AnchorTest developed during construction of 3600 anchors for the excavation support of the Kuntsevo multi-use complex in Moscow, Russia.

Anchor Testing Using Innovative Software on a Tablet

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Introduction

One of the features that distinguish ground anchors from other forms geotechnical engineering technology (e.g. piles, soil nails and rock bolts) is that there is a mandatory requirement to test every anchor before it is judged suitable for service. This requirement stems from the fact that the performance of anchors is highly sensitive to the quality of construction and this demands confirmation that every installation has been executed to the required standards.

Regardless of where in the world the anchors are installed the basic philosophy in testing remains the same; the anchor is subjected to tensile loading, above that which it is required to deliver in service, and then its behavior is assessed by monitoring either displacement or load loss and these are compared to established acceptance criteria. Depending on the amount of anchors involved this process can be time consuming, often involving engineers recording information in the field and then having to carry out calculations on site, or waiting until they get back to the office to analyze the data retrieved. This can lead to costly delays in the decision making process before anchors can be signed-off. It is often the case on projects that the contractor will acquire the data from the anchors and present the results of his analysis to the Engineer who will check these before authorizing further anchor installations or anchor lock-off, to allow excavation to next level of anchoring or to final level for foundation construction.

The use of laptops with spreadsheets has been used historically on some sites as a means of processing data but this is judged to be cumbersome and not well suited to the rigors of a construction site environment. An alternative tool, with full data analysis and data management capabilities, whilst satisfying the requirements for portability, was developed in a bid to create greater efficiency in the anchor testing process.

AnchorTest™ is an innovative software solution, developed and marketed by AnchorTest Limited. The solution has two components: a front-end tablet app which runs on the Apple iPad platform, and a back-end Cloud system running on Amazon Web Services with an online cross-platform website which can be accessed from any PC, tablet or even mobile smartphone. AnchorTest is programmed to accommodate the major anchor testing codes and incorporates an intuitive user interface which is revolutionary compared to conventional engineering software designs. The use of this tool creates an environment where the testing of ground anchors has effectively become a paperless exercise with greater efficiency and access to instantaneous feedback on the performance of anchors in relation to established acceptance criteria.

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The Development of AnchorTest

The support of the deep basement for the Kuntsevo mixed-use development complex in Moscow, Russia required the installation of some 3600 anchors. These installations supported an excavation depth of 82 feet with a diaphragm wall of 148 feet overall depth and 1969 feet perimeter comprising six levels of anchors. The challenging ground conditions demanded the use of specialist ground anchor technology to achieve the required working loads and single bore multiple anchors (SBMAs) were specified. The three unit SBMAs required the use of three hydraulically synchronized stressing jacks for each anchor and this generated 10800 load extension data plots for the proof tests required to satisfy the specification.

The analysis and management of the data produced from the preproduction tests and the mandatory proof testing of thousands of anchors proved challenging. The project specification stipulated that no anchors could be accepted into the works until the results from acceptance tests were examined and signed-off by the client's representatives and this process often created delays. These issues paved the way for the development of AnchorTest. At Kuntsevo, the protocols for the delivery of data had already been established during the development phases of the software package, so although the final product was not used on the project, the concept design and preliminary trial versions were optimized as a direct result of the works carried out at Kuntsevo (Figure 1).

The completed product is now fully enabled and available for use on all types of ground anchor applications to permit paperless real-time analysis, data management, GPS-based automatic location and weather information retrieval, and incorporates the acceptance criteria for major international ground anchor codes of practice (including PTIDC35.1-14 and BS8081:1989). This innovation provides a more reliable and convenient way to process data, both in the field and in the office, and effectively moves anchor testing beyond the limits imposed by data input using spreadsheets on laptops and PCs.

