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5.24 UNKNOWN FOUNDATION INVESTIGATION

5.24.1 Introduction

It was estimated that approximately one-fifth of the bridges on the National Bridge Inventory (NBI) have unknown foundations in terms of the type and/or depth. A large number of older non-federal-aid and to a lesser extent federal-aid bridges do not have any design or as-built plans on file to document the type, depth, geometry, or materials incorporated into their foundations. These bridges with unknown foundations pose a potential problem from a scour safety perspective. Since the undermining of bridge foundations poses a risk to the public safety, it is crucial to evaluate all bridges over or near water and determine their susceptibility to scour. In addition to scour concerns, unknown foundations are also a concern when a bridge is considered for improvements.

The evaluation of unknown foundations can be conducted either by conventional methods, such as physically disruptive excavation, coring, or boring methods, as well as less invasive nondestructive evaluation (NDE) methods. Conventional methods are typically considered to be expensive, destructive, and limited in their application. Therefore, research emphasis has recently been placed on NDE methods that can inexpensively and reliably determine the foundation properties.

The items important in the evaluation of these unknown foundations are:

1. Foundation Depth – the bottom elevation of the footing, piles, or combined system.

2. Foundation Type – shallow (footings), deep (piles or shafts), or a combined system.

3. Foundation Geometry – buried substructure dimensions, pile locations, etc.

4. Foundation Materials – steel, timber, concrete, masonry, etc.

5. Foundation Integrity – condition state of foundation materials.

The foundation depth and type, if unknown, are considered to be the most critical pieces of information in a scour evaluation. The foundation geometry, materials, and integrity are frequently desired when improvements are being considered near or to a structure.

In determining which NDE methods might be useful, the ability of the method to detect and to delineate the foundation components from the surrounding environment is often the deciding factor. The subsurface environment typically consists of a mixture of air, water, slope protection materials, soil, and/or rock. Thus, the method needs to consider the wide range of substructure, geological, and hydrological conditions at a particular structure site.

The NDE methods used for unknown foundation investigation can be categorized into either Surface Methods or Borehole Methods. Surface methods are generally less invasive since they do not require soil disruption like borehole methods. Although the following list provides a brief sample of applicable methods, the inspector should be aware that other methods are also currently being researched and implemented.

Currently used Surface Methods include:

1. **Sonic Echo/Impulse Response (SE/IR) Test:** The source and receiver are placed on the top and/or sides of the exposed pile or columnar shaped substructure. The depth of the reflector is calculated using the identified echo time(s) for SE tests, or resonant peaks for IR tests.

2. **Bending Wave Test:** Two horizontal receivers are mounted a few feet apart on one side of an exposed pile and then the pile is impacted horizontally on the opposite side a few feet above the topmost receiver. This method is based on the dispersion characteristics and echoes of bending waves traveling along very slender members like piles.

3. **Ultra-seismic Test (UST):** An exposed substructure is impacted with an impulse hammer to generate and record the travel of compression or flexural waves down and up the substructure at multiple receiver locations.

4. **Spectral Analysis of Surface Waves (SASW) Test:** This involves determining the variation of surface wave velocity verses depth in layered systems. The bottom depths of exposed substructures or footings are indicated by slower velocities of surface wave travel in underlying soils.

5. **Ground Penetrating Radar (GPR):** This method uses a radio frequency signal that is transmitted into the subsurface and records the reflection echoes from the concrete/soil interface to determine the unknown depth.

Currently used Borehole Methods include:

1. **Parallel Seismic Test:** An exposed foundation substructure is impacted either vertically or horizontally with an impulse hammer to generate compression or flexural waves that travel down the foundation and are reflected by the surrounding soil. The reflected compression wave arrival is tracked at regular intervals by either a hydrophone receiver or geophone receiver.

2. **Borehole Radar Test:** A transmitter/receiver radar antenna is used to measure the reflection of radar echoes from the side of the substructure foundation.

3. **Induction Field:** A magnetic field is induced around the steel of the pile or reinforced concrete foundation. The field strength will decrease significantly below the bottoms of the foundation.

5.24.2 Applications

Applications vary depending on the chosen nondestructive evaluation (NDE) method. Refer to Figure 5.24.2-1 for a comparison of the NDE applications.

Method		Applications	Advantages
Surface	Sonic Echo/Impulse Response	Most useful for columnar or tabular structures. Best penetration attained in loose soils. Good for determining thickness and geometry.	Lower cost equipment and inexpensive testing. Data interpretation may be able to be automated. Theoretical modeling should be used to plan field tests.
Surface	Bending Wave	Most useful for a purely columnar substructure. Best penetration attained in loose soils.	Lower cost equipment and inexpensive testing. Theoretical modeling should be used to plan field tests. The horizontal impacts are easy to apply.
Surface	Ultraseismic	Best penetration attained in loose soils. Good for determining thickness and geometry.	Lower cost equipment and inexpensive testing. Can identify the bottom depth of foundation inexpensively for a large class of bridges. Combines compressional and flexural wave reflection tests for complex substructures.
Surface	Spectral Analysis of Surface Wave	Good for determining thickness and geometry.	Lower cost equipment and inexpensive testing. Shows variation of bridge material and subsurface velocities verses depth and thickness of accessible elements.
Surface	Surface Ground Penetrating Radar	Can indicate geometry of inaccessible elements and bedrock depths.	Lower testing costs. Fast testing times.
Borehole	Parallel Seismic	Accurate for determining foundation bottom depths for a large range of structures. Under certain conditions can indicate foundation orientation.	Lower cost equipment and inexpensive testing. Can detect foundation depths for largest class of bridges and subsurface conditions.
Borehole	Borehole Radar	Good at determining foundation parameters. Sensitive to detecting steel or steel reinforced members.	Relatively easy to identify reflections from the foundation; however, imaging requires careful processing.
Borehole	Induction Field	Highly sensitive to detecting steel or steel reinforced members that are electrically connected to the surface.	Lower cost equipment Easy to test. Compliments Parallel Seismic in determination of pile type.

Figure 5.24.2-1: Comparison of NDE Methods

5.24.3 Limitations

Limitations vary dependent on the chosen nondestructive evaluation (NDE) method. Refer to Figure 5.24.3-1 for a comparison of the NDE limitations.

Method		Limitations
Surface	Sonic Echo/Impulse Response	Response complicated by bridge superstructure elements. Can only detect large defects. Stiff soils and rock limit penetration.
	Bending Wave	Response complicated by various bridge superstructure elements. Response complicated by stiff soils that may show only depth to the stiff soil layer.
	Ultraseismic	Cannot image piles below cap. Difficult to obtain foundation bottom reflections in stiff soils.
	Spectral Analysis of Surface Wave	Cannot image piles below cap. Use restricted to bridges with flat, longer access for testing.
	Surface Ground Penetrating Radar	Higher cost equipment. Signal quality is highly controlled by environmental factors. Adjacent substructure reflections complicate data analysis.
Borehole	Parallel Seismic	Difficult to transmit large amount of seismic energy from pile caps to smaller (area) piles.
	Borehole Radar	Radar response is highly site dependent (very limited response in conductive, clayey, salt-water saturated soils).
	Induction Field	The reinforcement in the columns is required to be electrically connected to the piles underneath the footing. Only applicable to steel or reinforced structures.

Figure 5.24.3-1: Comparison of NDE Limitations.

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