

时代教育·国外高校优秀教材精选

基础设计：理论与实践

(英文版·原书第2版)

Foundation Design

Principles and Practices

(美)唐纳德 P. 科杜图 (Donald P. Coduto) 著



机械工业出版社

English reprint copyright ©2004 by Pearson Education North Asia Limited and China Machine Press.
Original English Language title: Foundation Design: Principles and Practices, Second Edition by Donald
P. Coduto.

ISBN 0-13-589706-8

Copyright ©2001 by Prentice-Hall, Inc.

All rights reserved.

Published by arrangement with the original publisher, Pearson Education, Inc., publishing as Prentice-Hall, Inc.

本书封面贴有 Pearson Education(培生教育出版集团)激光防伪标签。无标签者不得销售。

For sale and distribution in the People's Republic of China exclusively(except Taiwan, Hong Kong SAR and Macao SAR)

仅限于中华人民共和国境内(不包括中国香港、澳门特别行政区和中国台湾地区)销售发行。

北京市版权局著作权合同登记号:图字:01-2004-1643

图书在版编目(CIP)数据

基础设计:理论与实践:第2版/(美)科杜图(Coduto, D. P.)著.

—北京:机械工业出版社,2004.7

时代教育·国外高校优秀教材精选

ISBN 7-111-14526-7

I. 基... II. 科... III. 工程设计—高等学校—教材—英文 IV. TB21

中国版本图书馆CIP数据核字(2004)第047375号

机械工业出版社(北京市百万庄大街22号 邮政编码 100037)

责任编辑:马军平 封面设计:饶薇

责任印制:施红

北京铭成印刷有限公司印刷·新华书店北京发行所发行

2004年6月第1版·第1次印刷

1000mm×1400mmB5·28.375印张·2插页·1107千字

定价:69.00元

凡购本书,如有缺页、倒页、脱页,由本社发行部调换

本社购书热线电话(010)68993821、88379646

封面无防伪标均为盗版

Contents

Preface	xiii
Notation and Units of Measurement	xv
PART A – GENERAL PRINCIPLES	1
1. Foundations in Civil Engineering	3
1.1 The Emergence of Modern Foundation Engineering	4
1.2 The Foundation Engineer	6
1.3 Uncertainties	7
1.4 Building Codes	9
1.5 Classification of Foundations	10
<i>Key to Color Photographs</i>	11
2. Performance Requirements	14
2.1 Design Loads	15
2.2 Strength Requirements	24
<i>Questions and Practice Problems 2.1–2.4</i>	25
2.3 Serviceability Requirements	25
<i>Questions and Practice Problems 2.5–2.8</i>	41
2.4 Constructibility Requirements	41
2.5 Economic Requirements	43
<i>Summary</i>	44
<i>Comprehensive Questions and Practice Problems 2.9–2.14</i>	45
3. Soil Mechanics	47
3.1 Soil Composition	47
3.2 Soil Classification	55
<i>Questions and Practice Problems 3.1–3.4</i>	56
3.3 Groundwater	57
3.4 Stress	59
<i>Questions and Practice Problems 3.5–3.6</i>	62
	vii

3.5 Compressibility and Settlement	63
<i>Questions and Practice Problems 3.7</i>	80
3.6 Strength	81
<i>Questions and Practice Problems 3.8–3.10</i>	97
<i>Summary</i>	98
<i>Comprehensive Questions and Practice Problems 3.11–3.16</i>	100
4. Site Exploration and Characterization	102
4.1 Site Exploration	103
4.2 Laboratory Testing	113
<i>Questions and Practice Problems 4.1–4.4</i>	114
4.3 In-Situ Testing	115
<i>Questions and Practice Problems 4.5–4.7</i>	138
4.4 Synthesis of Field and Laboratory Data	138
4.5 Economics	138
<i>Summary</i>	140
<i>Comprehensive Questions and Practice Problems 4.8–4.11</i>	141
PART B – SHALLOW FOUNDATION ANALYSIS AND DESIGN	143
5. Shallow Foundations	145
5.1 Spread Footings	145
5.2 Mats	152
5.3 Bearing Pressure	153
<i>Summary</i>	167
<i>Comprehensive Questions and Practice Problems 5.1–5.9</i>	168
6. Shallow Foundations—Bearing Capacity	170
6.1 Bearing Capacity Failures	171
6.2 Bearing Capacity Analyses in Soil—General Shear Case	173
<i>Questions and Practice Problems 6.1–6.3</i>	186
6.3 Groundwater Effects	187
6.4 Allowable Bearing Capacity	190
6.5 Selection of Soil Strength Parameters	193
<i>Questions and Practice Problems 6.4–6.10</i>	197
6.6 Bearing Capacity Analyses—Local and Punching Shear Cases	198
6.7 Bearing Capacity on Layered Soils	199
6.8 Accuracy of Bearing Capacity Analyses	201
6.9 Bearing Spreadsheet	203
<i>Questions and Practice Problems—Spreadsheet Analyses 6.11–6.13</i>	203
<i>Summary</i>	204
<i>Comprehensive Questions and Practice Problems 6.14–6.17</i>	205
7. Shallow Foundations—Settlement	207
7.1 Design Requirements	208