Key Features of AnchorTest With Particular Reference to PTI DC35.1-14

The software is currently programmed to accommodate full data analysis in accordance with PTI DC35.1-14 and BS8081:1989. Further updates will provide the user with access to the

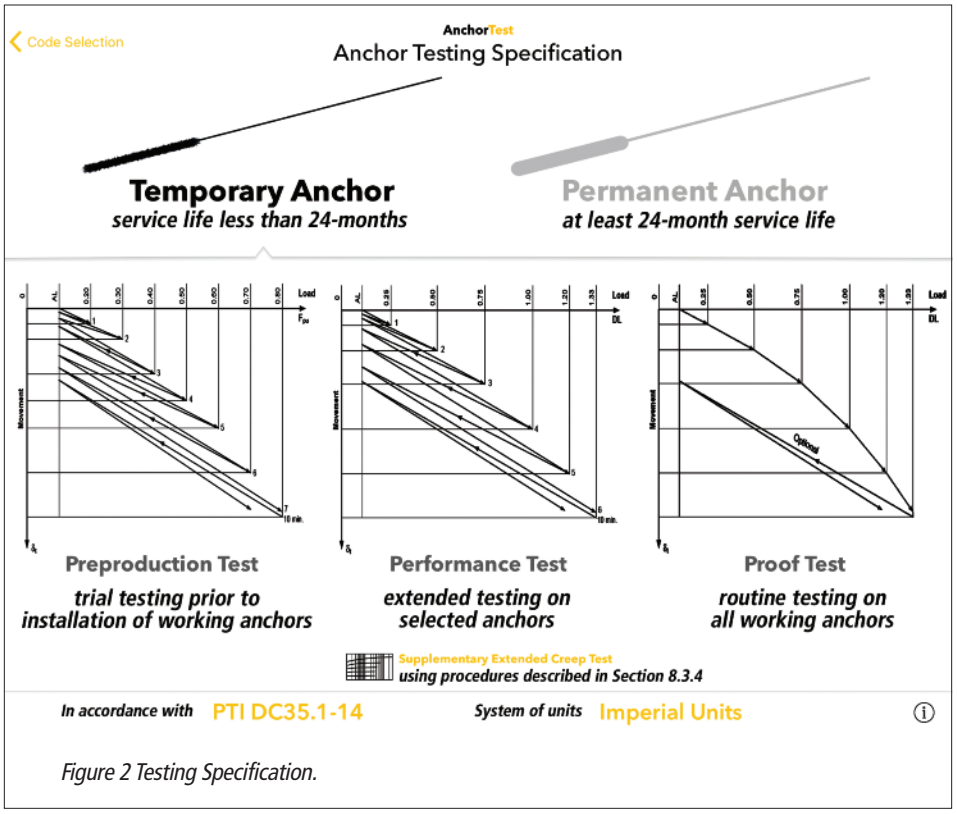

Figure 2 Testing Specification.

