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# Determining Depth of Foundation of an Existing Bridge using Geophysical Non-Destructive Tests – A Case Study

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**Abstract.** To determine the depth of an existing bridge foundation for construction of an underground rail corridor, parallel seismic tests (PST) and low-strain pulse echo method (PIT) were used. Since the tunnel alignment crosses an old bridge, the depth of the bridge foundations was evaluated by non-destructive geophysical tests to assess the impact of tunnelling on the existing structure. The side of the piles were exposed to perform the pile integrity test. A borehole was drilled adjacent to two piles and cased with a PVC pipe. The paper presents results of the parallel seismic tests and PIT conducted on two piles below the bridge abutments. The test results confirmed that the pile lengths ranged from 8 to 9 m.

**Keywords:** Depth of Unknown foundation, Pile Integrity Test, Parallel Seismic Test.

## 1 Introduction

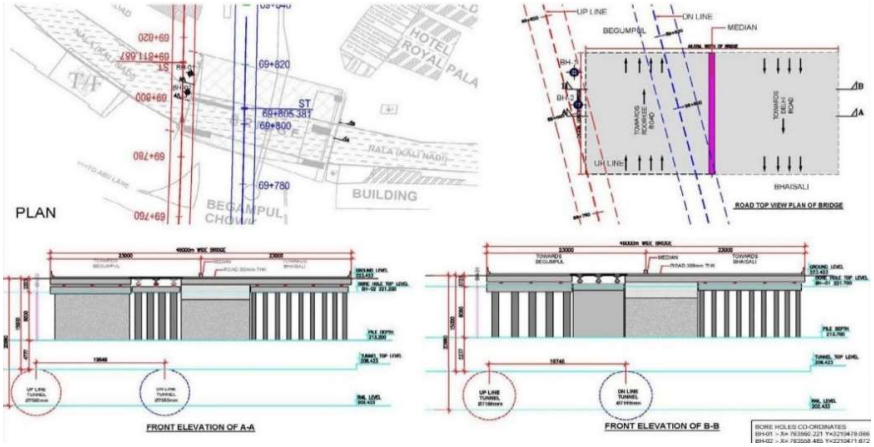
With the development of rapid mass transport corridors in the country, there is an increasing demand for determining the depth of foundation of existing bridges, particularly in cases where an underground tunnel portion passes below the bridge. The paper presents a case study of determining the depth of piles for a bridge across a minor river along the Meerut-Delhi section of the alignment of a transport corridor. It was necessary to ascertain the depth of the existing foundation system at this location, to make sure that the tunneling activities shall not be affected.

## 2 Bridge Details and Tunnel Alignment

The 24 m long bridge over Kali Nadi has a 50+ years old bridge along with a second new bridge constructed parallel to it. The underground railway tunnel passes beneath this bridge. So, it was necessary to ascertain the presence and depth of the existing foundation system at this location, to make sure that the tunneling activities shall not be affected. A photograph of the bridge is illustrated on Fig. 1.

**Fig. 1.** A view of the bridge

The tunnel alignment crosses below the bridge on one side. Fig. 2 illustrates the bridge relative to the tunnel alignment.




Top Left: Plan of road bridge over drain Top Right: Alignment of tunnel relative to road bridge
Bottom Left: Elevation - Section AA Bottom Right: Elevation - Section BB

**Fig. 2.** Plan and Elevation

## 3 Borehole Data

The project area belongs to the Indo-Gangetic alluvium. Two boreholes were drilled adjacent to two piers of the bridge to 50 m depth. The soils are deposits of the Ganga, Yamuna and their tributaries [1]. Fig. 3 illustrates the borehole drilling in progress.

**Fig. 3.** Borehole in progress

Fine sand is primarily encountered in the area. SPT values range from 10 to 20 to 8 m depth, 22 to 47 to 16 m depth and exceed 50 below 16 m depth. Groundwater was met at 22-23 m depth. Typical borehole data is presented on Fig. 4.

