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DEEP FOUNDATIONS

Anchor Testing Data Management

Emergency Landslide Stabilization

Predicting Drilled Shaft Capacity

HMG Stabilizes Historic Structure

2017 OPA Winner Expansion and Preservation of Andrew Mellon Building

COVER STORY

14 2017 OPA Winner, 1785 Massachusetts Ave. NW, Washington, D.C.

Richard Guenther, P.E., SungJe Chi, P.E., and Daniel Stevenson, P.E.

The service area of the historic Andrew Mellon Building was expanded from 72,000 to 100,000 sq ft (6,690 to 9,290 sq m) and a new basement level was added below the existing foundations. Micropiles, hand excavated underpinning pits and tiebacks were used to provide vertical and excavation support to the existing columns and spread footings during construction of the new basement level, while preserving the limestone façade and plaster interiors.

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65 Real-Time Anchor Testing and Data Management

Dr. Devon K.V. Mothersille, CEng FICE, and Bora Okumusoglu, MSc.

To improve efficiency in the ground anchor testing process, the software platform, AnchorTest, was developed to provide full data analysis, data management capabilities, portability, and instantaneous real-time feedback on the performance of ground anchors in relation to established acceptance criteria. Once the testing is complete, the user can synchronize the recorded data and photographic information to the Cloud.

Real-Time Anchor Testing and Data Management

AnchorTest™ is an innovative software package, specifically developed for tablets, that permits ground anchor test data assessment and management in real time. The solution has two components: a front-end tablet app runs on the Apple iPad platform, and a back-end Cloud-based system running on Amazon Web Services with an online cross-platform website, which can be accessed from any PC, tablet or even mobile smartphone. This tool provides full data analysis and data management capabilities and portability to create greater efficiency in the anchor testing process. AnchorTest is programmed to accommodate the major international 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.

Historically, project personnel record and analyze the results from anchor load tests using spreadsheets and a laptop computer and/or on predesigned paper-based test sheets (usually as a backup of the testing). In addition, the processing of the test results is not typically performed in real time as the testing progresses — the calculations and analysis are performed either afterward while still on site (if a field office is available) or after returning to the office. Undoubtedly, on larger projects containing numerous anchors where multiple anchor tests may be performed at the same time, processing, analyzing and accepting the load test data and results can be especially time consuming, which could cause delays to the construction schedule.

Development

The need for a more automated and digitized approach to record, process and analyze the data from anchor load tests was highlighted at a deep basement project for a mixed-use development complex in Moscow, Russia. The diaphragm wall supporting the structure was approximately 1,970 ft (600 m) in perimeter length and about 148 ft (45 m) deep, with an excavated depth of about 82 ft (25 m), which required six levels of single bore multiple anchors (SBMAs). This project provided a challenge to recording, processing and signing off on the data generated from some 3,600 3-unit SBMAs. More specifically, for this project, three hydraulically synchronized stressing jacks were used to stress and proof test each 3-unit SBMA, which resulted in nearly 10,800 data plots of the load-extension tests being generated. This project served as the main impetus in the conceptual design and optimization of AnchorTest.