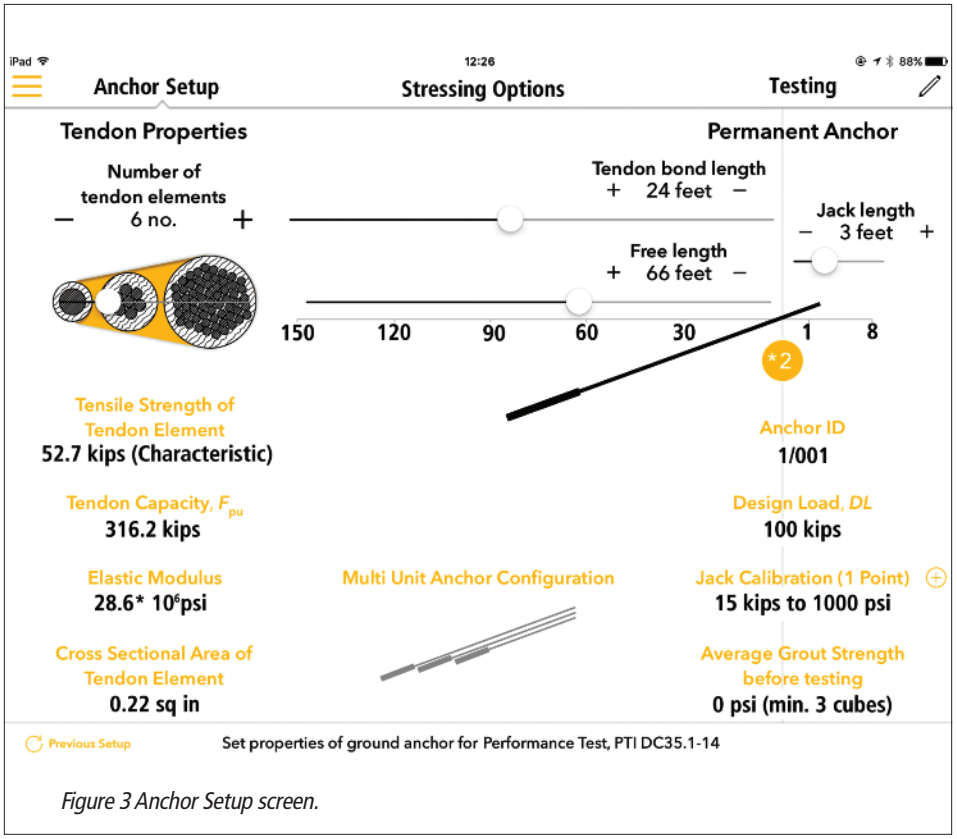

Figure 3 Anchor Setup screen.

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new EN ISO 22477-5 (the International Standards Organization standard for the testing of grouted anchors). Users can also arrange unique access to bespoke modules within the software that specifically caters for the requirements of particular specifications.

One of the main design requirements was that the software is intuitive, in other words no instruction manual is required permitting an engineer, familiar with the testing of anchors, to navigate through the various screens.

The software provides Cloud synchronization facilities that permit any authorized user (e.g. contractor's engineers, anchor expert or client's engineers) to access the data from a remote location via the internet using a username and password.

In relation to PTI DC35.1-14 the software provides full analyses of both temporary and permanent anchors for Preproduction, Performance and Proof tests including supplementary extended creep tests, if required (Figure 2). Following the input of tendon properties at the ANCHOR SETUP screen (Figure 3), the tables required for the presentation of field data are automatically generated for the nominated number of cycles on the STRESSING OPTIONS screen (Figure 4). As the field data is generated it is conveniently input into the software via real-time on-screen guidance and data plotting with built-in timer and image capture capabilities on the TESTING screen (Figure 5). The analyses of creep is carried out instantaneously and the user is informed of anchor performance via dialogue boxes that pop up throughout the testing process providing real-time feedback on the creep behavior and the apparent tendon free length assessment of the anchor.

On completion the user is able to synchronize the data to the Cloud and the AnchorTest software produces a Microsoft Excel compatible results summary comprising; overall results summary table (indicating conformant and non-conformant anchors), test readings, analysis results, test plots (cyclic loading data), apparent tendon free length plot and any notes that have been recorded during testing. The user is also able to record photographic information which is also stored in the Cloud database for the particular test.

Additional features include a battery power assessment, where the software calculates the length of the test and compares it to the battery life available. If inadequate power is available, then the user is reminded to connect the iPad to an external power source (e.g. portable

