[ESS32]

UNIVERSITY OF BOLTON

SCHOOL OF ENGINEERING

BEng(HONS) IN CIVIL ENGINEERING

SEMESTER ONE EXAMINATION 2019/2020

GEOTECHNICAL ENGINEERING & GROUND IMPROVEMENT

MODULE NO: CIE6003

Date: Tuesday 14th January 2020 **Time: 10.00 am – 1.00 pm**

INSTRUCTIONS TO CANDIDATES:

There are FIVE questions.

Answer FOUR questions.

All questions carry equal marks.

Marks for parts of questions are shown in brackets.

Supplementary Geotechnical Information is provided on pages 9-11.

Lined Graph Paper and Supplementary Answer Sheets are available for your use.

Ensure that you write your Candidate Number or Desk Number on each Figure, Supplementary Sheet or Sheet of Graph Paper you use to answer the selected questions.

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Question 1

Figure Q1 shows a 6.0 m high gravity retaining wall with relevant material properties. (Assume that the wall has a smooth back).

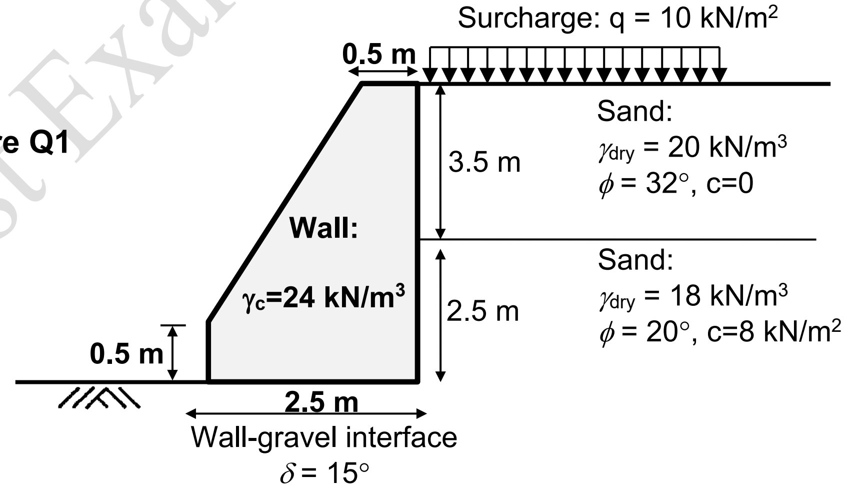
a) Sketch the earth pressure diagram for the retained soil, labelling all relevant values. You may assume the soil and the wall to be free-draining (so that there is no pore water), and that movement of the wall is sufficient for active conditions to develop in the soil. **(8 marks)**

b) Determine the total force (F) and moment (M) acting about the level of the base of the wall due to earth pressure. **(5 marks)**

c) Assuming that friction between the base of the wall and the gravel is equal to δ=15°, determine the factors of safety against sliding and overturning. **(7 marks)**

d) Knowing that recommended factors of safety against sliding and overturning are 1.5 and 2.0 respectively, what design modifications should be introduced for the problem shown in Fig. Q1 to increase the factors of safety to their minimum acceptable limits? Discuss and use sketches to illustrate your answer as appropriate. **(5 marks)**

Figure Q1



Total 25 marks

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Question 2

The cross-section of an earth dam on an impermeable base is shown in Figure Q2. The stability of the downstream slope is to be investigated using the slip circle shown. Given that: γ_{sat} = 19 kN/m^3, c' = 15 kN/m^2, ϕ' = 32°, R= 9 m, θ = 86.7°. The weights of slices and r_u values obtained from a flow net are given in the table below:

Slice No.	1	2	3	4	5
r_u	47	120	165	175	80
W (kN)	0.34	0.44	0.38	0.28	0.07
α (°)	-13	10	21	36	52

(a) Determine the factor of safety using the conventional approach:

$$F = \frac{\sum(c' \times R \times \theta) + \sum(W \times \cos(\alpha) - u \times l)tan\phi'}{\sum(W \times \sin(\alpha)}$$