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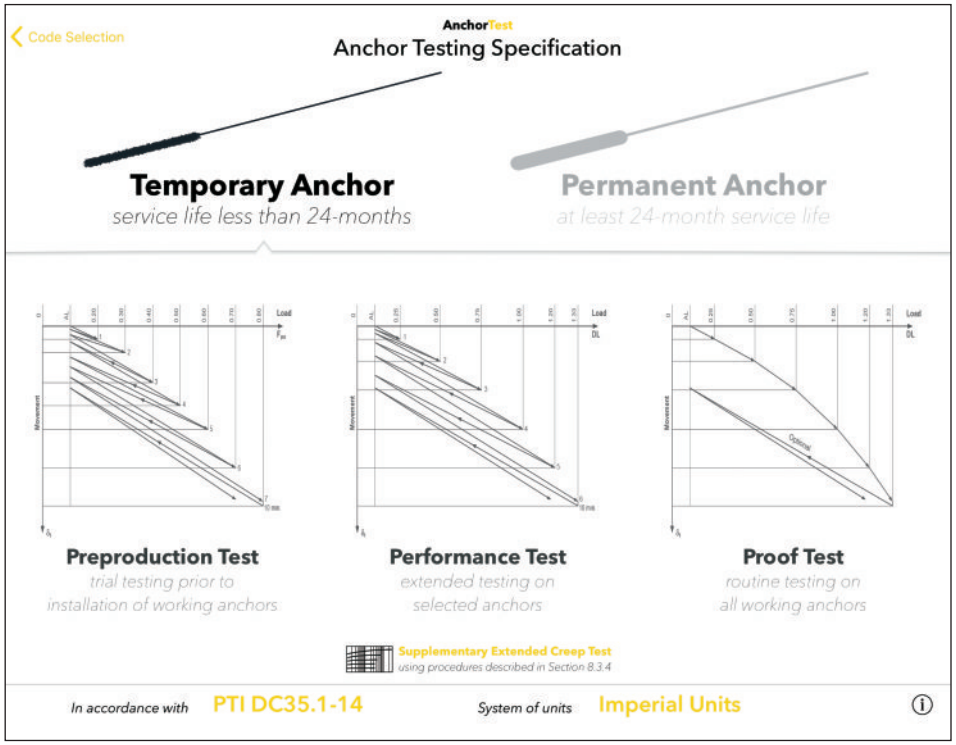
The completed product is now fully enabled and available for use with all types of ground anchor applications to permit paperless real-time analysis, data management, GPS-based automatic location and weather information retrieval. More importantly, the tool in its suite of program modules incorporates acceptance criteria for major international ground anchor codes of practice, including Post-Tensioning Institute (PTI) *DC35.1-14* and the U.K. Code of Practice *BS8081:1989* and, more recently, with the revised version of the code, *BS8081:2015*. 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.

The software platform is programmed to accommodate full data analysis in accordance with PTI *DC35.1-14* and *BS8081:1989*, and further updates will provide the user with access to the new International Standards Organisation (ISO) standard for the testing of grouted anchors, *EN ISO 22477-5*. In addition, users can arrange unique access to bespoke modules within the software that specifically caters to the requirements of particular specifications.

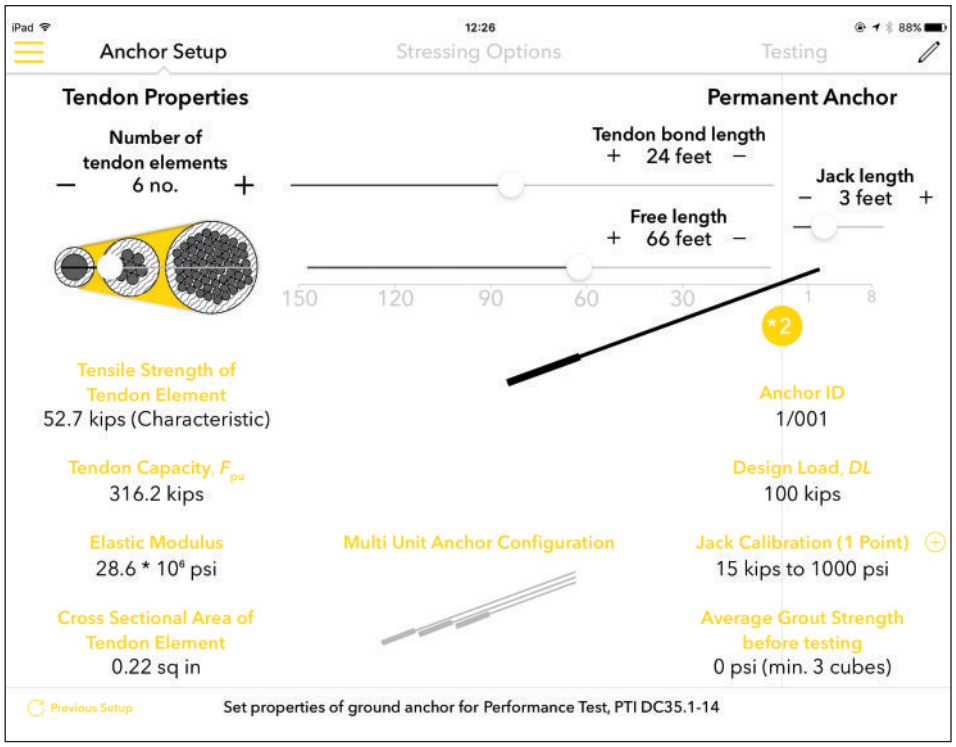
One of the main design requirements was that the software be intuitive; in other words, no instruction manual was to be required permitting an engineer, familiar with the testing of anchors, to navigate through the various screens in the software platform. Moreover, the software provides Cloud synchronisation facilities that permit any authorised 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.

