORTATION PROJECTS

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Project Purpose

- NCHRP identified a need for a comprehensive compilation of current and successful practices that address construction vibration impacts on historic buildings adjacent to roadway construction projects
- The goal of this compilation is to help historic preservation resource agencies and organizations, departments of transportation (DOTs), and the public understand the technical aspects of vibration impact studies.



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Approach

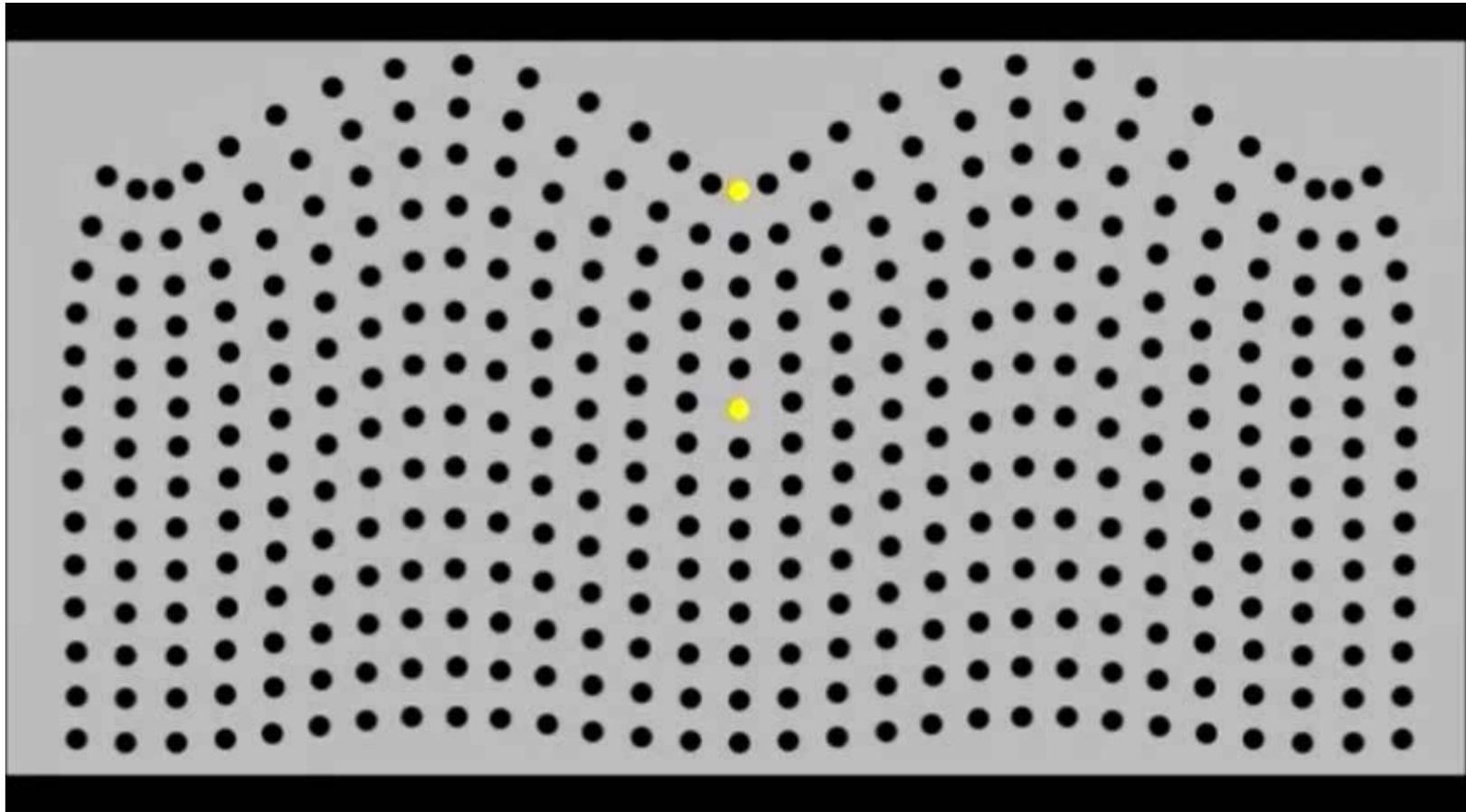
- Conducted a review of literature authored in the United States and abroad
 - fragility of historic structures and their susceptibility to damage,
 - monitoring of vibration transmission from construction projects,
 - mitigating potentially damaging vibration.
- The research team also surveyed state DOTs and other agencies
 - understand how they currently address this issue
 - identify several case studies that illustrate how construction vibration effects on historic buildings have been recently evaluated.
- Team developed a recommended guideline approach for addressing construction vibration effects on historic buildings