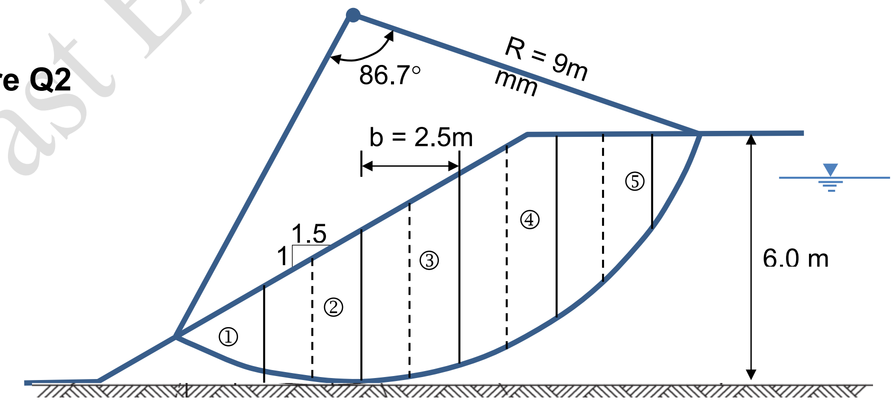
Where $u = r_u \times \gamma \times z = r_u \times \frac{W}{b}$ **(12 marks)**

(b) Determine the factor of safety using the rigorous approach and comment on the obtained results.

$$F = \frac{\sum(c' \times l) + \sum(W \times \cos(\alpha) - u \times l)tan\phi'}{\sum(W \times \sin(\alpha)}$$

(13 marks)

Figure Q2



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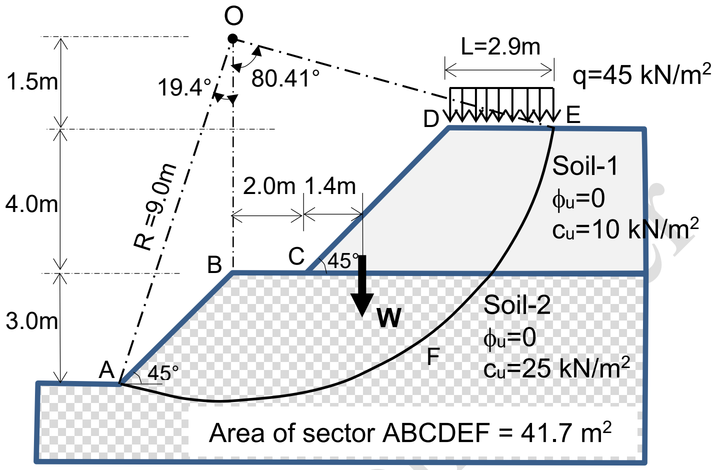
Question 3

For the given embankment detailed in Figure Q3a, determine the factor of safety for the assumed failure surface. The unit weight (γ) for both soils is 19 kN/m^3.

(8 marks)

Figure Q3a

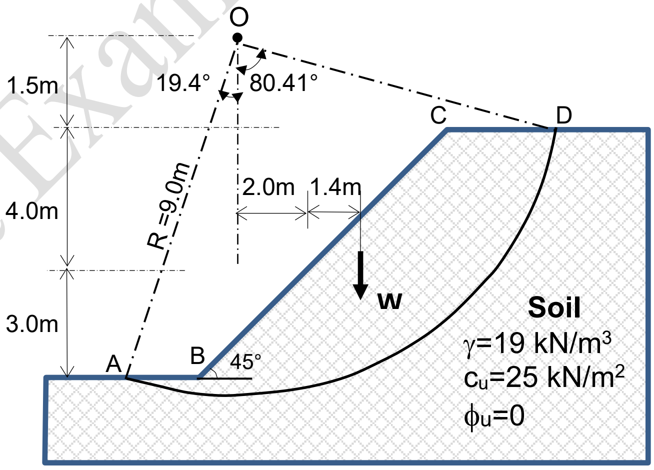


b) By ignoring the surcharge (q=0 kN/m^2), determine the factor of safety for allowed dry tension cracks. **(5 marks)**

c) Using Taylor's chart calculate the new factor of safety if the above embankment is replaced by the one shown in Figure Q3b. The firm stratum is at depth DH=14m.

