Boring Spacing

Depending on the area under study. Grid systems may be appropriate in uniform conditions. The spacing usually range from 30 ft to 1600 ft. The following spacing may be adopted for

wide range of constructions:

Multistory buildings	*30 ft to 100 ft*
Residential subdivision	*800 ft to 1600 ft*
Warehouses, Industrial plants	*60 ft to 200 ft*
Dams and Dikes	*130 ft to 260 ft*
Highways and railways	*800 ft. to 1600 ft.*

In general spacing may vary depending on the irregularity of the site geology.

Depth of Boring

Boring should be extended through any unsuitable foundation strata (unconsolidated fill, organic soils, compressible layers) until soil of acceptable bearing capacity is reached. In general, boring should be extended to at least 1.5 to 2 times the minimum width of the loaded area.

In the case of vary heavy structures (bridges), boring in most cases are extended to bed rock, or at least one boring should be extended to bedrock.

The following empirical equations can be used to estimate the minimum depth of borings in office buildings:

$D_{boring} = 3\ S^{0.7}$ *(for light steel or narrow concrete buildings)*

$D_{boring} = 6\ S^{0.7}$ *(for heavy steel or wide concrete buildings)*

where S = number of stories in meter

1-3 Sample Recovery

Soil samples obtained during subsurface sectioning are either:

I. Disturbed

II. Undisturbed

Disturbed soil samples are used for:

- Grain size analysis
- Determination of index properties
- Organic content
- Specific gravity

Undisturbed samples are used for:

- As above
- Determining mechanical properties
- Determining hydraulic properties

Methods Of Sample Recovery

1. By hand
2. Split spoon
3. Scraper bucket
4. Thin wall tube (Shelby tube)

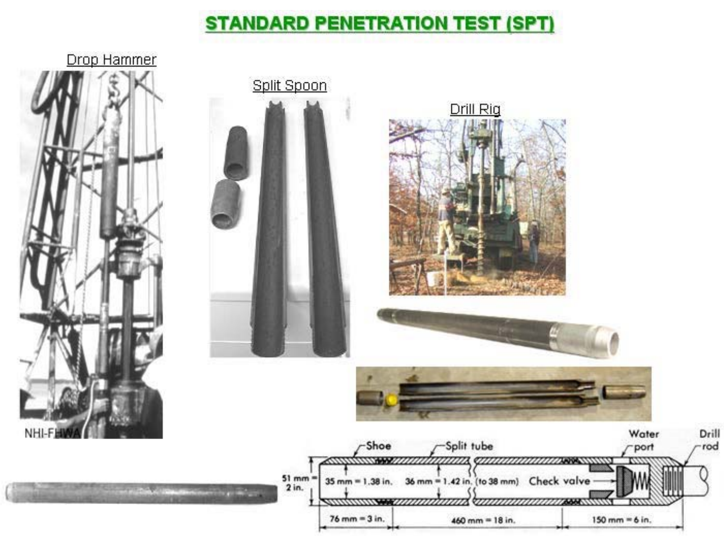
The testing method was standardized in 1958 as ASTM D1586.

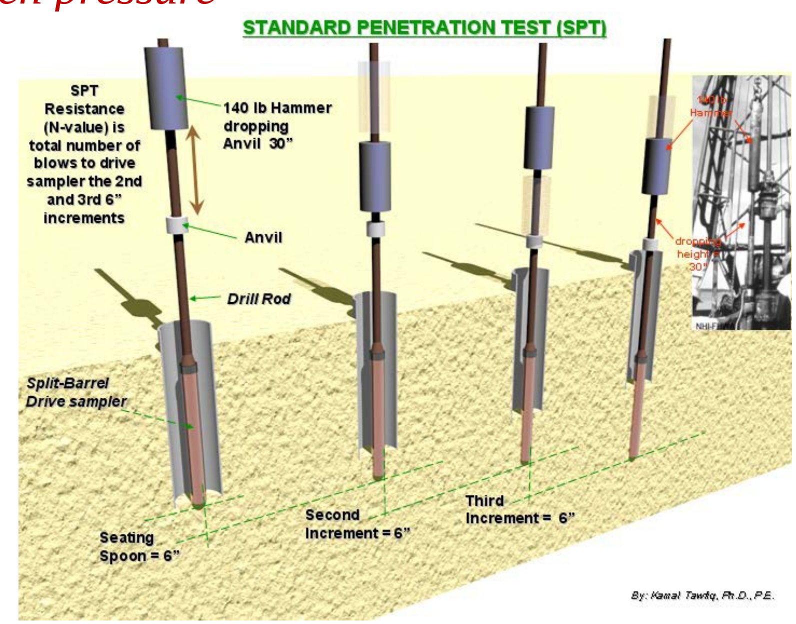
The test consists of:

- *Using a 140 lb driving mass (W) falling free from a height of 30 in. (h) to*
- *Drive the standard split spoon sampler a distance of 18 in. into the soil, and*
- *Counting the number of blows (N) to drive the sampler 12 in. (6 in. + 6 in.).*
- *Theoretical free-fall energy of the SPT hammer* $E_{theo} = W.h = (140\ lb)(30in) = 4200$ *in-lb.*
- *The boring log should show "refusal" and should be halted if:*

