

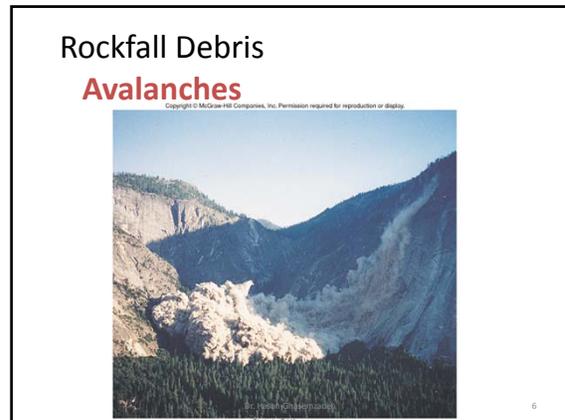
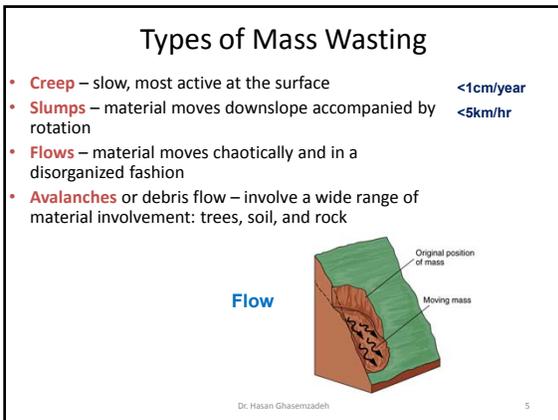
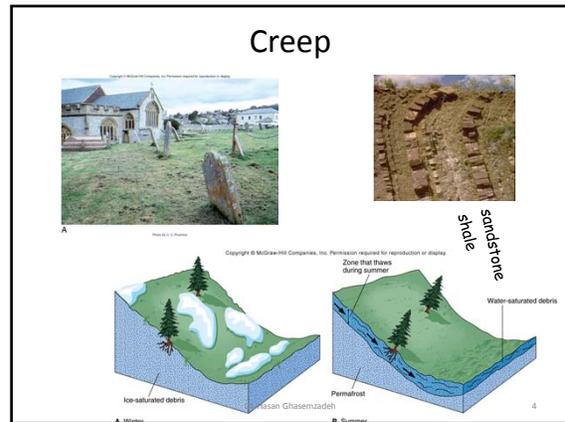
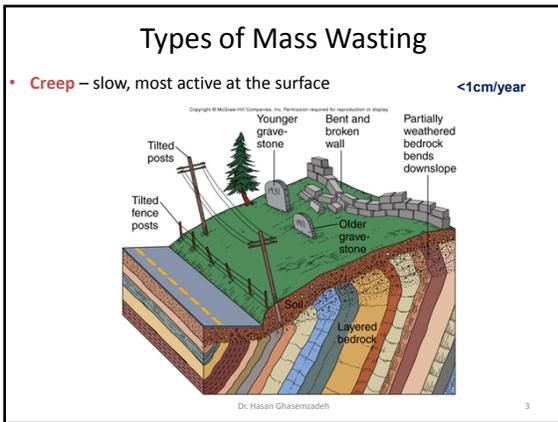


فهرست عناوین و فصول

- ۱- مقدمه
- ۲- طبقه بندی سنگها
- ۳- خواص فیزیکی و مکانیکی سنگ ها
- ۴- رفتار سنگ ، معیارهای خرابی و شکست
- ۵- تنش های در جا در سنگ
- ۶- صفحات ضعیف در سنگها
- ۷- کاربرد مکانیک سنگ در مهندسی