(5 marks)

Figure Q3b



d) What remedial actions you suggest to improve the stability of the slope shown in Figure Q3a? Discuss and use sketches to illustrate your answer as appropriate.

(7 marks)

Total 25 marks

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Question 4

a) Discuss why undrained soil shear strength parameters are important for the design of shallow foundations, and suggest when drained parameters could be used for civil engineering foundations, and why.

(9 marks)

b) A pad foundation, 3.0m square is to be located at a depth of 1.5m in a uniform bearing stratum of firm clay. The water table level is at an assumed depth of 1.5m below ground level (from a recent and reliable site investigation). The clay soil properties are as follows;

Bulk unit weight	γ = 20.0 kN/m^3
Saturated unit weight	γ_{sat} = 22.0 kN/m^3
With respect to Total Stresses	c_u = 55.0 kN/m^2
	Φ_u = 0^0
With respect to Effective Stresses	c^l = 8 kN/m^2
	Φ^l = 32^0

Determine the safe bearing load that the foundation can support in the short term (in kN). Use the formulae provided on page 9 and also Figure Q4 on page 6 (as appropriate).

(16 marks)

NOTE: State any assumptions made in your calculations for Q4 b).

Total 25 marks

Question 4 continues over the page….

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Question 4 continued….

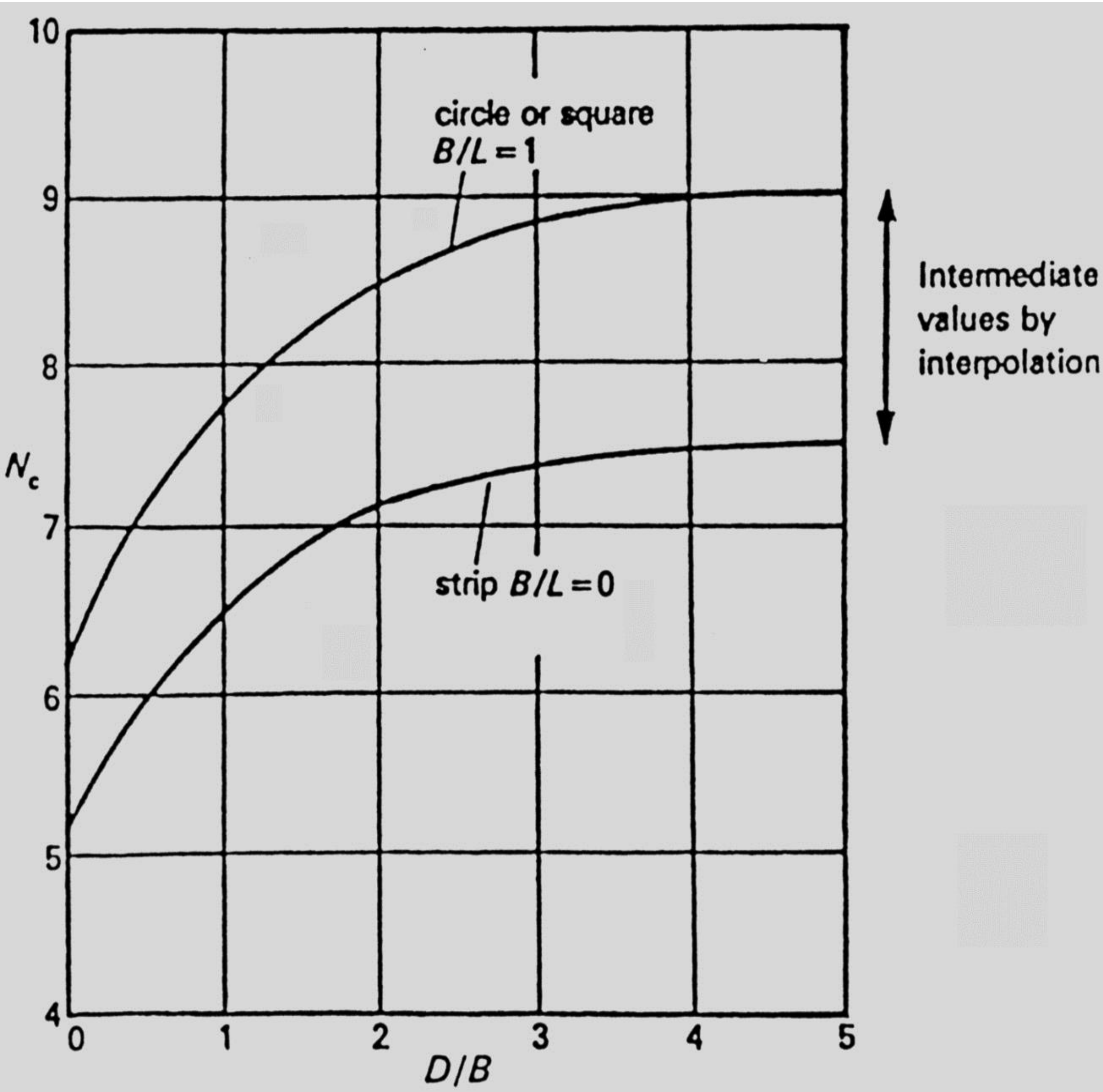

Figure Q4

Question 4 continues over the page….

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Question 4 continued….

ϕ	N_c	N_q	N_γ
0	5.14	1.0	0
1	5.4	1.1	0
2	5.6	1.2	0
3	5.9	1.3	0
4	6.2	1.4	0
5	6.5	1.6	0.1
6	6.8	1.7	0.1
7	7.2	1.9	0.2
8	7.5	2.1	0.2
9	7.9	2.3	0.3
10	8.4	2.5	0.4
11	8.8	2.7	0.5
12	9.3	3.0	0.6
