Foundation Design: Presumptive vs. Measured Strength of the Burlington Limestone

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Overview

The campus of the University of Missouri is underlain by Burlington Limestone. The foundations of new structures on campus are often placed into this bedrock, as it provides superior strength and stability. When designing deep foundations, the strength of the bedrock must be known, and this strength influences how robust the foundation must be. The weaker the bedrock, the larger and more expensive the foundation. Often, foundation designers will use an assumed, or "presumptive," value of strength for the bedrock, rather than sample and test the rock. By necessity, a presumptive strength must be very conservative, resulting in an overly robust and expensive foundation.

Hypothesis

The use of presumptive rock strengths is resulting in over-designing new foundations on Burlington Limestone. We can reduce foundation costs by using the measured rock strengths for design while still maintaining high reliability (safety).

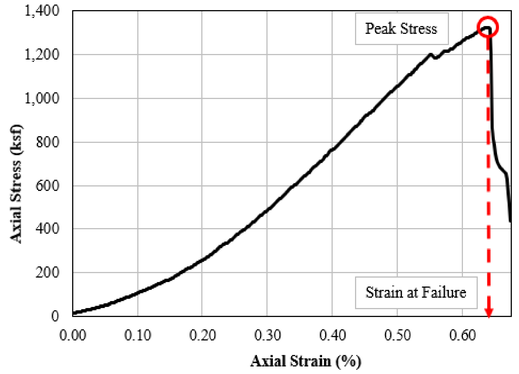
Methodology

Measuring rock strength involves collecting field-drilled samples from a site and testing them in a lab via an unconfined compression test. Twenty (20) specimens of Burlington Limestone were collected near Mizzou's campus. The rock cores were 2 inches in diameter and were cut into 4-inch lengths. Five such specimens are shown below:

Each specimen underwent an unconfined compression test, where a machine increases the axial load on the rock until it cracks, as shown at right. The maximum load, or stress, applied to the specimen is recorded as its unconfined compressive strength (q_u), measured in kips (1,000 pounds) per square foot (ksf).

Methodology

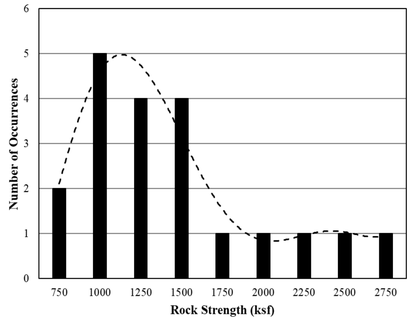
The unconfined compression test records the axial stress and strain of the rock specimen, expressed in the following plot:



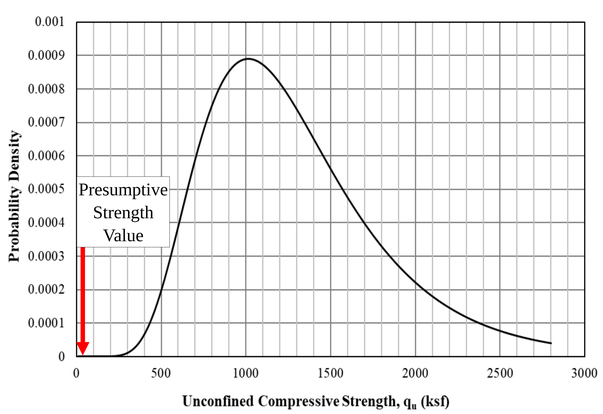
This plot shows the build-up of stress and resulting strain on the specimen. The peak stress is reached when the specimen cracks in a rapid failure. Twenty (20) rock cores were tested.

Results

Testing Results	
Maximum Strength (ksf)	2691
Minimum Strength (ksf)	589
Average Strength (ksf)	1300
Standard Deviation (σ)	551.4
Coefficient of Variation (c.o.v.)	0.42
Average Peak Strain (%)	0.675



The histogram of the measured rock strengths shows a lognormal distribution. The average strength was 1300 ksf, with a standard deviation of 551 ksf. These parameters produced a probability density function (PDF - below) and cumulative density function (CDF – top right). The CDF shows the probability that Burlington Limestone rock will fall below a certain strength.



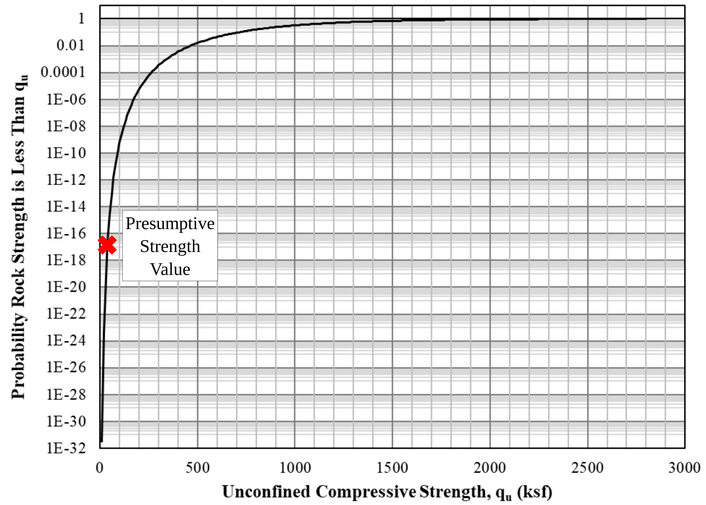
Presumptive Strength
40 ksf

Average Measured Strength
1300 ksf

Excessive Cost!

Results

On both probability plots, the commonly used presumptive value of rock strength, 40 ksf (Dummerth, 2017), is marked in red.



The results show that the common presumptive value of rock strength, 40 ksf, is well below the measured strengths - the rock has a very low chance (one in 10^{17}) of being weaker. A strength value of 270 ksf has a one in ten-thousand (1/10,000) reliability, or probability that the actual rock strength will be less. Using this value, which is six-times higher, would decrease the foundation costs for a structure, while still maintaining a high level of safety.

Conclusions

The strength of the Burlington Limestone beneath Mizzou's campus is far stronger than the presumptive strengths many designers are using. Using measured results will prevent the over-designing of new foundations on Mizzou's campus and reduce costs. Every new project on campus should include rock sampling and testing, and the results should be kept in a database. This will make foundation design safer and more economical year after year.

What's next? More rock specimens must be tested to ensure representative results and to document the geologic variability of the Burlington formation.

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