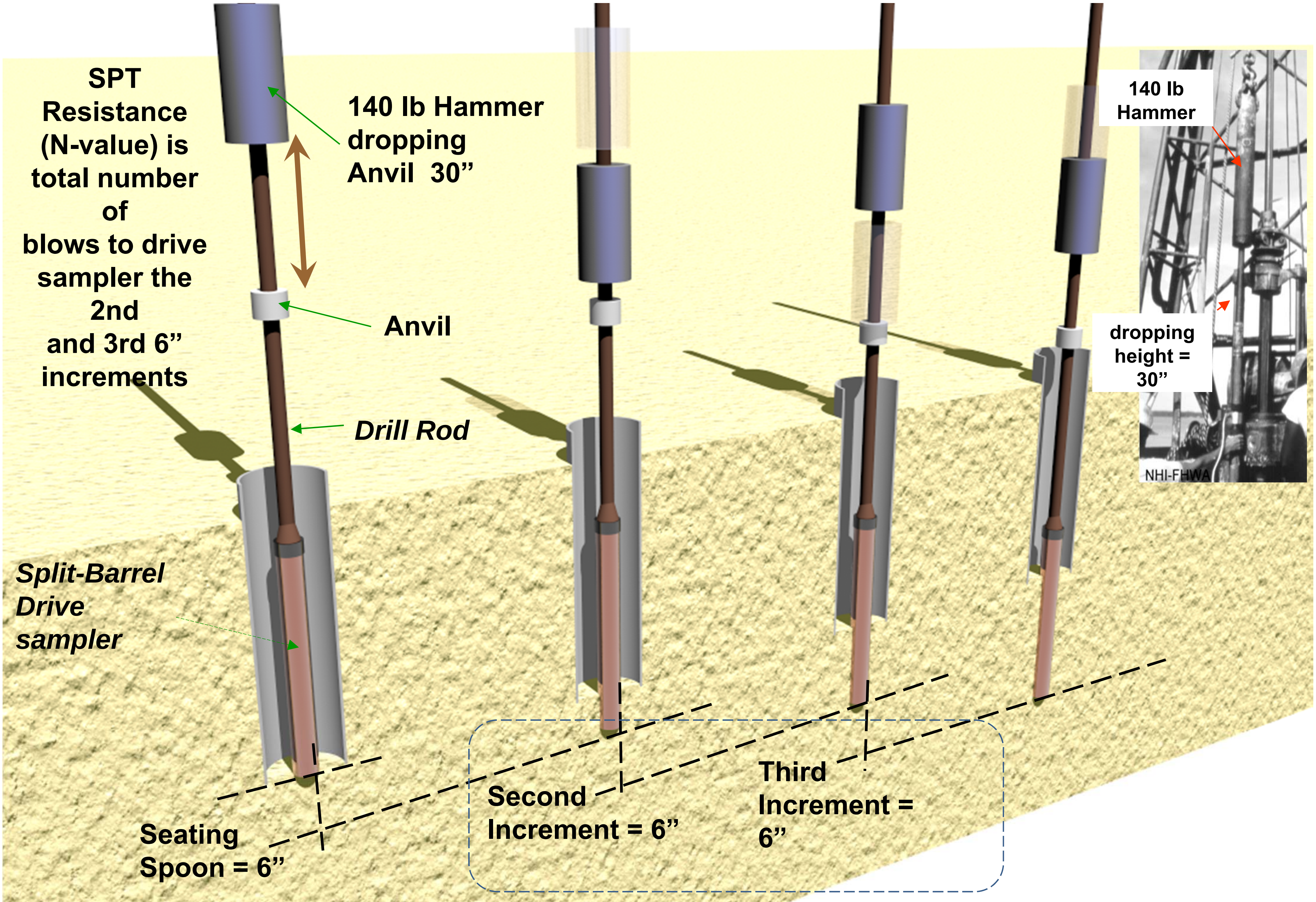
  a- 50 blows are required for any 150 mm increment b- 100 blows are obtained

  c- 10 successive blows produced no advance.
- *- N should be corrected for the increase of the overburden pressure*





