



World Leaders in Deep Foundation Load Testing

A DEEP FOUNDATION PARADOX

Paradox - *A statement or doctrine seemingly absurd or contradictory to common notions or to what would naturally be believed, but is in fact really true.* (As defined by Webster's Dictionary)

Does a paradox exist in the deep foundation industry? The short answer, based on our empirical observations: YES, absolutely. If so, what relevance does this paradox have to us? And further, "What paradox?"

Loadtest describes the paradox as, "Spending more, sometimes a lot more, on mitigating (in some instances even eliminating) uncertainty and risks found in the design and construction process of a deep foundation system leads to a higher quality, safer foundation system at lower cost." With almost twenty years of deep foundation testing experience around the world, our observations, coupled with some startling new analyses, confirms our suspicions about this apparently paradoxical improbability.

How could such a paradox have developed in the deep foundation industry in the first place? We have identified uncertainty and risk as the primary culprits. The standard design approach of assuaging our concerns about deep foundation uncertainties, based on limited geotechnical data and knowledge (i.e., insitu and laboratory testing), leads to overdesigning foundation systems using presumptive code values, lower limits of both estimated side shear and end-bearing values and a "safety factor." This standard of practice for many designers makes sense, considering their financial and professional liability related to geotechnical uncertainties and global (or systemic) risk.

This "standard" approach leads to the owner paying for the risks and uncertainty of the deep foundation system, whether identified or not. We often hear this common response to the conundrum: "But uncovering these risks and uncertainties would cost way too much!" followed by "The owner will not pay for this extra work – more geotechnical work and higher levels of construction QA/QC." Sadly, however, whether he knows it not (usually he does not) the owner does pay for it, or essentially pays for a design which mollifies the uncertainty through overdesign. We estimate that overdesign, in varying degrees, exists in more than 90% of all foundation systems.

So how much risk does the owner actually pay for? To explore this fully would require much more space than we have here, but a simple (though not too simple) calculation does help in determining the financial impact of the risk. As an armchair exercise, using a Resistance Factor design approach, let us assume that an original design utilizes a RF of 0.4 (approximate Factor of Safety of 2.5) resulting in a cost for this design of \$5 million. Now we recalculate this design with a RF of 1.0 resulting in a revised cost of, say, \$3.5 million. This \$1.5 million cost difference between the RF of 0.4 and 1.0 designs gives you some idea of the costs related to the way we deal with the risks and uncertainties associated with the site variability and the construction process. We call this the Risk Premium. Paradoxically, in this example, we could possibly spend \$1.0 million on enough geotechnical and QA/QC testing work to eliminate all the risk and uncertainty, thus giving the owner a better, safer foundation with a 10% cost reduction when compared with the standard design approach. We call this the Risk Premium Paradox.

You may have concerns about using a RF of 1.0, even for estimating purposes, but keep in mind that in order to build such a system you would have to eliminate all uncertainty or associated risks in the design, site variability and construction process. If we did build such a system, we would also have the safest possible foundation system simply because we eliminated all risk and uncertainty. Impossible, improbable – perhaps – but other industries actually do it routinely. Even in the foundation industry we have earth anchor systems typically installed and 100% tested (thus removing virtually all uncertainty) as standard operating procedure.

The projects highlighted inside have all benefited from mitigating the uncertainties of deep foundation design. Most of the savings have occurred by implementing a pre-design test program, a significant step in the right direction of wresting the economic benefits out of the Risk Premium. We believe that more extensive geotechnical investigation, coupled with pre-design load testing and high levels of QA/QC during construction, will only enhance the incentives to explore this **deep foundation paradox** as it now exists.



DUBAI, UAE

SINGAPORE

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FRANK R. LAUTENBERG STATION AT SECAUCUS JUNCTION

In 1994, while working on an adjacent section of the Kearney Connection, a New Jersey Transit project, Case Foundation performed two preliminary load tests as part of the foundation design process for the nearby, proposed Secaucus Transfer Station. The drilled shafts under construction on the nearby project, in similar subsurface conditions, required 10- to 17-foot-long rock sockets designed to support a compressive load of 600 tons. After reviewing data from the two preliminary O-cell® load tests and incorporating the information into their design, foundation engineers altered the required socket lengths to two and a half feet of rock embedment to carry the same 600-ton design load. Estimated savings on the foundations, as reported by Engineering News Record, amounted to \$9,000,000.

The O-cell data proved the side shear was 200 psi, as opposed to the 100 psi that was originally estimated.

- **Location** Secaucus, NJ
- **Owner** NJ Transit
- **Client** Case Foundation Company
- **Designers** Brennan Beer Gore Architects
- **Geotechnical Engineer** Converse Consultants East
- **Foundation Contractor** Case Foundation Company
- **Subsurface** Overburden underlain by fractured rock
- **Shaft Diameter** 66 in.
- **Shaft Length** TS1 58.8 ft.
TS2 47.1 ft.
- **O-cell Configuration** 2 x 34 in. O-cells

MAX. LOAD

- TS1 4,862 kips (21.6 MN)
- TS2 3,984 kips (17.7 MN)

O-CELL EXPANSION

- **Upward** TS1 0.3664 in.
TS2 0.8997 in.
- **Downward** TS1 1.015 in.
TS2 0.5660 in.



ARTHUR RAVENEL JR. BRIDGE

Completed in 2005, the Arthur Ravenel Jr. Bridge, honoring the former South Carolina Senator, is the longest suspension bridge on the east coast of the United States. Contractors constructed more than 400 drilled shafts to support the 2.5 mile bridge from Charleston South Carolina to Mt. Pleasant South Carolina spanning the Cooper River. The South Carolina Department of Transportation (SCDOT) turned to design-build as the preferred project delivery method, and the choice certainly paid dividends since the bridge was under-budget and opened one year ahead of schedule.

