

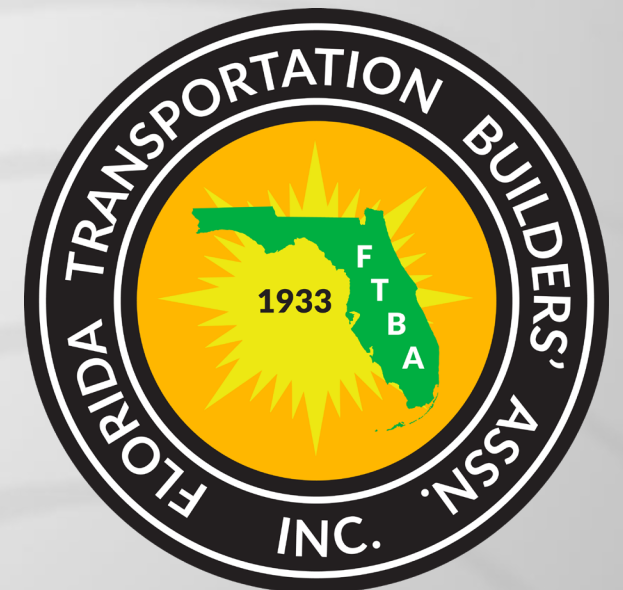
Controlling Vibrations from Close-in Pile Driving

Presented by:

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FTBA Construction Conference 2021

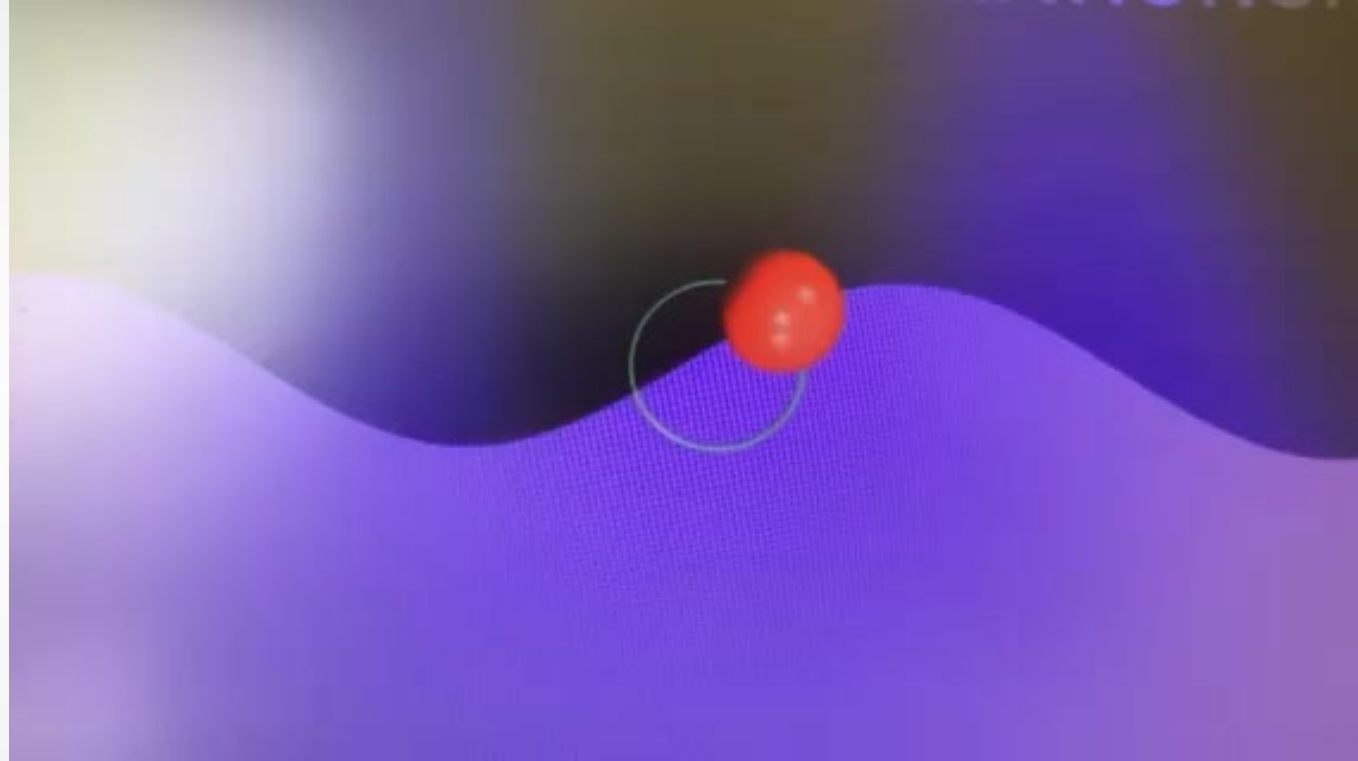


Topics

- Types of Vibrations from Driven Piles.
- Structural Response.
- Vibration Standards for Damage Prevention.
- Soil Types and Settlement Susceptibility.
- Prediction of Vibration Effects.
- Monitor Existing Structures in accordance with Section 108

