Environmental Geology Mass Wasting / Slope Stability Problem Set

(1) A block of rock is perched on a cliff with 5000 joules of potential energy. The cliff is 200 feet high, calculate the mass of the block of rock (show all of your work, answer in kg).

(2) A block of rock is perched on a cliff 500 feet high and weighs 5000 pounds. Calculate the amount of potential energy in the system (show all of your work, answer in joules).

(3) A mass of rock material is sliding down a bedrock slope at a velocity of 2 mi/hr. The total kinetic energy in the system is 10,000 joules. Determine the mass of the sliding rock material (show all of your work, answer in kg).

(4) A boulder that weighs 5 tons has rolled onto a bridge that measures 200 ft long and 50 ft wide. What is the stress load of the boulder on the bridge (answer in N per sq. meter).

(5) A block of rock (better known as a "BFR") is pushed off of a cliff and has a density of 3.0 gm/cm^3. The dimensions of the block are roughly 5 m x 6.2 m x 3.2 m. The cliff is 300 ft high. Calculate the amount of work expended by the time the rock hits the ground beneath.

(6) A block of rock is sitting on a slope of 35 degrees. The density of the block is 4.0 gm/cm^3. The dimensions of the block are roughly 3.0 m x 2.1 m x 7.0 m. Calculate the normal force and shear force exerted on the block of rock. (show all of your work, answer in N per sq. meter).

(7) A block of rock is sitting on an inclined slope. The shear force is 10 kN and it's mass is 5000 kg. Determine the slope angle. Calculate the normal force (answer in N)

(8) A mass of colluvium measures 0.4 km (width) x 0.2 km (length) x 0.15 km (thickness). The bulk density of the colluvium is 2.1 Mg/m^3 (that's "megagram" per cubic meter). Calculate the following for the mass: (a) specific weight (N per cubic meter) (b) normal stress (kN per sq. m) (c) shear stress (kN per sq. m). Show all of your work.

$\theta = 12^\circ$

(9) A 3.6 m thick mass of regolith rests on top of a sloping bedrock surface. The hillslope is 12 degrees and the factor of safety is 1.2. A geotechnical engineering firm conducted an in-situ slope stability analysis with the following results:

regolith cohesion = 3245 N/m^2
effective normal stress = 45789 N/m^2
density = 2.3 gm/cm^3
specific wt. = 25921 N/m^3

* ASSUME THAT THE TOTAL SHEAR STRENGTH IS EQUAL TO THE TOTAL SHEAR FORCE ACTING ON THE MATERIAL

Determine the angle of internal friction of the material. (degrees)

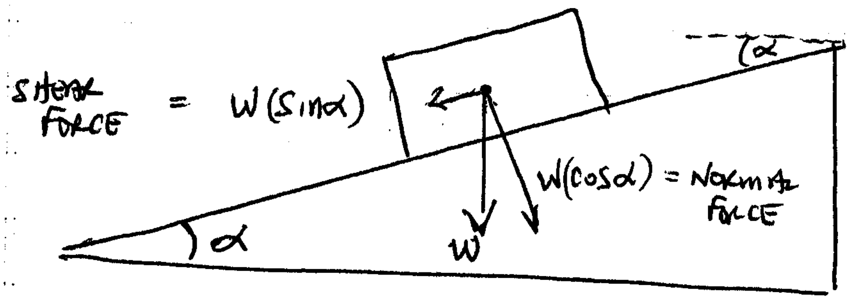
Determine the shear force acting on the material. (N)

Determine the normal force acting on the material. (N)

Calculate the total weight of material (N).

ENVIRONMENTAL GEOLOGY – SLOPE STABILITY EQUATIONS

(1) BLOCK OF MASS ON SLOPE



W = Weight of Block (NEWTONS = $\frac{kg\text{-}m}{sec^2}$) = mg = ρgV = γV

m = mass, g = 9.8 m/sec², ρ = density, V = volume, γ = unit wt.

α = SLOPE ANGLE

Shear Force τ_s = W (Sin α) DOWNSLOPE FORCE

Normal Force σ_n = W (cos α) PERPENDICULAR FORCE

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(2) POTENTIAL ENERGY $E_p = mgh$

m = mass (kg)
g = 9.8 m/sec²
h = height (m)

$E_p = \frac{kg\text{-}m^2}{sec^2}$ = JOULE

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(3) KINETIC ENERGY $E_k = \frac{1}{2} m v^2$

m = mass (kg)
V = velocity (m/sec)

$E_k = \frac{kg\text{-}m^2}{sec^2}$ = JOULE

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(4) STRESS = F/A F = Force = WEIGHT = mg kg-m/sec² = NEWTON

A = AREA (m²)

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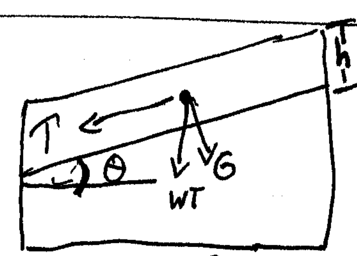
(5) THICK MASS OF REGOLITH ON SLOPE

wt = mg (N)

γ = wt/volume (specific weight)

$\sigma = \gamma h (\cos^2 \theta)$ = normal stress (N/m²)

$\tau = \gamma h (\cos \theta)(\sin \theta)$ = shear stress (N/m²)



h = thickness of REGOLITH
θ = SLOPE ANGLE

Mass Wasting and Hillslope Processes

I. Hillslope Physics / Physical Properties of Regolith

A. Basics of Slope Stability

1. Fundamental Terms

a. Energy - ability to do physical work

(1) Mechanical Energy

(a) **Potential Energy - energy of position**

$$Ep = mgh$$

where Ep = potential energy (joules), m = mass (kg), g = acceleration due to gravity (9.8 m/sec^2), h = height of material above reference surface (m)