Report Outline

- Introduction
- Background on Vibration and Damage
- Section 106 Process
- Literature Review
- Transportation Agency Survey
- Case Studies
- Recommendations
- Conclusion
- References

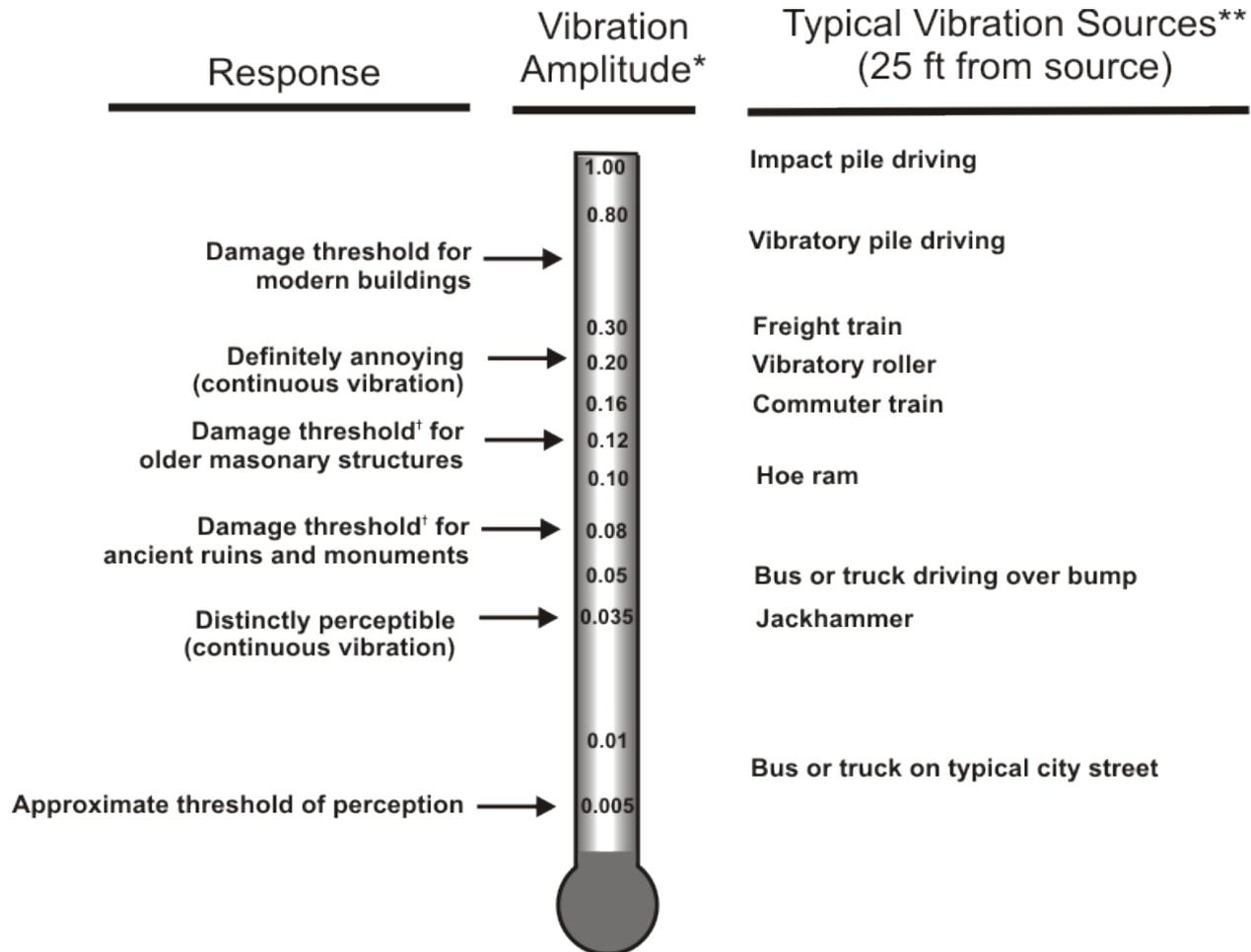


Vibration 101



Animation courtesy of Dan Russell – Pennsylvania State University

Vibration 101



* Peak particle velocity (inches/sec)

** Actual vibration levels are dependent on many factors

† Approximate threshold for cosmetic damage

What is an Historic Building?

