NANYANG TECHNOLOGICAL UNIVERSITY

SEMESTER 2 EXAMINATION 2009-2010

CV2302 – GEOTECHNICAL ENGINEERING

April/May 2010 **Time Allowed: 2½ hours**

INSTRUCTIONS

1. This paper contains **FOUR (4)** questions and comprises **EIGHT (8)** pages.
2. Answer all **FOUR (4)** questions.
3. An **Appendix** of **THREE (3)** pages is attached to the question paper.
4. This is a Closed-Book Examination.
5. All questions carry equal marks.

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1. The soil profile of a site is shown in Figure Q1.

   (a) The SPT blowcounts at A and B are both equal to 20.

   (i) Specify the types of laboratory test to be conducted on samples retrieved at "A" and "B".

   (2 Marks)

   (ii) Correct the measured blowcounts at "A" and "B" for equipment and effective overburden pressure. An automatic trip hammer with an efficiency of 0.73 was used. The borehole size was 150 mm and sample liner was not used.

   (4 Marks)

   (iii) Give a qualitative comparison of the soil strength at "A" and "B".

   (2 Marks)

   (iv) In order to obtain good quality samples at "A", what is the recommended soil sampler? What types of laboratory test would you recommend for the soil samples obtained?

   (4 Marks)

Note: Question No.1 continues on page 2.

(b) Concrete blocks are used to form a temporary retaining wall as shown in Figure Q1. The wall is used to resist a lateral force pushing on the wall.

(i) Compute the horizontal force acting on the wall at failure using Rankine's theory.

(4 Marks)

(ii) Compute the horizontal force acting on the wall at failure using the log spiral method.

(4 Marks)

(iii) Sketch the failure surfaces according to Rankine's theory and the log spiral method.

(2 Marks)

(iv) Explain why Rankine's theory yielded a lower horizontal force at failure.

(3 Marks)