Fundamental Definitions of Ground Vibrations

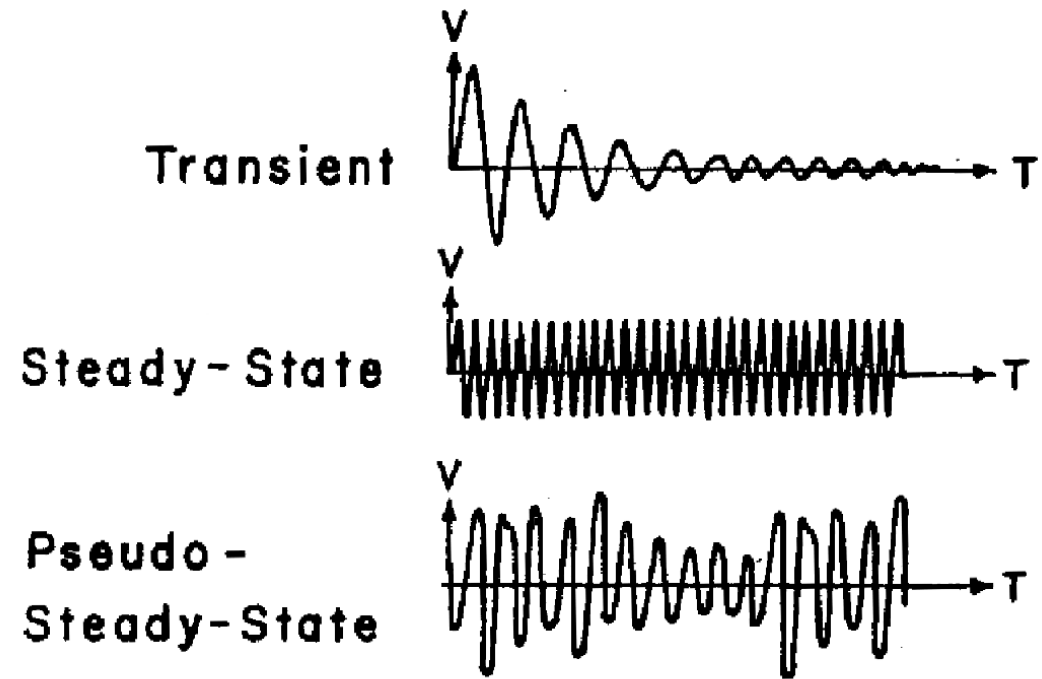
- Particle Velocity - The rate of particle motion in a medium. It is typically expressed in inches or millimeters per second (in/s or mm/s).
- Frequency - number of cycles over a given amount of time (typically a second). It is expressed as cycles per second or Hertz (Hz).



Types of Vibrations from Driven Piles

- Transient or Impact Vibrations.
- Steady State or Continuous Vibrations.
- Pseudo-Steady-State Vibrations.

