Soil Stress

Air Hockey Game
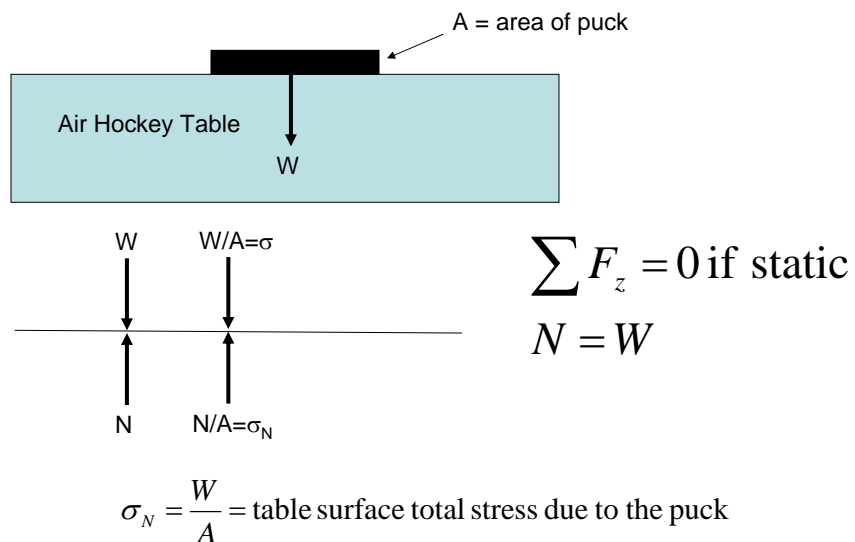
A = area of puck

Air Hockey Table

W

W   W/A=σ

N   N/A=σ$_N$

$$\sum F_z = 0 \text{ if static}$$

$$N = W$$

$$\sigma_N = \frac{W}{A} = \text{table surface total stress due to the puck}$$

Air Hockey Game with Fan on

A = area of puck

upwards air pressure

W

Air Hockey Table

$U = \mu_{air} A = air\ force$ acting on bottom of puck
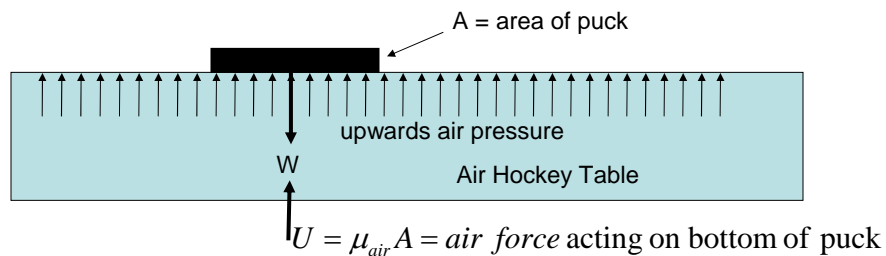
Air Hockey Game with Fan on

A = area of puck

upwards air pressure (μ_{air})

W = weight of puck

$$\sum F_z = 0$$

$$N' = W - U$$

$$\frac{N'}{A} = \frac{W}{A} - \frac{U}{A}$$

$$\sigma' = \sigma - \mu_{air}$$

$U = \mu_{air} A = air\ force$ acting on bottom of puck

N' = effective normal force of puck on table
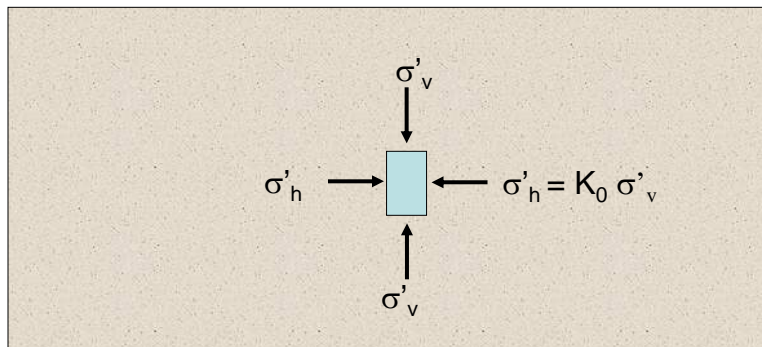
In force form