Units: $1\ J = 1\ kg\text{-}m^2/sec^2$

(b) **Kinetic Energy - energy of motion**

$$Ek = 0.5mV^2$$

where Ek = kinetic energy (joules), m = mass (kg), V = velocity (m/sec)

Units: $1\ J = 1\ kg\text{-}m^2/sec^2$

b. **Force - push or pull action on a mass of material**

Newton's Second Law: $F = ma$

where F = force (newtons), m = mass (kg), a = acceleration (m/sec^2)

Units: $1\ N = 1\ kg\text{-}m/sec^2$

c. **Weight = pulling force of the Earth under the influence of gravity**

$$Wt = F = mg$$

where Wt = weight (N), F = force (N), m = mass (kg), g = acceleration due to gravity (9.8 m/sec^2)

d. **Stress - Force acting per unit surface area.**

$$stress = F/A$$

where stress is in N/m^2, A = area (m x m = m^2)

e. **Work - displacement of mass when acted upon by force**

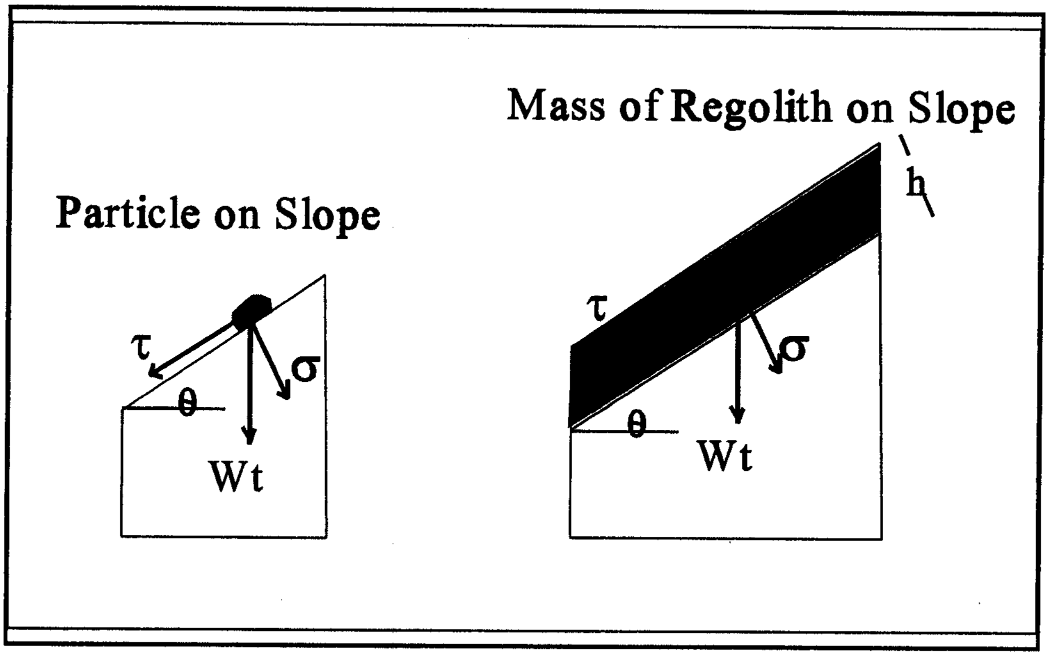
e.g. sliding mass of regolith

$$W = Fd$$

where W = work (J), F = force (N = 1 kg-m/sec^2), d = distance of mass displacement (m)

Units 1 J = 1 N-m = 1 kg-m^2/sec^2

2. Forces acting on Slope Material



Particle-on-Slope Equations:

τ = shear force parallel to slope (N)
σ = normal force perpendicular to slope (N)
θ = slope angle relative to horizontal plane (degrees)
Wt = weight of particle or mass of material (N)

$$Wt = mg = \text{weight of particle (N)}$$

$$\sigma = Wt (\cos \theta) = \text{normal force (N)}$$

$$\tau = Wt (\sin \theta) = \text{shear force (N)}$$

Mass-on-Slope Equations:

** Note: here we assume that a mass of regolith overlies a potential failure plane. The failure plane is a surface in 3-d with area. Thus, forces are applied per unit area, resulting in stresses. **

τ	= shear stress parallel to failure plane (N/m^2)
σ	= normal stress perpendicular to failure plane (N/m^2)
θ	= slope angle relative to horizontal plane (degrees)
γ	= specific weight of mass = Wt / volume (N/m^3)
h	= thickness of regolith above failure plane (m)

$$Wt = mg = kg\text{-}m/sec^2 = N$$

$$\gamma = Wt / volume = N/m^3 = \text{specific weight}$$

$$\sigma = \gamma h (\cos^2\theta) = \text{normal stress } (N/m^2)$$

$$\tau = \gamma h (\cos\theta)(\sin\theta) = \text{shear stress } (N/m^2)$$

Coulomb Equation (Measure of Total Shear Strength)

$$S = c + \sigma' \tan\phi$$

where S = total shear strength (N/m^2), c = cohesion (N/m^2), σ' = effective normal stress (N/m^2), ϕ = angle of internal friction

so...

$$F = \sigma / \tau$$ (Safety Factor)

$F < 1$: slope failure
$F > 1$: Slope stability
$F = 1$: slope failure threshold