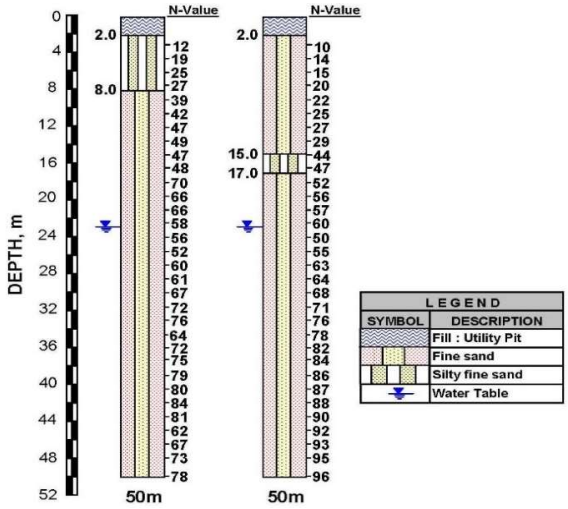



**Fig. 4.** Borehole data

## 4 Non-Destructive Testing

The pulse-echo response test and the parallel seismic test are the most popular tests used to determine the depth of unknown foundations [2]. The authors have used these tests effectively to make reasonable assessment foundation depths for several projects including that of a railway bridge in Delhi which was located along the alignment of a metro line [3] and well foundations for a bridge in Haryana [4].

### 4.1 Sonic Pulse-Echo Response

The sonic pulse-echo response test (also known as Pile Integrity Test, PIT) involves measuring reflections of stress waves from the foundation-bottom. The test is commonly used to determine depth and quality of newly constructed piles and has been effectively been used to assess the depth of unknown foundations.

The PIT test is carried out by hitting the top or side of the foundation with a hand-held hammer as per IS: IS: 14893-2021 [5]. An accelerometer fixed on the side of the foundation was used to record the response. An acoustic wave generated by the impact propagates down the pile and reflected back from the pile tip which is interpreted to assess the pile depth and its integrity.

The analysis is based on wave equation principle. As a stress wave propagates through the pile concrete, it is reflected back from an interface that has a different modulus of elasticity. Fig. 5 presents photographs of the test in progress.

**Fig. 5.** Sonic pulse-echo test in progress on the underside of the bridge

Each pile was tested 5-6 times to confirm the response. The response obtained and the profile interpreted for two piles [6] is presented on Fig. 6 and 7.

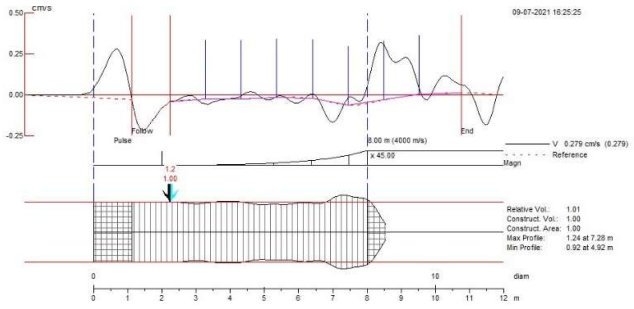



**Fig. 6.** Pile 1-2 Sonic Echo Response

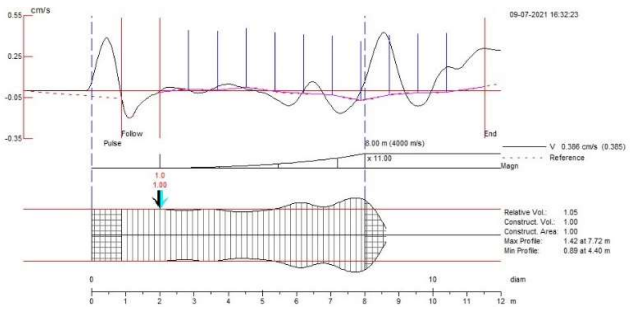



**Fig. 7.** Pile 2-1 Sonic Echo Response

The PIT is a very well-established method and gives consistent results [7, 8]. Evaluating the test results, the pile length is expected to be about 8 m.

### 4.2 Parallel Seismic Test

The Parallel Seismic (PS) method is applied to determine the lengths of deep foundations. IRC-123 [9] suggests the use of the test for determining foundation depth. The method requires the installation of cased borehole close to the foundation being tested. Some portion of the structure that is connected to the foundation must be exposed for the hammer impacts. A borehole is drilled as close as possible to the foundation. The borehole should extend below the expected bottom of the foundation.