In stress form

Shear Resistance

- Shear resistance is controlled by normal stress the table feels (effective stress) not the total stress created by the puck.

$$If\ W = U \quad N' = 0$$
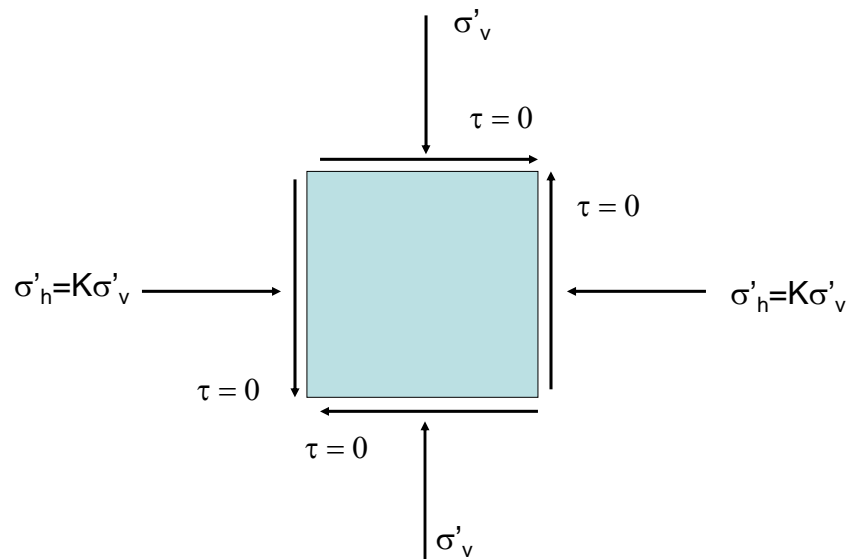
$$If\ \sigma = \mu \quad \sigma' = 0$$

- Effective stress is the net stress difference between the downward total stress and the upward stress reduction created by the air pressure acting on the puck

Stress in Soil mass

Note: If no soil movement there will be no shear stress

Stresses on Soil Element

$$\sigma'_v$$

$$\tau = 0$$

$$\tau = 0$$

$$\sigma'_h = K\sigma'_v \qquad\qquad \sigma'_h = K\sigma'_v$$

$$\tau = 0$$

$$\tau = 0$$

$$\sigma'_v$$
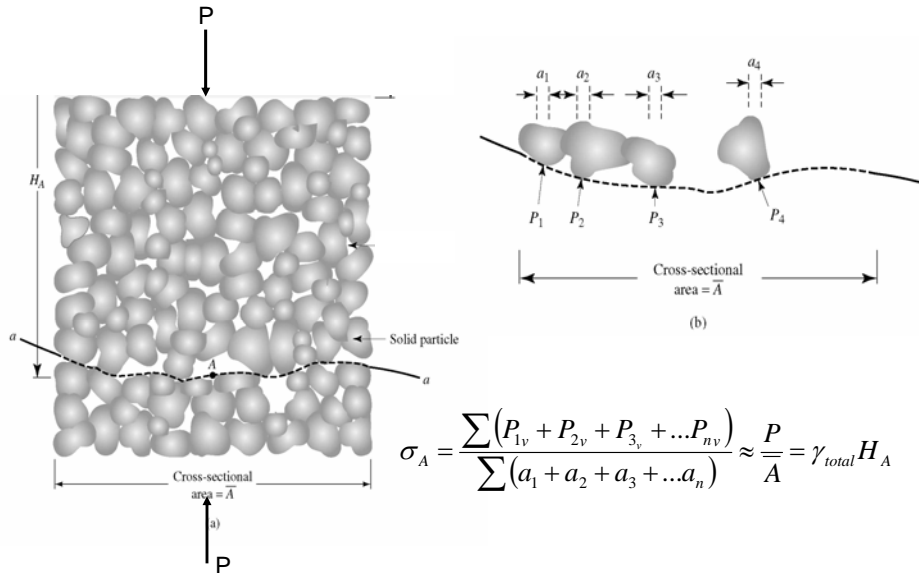
Earth Pressure Coefficient