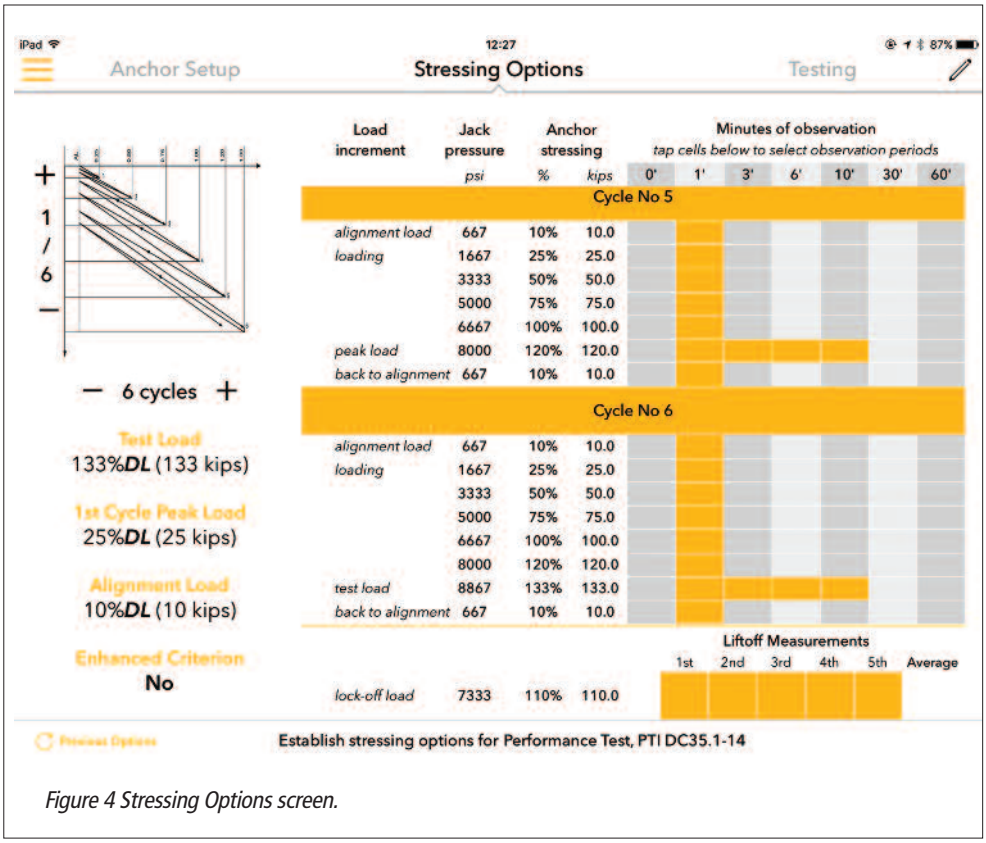

Figure 4 Stressing Options screen.

