2. Subsurface Investigation

2.1 General

- Site Investigation is the process by which geological, geotechnical, and other relevant information which might affect the construction or performance of a civil engineering or building project is acquired.

- Objectives

  1) Site Selection
  2) Foundation and earthworks design
  3) Temporary works design
  4) The effects of the proposed project on its environment
  5) Investigation of existing construction
  6) The design of remedial works
  7) Safety check for pre-existing structures

- (Geotechnical) Subsurface exploration
  ⇒ The process of determining the structures of subsoil and their physical properties

- Informations to get from subsurface investigation
  (1) Finding out compositions of subsoil (the thickness, continuity and area of existing layer and the location of bedrock).
  (2) Sampling the soil (and the rock) and determining its mechanical properties by field and lab tests.
  (3) Basic information of groundwater flow.

2.2 Subsurface Exploration Program

1) Collection of preliminary information

* Information regarding the type of structure to be built and its general use
* A general idea of the topography and the type of soil to be encountered near and around the proposed site

2) Reconnaissance

(a) The general topography of the site and possible existence of drainage ditches
(b) Soil stratification from deep cuts
(c) Type of vegetation at the site
(d) High-water marks on nearly building and bridge abutments
(e) Ground water levels from checking nearby wells
(f) Type of construction nearby and existence of any cracks in walls or other problems

3) Site Investigation

- Consisting of planning, making some test boreholes, and collecting soil samples

- Planning the site investigation

1) Depth of Borings

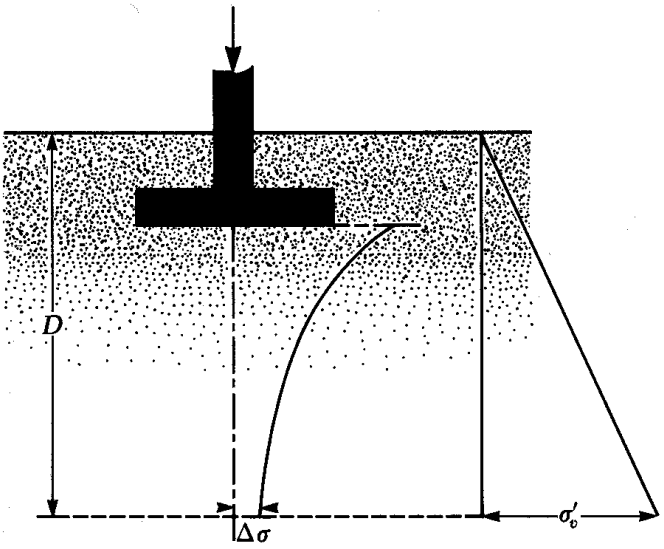
- Reservoirs : a) Depth of the base of the impermeable stratum or b) not less than 2 × maximum hydraulic head expected.
- Foundations :

a) All borings should be carried to a suitable bearing strata.

b) Determination of the approximate minimum depth of boring

i) Determine net increase of stress, $\Delta\sigma$

ii) Estimate the variation of the vertical effective stress, σ_v'

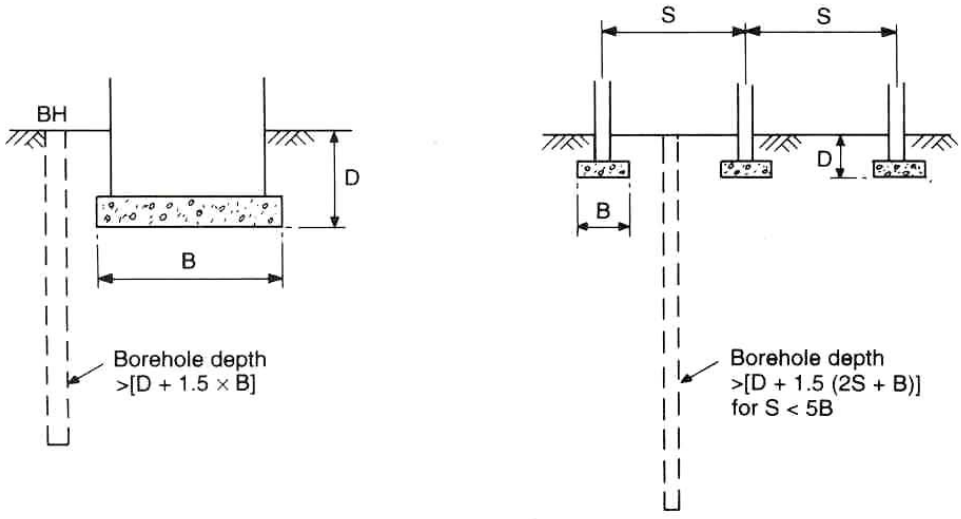


iii) Determine the depth, $D=D_1$ at $\Delta\sigma=1/10\ q$

(Here, q = estimated stress at the foundation)