13	9.8	3.3	0.8
14	10.4	3.6	1.0
15	11.0	3.9	1.2
16	11.6	4.3	1.4
17	12.3	4.8	1.7
18	13.1	5.3	2.1
19	13.9	5.8	2.5
20	14.8	6.4	3.0
21	15.8	7.1	3.5
22	16.9	7.8	4.1
23	18.1	8.7	4.9
24	19.3	9.6	5.7
25	20.7	10.7	6.8
26	22.3	11.9	7.9
27	23.9	13.2	9.3
28	25.8	14.7	10.9
29	27.9	16.4	12.8
30	30.1	18.4	15.1
31	32.7	20.6	17.7
32	35.5	23.2	20.8
33	38.6	26.1	24.4
34	42.2	29.4	28.8
35	46.1	33.3	33.9
36	50.6	37.8	40.0
37	55.6	42.9	47.4
38	61.4	48.9	56.2
39	67.9	56.0	66.8
40	75.3	64.2	79.5

Table Q4

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Question 5

a) A bored pile (15m long and 600mm in diameter) for a series of retail buildings on a scheme is to be installed into the following soil profile;

Depth m	Description	Unit Weight kN/m³	c_u kN/m²	Adhesion Factor α
0 – 6	Very soft CLAY	21.0	20.0	0.6
6 – 10.5	Firm CLAY	21.5	95.0	0.55
10.5 - 25	Very stiff CLAY	22.0	175.0	0.5

The above clay strata are taken as being fully saturated.

i) Determine the safe load the pile can carry.

NOTE: Clearly state any assumptions made in your calculations

(15 marks)

ii) With the same soil profile as above evaluate how a greater carrying capacity could be obtained at each required loading point.

NOTE: Calculations are NOT required for your answer to Q5a)ii) but discuss all available options.

(5 marks)

b) Given the very soft clay layer highlighted above from ground level down to 6m, discuss the impact that will have on the scheme and describe the geotechnical issues that might arise and propose ways to mitigate against such geotechnical issues to provide a stable platform for the scheme.

(5 marks)

Total 25 marks

END OF QUESTIONS

Please turn the page (for Supplementary Geotechnical Information)….