Real-Time Testing and Data Management

The software provides full analyses of both temporary and permanent anchors for preproduction, performance and proof tests, including supplementary extended creep tests, if required. Following the input of tendon properties on the anchor test setup screen, the tables required for the presentation of field data are automatically generated for the nominated number of cycles on the stressing options screen.



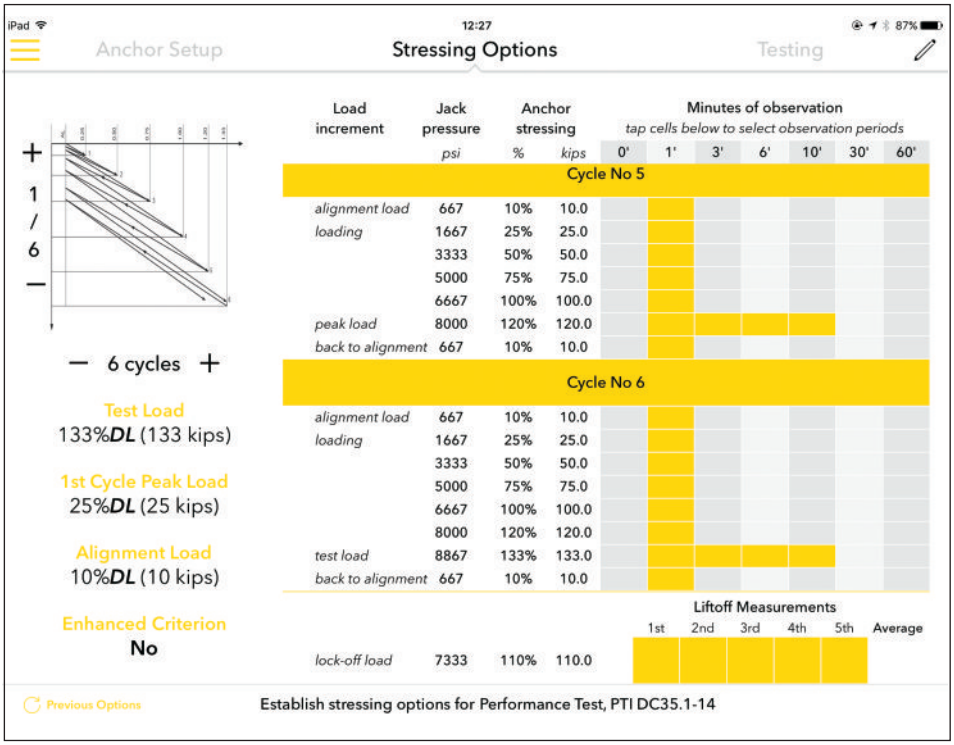
Testing specification screen capture



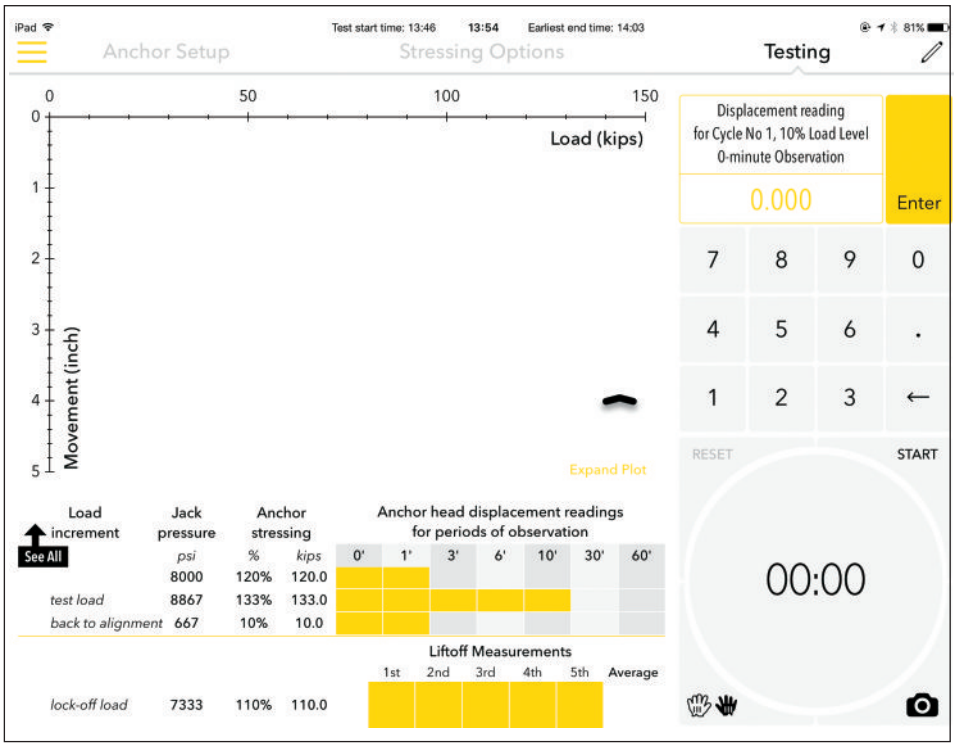
Anchor test setup screen capture

As the field data are generated, the data is conveniently input into the software via real-time on-screen guidance and data plotting using the built-in timer and image capture capabilities on the testing screen. The analysis of creep is performed instantaneously, and the user is informed of the anchor's performance via dialogue boxes that pop up throughout the testing process, which provide real-time feedback on the creep behaviour and the apparent tendon free length assessment of the anchor.

On completion, the user is able to synchronise the data to the Cloud and the software produces a Microsoft Excel-compatible results summary containing: an



Stressing options screen capture



Testing screen capture (reference to PTI DC35.1-14)

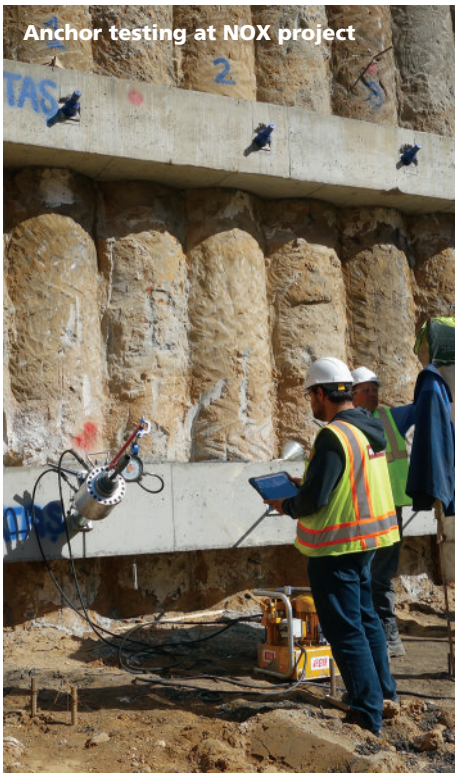
overall results summary table (indicating conformant and nonconformant anchors), test readings, analysis results, test plots (cyclic loading data), apparent tendon free length plots and any notes that have been recorded during the testing. The user can also record and store photographic information in the Cloud 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, the user is reminded to connect the iPad to an external power source (e.g., portable battery or main power) before commencing with the test. Because of the standard 10-hour battery life on iPad devices, users should be able to get through a whole day on the site without the need to charge their device.

Prior Works

In "Anchor Testing Using Innovative Software on a Tablet" published in the October 2016 issue of ADSC *Foundation Drilling* magazine, the authors described two case histories where AnchorTest was used successfully. For the U.S. Embassy New Office Annex (NOX) project in Moscow, Russia, the software platform was used to process test data in a timely manner, which facilitated quick decision making that allowed construction work to progress within the tight schedule. The software enabled the contractor to perform its work on time and within budget with less engineering and administrative staff support due to automated and real-time data analysis along with instant and paperless distribution of compliance reports.