$$K = \frac{\sigma'_h}{\sigma'_v}$$

K_o = lateral earth pressure coefficient at rest

K_a = Active Earth pressure coefficient

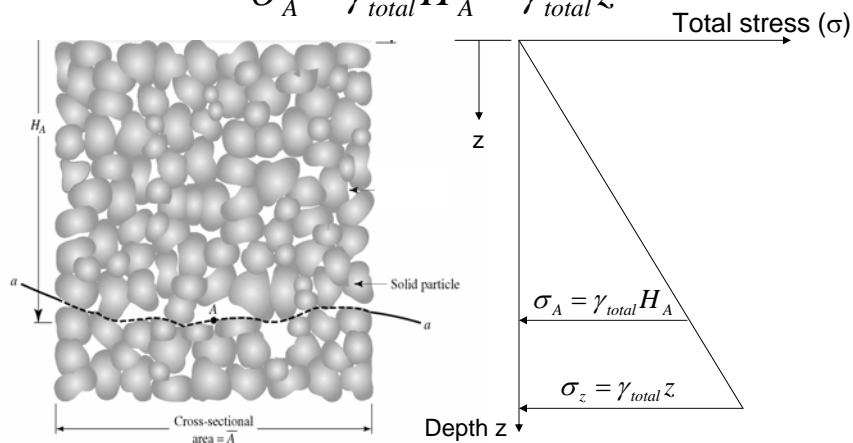K_p = Passive earth pressure coefficient

Vertical Total Stress

P

$$\sigma_A = \frac{\sum\left(P_{1_v} + P_{2_v} + P_{3_v} + ...P_{n_v}\right)}{\sum\left(a_1 + a_2 + a_3 + ...a_n\right)} \approx \frac{P}{\overline{A}} = \gamma_{total}H_A$$

P

Vertical Total Stress

• We do not know the actual particle to particle load or contact area

• We can determine the average total stress at Point A using the soil total unit weight
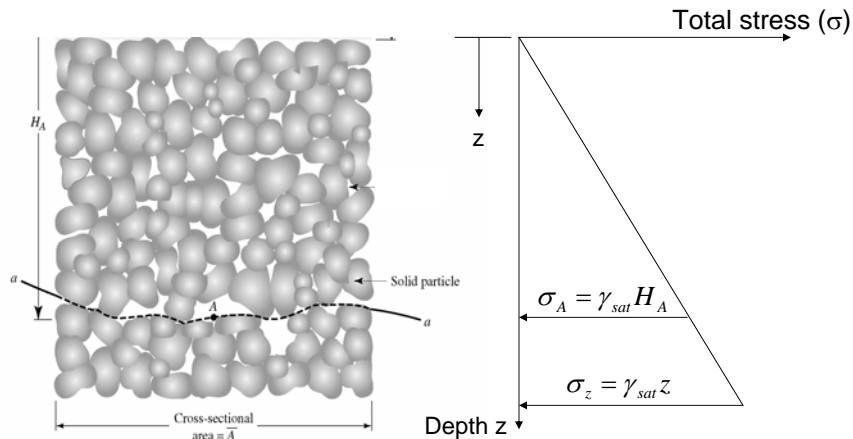
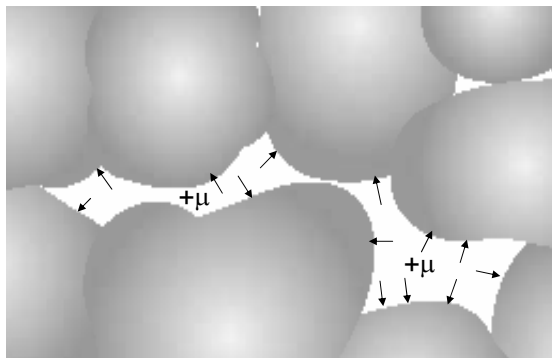$$\sigma_A = \gamma_{total}H_A = \gamma_{total}z$$

