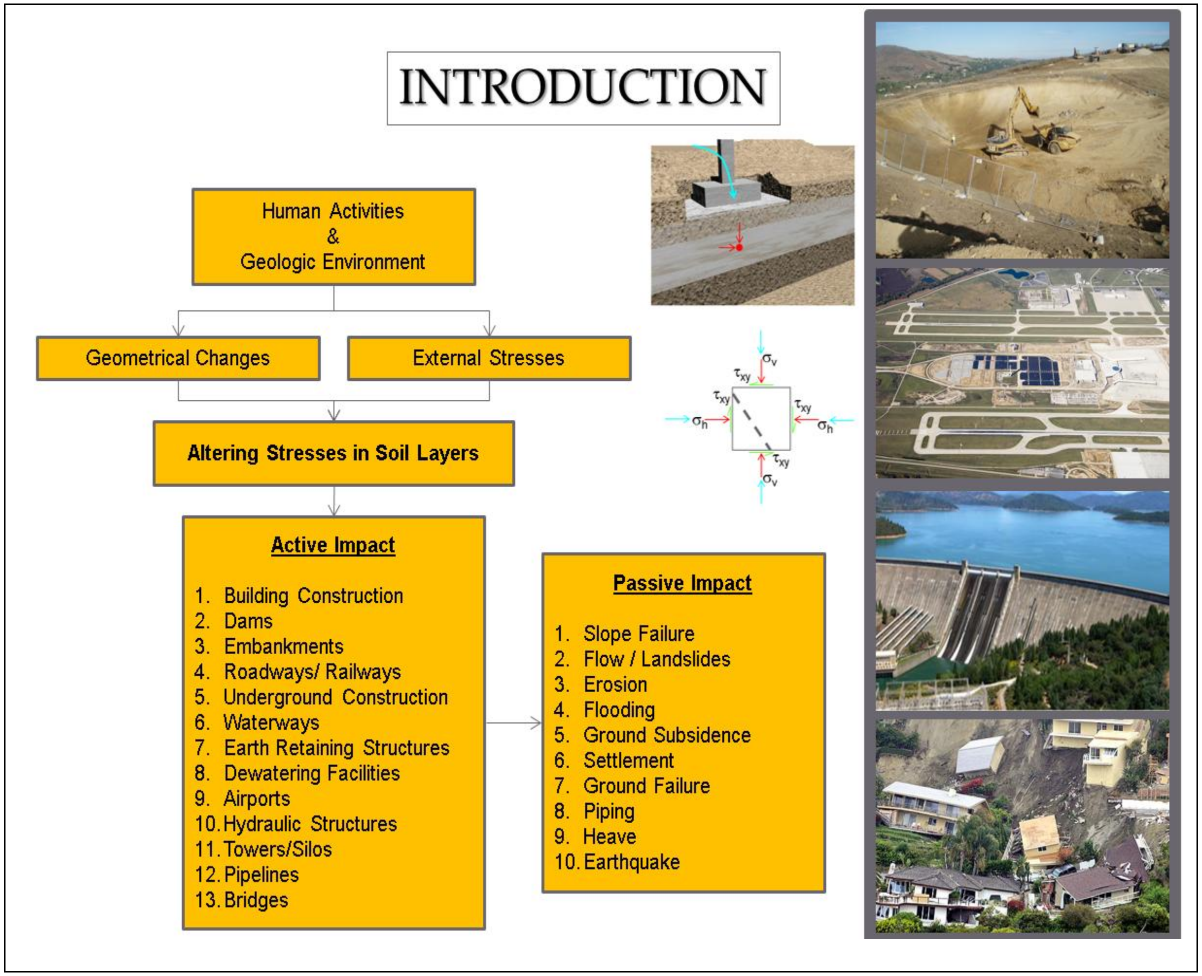
FAMU-FSU COLLEGE OF ENGINEERING
DEPARTMENT OF CIVIL & ENVIRONMENTAL ENGINEERING

INTRODUCTION

What is Geotechnical Engineering?

It is the art and the science of utilizing the scientific principles of the soil mechanics, rock mechanics, soil dynamics, and engineering geology to analyze and design different soil and soil-structure interaction systems.

To work on any geotechnical project, one needs to understand the interaction between the human activities and the geologic environment (**Why ??????????)**



This, however, requires skill and knowledge to

1- Identify and describe rock & soil types
2- Identify and describe rock & soil formations
3- Identify ground water conditions.
4- Recognize the potential for the passive impact on the proposed project.