Types of Construction Vibrations

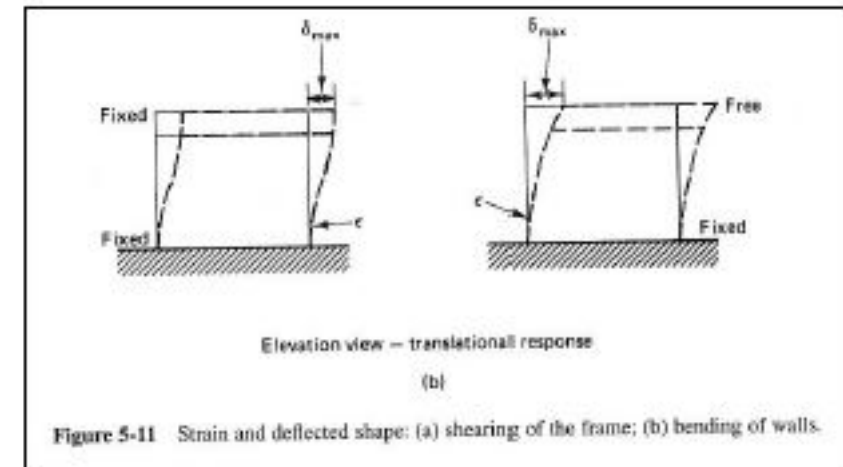
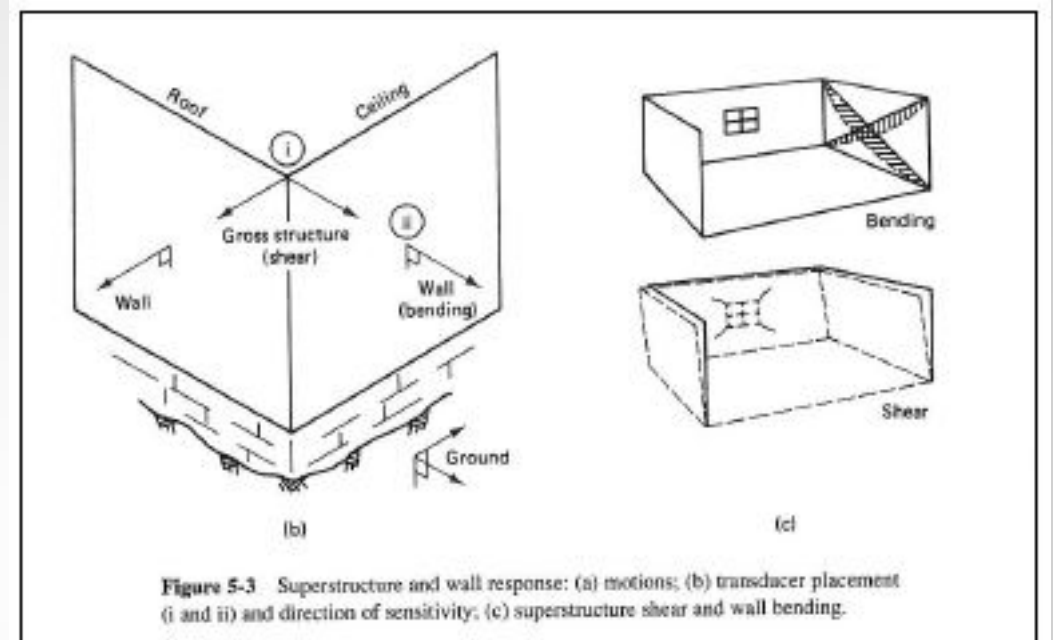


V = Vibration Amplitude

T = Time

Structure Response

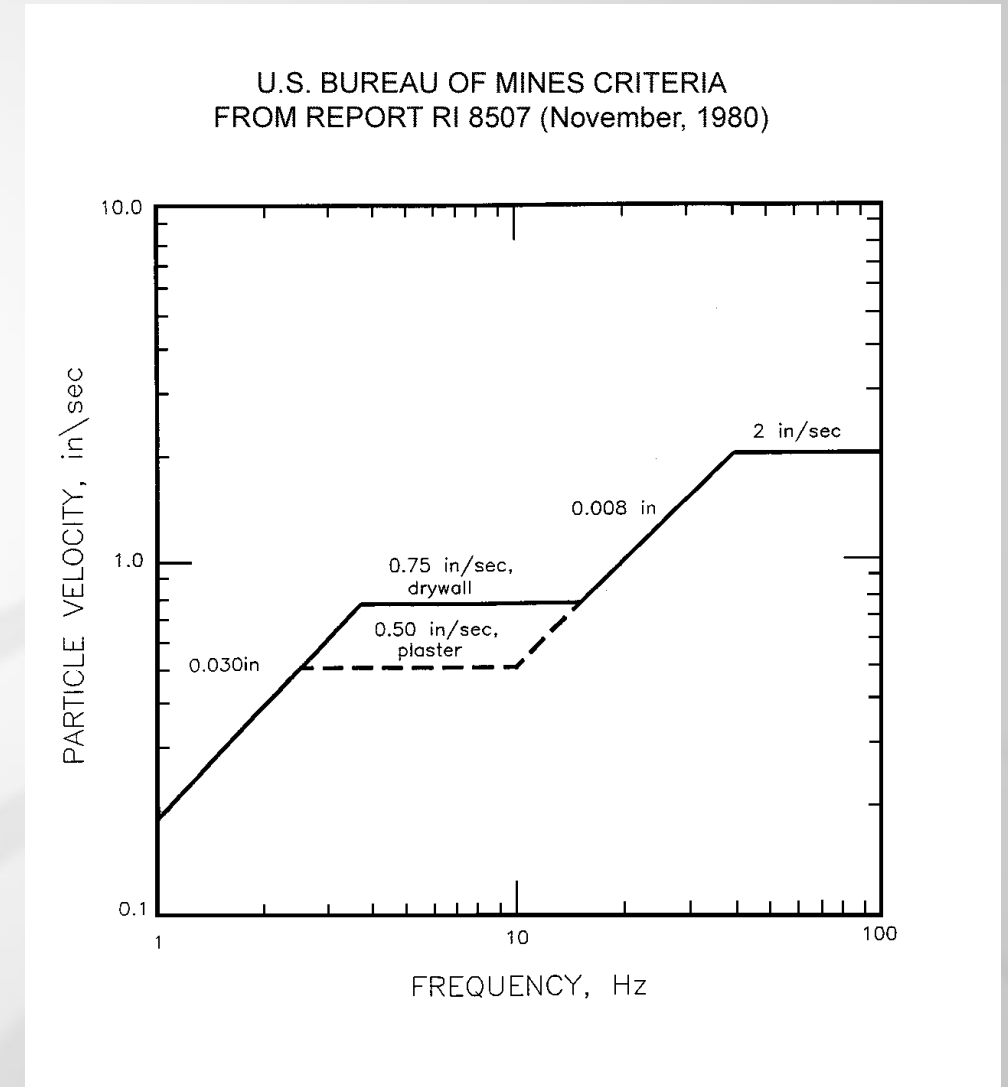
- If vibration response of a building cannot be measured, then its fundamental frequency must be estimated from the physical properties of the structure (Dowding, 1996).
- This approximation formula is $f = 1/0.1N$.
- Substitution of 1 and 2 for N yields f values of 10 and 5 Hz for one and two-level residential structures.
- This estimate compares favorably with the findings of the US Bureau of Mines (1980) which published the range of natural frequencies for low-rise structures to be between 4 and 12 Hz.
- If the ground vibration frequency closely matches the natural frequency of a structure or structural component, the structure or component will tend to respond more vigorously.



