Site Investigation and Piling
- What Architects Need to Know

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CONTENTS

INTRODUCTION

The main purpose of this lecture is to provide some guidance notes on the site investigaiton and piling for common projects to young architects

OBJECTIVES OF SITE INVESTIGATION

- Provide adequate information for site assessment, safe and economical designs of temporary and permanent works
- Choice of site and layout arrangement
- Provide adequate information for planning and assessment fo the best method of construction, foresee construction difficulties and finding ways to mitigate the problems that might delay the construction and installation
- Provide adequate information for assessment of safety

DESK STUDY

- **Topographic Maps**
  - *examine earthwork, soft ground and slope for site reconnaissance and planning of ground investigation*

- **Geological maps and memoirs**
  - *for planning of ground investigation; methods of ground invewstigation; extent of field and laboratory testing.*

- **Site Histories**
  - *old foundations, tunnel, underground services and etc.*

- **Results of Adjacent and Nearby Ground Investigation**
  - *for more efficient an economical ground investigation*

- **Details of Adjacent Structures and Foundations**
  - *for safety assessment and prevention of foundation failure/settlement of adjacent properties due to proposed foundaiton works*

- **Aerial Photographs**
  - *indication of geomorphology features, land use, problem areas and layout arrangement*

  - *particularly useful for highways and hillslope developments*

SITE RECONNAISSANCE

- **Confirm and obtain additional information of site**

- **Examine adjacent and nearby development**
  - *exposed cut*
  - *cracks and settlements of adjacent buildings*
  - *predilapidation survey*

- **Compare the surface features and topography with data obtainable in the desk study**
  - *check presence of fill and cut areas*
  - *check for exposed services markings*

- **Locate and study the outcrops, previous slips**
  - *stability characteristics*

METHODS OF GROUND INVESTIGATION

- **Light Dynamic Penetrometer and Hand Auger**

- **Excavation and Borehole**
  - *Trial pits*
  - *Sampling of soil and rock*
  - *Groundwater monitoring via piezometer*
  - *SPT*
  - *Vane shear test*

- **Static Dutch Cone Penetrometer**

- **Piezocone**

1) **Light Dynamic Penetrometer and Hand Auger**

JKR or Mackintosh probe (Preliminary Investigation)

- Hammer weight = 5kg
- Drop Height = 280mm (JKR Probe)
- Depth < 12m or 400 blows/300mm
- Cheap and quick

USE

- Localised Soft Area/ Weak Layer or Spot or Slip Plane
- Determine Hard Layer or Shallow Bedrock especially Limestone Profile
- Preliminary Subsoil Information (consistency & Cu)
- Assist in Interpolation between Boreholes or Piezocones

Limitations

- Shallow depth (deeper depth in coarse materials give misleading results)

Human errors are high

- varies in drop weight or exerting force, give misleading results
- wrong counting unless use mechanical counter

Precautions

- drop of hammer should be a free fall and consistent drop height
- components and apparatus properly washed and oiled

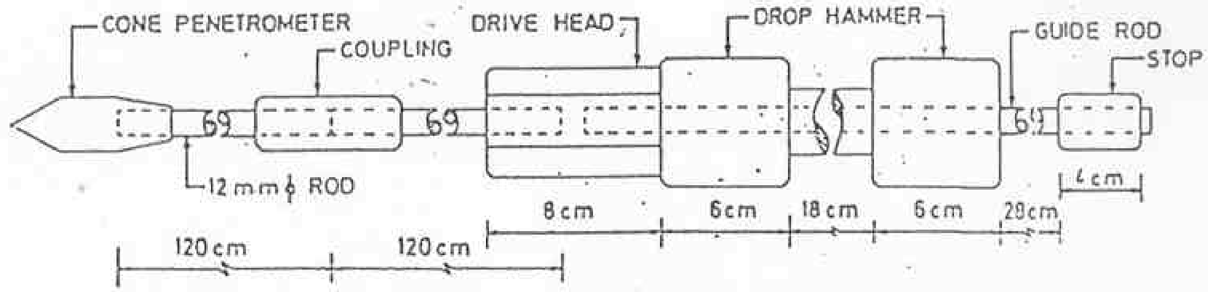
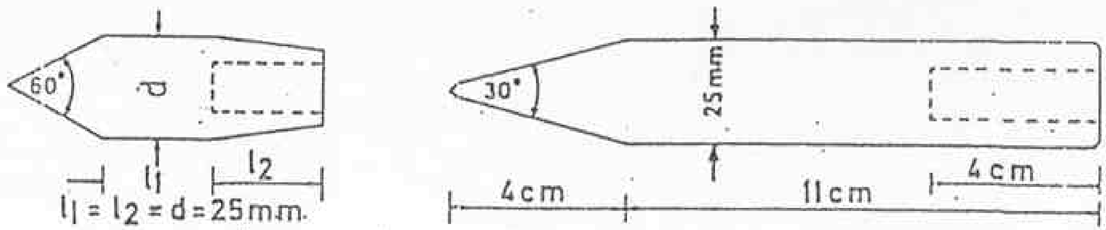


