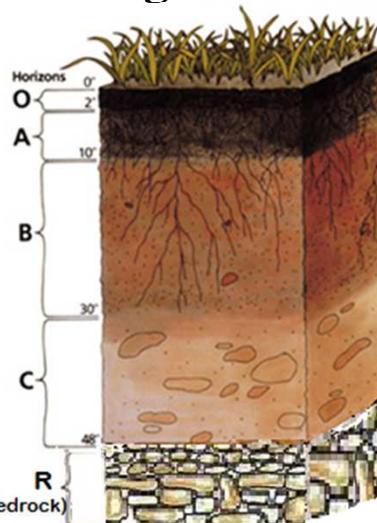
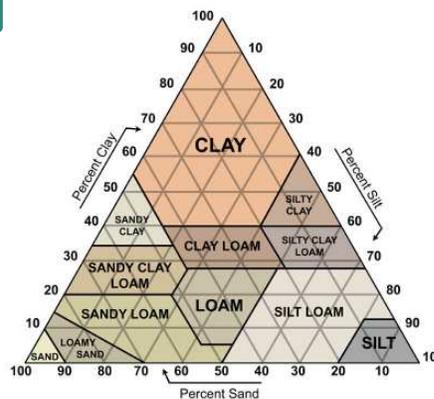


 **Module 5**
Soil Engineering





Agricultural understanding of Soil



Soil to an Engineer

Soil is a material that can be:

- **built with:** embankments, dams, channels
- **built on:** roads, runways, foundations, bridge piles
- **built in:** tunnels, culverts, basements
- **supported:** retaining walls



Soils in Stormwater

An intersection of both views:

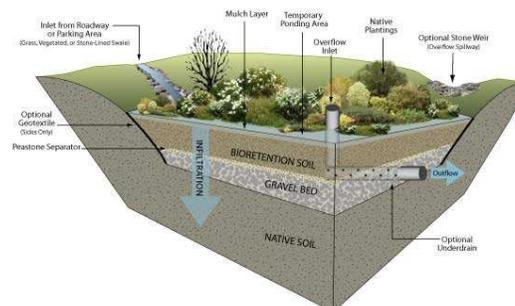
BMP construction

Stormwater conveyance

Infiltration

Drainage

Plant establishment



Hydraulics



The flow and distribution of water over and through soil.



Soil Mechanics



The science of understanding and modeling how soil will respond to externally applied forces.



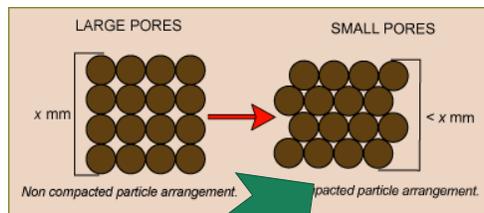
Goal = Stability

Shear strength

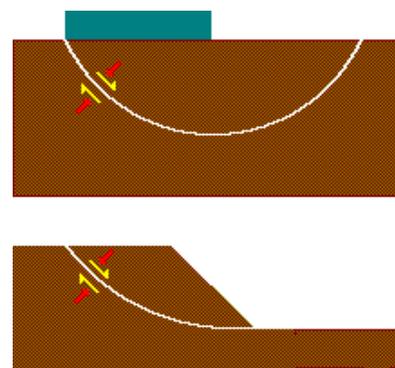
- Grain size (texture) and shape
- Consistency/Cohesiveness
(water content vs. stress response)



Shear Strength



Sliding of soil particles



Soil Mechanics

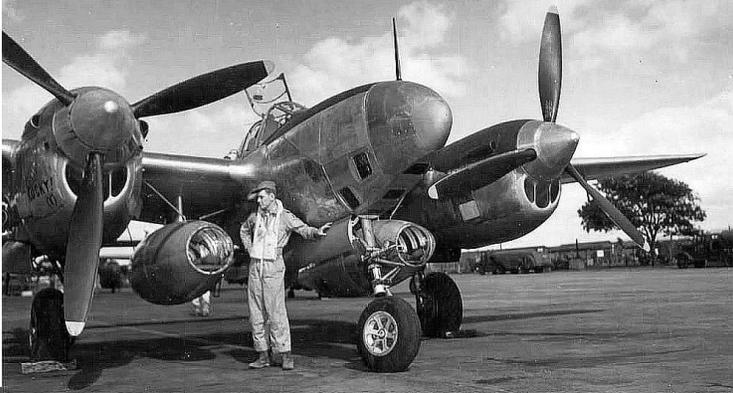
- Soil particles
- Density
- Moisture content
- Pressure applied
- Strength
- Stiffness
- Permeability