Vibration Standards

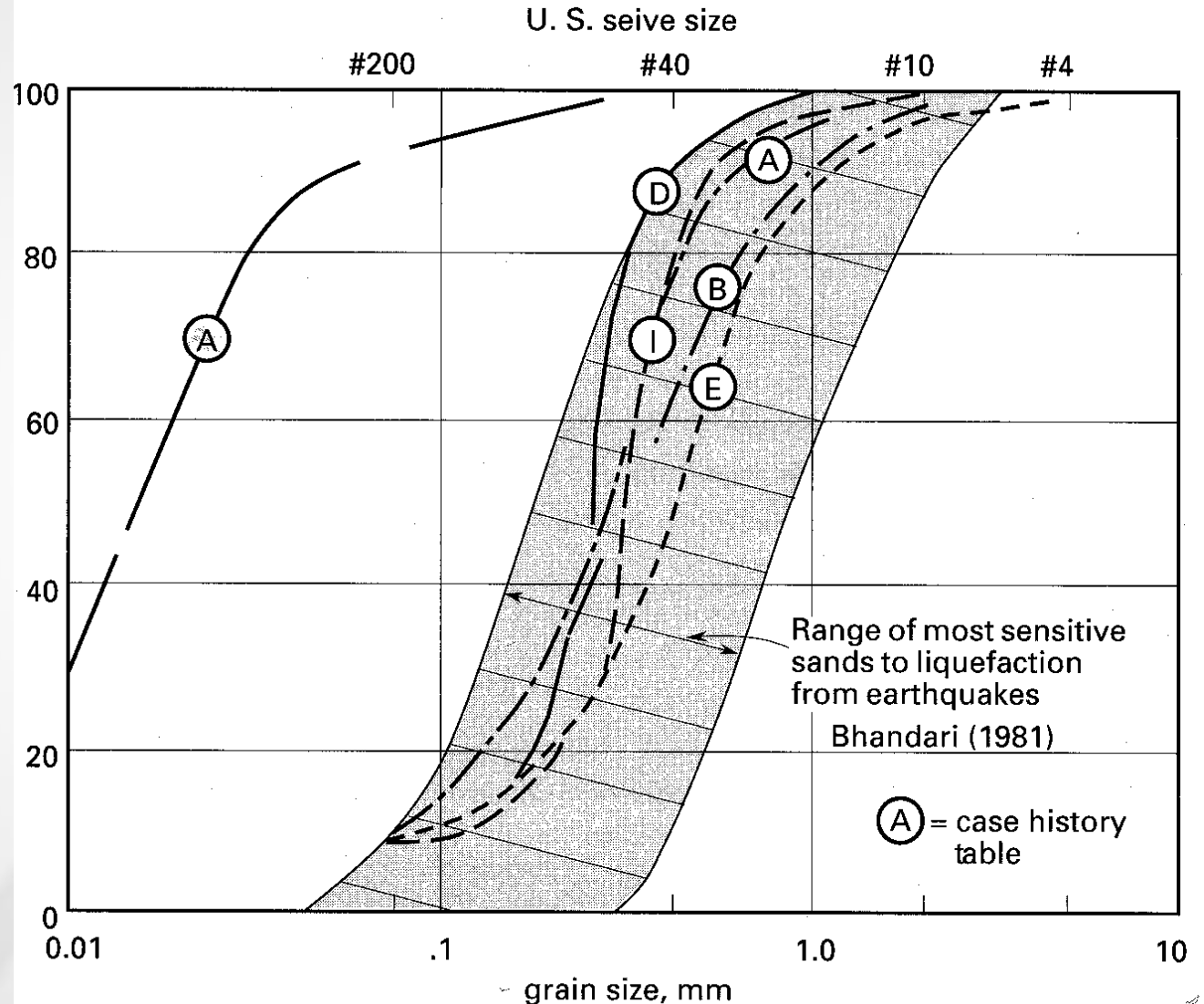
Decades of Research for Blasting Industry