FIG. S1a GENERAL ARRANGEMENT OF J.K.R. PROBE



(a) J.K.R. PROBE

(b) MACKINTOSH PROBE

FIG. S1b POINTER GEOMETRY OF LIGHT DYNAMIC CONE PENETROMETERS

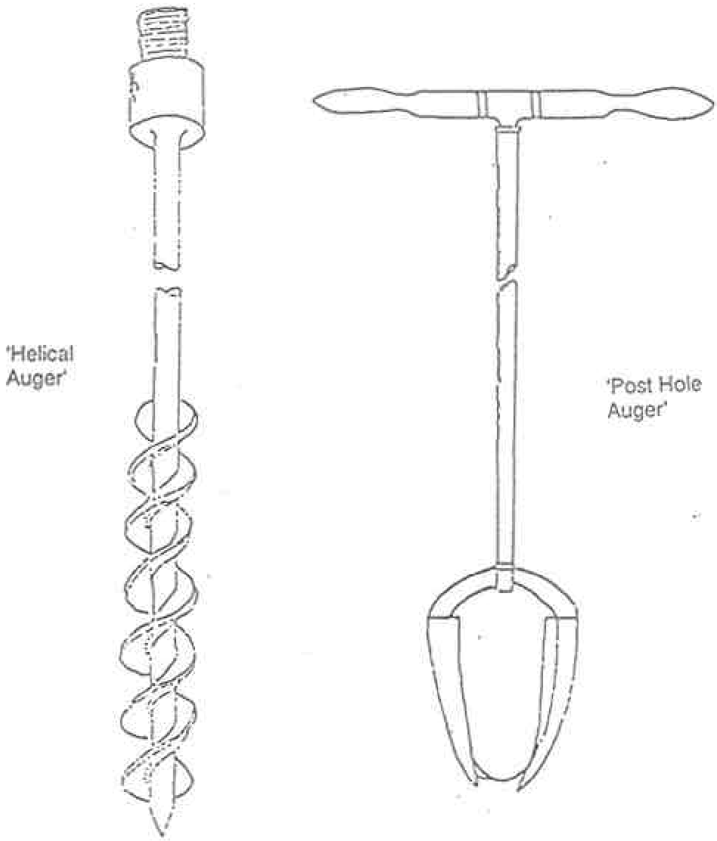
HAND AUGER

Usually use together with JKR probe to determine the type of soil and ground water

- depth ≤ 5m

Limitation

- disturbed sample often get mixed
- limited use



TYPES OF AUGERS

Excavation

Use back-hoe excavator for prospecting fill materials or exposing materials at shallow depth such as cobbles, boulders, obstruction to test and etc

- depth ≤ 5m
- allow collection of bulk and block samples
- allow plate bearing test and JKR probe test inside the pit

Safety Precautions

- stability of sides or slopes
- barricades if the pit needs to be left overnight for further testing
- backfill and compact properly after use

Boreholes

Boreholes is sometime called deep boring. The details of boring, sampling and testing are described in BS 5930:1981.

