BELPACIFIC
SHORING & FOUNDATIONS

CYCLIC QUASI-STATIC LOAD TESTS ON MICROPILES

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West Branch Combined Sewer Overflow (CSO) Facility

- **Wet & Dry Shotcrete**
- **Structural Shotcrete**
- **Seismic Anchors**
- **Micropiles / Minipiles**
- **Cementitious Grouting**
- **Chemical Grouting**

ESTABLISHED IN 1954
100% CANADIAN

INTRODUCTION

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- **Recently, 212 GEWI-Piles were installed in New Westminster, BC, to support a 20,000 m^3 partially submerged buried storage tank subject to cyclic loading.**

- **Following, two pre-production full scale verification cyclic load tests are reviewed**

- **"Cyclic" loading, as described in this paper, refers to quasi-static alternating compression and tensile loads, with no dynamic component. Details of this type of pile response are provided.**

- **The GEWI-Piles were installed by a local specialty foundation contractor, Southwest Contracting Ltd.**

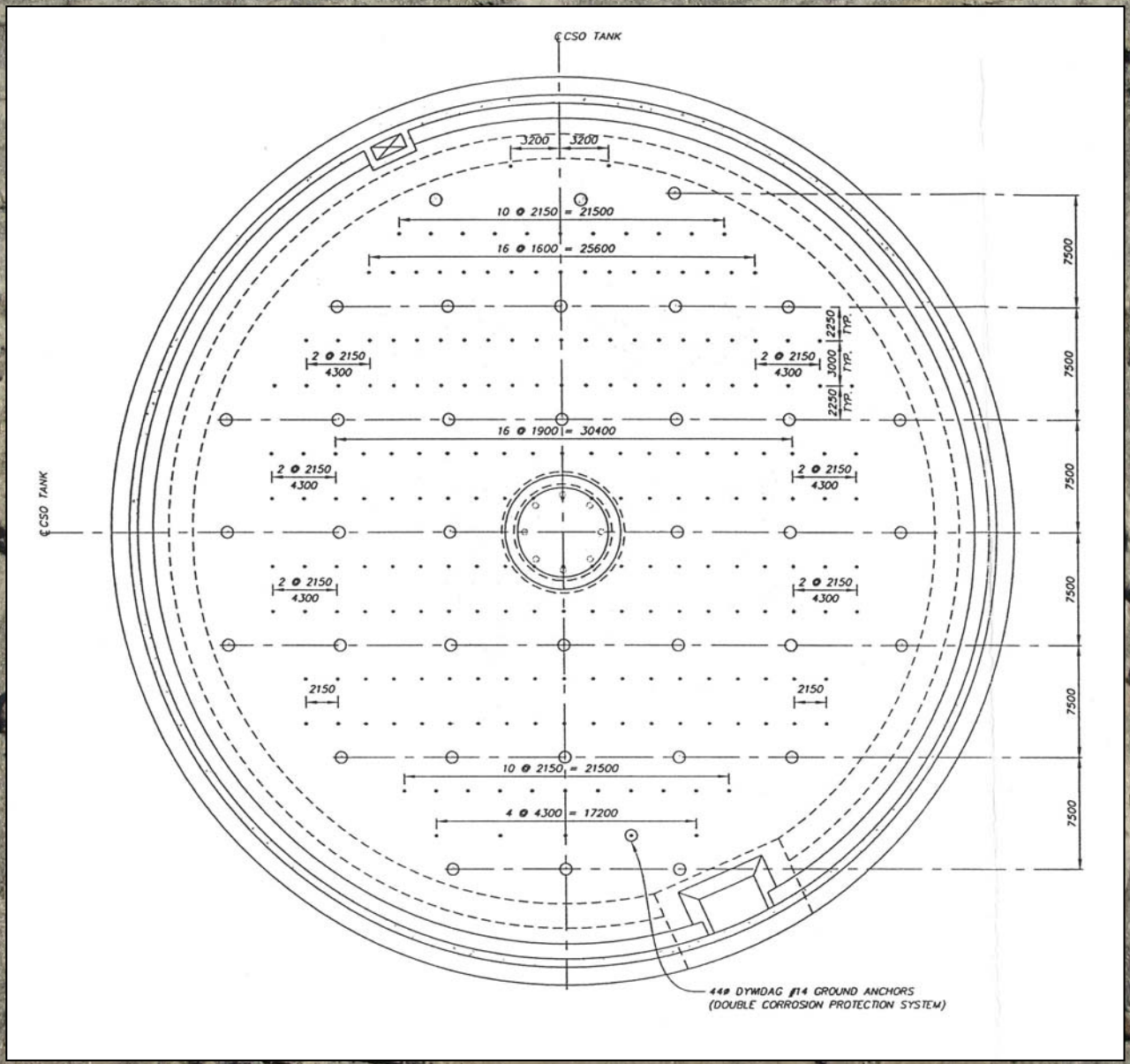

Figure 2a. GEWI-Pile Layout Plan

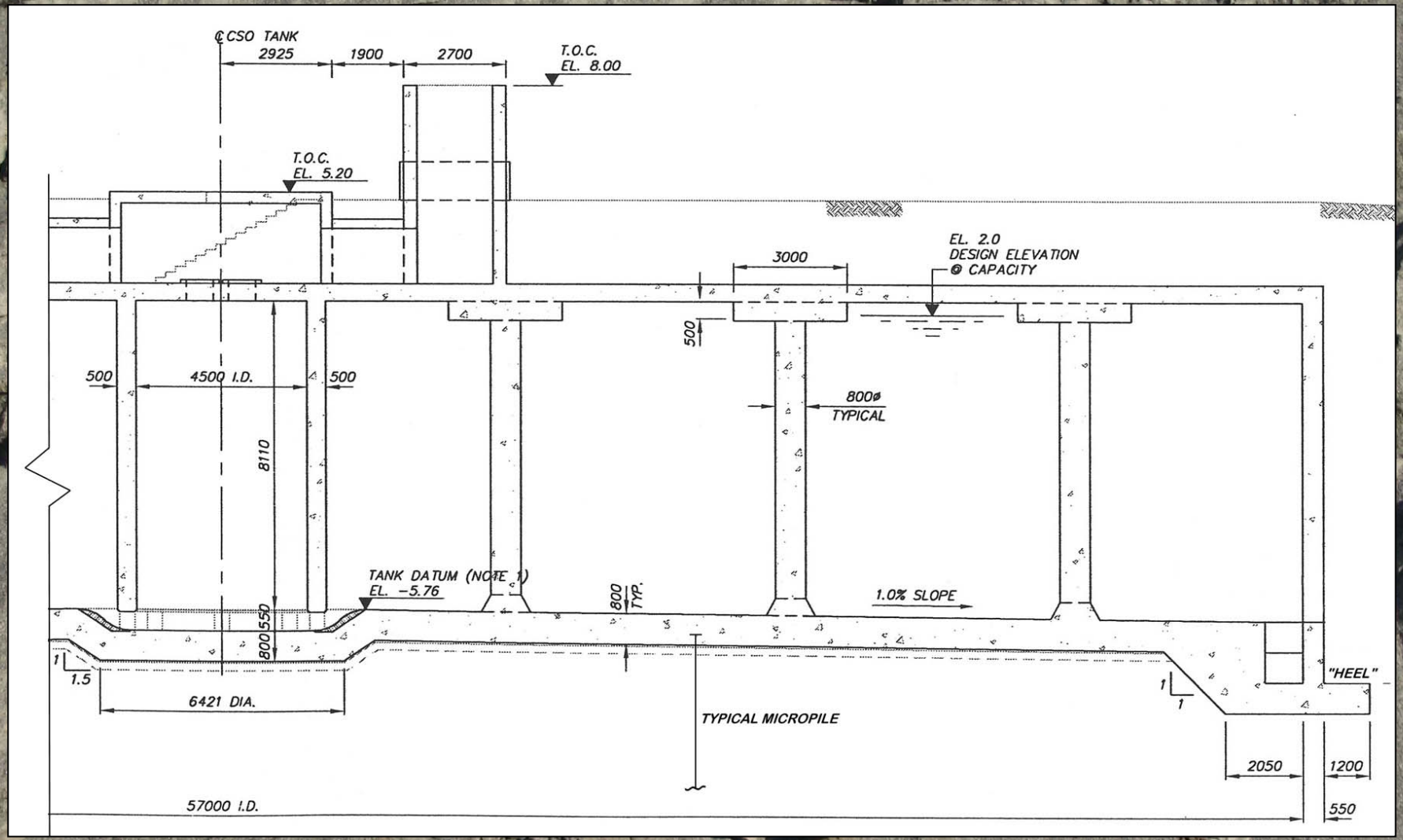

Figure 2b. Tank Section

DESIGN

- **The tank structure required foundations to resist uplift forces due to buoyancy caused by groundwater table rise and compression forces caused by filling of the tank.**

Cyclic loading per GEWI-Pile:

- **Max. factored tension load = 380 kN**
- **Max. working tension load = 200 kN**
- **Max. working compression load (including 12 mm creep effect) = 600 kN**
- **Max. working compression load (no creep effect) = 140 kN**

"Heel"

- **The Engineers designed the "heel" to resist uplift forces due to buoyancy along the perimeter of the tank so no cyclic effects.**
- **Long term creep in the soils near the centre of the tank was anticipated to be, as much as, 12 mm.**

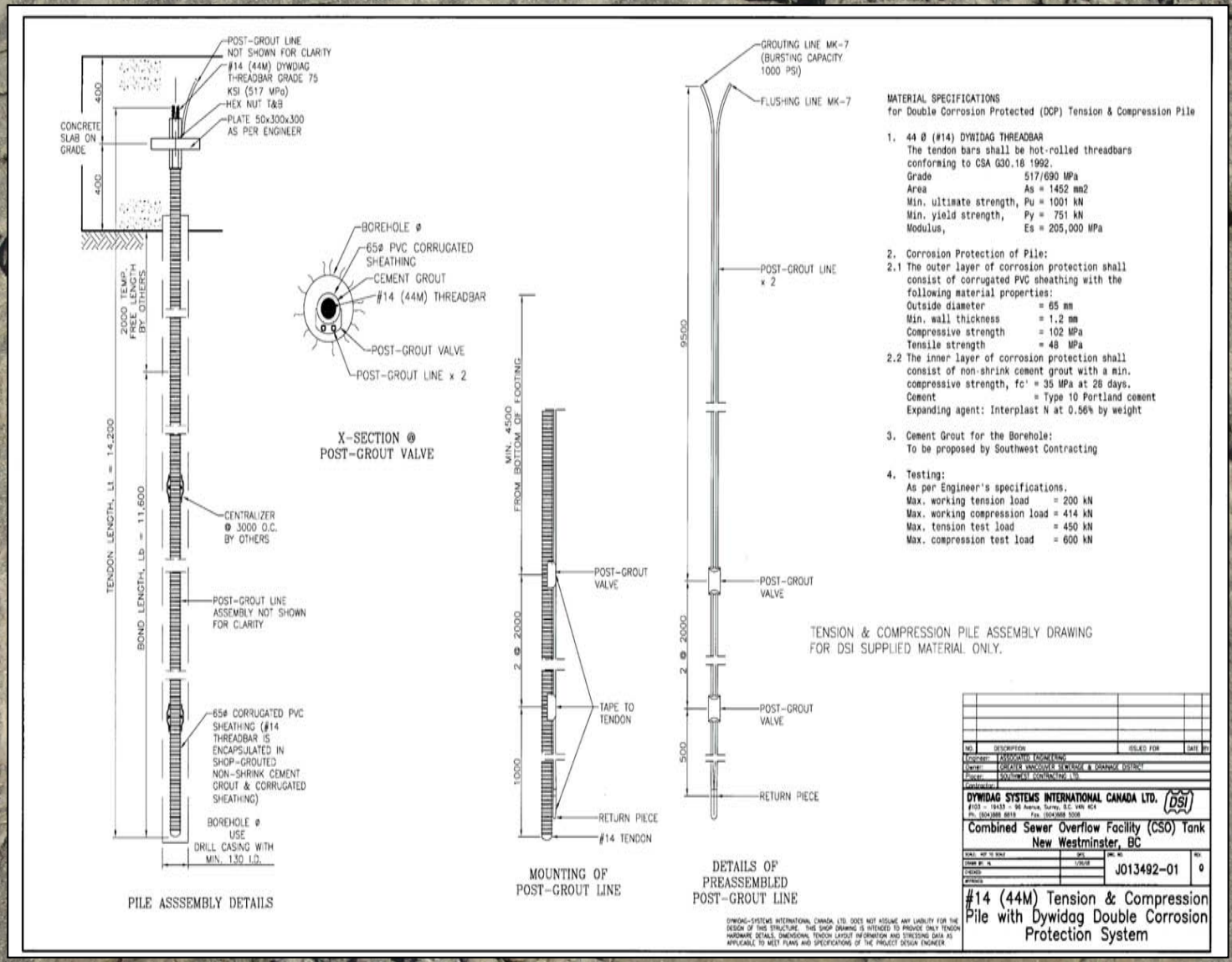

Figure 3. Micropile Shop Drawing

GENERALIZED SOIL PROFILE

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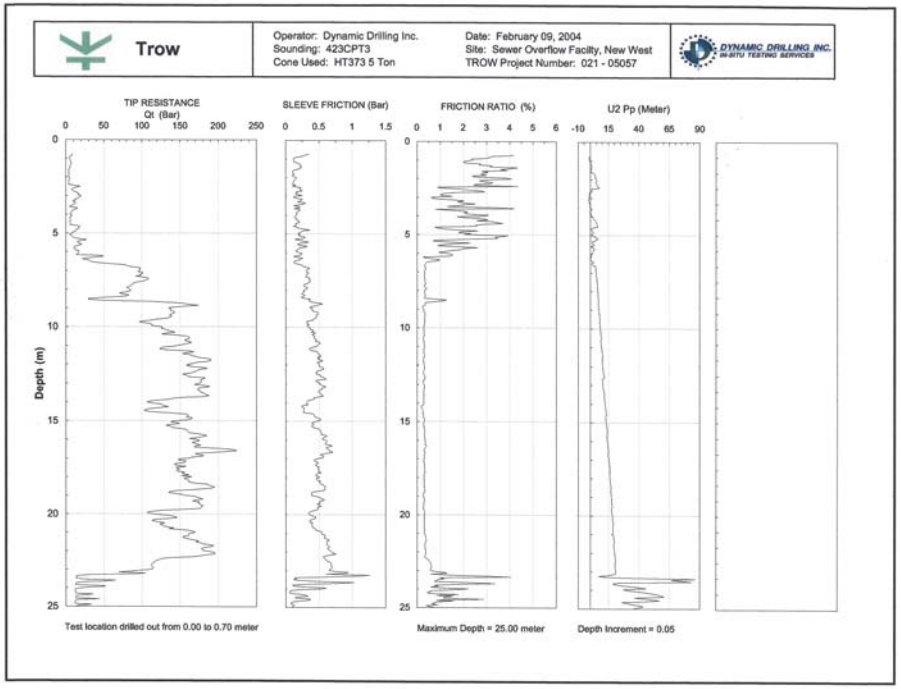