The test is based on the principle that an impact to the exposed structure generates wave energy that travels down the foundation. The energy wave can be tracked by depth with receivers in a nearby parallel boring to determine when the signal weakens, and slows down. This indicates the receiver has gone beyond the bottom of the foundation, and the depth is determined. Fig. 8 illustrates a schematic of the test setup.

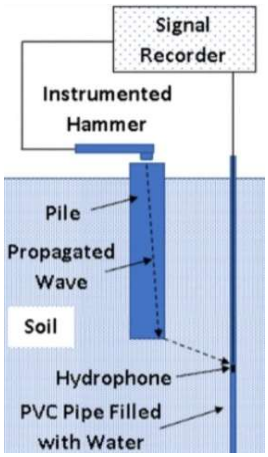
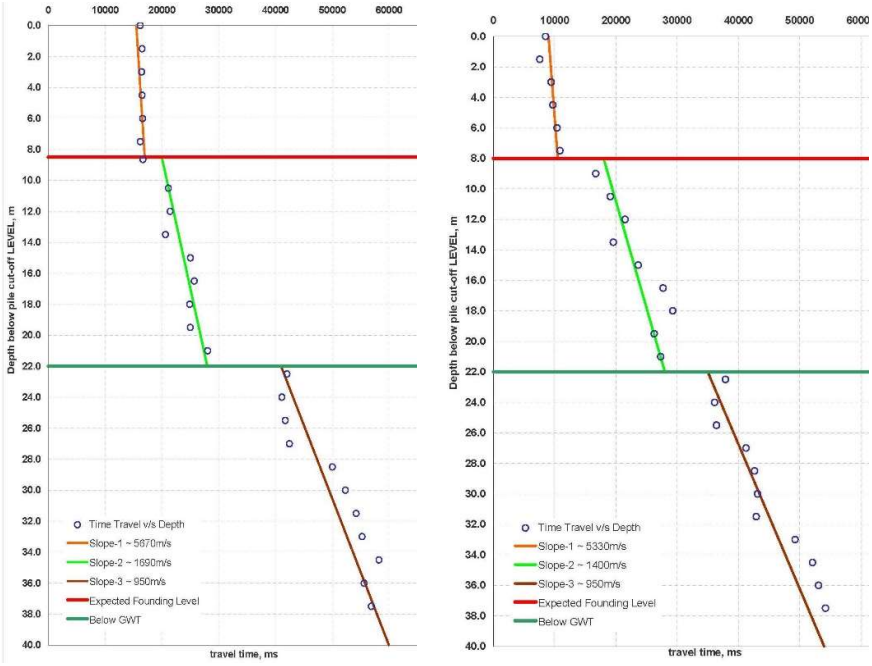



**Fig. 8.** Schematic of parallel seismic test

Fig, 9 presents the test results at two pile locations.




Parallel Seismic Test – Pile 1 Parallel Seismic Test – Pile 2

**Fig. 9.** Parallel seismic test results

Reviewing the test results, it is evident that the pile probably extends to 8-9 m depth. The second break in velocities is likely to be due to the groundwater level and the dense nature of the sand. and This matches well with the results of the pulse-echo response test. Combining the results of both tests, it is reasonable to conclude that at this bridge location, the piles extend to 8-9 m depth.

## 5 Closing Remarks

Parallel Seismic (PS) test in conjunction with low strain pulse echo (PIT) is a versatile NDT method of determining the specifications of unknown bridge foundations. It is a cost-effective, time-saving and fairly reliable if the borehole for testing is close to the foundation. The case study demonstrates successful use of these tests to assess the depth of old foundations. Experience has shown that the methods can predict foundation depth with about ±10% error.

The authors highlight here that although the test is very useful and provides reliable data for interpretations, indirect geophysical tests do have some limitations and decisions on site should be taken carefully considering these limitations. Engineers should realize that there are no guarantees when geophysical tests are interpreted.

Indirect methods may not always be as clear-cut as one expects them to be. Unexpected ground conditions, particularly at depth can produce unusual results that are difficult to interpret. Some of the limitations of the test include the following:

1. Defects in the piles could lead to wrong interpretations.
2. While the accuracy is reasonably good if the distance between the foundation and borehole is small, foundation depth is overestimated with increasing distance.
3. Ambient noise and other unusual ground conditions could affect the results.
4. If the strata conditions change abruptly, this could also result in change in wave-velocities.

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