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Supplementary Geotechnical Information

q_f = ultimate bearing capacity

q_n = net bearing capacity $= q_f - \sigma_o = q_f - \gamma D$ (Total stresses)

$= q_f - \sigma_o^1 = q_f - (\gamma D - \gamma_w h_w)$ (Effective stresses)

q_s = safe bearing capacity = $\frac{q_n}{F}$ and $F = \frac{q_f}{q_n}$ = 3.0 usually

q_a = allowable bearing capacity = $\frac{q_n}{F} + \gamma D = \frac{q_f - \gamma D}{F} + \gamma D$

Shallow Foundations

c , ϕ soil

Terzaghi : $q_f = c\,N_c\,s_c + \gamma\,D\,N_q\,s_q + 0.5\,B\,\gamma\,N_\gamma\,s_\gamma$

Where N_c ; N_q ; N_γ ; s_c ; s_q ; s_γ are bearing capacity and shape factors (from Table Q4 earlier)

Shape of footing	s_c	s_q	s_γ
Strip	1.0	1.0	1.0
Rectangle	1.0 + (B/L)(N_q/N_c)	1.0 + (B/L)tanϕ'	1.0 – (B/L)0.4
Circle or square	1.0 + (N_q/N_c)	1.0 + tanϕ'	0.6

- modified when Water Table present, γ_{sub} or $\gamma' = \gamma_{sat} - \gamma_w$

c_u soil (ϕ_u =0)

Skempton : $q_f = cN_c + \gamma D$ N_c from Skempton's graph (Figure Q4 for D/B values)

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Retaining walls

$K_a = \frac{1-sin\phi}{1+sin\phi}$; $K_p = \frac{1+sin\phi}{1-sin\phi}$

$\sigma_{ha} = K_a\sigma_v - 2c\sqrt{K_a}$; $\sigma_{hp} = K_p\sigma_v + 2c\sqrt{K_p}$

Slope stability

- Dry tension cracks $z = \frac{2c_u - q}{\gamma}$

$F = c_u/(N_s \times \gamma \times H)$

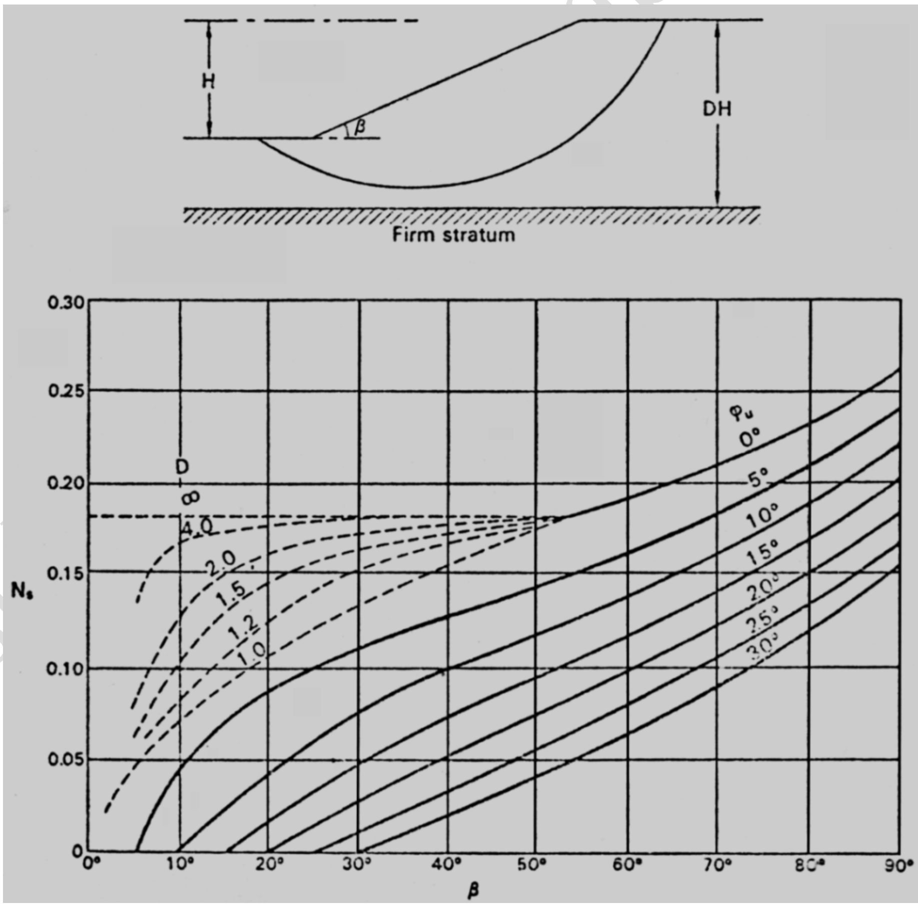

Figure A1: Taylor's chart for undrained slope stability.