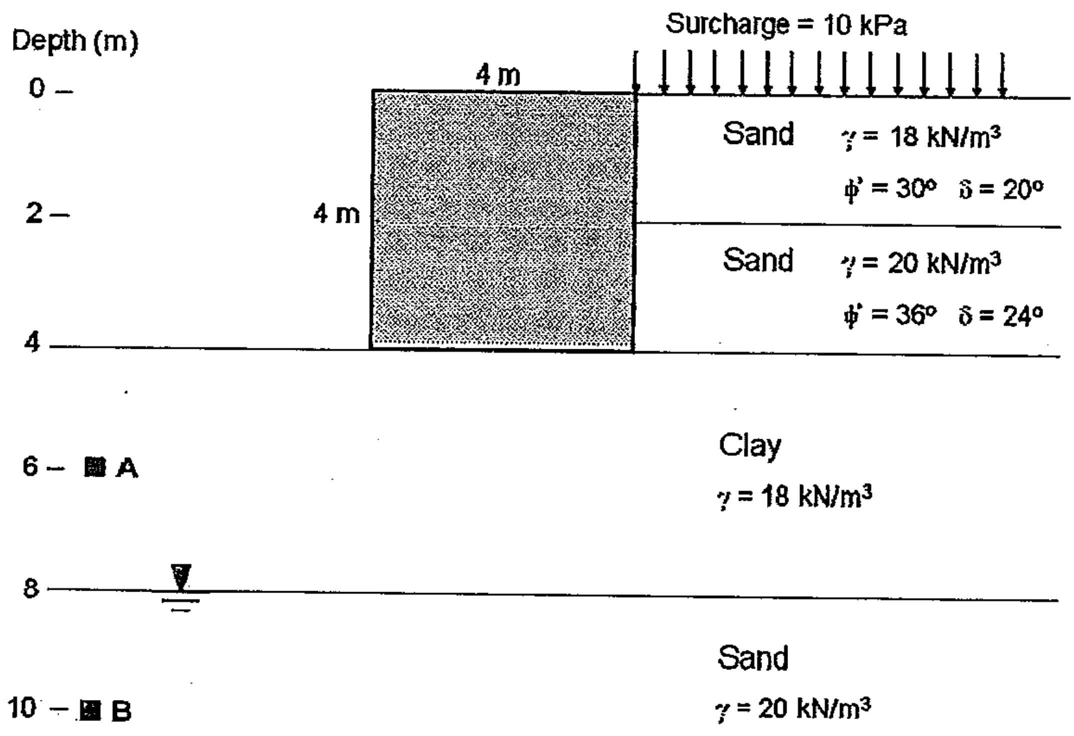


Figure Q1

Note: Relevant tables and formulas are included in the Appendix.

2. (a) A single story warehouse is to be constructed on a stiff clay deposit as shown in Figure Q2a. The foundation support is a flexible concrete slab. The building weight inclusive of dead and live load is equivalent to a uniform surcharge of 20 kPa.

(i) Compute the immediate settlement at the center and corner of the building.

(6 Marks)

(ii) Compute the consolidation settlement at the center and corner of building. The coefficient of volumetric compressibility (m_v) of the stiff clay is 0.06 m^2/MN.

(6 Marks)

(b) An earth dam is to be constructed at a nearby site. The design geometry is shown in Figure Q2b. The length of the dam is 120 m. The permeability of the foundation soil is 1×10^{-6} m/s. The unit weight of fill in the earth dam is estimated to be 20 kN/m^3.

(i) Construct a flownet beneath the earth dam. You need to reconstruct the geometry in your answer book.

(7 Marks)

(ii) Compute the flow quantity in litres per hour. (3 Marks)

(iii) Determine the pore pressures at "A" and "B". (3 Marks)

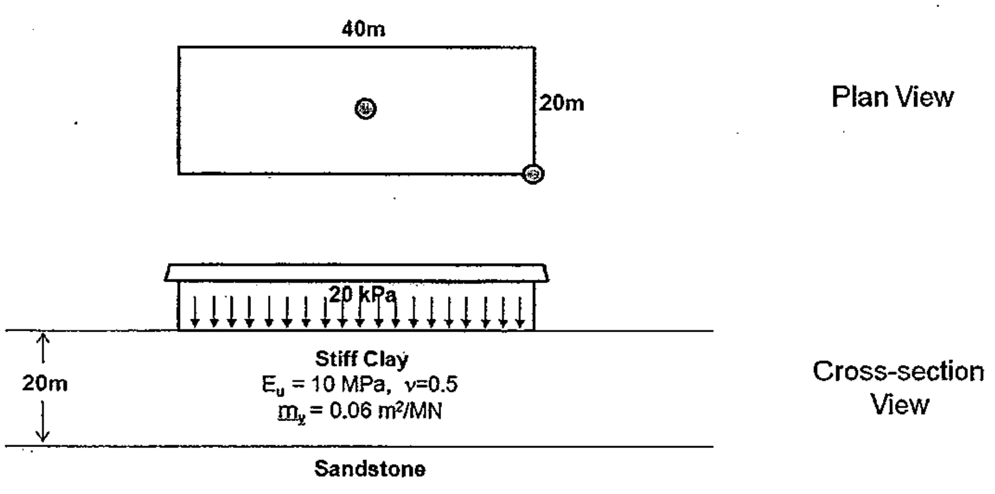


Figure Q2(a)

Note: Question No.2 continues on 4.