- Blast Vibrations and Impact Hammer Pile Driving both Generate Transient Vibrations.
- Standards in Units of Particle Velocity/Frequency Dependent.
- Standards are Designed to Protect Drywall and Plaster from Cosmetic Cracking.
- Structural Damage would require 2 to 5 times Higher Vibrations than the Generally Applied Standards.
- Other standards are mentioned in our paper, including those for Historic Structures, Green Concrete, Engineered Structures, Sensitive Equipment, Human Response and Soil Settlement.



Soil Settlement

- Dynamic settlement from pile driving induced vibrations is mostly related to the consolidation of non-cohesive soils.
- Soils most susceptible to consolidation from vibrations are poorly graded, single sized sands with relative densities less than about 50 percent of the maximum compaction density (Very Loose to Medium (N-counts of 0 to 15)).
- Vibration levels as low as 0.10 in/sec measured at the ground surface have been found to have caused settlement in the surrounding soil in some case studies published for susceptible sites.



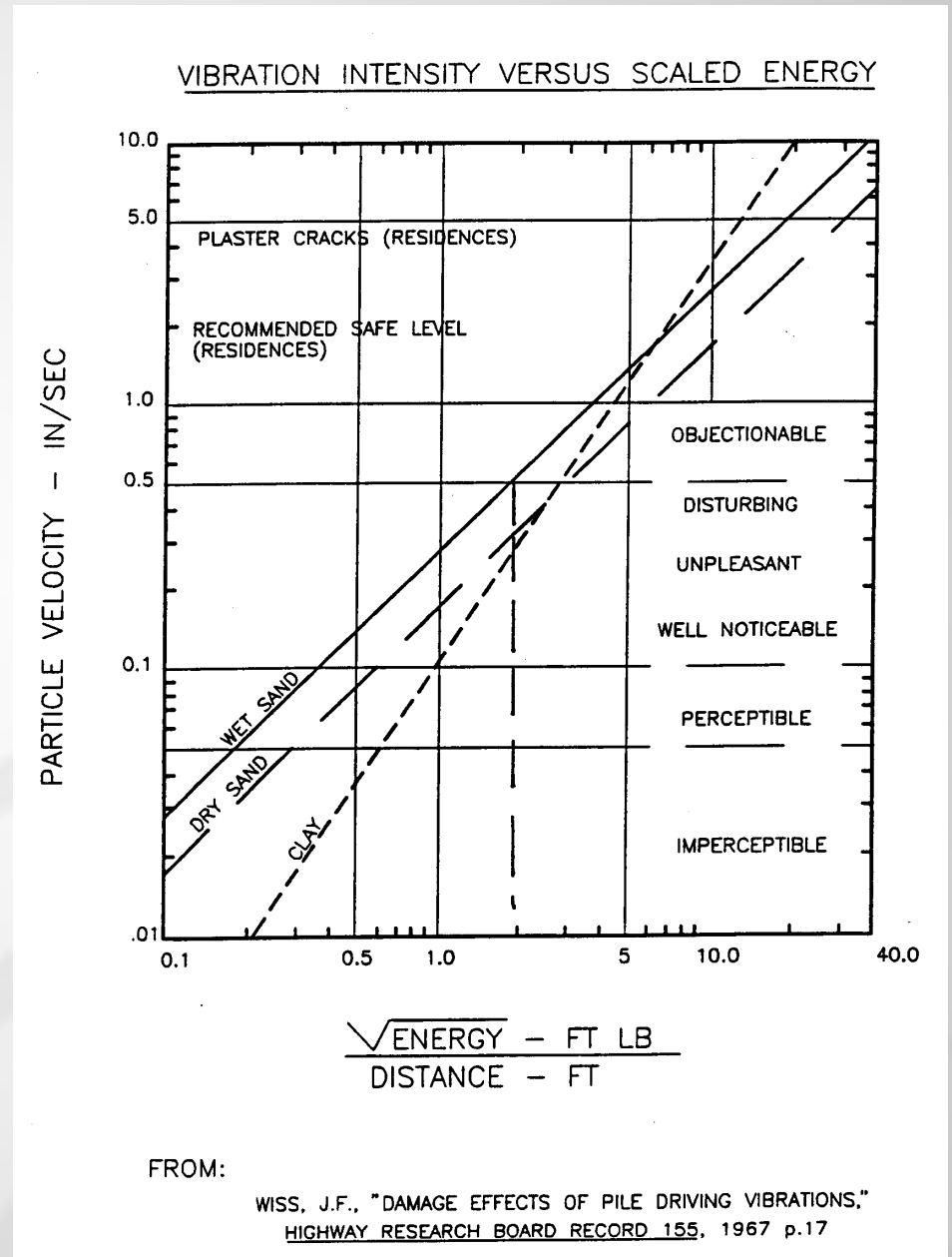
Estimating Effects

➤ Prediction –

- Prediction Graphs – Empirical (Scaled Energy and Soil Type)
- Site Specific Regression Analysis (during Test Pile Program)

➤ Monitoring –

- Pre- and Post-Inspection
- Settlement Monitoring
- Vibration Monitoring



Monitoring Effects in accordance with Section 108 – Monitor Existing Structures

- Provides guidance on monitoring settlement, vibration, and groundwater. Also specifies pre- and post-construction inspection of adjacent structures.
 - Does not modify requirements or responsibilities for preservation of existing properties from damage.
 - Requires contractor to employ methods that will not produce damaging vibrations, soil movement, soil loss, or instability of existing structures.

Section 108 – Monitor Existing Structures (Cont.)

- 108-2.1 Inspection and Settlement Monitoring
 - 108-2.1.1 Miscellaneous Structures (When doing foundation work for signs signals, lighting, or ITS structures) – inspect and monitor for settlement existing structures indicated in plans.
 - 108-2.1.2 Other Structures – During excavation, constructing retaining walls, foundation work for bridges, buildings, or structures other than miscellaneous, inspect and monitor for settlement as follows:
 - As shown in Plans