THE BASIS FOR AN ADEQUATE ASSESSMENT OF ANY FOUNDATION PROJECT SHOULD BE THROUGH "GEOTECHNICAL INVESTIGATION"

The general objectives of the Geotechnical Investigation are:

1- Define lateral distribution of soil layers
2- Define groundwater conditions
3- Identify geologic hazards
4- Procure samples
5- Perform In-Situ testing (SPT or CPT)
6- Determine soil and rock properties

GEOTECHNICAL INVESTIGATION

1- Site Exploration
2- Measurements of Soil Properties
3- Field Instrumentation
4- Identifying Engineering Problems

1- Site Exploration

The general objectives of the exploration program for any project are:

1- Define the depth of the proposed foundation
2- Evaluate the load-bearing capacity of the foundation
3- Estimate the probable settlement
4- Identify potential foundation problems
5- Define ground water conditions
6- Predict lateral earth pressure
7- Establish method of construction
8- Determine suitability of the site material for construction

The site exploration program should include the following:

1-1 Data Collection	1- Type of structure 2- General use of the structure 3- Column load 4- Column spacing 5- Building code	

	6- Basement requirements 7- Topography maps 8- Geologic maps 9- Soil maps 10- Groundwater maps 11- Reports, Aerial photographs, satellite images, etc	
1-2 Terrain Analysis	**Using remote sensing and landform interpretation techniques to determine:** 1- Geomorphic characteristics of the site (Landform) 2- Relief amplitudes 3- Drainage basins 4- Vegetation 5- Climate conditions, weathering, frost action, erosion, and mass wasting.	
1-3 Site Reconnaissance	**A trip to inspect the field:** 1- General topography, existing of drainage, ditches, etc. 2- General conditions of the soil 3- Type of vegetation 4- Surface water condition 5- Accessibility of the site	
1-4 Subsurface Sectioning	**This includes the following:** 1- Seismic refraction (For large areas) 2- Test pits (for shallow depths) 3- Auger boring (Manual, Mechanical) 4- Wash boring 5- Core boring ***The depth and the interval of the subsurface sectioning is governed by:*** *1- Type of construction* *2- Column Load* *3- Column Spacing* **Test boring is the most usable method** In planning and executing the test Boring you need to know: 1- Equipment Selection 2- Boring Spacing 3- Boring Depths	**1-4-1. Equipment Selection** This depends on: *1- Terrain features* *2- Accessibility* *3- Geologic Conditions* *4- Boring depths* *5- Sample types* *6- Nature of the project* **1-4-2. 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: 1- Multistory buildings --------- 30 ft to 100 ft 2- Residential subdivision -------- 800 ft to 1600 ft 3- Warehouses, Industrial plants ----- 60 ft to 200 ft 4- Dams and Dikes --------- 130 ft to 260 ft 5- Highways and railways -------- 800 ft. to 1600 ft. ***In general spacing may vary depending on the irregularity of the site geology.*** **1-4-3. Depth of Boring** 1- Boring should be extended through any unsuitable foundation strata (unconsolidated fill, organic soils, compressible layers) until soil of acceptable bearing capacity is reached. 2- In general, boring should be extended to at least 1.5 to 2 times the minimum width of the loaded area. 3- 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. 4- The following empirical equations can be used to estimate the minimum depth of borings in office buildings: $D_{boring} = 3\ S0.7$ (for light steel or narrow concrete buildings) $D_{boring} = 6\ S0.7$ (for heavy steel or wide concrete buildings) where S = number of stories in meter

1-5 Sample Recovery

1-5. SAMPLE RECOVERY

Soil samples obtained during subsurface sectioning are either:

1- Disturbed
2- Undisturbed

Disturbed soil samples are used for:

1- Grain size analysis
2- Determination of index properties
3- Organic content
4- Specific gravity

Undisturbed samples are used for:

1- As above
2- Determining mechanical properties
3- Determining hydraulic properties

