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Analytical and Practical Comparison of Various Test on Pile

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Abstract
High Strain Dynamic Pile Test (HSDT) is increasingly being used for pile load testing. HSDT offers a considerable savings of time, cost and requires very little space compared to the conventional static test. However, it is yet mandatory to compare HSDT tests with static load tests (SLT) to confirm the validity of HSDT as the results are generally site specific. This study presents comparison of static pile load test (SLT) vs HSDT and attempt is made to close the gap between theoretical and practical justification for replacing SLT with HSDT by identifying the problems while conducting and comparing both the tests. Also, a resourceful methodology is produced to conduct efficient comparison of SLT and HSDT which can be used at any site.
Keywords: *High Strain dynamic pile test, Static load test, comparison*

1. Introduction
Pile load testing is a significant and crucial milestone in construction projects to verify pile capacity and ensure the quality of construction. Compression pile load tests are typically conducted using static top-down loading, applied gradually over approximately 24 to 36 hours, with the load maintained at the desired capacity. However, preparing for static load tests (SLT) requires an additional 10 to 15 days, extending the total schedule for each test to about 15 days. To expedite this process and enhance project timelines, high-strain dynamic load testing (HSDT) has gained significant popularity due to its speed, cost-effectiveness, and simplicity. With readily available materials on site, HSDT allows for the testing of 4 to 5 piles per day. SLT provides a reasonably accurate simulation of the actual loading conditions of the pile. In contrast, HSDT generates transient high loading using a heavy hammer and analyzes pile capacity based on wave equations. However, HSDT does not precisely replicate the pile's working condition, raising questions about its efficiency and reliability.
Currently, Indian standards lack a dedicated procedure for High-Strain Dynamic Testing (HSDT), though ASTM D4945 provides detailed guidelines, and IRC 78-2014 references it. While Static Load Tests (SLT) are commonly used, HSDT is not widely adopted in India. However, due to technological advancements, many agencies now have the necessary instruments for HSDT. According to ASTM D4945, the accuracy of static pile capacity estimates from HSDT depends on several factors, such as pile installation, material properties, soil characteristics, test data quality, and engineering judgment. In the absence of experience with these variables, an SLT is recommended for verifying static capacity estimates. IRC 78-2014 suggests using HSDT for quick pile capacity assessments, provided there are correlations with SLT results. However, HSDT should not be used to increase design capacity without proper calibration. As existing codes don't specify calibration parameters, inconsistent practices have led to potential issues with pile failure.

1.1 Objectives of The Study
- To compare SLT and HSDT results.
- To identify challenges and solutions in SLT and HSDT implementation.
- To evaluate calibration parameters for HSDT based on site-specific conditions.
- To propose guidelines for standardizing the calibration process between SLT and HSDT for improved reliability and efficiency.

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This study highlights the need to correlate SLT and HSDT results and develop a framework for calibration to enhance the reliability and safety of pile testing. This study focuses on determining pile capacities using analytical methods and field tests (HSDT and SLT).

- **Analytical Method**: Pile capacity is estimated using empirical formulas, such as the Cole and Stroud method for rock socketed piles, which uses SPT values to estimate shear strength and calculate capacity. [1-5]
- **Dynamic Pile Load Test (HSDT)**: Uses a Pile Driving Analyzer (PDA) to measure forces and velocities during hammer blows. CAPWAP analysis refines these results, offering a more accurate estimate of the pile's static capacity.
- **Static Pile Load Test (SLT)**: A top-down load is applied incrementally, with settlement measured at each stage. After the final load is applied, it is maintained for 24 hours, followed by unloading stages to assess pile behaviour.

The study highlights the importance of combining analytical methods with field testing to accurately determine pile capacity, especially in complex soil and rock conditions.

2. Project Details

Pile load tests were conducted at two sites, each involving one static load test and one dynamic load test. The results were verified and approved by the relevant authorities.

2.1 Navapur Site

- **Soil Profile**: The site features vesicular basalt with highly weathered rock near the surface, transitioning to fresh rock at greater depths.
- **Pile Details**: Piles were installed using hydraulic rotary rigs and stabilized with a permanent liner. Concrete grade M35 was used for construction. [6-10]
- **Static load test**: 15th July 2021
- **Dynamic load test (HSDT)**: 18th July 2021
- **Pile Specifications:** Static Load Test: Pile No. LP16-P3, 11 m length, Dynamic Load Test: Pile No. LP16-P6, 12.4 m length Figure 1 shows Navapur Site.

Figure 1 Navapur Site

2.2 Titwala Site

- **Soil Profile**: The soil includes in situ silty soil with gravels and boulders, followed by weathered and fresh amygdaloidal basalt layers.
- **Pile Details**: Hydraulic rotary rigs were used for boring, with M35 grade concrete.
- **Static load test**: 29th October 2021
- **Dynamic load test (HSDT)**: 1st November 2021
- **Pile Specifications:** Static Load Test: Pile No. LP16-P6, 11 m length, Dynamic Load Test: Pile No. RP-24/01, 12.4 m length Figure 2 shows Titwala Site

Figure 2 Titwala Site

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3. Results and Discussion

The study compares the results of static load tests (SLT) and high-strain dynamic tests (HSDT) for determining pile capacities at two sites, Navapur and Titwala. The discussion includes calibration factors and site-specific factors influencing the results.

3.1 Capacity by Analytical Methods

3.1.1 Navapur

- **Method**: The Cole and Stroud method (IS 2911 Part 1) is used for calculating pile capacity in weathered rock.
- **Formula**: Calculations for skin friction and end bearing yield a safe pile capacity of 711 tons, with a design capacity of 300 tons.
- **Details**: Ultimate skin friction and end bearing are calculated for different strata, and the total safe pile capacity is considered to be 711 tons, with a design value of 300 tons.