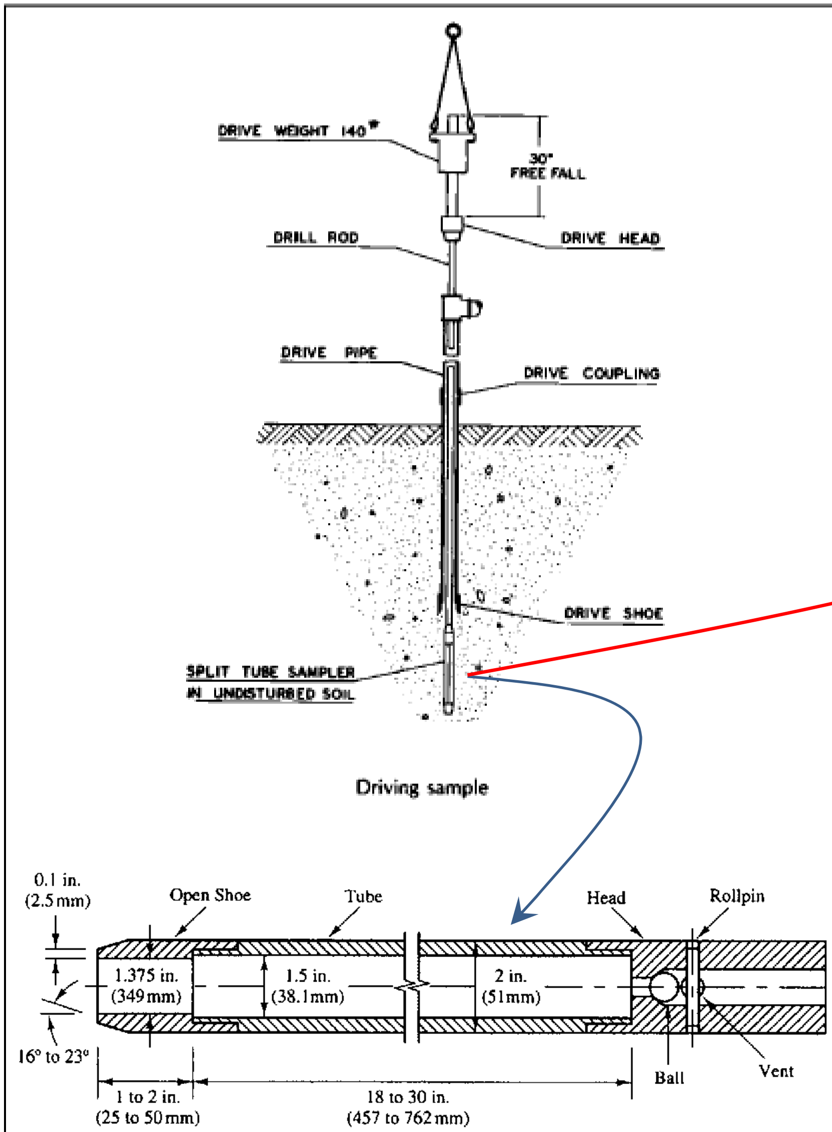
STANDARD PENETRATION TEST (SPT)



1. Record N for the all the increments (6”+6”+6”)
2. You N_{field} value – is only for second and third increments
3. Correct N_{field} to N_{60} -- This is the value that you use in the design

$$N_{60} = 1.67\, E_m C_b C_r N$$

Soil Sampling - Split Spoon
Used in the Standard Penetration Test (SPT)



The SPT sampler (Adapted from ASTM D1586; Copyright ASTM, used with permission)

STANDARD PENETRATION TEST (SPT)

SPT vs. Relative Density of Sand

Meyerhoff (1956)

State of Packing	Relative Density	Standard Penetration Resistance (N)	Static Cone Resistance (q_c)	Angle of Internal Friction (ϕ')
	Percent	Blows / ft	Tsf or kgf/cm^2	Degrees
Very Loose	< 20	< 4	< 20	< 30
Loose	20 – 40	4 –10	20 – 40	30 – 35
Compact	40 – 60	10 –30	40 – 120	35 – 40
Dense	60 – 80	30 – 50	120 – 200	40 – 45
Very Dense	> 80	> 50	> 200	> 45

SPT vs. Undrained Shear Strength

Soil Consistency	SPT N	S_u (psf)	S_u (kPa)
Very Soft	< 4	< 250	< 12
Soft	2 – 4	250 – 500	12 – 25
Medium	4 - 8	500 – 1000	25 – 50
Stiff	8 – 15	1000 – 2000	50 – 100
Very Stiff	15 – 30	2000 – 4000	100 – 200
Hard	> 30	> 4000	> 200

Terzaghi et al. (1996)

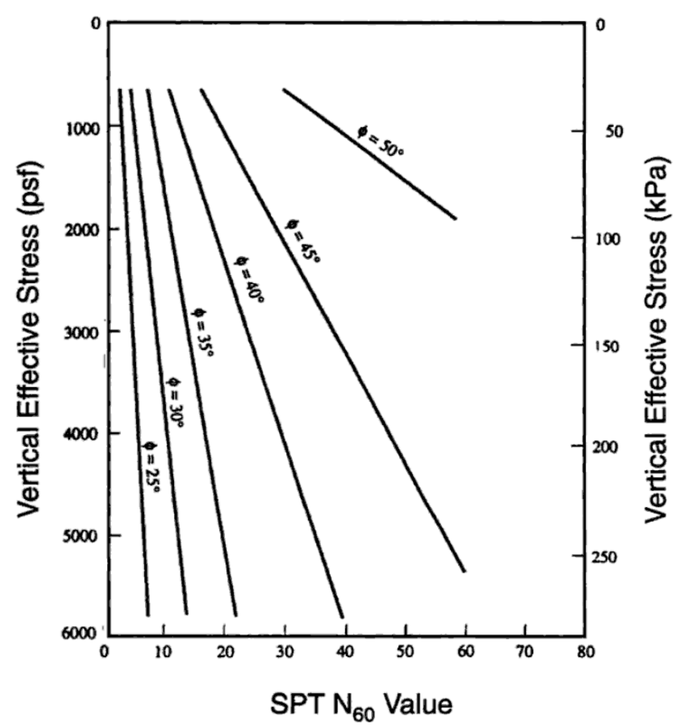
Corrections are normally applied to he SPT blow count to account for differences in:
energy imparted during the test (60% hammer efficiency) the stress level at the test depth

The following equation is used to compensate for the testing factors (Skempton, 1986):

$$N_{60} = 1.67\, E_m C_b C_r N$$

Field Number of Blows (N_{field})

where N_{60} = SPT N-value corrected for field testing procedures
E_m = hammer efficiency (for U.S. equipment, E_m equals 0.6 for a safety hammer and equals 0.45 for a doughnut hammer)
C_b = borehole diameter correction (C_b = 1.0 for boreholes of 65- to 115-mm diameter, 1.05 for 150-mm diameter, and 1.15 for 200-mm diameter hole)
C_r = rod length correction (C_r = 0.75 for up to 4 m of drill rods, 0.85 for 4 to 6 m of drill rods, 0.95 for 6 to 10 m of drill rods, and 1.00 for drill rods in excess of 10 m)
N = measured SPT N-value



