GEOTECHNICAL REPORTS AND HOW TO MAKE SENSE OF THEM

A Seminar Presentation by
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Contents of a Geotechnical Report

- **Contents vary depending on goals, size of project, types and importance of structures, etc.**
- **A geotechnical report is expected to include some or all of the following:**
  - **Summary Geology of the site**
  - **A plan of field investigation**
    - **Boreholes**
    - **Drilling into bedrock**
    - **Test Pits**
    - **Other**
  - **Index Testing**
    - **Sieve analysis**
    - **Atterberg Limits**
    - **Classification**

Contents of a Geotechnical Report

Continued

- **Laboratory Testing**
  - **Strength Tests**
    - **Material Parameters (c, ϕ)**
  - **Compressibility Tests**
    - **Modulus of elasticity**
    - **Compression and recompression index**
  - **Swelling Tests**
    - **Swelling index**
    - **Swelling pressure**
  - **Chemical Tests**
    - **Sulfates**
    - **Chlorides**
    - **pH**

Contents of a Geotechnical Report *Continued*

- **Shallow footings**
  - **Allowed pressures**
  - **Maximum Settlements**
  - **Often missing from the Geotechnical Reports:**
    - **Effects of depth of embedment**
    - **Effects of footing size**
    - **Effects of load inclination**
    - **Effects of load eccentricity**
    - **Seismic effects**
- **Pile foundations**
  - **Recommended minimum length and cross-section**
  - **Allowed axial loads**
  - **Settlement (some times)**
  - **Often missing from the Geotechnical Reports:**
    - **Lateral load bearing capacity**

Contents of a Geotechnical Report
Continued

- **Other information that is <u>often</u> missing**
  - **Factors of safety that were used for the pressure and load recommendations**
  - **Description of the basis of design**
  - **Justification of the recommendations**
  - **IN OTHER WORDS: NO CALCULATIONS PACKAGE**

Evaluation of Recommendations

- **Issues**
  - **Recommendations are often unsubstantiated**
  - **This makes it hard for the user of a geotechnical report to verify any of the recommendations**
  - **A significant problem with unsubstantiated reports, is that they handicap the QA/QC processes of the firm that produces them AND the engineers that use them.**
  - **Geotechnical Engineering is based much more on Standard Engineering Practice rather than Codes**

Evaluation of Recommendations *Continued*

- **Should we verify?**
  - **Trust <u>BUT</u> verify**
  - **Geotechnical Engineers are often very conservative**
  - **At times, geotechnical reports received from the same company on different sites appear to be suspiciously similar**
  - **Geotechnical Engineers have developed the culture that if their evaluations are higher than the ones specified by IBC, they cannot be correct**

Evaluation of Recommendations *Continued*

Here are the presumptive load-bearing values from IBC, followed by the instruction for use (article1806.2)

TABLE 1806.2
PRESUMPTIVE LOAD-BEARING VALUES

CLASS OF MATERIALS	VERTICAL FOUNDATION PRESSURE (psf)	LATERAL BEARING PRESSURE (psf/ft below natural grade)	LATERAL SLIDING RESISTANCE	
			Coefficient of friction[a]	Cohesion (psf)[b]
1. Crystalline bedrock	12,000	1,200	0.70	—
2. Sedimentary and foliated rock	4,000	400	0.35	—
3. Sandy gravel and/or gravel (GW and GP)	3,000	200	0.35	—
4. Sand, silty sand, clayey sand, silty gravel and clayey gravel (SW, SP, SM, SC, GM and GC)	2,000	150	0.25	—
5. Clay, sandy clay, silty clay, clayey silt, silt and sandy silt (CL, ML, MH and CH)	1,500	100	—	130

For SI: 1 pound per square foot = 0.0479 kPa, 1 pound per square foot per foot = 0.157 kPa/m.

a. Coefficient to be multiplied by the dead load.

b. Cohesion value to be multiplied by the contact area, as limited by Section 1806.3.2.

1806.2 Presumptive load-bearing values. The load-bearing values used in design for supporting soils near the surface shall not exceed the values specified in Table 1806.2 unless data to substantiate the use of higher values are submitted and *approved*.