- A building that is listed in or qualifies for listing in the National Register of Historic Places (NRHP).
- A building identified as historic under state or local historic preservation laws.



Section 106 of the National Historic Preservation Act

- Section 106 of the National Historic Preservation Act (NHPA) establishes a process to evaluate potential effects on historic properties that may be caused by federally-funded or approved projects.
- This process applies to potential damage to historic properties caused by construction vibration.



Section 106 of the National Historic Preservation Act

- Four-step process for evaluating impacts on historic properties:
 - Step 1. Initiate the process.
 - Step 2. Identify the area of potential effect and historic resources therein
 - Step 3. Assess effects.
 - Step 4. Resolve adverse effects.

Literature Search

- Conducted a literature search to gather the most recent information available
- On-line search tools, information from survey
- Research team assembled 64 reference documents, including:
 - published journal articles,
 - project reports,
 - national and international standards,
 - government guidelines,
 - government regulations, and
 - books related to the subject.

Literature Search

- Team reviewed this material for the level of relevance.
- Devised a rating scheme that focused on the relevance of the material.
- Identified 14 relevant areas or content categories for characterizing the material.



Literature Search

Some conclusions from the search:

- There is consensus on many issues relating to protecting historic structures.
- There is no consensus concerning appropriate vibration limits.
- Most of the research in the field of building damage comes from blasting vibration and its effect on modern structures.
- Blast effect researchers tend to recommend higher levels of vibration than researchers whose studies involve lower levels of vibration such as that associated with roadway traffic.

Literature Search

More conclusions from the search:

- There is very little research pertaining to the subject of common construction vibration.
- Unlikely that additional government research on construction vibration will happen any time soon.
- Procedures for documenting the existing condition of buildings and monitoring vibration are well established.
- Many state DOTs have procedures for controlling and monitoring blast vibration.

Literature Search

More conclusions from the search:

- California appears to be the only DOT which has produced a set of detailed procedures for controlling general construction vibration associated with transportation projects.
 - *Transportation- and Construction-Induced Vibration Guidance Manual (2006)*
- Probably necessary to adopt a cautious approach to setting limits and to allow for flexibility on a case-by-case basis.

Literature Search

Vibration Criteria



Reference Source	Remarks on Vibration Source	Remarks on Building or Structure	Remarks on Type of Damage	Vibration Limit - PPV (inches/sec)
British Standards Institute (1993)	All (including blasting)	Unreinforced or light framed structures	Cosmetic	0.6 to 2.0† (historic buildings may require special consideration)
Sedovic (1984)	All	Historic buildings in good state of maintenance	--	0.5
City of New York City (1988); Esrig and Ciancia (1981)	Blasting, pile driving and vehicular traffic	Structures which are designated NYC landmarks, or located within an historic district or listed on the NHRP	--	0.5
Whiffin and Leonard (1971)	Traffic	Buildings with plastered walls and ceilings	Architectural damage and risk of structural damage	0.4 to 0.6
Rudder (1978)	Traffic	All	Structural damage possible	0.4
City of Toronto (2008)	All (blasting not mentioned)	All buildings	--	0.3 to 1.0† (lower limits may be identified by professional engineer)
Konon and Schuring (1985)	Transient	Historic buildings	Cosmetic	0.25 to 0.5†
Swiss Standards Association (1992)	All (blasting, construction equipment, and road traffic)	Historic and protected buildings	--	0.2 to 0.5†
Federal Transit Administration (2006)	All	Non-engineered timber and masonry buildings	--	0.2
Sedovic (1984)	All	Historic or architecturally important buildings in deteriorated state of maintenance	--	0.2
Whiffin and Leonard (1971)	Traffic	Buildings with plastered walls and ceilings	Threshold of risk of architectural damage	0.2
Feilden (2003)	All	All buildings	Threshold for structural damage	0.2
Rudder (1978)	Traffic	All	Minor damage possible	0.2
Konon and Schuring (1985)	Steady state	Historic buildings	Cosmetic	0.13 to 0.25†
Deutsches Institut für Normung DIN 4150-3 (1999)	All	Buildings of great intrinsic value	Any permanent effect that reduces serviceability	0.12 to 0.4†
Federal Transit Administration (2006)	All	Buildings extremely susceptible to vibration	--	0.12
American Association of State Highway and Transportation Officials (2004)	All	Historic sites and other critical locations	Threshold for cracks (cosmetic)	0.12
Esteves (1978)	Blasting	Special care, historical	--	0.1 to 0.4††
Rudder (1978)	Traffic	All	Threshold of structural damage	0.1
Whiffin and Leonard (1971)	Traffic	Buildings with plastered walls and ceilings	Virtually no risk of architectural damage	0.1
Feilden (2003)	All	All buildings	Threshold for plaster cracking	0.08
Whiffin and Leonard (1971)	Traffic	Ruins and ancient monuments	--	0.08