7.2 Overview of Settlement Analysis Methods	208
7.3 Induced Stresses Beneath Shallow Foundations	210
<i>Questions and Practice Problems 7.1–7.4</i>	217
7.4 Settlement Analyses Based on Laboratory Tests	217
<i>Questions and Practice Problems 7.5–7.8</i>	229
7.5 Settlement Spreadsheet	229
<i>Questions and Practice Problems—Spreadsheet Analyses 7.9–7.13</i>	230
7.6 Settlement Analyses Based on In-Situ Tests	231
<i>Questions and Practice Problems 7.14–7.16</i>	241
7.7 Schmertmann Spreadsheet	242
<i>Questions and Practice Problems—Spreadsheet Analyses 7.17–7.21</i>	242
7.8 Settlement of Foundations of Stratified Soils	243
7.9 Differential Settlement	244
<i>Questions and Practice Problems 7.22–7.23</i>	250
7.10 Rate of Settlement	250
7.11 Accuracy of Settlement Predictions	251
<i>Summary</i>	257
<i>Comprehensive Questions and Practice Problems 7.24–7.27</i>	258
8. Spread Footings—Geotechnical Design	259
8.1 Design for Concentric Downward Loads	259
<i>Questions and Practice Problems 8.1–8.9</i>	271
8.2 Design for Eccentric or Moment Loads	273
8.3 Design for Shear Loads	276
<i>Questions and Practice Problems 8.10–8.12</i>	278
8.4 Design for Wind or Seismic Loads	279
8.5 Lightly-Loaded Footings	281
<i>Questions and Practice Problems 8.13–8.14</i>	285
8.6 Footings On or Near Slopes	285
8.7 Footings on Frozen Soils	288
8.8 Footings on Soils Prone to Scour	293
8.9 Footings on Rock	296
<i>Questions and Practice Problems 8.15–8.20</i>	296
<i>Summary</i>	298
<i>Comprehensive Questions and Practice Problems 8.21–8.24</i>	299
9. Spread Footings—Structural Design	301
9.1 Selection of Materials	303
9.2 Basis for Design Methods	303
9.3 Design Loads	305
9.4 Minimum Cover Requirements and Standard Dimensions	306
9.5 Square Footings	307
<i>Questions and Practice Problems 9.1–9.8</i>	324
9.6 Continuous Footings	326
<i>Questions and Practice Problems 9.9–9.10</i>	330

9.7 Rectangular Footings	331
9.8 Combined Footings	333
9.9 Lightly-Loaded Footings	333
9.10 Connections with the Superstructure	335
<i>Questions and Practice Problems 9.11–9.15</i>	349
<i>Summary</i>	350
<i>Comprehensive Questions and Practice Problems 9.16–9.17</i>	351
10. Mats	352
10.1 Rigid Methods	354
10.2 Nonrigid Methods	356
10.3 Determining the Coefficient of Subgrade Reaction	362
10.4 Structural Design	365
10.5 Settlement	366
10.6 Bearing Capacity	367
<i>Summary</i>	367
<i>Comprehensive Questions and Practice Problems 10.1–10.5</i>	368
PART C – DEEP FOUNDATION ANALYSIS AND DESIGN	371
11. Deep Foundations	373
11.1 Types of Deep Foundations and Definitions	374
11.2 Load Transfer	376
11.3 Piles	378
<i>Questions and Practice Problems 11.1–11.8</i>	400
11.4 Drilled Shafts	402
<i>Questions and Practice Problems 11.9–11.11</i>	418
11.5 Caissons	418
11.6 Mandrel-Driven Thin-Shells Filled with Concrete	421
11.7 Auger-Cast Piles	423
11.8 Pressure-Injected Footings	425
11.9 Pile-Supported and Pile-Enhanced Mats	429
11.10 Anchors	429
<i>Questions and Practice Problems 11.12–11.14</i>	432
<i>Summary</i>	432
<i>Comprehensive Questions and Practice Problems 11.15–11.17</i>	434
12. Deep Foundations—Structural Integrity	435
12.1 Design Philosophy	436
12.2 Loads and Stresses	438
12.3 Piles	441
<i>Questions and Practice Problems 12.1–12.5</i>	453
12.4 Drilled Shafts	454
<i>Questions and Practice Problems 12.6–12.7</i>	461