 - 5 X drilled shaft or auger cast pile diameters or equal to depth of such, whichever is greater (measured from center of foundation element being constructed).
 - 3 X depth of excavation
 - 200 feet of sheet piling (installation or extraction)
 - 100 feet of soldier pile installation and extraction
 - Pile driving is scaled energy based:
 - $0.25 \times \sqrt{RE}$ for inspection and documentation (pre- and post-construction)
 - $0.5 \times \sqrt{RE}$ for settlement monitoring

Section 108 – Monitor Existing Structures (Cont.)

- 108-2.1.3 Roadway Compaction Operations
 - Embankment Compaction
 - Asphalt Compaction
 - Paving or Milling and Resurfacing
 - Inspection and Settlement Required
 - As Shown in Plans
 - Refer to the Roadway Plans, “Summary of Monitor Existing Structures” Table in the Summary of Quantities Sheets
 - Within 75 feet of vibratory compaction

Section 108 – Monitor Existing Structures (Cont.)

- 108-2.1.4 Inspection and Documentation Requirements
 - To be performed in conjunction with an independent qualified Specialty Engineer
 - Prior to construction.
 - Inspect and document pre-existing cracks, settlement, or other damages that might otherwise become the subject of a claim. Include digital images and an image log describing the images. Location plan helpful.
 - Submit two copies, signed and sealed by Specialty Engineer.
 - Post-Construction
 - Re-inspect and document any new conditions and if damage is observed, provide a determination whether damage is due to construction.
 - Unless otherwise indicated in the contract documents, inspecting and documenting bridges, sign, signal, lighting, and ITS structures owned by the Department not required (but could be prudent).
 - Department to make necessary arrangements for right-of-way entry.

Inspection



Section 108 – Monitor Existing Structures (Cont.)

- 108-2.1.5 Settlement Surveying and Monitoring
 - Engineer's approval for number and locations of points
 - +/-0.005-foot accuracy, reporting with a precision of 0.001 foot
 - Threshold of movement is +/- 0.01 foot
 - If threshold reached or exceeded or damage is observed, stop construction, stabilize site, and submit corrective action plan.
 - Monitoring frequency:
 - Pre-construction
 - Daily during pile driving, compaction, foundation drilling
 - Weekly, for two weeks after pile driving
 - During excavation, blasting, or as directed by Engineer

Settlement



Seismic Surveys, Inc.