A) Rotary drilling by circulating fluid (water bentonite or air foam) is most common method

B) Wash boring utilises the percussive action of a chisel bit to break up materials and flush to the surface by water or drilling fluid pumping down the hollow drill rods

- *Borehole usually includes boring, sampling, in-situ testing and water-table observations*
- *Depth usually £ 100m*
- *Drill through all soils and core through all rocks*

Sizes of Commonly-used Core-barrels, Casings and Drill Rods Used

Core - barrels						Casings			Drill Rods			
Double - tube			Triple - tube			Flush - jointed			Flush - coupled			
Design	Nominal Diameter		Design	Nominal Diameter		Design	OD	ID	Design	Rod		Coupling
	Core	Hole		Core	Hole					OD	ID	ID
TNW	61	76	NMLC	52	76	NW	89	76	BW	54	44	19
T2-76	62	76				HW	115	101	NW	67	57	35
T2-101	84	101	HMLC	64	99	PW	140	126	HW	89	80	60
T6-101	79	101										
			Mazier*	74	101	PW	140	126	NW	67	57	35
			3C-MLC**	76	111							
			4C-MLC**	102	140	SW	168	153	HW	89	80	60

Legend :

* With retractor shoe

** With or without retractor shoe

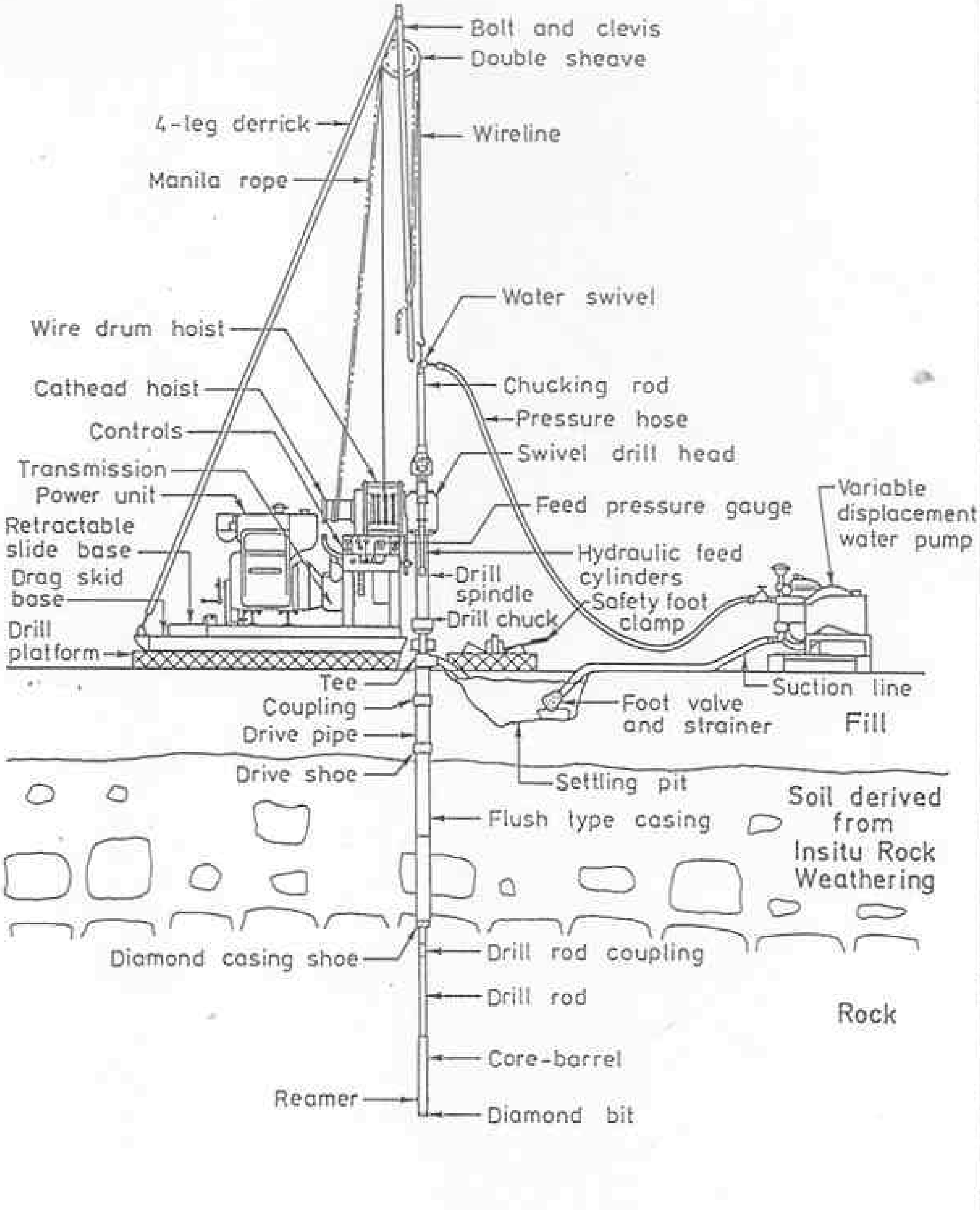
OD Outer diameter

ID Inner diameter

Notes : (1) This list is not exhaustive and should not imply the exclusion of other recognised core barrels and casing/rods systems.

(2) For additional information, reference can be made to BS 4019 : Part 1 (BSI 1974a) on rotary core drilling equipment and Figure 29 of BS 5930 (BSI, 1981a).

(3) All dimensions are in millimetres.



Note : Figure adopted from Acker Drill Co. Inc. data.

Typical Configuration of a Rotary Drilling Rig

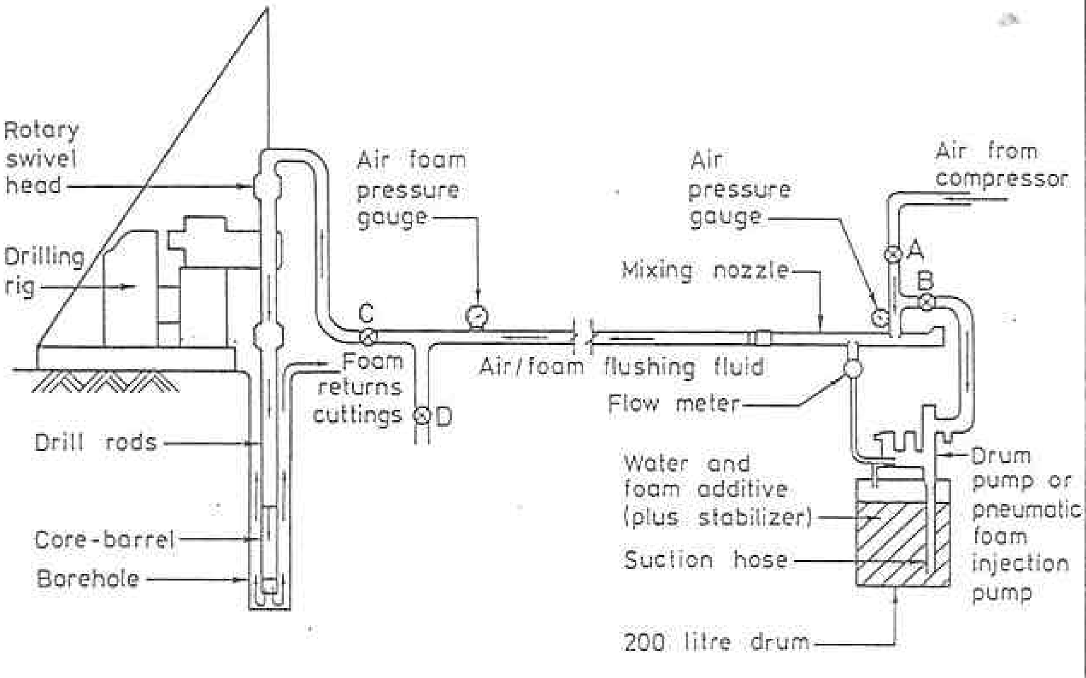
Valves :