12.5 Caps	461
12.6 Grade Beams	461
<i>Summary</i>	462
<i>Comprehensive Questions and Practice Problems 12.8–12.17</i>	464
13. Deep Foundations—Axial Load Capacity Based on Static Load Tests	465
13.1 Load Transfer	466
<i>Questions and Practice Problems 13.1–13.3</i>	476
13.2 Conventional Load Tests	476
13.3 Interpretation of Test Results	480
<i>Questions and Practice Problems 13.4–13.6</i>	482
13.4 Mobilization of Soil Resistance	483
13.5 Instrumented Load Tests	485
13.6 Osterberg Load Tests	488
13.7 When and Where to Use Full-Scale Load Tests	490
<i>Summary</i>	491
<i>Comprehensive Questions and Practice Problems 13.7–13.9</i>	492
14. Deep Foundations—Axial Load Capacity Based on Analytic Methods	494
14.1 Changes in Soil During Construction	495
<i>Questions and Practice Problems 14.1–14.3</i>	499
14.2 Toe Bearing	500
14.3 Side Friction	513
14.4 Upward Load Capacity	527
<i>Questions and Practice Problems 14.4–14.11</i>	530
14.5 Analyses Based on CPT Results	532
<i>Questions and Practice Problems 14.12</i>	537
14.6 Group Effects	537
14.7 Settlement	543
<i>Questions and Practice Problems 14.13–14.19</i>	553
<i>Summary</i>	554
<i>Comprehensive Questions and Practice Problems 14.20–14.27</i>	555
15. Deep Foundations—Axial Load Capacity Based on Dynamic Methods	559
15.1 Pile-Driving Formulas	559
15.2 Wave Equation Analyses	563
15.3 High-Strain Dynamic Testing	569
15.4 Low-Strain Dynamic Testing	577
15.5 Conclusions	577
<i>Summary</i>	578
<i>Comprehensive Questions and Practice Problems 15.1–15.9</i>	579

16. Deep Foundations—Lateral Load Capacity	581
16.1 Batter Piles	582
16.2 Response to Lateral Loads	584
16.3 Methods of Evaluating Lateral Load Capacity	589
<i>Questions and Practice Problems 16.1–16.5</i>	596
16.4 <i>p</i> - <i>y</i> Method	597
16.5 Evans and Duncan’s Method	600
<i>Questions and Practice Problems 16.6–16.9</i>	611
16.6 Group Effects	613
16.7 Improving Lateral Capacity	616
<i>Summary</i>	616
<i>Comprehensive Questions and Practice Problems 16.10–16.14</i>	618
17. Deep Foundations—Design	619
17.1 Design Service Loads and Allowable Definitions	620
17.2 Subsurface Characterization	620
17.3 Foundation Type	620
17.4 Lateral Load Capacity	622
17.5 Axial Load Capacity	624
17.6 Driveability	626
17.7 Structural Design	626
17.8 Special Design Considerations	627
17.9 Verification and Redesign During Construction	630
17.10 Integrity Testing	631
<i>Summary</i>	634
<i>Comprehensive Questions and Practice Problems 17.1–17.7</i>	635
PART D – SPECIAL TOPICS	637
18. Foundations on Weak and Compressible Soils	639
18.1 Deep Foundations	640
18.2 Shallow Foundations	644
18.3 Floating Foundations	646
18.4 Soil Improvement	647
<i>Summary</i>	652
<i>Comprehensive Questions and Practice Problems 18.1–18.5</i>	653
19. Foundations on Expansive Soils	655
19.1 The Nature, Origin, and Occurrence of Expansive Soils	656
19.2 Identifying, Testing, and Evaluating Expansive Soils	669
19.3 Estimating Potential Heave	679
19.4 Typical Structural Distress Patterns	684
19.5 Preventive Design and Construction Measures	685
19.6 Other Sources of Heave	695
<i>Summary</i>	698
<i>Comprehensive Questions and Practice Problems 19.1–19.9</i>	699