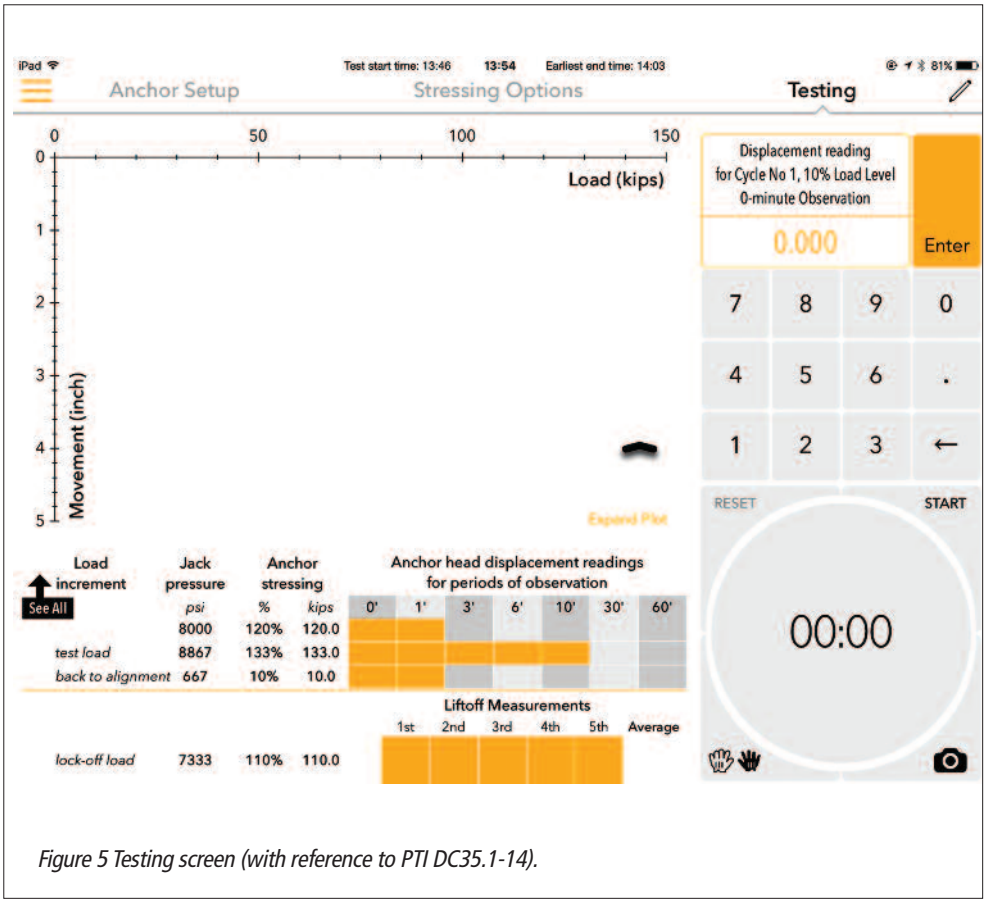

Figure 5 Testing screen (with reference to PTI DC35.1-14).

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Figure 6 AnchorTest on the field for NOX Project, Moscow.

battery or mains) before commencing with the test. It is noteworthy that due to standard 10-hour battery life on iPad devices, users are able to get through a whole day on the site without need to charge their device.

As tablet and web technologies advance further in replacing the traditional PC platform, further updates and enhancements to AnchorTest will also be available to software license holders.

Case Histories

AnchorTest Implemented at the US Embassy in Moscow, Russia

Between mid-June and mid-August 2015, AnchorTest was successfully implemented within the framework of the inspection and testing plan for the ground engineering works at the U.S. Embassy New Office Annex (NOX) in Moscow, Russia by specialist anchor subcontractor Kasktas AS.

For a retained height of 42 feet in mixed Moscow soils comprising glacial

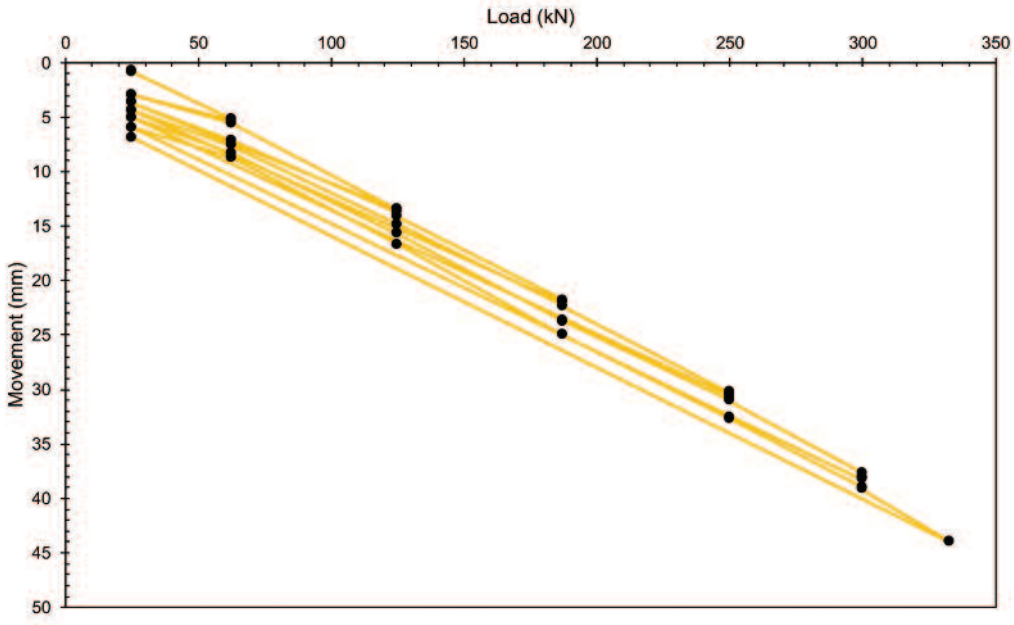

Figure 7 Load vs Movement (a) and its graphical analysis (b) by Anchor Test.