Figure 1. CPT04-3 Log

Table 1. Generalized Soil Profile

Soil Unit	*Thickness*	*Description*
Unit a1	*0 to 1.5 m*	*silty sand, sandy silt – FILL*
Unit a2	*4 to 5 m*	*soft to firm sandy SILT - FILL?*
Unit b1	*2 to 2.5 m*	*loose to medium dense sand*
Unit b2	*12 to 15 m*	*medium dense to dense SAND*
Unit c	*> 2 m*	*interbedded SILT or CLAY and SAND*

(Uthayakumar and Macleod 2004)

Drill string advancement

Due to the sandy soils and high groundwater table, a cased direct circulation drill system was specified with the objective to minimize disturbance at the soil-grout interface and ground loss.

- **Disposed cuttings shall not exceed 110% of the theoretical drill hole volume.**
- **Casing shall not have an O.D. < 133 mm**
- **The use of air drilling is not permitted**
- **Drilling using augers is not permitted**

DRILLING

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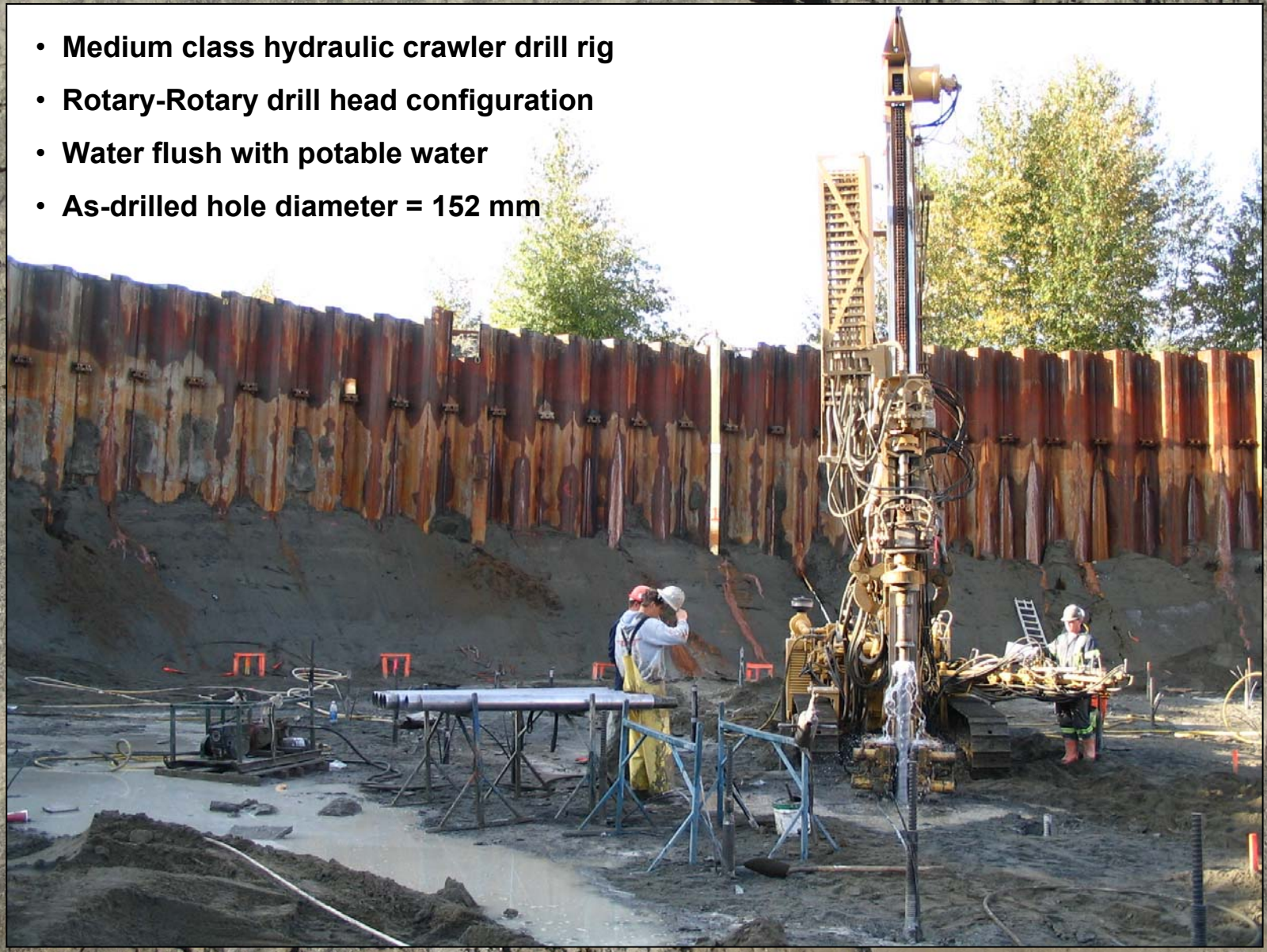
- **Drilling was performed inside a full cut-off wall, extending to a silt/clay layer at -22 m elevation located at the crest of a sloped excavation.**
- **The drill hole was advanced from -6.8 m elevation during on-going dewatering activities.**
- **Diesel/hydraulic rig utilizing double head duplex overburden drilling method advanced a 133 Ø temporary casing.**

- **Medium class hydraulic crawler drill rig**
- **Rotary-Rotary drill head configuration**
- **Water flush with potable water**
- **As-drilled hole diameter = 152 mm**



INSTALLATION

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- **Full length GEWI-Piles were installed using a zoom boom type machine**
- **No couplers used since GEWI-Piles ordered full-length from the factory.**
- **GEWI-Piles installed immediately after drilling then tremie grouted**

- **Microsil Anchor Grout**

  A high early strength, thixotropic, cement grout

- **Water : Cement Ratio < 0.35 was specified**

- **Primary grouting to 517 kPa minimum**

- **Pressure grouting thru the top of the casing at intervals as the casing was being pulled.**

- **One stage of post-grouting to 5,170 kPa minimum was performed prior to any testing.**

- **A subsequent test program, on-site, showed post-grouting had little influence on test results.**