20. Foundations on Collapsible Soils	701
20.1 Origin and Occurrence of Collapsible Soils	701
20.2 Identification, Sampling, and Testing	705
20.3 Wetting Processes	710
20.4 Settlement Computations	712
20.5 Collapse in Deep Compacted Fills	715
20.6 Preventive and Remedial Measures	715
<i>Summary</i>	718
<i>Comprehensive Questions and Practice Problems 20.1–20.10</i>	719
21. Reliability-Based Design	721
21.1 Methods	722
21.2 LRFD for Structural Strength Requirements	726
21.3 LRFD for Geotechnical Strength Requirements	727
21.4 Serviceability Requirements	730
21.5 The Role of Engineering Judgement	731
21.6 Transition of LRFD	731
<i>Summary</i>	732
<i>Comprehensive Questions and Practice Problems 21.1–21.4</i>	733
PART E – EARTH-RETAINING STRUCTURE ANALYSIS AND DESIGN	735
22. Earth-Retaining Structures	737
22.1 Externally Stabilized Systems	738
22.2 Internally Stabilized Systems	745
<i>Summary</i>	748
23. Lateral Earth Pressures	749
23.1 Horizontal Stresses in Soil	749
23.2 Classical Lateral Earth Pressure Theories	757
<i>Questions and Practice Problems 23.1–23.7</i>	766
23.3 Lateral Earth Pressures in Soils with $c \geq 0$ and $\phi \geq 0$	767
23.4 Equivalent Fluid Method	770
23.5 Presumptive Lateral Earth Pressures	773
<i>Questions and Practice Problems 23.8–23.13</i>	774
23.6 Lateral Earth Pressures From Surcharge Loads	777
23.7 Groundwater Effects	780
<i>Questions and Practice Problems 23.14–23.16</i>	783
23.8 Practical Application	783
<i>Summary</i>	785
<i>Comprehensive Questions and Practice Problems 23.17–23.18</i>	786
24. Cantilever Retaining Walls	787
24.1 External Stability	788
<i>Questions and Practice Problems 24.1–24.3</i>	802

24.2 Retwall Spreadsheet	803
<i>Questions and Practice Problems—Spreadsheet Analyses 24.4–24.6</i>	803
24.3 Internal Stability (Structural Design)	804
<i>Questions and Practice Problems 24.7–24.9</i>	816
24.4 Drainage and Waterproofing	817
24.5 Avoidance of Frost Heave Problems	821
<i>Summary</i>	822
<i>Comprehensive Questions and Practice Problems 24.10–24.17</i>	823
25. Sheet Pile Walls	826
25.1 Materials	826
25.2 Construction Methods and Equipment	830
25.3 Cantilever Sheet Pile Walls	830
25.4 Braced or Anchored Sheet Pile Walls	835
<i>Summary</i>	841
<i>Comprehensive Questions and Practice Problems 25.1–25.7</i>	842
Appendix A—Unit Conversion Factors	844
Appendix B—Computer Software	848
References	849
Index	875

Cantilever Retaining Walls

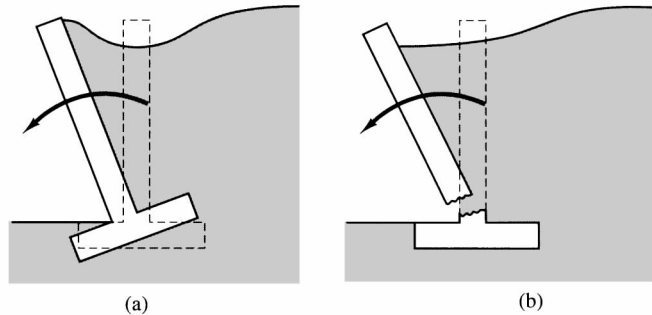
Theories require assumptions which often are true only to a limited degree. Thus any new theoretical ideas have questionable points which can be removed only by checks under actual conditions. This statement holds especially true for theories pertaining to soil mechanics because assumptions relative to soil action are always more or less questionable. Such theories may sometimes be checked to a limited degree by laboratory tests on small samples, but often the only final and satisfactory verification requires observations under actual field conditions.