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Figure 8 Completed anchored secant pile wall.

sand with sandy clay, and morainic deposits of sandy clay, a secant pile wall was constructed and supported with 3 rows of 16 permanent ground anchors (a total of 48). The anchors were prefabricated mono-bars with factory grouted bond lengths, only requiring coupling on-site during installation of tendon into the anchor bore holes. The tight schedule, highly demanding quality requirements and the constrained mobilization space on the site were all overcome by the decision to utilize prefabricated tendons.

The decision to use AnchorTest on this project facilitated the anchor construction cycle and tight schedule by providing a means to process data timeously and thereby creating an environment for quick decisions, which in turn allowed the work to progress in a reduced amount of time.

In accordance with the technical specification, which required strict compliance to PTI DC35.1-14 (Recommendations for Prestressed Rock and Soil Anchors); each anchor was subjected to Proof tests up to 133% of design load. Performance tests, with lift-off checks, were also required for two anchors at each anchor level (see typical results plots in Figure 7).

For all anchors, plotting of proof test data (load vs movement) and graphical analysis of proof test data (apparent free tendon length estimation) were conducted with AnchorTest to provide analyses in real-time as testing progressed.

Figure 9 61 Strand test anchor stressed with a 3372 kips capacity stressing jack at Hazelmere dam.

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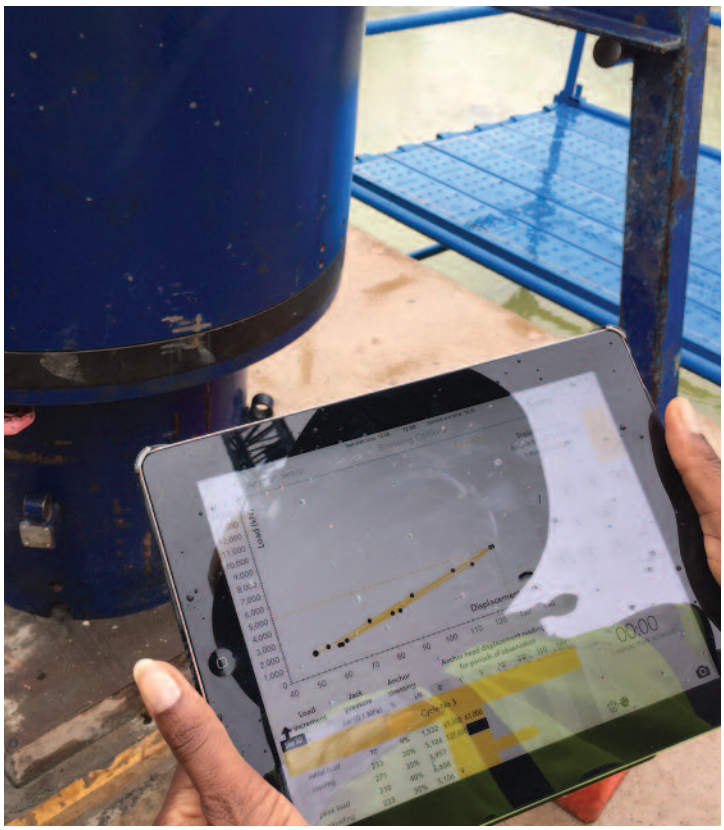

Figure 10 Implementation of AnchorTest software during test anchor programme at Hazelmere dam.

Test records were made directly accessible to the quality control department of the general contractor, Caddell Construction. Anchors were locked-off, at the latest by the next work day, following on-site testing. This was all made possible with the cross-platform AnchorTest Cloud component built into the AnchorTest software, linking it to the AnchorTest Cloud website.

AnchorTest enabled Kasktas to proof test, lock-off and hand-over the anchored section of the excavation on time and within budget with reduced engineering and administrative staff input, due to automated and real-time data analysis, together with instant and paperless distribution of compliance reports. The representatives of the Owner and the Engineer were particularly satisfied with the additional innovation introduced by the use of AnchorTest in realizing this challenging project (Figure 8).