Total stress (σ)

z

$\sigma_A = \gamma_{total}H_A$

$\sigma_z = \gamma_{total}z$

Depth z

Total Stress

• Saturated soil ($S_r = 1$) saturated unit weight = total unit weight

$$\sigma_A = \gamma_{sat} H_A = \gamma_{sat} z$$

Total stress (σ)

z

H_A

a

A

a

Solid particle

Cross-sectional area = $\bar{A}$

$\sigma_A = \gamma_{sat} H_A$
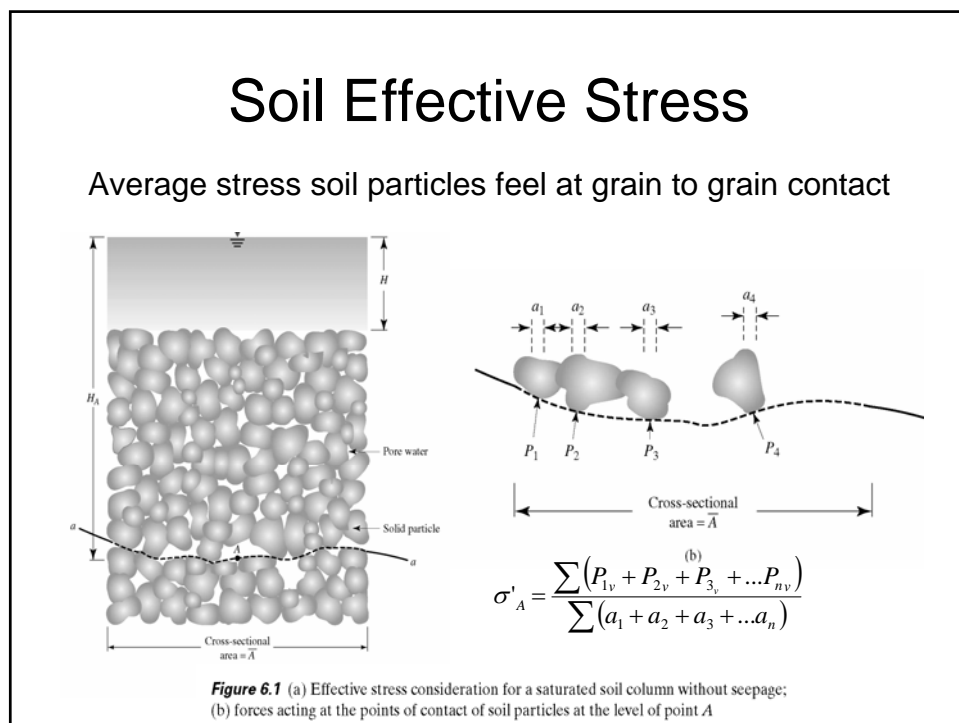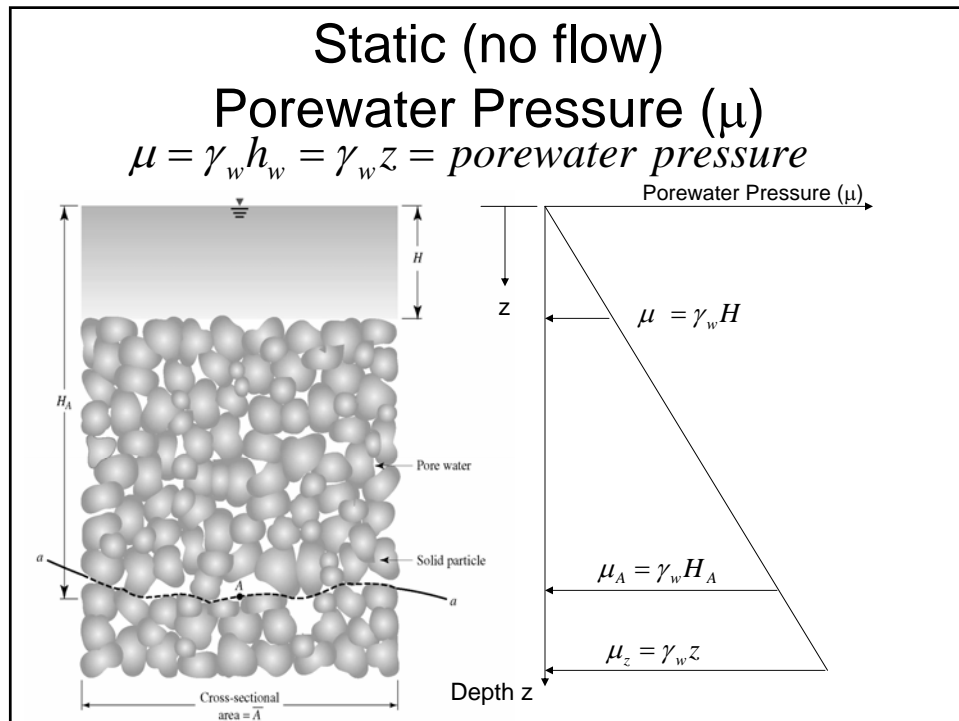
$\sigma_z = \gamma_{sat} z$