A Air supply control

B Foam pump speed control

C Drilling supply fluid control

D By-pass control



Typical Arrangement of Air Foam Mixing and Flushing System

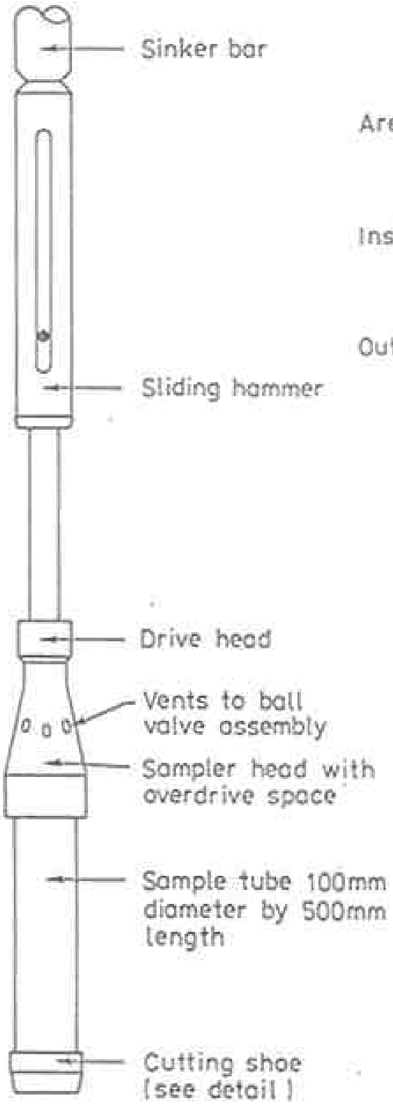
Rock Coring

Rotary core drilling is commonly used to advance the borehole and provide core samples for examination and testing.

$$\text{Core recovery (\%)} = \frac{\text{Length of recovered core}}{\text{Length of run}} \times 100$$

$$\text{RQD (\%)} = \frac{\Sigma \text{ of recovered core in pieces of} > 100 \text{ mm}}{\text{Length of run}} \times 100$$

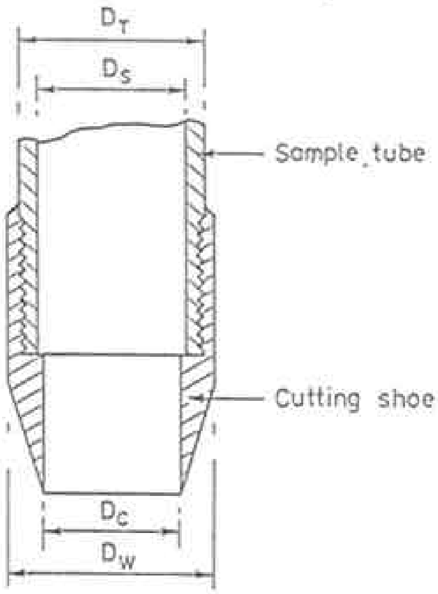
Note RQD = Rock Quality Designation



$$\text{Area ratio (\%)} = \frac{D_W^2 - D_C^2}{D_C^2} (100)$$

$$\text{Inside clearance (\%)} = \frac{D_S - D_C}{D_C} (100)$$

$$\text{Outside clearance (\%)} = \frac{D_W - D_T}{D_T} (100)$$



(a) U100 Sampling Arrangement

(b) Detail of Cutting Shoe and Definition of Sampler Proportions

Notes :

(1) The open-tube sampler may also be attached to drill rods and driven or pushed into the ground by the drilling rig or SPT hammer.