Evaluation of Recommendations *Continued*

- **The table 1806.2 of the previous slide was taken from IBC 2012. However, it is the same (or very similar) to the recommendations of previous as well as following versions of IBC.**
- **A careful read of article 1806.2 (also in the previous slide) indicates that these values are not to be exceeded UNLESS data to substantiate the use of higher values are submitted and approved.**
- **Through the years, it appears that many geotechnical engineers pay no credence to the "data to substantiate the use of higher values" part of this statement.**
- **All this statement means is that valid test data and accepted analytical tools may be used to allow the engineer to use higher bearing capacity values.**
- **It should be noted that decisions on allowed bearing loads SHOULD NOT be made without establishing the following:**
  - **What is the size of the footing?**
  - **What is the shape of the footing (square, rectangular, long)?**
  - **What is the depth of embedment?**
  - **What is the allowed settlement?**

Evaluation of Recommendations

Reality Check

- **Your vehicle (sedan) drives on tires which are inflated at approximately 30 psi. Your SUV tires are typically inflated to higher pressures (in the order of 40 psi)**
- **This means that the tires apply a pressure on the ground, which is equal to 30 psi**
- **30 psi is 4320 psf**
- **An allowed pressure of 1500 psf implies that you cannot drive your vehicle over that space, or even if you can, the tire will sink into the ground, leaving very deep marks.**
- **A construction truck has tires with pressures anywhere between 80 and 100 psi (11500 to 14400 psf). How will these trucks access a site with an allowed bearing pressure of 1500 psf?**

Evaluation of Recommendations
Reality Check - Continued

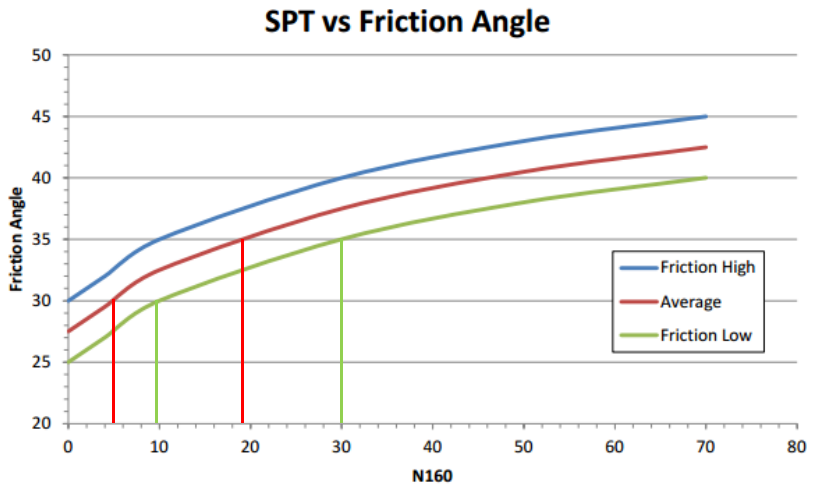
- **Bearing capacity is evaluated based on some variation of Terzaghi's equation:**
- $q_u = cN_c + \gamma D_f N_q + \frac{1}{2}\gamma B N_\gamma$
- $q_u = \gamma D_f N_q + \frac{1}{2}\gamma B N_\gamma$ **if we ignore cohesion.**
- **For** $\phi = 30^o$ **(loose sand), and depth of embedment of 4 ft, a square footing with width 5 ft. and soil density 100 pcf, the above equation produces an allowed bearing pressure of 5700 psf based on a factor of safety of 3. The corresponding settlement is 1.45 in. using calculations based on Schmertmann's theory.**
- **The above allowable pressure is reduced to 4200 psf if the settlement is to be reduced to 1.00 inch.**
- **For the same conditions, a LONG footing, restricted to 1 inch of settlement, has an allowed bearing pressure of 2500 psf!**

Evaluation of Recommendations
Reality Check - Continued

- **For $\phi = 35^o$ (medium dense sand), and depth of embedment of 4 ft, a square footing with width 5 ft. and soil density 100 pcf, and a restricted settlement of 1 in. results in an allowed bearing pressure of 8300 psf.**
- **For the same conditions, a long footing restricted to 1 inch of settlement has an allowed bearing pressure of 4800 psf!**
- **If you review your old geotechnical reports you will often find a disconnect between the tested friction angle ϕ and allowed bearing pressure.**
- **<u>It is not unreasonable</u> to ask justification for the recommendations presented in the geotechnical report.**