MIT Professor Donald W. Taylor (1948)

Cantilever retaining walls are the most common type of earth-retaining structure because they are often the most economical, especially when the wall height is less than about 5 m (16 ft). This chapter discusses the analysis and design of such walls.

The design of these walls must satisfy two major requirements: First, the wall must have adequate *external stability*, which means it must remain fixed in the desired location (except for small movements required to mobilize the active or passive pressures). Second, it must have sufficient *internal stability* (or *structural integrity*) so it is able to carry the necessary internal stresses without rupturing. Both of these requirements are shown in Figure 24.1. Walls that have insufficient external stability experience failure in the soil, while those that have insufficient internal stability experience structural failure in the wall itself. These are two separate requirements, and each must be satisfied independently. Extra effort in one does not compensate for a shortcoming in the other. For example, adding more rebars (improving the internal stability) does not compensate for a footing that is too short (a deficiency in external stability).

Figure 24.1 (a) A wall that lacks sufficient external stability moves away from its desired location because the soil fails; (b) A wall with inadequate internal stability (structural integrity) is unable to carry the necessary internal stresses and experiences a structural failure.



24.1 EXTERNAL STABILITY

A cantilever retaining wall must be externally stable in all the following ways:

- It must not *slide* horizontally, as shown in Figure 24.2a.
- It must not *overturn*, as shown in Figure 24.2b and Figure 24.3.
- The resultant of the normal force that acts on the base of the footing must be within the middle third of the footing, as shown in Figure 24.2c.
- The foundation must not experience a *bearing-capacity failure*, as shown in Figure 24.2d.
- It must not undergo a *deep-seated shear failure*, as shown in Figure 24.2e.
- It must not *settle* excessively, as shown in Figure 24.2f.

The external stability of a wall in each of these modes is dependent on its dimensions and on the forces between the wall and the ground. Figure 24.3 shows a wall that does not satisfy the overturning criteria and is slowly rotating outward.

When evaluating external stability, engineers consider the wall and the soil above the footing as a unit, as shown in Figure 24.4. We will refer to it as the *wall-soil unit* and evaluate its external stability using the principles of statics.

We can evaluate the external stability of a wall-soil unit only after its dimensions are known. Therefore, first develop a trial design using the guidelines in Figure 24.5, then check its external stability, and progressively refine the design. Continue this converging trial-and-error process until an optimal design is obtained (one that minimizes costs while satisfying all external stability criteria).

Sliding

We evaluate the sliding stability using a *limit equilibrium* approach by considering the forces acting on the wall-soil unit if it were about to fail. The factor of safety is the ratio of the forces required to cause the wall to fail to those that actually act on it.

