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CONSTRUCTION FAILURES

SOME OF THE WORST AND WHAT WE CAN LEARN FROM THEM

PLUS

40+ YEARS AS AN ENGINEER
Bio of Dave Wentland, P.E.

LOADTEST'S INNOVATIVE RIM-CELL
Verifies Shaft Performance

MARINE FOUNDATIONS
For a New Bridge in Brooklyn, NY

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ABOUT

As deep foundations must cope with greater loads and complex site conditions, Loadtest delivers solutions critical to design optimization and long-term performance. Our senior employees have over 200 years combined load test experience.

This experience base comes from Loadtest's involvement with world class projects in over 60 countries around the globe.

Numerous load test world records have been set using the O-cell method, including our current world record for total load of 36,333 Kips set in 2013 on the Louisville-Southern Indiana Ohio River Bridges Project.

LOADTEST'S INNOVATIVE RIM-CELL VERIFIES SHAFT PERFORMANCE

Loadtest's legacy is best represented by its historical commitment to innovation and continuous development of the Genuine Osterberg Cell, or *O-Cell*, and its numerous and storied applications in the deep foundation industry. The development of the method and its related analyses were instrumental in enabling increased design capacities for drilled shafts in the mid- to later 90's and into the first decade of the 2000's. The O-Cell's ability to prove capacities well beyond what had previously been possible made drilled shafts more economical, increasing their viability in a cost driven foundation market. Drilled shafts designed for a few hundred tons in the late 80's and early 90's are now routinely designed for up to a few thousand tons and in some cases, staggering loads of over 30,000 tons have been proven by the Genuine Osterberg Cell.

Loadtest applied that same innovative spark in developing the ***R**eliability **I**mprovement **M**ethod*, or ***RIM-Cell***, which brings to the industry a means for verifying performance of production drilled shaft. The concept of *every production pile is a tested pile*, previously available only to driven piles, is now possible for drilled shafts and auger cast piles. The economics of the RIM-Cell method allows for a variety of implementations.

- ***A quality control measure:*** Proof loading for shafts with construction quality concerns.
- ***A means to justify resistance (phi) factor:*** Allowing increased phi factors for LRFD code-based projects.
- ***An economical means to stiffen the foundation resistance:*** Confidently improve load response and prove the benefits of prestressing the tip of drilled shafts; providing certainty where base-grouting only leaves questions.
- ***A means to save time:*** Because the soil is not used to contain or seal the pressurized grout, the volume of grout is much smaller and delivery for proof-loading occurs in a matter of minutes, not in several stages and multiple pumping efforts as are required by conventional base grouting techniques.

Among the latest RIM-Cell applications was its use in cooperation with the University of Florida and the geotechnical research arm of the Florida Department of Transportation. As

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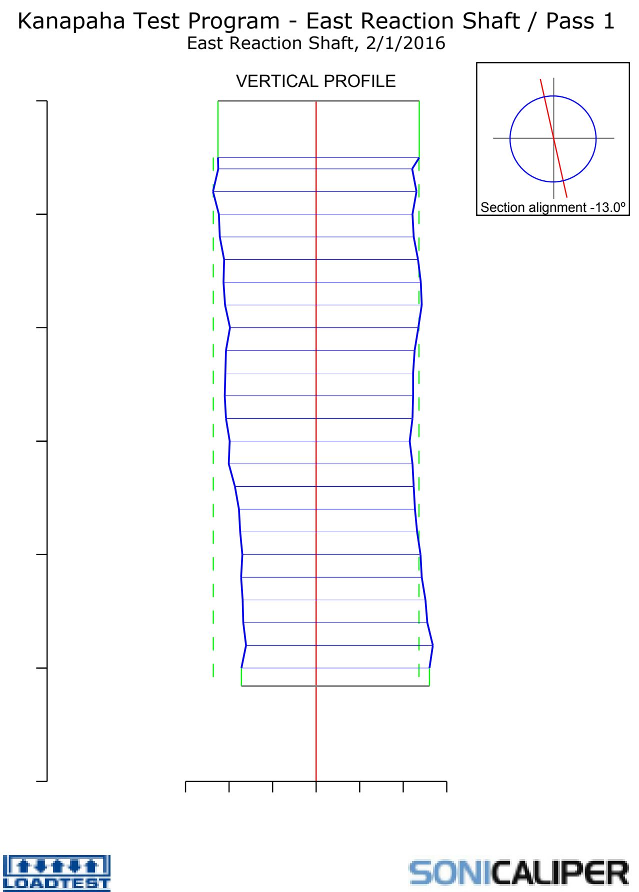