Empirical correlation between SPT N_{60} value, vertical effective stress, and friction angle for clean quartz sand deposits. (*Adapted from DeMello, 1971; reproduced from Coduto, 1994.*)

Presenting SPT in the Geotechnical Report

SPT

ENGINEERING SOIL TEST BORING RECORD

Elevation (ft-msl) +182.2	Stratum Depth (ft)	Visual Soil Description	Sample Depth (ft)	Sample Recovery (in)	Soil Sym. K	Penetration (blows/ft)	Remarks and raw SPT data
+180	0.3	Top soil, grass, and roots					
	7.0	Loose gray-brown clayey fine **SAND** (SC)	6.0	16		**7**	*(2+3+4)*
+170	14.5	Soft blue-tan clayey **SILT** (MH)	12.0	16		**3**	*(0+2+1)* *Groundwater z_w = 15.5 feet (Nov. 8, 2001)*
+160	21.5	Firm yellow-tan clean to slightly silty fine **SAND** (SP to SP-SM)	20.5	18		**32**	*(11+14+18)*
	30.0	Firm yellow-tan clean fine to medium **SAND** (SP)	28.0	11		**28**	*(+13+15+13)*
+150	39.0	Loose white to yellow slightly silty medium to coarse **SAND** (SP)	36.0	11		**5**	*(+2+3+2)*
+140	45.5	Very stiff green fine-medium sandy **CLAY** (CL)	43.5	16		**20**	*(+10+10+10)*
+130	60.2	Stiff green-gray silty to sandy **CLAY** (CL)	52.5	18		**15**	*(+6+7+8)*
+120	64.0	Dense white medium **SAND** (SP) with shells	63.5	10		**42**	*(+20+22+20)*
		REFUSAL at 64 feet					

Soil Symbols K (Unified Soil Classification System)

Top Soil
CL
MH
CH
SP

Other Symbols

Water Level

Driller:	
Boring Number:	AGB-1
Date Drilled:	Oct/29/2001
Job Number	32335
Site Location:	Florida
Test Method:	ASTM D 1586
Hammer Type:	Diedrich Automatic (ER =82%)
Sampler:	Drive (split-barrel)
Drilling Method:	Hollow Stem Augers
Make of Drilling Rig:	CME-850 (truck mounted)

Notes:

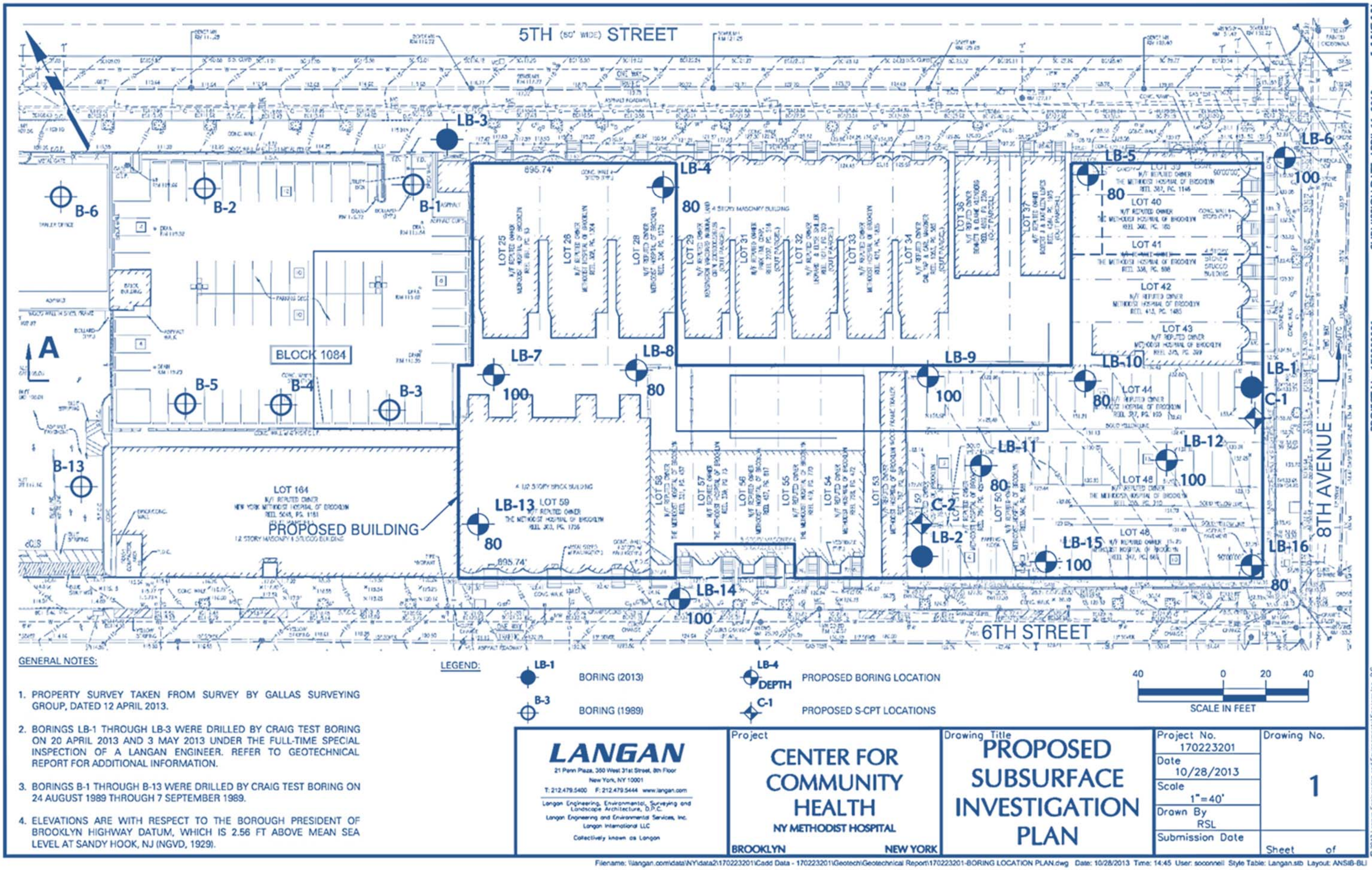
N = Penetration in blows per foot (ASTM D-1586)