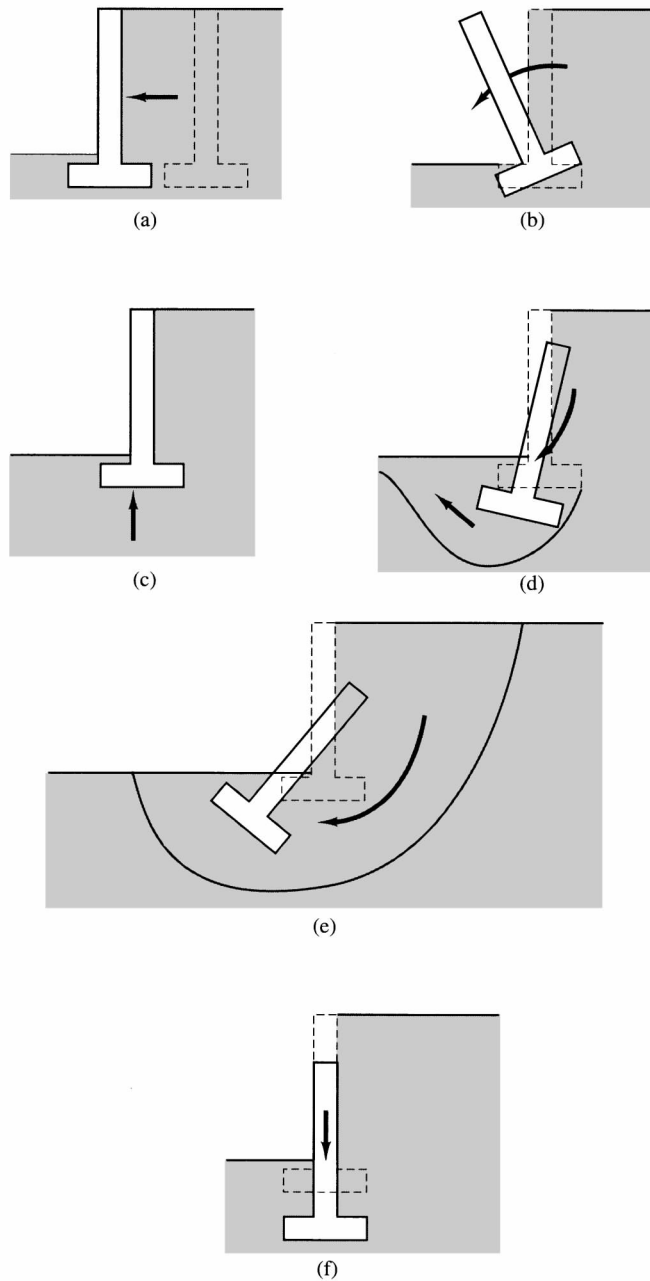


Figure 24.2 Potential external stability problems in a cantilever retaining wall: (a) sliding failure, (b) overturning failure, (c) normal force acting on the base of the footing not within the middle third, (d) bearing capacity failure, (e) deep-seated shear failure, and (f) excessive settlement.

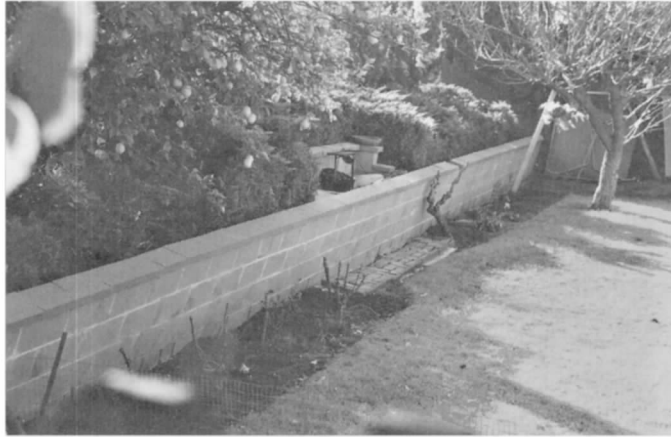


Figure 24.3 This retaining wall, which was backfilled with an expansive clay, is slowly failing by overturning and will eventually collapse. This photograph was taken approximately thirty years after construction.

The forces tending to cause sliding (known as the *driving forces*) are as follows:

- The horizontal component of the lateral earth pressures acting on the back of the wall-soil unit.
- Hydrostatic forces, if any, acting on the back of the wall-soil unit.
- Seismic forces from the backfill (these are beyond the scope of this chapter).

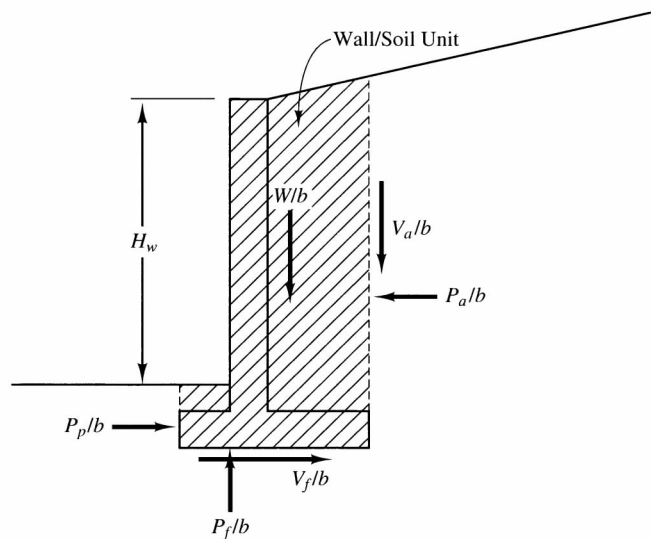


Figure 24.4 Forces acting between a cantilever retaining wall and the ground. The wall, footing, and backfill soil immediately above the footing form the wall-soil unit, which is used to perform external stability analyses.

