Drilled Shaft Design Parameters vs Risk & Money
Business Goals

- Protect the company
  - Make money
  - Reduce risk
    - But at what point is reducing risk counter productive?
    - And at what point is reducing risk negligent?
      - Who’s risk are being reduced? The owner’s or the geotechnical engineer’s?
SECTION 02 32 00

GEOTECHNICAL INVESTIGATIONS

PART 1 GENERAL

1.01 RELATED DOCUMENTS
   A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 1 Specification Sections, apply to this Section.

1.02 GEOTECHNICAL DATA
   A. A Soils Report is available from the Owner.
   B. The Soils Report is made available for the convenience of the Contractor. Data on the indicated subsurface conditions are not intended as representations or warranties of accuracy or continuity between soils borings. It is expressly understood that Owner will not be responsible for interpretations or conclusions drawn therefore by Contractor. Contractor may make additional test borings and other exploratory operations at his own expense and no additional cost to the Owner.

END OF SECTION
Reducing Risk in the Specifications

- Whose seal is missing?
- Is this indicative of the geotechnical engineer’s importance to the job?
- Is this indicative of the architect’s and owner’s perspective of the geotechnical engineer’s role on the job?
- Out of sight...out of mind?
Relevancy

- Is there a way to make the geotechnical engineer more relevant?
- ...a larger part of the project?
- ...an asset to the project?
- ...a key player throughout the design and construction process?
- *Consider stop doing what you’ve always done because it’s the way you’ve always done it*
Design Parameters

How do geotechnical engineers predict drilled shaft capacities?

Historical values?
Are they correct?
Where did they come from?

Commercial software?
Your still inputting variables, are they correct?

FHWA Guidelines?
\[ q_{BN} = N_{CR} \times q_u \]

Copy the last project? Or copy the engineer down the street?

Recommendation
Published Research

- **ADSC/Dan Brown & Associates**
  - **Lawrenceville, GA Load Test Program**
    - Rock auger only
    - 200 ksf allowable end bearing
    - 15 ksf allowable side friction
  - **Nashville, TN Load Test Program**
    - 6 inspectors rejected the bearing condition
    - 200 ksf allowable end bearing in “fair rock”
    - 500 ksf allowable end bearing in “sound rock”
    - 20 ksf allowable side friction
Common recommendation for hard rock: 100 ksf (kips per square foot)

\[
\frac{100 \text{ kips}}{\text{sq ft}} \times \frac{1 \text{ sq ft}}{144 \text{ sq in}} \times \frac{1000 \text{ lbs}}{1 \text{ kip}} = \frac{694 \text{ lbs}}{\text{sq in}}
\]

100 ksf = 694 psi

Or a good flowable fill
Load Testing

If a load test didn’t cost anything... would you use it more often?

If load test data from similar rock was available... would you use it?

The savings from a load test typically far exceeds the cost of the test.
# Boring Log

**Project:**

**Boring No.:** B-2A

**Total Depth:** 39.2'

**Elev.:**

**Location:** Nashville, TN

**Date:** 7/2/08

**Water at Completion of Drilling:** Not Encountered

**Boring Method:** Hollow Stem Auger

**Drill Type:** CME-550

**Driller:** LS

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<th>Sample</th>
<th>DESCRIPTION OF MATERIALS</th>
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Sample Project

30 drilled shaft structures
Axial working load of 3,000 kips
Rock at 15’ depth, earthen material above
Assume 1% reinforcing full depth
Design with End Bearing Only

**Option A**
- 50 ksf allowable end bearing value
- Diameter = 108”
- 18’ Rock Excavation
- Volume = 3,032 CY
- Rebar = 313,700 LBS
- Cost = $1,720,000

**Option B**
- 100 ksf allowable end bearing value
- Diameter = 78”
- 13’ Rock Excavation
- Volume = 1,342 CY
- Rebar = 139,660 LBS
- Cost = $1,085,000
Question: If a crane were attached to the top of a drilled shaft and an upward force equal to the weight of the drilled shaft (concrete + rebar) was exerted—will the shaft come out of the ground?

Most load tests indicate the top load is completely carried in skin friction and never reaches the tip of the drilled shaft. Yet skin friction is often ignored.

Conclusion: Skin friction exists in drilled shafts and should be used in conjunction with end bearing when determining the load bearing capacity of the drilled shaft.
Option C

- 100 ksf allowable end bearing value
- 3.5 ksf shear in the rock zone
- Diameter = 66”
- 11’ Rock Excavation
- Volume = 892 CY
- Rebar = 104,00 LBS
- Cost = $895,000
But is there a better solution?

Option D

Implement a load test program to determine actual design values

Take advantage of LRFD and modify your reduction factor

Gain data that can be used on future projects and continue to show Owners why you are valuable
Skin Friction Test Results

Mobilized Net Unit Side Shear
TS-1 - ADSC Research Project - Nashville, TN

Field value = 24 ksf

Historical value = 3.5 ksf
End Bearing Test Results

Mobilized Unit End Bearing
TS-1 - ADSC Research Project - Nashville, TN

Note: This analysis assumes that the entire applied load is taken in end bearing over the 39-inch diameter loaded area at the base of the pile (36" bottom plate plus 2:1 load distribution over the 0.25 ft below the O-cell)

Range of historical values

LOADTEST, Inc. Project No. LT-9507
Verified Ultimate Capacities

- 500 ksf ultimate end bearing value
- 24 ksf ultimate shear value

Less rock excavation equals faster construction schedule

Working Capacities

- LRFD Value of 0.6
- 300 ksf allowable end bearing
- 14.4 ksf shear

Smaller diameter shaft, smaller equipment, less materials used

Parameters

- Diameter = 36”
- Rock excavation reduced to 8 lf
- Volume = 235 CY
- Rebar = 28,000 LBS

LEED credits?