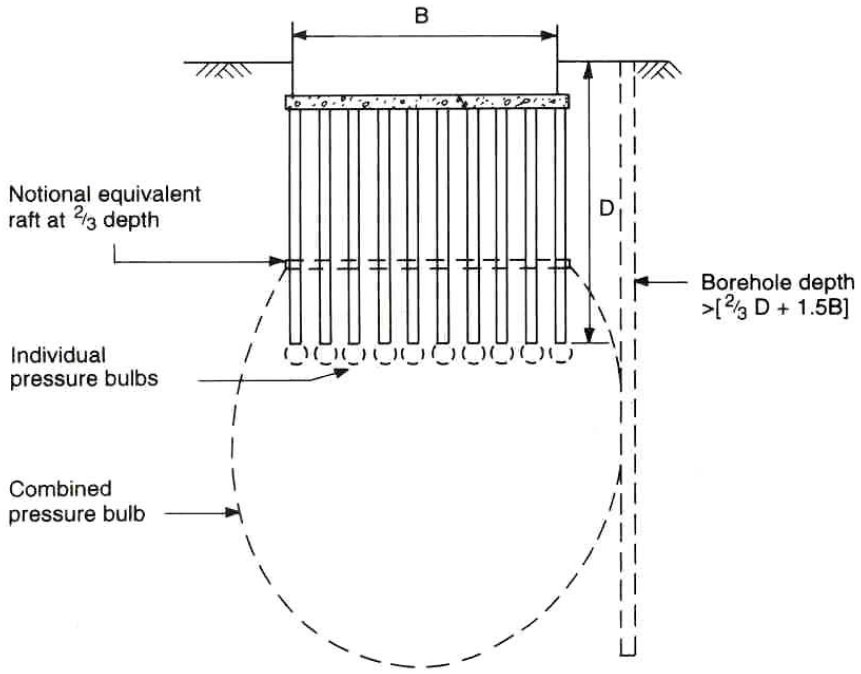
iv) Determine the depth, $D=D_2$ at $\Delta\sigma/\sigma_v'=0.05$

v) Minimum depth of boring is the smaller of D_1 and D_2 unless bedrock is encountered.



(a) Structure on isolated pad or raft

(b) Closely spaced strip on pad footings



(c) Large structure on friction piles

Fig. 1.5 Necessary borehole depths for foundations.

- Foundation on bedrock ⇒ The minimum depth of core boring = 3m

- For deep excavations ⇒ the depth of boring = 1.5 × the depth of excavation

- For roads
  * At least 5m below ground level where the finished road level is near existing ground level.
  * 5m below finished road level in cut
  * At least 1.5 times the embankment height in fill level
- For retaining walls
  3/4 – 3/2 times the wall height below the bottom of the wall
  (If only one survey, 2 times the wall height below the bottom of the wall)
- For dams
  1.5 – 2 times the height of the dam
  Borehole should penetrate soft or unstable materials but also permeable materials
- For embankments
  At least equal to the embankment height and ideally penetrate all soft soils if stability is to be investigated

< 보 링 의 깊 이 >

조사 대상	깊 이	비 고
단지조성, 매립지, 공항 등 광역부지	-절토 : 계획고하 2m -연약지반성토 : 연약지반 확인 후 견고한 지반 3~5m -호안, 방파제 등 : 풍화암 3~5m -구조물 : 해당구조물 깊이기준에 따른다.	절토에서 기반암이 확인이 안된 경우는 기반암 2m 확인, 조사공수 및 배치에 따라 부분적으로 계획고 도달전이라도 기반암 2m 확인하고 종료할 수 있음
지 하 철	-개착구간 : 계획고하 2m -터널구간 : 계획고하 0.5~1.0D -고가, 교량 등 : 기반암하 2m	개착, 터널구간에서 기반암이 확인 안된 경우는 기반암 2m 확인
고속전철 도로	-절토 : 계획고하 2m -연약지반성토 : 연약지반 확인 후 견고한 지반 3~5m -교량 : 기반암하 2m -터널(산악) : 계획고하 0.5~1.0D	절토, 터널에서 기반암이 확인 안된 경우는 기반암 2m 확인
건축물, 정차장, 하수처리장 등	-지지층 및 터파기 심도하 2m	터파기 심도하 2m 까지 기반암이 확인 안된 경우는 일부조사공에 대해 기반암 2m 확인