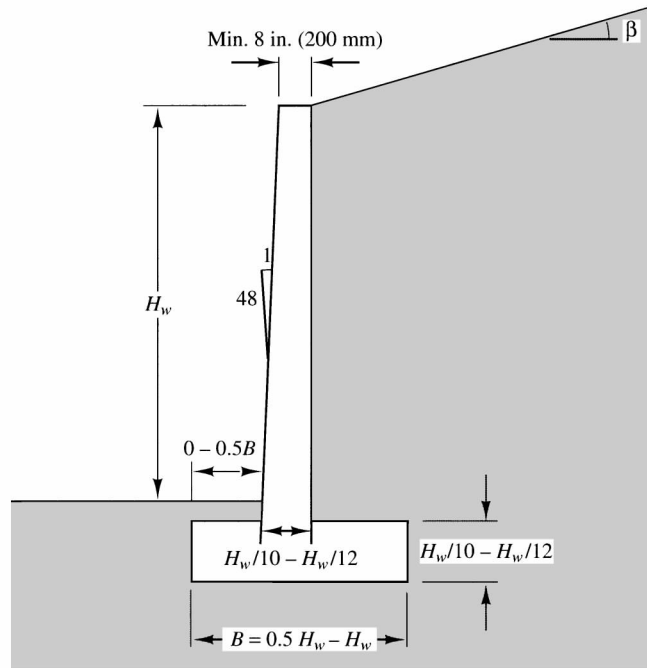


Figure 24.5 Suggested first trial dimensions for cantilever retaining walls back-filled with sandy soils. For short walls with strong soils and level backfill, the toe extension will be about $0.5B$. For weaker soils or inclined backfill, the toe extension will be less (with a corresponding increase in the heel extension).

These are countered by the following *resisting forces*:

- Lateral earth pressures acting on the front of the wall-soil unit.
- Sliding friction along the bottom of the footing.
- Hydrostatic forces, if any, acting on the front of the wall-soil unit.

The factor of safety, F , is defined as the ratio of the horizontal resisting forces, $\Sigma (P_R/b)$ to the horizontal driving forces, $\Sigma (P_D/b)$:

$$F = \frac{\Sigma(P_R/b)}{\Sigma(P_D/b)} \tag{24.1}$$

The unit length, b , is usually 1 ft or 1 m.

IBC 1610.2 requires a factor of safety against sliding of at least 1.5. This criterion is suitable for walls backfilled and supported on sands, sandy silts, gravels, or rock. However, if the backfill or the underlying soil is a clay or clayey silt, design for a factor of safety of at least 2.0. This higher factor of safety is justified because of the historically poorer performance of such walls (Duncan et al., 1990), and because the shear strength of clayey soils is less reliable.

The resisting force is typically computed using Equation 8.8, which uses allowable coefficient of friction and passive pressure values (i.e., a factor of safety has already been

applied to these values). Thus, this design procedure produces a compound factor of safety against sliding: the first is applied by the geotechnical engineer when developing design values of μ_a and λ_a , and the second by the structural engineer when performing the sliding analysis. This compounding typically produces a “true” factor of safety between 2.5 and 3.5, which is probably appropriate.

The use of Equation 8.8 in this analysis also implicitly double-counts part of the active earth pressure. This is conservative, and helps keep the lateral movements under control.

Example 24.1—Part A

A 12-ft tall retaining wall supports a backfill inclined at a slope of 4:1 as shown in Figure 24.6. The soil behind the wall is a fine to medium sand with the following properties: $c' = 0$, $\phi' = 35^\circ$, and $\gamma = 122 \text{ lb/ft}^3$. The soil below the footing is also a fine to medium sand: Its properties are $c' = 0$, $\phi' = 38^\circ$, $\gamma = 125 \text{ lb/ft}^3$, and the allowable bearing pressure, q_A , is 5000 lb/ft^2 . Determine the required footing dimensions to satisfy external stability criteria.