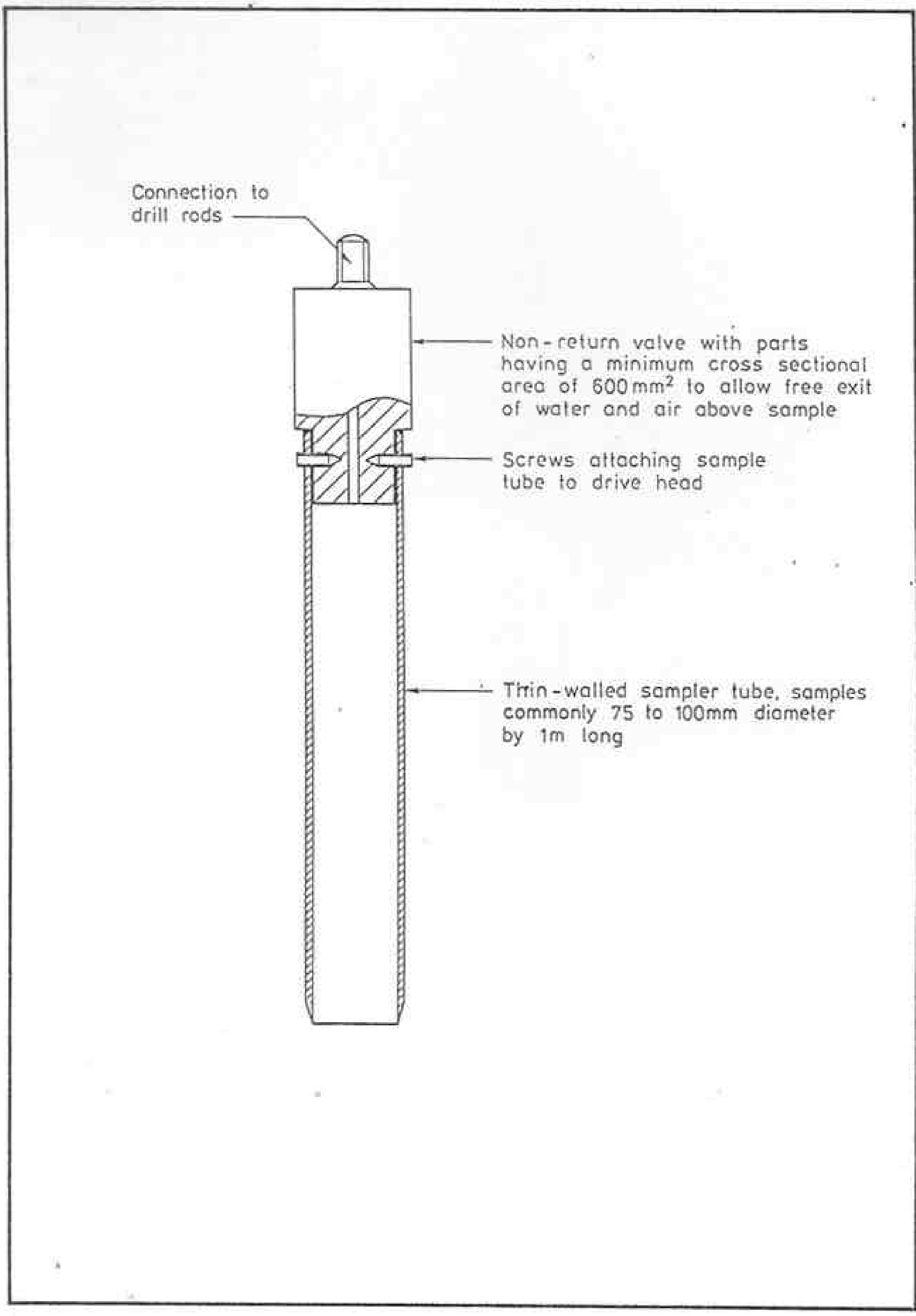
(2) Two sample tubes may be coupled together to provide a longer sample or additional overdrive space.

(3) The vents in the sampler head should have a minimum collective cross sectional area of 600 mm² to allow free exit of air and water above the sample.