† frequency-dependent criteria

†† depending on soil type and frequency

Literature Search

Vibration Criteria

- Clearly there is a wide range of opinion on appropriate vibration limits for historic buildings and structures.
- At one end of the range is a conservative limit of 0.10 inches/sec except in the case of ancient ruins where 0.08 inches/sec is considered appropriate by some.
- At the other end of the range, some would consider 0.50 inches/sec or even 2.0 inches/sec to be appropriate.

Literature Search

Current Practices

- Current practices for addressing vibration vary considerably.
- Most jurisdictions recognize a need to document the condition of the affected buildings prior to starting construction.
- Where vibration limits are specified, vibration monitoring is required.
- Most mitigation measures included in project contract documents tend to be generic but do provide some means and methods that contractors can follow when vibration limits are exceeded.

Literature Search

- Although current practices vary considerably there is general agreement on the procedures to follow when dealing with construction vibration.

Literature Search

- Consultation between historic building owner, development team and reviewing agencies
- Documentation of building conditions prior to commencement of adjacent work
- Establishment of vibration limits based on building conditions, founding soil conditions, and type of construction vibration.
- Implementation of vibration mitigating measures on the construction site and/or at the historic building, which could include specific means and methods or protective measures.
- Vibration monitoring during construction
- Regular condition surveys and reviews during construction to identify damage, to evaluate the efficacy of protective measures already in place, and to identify and implement additional corrective steps.

Transportation Agency Survey

- The research team conducted a survey of transportation agencies and consultants to collect and synthesize information on successful practices currently in use.
- The research team developed an on line survey using Survey Monkey
 - Does the agency have a process (formal or informal) in place for evaluating the effects of vibration on historic buildings?
 - Has the agency ever had to deal with vibration effects on historic buildings
 - Has the agency every evaluated a building for susceptibility to damage from vibration or documents existing damage?
 - Has the agency ever conducted vibration monitoring to protect a historic building

Transportation Agency Survey

- State Departments of Transportation (DOTs).
- Transit Agencies.
- Turnpike and Toll Road Authorities.
- Federal Highway Administration (FHWA) staff.
- State Historic Preservation Offices (SHPOs).
- Members of TRB ADC40 Committee on Transportation-Related Noise and Vibration.
- Members of TRB ADC50 Committee on Historic and Archaeological Preservation in Transportation.

Transportation Agency Survey

Response Numbers

- 506 requests were sent.
- 138 total responses were received
- 59 participants completed the entire survey
- 6 consultants
- 45 State DOT
- 34 unique states (several states had multiple responses)
- 5 SHPO
- 2 Canadian provinces

Transportation Agency Survey

Response Overview

- 30 agencies indicated that they have had to consider the effects of construction vibration on historic buildings
- 30 agencies indicated that they have a process in place
- However, the responses generally indicated, however, that established, formal processes for addressing this issue are not in place
- Informal processes involving communication between the project development team and the cultural resources specialists are typical.
- In many cases, respondents cited only one or two instances in recent history where construction vibration effects on historic buildings were a concern.
- Because the issue rarely arises, the respondents indicated that there has been little need to establish formal processes.

Transportation Agency Survey

Process Trigger

- Compliance with Section 106 of the National Historic Preservation Act and with state and federal environmental laws
- Several states use the “200 foot” rule
- Michigan uses a “100 foot” rule
- Iowa uses 500 to 1,000 feet depending on site conditions

Transportation Agency Survey

- 29 agencies responded that they have conducted or commissioned a technical survey of a historic building to assess susceptibility to structural or architectural damage
- 35 agencies have conducted or commissioned a pre-existing condition survey of a historic building for the purposes of documenting existing cracks, foundation settlement, or other pre-existing damage (structural or architectural) prior to construction of a project.

