CH. 3

3.0 Introduction

<u>Soil</u> :	loose materials	organic	
		Inorganic	in ground
Rock			
	properties: scribe soil	water content (w) unit weight (γ) particle size & shape	

texture

aggregate structure

consistency & sensitivity

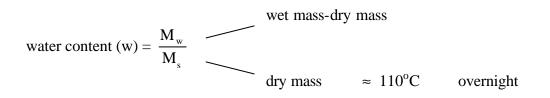
organic content

Soil classification & description system

3.1 Water in soils

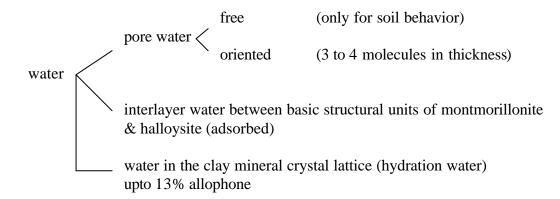
3.1.1 Free water & hydration water

Soil = solid + void water air



Moisture content

$$w = \frac{0 - dry}{300\%}$$
 organic & marine soils



3.1.2 Capillarity

water rise due to surface terrain between soil particles & water

results from differences in the forces of attraction between water molecules & those on solid particle surfaces.

Capillary rise \propto ("void" diameter -1)

Weight of water = surface tension forces

$$g\left(p\frac{d^4}{\Delta}h_c\right) = T \operatorname{Cor} \alpha * \pi d$$

$$h_c = \frac{4T}{\partial_w d} \operatorname{Cor} a$$

For soil

 $\alpha = 0$

d = 20% D_{10} effective particle size

$$T = 75 \text{ dyn/cm}$$

 $H_c = 1.5 / D_{10}$ c'n c'n

<u>3.1.3 Omit</u>

3.2 Grain size & shape

	boulders	12 in	clay (can't be seen by unaided eye)
Cohesionless	(granular)	- grav - sand - silt	o coarse o medium o fine
Cohesive	clay	+ wat	ter \rightarrow plastic
Tests - siev - hyd	e analysis rometer analysi		> 0.075 mm < 0.075 mm
Unified Soil (Classification S	ystem (USCS) - G 4.75-85 mm - S 0.075-4.75 - m hydro - c <0.002 2μ m
Cohesionless	particle sizeparticle shapacking		
Cohesive	 clay minera water particle arra (struct) 	ngemen	nt - disperses (freshwater – dense) - flocculated (seawater - highly compressible)

Soil Aggregate

- Three phase system
 solid
 liquid (water)
 gas (air)
- Phase diagram
- Phase relationships

Vols:- V, V_a , V_w , V_s inter-relationships Weights:- W, W_a , W_w , W_s

5 unknowns	\rightarrow	5 equations	-	for dry or sat.
				4 equations

* dimensional parameters:

$$\boldsymbol{g}_{w} = \frac{W_{w}}{V_{w}}$$

 $\boldsymbol{g}_{s} = \frac{W_{s}}{V_{s}}$

$$\boldsymbol{g} = rac{W}{V}$$
 γ_{sat} if $V_a = 0$

$$\boldsymbol{g}_{\mathrm{d}} = \frac{\mathrm{W}_{\mathrm{s}}}{\mathrm{V}}$$

$$\gamma_b = \gamma' = \gamma_{effective} = \gamma_{sat} - \gamma_w$$

Density $\rho = \gamma/g$ gravitational acceleration = 9.81 m/sec² = 32.2 ft/sec²

weights = mass * g

Dimensionless parameters"

$$e = \frac{V_v}{V_s}$$

$$n = \left(\frac{V_v}{V}\right) * 100\%$$

$$S_r = \left(\frac{V_w}{V_v}\right) * 100\%$$

$$w = \left(\frac{W_w}{W_s}\right) * 100\%$$

$$G_s = \frac{g_s}{g_w}$$

5 equations:

$$V = V_{s} + V_{w} + V_{a}$$

$$W = W_{s} + W_{w}$$

$$W_{a} = 0$$

$$w = W_{w}/W_{s}$$

$$G_{s} = \frac{W_{s}/V_{s}}{W_{w}/V_{w}}$$

$$\gamma_{w} = 9.81 \text{ kN/m}^{3} = 62.4 \text{ lb/ft}^{3}$$

$$W_{s} = \frac{W}{1+w}$$

$$W_{w} = w W_{s}$$

$$V_{s} = \frac{W_{s}}{G_{s}g_{w}}$$

$$= W_{w}/\gamma_{w}$$

$$V_{a} = V - V_{w}$$
Table 3.4

- 3.4 Consistency & Sensitivity of Clays
 - composition
 - size
 - specific surface area