۱- بایداری شیروانی سنگی - ریزش سنگ

- ۲- پی بر بستر سنگی
- ۳- تونل



Types of Mass Wasting

- **Creep** – slow, most active at the surface <1cm/year
- **Slumps** – material moves downslope accompanied by rotation <5km/hr
- **Flows** – material moves chaotically and in a disorganized fashion
- **Avalanches** or debris flow – involve a wide range of material involvement: trees, soil, and rock
- **Slides** – material moves as cohesive unit along a clearly define surface >5km/hr
- **Falls** – material free falls upon failure or undercutting, motion is rapid
 - **Rockfalls** are the most common form

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Slide, Flow, Fall

Fall

Original position of cliff
Falling rock
Waves

Slide

Original position of mass
Moving mass
Tree was here
Original position
Moving mass

Translational slide Rotational slide

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Landslide

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Failure mode

Topping Failure

a. Planar Topping b. Block Topping

Plane Failure

Failure Surface
Failure Block
Failure Direction

Wedge Failure (3D)

Slope Face
Slope Angle
Friction Angle
Discontinuity dip

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تحليل پایداری شیروانی

روش های تحلیل شیروانی

- ۱- تحلیل با استفاده از فرمول های موجود
- ۲- تحلیل با استفاده از گراف های موجود
- ۳- تحلیل عددی به کمک رایانه

تحليل پایداری شیروانی

مدل سازی پیوسته و ناپیوسته

Classes of rock strength

Sliding surface along discontinuity?

Yes

Joints parallel to face
Pair of intersecting joints

Use discontinuity shear strength

No

Closely fractured rock
Weak, massive rock

Use rock mass shear strength

Slide of Jointed Rock in Slope

Stable

 $\psi \leq \phi$

Unstable

 $\psi > \phi$

Slide of Jointed Rock in Slope

Dry cracks

Limiting Equilibrium: $W \cdot \sin \psi = R = c \cdot A + W \cdot \cos \psi \cdot \tan \phi$

water in cracks

Limiting Equilibrium: $W \cdot \sin \psi + U = R = c \cdot A + (W \cdot \cos \psi - U) \cdot \tan \phi$

Effect of water in tension crack

(a) Tension crack at head

(b) tension crack on slope face

Safety Factor

Geometry

Free body diagram

$\gamma_w =$ unit weight of water
 $\gamma =$ unit weight of rock

- the rock mass is impermeable,
- the sliding block is rigid,
- the strength of the sliding plane is given by the Mohr-Coulomb criterion
- all forces pass through the centroid of the sliding block

$$F = \frac{c'(H-z) \cos \psi_p + (W \cos \psi_p - U - V \sin \psi_p) \tan \phi'}{V \cos \psi_p + W \sin \psi_p}$$