The logo for the Virginia Department of Environmental Quality (DEQ) is located in the bottom right corner of the slide. It features a stylized green and blue landscape with a river and trees, followed by the letters 'DEQ' in a bold, sans-serif font. Below the letters, the text 'VIRGINIA DEPARTMENT OF ENVIRONMENTAL QUALITY' is written in a smaller, all-caps font.

Unified Soil Classification System

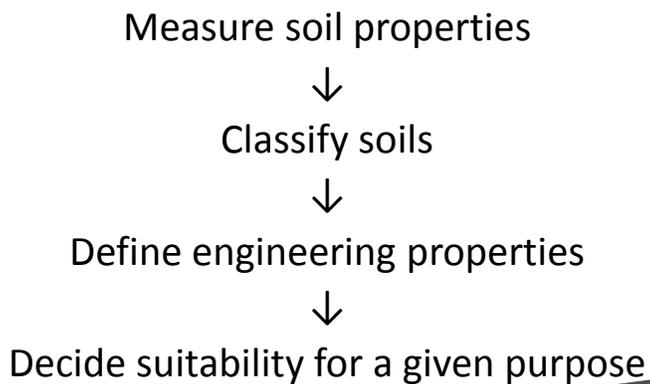
Developed in WWII for airfield



A black and white photograph of a B-24 Liberator bomber aircraft on a runway. A person in a uniform stands next to the aircraft, providing a sense of scale. The aircraft is a four-engine, heavy bomber with a high-wing configuration and a tail gun turret. The background shows a clear sky and some trees in the distance.

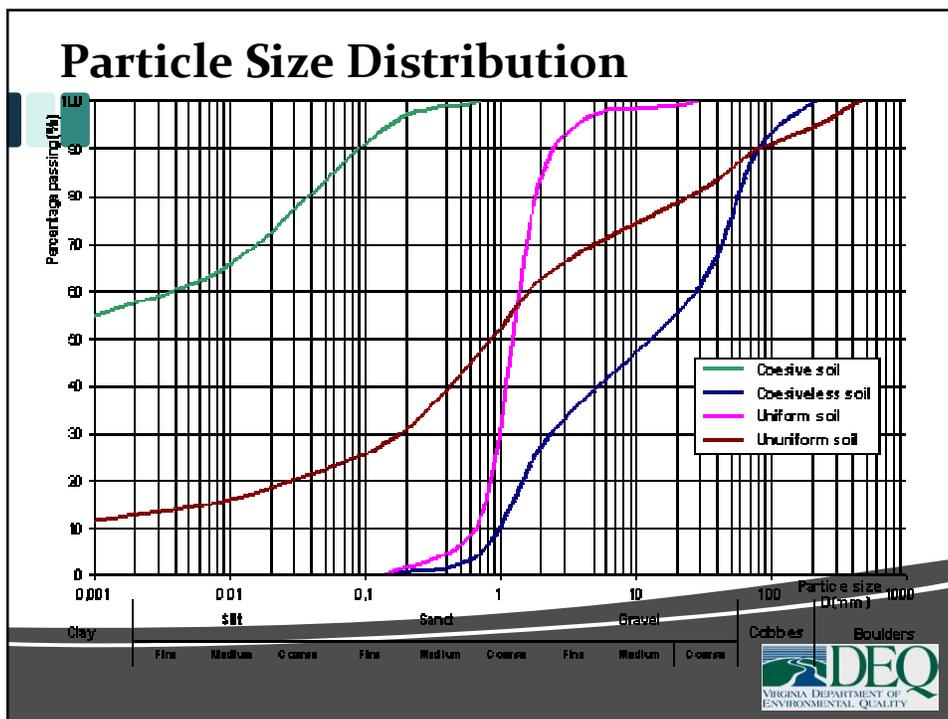
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Unified Soil Classification System