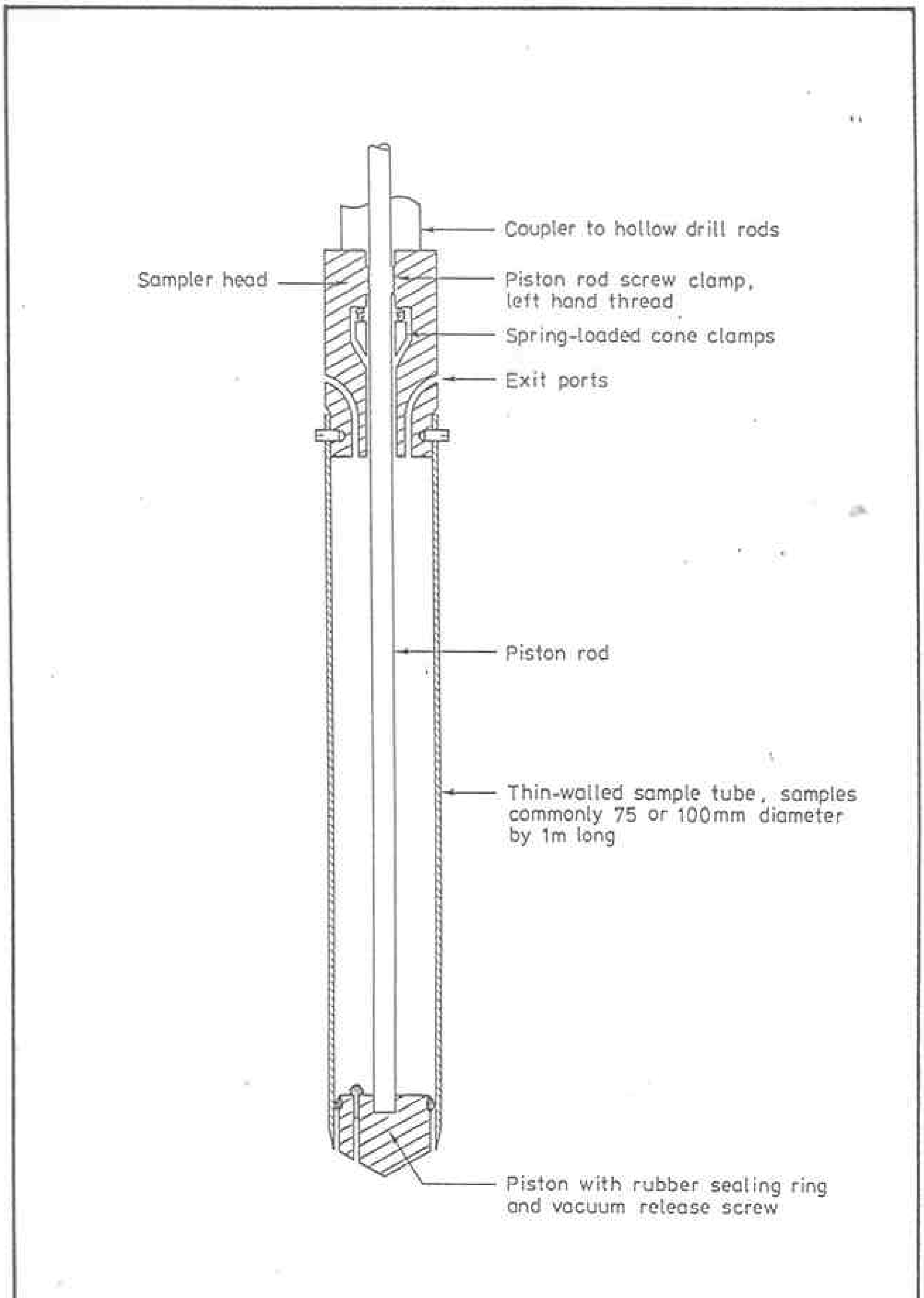
(4) A core-catcher device (not shown) may also be included with the cutting shoe.

(5) Samplers smaller in diameter than the U100 are available which are of similar design.