N_{60} = (E_f/60) * $N_{measured}$ = Energy-Corrected N-value

E_f = Energy Efficiency of Hammer Used

ER = energy ratio per ASTM D-4633

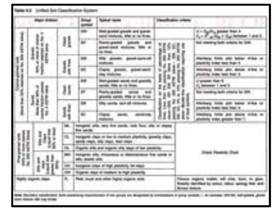
Soil Boring Map



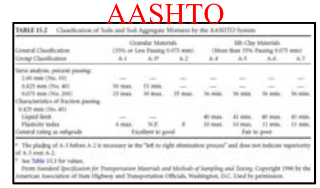
Soil Classification

The separation of soil into classes or groups each having similar characteristics and potentially similar behaviour

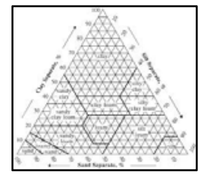
Unified Soil Classification System



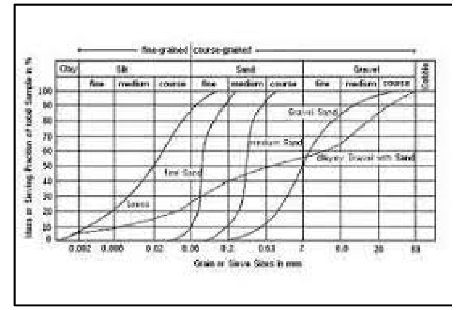
AASHTO



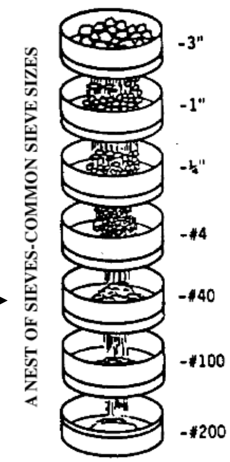
USDA Soil Textural Classification System



Grain Size Distribution

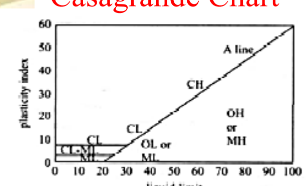


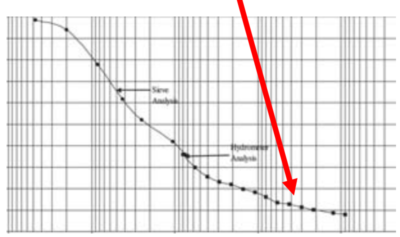
- Few simple (routine) tests are used to classify soils.
  - Gradation …… Sieve Analysis
  - Atterberg Limits ……..
  - Hydrometer Analysis …