Particle size analysis





Soil Cohesiveness

Response to stress with increasing moisture

Hard	← Shrinkage Limit	
Friable	← Plastic Limit	} Plasticity Index
Plastic	← Liquid Limit	
Liquid		

Toughness and dry strength increase with increasing plasticity index



Soil Group Symbols

- Gravel – G
- Sand – S
- Silt – M
- Clay – C
- Organic – O
- Peat – Pt
- Well Graded- W
- Poorly Graded – P
- High liquid limit – H
- Low liquid limit – L

COARSE-GRAINED SOILS
(more than 50% of material is larger than No. 200 sieve size.)

GRAVELS More than 50% of coarse fraction larger than No. 4 sieve size	Clean Gravels (Less than 5% fines)		
		GW	Well-graded gravels, gravel-sand mixtures, little or no fines
		GP	Poorly-graded gravels, gravel-sand mixtures, little or no fines
	Gravels with fines (More than 12% fines)		
		GM	Silty gravels, gravel-sand-silt mixtures
		GC	Clayey gravels, gravel-sand-clay mixtures
SANDS 50% or more of coarse fraction smaller than No. 4 sieve size	Clean Sands (Less than 5% fines)		
		SW	Well-graded sands, gravelly sands, little or no fines
		SP	Poorly graded sands, gravelly sands, little or no fines
	Sands with fines (More than 12% fines)		
		SM	Silty sands, sand-silt mixtures
		SC	Clayey sands, sand-clay mixtures


VIRGINIA DEPARTMENT OF ENVIRONMENTAL QUALITY

FINE-GRAINED SOILS
(50% or more of material is smaller than No. 200 sieve size.)

SILTS AND CLAYS Liquid limit less than 50%		ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity
		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
		OL	Organic silts and organic silty clays of low plasticity
SILTS AND CLAYS Liquid limit 50% or greater		MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts
		CH	Inorganic clays of high plasticity, fat clays
		OH	Organic clays of medium to high plasticity, organic silts
HIGHLY ORGANIC SOILS		PT	Peat and other highly organic soils


VIRGINIA DEPARTMENT OF ENVIRONMENTAL QUALITY

HSG	USDA	Unified
A	gravel sandy gravel	GW GP GM SW
	silty gravels	
B	sand loamy sand sandy loam	SP
		SM
	loam, silt loam	MH
C	Sandy clay loam	ML
D	clay loam	GC
	silty clay loam	SC
	sandy clay	CL
	silty clay	OL
	clay	CH OH



	Name	Value as foundation when not subject to frost action	Value as base directly under bituminous pavement	Drainage Characteristics
GW	Well-graded gravels or gravel-sand mixtures, little or no fines	Excellent	Good	Excellent
GP	Poorly graded gravels or gravel-sand mixtures, little or no fines	Good to excellent	Poor to fair	Excellent
GM _{du}	Silty gravels, gravel-sand-silt mixtures	Good	Fair to good	Fair to poor
		Good	Poor	Poor to practically impervious
GC _s	Clayey gravels, gravel-sand-silt mixtures	Good	Poor	Poor to practically impervious