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Effect of water in sliding

Gravity

Water

permeable rock

Water softens shale below saturated sandstone

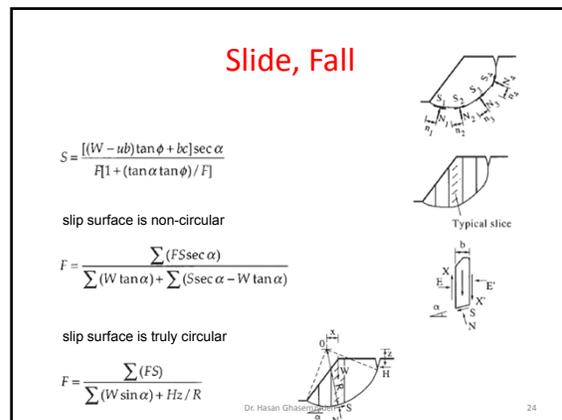
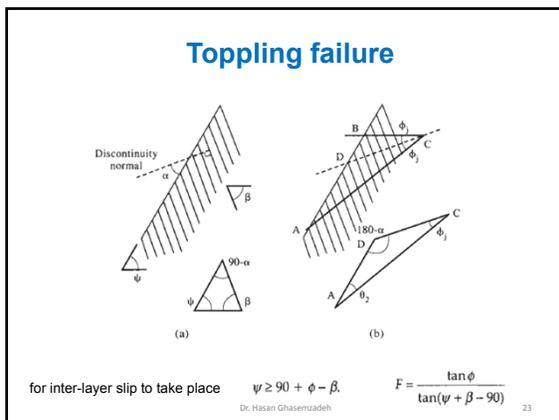
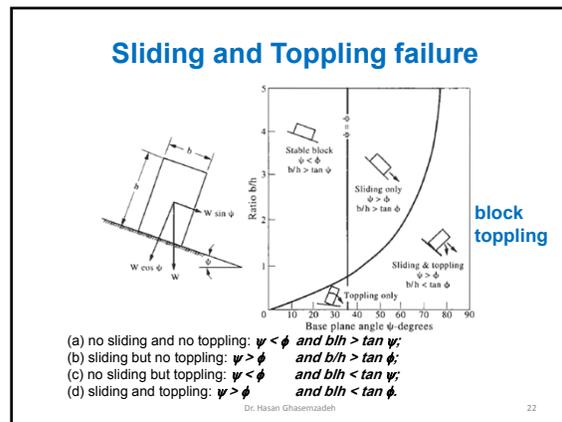
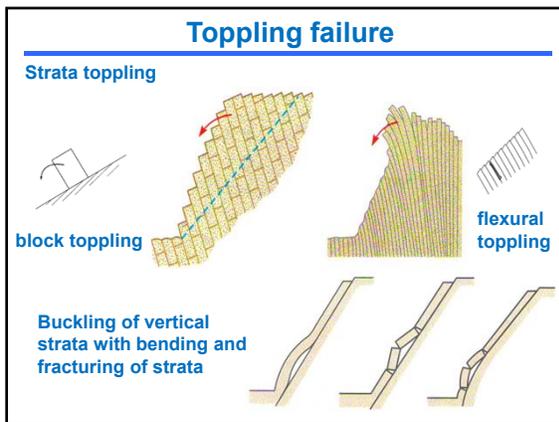
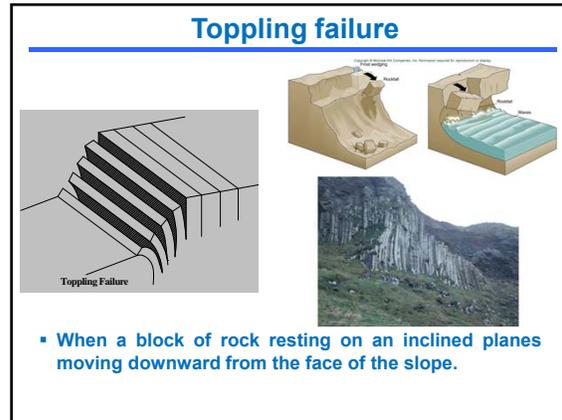
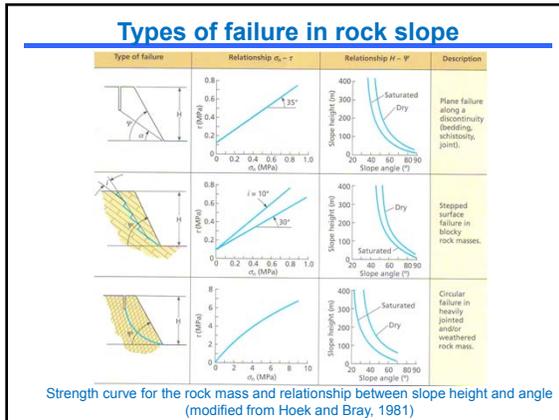
Sliding along wet shale layer, which acts as a lubricant

Forces acting on slope

Forces acting on a planar slide surface

Forces exerted by a resistant external element (anchor) applied to the slope

W: Weight of block
N: Normal force on AB
R: Resistant force ($R_c + R_s$)
U: Force of water



Wedge failure

Wedge formed by bedding and orthogonal joints in sandstone (US60, Globe, AZ)
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Slide, Fall