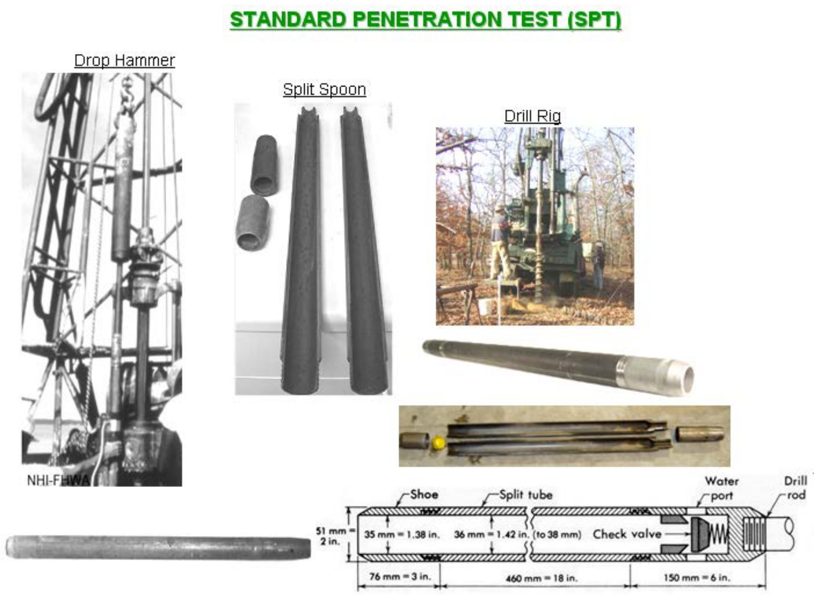
1-5-1 Methods Of Sample Recovery

1- By hand
2- Split spoon
3- Scraper bucket
4- Thin wall tube (shelby tube)

Split spoon sampling method is used to obtain disturbed and undisturbed samples.
- The sampler is driven into the soil by a hammer.
- The weight of the hammer is 140 lb.
- The number of blows (N) required to penetrate the spoon of three 6 in. intervals are added and recorded.

This procedure is called the Standard Penetration Test (SPT)

- Actually, the Standard Penetration Number N is the number of blows (N) of the last two intervals (12 in). The first interval (6 in.) is usually discarded (why ???).



THE STANDARD PENETRATION TEST (SPT)

- The SPT which was developed in 1902 by Colonel Charles Gow of the Raymond Pile Company. Karl Terzaghi in 1947 recommended seating correction for the SPT values.
- It is currently one of the most popular and economical in situ test to obtain subsurface information.

- It is estimated that 85% to 90% of conventional foundation design in the USA is made using the SPT.

- The testing method was standardized in 1958 as ASTM D1586.

- The test consists of:

1 - Using a 140 lb driving mass (W) falling free from a height of 30 in. (h) to
2 - Drive the standard split spoon sampler a distance of 18 in. into the soil, and
3 - Counting the number of blows (N) to drive the sampler 12 in. (6 in. + 6 in.).

Theoretical free-fall energy of the SPT hammer

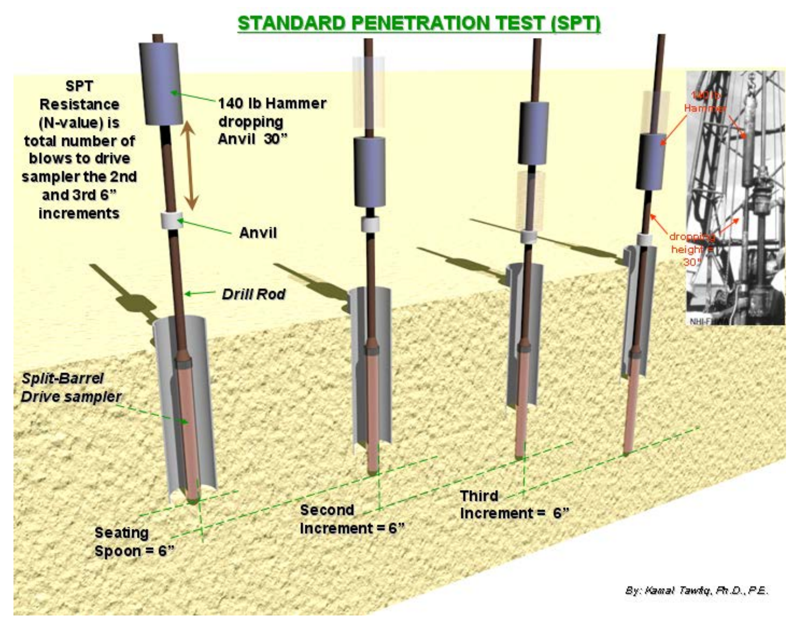
$E_{theo} = W.h$

$= (140\text{ lb})(30\text{in}) = 4200$ 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)

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):