Transportation Agency Survey

Vibration criteria for potential damage

- FTA transit noise and vibration manual
- Caltrans vibration manual
- U.S. Bureau of Mines blasting criteria.
- Dowding “Blasting Vibration Monitoring and Control”
- Illinois DOT Transportation Bureau of Design & Environment Manual
- Various agency-specific thresholds 0.12 to 2 inches/sec

Transportation Agency Survey

Vibration Monitoring

- 31 agencies have conducted or commissioned vibration monitoring for a historic building during project construction for the purposes of limiting or controlling vibration received at that building or to determine effects on that building.
- Of these only 18 have determined that vibration had the potential to cause damage.
- Damage was not necessarily indicated but where precaution through monitoring was needed as a result of community concerns or perceived high sensitivity of a building by the public and public agencies.

Transportation Agency Survey

Methods to Reduce Vibration

- Requiring the use of oscillating rollers instead of vibratory rollers to compact pavement.
- Jetting of piles to reduce vibration from impact pile driving.
- Use of non-vibratory compaction methods.
- Prohibiting blasting “in the vicinity of a masonry building.”
- Shoring of buildings during construction.
- Limiting the energy on pile driving hammers and pavement breakers,
- Using drilled shaft foundations in place of driven piles
- Packing up and moving fragile personal property off site.
- Construction of a trench between construction equipment and a building.

