SOLUTIONS MANUAL FOR

"THE ENGINEERING OF FOUNDATIONS"

BY RODRIGO SALGADO

PREFACE

This manual was prepared to accompany "The Engineering of Foundations" a McGraw-Hill text. I prepared it with the assistance of Hoyoung Seo and Prasenjit Basu, Ph.D. students at Purdue University in 2006. When I was looking for someone to help me develop the solutions to the problems in the book, Hoyoung and Prasenjit were indicated to me as two of the most detail-oriented individuals that anyone could ever hope to meet. I have found that to be true, and have enjoyed working with both greatly in the preparation of the manual.

We have developed solutions in detail, providing intermediate steps and numbers to facilitate the work of instructors and their teaching assistants. In many cases, MS Excel spreadsheets were used to solve the problems. Rounding functions available in Excel were used in intermediate steps (a procedure that reproduces hand calculations with intermediate rounding). We often used higher precision than would be typically used in practice with the goal of facilitating checking student calculations, particularly in intermediate steps. Final results were in most cases rounded to more appropriate precision levels. Many of the problems are open-ended or design-oriented, in which case there is not a single solution. In these cases, we have provided what we deem to be the best solution, and have sometimes gone beyond a number of iterations that would typically be considered sufficient.

The manual is a large document, which took considerable effort to prepare in time for publication with the textbook. We would therefore appreciate receiving feedback concerning the solutions, including any possible error that may have evaded us. I will update it twice a year.

R.S.

West Lafayette, IN 47906

CHAPTER 1 THE WORLD OF FOUNDATION ENGINEERING

Conceptual Problems

Problem 1-1 Define all the terms in bold contained in the chapter summary.

SOLUTION:

Engineering science: Engineering science is a general term used to describe the elements of mathematics, physics (notably mechanics and its branches), chemistry and biology that may be used to solve engineering problems.

Empirical rules: Empirical rules are rules based on experience or the observation of experiments without reference or basis on the scientific method or on theory.

Experience: Experience is the accumulated knowledge of a professional or profession. It allows insights that help connect theoretical knowledge to real problems and thus to better execute.

SI units: Are units that are part of the SI, an absolute system in which the basic units are the meter, the kilogram and the second. SI is not synonious with "metric". It is almost universally used. Key SI units are as follows:

S-Table 1-1

Quantity	SI
L(length)	m
M (mass)	kg
T(time)	s
F(force)	Newton (N)
$g_c =$	$1 (m/s^2)$ (kg/N)

U.S. customary units: The US customary system of units is largely based on the original English system. U.S. units are based on the foot (ft) for length and pound for force. The following are key units in the US customary system:

S-Table 1-2

Quantity	Absolute or LMT system	Gravitational or LFT system
L (length)	ft	ft
M (mass)	lb	lb
T (time)	s	s
F (force)	poundal	slug
$g_c =$	$1 (ft/s^2)$ (lb/poundal)	$1 (ft/s^2)$ (slug/lbf)

End

Problem 1-2 Obtain a code (either a local code or a broader code if a local code is not available) and the ASTM standard for the cone penetration test (CPT). Can you distinguish between the goals of each document? Explain both what the goals are and how they are achieved by the way the document is organized and written.

SOLUTION:

Code and Standard collected:

Foundation code: *Building Code Requirements for Structural Concrete (ACI 318-05) and Commentary (ACI 318R-05)*

ASTM standard: *D3441-98 Standard Test Method for Mechanical Cone Penetration Tests of Soil.*

Goal:

The goal of the code is to provide minimum requirements for design and construction of structural concrete elements of any structure erected under requirements of the legally adopted general building code (as per ACI 318R-05). Its purpose is to make sure that if a concrete structure is designed according to code specifications, then it will be safe and economic.