Cost

- $574,000 Plus $80,000 load test
- Total Cost = $664,000
**Simple Decision Variance**

**Options A-C**
- **Diameter**: 66” - 108”
- **Volume**: 892 to 3,032 CY
- **Rebar**: 104,000 to 313,700 LBS
- **Cost**: $895,000 to $1,720,000

**Option D**
- **Diameter**: 36”
- **Volume**: 235 CY
- **Rebar**: 28,000 LBS
- **Cost**: $664,000 (including load test)
COST RAMIFICATIONS OF DESIGN PARAMETERS

CASE STUDIES
Downtown Atlanta

**Original Design**
- 72” diameter
- 55’ deep
- 5’ embedment into Fractured Biotite with Gneiss at the tip
- 80 ksf end bearing
- $2,000,000 foundation package

**Proposed Change**
- Building height increased leading to increased loads.
- Could 100-120 ksf be proven via a load test to avoid a change order?

**Post Load Test**
- 338 ksf at 0.05” bearing displacement
- Side shear carried 2,600 kips at less than 0.10” movement
- First win: No change order, saved $150,000 net of $50,000 load test
- Second win: Concern for hard rock excavation subsided. Smaller shaft sizes. Estimating an additional $500,000 savings
Concern for downdrag due to fill material
Permanent coated casing designed to negate effects of downdrag

Geotechnical report indicated an allowable rock end bearing of 90 ksf
Allowable skin friction in rock = 5 ksf
5’ rock socket required to achieve design capacities

Measured unit end bearing = 600 ksf
Measured skin friction in rock = 10.9 ksf
Based on load test results...permanent coated casing eliminated...rock socket lengths reduced...drilled shaft diameters reduced

Base Bid = $2,250,000
Total credit to owner = $421,000

Cost of the load test is irrelevant...
Owner saved $421,000!
Bryant-Denny Stadium – Tuscaloosa, AL

Project was over budget and looking for value engineering suggestions.

Conservative engineering practice of neglecting skin friction in soil above a rock socket was used in design.

A drilled shaft load test was recommended, but was initially rejected by design team.

It was suggested the design parameters used in the design were adequate and no significant gain would be yielded.

As-bid allowable skin friction value in soil above rock = 0 ksf

Actual allowable skin friction value in soil above rock = 2.2 ksf
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RESULTS:
Significant reduction in shaft diameters and rock sockets

A portion of the project utilized augercast piles; all augercast piles were replaced with the more economical drilled shafts

Total savings to University of Alabama ~$325,000
(Original bid ~$1,200,000)
Some Other Examples of Post Load Test Changes:

- **Louisville and Southern Indiana Ohio River Downtown Bridge**
  - Design End Bearing: 0 ksf
  - Actual End Bearing: 600 ksf

- **UTA Trax North Temple Bridge, Salt Lake City, UT**
  - All shafts reduced 25%-40% in diameter and length
  - cost savings = $600,000

- **Sellwood Bridge, Portland, Oregon**
  - Existing load test data allowed the contractor to eliminate or shorten significantly all 30 rock sockets

- **St. Joseph Outpatient Hospital, Chicago, Illinois**
  - Original design included belled shafts on hardpan with end-bearing values of 15-25 ksf. (The bells collapsed). Load tests showed end-bearing on dolomite (5-10 feet below the hardpan) using a design end-bearing value of 180 ksf.
- **Project in California**
  - Foundation estimate: $850,000
  - Cost of test: $79,000
  - VE Foundation result: $610,000
  - Net Savings: $161,000

- **Project in Florida**
  - Foundation estimate: $6,200,000
  - Cost of test: $365,000
  - VE Foundation result: $4,980,000
  - Net Savings: $855,000
- **Project in North Carolina**
  - Foundation estimate: $32,500,000
  - Cost of test: $2,000,000
  - VE Foundation result: $24,500,000
  - Net Savings: $6,000,000

- **Project in New Jersey**
  - Foundation estimate: $18,000,000
  - Cost of test: $255,000
  - VE Foundation result: $8,900,000
  - Net Savings: $8,845,000
- **Project in South Carolina**
  - Foundation estimate: $160,000,000
  - Cost of test: $7,500,000
  - VE Foundation result: $125,000,000
  - Net Savings: $27,500,000

- **Project in Georgia**
  - Foundation estimate: $3,276,000
  - Cost of test: $240,000
  - VE Foundation result: $3,003,000
  - Net Savings: $33,000
SUMMARY

• It is feasible to increase your fees, reduce your risks, and become a valuable member of the design team.
• Additional testing can improve conservative designs; while managing risks and reducing budgets.
• Drilled shafts in particular are one of the most reliable, most inspected, highest capacity deep foundation systems in the country; and yet one of the most inefficiently designed foundations.
• Innovative thinking and improved design work can save significant money.