CYCLIC LOAD TEST ARRANGEMENT

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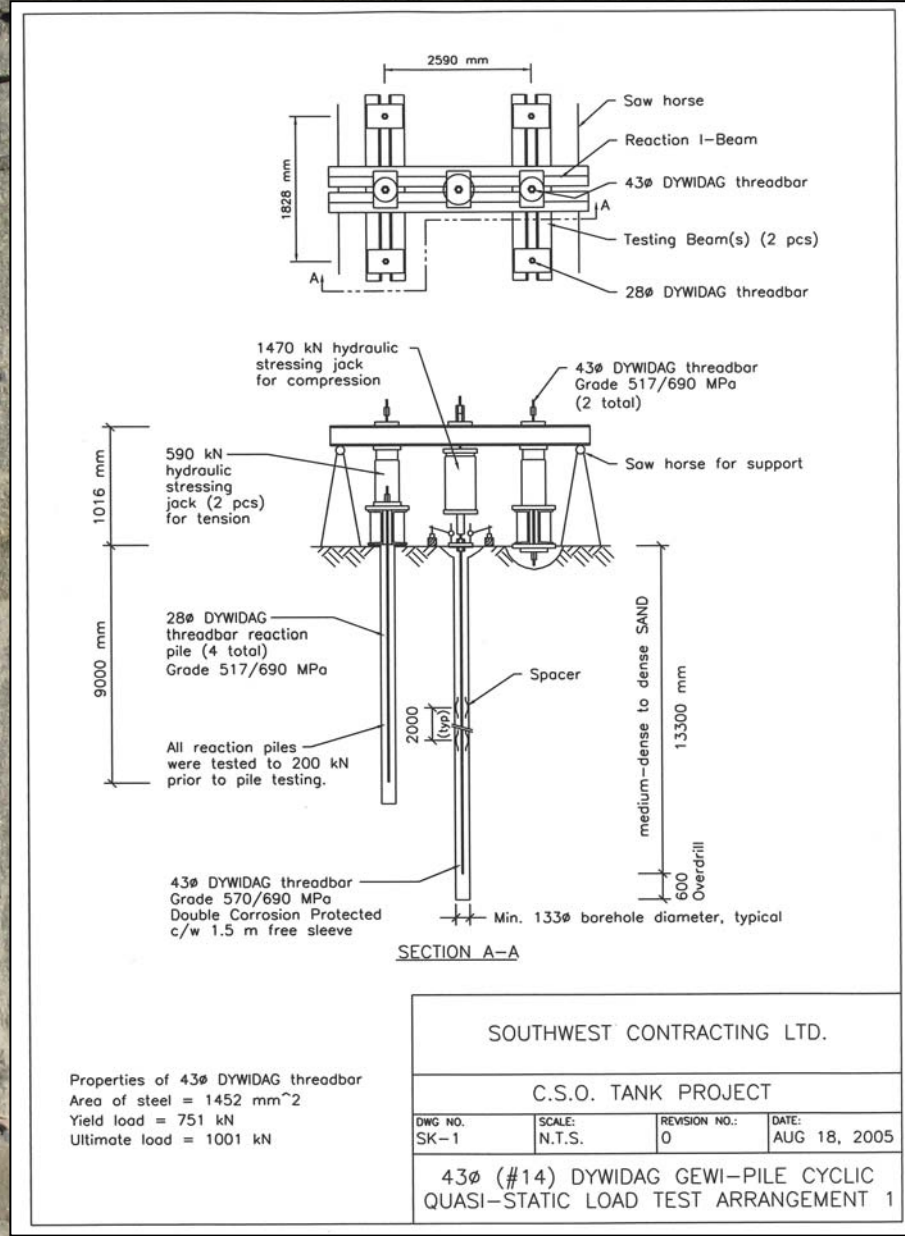
- **Reaction I-Beam repeatedly tilted during tension loading and translated laterally due to slight off-centered loading.**
- **Further alterations to the initial framework were ruled out. Consequently the jacking arrangement was modified.**
- **During each load reversal the top nuts of each reaction pile and test pile were loosened and tightened, respectively, in order to change loading direction.**



Test setup 1

CYCLIC LOAD TEST ARRANGEMENT

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Test setup 1

CYCLIC LOAD TEST ARRANGEMENT

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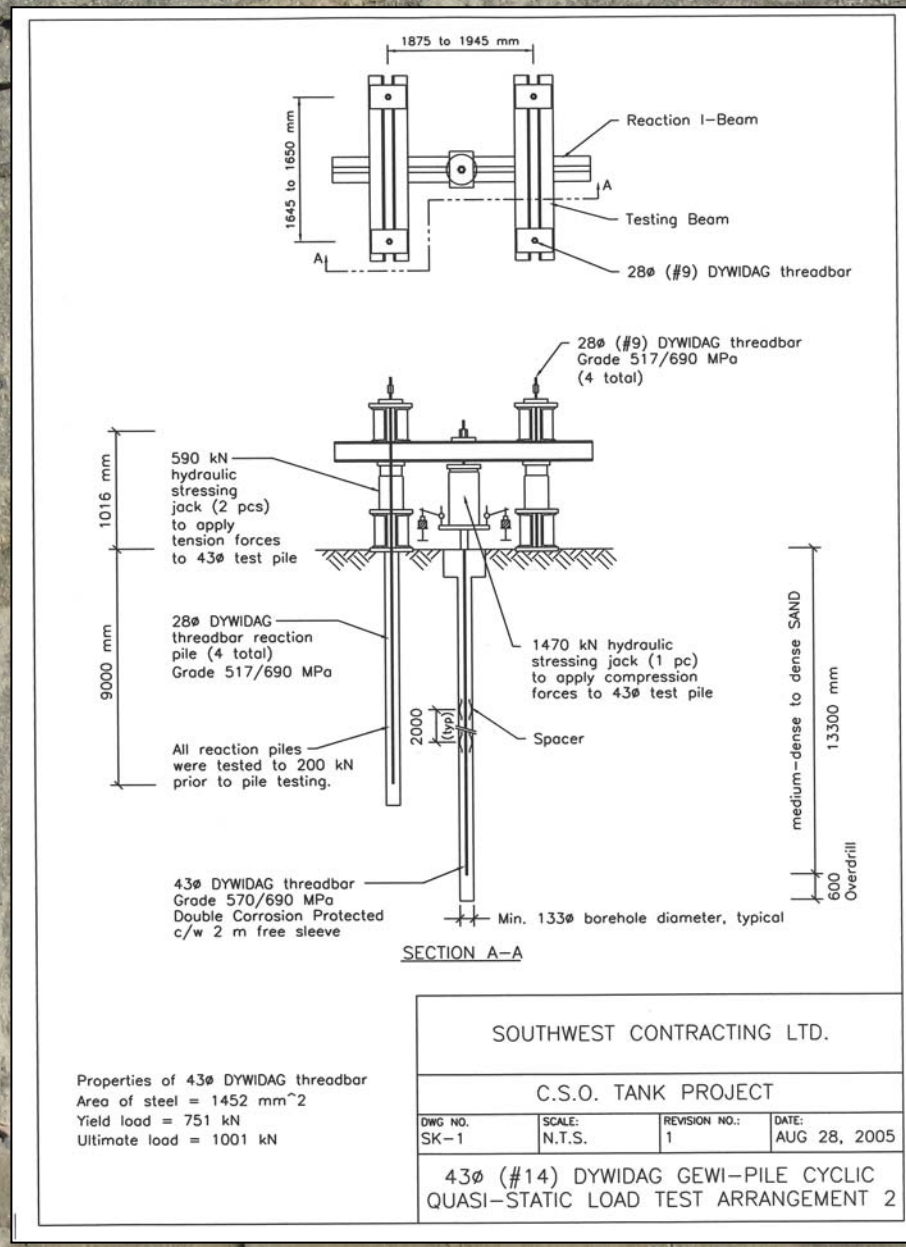
- **Added test beams overtop the original test setup**
- **Test setup did not meet ASTM standards with respect to spacing of the reaction piles and test pile. No standard was specified during tendering.**
- **Recommend future test setups meet ASTM standard D3689 for tension tests and ASTM D1143-81 for compression tests.**