Atterberg 1911 Swedish limits

- 1. upper limit of viscous flow
- \rightarrow 2. LL
 - 3. sticky limit
 - 4. cohesion limit
- \rightarrow 5. plastic limit (PL)
- \rightarrow 6. shrinkage limit (SL)
 - LL: water content @ lower limit of viscous flow
 - PL: water content @ lower limit of plastic state
 - SL: water content @ lower limit of volume change
- * Plastic Index PI = LL PL
- * Liquidity Index $LI = \frac{W_n PL}{PI}$
- * Activity Index A = PI/PC % of clay (< .002 mm)

	А
inactive	<.75
Normal	.75 – 1.25
Active	> 1.25

- * Plasticity chart PI vs. LL p.89
- 3.5 Organic Soils <u>Omit</u>

3.6 Soil Classification

• Soil classification system: common language for geo tech. engrs.

- eliminate soil behavior & expected problems

- Soil types
- Soil categories
- Soil designations
 - highway (AASHTO) Am. Assoc. of State Highway
 - agricultural (USDA)
 - civil eng. (USCS) Unified Soil Classification system

Based on - particle size - Atterberg limits

Coarse grained	 cobbles gravel sand	G S
Fine grained	- silt - clay	m c
Peat	- organic	0

<u>3.6.1</u> USCS

• 1948 Capegrande

Coarse - grain size distribution + plasticity of times well-grade (w) poorly grade (p)

Fine - plasticity (LL, PL)

- Sieve analysis

- Att. Limits

	Low (L)	
PI = LL - PL	SO	grain size 10, 30, 60% finer
	High (H)	
$C_u = D_{60}/D_{10}$		mity coefficient
$C_z = (D_{30})^2 / (D_{10} \cdot D_{60})^2$) coeff.	of curvature

Single classification group symbol

Dual symbol	CL - ML
	GW - GM

1.	Coarse-grained Fine-grained	50% retained on # 200)
2.	Coarse-grained	Gravel (G) Sand (S)	50% retained on # 4
3.	Passing # 200	LL & PL 12% $C_u \& C_z$ 5% well-grade (W) poorly graded (P)	

with 'sand' of $\geq 15\%$

4. Fine-grained ----- LL & PL \rightarrow plasticity chart

<u>3.6.2</u> AASHTC

<u>1920's</u>		PSD, LL, PL #10, #40, #200
A-1 A-2 A-3	granular	
A-4 A-5 A-6 A-7	fine-grained	
A-8	organic	

BD

* Group Index:
$$GI = 0.2A + 0.005AC + 0.01$$

 $\begin{array}{l} A = F - 35 \\ B = LL - 40 \\ C = F - 15 \\ D = PI - 10 \\ F = \% \ passing \ \# \ 200 \end{array}$

For A-2-6 & A-2-7 \rightarrow GI = 0.01 BD

GI:: (integral)

Classification Procedure

- Sieve analysis # 10 40 200
- LL & PL
- Fig. 3.18 from left to right

(process of elimination)

3.7 Typical values

• Relative density (D_r) for granular soils

$$D_r = \frac{\left(e_{\max} - e\right)}{\left(e_{\max} - e_{\min}\right)} * 100\% = \frac{\left[1 - \left(\frac{\boldsymbol{g}_{d,\min}}{\boldsymbol{g}_d}\right)\right]}{\left[1 - \left(\frac{\boldsymbol{g}_{d,\min}}{\boldsymbol{g}_{d,\max}}\right)\right]} * 100\%$$

$$\left(rac{oldsymbol{g}_d - oldsymbol{g}_{d, \min}}{oldsymbol{g}_{d, \max} - oldsymbol{g}_{d, \min}}
ight) st rac{oldsymbol{g}_{d, \max}}{oldsymbol{g}_d}$$

H.W.