The goal of the standard is to provide the details of the cone penetration test method and make sure that the cone penetration test performed at different sites follow approximately the same procedures and uses similar equipment. The test method depicted here covers the determination of end bearing and side friction, the components of penetration resistance that are developed during the steady, slow penetration of a pointed rod into soil (as per ASTM D3441-98).

Achievement of goals:

The code provides the rules for design of all concrete structures including building foundations. It gives a detailed view of plain and reinforced concrete design, concrete containing prestressing steel, and nonprestressed reinforcement in different chapters. It covers all design details and achieves its goal.

In contrast, the standard gives the details of the test procedures to be followed at the time of the test is performed, of the type of penetrometer to be used, and of techniques, precautions and interpretation of the test results. This ensures a standard of repeatability for cone penetration testing anywhere it is performed so long as the recommendations of the standard are followed.

End

Problem 1-3 What are the engineering licensing requirements for your state or country?

SOLUTION:

In Florida, for example, the licensing requirements are as follows:

1. obtaining a civil engineering degree (preferably from an ABET-accredited institution),

2. taking Fundamentals of Engineering (FE) exam focusing on engineering science and becoming an Engineer Intern (EI) or Engineer-in-Training (EIT),

3. gaining engineering experience for a certain time, preferably under the supervision of someone already having an engineering license, and being involved in work of increasing responsibility,

4. taking the second exam in the licensure process, the Principles and Practice of Engineering (PE) exam.

Those who pass this exam become professional engineers in the state in which they take the exam.

(Reference: http://www.ncees.org)

End

Problem 1-4* Select a firm working in the foundation engineering industry. The company may be active in your area, you may have worked as an intern for it, or someone you know may have worked for this firm. Research the company's operations. Which niche(s) of the market is the firm in? Is it a private or public company? How is it organized? What positions do engineers occupy in this firm? Do you have access to the financial reports of the company? Can you identify any of the financial ratios we discussed? If so, would you be able to gauge how well this firm is doing?

SOLUTION:

No solution provided.

End

Problem 1-5 Can you identify a major conference that has taken place this year with focus on foundation or geotechnical engineering? Which organization was mostly responsible for organizing the conference? Provide examples of topics that were discussed in the conference.

SOLUTION:

Major conference on Geotechnical Engineering-**Geo-frontiers, 2005**

The **Geo-Institute (G-I)** was mostly responsible for this.

Some of the main topics discussed are as follows-

- Foundations

  Ex: Duncan, J. M., Robinette, M. D., and Mokwa, R. L. (2005). "Analysis of laterally loaded pile groups with partial pile head fixity." *Geo-Frontiers 2005, Jan 24-26 2005,* American Society of Civil Engineers, Reston, VA 20191-4400, United States, Austin, TX, United States, 825-840.

- Waste Containment

  Ex: McRory, J. A., and Ashmawy, A. K. (2005). "Polymer treatment of bentonite clay for contaminant resistant barriers." *Geo-Frontiers 2005, Jan 24-26 2005,* American Society of Civil Engineers, Reston, VA 20191-4400, United States, Austin, TX, United States, 3399-3409.

- Slopes and Retaining Structures

  Ex: Richards, K. S., and Reddy, K. R. (2005). "Slope failure of embankment dam under extreme flooding conditions: Comparison of limit equilibrium and continuum models." *Geo-Frontiers 2005, Jan 24-26 2005,* American Society of Civil

Engineers, Reston, VA 20191-4400, United States, Austin, TX, United States, 2987-2998.

- Earthquake Engineering & Soil Dynamics-

Ex: Carraro, J. A. H., Bandini, P., and Salgado, R. (2005). "Liquefaction resistance of clean and silty sands from cone penetration resistance." *Geo-Frontiers 2005, Jan 24-26 2005,* American Society of Civil Engineers, Reston, VA 20191-4400, United States, Austin, TX, United States, 1337-1351.