Test setup 2

CYCLIC LOAD TEST ARRANGEMENT

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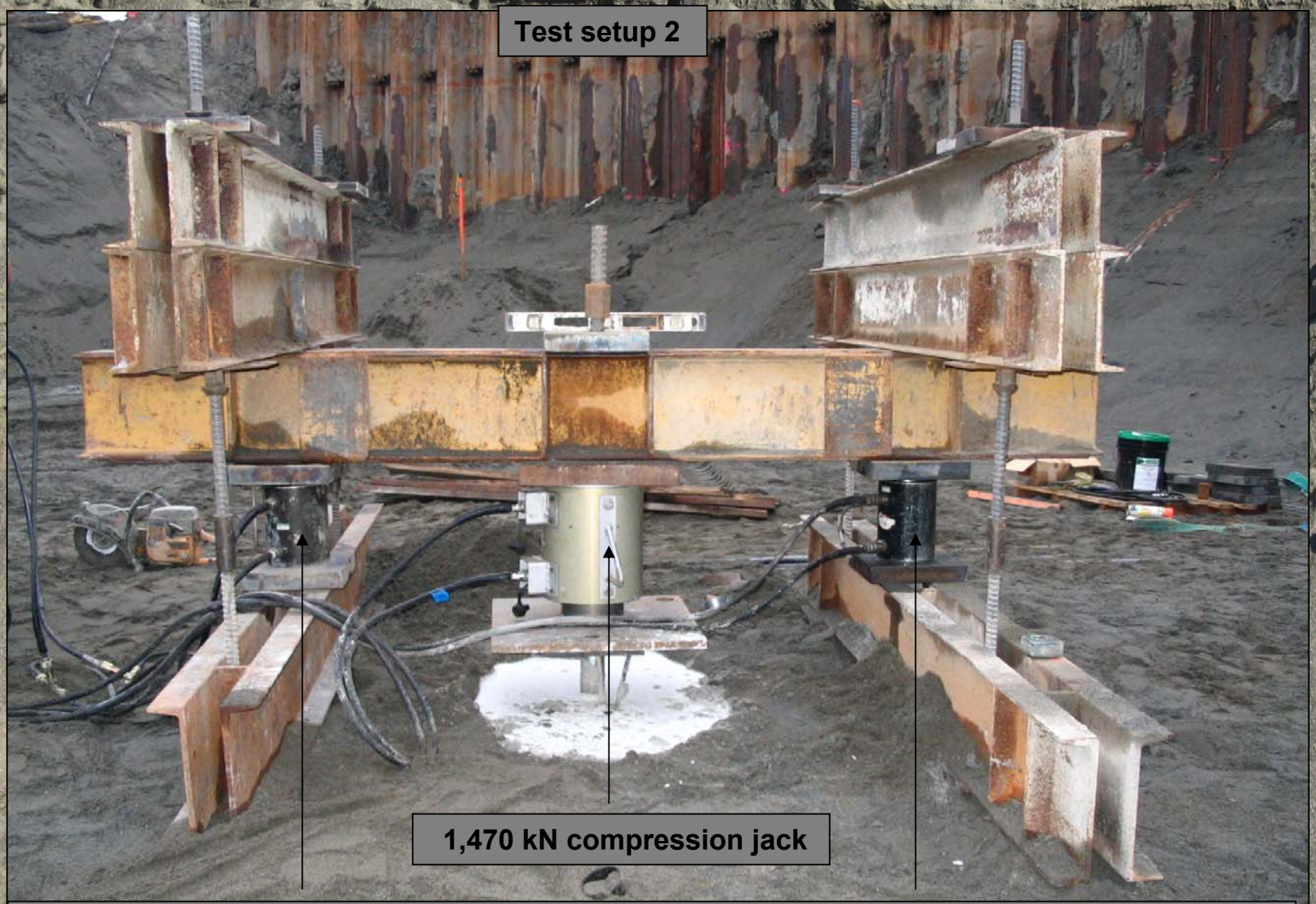

Two 590 kN tension jacks synchronized by hydraulically connecting each to the same hydraulic power pack.

CYCLIC PERFORMANCE TEST PROCEDURE

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Four performance verification tests in total were performed on each test GEWI-Pile in the following sequence:

1. **A 250 kN tension test in accordance with PTI-1996.**
2. **A 175 kN compression test in accordance with PTI-1996**
3. **A cyclic test starting from a 250 kN tension alignment load to 600 kN compression load by increasing compression loading 75 kN each successive cycle.**
4. **A 450 kN tension test in accordance with PTI-1996**

PERFORMANCE & EXTENDED CREEP TEST RESULTS

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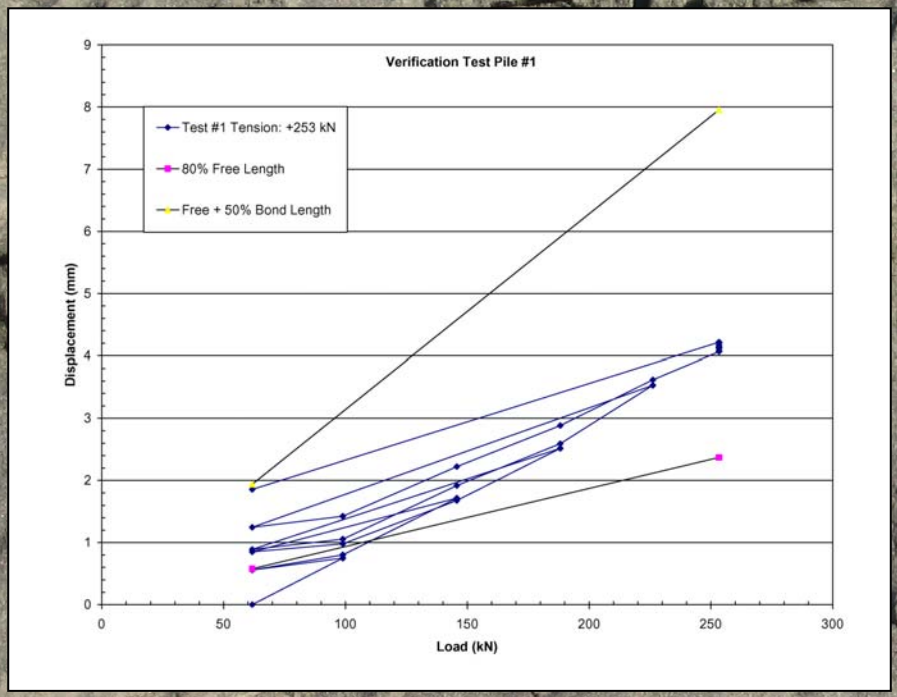