Depth z

Positive Porewater Pressure

+μ acts normal to soil particles and is equal in all directions

• pushes soil grains apart resulting in a decrease in soil particle to particle contact

+μ

+μ

Static (no flow)
Porewater Pressure (μ)

$$\mu = \gamma_w h_w = \gamma_w z = porewater\ pressure$$

Porewater Pressure (μ)

$\mu = \gamma_w H$

$\mu_A = \gamma_w H_A$

$\mu_z = \gamma_w z$

Depth z

Soil Effective Stress

Average stress soil particles feel at grain to grain contact

$$\sigma'_A = \frac{\sum \left(P_{1_v} + P_{2_v} + P_{3_v} + ... P_{n_v} \right)}{\sum \left(a_1 + a_2 + a_3 + ... a_n \right)}$$

Figure 6.1 (a) Effective stress consideration for a saturated soil column without seepage; (b) forces acting at the points of contact of soil particles at the level of point A
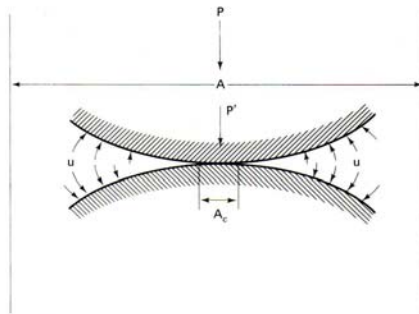
Total Stress

Fig. 7.8   Particles in solid contact (after Skempton, 1960).

$$P = P' + (A - A_c)\mu$$

$$\frac{P}{A} = \frac{P'}{A} + \frac{(A - A_c)}{A}\mu$$

$$\sigma = \sigma' + (1 - \frac{A_c}{A})\mu$$

$$if \ \frac{A_c}{A} \ is \ very \ small \approx zero$$

$$\sigma = \sigma' + \mu$$

Soil Effective Stress

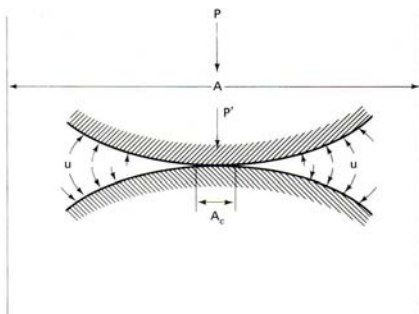Average stress soil particles feel at grain to grain contact

Fig. 7.8   Particles in solid contact (after Skempton, 1960).

$$\sigma = \sigma' + \mu$$

Terzaghi's effective stress equation

$$\sigma' = \sigma - \mu$$

Ground Water Table

Definition:
- Surface on which the fluid pressure in the pores of the porous media is exactly atmospheric
- Location is revealed by the level at which water stands in a shallow open well

Aquifers

- In an unconfined aquifer the water table forms the upper boundary of the aquifer
- A confined aquifer is an aquifer confined by two aquitards – water level surface is a potentiometric surface
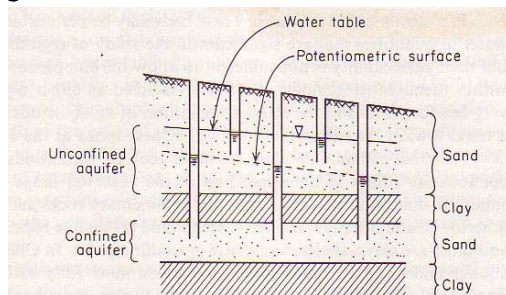

Figure 2.16 Unconfined aquifer and its water table; confined aquifer and its potentiometric surface.