- Erosion Control

Ex: Anderson, C. E., and Stormont, J. C. (2005). "Gravel admixtures for erosion protection in semi-arid climates." *Geo-Frontiers 2005, Jan 24-26 2005,* American Society of Civil Engineers, Reston, VA 20191-4400, United States, Austin, TX, United States, 1573-1584.

- Soil Improvement & Grouting

Ex: Ho, C. E., Lim, C. H., and Tan, C. G. (2005). "Jet grouting applications for large-scale basement construction in soft clay." *Geo-Frontiers 2005, Jan 24-26 2005,* American Society of Civil Engineers, Reston, VA 20191-4400, United States, Austin, TX, United States, 1695-1709.

- Pavements

Ex: Chen, R. H. L., Leng, J., and Zhao, A. (2005). "Performance of concrete pavements using geocomposite drainage layer." *Geo-Frontiers 2005, Jan 24-26*

2005, American Society of Civil Engineers, Reston, VA 20191-4400, United States, Austin, TX, United States, 3919-3924.

End

Problem 1-6 Visit the library and get acquainted with five journals in the field of geotechnical and foundation engineering. List them here.

SOLUTION:

1. Journal of Geotechnical and Geoenvironmental Engineering
2. Canadian Geotechnical Journal
3. Geotechnique
4. International Journal for Numerical and Analytical Methods in Geomechanics
5. International Journal of Geomechanics

End

Problem 1-7 Define system of units.

SOLUTION:

A system of units is the set of units necessary to express all quantities of a field of science. It is built upon a set of mutually independent fundamental or basic units, which are units from which all other units in a system can be obtained. Units of mass, length and time are usually taken as the fundamental units in mechanics. In this case, force, acceleration, and velocity units can all be derived from them.

End

Problem 1-8 What is a fundamental quantity? A derived quantity?

SOLUTION:

Fundamental quantities are independent quantities from which all other physical quantities in a system can be obtained.

Ex: mass (m), length (l) and time (t) (sometimes temperature (T)) are usually taken as the fundamental quantities in mechanics. In this case, force, acceleration, and velocity can be derived from them.

Derived quantities are quantities derived from independent quantities.

Ex. - Force (F), acceleration (a), and velocity (v) are some derived quantities in mechanics.

End

Problem 1-9 What are significant figures?

SOLUTION:

Significant figures are all digits in a number that are meaningful in the sense of having been measured or folllwing from calculations based on a measurement. All the zero and non-zero figures measured using an analog device and the first approximated digit, or, alternatively, all of the figures obtained using a digital instrument are significant numbers. A measured load of 20.4 kN has three, and 212.15 kN has 5 significant figures.

While use of significant figures in science is essential, geotechnical engineering calculations do not typically use the concept of significant figures, which would require appropriate intermediate rounding of calculated numbers. Numbers are typically punched in calculator, spreadsheet or programs and rounded at the end.

End

Quantitative Problems

Problem 1-10 Find the value of a pressure of 180kPa in MPa, kgf/cm^2, tons per square foot (tsf), kilo-pounds per square foot (ksf) and pounds per square foot (psf).

SOLUTION:

180kPa = 180/1000= 0.18MPa

$$180\text{kPa} = \frac{180\text{kN}}{1\text{m}^2} = \frac{180\left(1000/9.81\right)\text{kgf}}{\left(100\times100\right)\text{cm}^2} = \left(180\times0.0102\right)\text{kgf}/\text{cm}^2 = 1.84\text{kgf}/\text{cm}^2$$

$$180\text{kPa} = \frac{180\text{kN}}{1\text{m}^2} = \frac{180\left(\frac{1000}{9.81}\right)\times\left(\frac{1000}{453.6\times2000}\right)\text{ton}}{\left(3.28\times3.28\right)\text{ft}^2} = \left(180\times0.0104\right)\text{tsf} = 1.87\text{tsf}$$