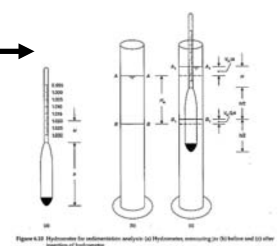


Liquid Limit
Plastic Limit
Plasticity Index

Casagrande Chart







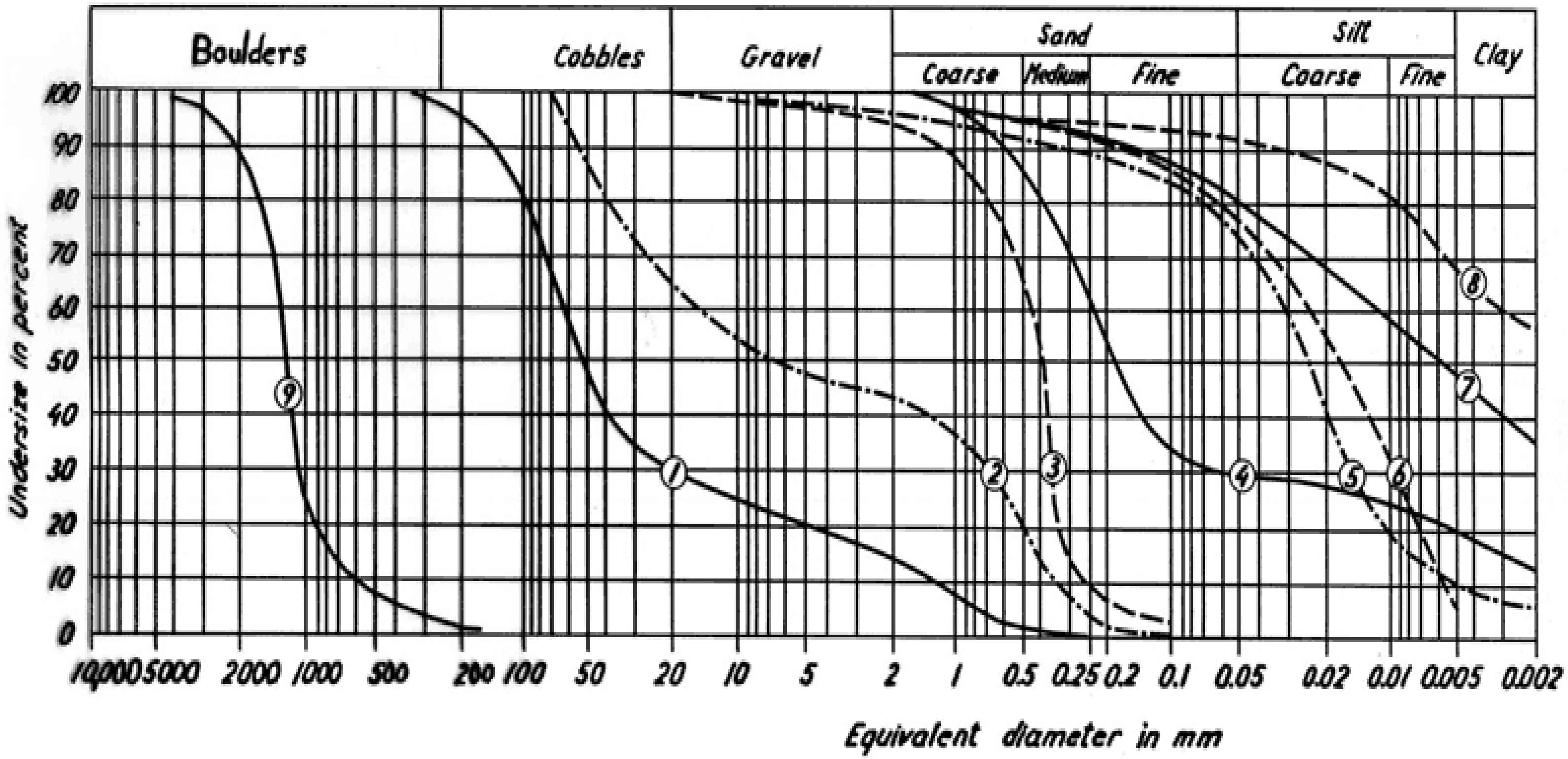
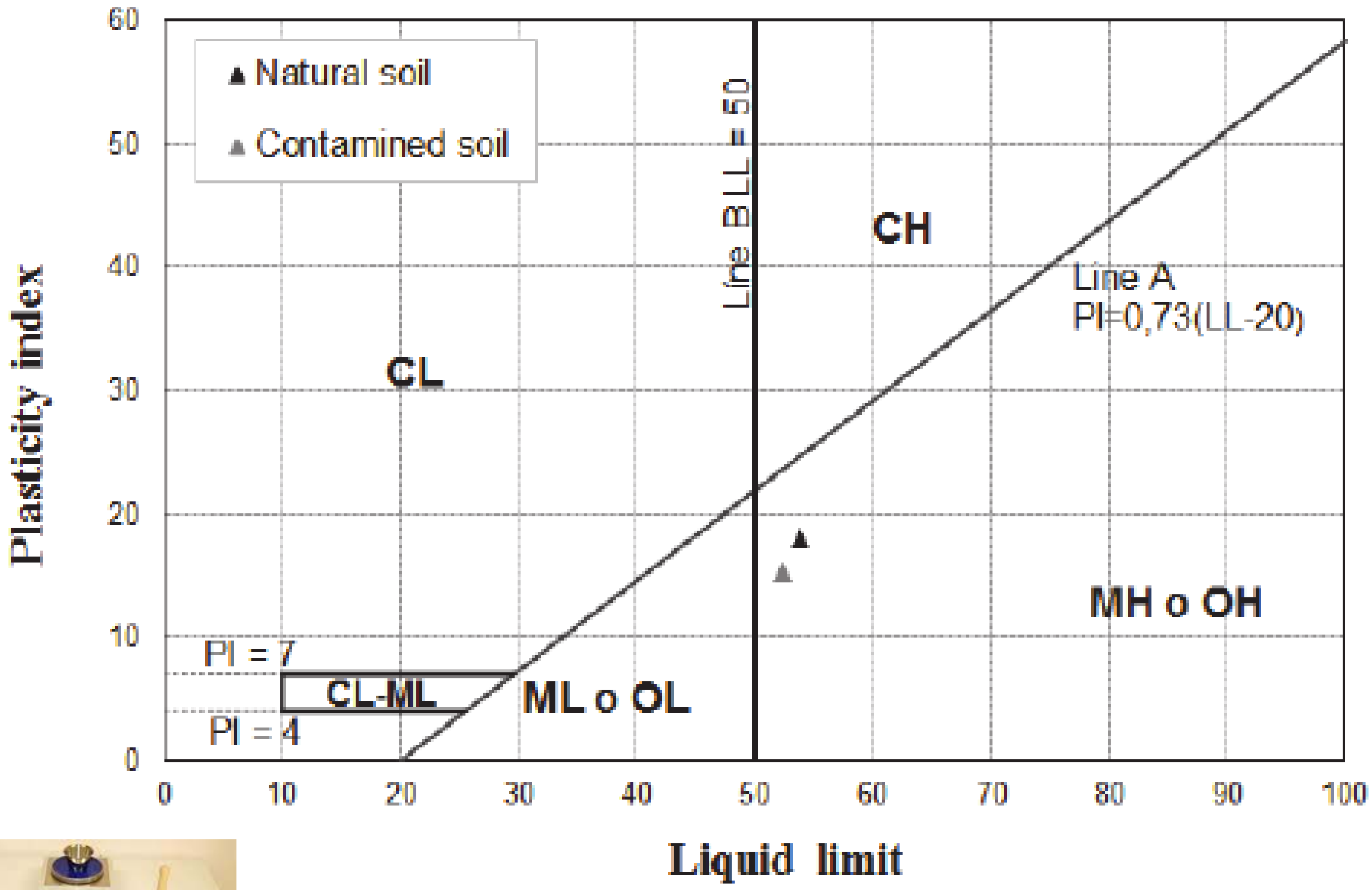