SoniCaliper Side Cross Section View – East Reaction shaft.

a purely unrelated part of the primary research effort, Loadtest installed RIM-Cells in each of two shafts constructed as reaction for a conventional top load testing of the subject research shaft. The RIM-Cells were installed to demonstrate the measurable response of the shafts to RIM-cell proof loading. Both reaction shafts were built using construction techniques common to Florida karst region soils. The first was built with no construction issues, but the second reaction shaft experienced a number of construction issues, both typical and atypical to the Florida karst region. These two shafts illustrated both the variability of two otherwise identical shafts constructed within close proximity, as well as the value of RIM-Cell proof loading to reveal and quantify the performance of each.

The East reaction shaft was constructed using a 46-inch ID surface casing, approximately 6 feet in length, to stabilize the excavation near the surface. Excavation continued with an auger until the water table was reached at approximately 30 feet below ground surface. A polymer slurry was then introduced into the excavation and mixed in the excavation. When Florida limerock was encountered at 40 feet of depth, the excavation was advanced using a rock auger to achieve the planned tip elevation. Base cleanout was accomplished with a cleanout bucket. The excavation bottom appeared satisfactory and the excavation was stable. The excavation was then profiled using the SoniCaliper prior to concrete placement.

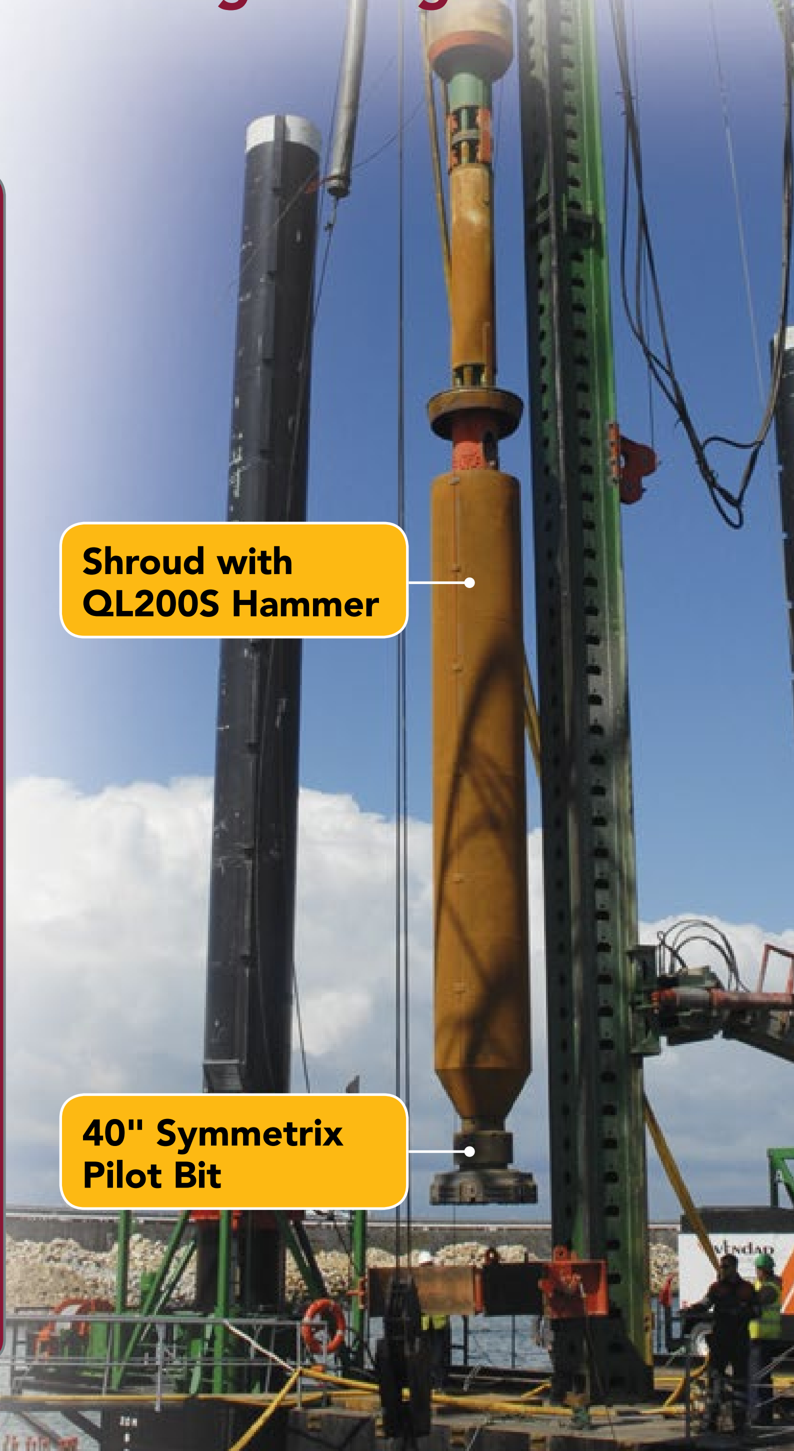
The West reaction shaft was constructed similarly using the construction techniques described for the East shaft, but with a different outcome. After reaching a depth of approximately 30 feet below ground surface, the previously used polymer slurry from the east shaft excavation was added so the excavation could continue. As the excavation advanced, a loss of slurry occurred and the excavation collapsed at approximately 40 feet below ground surface. Additional slurry was added to the excavation in addition to additional water (pumped from standing surface water on site) in an attempt to stabilize the excavation.

The addition of the slurry somewhat stabilized the excavation, allowing for continued advancement to the planned tip depth. During this time, the slurry in the excavation was approximately 30 feet below the ground surface. As the excavation to shaft tip continued, the bottom of the digging bucket became detached and was permanently lost in the excavation. Numerous attempts were made both to retrieve the lost digging tool as well as to clean the base of the excavation. After appreciable effort, a conclusion was reached deeming

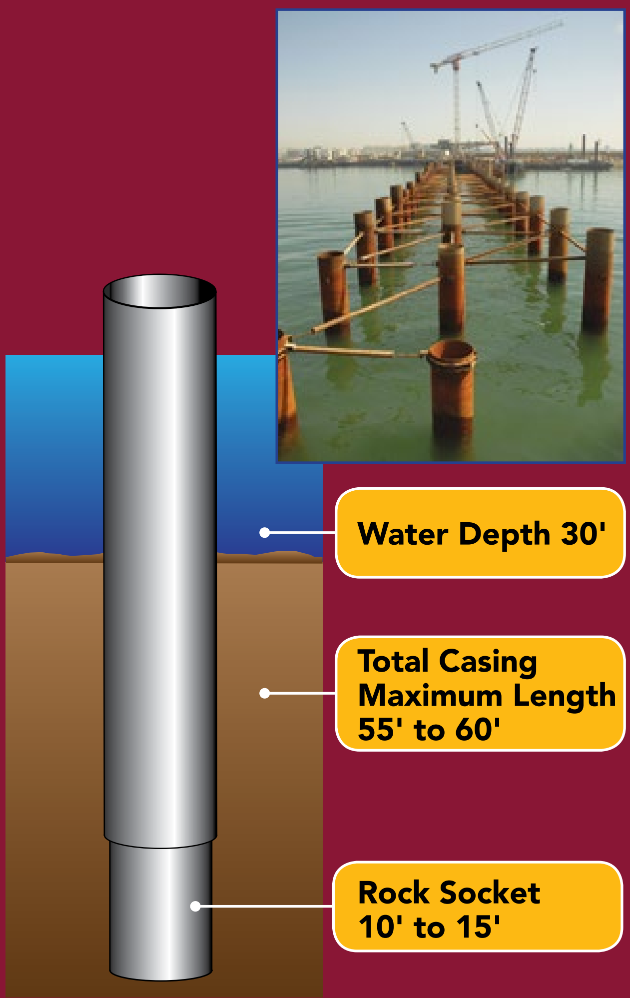
RIM-Cell attached to the bottom of the reinforcement cage.