AnchorTest Implemented at Hazelmere Dam, South Africa

Hazelmere Dam is a 147 feet high, 1568 feet long concrete gravity structure constructed in circa 1977 on the Mdloti River in the Kwazulu Natal Province of South Africa. The structure comprises 32 concrete monoliths each approximately 49 feet wide ranging in height from 49 to 147 feet and set on a slightly curved radius in plan of 2379 feet.

In order to meet the demands of increased water requirements due to population expansion and industrial development, the decision was made by the Department of Water and Sanitation to increase the full supply level of the dam from 282 feet to 305 feet. Extensive feasibility studies established that the optimum solution to facilitate the 23 feet raising was to install some 84 high capacity rock anchors through the concrete superstructure into the underlying rock for overall stability. Of major significance was the fact that the rock anchors comprised tendons of up to 91 strands and 295 feet long that were subjected to proof loads of up to 4280 kips, equalling the largest ever imposed on a post-tensioned dam. In addition, a comprehensive test anchor program involved the largest sacrificial anchors ever installed (Figure 9). All the analysis and management of data was carried out using AnchorTest (Figure 10).

The data produced for Proving (Preproduction) tests (Figure 11a & 11b), on-site Suitability (Performance) tests and on-site Acceptance (Proof) tests were all analyzed and managed using AnchorTest.

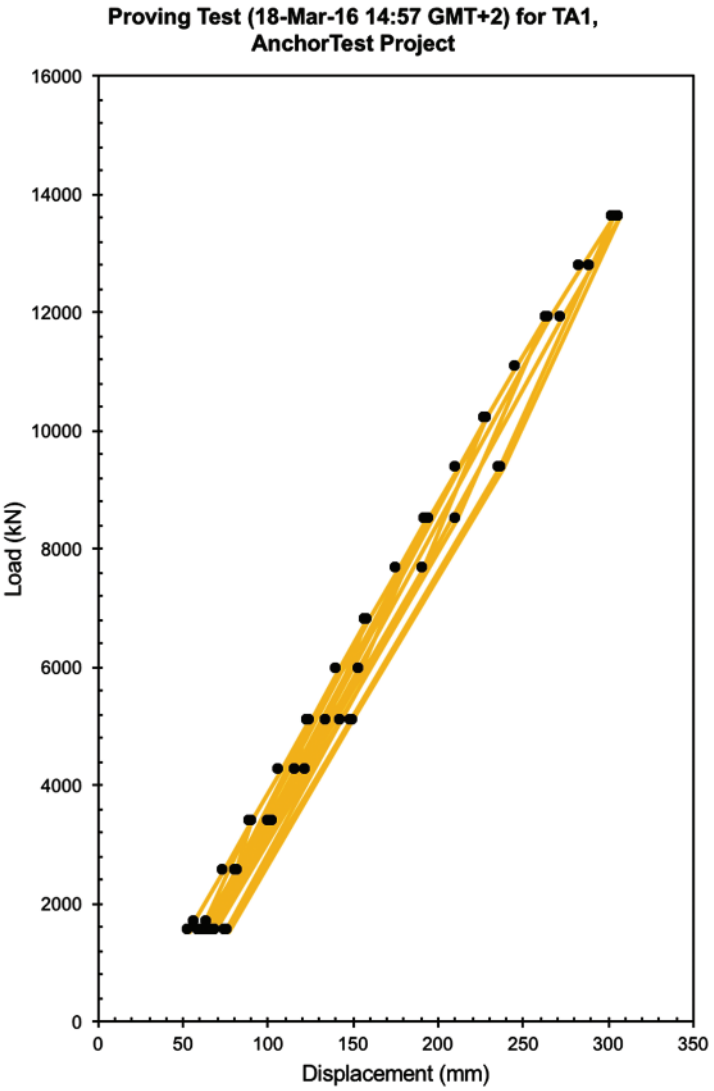

Figure 11a AnchorTest output for Proving tests with cyclic loading executed in accordance with BS8081:1989.