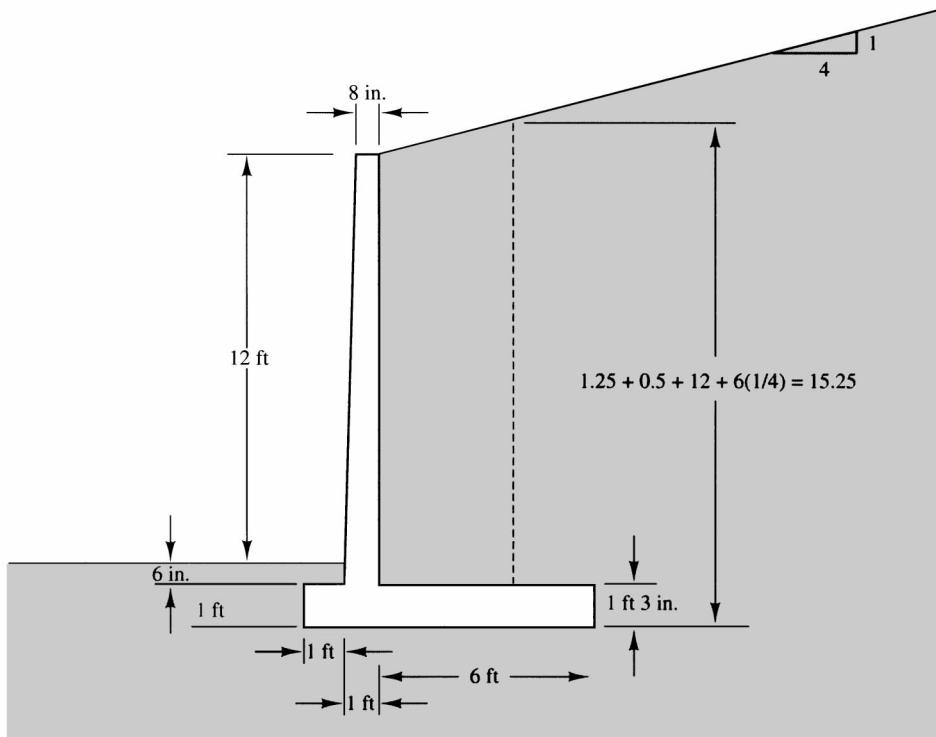


Figure 24.6 Trial dimensions for retaining wall, Example 24.1.

Solution

Select the trial dimensions using Figure 24.5. These trial dimensions are shown in Figure 24.6.

Develop the geotechnical design parameters

Active earth pressure—use Coulomb's method (Equation 23.19). Rankine's method also would be acceptable.

$$\beta = \tan^{-1}(1/4) = 14^\circ$$

$$\phi_w = (2/3)(35^\circ) = 23^\circ$$

$$\begin{aligned} K_a &= \frac{\cos^2(\phi - \alpha)}{\cos^2\alpha \cos(\phi_w + \alpha) \left[1 + \sqrt{\frac{\sin(\phi + \phi_w) \sin(\phi - \beta)}{\cos(\phi_w + \alpha) \cos(\alpha - \beta)}} \right]^2} \\ &= \frac{\cos^2(35 - 0)}{\cos^2 0 \cos(23 + 0) \left[1 + \sqrt{\frac{\sin(35 + 23) \sin(35 - 14)}{\cos(23 + 0) \cos(0 - 14)}} \right]^2} \\ &= 0.291 \end{aligned}$$

$$G_h = \gamma K_a \cos\phi_w = 122(0.291) \cos 23^\circ = \mathbf{33 \text{ lb/ft}^3} \quad \Leftarrow \text{Answer}$$

$$G_v = \gamma K_a \sin\phi_w = 122(0.291) \sin 23^\circ = \mathbf{14 \text{ lb/ft}^3} \quad \Leftarrow \text{Answer}$$

Per Table 8.3: $\mu = 0.45\text{--}0.55$

Per Equation 8.12: $\mu = \tan [0.7 (38)] = 0.50$

Use $\mu = 0.50$

$$\mu_a = \frac{\mu}{F} = \frac{0.50}{1.5} = \mathbf{0.33} \quad \Leftarrow \text{Answer}$$

$$\begin{aligned} \lambda_a &= \frac{\gamma [\tan^2(45^\circ + \phi/2) - \tan^2(45^\circ - \phi/2)]}{F} \\ &= \frac{125 [\tan^2(45^\circ + 38^\circ/2) - \tan^2(45^\circ - 38^\circ/2)]}{2} \\ &= 248 \text{ lb/ft}^3 \quad \text{use } \mathbf{250 \text{ lb/ft}^3} \quad \Leftarrow \text{Answer} \end{aligned}$$

These geotechnical design parameters, along with the allowable bearing pressure given in the problem statement, are normally developed by the geotechnical engineer.

Evaluate sliding stability of trial design

$$\begin{aligned} H &= 1.25 + 0.5 + 12 + 6(1/4) \\ &= 15.25 \text{ ft} \end{aligned}$$