[453.6g = 1lb, and 1m = 3.28ft are used in calculation]

$$180\text{kPa} = \frac{180\text{kN}}{1\text{m}^2} = \frac{180\left(\frac{1000}{9.81}\right)\times\left(\frac{1000}{453.6\times1000}\right)\text{kilo}-\text{pounds}}{\left(3.28\times3.28\right)\text{ft}^2} = \left(180\times0.0209\right)\text{ksf} = 3.76\text{ksf}$$

$$180\text{kPa}=\frac{180\text{kN}}{1\text{m}^2}=\frac{180\left(\frac{1000}{9.81}\right)\times\left(\frac{1000}{453.6}\right)\text{pounds}}{\left(3.28\times3.28\right)\text{ft}^2}=\left(180\times20.89\right)\text{ psf}=3760.2\text{ psf}$$

End

Problem 1-11 Water has unit weight of 62.4pcf. Starting from this number, obtain the unit weight of water in kN/m^3.

SOLUTION:

Unit weight of water = 62.4 pcf

$$62.4\text{pcf} = \frac{62.4\text{lb}}{\text{ft}^3} = \frac{62.4\left(\frac{453.6}{1000}\right)\times\frac{9.81}{1000}\text{kN}}{(0.3048)^3\ \text{m}^3} = 9.81\text{kN/m}^3$$

Unit weight of water in kN/m^3 unit is 9.81kN/m^3 answer

[1 lb= 453.6g and 1 ft = 0.3048m are used in the calculation]

End

Problem 1-12 A clay has unit weight of 15 kN/m^3. What is its unit weight in pcf?

SOLUTION:

Unit weight of clay = 15 kN/m^3

$$15\text{kN/m}^3 = \frac{15\times\frac{1000}{9.81}\left(\frac{1000}{453.6}\right)\text{lb}}{(3.28)^3\ \text{ft}^3} = 95.5\ \text{pcf}$$ answer

End

Problem 1-13 A load of 300kN is applied on a square foundation element with side B = 2 meters. Assuming a construction tolerance of 5cm for the sides of the foundation element, what is the range of the average pressure acting on the base of the element?

SOLUTION:

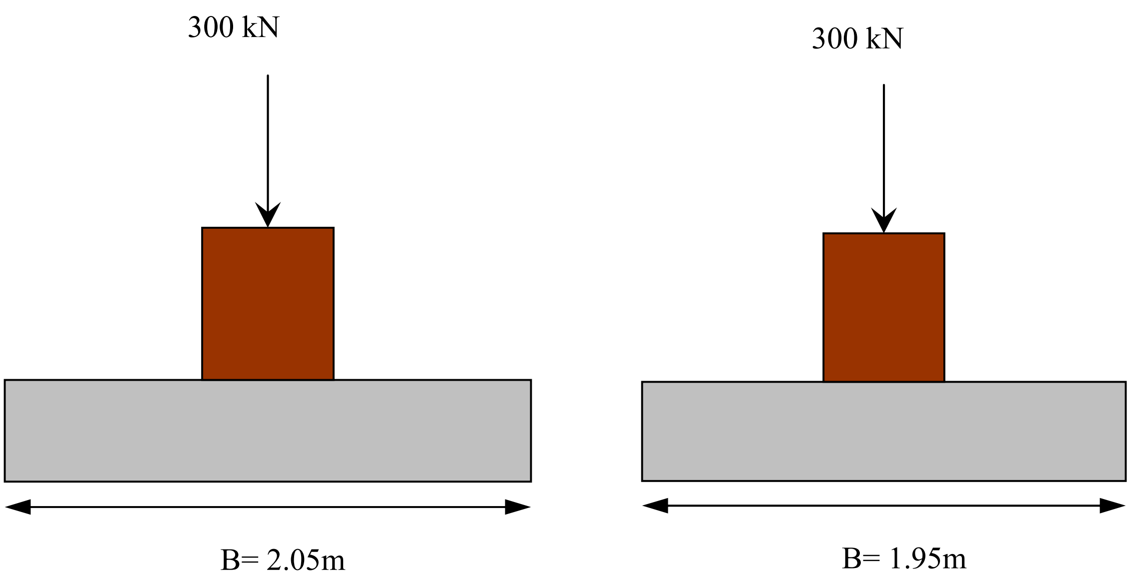
Construction tolerance = 5cm

So, B will vary from 1.95m to 2.05m.