At the Hazelmere Dam on the Mdloti River in the Kwazulu Natal Province of South Africa, 84 ultra-high capacity rock anchors were installed through the concrete superstructure into the underlying rock to provide resistance and enhance stability to the structure as the full supply level of the dam was raised by 23 ft (7.0 m) from 282 to



Anchor testing at NOX project

61-strand anchor test at Hazelmere Dam

305 ft (86.0 to 93.0 m). The rock anchors comprised tendons from 61 strands up to 91 strands and 295 ft (90.0 m) long. The maximum proof loads subjected to the largest anchors were as great as 4,280 kips (19,038 kN), which were the largest ever imposed on a post-tensioned dam. All of recording, real-time analysis and management of test data for the preproduction, performance and proof tests was performed using the software tool.

Corniche Towers

The Corniche Towers complex is located across a popular area of Abu Dhabi's Corniche district. The towers are oriented to achieve unobstructed views of the Corniche and the sea. The project consists of the construction of three towers, each more than 30 stories in height comprising residential apartments, offices and retail floors at the podium levels. Beneath the podium level, there are four levels of the common basement, which will accommodate underground car parking.

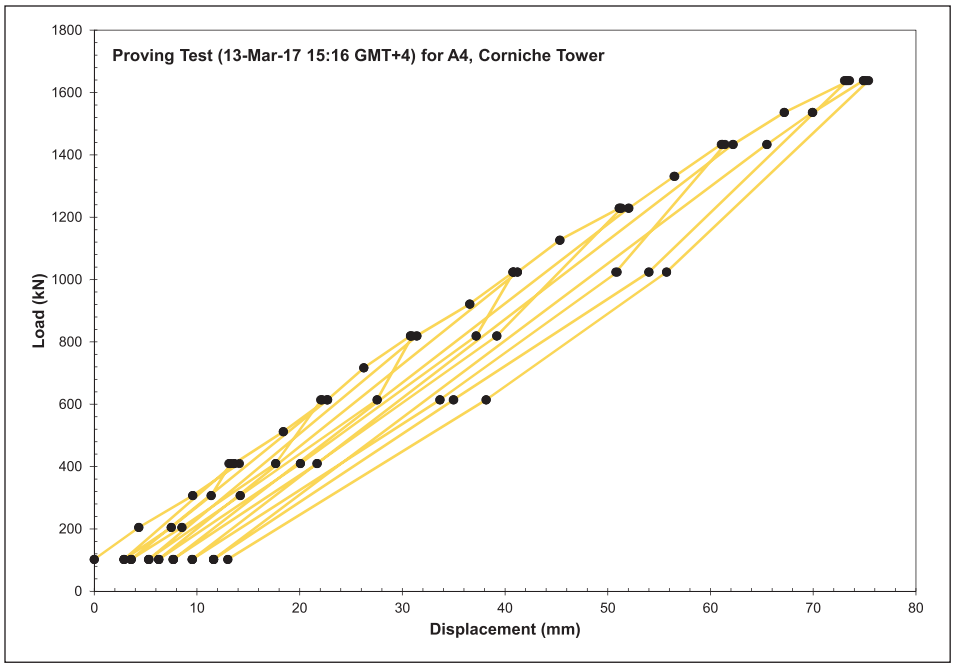
BAUER Geotechnical Specialized Foundations was contracted to design and execute specialist foundation works and deep excavation shoring for the complex. Some 600 temporary ground anchors around the main pit, combined with steel strut pipes at the corner locations and along the short-span corridor, support diaphragm and secant pile walls that will form the shoring structure for the approximately 66 ft (20 m) deep excavation. At the Corniche Road side, removable anchors will be implemented to avoid conflict with future infrastructure development plans proposed by the municipality.