주 : 1. 별도의 조사목적이 있는 경우는 기술자 판단에 따라 깊이를 조정하여 실시토록 한다.
2. 기반암은 연암 또는 경암을 의미함

- Approximate spacing of borings
  - Depending on the type of structures and soil conditions

Type of project	Spacing(m)
Multistory building	10~30
One story industrial plants	20~60
Highways	250~500
Residential areas	250~500
Dams	40~80

< 보 링 의 배 치 >

조 사 대 상	배 치 간 격	비 고
단지조성, 매립지, 공항 등 광역부지	◦ 절토 : 100 ~ 200m 간격 ◦ 연약지반성토 : 200 ~ 300m 간격 ◦ 호안, 방파제등 : 100m 간격 ◦ 구조물 : 해당구조물 배치기준에 따른다	대절토, 대형단면등과 같이 횡단방향의 지층구성 파악이 필요한 경우는 횡방향 보링을 실시한다.
지 하 철	◦ 개착구간 : 100m 간격 ◦ 터널구간 : 50 ~ 100m 간격 ◦ 고가, 교량 등 : 교대 및 교각에 1 개소씩	〃
고속전철, 도로	◦ 절토 :절토고 20m 이상에 대해 150~200m 간격 ◦ 연약지반성토 : 100 ~ 200m 간격 ◦ 교량 : 교대 및 교각에 1 개소씩 ◦ 터널(산악) : 갱구부 2 개소씩으로 1 개터널에 4 개소 실시하며 필요 시 중간부분도 실시함, 갱구부 보링간격은 30 ~ 50m 중간부간격은 100 ~ 200m 간격	〃
건축물, 정차장, 하수처리장 등	◦ 사방 30 ~ 50m 간격, 최소한 2 ~ 3 개소	

주 :
① 지층상태가 복잡한 경우는 기준을 1/2 축소하여 실시토록하고 기준에 없는경우는 유사한 경우를 참조하여 판단한다.
② 토피가 얕은터널, 충적층과 암반의 경계부분을 지나는 터널, 연약지반에서 과거에 수로였던 지점, 사면에서 단층이나 파쇄대 주변은 필요에 따라 추가하여 계획.

- Exploration cost = 0.1~0.5% of the cost of structures

2.3 Exploratory Borings in the Field

* Provide the opportunity to obtain samples for visual description and laboratory testing, to perform in situ testing and to allow the installation of instrumentation such as piezometers.

1) Test-pit

Max depth = 4 ~ 5m

2) Auger boring (Continuous flight auger)

* Bring the loose soil from the bottom of the hole to the surface ⇒ identifying the soil.
* Can detect changes in soil type by noting changes in the speed and sound of drilling

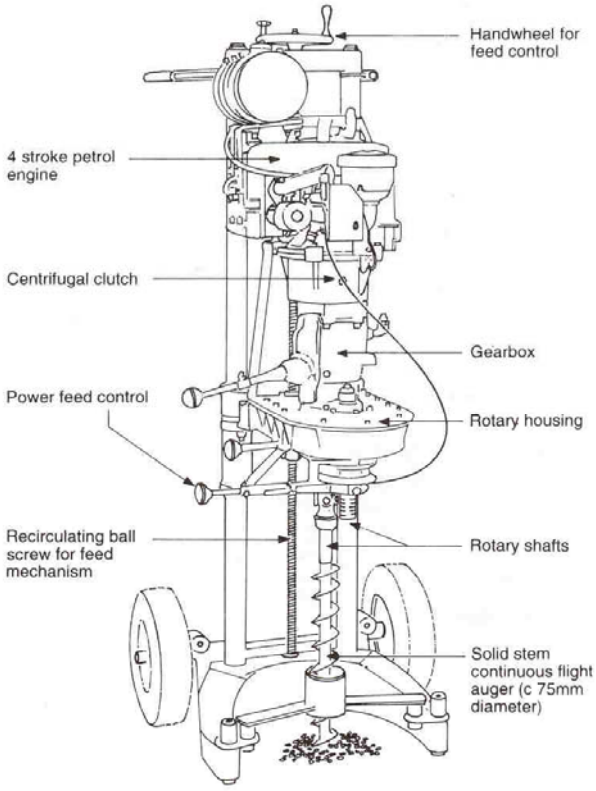


Fig. 5.5 Mobile 'Minuteman' small diameter solid stem continuous-flight auger rig.