Figure 5.3. Particle-size distribution curves for sediments in Czechoslovakia (Bazant, 1979): 1. Vltava River gravel; 2. "Gap-graded" gravel; 3. Letna terrace, uniform sand; 4. Pankvac terrace, gap-graded clayey sand; 5. Micovna loess; 6. Hodonin silt; 7. Ruzyne clay; 8. Branany bentonite; 9. Quartzite talus from Boulder Mountain, Black Hills, South Dakota.

Casagrande Chart



UNIFIED SOIL CLASSIFICATION

(Including Identification and Description)

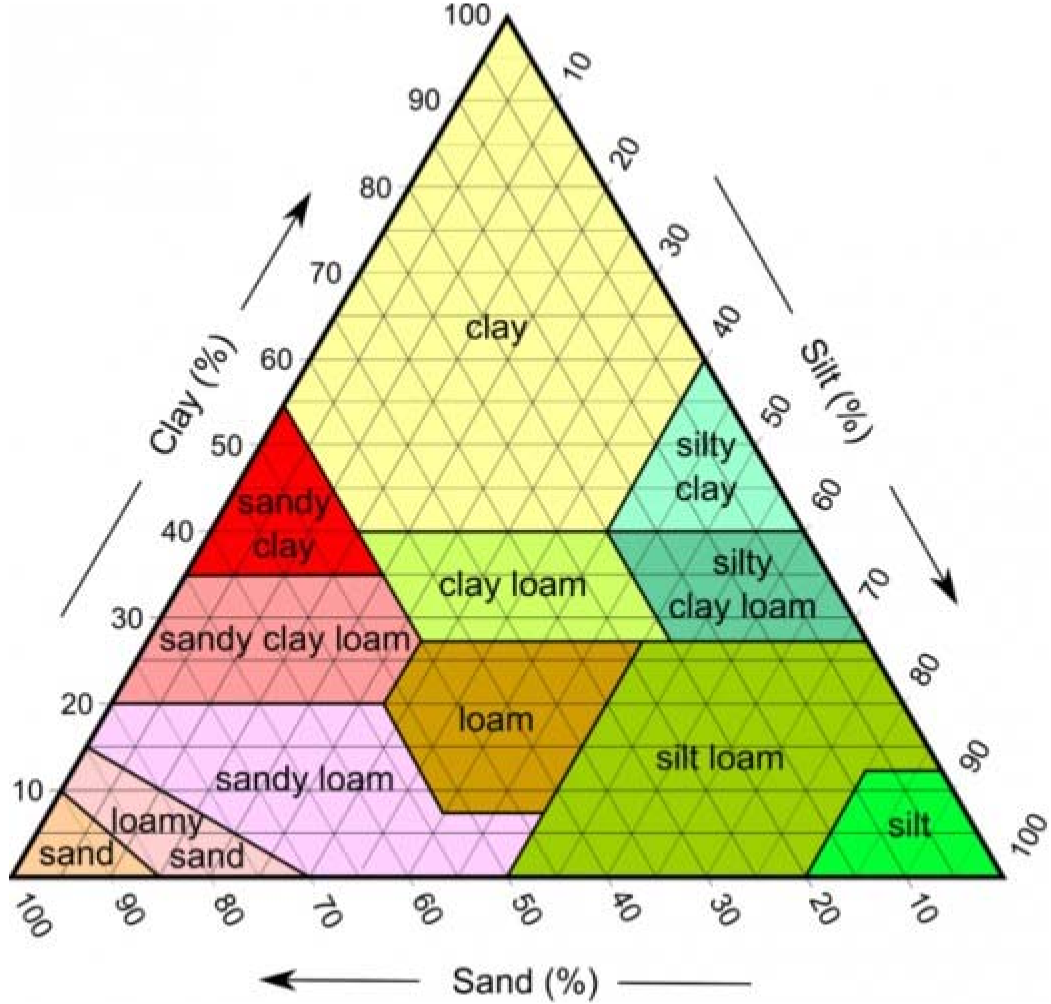
Major Divisions			Group Symbols	Typical Names	Field Identification Procedures (Excluding particles larger than 3 in. and basing fractions on estimated weights)			Information Required for Describing Soils
1	2		3	4	5			6
Coarse-grained Soils More than half of material is *larger* than No. 200 sieve size. (The No. 200 sieve size is about the smallest visible to the naked eye.)	Gravels More than half of coarse fraction is larger than No. 4 sieve size. (For visual classification, the ½-in. size may be used as equivalent to the No. 4 sieve size)	Clean Gravels (Little or no fines)	GW	Well-graded gravels, gravel-sand mixture, little or no fines.	Wide range in grain size and substantial amounts of all intermediate particle sizes.			For undisturbed soils add information on stratification, degree of compactness, cementation, moisture condition, and drainage characteristics.
			GP	Poorly graded gravels or gravel-sand mixture, little or no fines.	Predominantly one size or a range of sizes with some intermediate sizes missing.			Give typical name; indicate approximate percentages of sand and gravel, maximum size; angularity, surface condition, and hardness of the coarse grains; local or geologic name and other pertinent descriptive information; and symbol in parentheses.
		Gravels with Fines (Appreciable amount of fines)	GM	Silty gravels, gravel-and-silt mixtures.	Nonplastic fines or fines with low plasticity (for identification procedures see ML below).			
			GC	Clayey gravels, gravel-and-clay mixtures.	Plastic fines (for identification procedures see CL below).			
	Sands More than half of coarse fraction is smaller than No.4 sieve size.	Clean Sands (Little or no fines)	SW	Well-graded sands, gravelly sands, little or no fines.	Wide range in grain size and substantial amounts of all intermediate particle sizes.			Example:
			SP	Poorly graded sands or gravelly sands, little or no fines.	Predominantly one size or a range of sizes with some intermediate sizes missing.			Silty sand, gravelly; about 20% hard, angular gravel particles ½-in. maximum size; rounded and subangular sand grains, coarse to fine; about 15% nonplastic fines with low dry strength; well compacted and moist in place; alluvial sand; (SM).
		Sands with Fines (Appreciable amount of fines)	SM	Silty sands, sand-silt mixtures.	Nonplastic fines or fines with low plasticity (for identification procedures see ML below).			
			SC	Clayey sands, sand-clay mixtures.	Plastic fines (for identification procedures see CL below).			
Fine-grained Soils More than half of material is *smaller* than No. 200 sieve size.					Identification Procedure on Fraction Smaller than No. 40 Sieve Size.			
					Dry Strength (Crushing Characteristics)	Dilatancy (Reaction to shaking)	Toughness (Consistency near PL)	
	Silts and Clays Liquid limit is less than 50		ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity	None to slight	Quick to slow	None	For undisturbed soils add information on structure, stratification, consistency in undisturbed and remolded states, moisture and drainage conditions
			CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.	Medium to high	None to very slow	Medium	
			OL	Organic silts and organic silty clays of low plasticity.	Slight to medium	Slow	Slight	Give typical name; indicate degree and character of plasticity; amount and maximum size of coarse grains; color in wet condition; odor, if any; local or geologic name and other pertinent descriptive information; and symbol in parentheses.
	Silts and Clays Liquid limit is greater than 50		MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.	Slight to medium	Slow to none	Slight to medium	
			CH	Inorganic clays of high plasticity, fat clays.	High to very high	None	High	
			OH	Organic clays of medium to high plasticity, organic silts.	Medium to high	None to very slow	Slight to medium	Example: Clayey silt, brown; slightly plastic; small percentage of fine sand; numerous vertical root holes; firm and dry in place; loess; (ML)
Highly Organic Soils			Pt	Peat and other highly organic soils.	Readily identified by color, odor, spongy feel and frequently by fibrous texture			