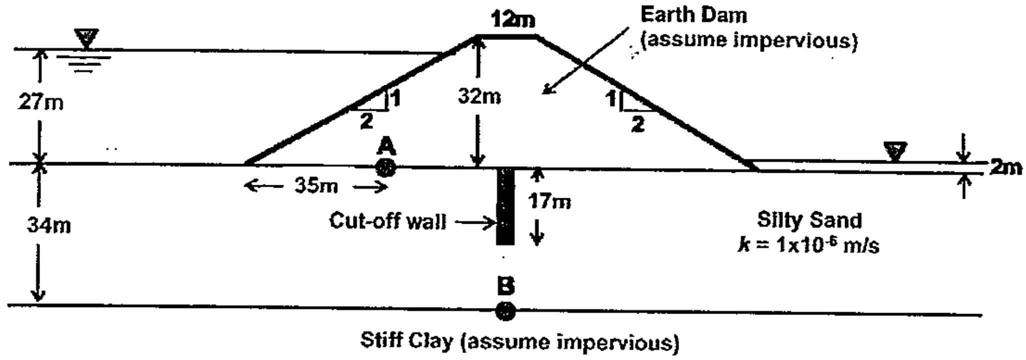


Figure Q2(b)

Note: Relevant tables and formulas are included in the Appendix.

3. (a) In the slope stability method of slices, the soil mass above the slip surface is divided into a number of slices. Figure Q3(a) shows forces acting on a slice.

(i) State the assumption used in the Fellenius (or Swedish) method and derive an equation for the effective normal force on the base of the slice N' in accordance with the Fellenius (or Swedish) method by considering the equilibrium of forces normal to the base of the slice.

(5 Marks)

(ii) State the assumption used in the Bishop method and derive an equation for the effective normal force on the base of the slice N' in accordance with the Bishop method by considering the equilibrium of forces in the vertical direction.

(5 Marks)

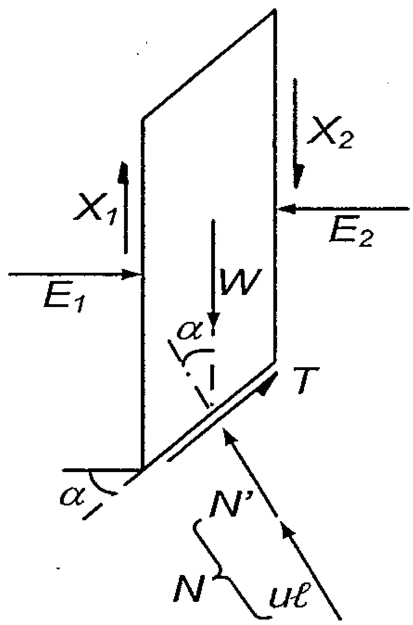
(iii) State the assumption used in the Spencer method and derive an equation for the effective normal force on the base of the slice N' in accordance with the Spencer method by considering the equilibrium of forces in the vertical direction.

(5 Marks)

Note: Question No.3 continues on page 6.

(b) Figure Q3(b) shows a long slope of a residual soil with a unit weight of 19 kN/m^3 above and below water table and shear strength parameters: c' = 0 and ϕ' = 30°. The slope is inclined at 25° to the horizontal. A potential slip surface on a plane parallel to the slope surface is located at a depth of 5m. The water table is always parallel to the slope surface and its location may vary from the depth of the potential slip surface to the slope surface. Determine the minimum and maximum factor of safety along the potential slip surface. Briefly explain whether it is possible to reach the calculated minimum factor safety.

(10 Marks)

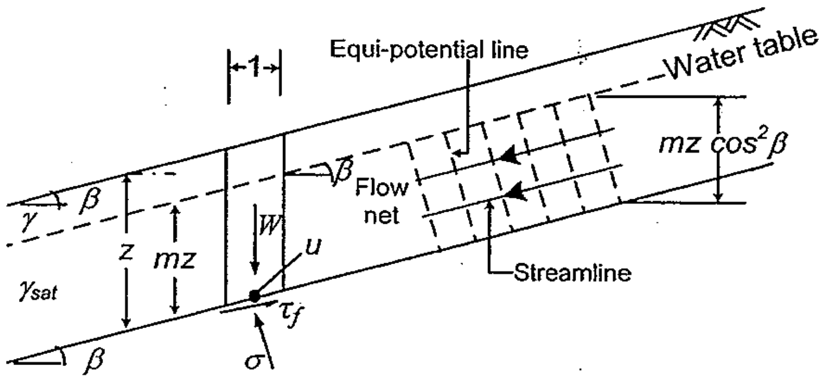


Note:

W	=	total weight of the slice
N	=	total normal force on the base of the slice
N'	=	effective normal force on the base of the slice
u	=	pore water pressure at the centre of the base of the slice
ℓ	=	length of the base of the slice
α	=	inclination of the base of the slice to the horizontal
T	=	shear force on the base of the slice
X_1, X_2	=	shear force on the side of the slice
E_1, E_2	=	total normal forces on the sides of the slice

Figure Q3(a)

Note: Question No.3 continues on page 7.



Plane Translational Slip

$$F = \frac{\left[\{(1-m)\gamma + m\gamma_{sat}\}z\cos^2\beta - mz\gamma_w\cos^2\beta\right]\tan\phi'}{\{(1-m)\gamma + m\gamma_{sat}\}z\sin\beta\cos\beta}$$

Note:

W	=	total weight of the slice
u	=	pore water pressure at the centre of the base of the slice
τ_f	=	shear strength along the base of the slice
σ	=	normal stress on the base of the slice
β	=	inclination of the slope to the horizontal
z	=	depth of the slip surface
F	=	factor of safety
γ_{sat}	=	saturated unit weight of soil
γ_w	=	unit weight of water
ϕ'	=	effective friction angle of soil

Figure Q3(b)

4. (a) Briefly explain the role of water in affecting stability of slope and the working principles of (two) preventive measures that can be used to minimize the effect of water on slope stability.

(7 Marks)

(b) Briefly explain why preloading with vertical drains is an appropriate improvement method for soft clay and in-situ densification is appropriate for loose sand. In addition, briefly explain the working principles of the preloading method with vertical drains and the in-situ densification method.

(8 Marks)

(c) A landfill site requires a compacted soil cover for minimizing water infiltration into the landfill. Should the liner be compacted at the dry or at the wet of optimum condition? Give reason for your answer.

(5 Marks)

(d) A sand deposit of 10 m thick has a relative density of 20%, a maximum void ratio of 0.9 and a minimum void ratio of 0.25. The sand deposit is located near a residential area and it requires a densification procedure in order to have a relative density of 80%. Briefly explain the working principle of an appropriate method that can be used for the densification of the sand deposit and calculate the expected void ratio to be achieved after the densification works.

(5 Marks)

END OF PAPER

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1.a) i). A → disturbed clay → w moisture content. Atterberg limits.
B → sand → Fine content. Sieve analysis..

ii). $N_{60} = \frac{E_m C_B C_S C_R N}{0.6}$

$N_{60A} = \frac{0.73 \times 1.05 \times 1.2 \times 0.75 \times 20}{0.6} = 23$ #

$N_{60B} = \frac{0.73 \times 1.05 \times 1.2 \times 0.95 (\text{or } 0.85) \times 20}{0.6} = 29\ (\text{or } 26).$

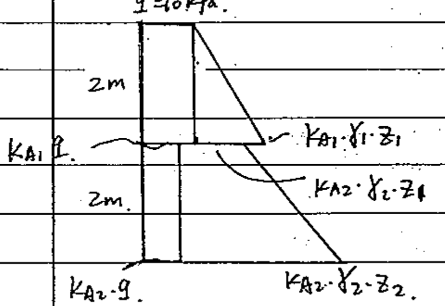
$C_N = \frac{10}{\sqrt{\sigma_B'}} = \frac{10}{\sqrt{18 \times 4 + 10 \times 2}} = 1.04 < 2.$

$\therefore N_{60corrB} = C_N N_{60B} = 1.04 \times 29\ (\text{or } 26) = 30\ (\text{or } 27)$ #

iii). $\tau_A \backsim \tau_B$

iv). Thin-wall sampler.
Consolidation test. Atterberg limits test. W test. UC test.