Evaluation of Recommendations
Reality Check - Continued

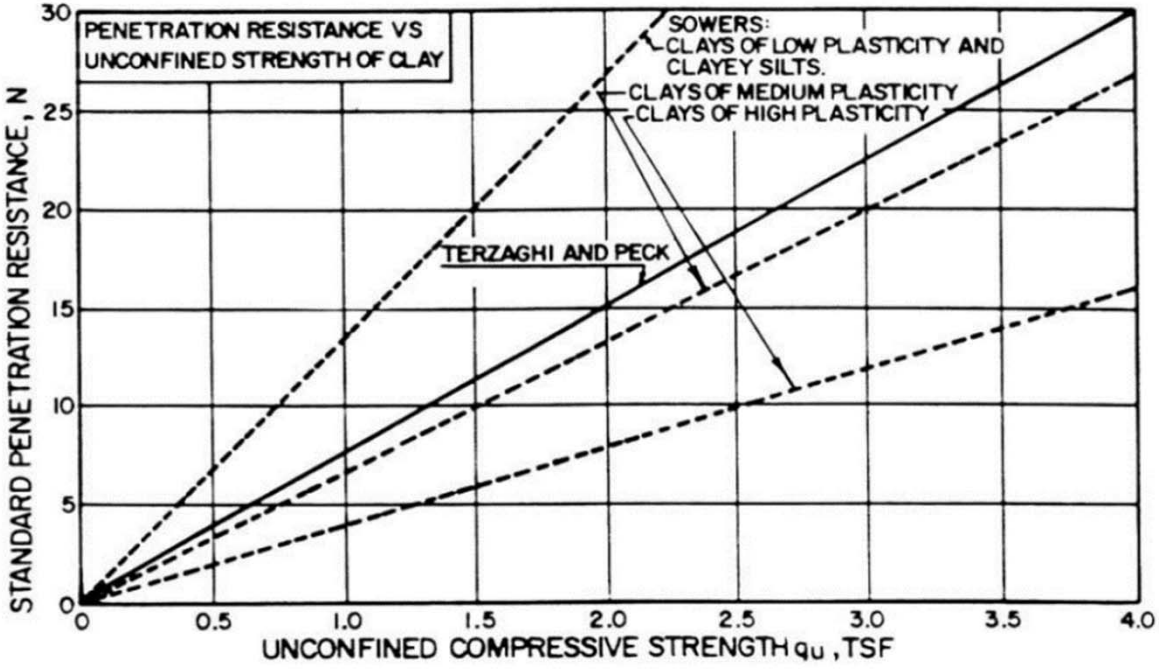
As can be seen here, from the Caltrans manual, a friction angle of 30 degrees corresponds to SPT blow counts, *corrected for depth*, between 5 and 10 (ignoring the less conservative upper range of values).



Evaluation of Recommendations
Reality Check - Continued

Similarly, from the chart below, a clay of medium plasticity with an SPT blow-count of 10 has an unconfined compression strength $q_u = 1.5\ tsf = 3000\ psf$. This is equivalent to an undrained shear strength $s_u = 1500\ psf$.

For this soil, and depth of embedment of 4 ft, a square footing with width 5 ft. has an allowed bearing pressure of 2800 psf based on allowed settlement of 1.00 in. The corresponding factor of safety against failure is 4. The numbers are better for a low plasticity clay or silt.



In Conclusion

- **Geotechnical reports represent the experiences of the Geotechnical Engineers that have prepared them**
- **HOWEVER, geotechnical reports may also represent the most conservative instincts of the Geotechnical Engineer, and may offer unnecessarily expensive solutions IF these recommendations are unchallenged**
- **Geotechnical Engineers tend to provide recommendations based on their past experiences on similar soils, and may skip essential testing. HOWEVER, conditions are not always as similar as they appear.**
- **The ability of the Structural or Geotechnical Engineer to independently verify the recommendations of the geotechnical report is thus essential**

In Conclusion
Continued

- **The difficulty of verification effort increases in this order:**
  - **Allowable pressures of shallow footings**
  - **Evaluation of settlements of shallow footings, although in MOST cases a factor of safety of 3 should guarantee settlements that do not exceed one inch**
  - **Swelling pressure and minimum pressure of a shallow footing in swelling soils**
  - **Allowed axial capacity of piles and drilled shafts**
  - **Evaluation of settlements of piles and drilled shafts**
  - **Evaluation of the ability of piles and drilled shafts to resist uplift in swelling soils**
  - **Capacity of piles to resist lateral loads**
  - **Pile groups under axial compression**
  - **Pile groups under lateral forces**
  - **Flexible retaining structures**
  - **Slope Stability**
- **Geotech Master™ (http://qsystemsengineering.net/default.html), when used property, can be very helpful on the effort to achieve proper, safe, yet economical, designs.**