S-Table 1-3

Length of each side (m)	Load (kN)	Base Pressure (kPa)
1.95	300	$\frac{300}{(1.95)^2} = 78.9$
2.05	300	$\frac{300}{(2.05)^2} = 71.4$

So the base pressure will vary from 71.4 kPa to 78.9 kPa.[answer]



S-Figure 1-1

End

Problem 1-14 The small-strain shear modulus of a certain sand is given by

$$G_0 = 600\frac{(2.9-e)^2}{1+e}\sigma'_m{}^{0.5}$$

for both G_0 and σ'_m in tsf. Find the equivalent dimensionless equation.

SOLUTION:

The equation contains only two terms with dimension FL^{-2}, one on each side (G_0 and σ'_m). Other term in the equation (e) is dimensionless. Thus dividing those terms by a reference stress (dimension FL^{-2}) will make the equation dimensionless. As both G_0 and σ'_m are in unit of tsf, choosing the reference stress p_A=1tsf will work.

Thus, the desired dimensionless equation is obtained as follows:

$$\frac{G_0}{p_A} = 600\frac{(2.9-e)^2}{1+e}\left(\frac{\sigma'_m}{p_A}\right)^{0.5} \quad \text{answer}$$

End

Problem 1-15 Calculate G_0 with the correct number of significant figures using the equation obtained in Problem 1-14 for a soil with e = 0.59 and σ'_m = 350kPa.

SOLUTION:

e = 0.59

σ'_m = 350kPa = 0.35MPa

p_A = 1tsf = 100kPa = 0.1MPa

Using the equation obtained in Problem 1-14, we get,

$$G_0 = 600p_A \frac{(2.9-e)^2}{1+e}\left(\frac{\sigma'_m}{p_A}\right)^{0.5} = 600\times 0.1\frac{(2.9-0.59)^2}{1+0.59}\left(\frac{0.35}{0.1}\right)^{0.5} = 376.71 \approx 377\text{MPa}^{\text{answer}}$$

End

Foundation engineering studies are critical for all structures placed on, founded in, or anchored to the seabed. The impact of the proposed structures has also to be assessed for their effect on other structures and their influence on the local (and regional) environment (e.g., scour). Surveyors and geophysicists use high-resolution geophysical systems to image the proposed work location(s), to assist engineers with their preliminary studies, and to generate data on the surrounding area for environmental impact assessments. Foundation is the part of a structure on which the building stands. The solid ground on which it rests is known as foundation bed. Why a Foundation is Provided.Â Depending on the soil profile, size, and load of the structure, engineers chose different kinds of foundation. Types of Foundation. In general, all foundations are divided into two categories, - shallow and deep foundations. The terms Shallow and Deep Foundation refer to the depth of the soil at which it is placed. Generally, if the width of the foundation is greater than the depth, it is labeled as the â€œShallow Foundationâ€. If the width is smaller than the depth of the foundation it is called as â€œDeep Foundation.â€ However, deep foundation and shallow foundation can be classified as shown in t Shallow foundations are typically used where the loads imposed by a structure are low relative to the bearing capacity of the surface soils. Deep foundations are necessary where the bearing capacity of the surface soils is not adequate to support the loads imposed by a structure and so those loads need to be transferred to deeper layers with higher bearing capacity.Â Diaphragm walls are made by excavating a deep trench that is prevented from collapsing by being filled with engineering slurry such as bentonite and then the trench is filled with reinforced concrete panels, the joints between which can be water-tight. This is commonly used for top-down construction, where a basement is constructed at the same time as above ground works are carried out.