Construction of foundations at Corniche Towers

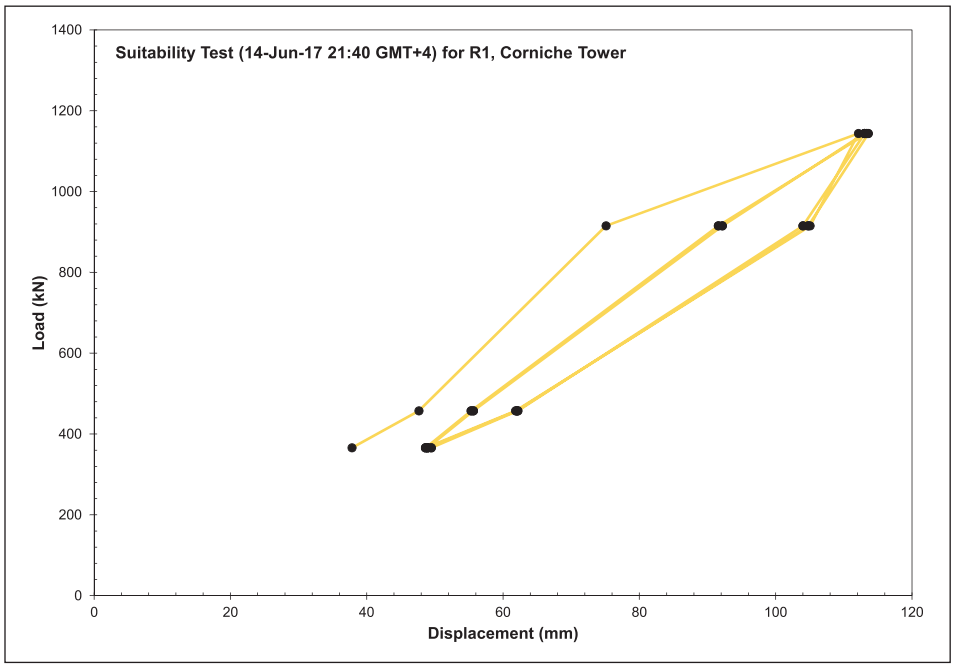
Architectural drawing of Corniche Towers

The working load of the ground anchors vary from about 205 to 255 kips (915 to 1,125 kN). The contractor utilized AnchorTest during the preliminary investigation testing of the vertically installed test anchors and for the preliminary suitability testing of the SBMA removable anchors. During these trials, a maximum testing load of about 382 kips (1,700 kN) was imposed, and all of the associated data was analysed with and submitted using the software.

In June 2017, in accordance with requirements of the relevant code for the project, *BS8081:1989*, the vertically installed removable SBMA anchors were



Proving (preproduction) test data for test anchor



Suitability (performance) test data for removable trial anchors

tested up to a maximum load of about 260 kips (1,150 kN), which was about 1.25 times the required working load. The execution of the production ground anchors is planned for August 2017, and AnchorTest will be used for the routine on-site acceptance testing work, in accordance with the QA/QC requirements, before locking-off each anchor.

Summary

The software has proved effective in optimizing the process of anchor testing, and it is currently programmed to execute data analysis in accordance with PTI *DC35.1-14*, *BS8081:1989* and *BS8081:2015*, and will soon incorporate the International Standard Organization *EN ISO 22477-5* standard (Testing of grouted anchors). In addition, special custom development arrangements can be made to create bespoke modules for specific project specifications. The software platform has been implemented successfully in anchor works in a number of countries, including Australia, Russia, South Africa, Turkey and the United Arab Emirates, and has recently been adopted by a major foundation contractor in the United States.

Devon K.V. Mothersille is the managing director of Geoserve Global and Single Bore Multiple Anchor. He has a doctorate in ground anchor technology, is an active member of Euro-committees tasked to implement EC7 standards for anchors and is a Fellow of the Institution of Civil Engineers (UK).

Bora Okumusoglu is the founder of hetGE, a software company creating intuitive mobile and Cloud-based specialized engineering tools. He has a master's degree in geotechnical engineering, and has been working in the ground engineering industry for over 14 years in many countries including Japan, Turkey, Russia and United Arab Emirates, where he leads the recently-established regional design office of BAUER Spezialtiefbau GmbH.

Use of AnchorTest for real-time analysis