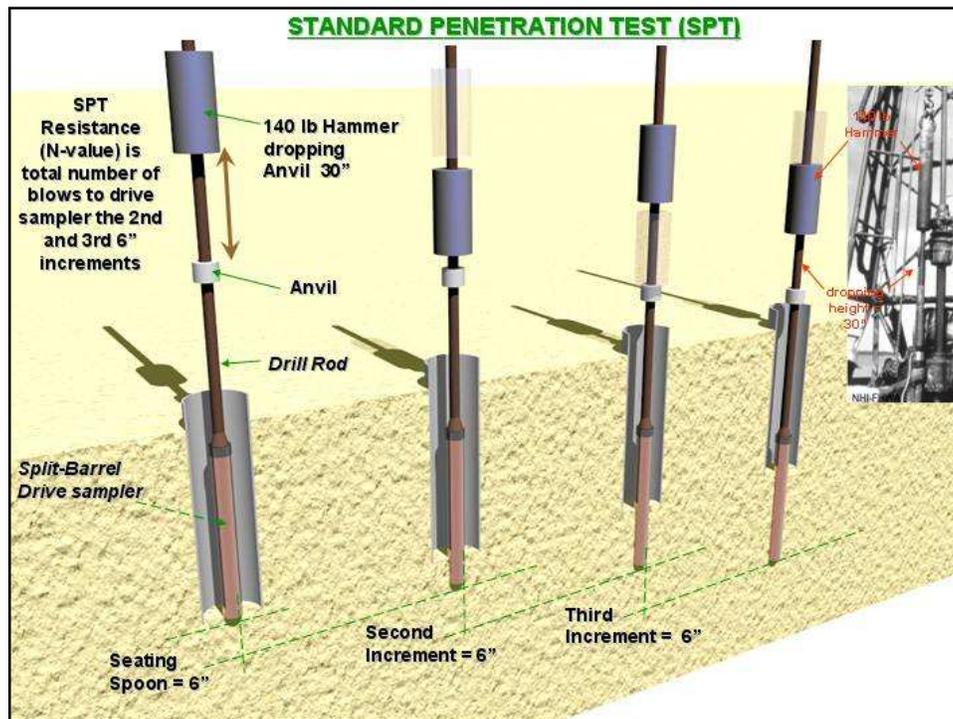


	Name	Value as foundation when not subject to frost action	Value as base directly under bituminous pavement	Drainage Characteristics
SW	Well-graded sands or gravelly sands, little or no fines	Good	Poor	Excellent
SP	Poorly graded sands or gravelly sands, little or no fines	Fair to good	Poor to not suitable	Excellent
SM _{du}	Silty sands, sand-silt mixtures	Good	Not suitable	Fair to poor
		Fair to good	Not suitable	Poor to practically impervious
SC	Clayey sands, sand-clay mixtures	Fair to good	Not suitable	Poor to practically impervious




	Name	Value as foundation when not subject to frost action	Value as base directly under bituminous pavement	Drainage Characteristics
ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity	Fair to poor	Not suitable	Fair to poor
CL	inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays	Fair to poor	Not suitable	Practically impervious
OL	Organic silts and organic silt clays of low plasticity	Poor	Not suitable	Poor to practically impervious
MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts	Poor	Not suitable	Fair to poor
CH	Inorganic clays of high plasticity, fat clays	Poor to very poor	Not suitable	Practically impervious





Standard Penetration test

- Granular soils: indicator of the density and compressibility
- Cohesive soils: check the consistency

Standard Penetration Test

The N-values derived from the SPT are used in conjunction with footing width and depth and groundwater height to determine a soil's bearing capacity



General SPT Interpretation

DENSITY		CONSISTENCY	
Term	N-Value	Term	N-Value
Very Loose	0-4	Very Soft	0-1
Loose	5-10	Soft	2-4
Medium-Dense	11-30	Medium Stiff	5-8
Dense	31-50	Stiff	9-15
Very Dense	>50	Very Stiff	16-30
		Hard	>30



Samples of Tests		SPT			Strata Description
Type	Depth, m	N	Depth	Legend	
D	0.30		0.20		Tarmac over hardcore
B	0.50				Made ground (clay with brick rubble)
B	1.00-1.50	10	0.90		Brown clay with flints
D	1.75				
B	2.00-2.50	19	2.30		Brown-grey sand with some clay binder
D	2.75				
D	3.00-3.50	24			
D	4.00				
D	4.50-5.00	35	4.50		Brown sandy clay with flints
D	5.50				
D	6.00-6.50	17			

Boring Log



Useful information in the Boring Log

Look at changes with depth

- SPT N-values
- Soil descriptions
- Groundwater/Cave-in depth
- Notes