3.1.2 Titwala

- **Method**: Analytical pile capacity is determined using IRC code provisions.
- **Formula**: The total pile capacity is derived by summing the end bearing and side socket shear contributions.
- **Details**: Based on empirical coefficients and strength parameters, the pile capacity is determined to be 650 tons with a factor of safety applied.

3.2 High Strain Dynamic Test Results

3.2.1 Navapur Site

- **Pile No.**: LP16-P6
- **Pile Capacity**: 507.9 tons
- **Skin Friction**: 201.8 tons
- **End Bearing**: 306.1 tons
- **Displacement**: 2.1 mm at 450 tons test load
- **Compressive Stress**: 6.0 N/mm²
- The CAPWAP analysis showed a total pile capacity of 507.9 tons at the time of testing with a pile top displacement of 2.1 mm.

3.2.2 Titwala Site

- **Pile No.**: RP-24/01
- **Pile Capacity**: 1410.8 tons
- **Skin Friction**: 878.7 tons
- **End Bearing**: 532 tons
- **Displacement**: 3.3 mm at 975 tons test load
- The CAPWAP results showed a significantly higher capacity of 1410.8 tons for the Titwala pile.

3.3 Static Load Test Results

3.3.1 Navapur Site

- **Pile No.**: LP16-P3
- **Design Load**: 300 tons, **Test Load**: 450 tons
- **Maximum Settlement**: 17.9 mm at 450 tons
- The static load test results are summarized with incremental loading, showing settlements up to 17.9 mm at the test load.

3.3.2 Titwala Site

- **Design Load**: 650 tons, **Test Load**: 1625 tons
- **Maximum Settlement**: 9.1 mm at 1625 tons
- The load-settlement curve indicates a settlement of 9.1 mm at the maximum test load, with detailed load increments provided.

3.4 Comparison of Dynamic and Static Pile Load Tests

3.4.1 Navapur Site Comparison

- **Pile No:** LP16-P3
- The comparison of load-settlement curves from both static and dynamic tests shows that the dynamic test results are in good agreement with the static test up to the design load but diverge as the load increases.
- **Dynamic to Static Capacity Ratio**: The ratio of dynamic to static test capacity is 1.12, indicating close agreement. Figure 3 shows Load Settlement Response

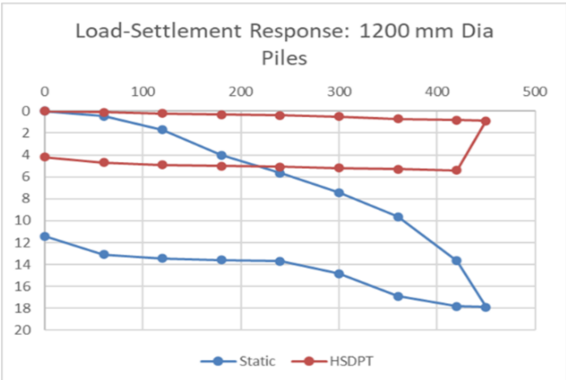

Figure 3 Load Settlement Response

3.4.2 Titwala Site Comparison

- **Pile No.**: RP-24/01

- **Dynamic Test**: The load-settlement curve from dynamic tests matches the static test up to approximately 60% of the design capacity, beyond which the curves begin to diverge.
- **Dynamic to Static Capacity Ratio**: The ratio of dynamic to static test capacity is 2.0, with the dynamic test showing significantly higher capacity than the static test. Figure 4 shows Load Settlement Response [11-15]

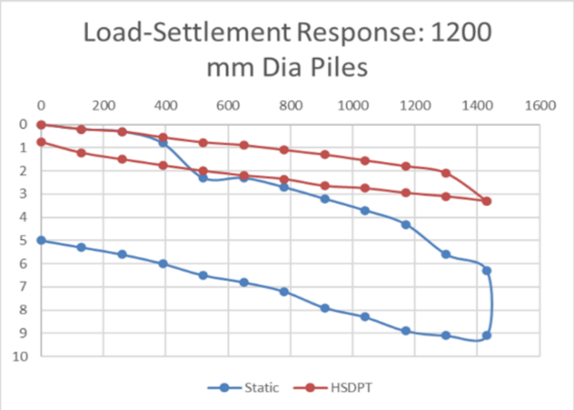

Figure 4 Load Settlement Response

3.4.3 Discussion

- **Navapur Site**: The settlement curves from both tests align well up to 150% of the working load, confirming the validity of the dynamic test results. However, as the load increases, the static test results diverge, indicating the time-dependent nature of the settlement process in rock.
- **Titwala Site**: The dynamic load test showed better alignment with the static test at lower load levels, with significant divergence beyond 60% of the design load.

Conclusion

Standardization of dynamic load test is site specific, but consists of several parameters to define the consistency with static load test. The comparison of static and dynamic load tests discussed in the report explains specific criteria by which the dynamic load test can be standardized or calibrated. Dynamic load test when conducted majority time only gives elastic settlement of pile and soil. However, if soil has to undergo plastic settlement, dynamic test will not provide substantially satisfying result. Compressive stresses will be quite higher than tensile stresses in end bearing piles. However, if large quakes (settlement occurs) a reduced tensile stress will be observed. Load-settlement curves of HSDT and SLT tests must be matched atleast upto 150% to satisfactorily calibrate HSDT. A novel list of criteria is developed to identify the accuracy of HSDT.

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