
VDOT

A Virginia DOT Approach to Statistical Geotechnical Analysis Based on Limited Data

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Introduction

The Issue: Geotechnical Data is often limited, especially for a specific project.

The Problem: How to be confident of your data.

The Solution: Apply consistent judgment and/or a rigorous statistical analysis to back up your engineering judgment. Always strive for rigor, consistency, and transparency.

Introduction

What statistical devices to use?

At VDOT Materials Geotechnical, we have begun looking at various easily implemented methods based on being (95%) confident in your average or “best” value.

Introduction

- Began by looking at t-test to answer question: How do you know your average is good when you have limited data?
- There is a lot written about standard deviation, but not about ensuring your mean “best’ value” is correct.

Introduction

Pieced methods together from:

- t-test and CI work from “Statistics for Dummies”
- ASTM E122 – Sample Sizes
- 2δ – Empirical rule-of-thumb
- Background and Chauvenet’s Criterion from “An Introduction to Error Analysis” by Taylor
- Making no claim of independence among methods.

T-test

- Usual rule of thumb (CLT), you need about 30 samples to assume a good distribution.
- If you have <30 samples, the Student t-test distribution should be used.
- This test invokes a penalty for having limited data – the fewer samples, the greater the penalty (weaker or larger the confidence interval).

Other devices

We will apply the t-test to get our best, conservative average value to use.

For comparison, we may analyze other standard deviation based methods.

We examine extreme values.

Are looking to begin building database with these devices.

ASTM E122

ASTM E122

Generally, ASTM has a method for everything. Peruse standards.

E122

- Uses the Empirical (3δ) rule
- Points out less knowledge, greater sample size req'd.
- Sample size accounts for precision desired.

ASTM E122

$n = (3\delta/E)^2$ (or use 2δ for 95% CI)

Allows you to calculate sample size you need based on precision you want (need estimate of δ)

Alternately, allows you to calculate precision if you already have the sample size.

2δ Rule

Empirical Rule says 95% of all data results should be within 2 standard deviations of sample mean.

Helps you to establish reasonable estimates of standard deviation.

Should not be used to establish your confidence interval for average values.

Example #1

VDOT project – CH borrow shear strength based on 4 UU triaxial tests.

Values:

- 2,475 psf
- 2,310 psf
- 2,470 psf
- 2,705 psf

Example #1

Average value is 2,490 psf – use 2,490

T-test – use 2,300 psf

95% CI neglecting t-test – use 2,330 psf (even though n small, values close and rounded)

2δ method – use 2,170 psf

E122 – use 2,330 psf

Upshot – use 2,300 psf vice 2,490 psf; use in traditional way or with other statistical methods making use of STDEV

Example #2

VDOT project where 10 SPTs were made in a similar CH/CL/MH stratum.

Values (bpf):

- 27 -6
- 10 -10
- 13 -14
- 13 -8
- 16 -13

Example #2

Average value is 13 bpf – use 13

T-test – use 9 bpf

95% CI neglecting t-test – use 9 bpf

2δ method – use 1 bpf

E122 – use 9 bpf

Upshot – use 9 bpf vice 13 bpf

Example #2

Should any of the extreme data be dismissed?

27 bpf at high end, 6 and 8 bpf at low end.

Use Chauvenet's Criterion:

- Simple and rigorous.
- Result is throw out 27 bpf.
- New average and δ are 11 and 3.

Example #2

New average value is 11 bpf – use 11

T-test – use 9 bpf

95% CI neglecting t-test – use 9 bpf

2δ method – use 5 bpf

E122 – use 9 bpf

Upshot – use 9 bpf vice 11 bpf

Example #3

5 borings for a bridge (2 abutments).

Collected 5 cores, tested each in UC and PLT.

2 distinct rock types – gneiss and metasandstone.

Results were too few and widely varying to do anything with statistically.

Would point to more samples needed.

Other considerations

Extrapolation of data:

If you measure uncertainty, you can extrapolate!

The further outside of your measured value range, the wider the error bars get.

See Taylor 1982, page 162.

Other considerations

Observational approach:

A lot of talk, not much documentation.

Afraid to document it? Not well organized?

Show calculations. Afraid? Too much liability? Too easy? Can show value of experience with statistical calcs.

Conclusions

Rigorous, transparent, consistent.

Statistical methods can be quick and comparable.

Can force “digging up” more data; get more out of databases.

Does not obviate judgment.

Significant figures are important!