Summary

For economic reasons the time allocated to the testing of anchors should be minimized without compromising the quality of data recorded. AnchorTest facilitates this by reducing valuable engineering time and human resources dedicated to processing data and making decisions on anchor performance in real-time.

Although it is a relative new innovation AnchorTest has now been successfully used in several countries around the world including Australia,

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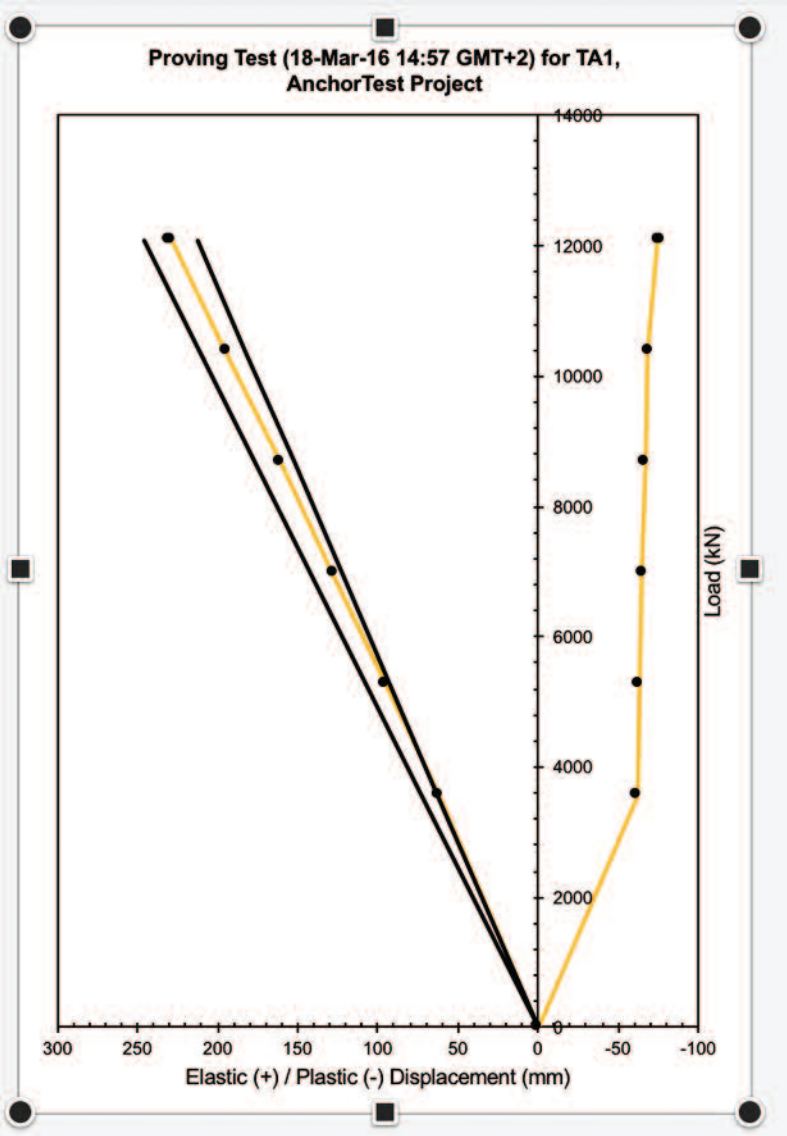

Figure 11b (right) AnchorTest output for Proving tests with assessment of apparent free tendon length executed in accordance with BS8081:1989.

Russia, South Africa, Turkey and the United Arab Emirates, and has recently been adopted by a major foundation contractor in the United States.

AnchorTest has proved effective in optimizing the process of anchor testing, and is currently programmed to execute data analysis in accordance with PTI DC35.1-14 and BS8081:1989 but will soon incorporate the International Standard Organization EN ISO 22477-5 (Testing of grouted anchors). In addition, special custom development arrangements can be made to create bespoke modules for specific project specifications.

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