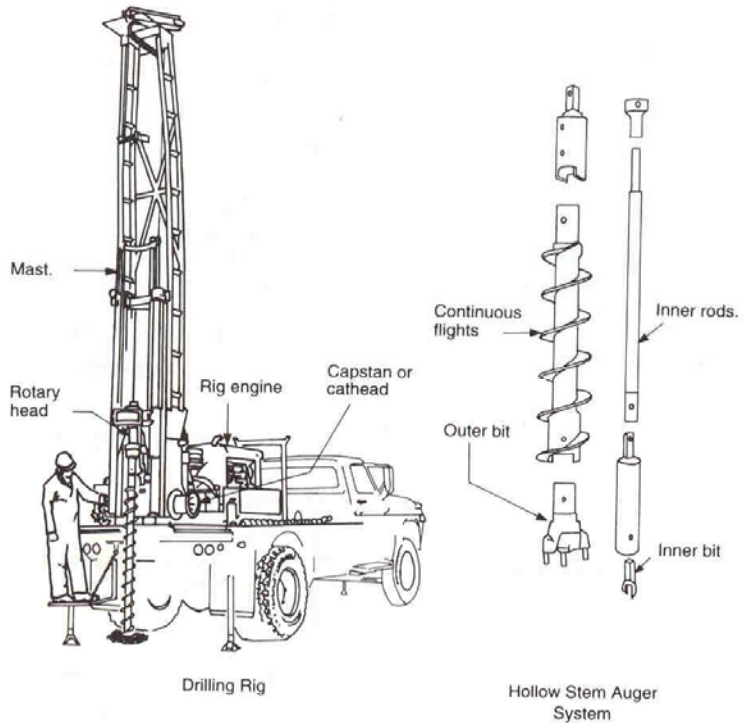


Fig. 5.6 Acker ADII drilling rig and hollow-stem auger system.

3) Rotary drilling

* Rotary drilling uses a rotary action combined with downward force to grind away the material in which a hole is made.

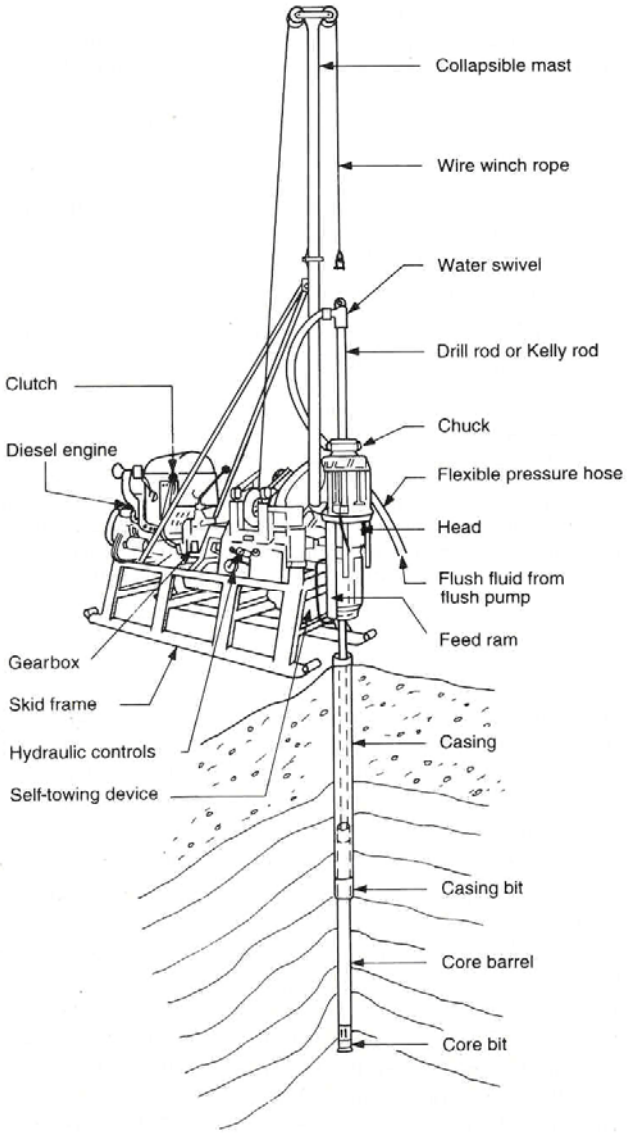


Fig. 5.9 Layout for small-scale rotary core drilling.

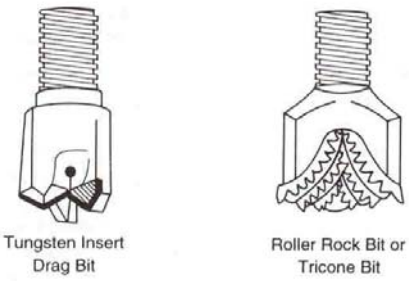


Fig. 5.10 Bits for rotary open holing.