The South Carolina Department of Transportation and Parsons Brinckerhoff utilized Osterberg Cell® technology to confirm and modify shaft design. LOADTEST completed a total of 14 O-cell® tests on this project. The first 12 tests (five single levels and seven multi-levels) were performed for foundation sub-contractor Trevilcos Corporation during the fall of 2000 on dedicated test shafts. The shaft diameters were 72 inches and 96 inches in diameter and depths ranged from 100 feet to 150 feet. LOADTEST also performed CSL and Sonic Caliper for Trevilcos during this testing phase. Representatives of Trevilcos, SM&E and the South Carolina Department of Transportation observed the test shaft construction and testing.

- **Initial cost estimate for foundation prior to load testing** \$175,000,000
- **Cost of foundation load testing (static, lateral and impact)** \$7,200,000
- **Cost of foundations utilizing the test data** \$132,000,000
- **Net savings** \$35,800,000

- **Location** Charleston, SC
- **Owner** South Carolina Department of Transportation
- **Client** Trevilcos Corp
- **Designers** Parsons Brinckerhoff
- **Geotechnical Engineer** S&ME, Inc.
- **Foundation Contractor** Skanska, Flatiron - JV
- **Subsurface** Silty and clayey sand (Cooper Marl)
- **Shaft Diameter** 96 in.
- **Shaft Length** 147.5 ft.
- **O-cell Configuration** 3 x 21 in. (530 mm) upper
3 x 21 in. (530 mm) lower

MAX. LOAD

- 5,516 kips (24.5 MN)



DISCOVERY BRIDGE

The “Gateway to Yankton” as this bridge has also been referred to was opened almost a year ahead of schedule in October 2008 and replaced the Meridian Bridge. This structure is part of Hwy 81 over the Missouri River connecting Yankton, South Dakota with Cedar County, Nebraska. The bridge, a four-lane steel girder concrete deck design, was conceived “in-house” by NDOR. The bridge is nearly 1,600 feet in length and is supported by five primary piers all located in the Missouri River.

As a result of the load test program for this project, a savings of approximately \$350,000 was realized. This savings was captured by performing the load tests at the pre-design stage and incorporating the test data into the final design of the foundation. An average of 22 feet of shale rock socket was saved from the final design, reducing the total socket lengths for the project by 528 linear feet.

- Cost of performing the pre-design loads \$250,000
- Net savings derived from the re-design \$350,000
- Location Hwy 81 Missouri River, Yankton, SD
- Owner Nebraska Department of Roads
- Designers Nebraska Department of Roads (Lymon Freeman, engineer for NDOR)
- Geotechnical Engineer NDOR Geotech Section, Kleinfelder, Inc.
- Foundation Contractor Jensen Construction Co. (bridge const)
- Subsurface Loose to medium dense sand underlain by Carlile Shale
- Shaft Diameter 96 in. (2,438 mm)
- Shaft Length 115 ft. (35 m)
- O-cell Configuration 3 x 21 in.

MAX. LOAD

- 4,522 kips (20.11 MN)

O-CELL EXPANSION

- Upward 0.207 in. (5.25 mm)
- Downward 0.504 in. (12.81 mm)



ALLEGHENY RIVER BRIDGE

This bridge straddles three primary modes of transportation, river, rail and road, as well as the majestic weathered cliffs and unique environment of the river shoreline. The struggle for the Pennsylvania Turnpike Commission (PTC) was to build an aesthetically pleasing bridge while being functional in this locale. The final design proposed by FIGG resulted in the first long-span concrete bridge to be constructed in Pennsylvania utilizing a pre-cast segmental construction process. This cantilever based construction method minimized disturbance to the multi-modal traffic over 100’ below on the river valley floor.

This bridge also utilized a pre-design load testing program championed by American Geotechnical & Environmental Services (AGES) allowing the final design to save significant costs for the owner (PTC). Initial estimates of the ROI (return on investment) of the test program were in the low six-figure area. Please note below the net result far surpassed this initial ROI estimate.

- Initial cost for load test program \$375,000 (approx.)
- Estimated net savings from the load tests as a result of foundation re-design \$50,000 - \$350,000
- Actual net savings realized by re-designing the foundations after load testing \$3,500,000
- Location Allegheny Valley Interchange Allegheny County, PA
- Owner Pennsylvania Turnpike Commission
- Client Walsh Construction
- Designers FIGG Bridge Engineers
- Geotechnical Engineer American Geotechnical & Environmental Svcs
- Foundation Contractor The Goettle Company
- Subsurface Alluvium, shale and sandy siltstone
- Shaft Diameter 84 in. (2,134 mm)
- Shaft Length 111.5 ft. (34 m)
- O-cell Configuration 3 x 26 in.

MAX. LOAD

- 16,454 kips (73.19 MN)

O-CELL EXPANSION

- Upward 0.297 in. (7.55 mm)
- Downward 0.280 in. (7.10 mm)



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LOADTEST SETS ANOTHER WORLD RECORD STATIC LOAD TEST: 36,036 TONS (321 MN) ST. LOUIS, MISSOURI

ON THE COVER

A DEEP FOUNDATION PARADOX

1

PROJECT PROFILES

- FRANK R. LAUTENBERG STATION AT SECAUCUS JUNCTION
- ARTHUR RAVENEL JR. BRIDGE

2

PROJECT PROFILES

- DISCOVERY BRIDGE
- ALLEGHENY RIVER BRIDGE

3

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