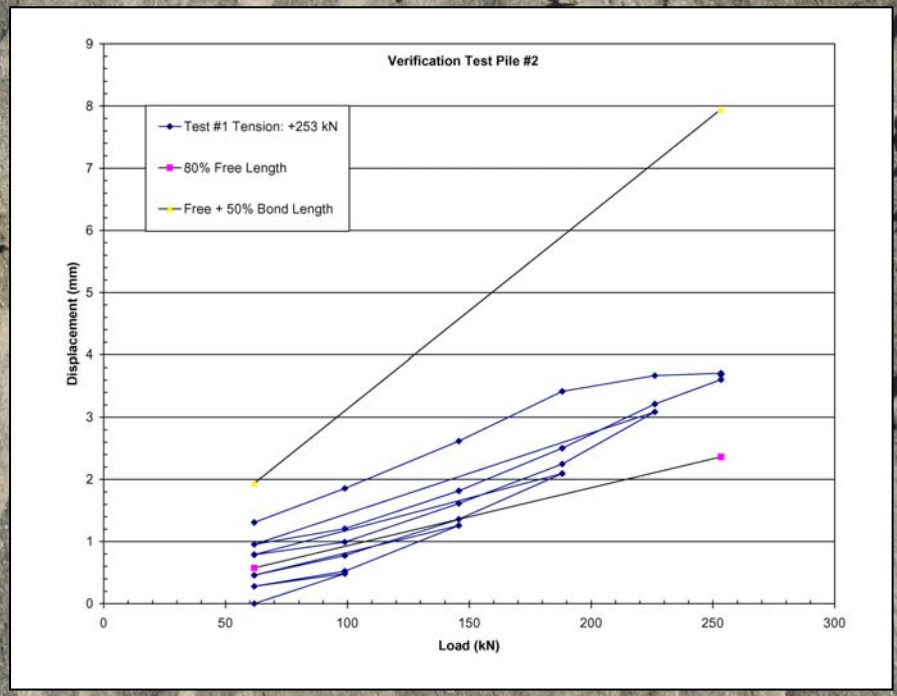

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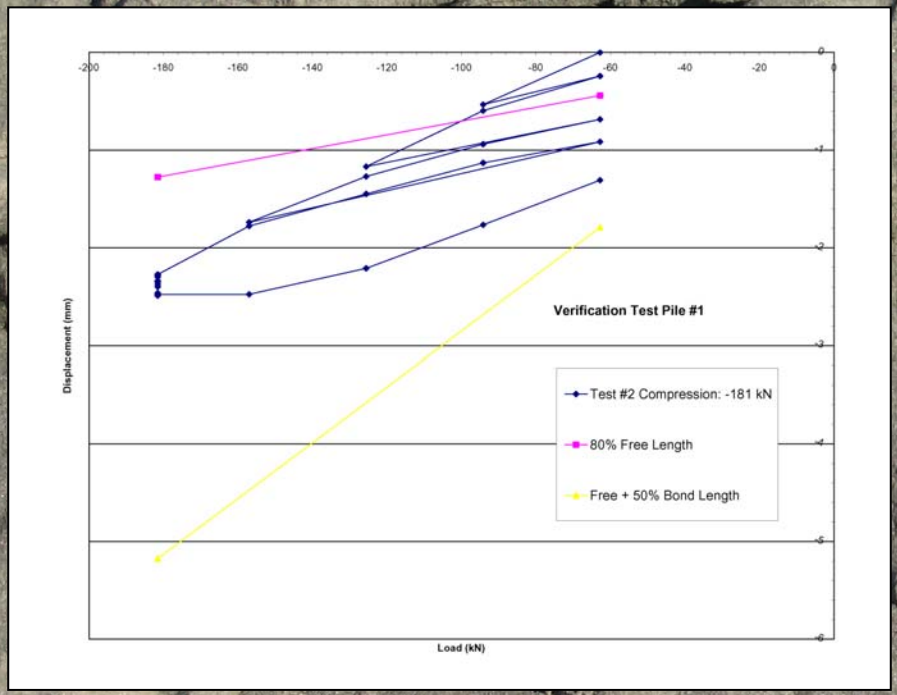

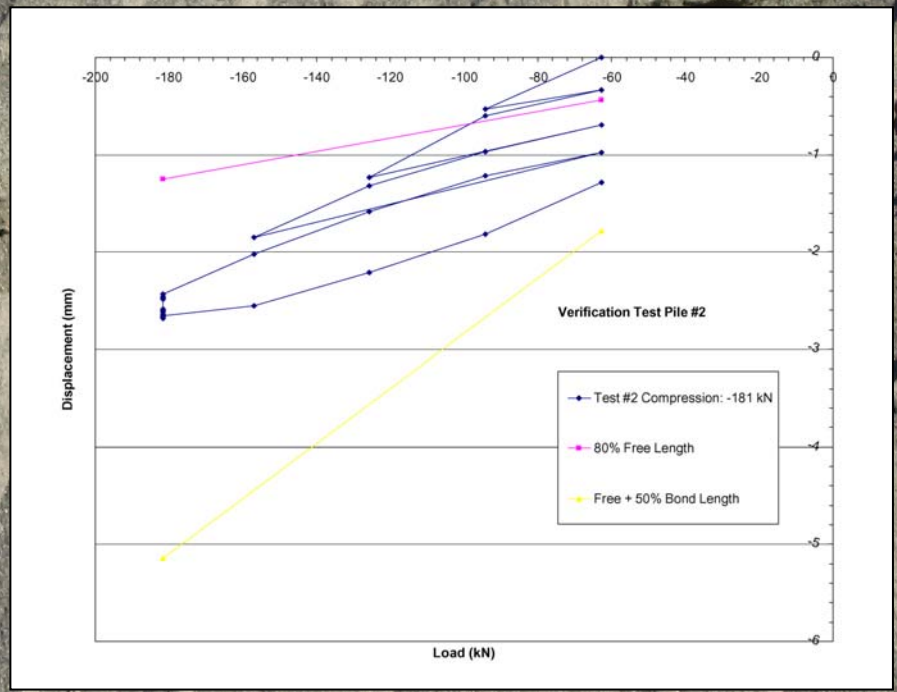

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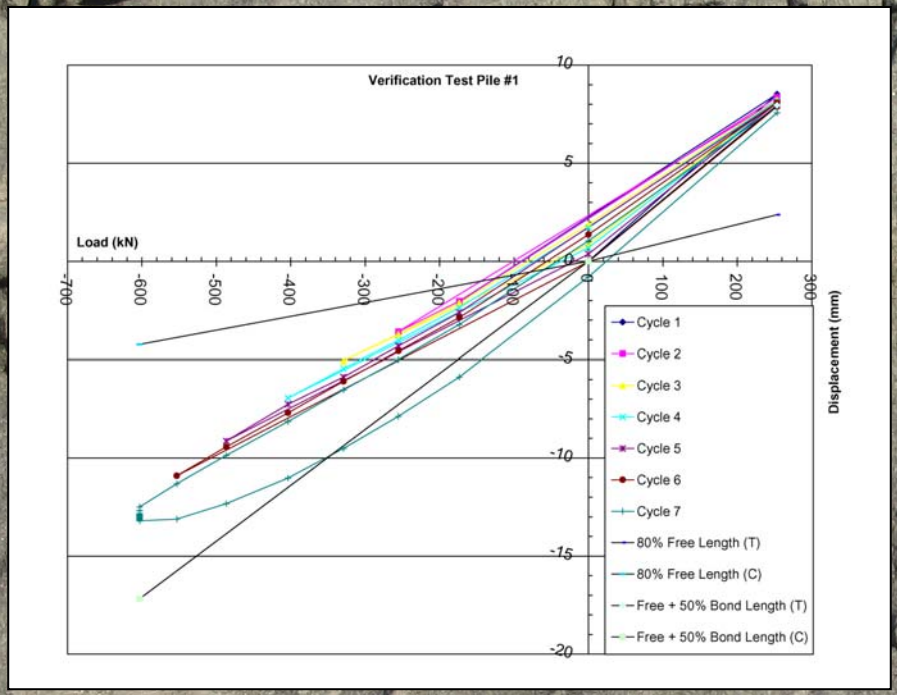