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Slide, Fall

$$FS = \frac{(R_A + R_B) \tan \phi}{W \sin \psi_i}$$

$$R_A + R_B = \frac{W \cos \psi_i \sin \beta}{\sin \frac{1}{2} \delta} \quad F = \frac{\sin \beta}{\sin \frac{1}{2} \delta} \times \frac{\tan \phi}{\tan \psi_i}$$

$$F = k_W \times F_P$$

wedge factor of safety = wedge factor x plane factor of safety

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Slide, Fall

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بایداری گوه

ضریب اطمینان از رابطه زیر بدست می آید
 $FS = A \tan \phi_A + B \tan \phi_B$
ضرایب از گراف ها بدست می آید
درزه با شیب کمتر Plan A نامیده می شود

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بایداری گوه

7.9 Wedge stability charts for friction only: A and B charts for a dip difference of 10°.
Rock Slope Engineering Duncan C. Wyllie and Christopher W. Mah

مثال پایداری گوه

گروه ناشی از صفحات ناپوستگی زیر را در نظر بگیرید

	Dip	Dip direction	Friction angle, ϕ
Plane A	45°	115°	34.5°
Plane B	75°	225°	37°
Difference	30°	110°	

1- تقاضای شیب ها و آزمایشات را بدست می آوریم
 2- گرافایی را انتخاب می کنیم که تفاوت شیب آنها برابر تفاوت شیب صفحات گوه باشد
 3- ضرایب از گراف ها بدست می آید ضریب A برای صفحه درزه با شیب کمتر است
 4- ضریب اطمینان از فرمول زیر بدست می آید

$$FS = A \tan \phi_A + B \tan \phi_B$$

مثال پایداری گوه

Charts for dip difference between planes forming the wedge of 30°

$$FS = A \tan \phi_A + B \tan \phi_B = 1.1 \tan 34.5 + 0.45 \tan 37 = 1.09$$

پایداری شیروانی همگن و همسانگرد

خاک چسبنده

Slope stability charts for $\phi = 0$ soils (after Janbu 1968)