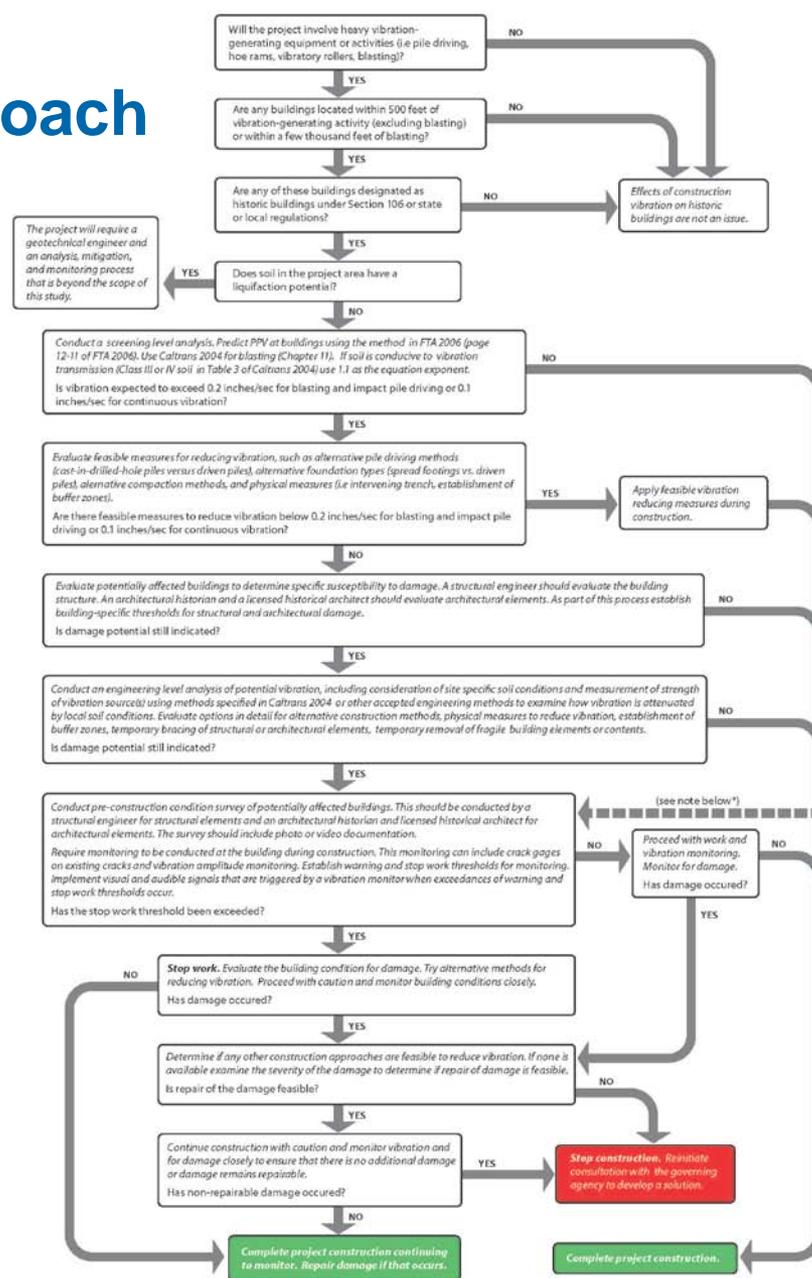
Transportation Agency Survey

- 16 agencies indicated that they have stopped work on a project as a result of complaints or exceedance of a pre-established threshold.
- Alternative construction methods were typically identified and employed.