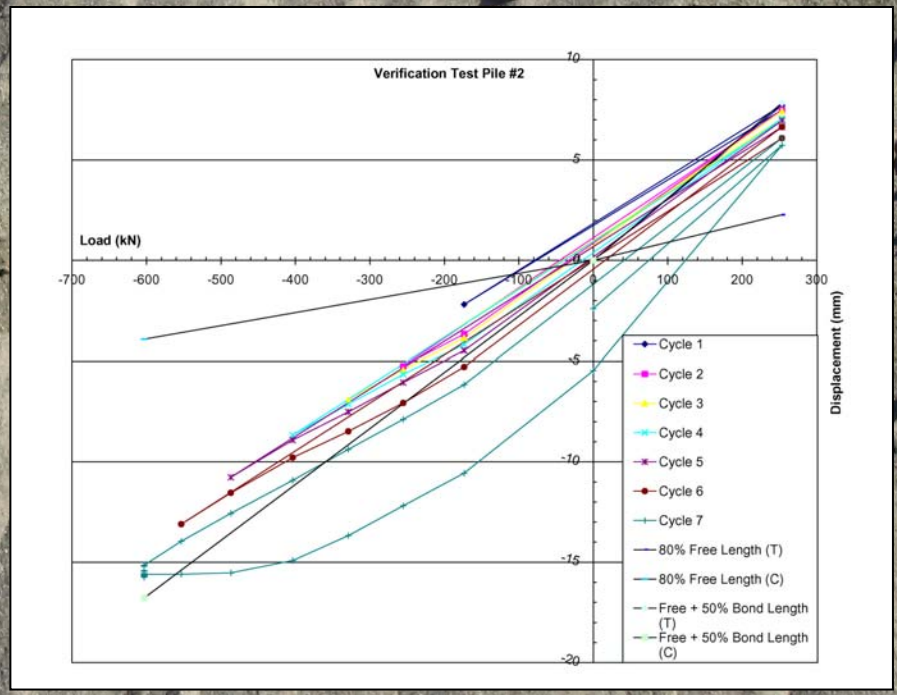

The shape of cycle 7 shows similar unloading stress histories and shows departure from a linear, reproducible cyclic loading pattern.

PERFORMANCE & EXTENDED CREEP TEST RESULTS

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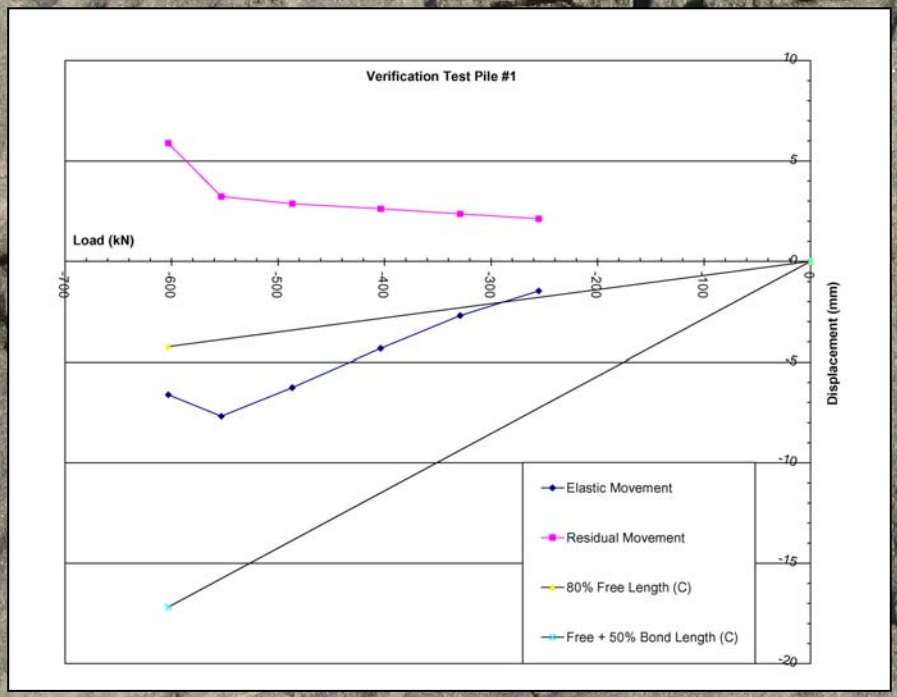

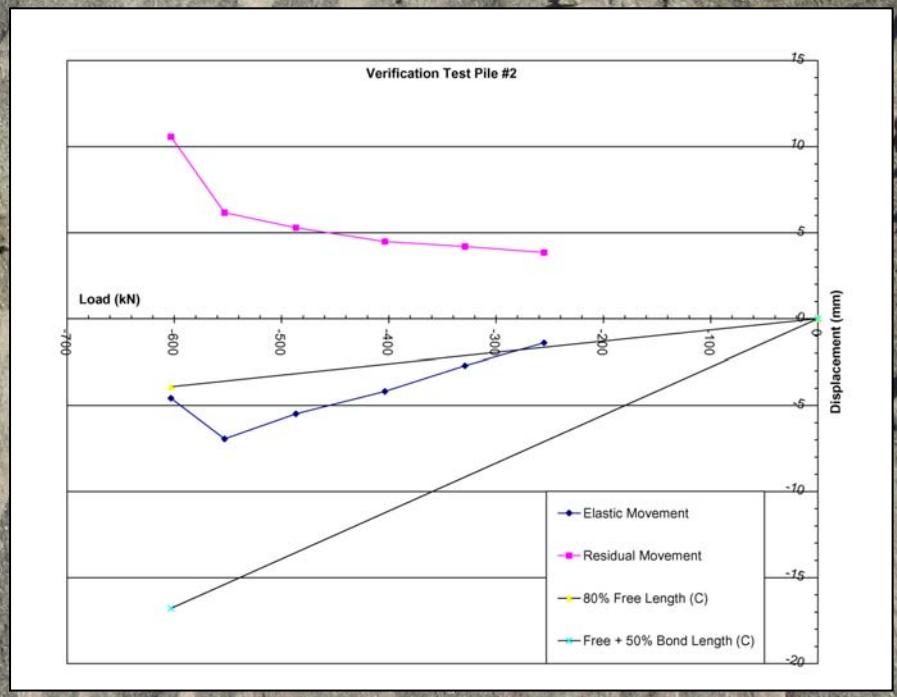

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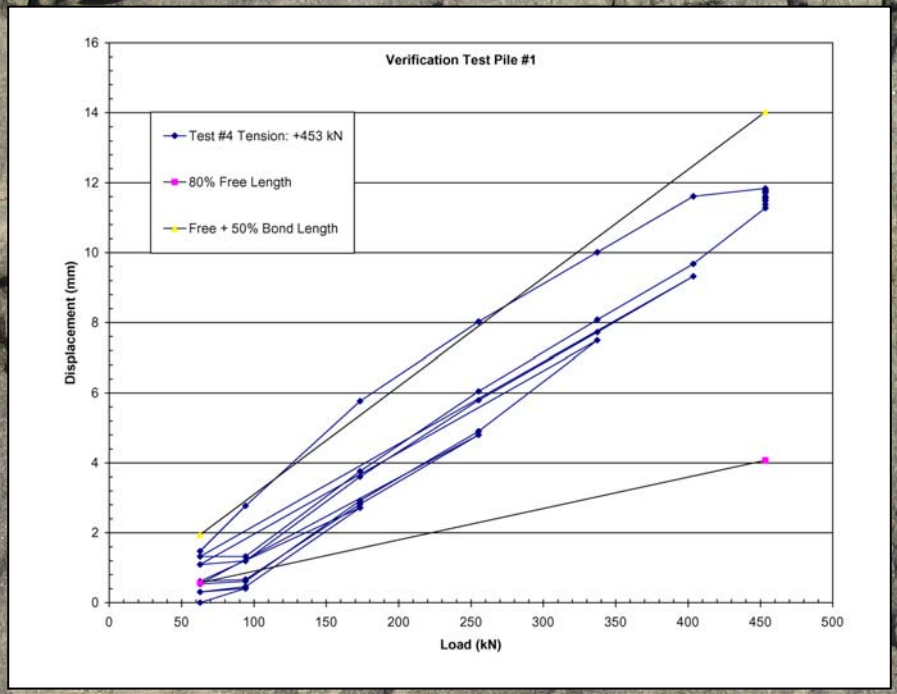