پایداری شیروانی همگن و همسانگرد

مختصات مرکز دایره لغزش

مختصات مرکز دایره لغزش

پایداری شیروانی همگن و همسانگرد

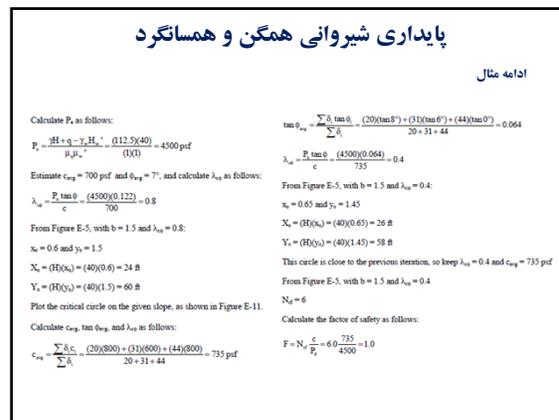
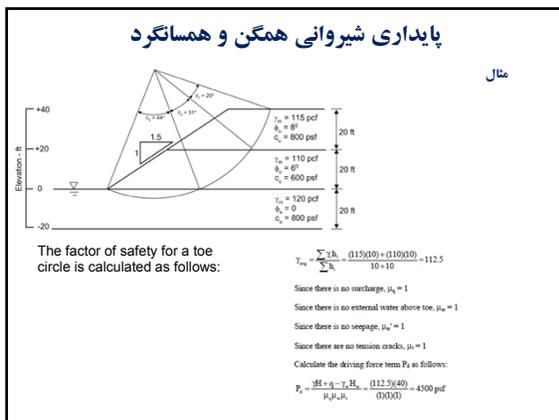
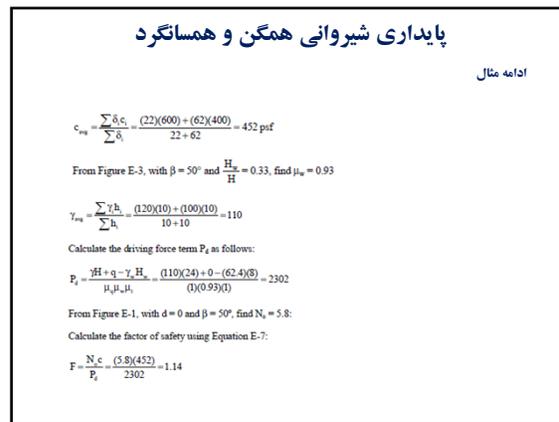
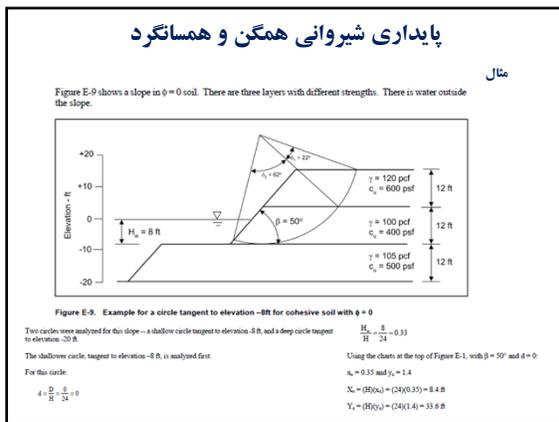
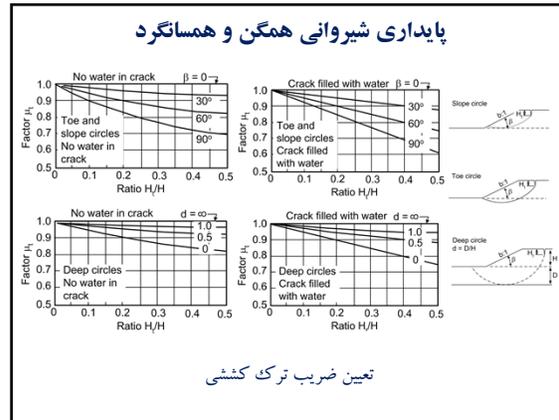
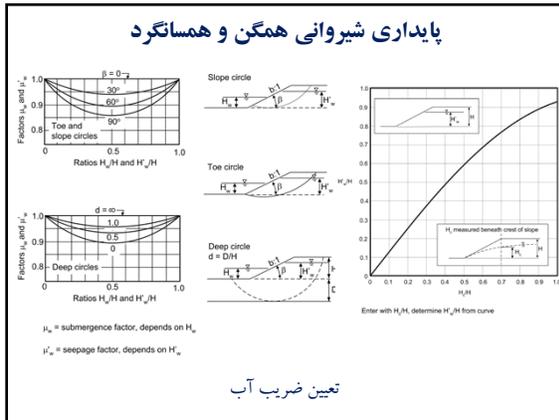
خاک دانه ای

Slope stability charts for $\phi > 0$ soils (after Janbu 1968)

پایداری شیروانی همگن و همسانگرد

تعیین ضریب سربار

تعیین ضریب سربار



پایداری شیروانی همگن و همسانگرد

شیروانی طولی

γ = total unit weight of soil
 γ_w = unit weight of water
 c' = cohesion intercept
 ϕ' = friction angle
 r_u = pore pressure ratio = $u/\gamma H$
 u = pore pressure at depth H

$r_u = \frac{X \gamma_w}{T \gamma} \cos^2 \beta$

$r_u = \frac{\gamma_w}{\gamma} \frac{1}{1 + \tan \beta \tan \theta}$

پایداری شیروانی همگن و همسانگرد

شیروانی طولی

1. Determine r_u from measured pore pressure or formulas at right.

2. Determine A and B from charts below.

3. Calculate $F = A \frac{\tan \phi'}{\tan \beta} + B \frac{c'}{\gamma H}$

Seepage emerging from slope

$$r_u = \frac{\gamma_w}{\gamma} \frac{1}{1 + \tan \beta \tan \theta}$$

پایداری شیروانی همگن و همسانگرد

مثال شیروانی طولی

$\gamma = 120 \text{ pcf}$
 $c' = 300 \text{ psf}$
 $\phi' = 30^\circ$
 $\tan \phi' = 0.577$