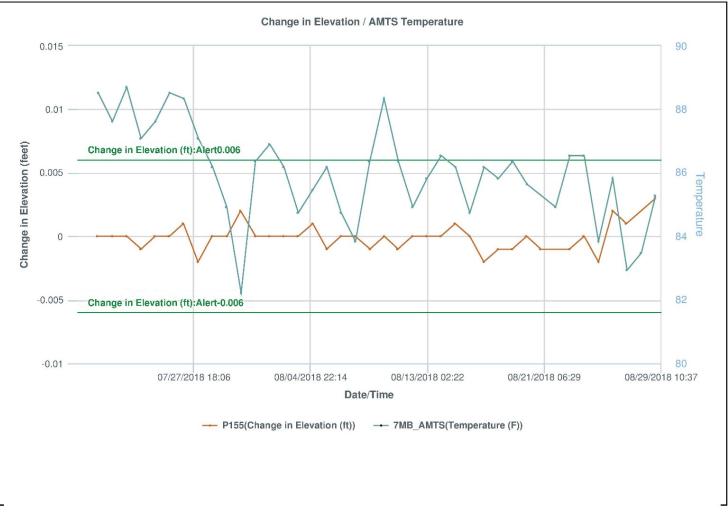
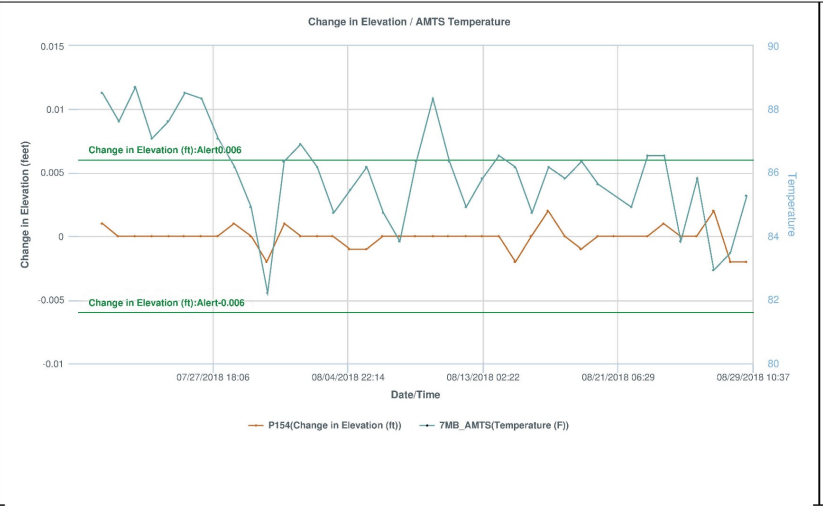
Seismic Surveys Monitoring Projects



Report No.3



7mBridge Report No.3



Section 108 – Monitor Existing Structures (Cont.)

- 108-2.2 Vibration Monitoring
 - Required when shown in the Contract Documents (Typically in the Summary of Monitor Existing Structures in the Roadway Plans)
 - To be performed by independent Specialty Engineer
 - Prepare a monitoring plan for Engineer's approval
 - Submit results within 24-hours of performing monitoring
 - An automated system can facilitate this very practically
 - Vibration threshold is a PPV of 0.5 in/sec
 - If vibrations exceed this threshold, or damage to the structure is observed, stop source of vibrations, backfill open excavation, notify Engineer and submit corrective action plan.