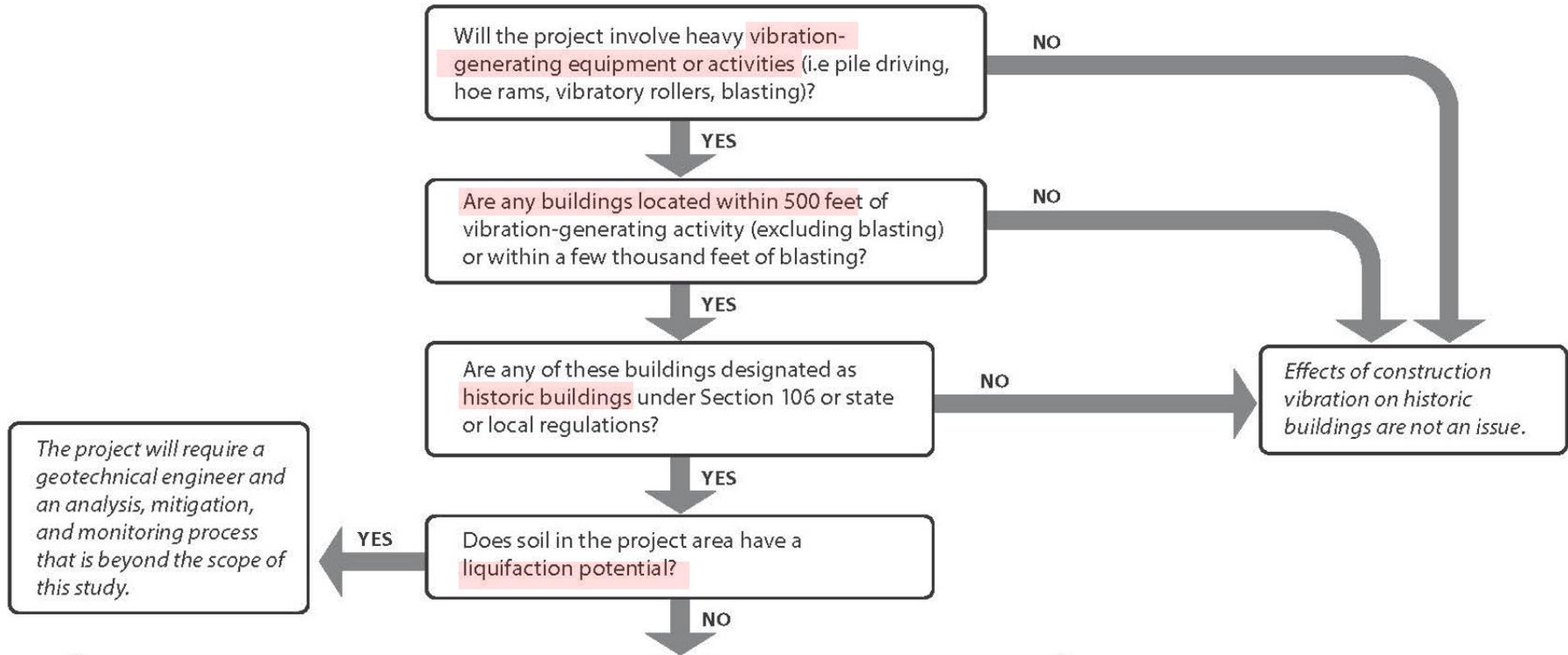
Case Studies

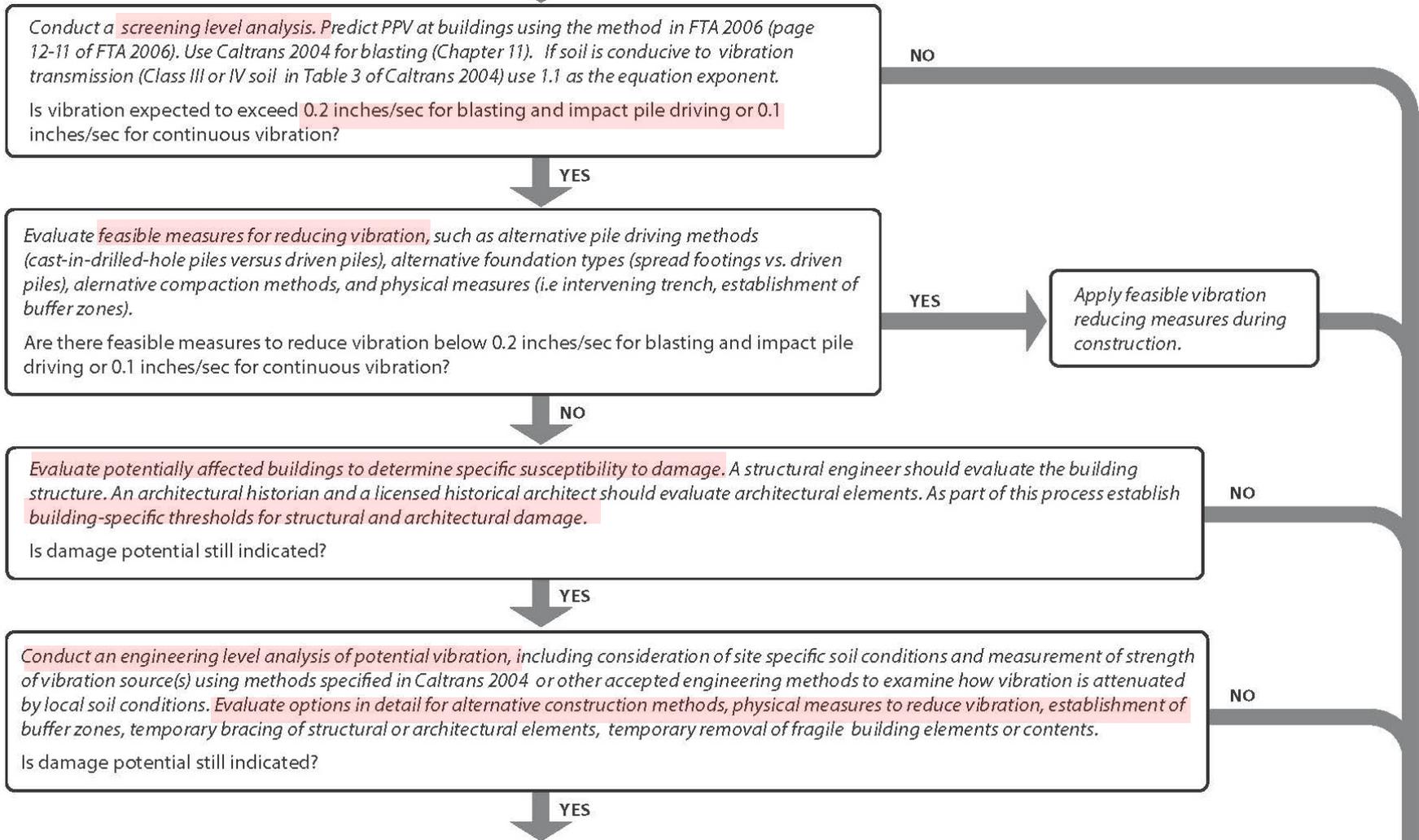
- Case Study #1: Sacramento Railyards Central Shops
- Case Study #2: Cypress Lawn Cemetery – Entrance Archway and de la Montaña Mausoleum
- Case Study #3: Gipfel Brewery Building, Milwaukee
- Case Study #4: Fraunces Historic District, New York City
- Case Study #5: Fort Point – San Francisco
- Case Study #6: Historic District, New York City
- Case Study #7: Presidio Buildings – Doyle Drive, San Francisco

