Redefining the Role of Geology in Site Geo-Characterization for LRFD Projects

Focus on karst terrain

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Two Approaches: ASD versus LRFD

- Values of Q and Rn are assumed to be unique with their probability of occurrence equal to one
- Selection of FS is subjective – it depends on the design models used and material parameters chosen and is not inherently related to the probability of component failure
- Risks and uncertainties associated with the safety of a system are defined in mathematical terms
- Uncertainties (or distributions) of load and resistance are assumed to be independent, random variables, and the design risk is defined by the probability of failure ($p_f$)

Figures from FHWA HI-98-032 (May 2001)
A Closer Look: LRFD

\[ \sum \gamma_i Q_i \leq \phi R_n \]

\( \gamma_i = \text{statistically based load factor (generally } > 1) \)
\( Q_i = \text{load} \)
\( \phi = \text{statistically based resistance factor (generally } < 1) \)
\( R_n = \text{ultimate resistance} \)

The value of \( \phi \) accounts for:
- Variability of soil and rock properties
- Reliability of equations used for predicting resistance
- Quality of the construction workmanship and quality control programs
- Extent of soil exploration (little versus extensive)
- Consequence(s) of a failure

Can a single \( \phi \) value represent the complexity of geology?

Incorporation of LRFD Aspects into Site Geo-Characterization

Rowe (1972) suggests categorizing projects into three groups based on site characterization requirements

- **CLASS A**: important and risky projects where the complexity of local geology necessitates extensive investigation and design decisions require a great deal of subsurface information

- **CLASS B**: the relationship between modest risk and tolerable uncertainties in site conditions makes the question of how much exploration and investigation is needed difficult to answer

- **CLASS C**: projects with routine use and low risk where relatively straightforward site conditions require little investigation

LRFD Necessary

LRFD not Necessary
Probability is in the model and not the ground (Baecher and Christian, 2003)

Once a geological formation (or formations) have been deposited, the spatial distribution of structures or material properties is fixed (neglecting changes over time).

We do not know the distribution but the distribution is not random.

Two distinct categories of uncertainty (distribution):

- Aleatory (inherent or natural) – represents the randomness of a property
- Epistemic – due to the lack of knowledge

LRFD Requires the Incorporation of Statistical Measures

Basic Statistics:

- Mean value $\bar{x} = \frac{\sum x_i}{N}$
- Standard deviation $\sigma = \sqrt{\frac{\sum (x_i - \bar{x})}{N-1}}$
- Coefficient of variation $COV = \sigma / \bar{x}$

Advanced Topics:

- Trend analysis
- Autocorrelation
- Geostatistics
Focus on Karst Terrains

- Topography formed in unconsolidated sediments (soils) that overlie limestone, dolomite or other soluble rock

- Want to associate weathering with properties

- Karstic limestone does not fit into any weathering classification system
  - Must develop site specific weathering descriptions and relationships

Karst Terrain Difficulties

**Undulating Bedrock Surface & Cavities**

*Within a horizontal distance of 10 m the bedrock depth drops 10 meters*
Karst Terrain Difficulties

Variable Properties with Depth

Difficult to obtain specimens for testing (7 specimens in 30 feet of core). Need to use index tests to augment data.

Properties do not necessarily improve with depth

Properties are quite variable

Karst Terrain Difficulties

Require Incorporation of Geophysics

This is not a single limestone unit as indicated in the drilling logs
Facilitating the Adoption of LRFD Methodologies

This is the responsibility of geotechnical engineers and engineering geologists who are well versed in site geo-characterization.

LRFD methodologies are important to use, especially for sites with complex geology and important structures.

What can “WE” do?

- Education and training of future and practicing geo-professionals
- Educate the public and other design and construction professionals on the importance of site geo-characterization
- Incorporate appropriate methodologies into geo-design software