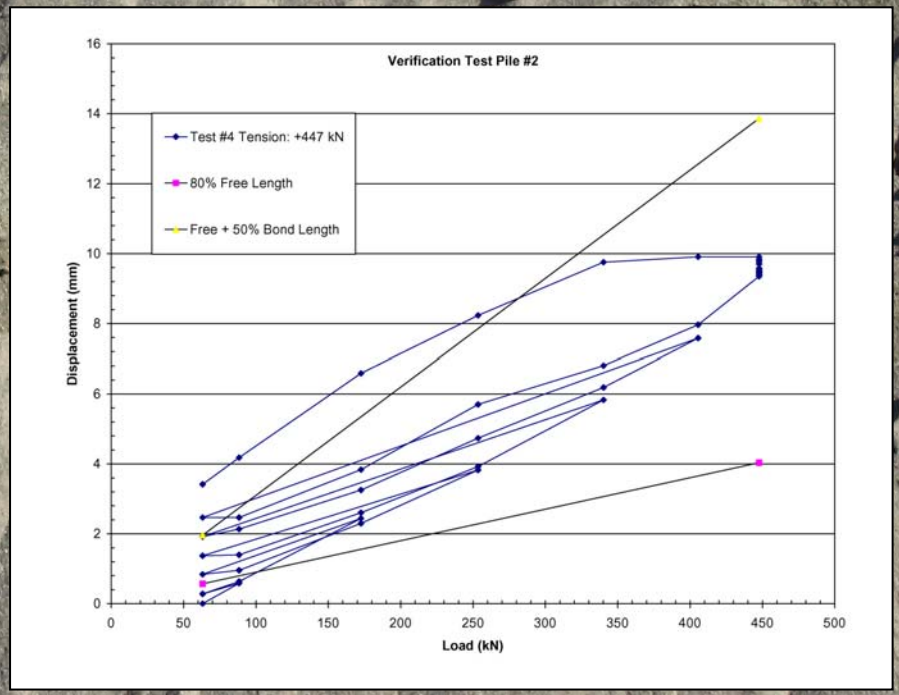

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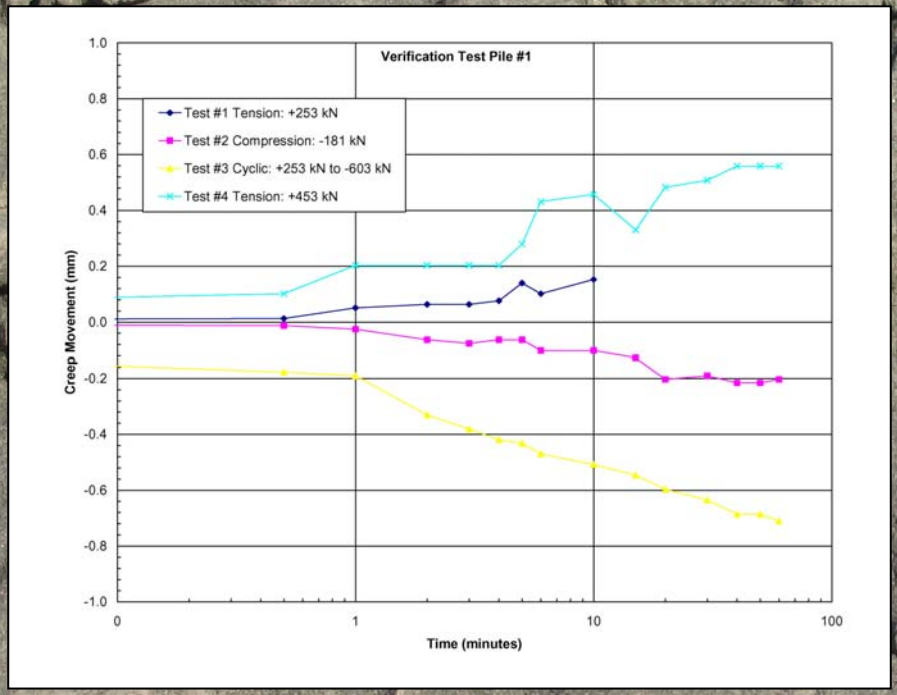

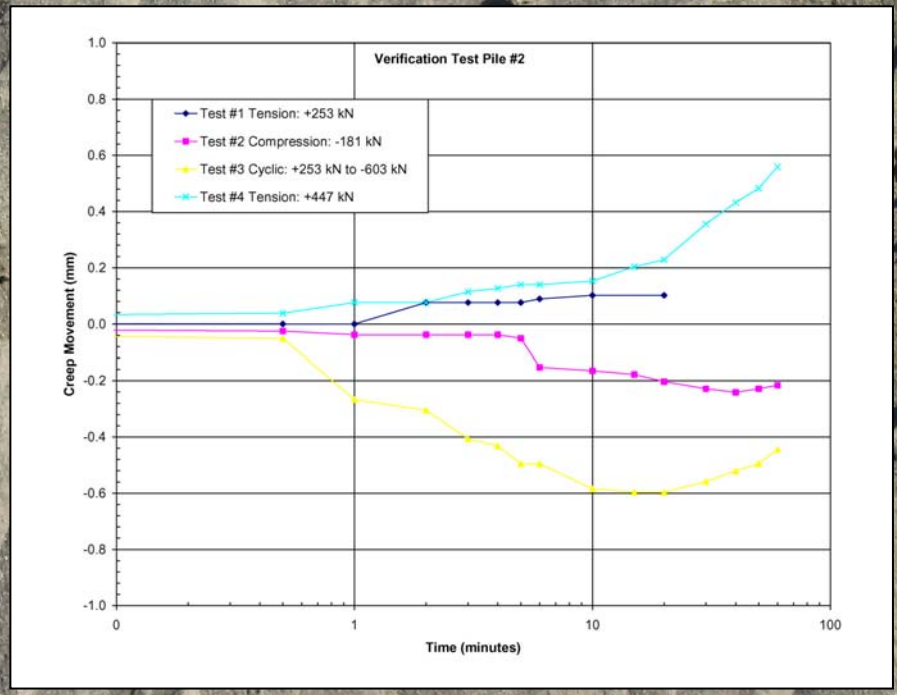

Log-linear increasing displacement to – 0.71 mm during the final two log cycle

Non-log-linear displacement to – 0.61 mm during the final two log cycle

Based on the test results of the two verification cyclic load tests, the installed GEWI-Piles were considered adequate to sustain their design loads

Recommendations

1. **Use of strain gauges in future tests to determine shape of the load distribution along the fixed anchor and its behavior under cyclic loading**
2. **Repeated cyclic loading at design load to determine how the number of load cycles affects load holding capacity.**