$\beta = 20^\circ$
 $\tan \beta = 0.364$
 $\cot \beta = 2.75$

For seepage parallel to slope:
 $X = 8 \text{ ft}$ and $T = 11.3 \text{ ft}$
 $r_u = \frac{X \gamma_w}{T \gamma} \cos^2 \beta = \frac{8 \cdot 62.4}{11.3 \cdot 120} (0.94)^2 = 0.325$
 From Figure E-7, with $r_u = 0.325$ and $\cot \beta = 2.75$:
 $A = 0.62$ and $B = 3.1$

For horizontal seepage emerging from slope, $\theta = 0^\circ$
 $r_u = \frac{\gamma_w}{\gamma} \frac{1}{1 + \tan \beta \tan \theta} = \frac{62.4}{120} \frac{1}{1 + (0.364)(0)} = 0.52$
 From Figure E-7, with $r_u = 0.52$ and $\cot \beta = 2.75$:
 $A = 0.41$ and $B = 3.1$

Calculate the factor of safety, as follows:
 $F = A \frac{\tan \phi'}{\tan \beta} + B \frac{c'}{\gamma H} = 0.62 \frac{0.577}{0.364} + 3.1 \frac{300}{(120)(12)} = 0.98 + 0.65 = 1.63$

نغز در حالت وجود آب

Taylor's Chart

نغز در حالت وجود آب

Hoek & Bray Chart

نغز در حالت وجود آب

Hoek & Bray Chart

لغزش در حالت وجود آب

To demonstrate the use of the charts consider the case of a slope 10 m high with a slope of 20 degrees in a clayey soil with properties $c_u = 20 \text{ kN/m}^2$, $\phi_u = 5^\circ$, $c' = 2 \text{ kN/m}^2$, $\phi' = 25^\circ$, $\gamma_w = 16 \text{ kN/m}^3$. In the long term the water table is at the surface for distances greater than 40 m behind the toe of the slope.

مثال

When using Hoek and Bray charts it is important that effective strength parameters c' and ϕ' are used.

- Determine the appropriate chart from the known position of the water table. In this example it is Chart 3
- Calculate $\frac{c}{\gamma H \tan \phi} = \frac{2}{16 \times 10 \times \tan 25} = 0.027$
- For slope angle 20° read off chart
 - either $\frac{c}{\gamma H F} = 0.0139$
 - or $\frac{\tan \phi}{F} = 0.518$
- Hence $F = 0.9$ (The slope would fail)

احتمال خرابی

Sau Mau Ping slope problem

1. Fixed dimensions:

Overall slope height	$H = 60 \text{ m}$
Overall slope angle	$\psi_f = 50^\circ$
Failure plane angle	$\psi_p = 35^\circ$
Upper slope inclination	horizontal
Bench width $b_{max} = H(\cot \psi_p - \cot \psi_f)$	$b_{max} = 35.34 \text{ m}$
Unit weight of rock	$\gamma_r = 2.6 \text{ tonnes/m}^3$
Unit weight of water	$\gamma_w = 1.0 \text{ tonnes/m}^3$

2. Random variables

	Mean values	Standard deviation	Distribution
Friction angle on joint surface	$\phi = 35^\circ$	± 5	Normal
Cohesive strength of joint surface	$c = 10 \text{ tonnes/m}^2$	± 2	Normal
Depth of tension crack	$z = 14 \text{ m}$	± 3	Normal
Distance from crest to tension crack	$b = 15.3 \text{ m}$	± 4	Normal
Depth of water in tension crack	$z_w = z/2$	min = 0, max = z	Exponential
Ratio of horizontal earthquake to gravitational acceleration	$\alpha = 0.08$	min = 0, max = 2α	Exponential