4) Wash boring

* Washboring is a relatively old method of boring small-diameter exploratory holes in fine-grained cohesive and non-cohesive soils.

5) Percussion boring

* A method that advances the borehole by raising and lowering a drilling bit (a claycutter or shell) to chop the soil.

2.4 Observation of Water Table

If possible,

- Establishing the highest and lowest possible levels of the water table during the life of project
- Water table is generally measured by lowering a chain or tape with/without electrical dipmeter into the borehole, after stabilizing ground water condition due to boring (At least, we need 24hrs.) ⇒ **Standpipe**

- In cases that
  1) Multiple water levels are existed or seepage between strata occurs;
  2) The considerable length of time is required for equalization of the level of water in the standpipe for highly impermeable layers,

  ⇒ Use **standpipe piezometer** to measure in-situ pore pressure over a limited depth

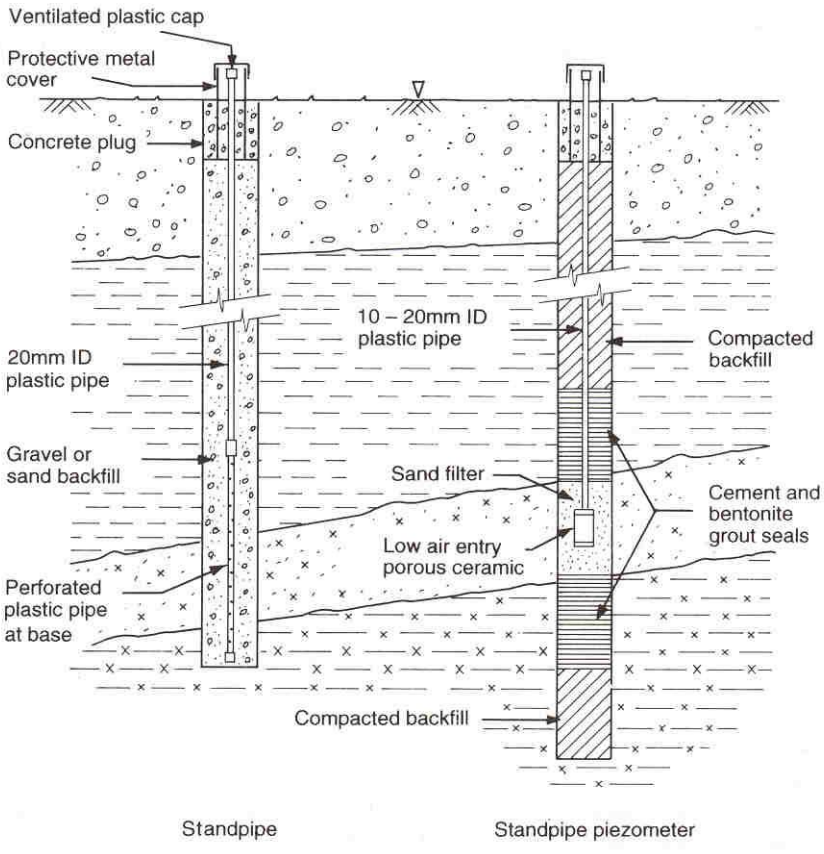


Fig. 10.1 Standpipe and standpipe (or Casagrande) piezometer.

2.5 Preparation of Boring Logs

⇒ Detailed information gathered from each borehole.

1. Driller's name
2. Job description and number
3. Number and type of boring and boring location
4. Date of boring
5. Subsurface stratification
6. Ground water level with date
7. N values and depth of SPT
8. Number, type, depth and identification of soil sample collected
9. Ground level
10. w_n, γ_d, LL and PL with depth

Boring Log

Name of the Project Two-story apartment building

Location Johnson & Olive St. Date of Boring March 2, 1982

Boring No. 3 Type of Boring Hollow stem auger Ground Elevation 60.8 m

Soil description	Depth (m)	Soil sample type and number	N	w_n (%)	Comments
Light brown clay (fill)					
Silty sand (SM)	1–2	SS-1	9	8.2	
*G.W.T. 3.5 m	3	SS-2	12	17.6	LL = 38 PI = 11
Light gray silty clay (ML)	4–5	ST-1		20.4	LL = 36 q_u = 112 kN/m^2
	6	SS-3	11	20.6	
Sand with some gravel (SP)	7				
End of boring @ 8 m	8	SS-4	27	9	

N = standard penetration number (below/304.8 mm)
w_n = natural moisture content
LL = liquid limit; PI = plasticity index
q_u = unconfined compression strength
SS = split-spoon sample; ST = Shelby tube sample

*Ground water table observed after one week of drilling

Figure. A typical boring log