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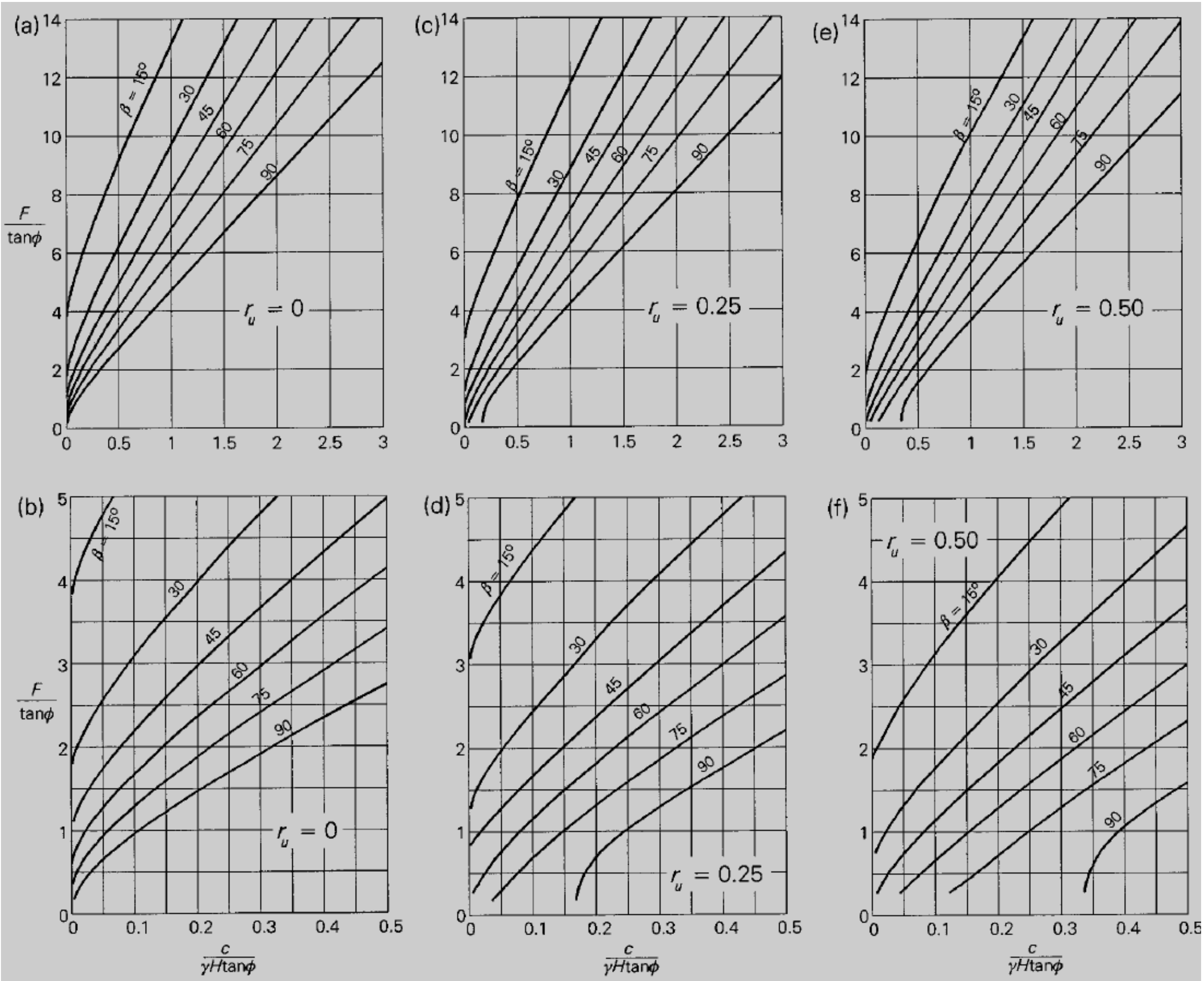

Figure A2: Stability charts for uniform slopes (R. L. Michalowski 2002).

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