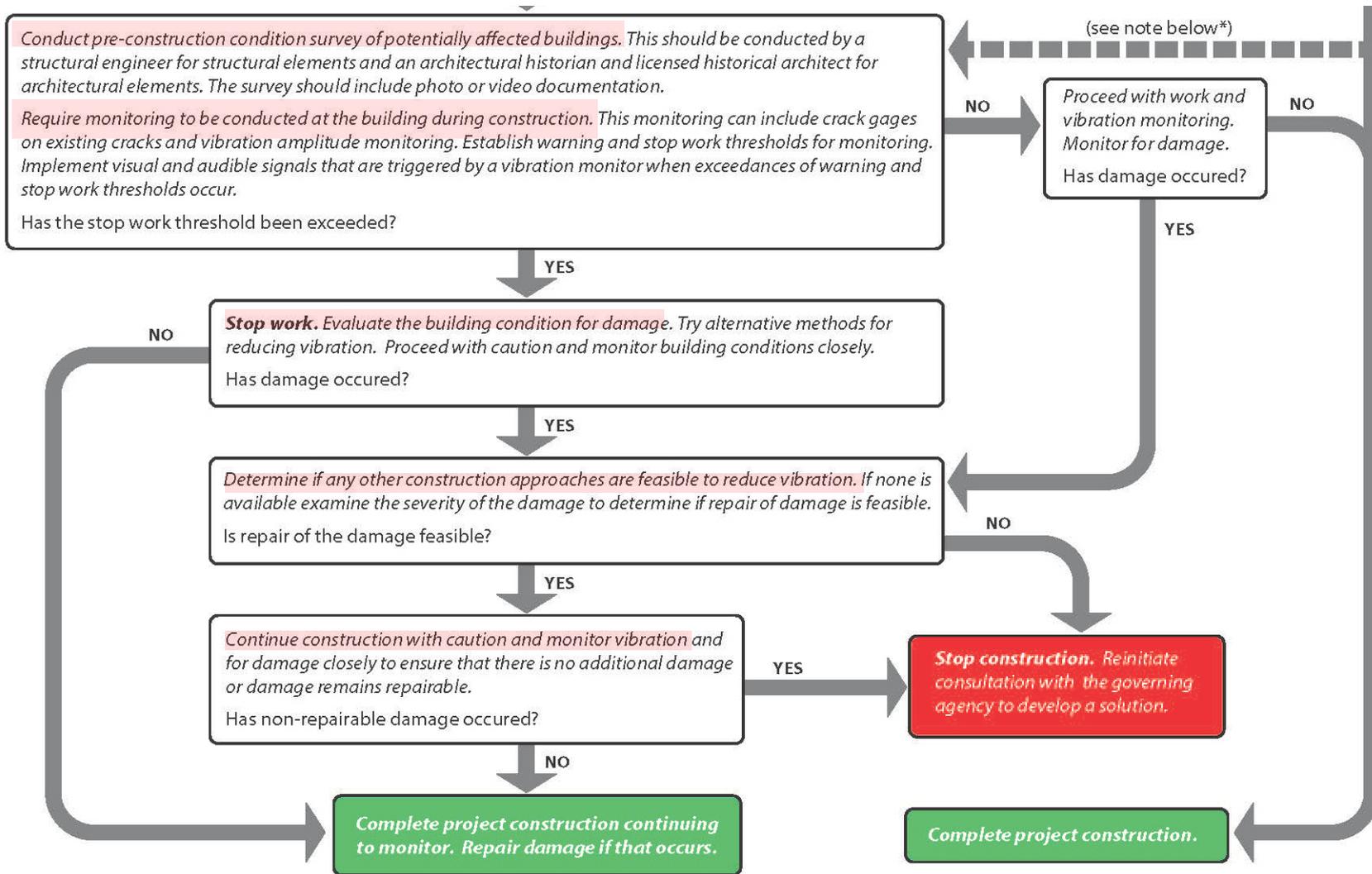
Suggested Guideline Approach



*Note: It may be desirable to conduct a pre-construction survey and to conduct monitoring even if the initial analysis indicates that damage is unlikely. Factors to consider would include the level of detail of the engineering information, the related confidence in the engineering analysis, the historical significance of the building, and the level of concern by the public and public agencies.







*Note: It may be desirable to conduct a pre-construction survey and to conduct monitoring even if the initial analysis indicates that damage is unlikely. Factors to consider would include the level of detail of the engineering information, the related confidence in the engineering analysis, the historical significance of the building, and the level of concern by the public and public agencies.

Questions?