Table 4.1 AASHTO Soil Classification System

General classification	*Granular materials (35% or less passing US No. 200 sieve)*			*Silt-clay materials (More than 35% passing US No. 200 sieve)*							
Group classification	A-1		A-3	A-2				A-4	A-5	A-6	A-7
	A-1a	A-1b		A-2-4	A-2-5	A-2-6	A-2-7				A-7-5 A-7-6
Sieve analysis											
Percent passing											
US No. 10 (2 mm)	50 max										
US No. 40 (420 μ)	30 max	50 max	51 max								
US No. 200 (75 μ)	15 max	25 max	10 max	35 max	35 max	35 max	35 max	36 min	36 min	36 min	36 min
Characteristics of fraction passing US No. 40 (420 μ)											
Liquid limit				40 max	41 min	40 max	41 min	40 max	41 min	40 max	41 min
Plasticity index	6 max		Non-plastic	10 max	10 max	11 min	11 min	10 max	10 max	11 min	11 min
Group index	0		0	0		4 max		8 max	12 max	16 max	20 max
Usual types of significant constituent materials	Stone fragments gravel and sand		Fine Sand	Silty or clayey gravel and sand				Silty soils		Clayey soils	
General rating as subgrade	Excellent to good							Fair to poor			

Note: A-8 is identified by visual classification, and is not shown in the Table.

Classification procedure: Proceeding from left to right in the chart, the correct group will be found by the process of elimination. The first group from the left consistent with the test data is the correct classification. A-7 group is subdivided into A-7-5 or A-7-6 depending on the plastic limit. For $w_p < 30$, the classification is A-7-6; for $w_p \geq 30$, it is A-7-5.



100
90
80
70
60
50
40
30
20
10
Clay (%)
Silt (%)
Sand (%)
clay
silty clay
sandy clay
clay loam
silty clay loam
sandy clay loam
loam
silt loam
sandy loam
silt
loamy sand
sand