b) i). $K_{A1} = \frac{1 - \sin 30^\circ}{1 + \sin 30^\circ} = 0.33$ $K_{A2} = \frac{1 - \sin 36^\circ}{1 + \sin 36^\circ} = 0.26$



$K_{A1} q = 0.33 \times 10 = 3.3$ kPa

$K_{A2} q = 0.26 \times 10 = 2.6$ kPa

$K_{A1} \cdot \gamma_1 \cdot z_1 = 0.33 \times 18 \times 2 = 11.88$ kPa

$K_{A2} \cdot \gamma_2 \cdot z_1 = 0.26 \times 20 \times 2 = 10.4$ kPa

$K_{A2} \cdot \gamma_2 \cdot z_2 = 0.26 \times 20 \times 4 = 20.8$ kPa.

$P_{A1} = 3.3 \times 2 + 2.6 \times 2 + \frac{1}{2} \times 11.88 \times 2 + \frac{1}{2} \times (10.4 + 20.8) \times 2$

$= 54.8$ kN/m. #

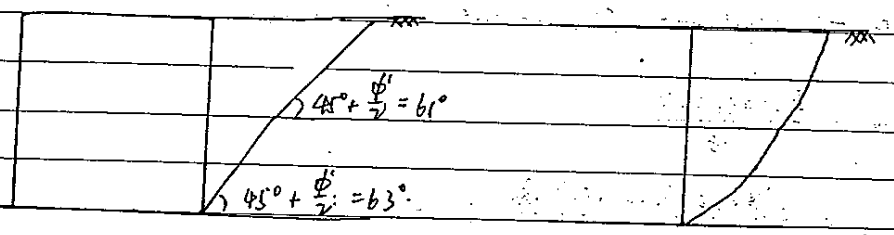
ii) $K_{AH_1} = 0.28$ $K_{AH_2} = 0.22$

$P_{A1} = 0.28 \times (10 \times 2 + \frac{1}{2} \times 18 \times 2^2) + 0.22 \times [10 \times 2 + \frac{1}{2} \times 20 \times (2 + 4) \times 2]$

$= 15.68 + 30.8$

$= 46.48$ kN/m. #

iii). Rankine's Log-spiral:



iv). Actually, Rankine's theory yielded a higher horizontal ~~to~~ force for a active case. This is because, in Rankine's theory, the friction between the wall and soil is neglected.

(For this question, I have checked with a professor after the exam, and he ~~had~~ has ~~conf~~ confirmed my result.)

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2. a> i> Center. $L/B = 40/20 = 2 \Rightarrow I_s = 1.53$

$$S_i = \frac{q \cdot B}{E}(1-\nu^2) I_s = \frac{20\times10^3\times20}{10\times10^6}\times(1-0.5^2)\times1.53 = 45.9\,mm$$ ※

Corner. $I_s = 0.76$.

$$S_i = \frac{20\times10^3\times20}{10\times10^6}(1-0.5^2)\times0.76 = 22.8\,mm$$ ※

ii> Center. $m = B/z = \frac{20}{10} = 2$. $n = L/z = \frac{10}{10} = 1$

$\Rightarrow I_r = 0.20$.

$\Delta\sigma_v = 4\times20\times0.20 = 16\,kPa$

$S_c = m_v \cdot H \cdot \Delta\sigma_v = 0.06\times20\times16 = 19.2\,mm$ ※

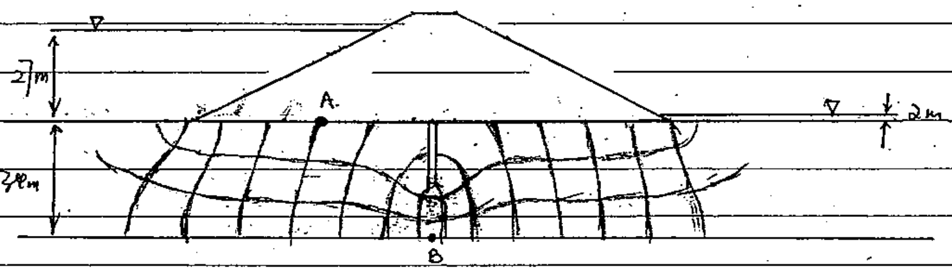
Corner. $m = \frac{40}{10} = 4$ $n = \frac{20}{10} = 2$.