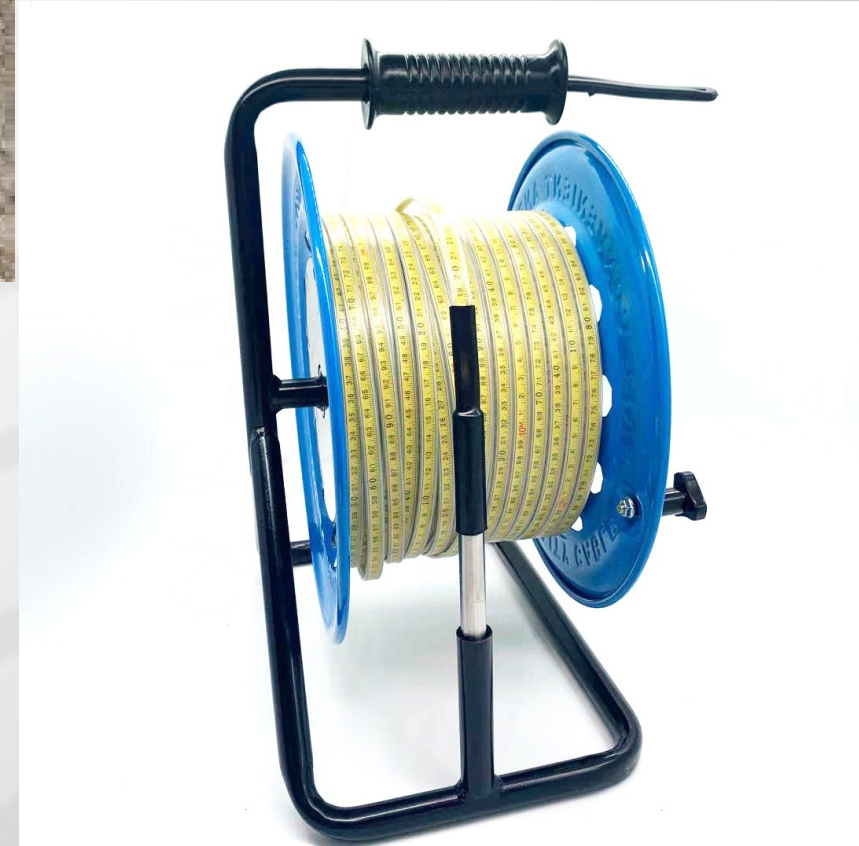
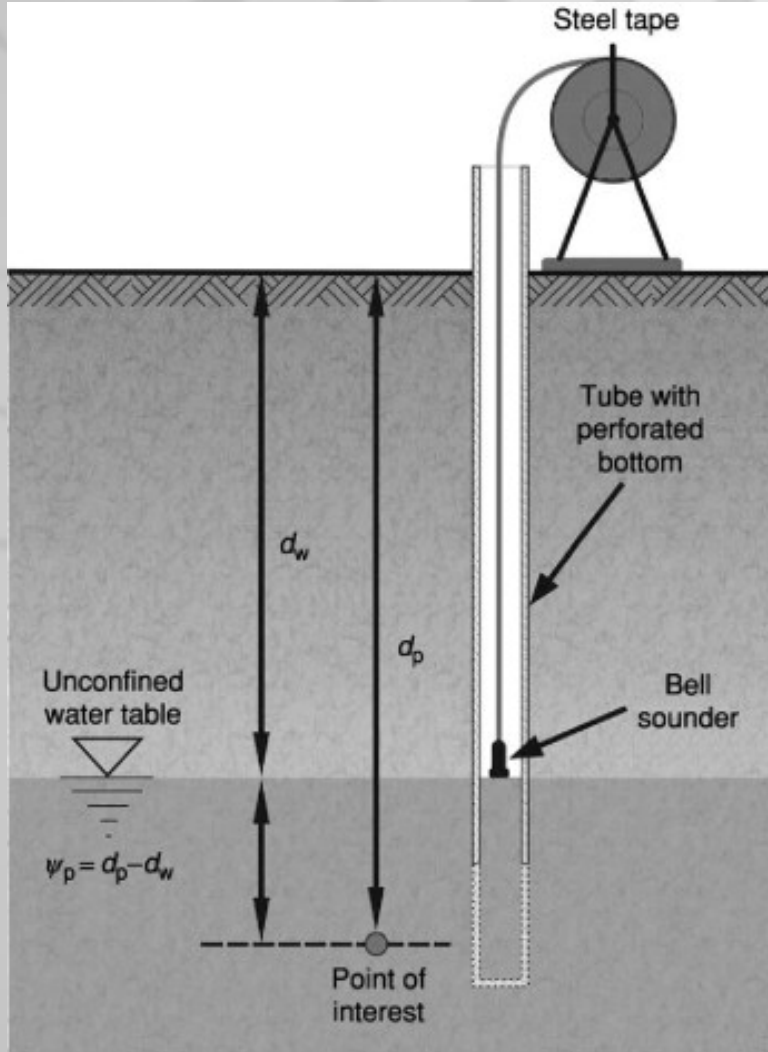
Vibration Monitoring



Section 108 – Monitor Existing Structures (Cont.)

- 108-2.3 Groundwater Monitoring
 - When shown in Contract Documents
 - Install a piezometer at the right of way line and near any structure that might be affected by dewatering, or as directed.
 - Monitor and record groundwater elevations
 - Monitoring Frequency:
 - Daily during dewatering and for one week after dewatering has ceased (or as approved by Engineer)
 - Notify Engineer if groundwater lowering of 12 inches or more.

Groundwater



Conclusions and Questions

- A comprehensive Monitor Existing Structures program is not only for specification compliance. It is a valuable loss prevention tool to mitigate the risk of causing damage and the risk of unwarranted claims.
- Miller, D. K., Anderson, M.W., & Hastings, P.T. (2020, October). Controlling Vibrations from Close-In Pile Driving. *Proceedings of the Forty-Fifth Annual Conference on Deep Foundations*, Deep Foundations Institute, Hawthorne, NJ.