Static Axial Compression Load Test for Pile Foundations

Design & Technology Series #18

Pile Foundations

Piles are a type of deep foundation. Common types used in Alberta Infrastructure projects include:

- Cast-in-place (CIP) concrete straight shaft piles
- CIP belled piles
- Continuous flight auger (CFA) piles

Design parameters for pile foundations are typically derived from semi-empirical methods (that rely on a combination of theoretical principles and field data) used in conventional geotechnical investigations.

Static Pile Load Tests

A static pile load test is a field test performed on a full-scale foundation to verify and refine design parameters obtained through geotechnical investigations. These tests include:

- Axial compression tests (downward load applied)
- Axial uplift (pullout) tests (upward load applied)
- Static lateral load tests (horizontal load applied)

Each test measures the pile's responses to the applied load, providing valuable data for foundation design.

Static Axial Compression Pile Load Test

Standard ASTM D1143 outlines seven separate procedures for performing this test with *Procedure A – Quick Test* most used. This test has three main variants:

- Traditional top-down test (without instrumentation along pile length)
- Instrumented top-down test
- Bi-Direction test (to ASTM D8169)

Verifying and refining design parameters through direct pile performance measurements may allow for an increase in the pile Geotechnical Resistance Factor (GRF), per the Canadian Foundation Engineering Manual (CFEM). This results in a 50% increase in pile resistance in compression, and 33% increase in tension, leading to cost-effective pile foundation designs.

The test provides insight into:

- The pile load-settlement relationship
- The geotechnical load capacity of the pile-soil system
- The load distribution along the pile depth
- Structural integrity and pile performance confirmation

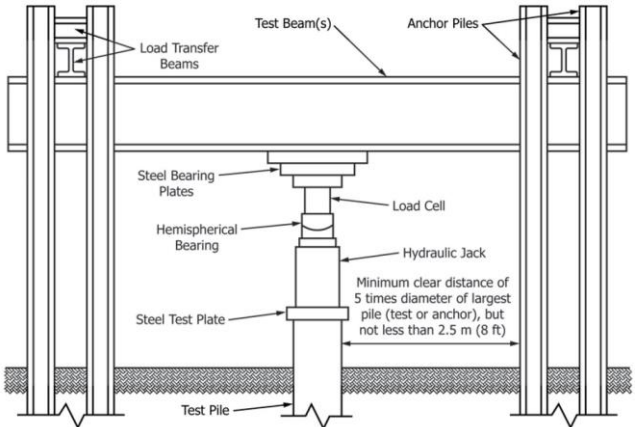

Fig. 1 – Schematic of static axial compression pile load test (Reprinted with permission from ASTM. Reference 1.)

Why do it?

The test confirms whether the pile design parameters provided by semi-empirical methods are reasonable. Revised pile design parameters may result in cost savings.

When Should it be Conducted?

A pile load test may be performed:

- During the Design Phase, typically arranged by the Owner in Design-Bid-Build (DBB) and Construction Management (CM) projects.
- During construction, arranged for by the Contractor in DBB, CM, Design-Build (DB), and Public-Private Partnership (P3) projects.

Factors influencing test timing include pile type, size, quantity, and initial geotechnical design parameters.

What does it Cost?

- Traditional top-down test: approx. $100,000
- Instrumented top-down test: approx. $150,000

A traditional top-down test allows for increased pile design parameters by use of a higher GRF in design, whereas an instrumented top-down test provides both increased (due to higher GRF) and refined parameters, resulting in optimized pile skin friction and end bearing resistance. Though more expensive, the instrumented test often leads to cost-effective designs that offset the higher initial investment.

Time Required for a Pile Load Test

A pile load test may typically take up to two (2) months and includes design of the test, installation of the test pile, curing of the CIP pile, setup of loading frame and reaction system, load testing of the pile, analysis of test results, and preparation of the report including revised geotechnical pile design parameters.

When to Consider a Pile Load Test?

A pile load test is beneficial in the following situations:

- Sites have poor soil conditions, and initial foundation cost estimates exceed budgeted amounts.
- Projects have extensive pile production (>3,000 meters total length), where refined parameters could lead to cost savings greater than the cost of the test.

It is not recommended for smaller projects with limited number and total length of piles.

What is the Outcome?

Depending on the type of static pile load test performed:

- A traditional top-down test: increased design parameters (due to higher GRF).
- Instrumented top-down test: both increased and refined design parameter, leading to more efficient and cost-effective foundations.

Business Case

A business case helps justify the expense of a pile load test. This involves:

- Preliminary design of the pile foundations using (1) initial design parameters per the geotechnical report, and (2) assumed higher design parameters due to the increased GRF permitted by the CFEM.
- Estimation of piles, pile caps, and related material quantities for each case.
- Use of historical cost data (minimum, maximum, average) to assess potential savings.

Refer to Figure 2 below for a summary snapshot of a business case.

		Total # of Piles Pile Set-up	Pile Concrete Class - Pile m^3	Pile Cap Concrete Class - C m^3	Pile Install Length m
Case 1	No Pile Load Test	195	1678	28	2790
Case 2	With Pile Load Test	175	997	1	2852
	Estimated Savings		**Cost of Test**		**Net Savings**
Minimum =	$ 324,796		$ 115,000		$ 209,796
Maximum =	$ 609,837		$ 115,000		$ 494,837
Average =	$ 428,182		$ 115,000		$ 313,182

Fig. 2 – Business case for pile load test

Case Study

The Stony Plain Central High School project was a DBB project. Initial foundation design parameters determined from conventional geotechnical investigation resulted in a foundation design that was significantly over budget. An instrumented top-down static axial compression pile load test was performed in the design phase on a production CFA pile of 0.6 m shaft diameter and 26 m length (see Figure 3).

Results showed significant improvements:

- Skin friction increased: 80% to 285%
- End bearing increased: 275% to 465%

These refined parameters resulted in cost-effective foundation design, saving approximately $2 million.

Fig. 3 - Static axial compression pile load test set-up at the Stony Plain Central High School.

Conclusion

A static axial compression pile load test can be invaluable for projects with challenging geotechnical conditions, offering cost savings and improved design reliability.

Technical Services can support the AI project management team by reviewing the geotechnical conditions and preparing a business case to determine the potential benefits of a pile load test.

References

1. ASTM. 2020. Standard Test Methods for Deep Foundation Elements Under Static Axial Compressive Load, ASTM D1143/D1143M-20. ASTM International, West Conshohocken, PA. www.astm.org.
2. The Canadian Geotechnical Society. 2023. Canadian Foundation Engineering Manual, 5th Edition. www.cgs.ca.

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