$\Rightarrow I_r = 0.24$.

$\Delta\sigma_v = 20\times0.24 = 4.8\,kPa$.

$S_c = 0.06\times20\times4.8 = 5.76\,mm$ ※

b>.



ii> $N_f = 3$. $N_d = 15$ $h = 27-2 = 25m$. $\Delta h = \frac{25}{15} = \frac{5}{3}$

$q = kh\frac{N_f}{N_d}\times b = 1\times10^{-6}\times25\times\frac{3}{15}\times120 = 0.6\,L/sec = 2160\,L/hr$ ※

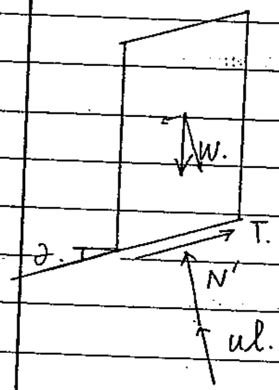
iii> $h_{Ap} = 27 - 4\times\frac{5}{3} = 20.33\,m$.

$u_A = \gamma_w \cdot h_{Ap} = 9.81\times20.33 = 199.47\,kPa$ ※

$h_{Bp} = 27+34-7.5\times\frac{5}{3} = 48.5\,m$

$u_B = \gamma_w \cdot h_{Bp} = 475.785\,kPa$ ※

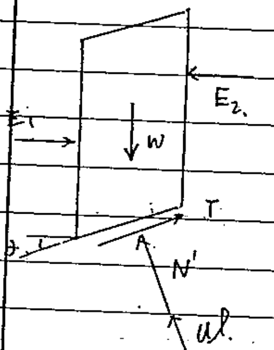
3 a) i). Assumption: For each slice the resultant of the interslice forces is zero, namely $\begin{cases} E_1 - E_2 = 0 \\ X_1 - X_2 = 0. \end{cases}$



$$N' + ul = W\cdot\cos\alpha$$

$$N' = W\cdot\cos\alpha - ul$$

ii). Assumption. The resultant forces on the sides of the slices are horizontal i.e. $X_1 - X_2 = 0$.

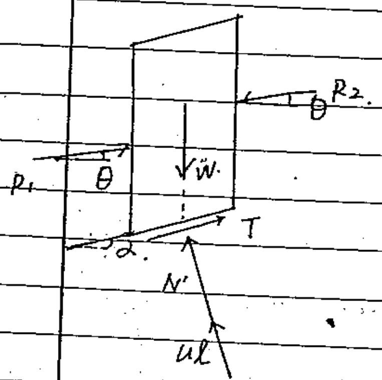


$$\begin{cases} (N'+ul)\cdot\cos\alpha + T\cdot\sin\alpha = W \\ T = \frac{\tau_f l}{F} = \frac{1}{F}(c'l + N'\tan\phi') \end{cases}$$

$$\Rightarrow (N'+ul)\cos\alpha + \frac{1}{F}(c'l + N'\tan\phi')\sin\alpha = W$$

$$\Rightarrow N' = \frac{W - \frac{c'l}{F}\cdot\sin\alpha - ul\cos\alpha}{\cos\alpha + \frac{\tan\phi'\sin\alpha}{F}}$$

iii). Assumption: the resultant interslice forces are parallel and in which both force and moment equilibrium are satisfied.



$$(N'+ul)\cdot\cos\alpha + (R_1 - R_2)\cdot\sin\theta + T\cdot\sin\alpha = W.$$

~~$N = W$~~

$$N' = \frac{W - (R_1 - R_2)\sin\theta - \frac{c'l}{F}\sin\alpha - ul\cos\alpha}{\cos\alpha + \frac{\tan\phi'\sin\alpha}{F}}$$