Simplify with Symmetrix

The answer to large casing installation



A "model" of a previously performed Symmetrix project:



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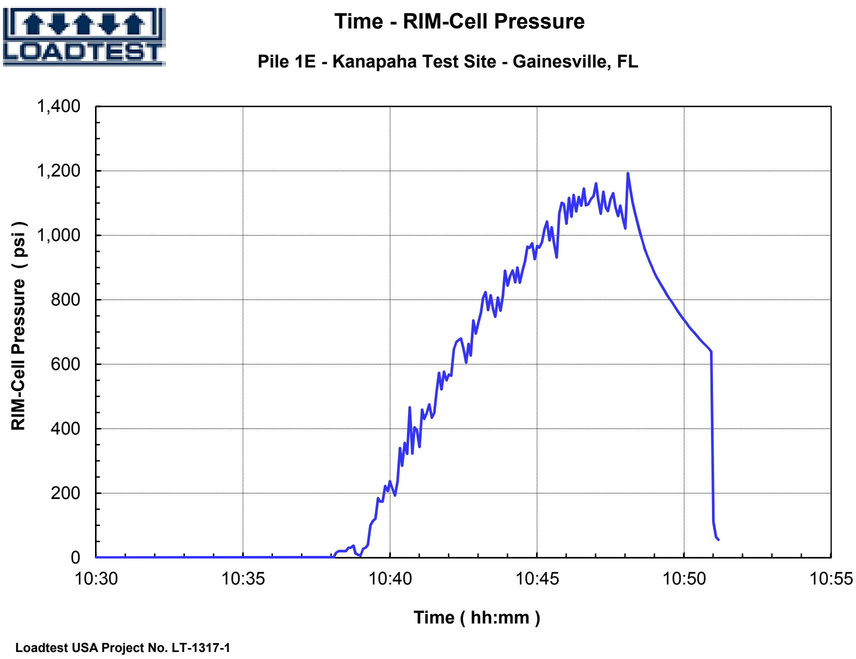
the excavation to be 'as good as it will get' and efforts to clean further were abandoned. The cage was then placed and concrete poured. During this time the excavation side wall above the level of the slurry continued to slough and fall into the into the excavation. Compared to the East reaction shaft, the West reaction shaft's bottom was very soft when measured with a weighted tape and that condition was confirmed by the behavior of the RIM-Cell proof loading response, shown in the plots below.

Due to the risk of equipment loss given the continuing side wall collapse, SoniCaliper inspection was not performed for the West reaction shaft excavation.