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

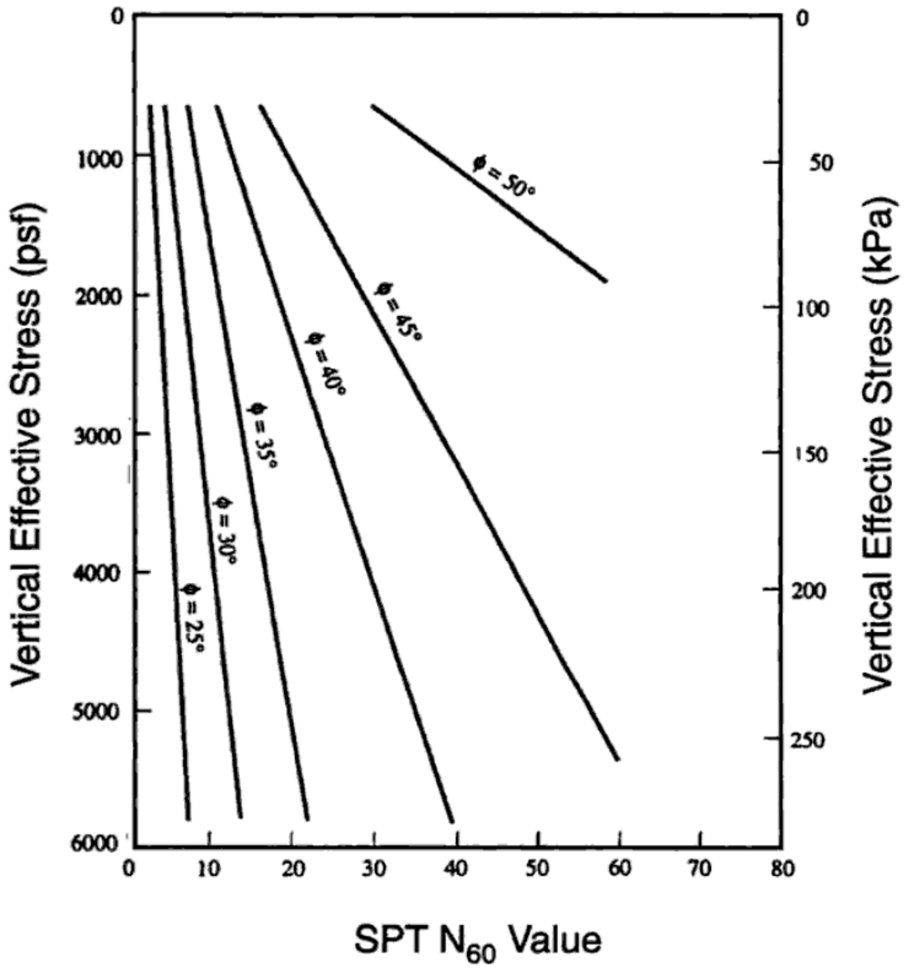
where N_{60} = SPT N-value corrected for field testing procedures

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.*)

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)

Standard Penetration test (SPT)

Advantages

- Many existing correlations
- Most contractors are capable of SPT testing
- Obtain sample (when using the spoon) of material that is tested
- Relatively cheap
- Robust
- Suitable for most soils

Disadvantages

- Ground at base of borehole is disturbed by drilling process
- Prone to errors by drillers (e.g. water head, depth measurement errors)
- Device imposes very complex strain paths to the soil and no theory at present is capable of predicting what are the most influential factors affecting the N value

Disadvantages

- Remolds soil and destroys important latent rock structure in residual soil
- Commonly performed at 1.5m intervals
- Dynamic test—does not measure static properties
- Energy rarely calibrated—can vary by a magnitude of 3

Presenting SPT values on the boring log:

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 N 60 (blows/ft)	Remarks and raw SPT data
+180	0.3	Top soil, grass, and roots					
		Loose gray-brown clayey fine **SAND** (SC)	6.0	16		**7**	*(2+3+4)*
	7.0						
+170		Soft blue-tan clayey **SILT** (MH)	12.0	16		**3**	*(0+2+1)* *Groundwater z_w = 15.5 feet (Nov. 8, 2001)*
	14.5						
		Firm yellow-tan clean to slightly silty fine **SAND** (SP to SP-SM)	20.5	18		**32**	*(11+14+18)*
+160	21.5						
		Firm yellow-tan clean fine to medium **SAND** (SP)	28.0	11		**28**	*(+13+15+13)*
+150	30.0						
		Loose white to yellow slightly silty medium to coarse **SAND** (SP)	36.0	11		**5**	*(+2+3+2)*
	39.0						
+140		Very stiff green fine-medium sandy **CLAY** (CL)	43.5	16		**20**	*(+10+10+10)*
	45.5						
+130		Stiff green-gray silty to sandy **CLAY** (CL)	52.5	18		**15**	*(+6+7+8)*
	60.2						
+120		Dense white medium **SAND** (SP) with shells	63.5	10		**42**	*(+20+22+20)*
	64.0	*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