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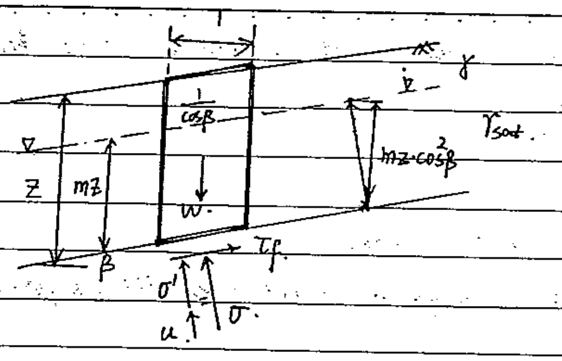
b).



$$W = \{(z - mz)\gamma + mz\,\gamma_{sat}\} \times 1 = \{(1-m)\gamma + m\gamma_{sat}\} z.$$

$$\sigma = \frac{W \cdot \cos\beta}{1/\cos\beta} = \{(1-m)\gamma + m\gamma_{sat}\} z \cdot \cos^2\beta$$

$$\tau = \frac{W \cdot \sin\beta}{1/\cos\beta} = \{(1-m)\gamma + m\gamma_{sat}\} \cdot z \cdot \sin\beta \cdot \cos\beta$$

$$u = mz \cdot \cos^2\beta \cdot \gamma_w.$$

$$F = \frac{\tau_f}{\tau} = \frac{(\sigma - u)\tan\phi'}{\tau} = \frac{[\{(1-m)\gamma + m\gamma_{sat}\} \cdot z\cos^2\beta - mz\gamma_w\cos^2\beta]\tan\phi'}{\{(1-m)\gamma + m\gamma_{sat}\} z \cdot \sin\beta \cdot \cos\beta}$$

If the soil is dry i.e. $m=0$.

$$F_{max} = \frac{\tan\phi'}{\tan\beta} = \frac{\tan 30^\circ}{\tan 25^\circ} = 1.24$$

If the soil is fully saturated i.e. $m=1$

$$F_{min} = \frac{\gamma'\tan\phi'}{\gamma_{sat}\tan\beta} = \frac{9 \times \tan 30^\circ}{19 \times \tan 25^\circ} = 0.59 < 1 \Rightarrow \text{impossible.}$$

The slope will fail before it reaches F_{min}.

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4. a> $\sigma = \sigma' + u$. High pore pressure will result in low σ', thus reducing the strength of the soil.

Measures : ① Surface drainage

i> providing appropriate grades.

ii> Use additional drainage measures like ditches paved with concrete

② Subsurface drainage

i> Perforated pipe drains

ii> Wells

iii> Horizontal drains.

b> Preloading for clay.

The permeability of soft clay is very low, therefore the weight of the fill causes the soil to consoliate, thus improving both their settlement & strength properties. The vertical drains accelerate the consolidation process

Working principle: Cover the soil with a temporary surcharge fill. Once the desired properties have been achived, the surcharge is removed.

In-situ densification for sand.

For sand, its properties are relate to its density. By increasing the density, the shear strength can be increased and compressibility, permeability ea will decrease.

Working principle: ~~Use vib~~ Densify the soil by vibration, including vibro-compaction, dynamic compation and blast densification.

c>. To minimizing water infiltration into the fill, wet of optimum should be used because the clays ~~will~~ have a more oriented fabric which minimize the permeability

wet. of. opt.

d>. $D_r = \frac{e_{max} - e}{e_{max} - e_{min}} = \frac{0.9 - e}{0.9 - 0.28} = 80\% \Rightarrow e = 0.38$

Vibro-compaction

Insert some types of vibrotary probe into the ground.

Then compact the ~~soil~~ sand using vibration.