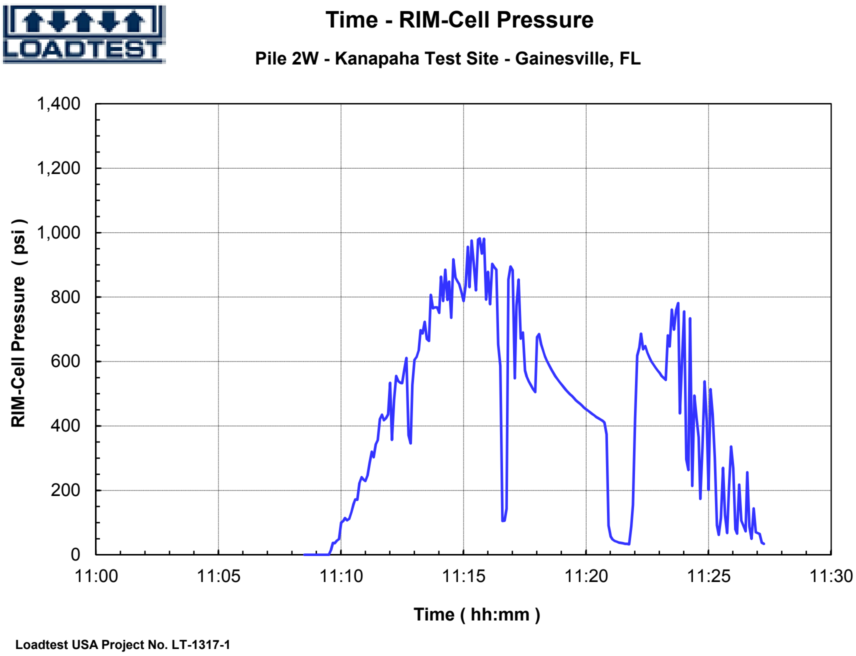
Placement of both reinforcement cages with the attached RIM-Cells was done smoothly and concrete was successfully placed using standard shaft concreting techniques. The slim profile of the RIM-Cell and its large center tremie pipe opening presented no restrictions to either installation, nor to concreting. The East shaft poured at about 15 cubic yards while the West shaft poured at just over 23 cubic yards, indicating a significant over pour compared to the theoretical 13 cubic yards.

RIM-Cell proof loading commenced approximately two months after construction at which time the concrete unconfined compressive strength indicated a strength of 6000 PSI.

The above time-pressure plots show the difference in proof loading between the East and West shafts. The East shaft required merely



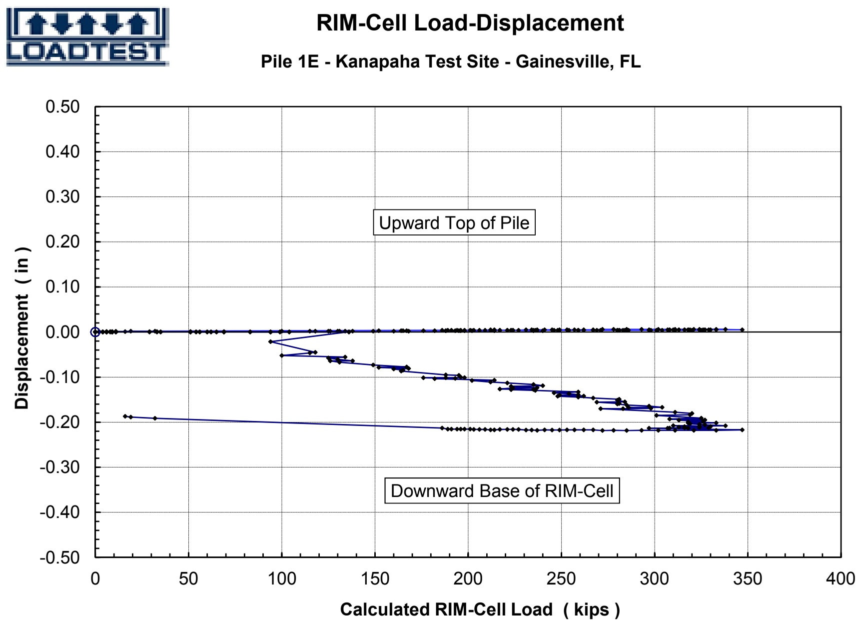
Time–Pressure grout curve East reaction shaft.



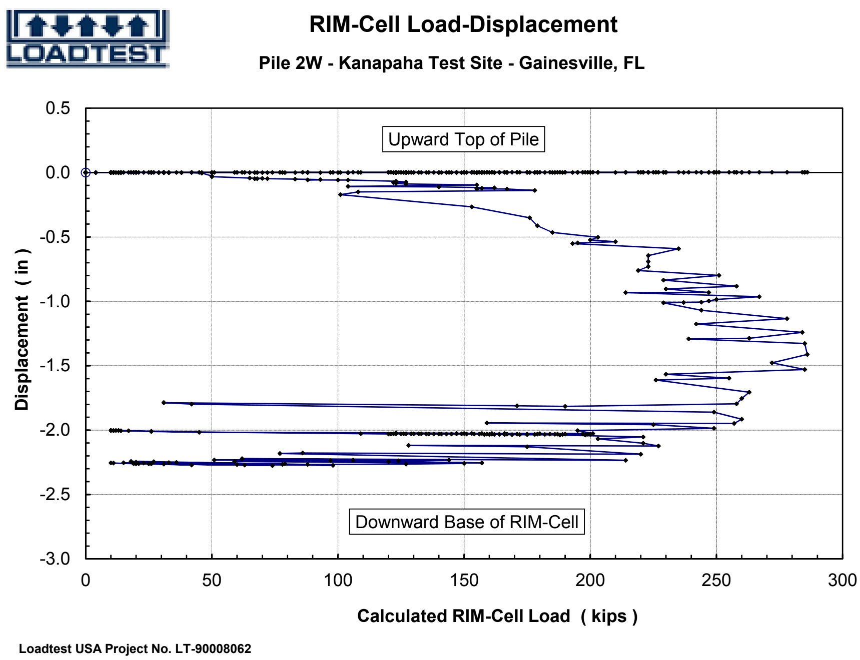
Time–Pressure grout curve West reaction shaft.

10 minutes to complete proof loading with a downward displacement of only 0.2 inches. The West shaft, with its soft base response required significantly more grout due to the excessive downward displacement, even requiring a brief pause to mix additional grout. Even with the unexpected delays and the additional grout volume, proof loading took less than 20 minutes.

As the above time-pressurization curves demonstrate, the RIM-Cells required only one grout pressurization cycle via each RIM-Cell's two flexible hoses. The West shaft's time-pressure response curve confirms the presence of the soft material at toe.



RIM-Cell Method curve from East reaction shaft depicting hard (clean) bottom response.



RIM-Cell Method curve from West reaction shaft depicting soft (dirty) bottom response.

The load deflection curve above from the East shaft shows a clean bottom response demonstrated by the RIM-Cell proof loading. Shaft performance was verified to a total of 700 kips with skin friction being the major contributor to the verification. In addition to stiffening the base response, an intrinsic benefit of RIM-Cell proof loading is the improvement in stiffness derived from reversal of frictional resistance in the shaft above the RIM-Cell. In this way, preloading with the RIM-Cell overcomes the typical strain incompatibility between mobilized skin friction and end bearing resistance in drilled shafts.

The West shaft RIM-Cell plot reveals a soft bottom response, as expected. The large downward displacement from the soft base consumed the entire standard RIM-Cell stroke during proof loading. Shaft capacity was generally confirmed to approximately 550 kips. While this proof loading does indicate some lock-in of skin friction reversal, it was limited by the soft bottom response, which indicated a lower capacity than suggested by the initial peak loads. This reinforces the importance of excavation cleanliness and construction quality for optimizing shaft performance.

As the data from the Kanapaha site demonstrates, the ***R**eliability **I**mprovement **M**ethod* combines ease of construction, timely results and certainty of shaft performance into an economical and convenient package. The RIM-Cell's confined pressurized area allows accurate assessment of applied loads and enables significantly lower grout volumes. This means less time guessing and grouting and more rapid project completion. In addition to accurately assessing performance with known loads and base displacements, the RIM-Cell method also enhances shaft performance by pre-compressing the shaft base and locking-in a stiffer response to service loading. This measurement of drilled shaft performance improves confidence that the foundation meets project design requirements and enables informed decisions should shaft behavior fail to meet such requirements. ■