General Purpose Open-tube Sampler



Thin-walled Sampler



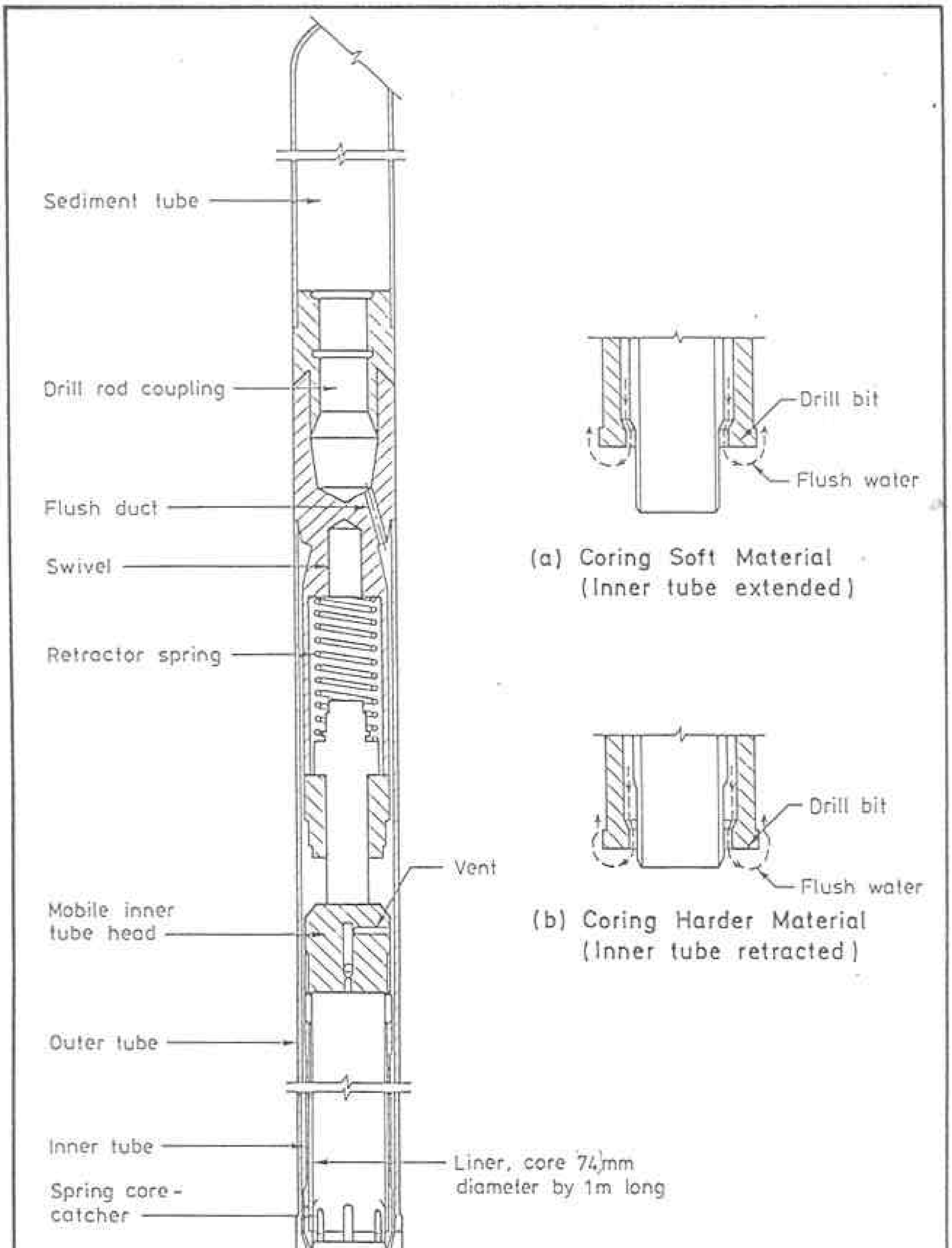
Thin-walled Stationary Piston Sampler

Continuous sampler

- for identifying sand lenses, description and classification tests
- usually for soft marine deposits

Mazier Sampler

- Triple-tube core-barrels containing detachable liners within the inner barrel
- Ideal for triaxial test as the diameter of core sampler is 74mm
- To sample “undisturbed” soil samples from stiffer soil stratum



Example of a Retractable Triple-tube Core-barrel (Mazier)

Care in Boreholes

- levels and coordinates must be taken and properly recorded
- photographs of setting up and samples should also be taken

Care in Sampling

- **Sampler**
  - *distorted or blunt cutting edge or dirty tubes should not be used*
  - *check sizes of components and condition*
  - *thin-walled sampler must be properly cleaned and greased*

- **Samples**

  - *Properly sealed and labelled to prevent lost of water when moisture content is required*
  - *Thin-walled sample must be sealed with a layer of grease, follow by non-shrink wax and tape to prevent loss of moisture (excess grease by the side of tube for wax placement must be removed to ensure good contact between wax and the inner side of sampler)*
  - *Properly stored and packed for transport to prevent disturbance during transportation*

Groundwater

- Water level observation in completed boreholes and existing wells if any should be taken daily during the ground investigation, particularly in the morning (rain for the preceding night must be recorded and the borehole protected against surface in flow)
  - *long response time and misleading if rain water enters borehole*

- Measurement over a period of time is required to establish the water table during the period of investigation. Seasonal variation and tidal has influence on the water table

- Piezometer should be used for accurate and longer time measurement of ground water level
  - *shorter response time*

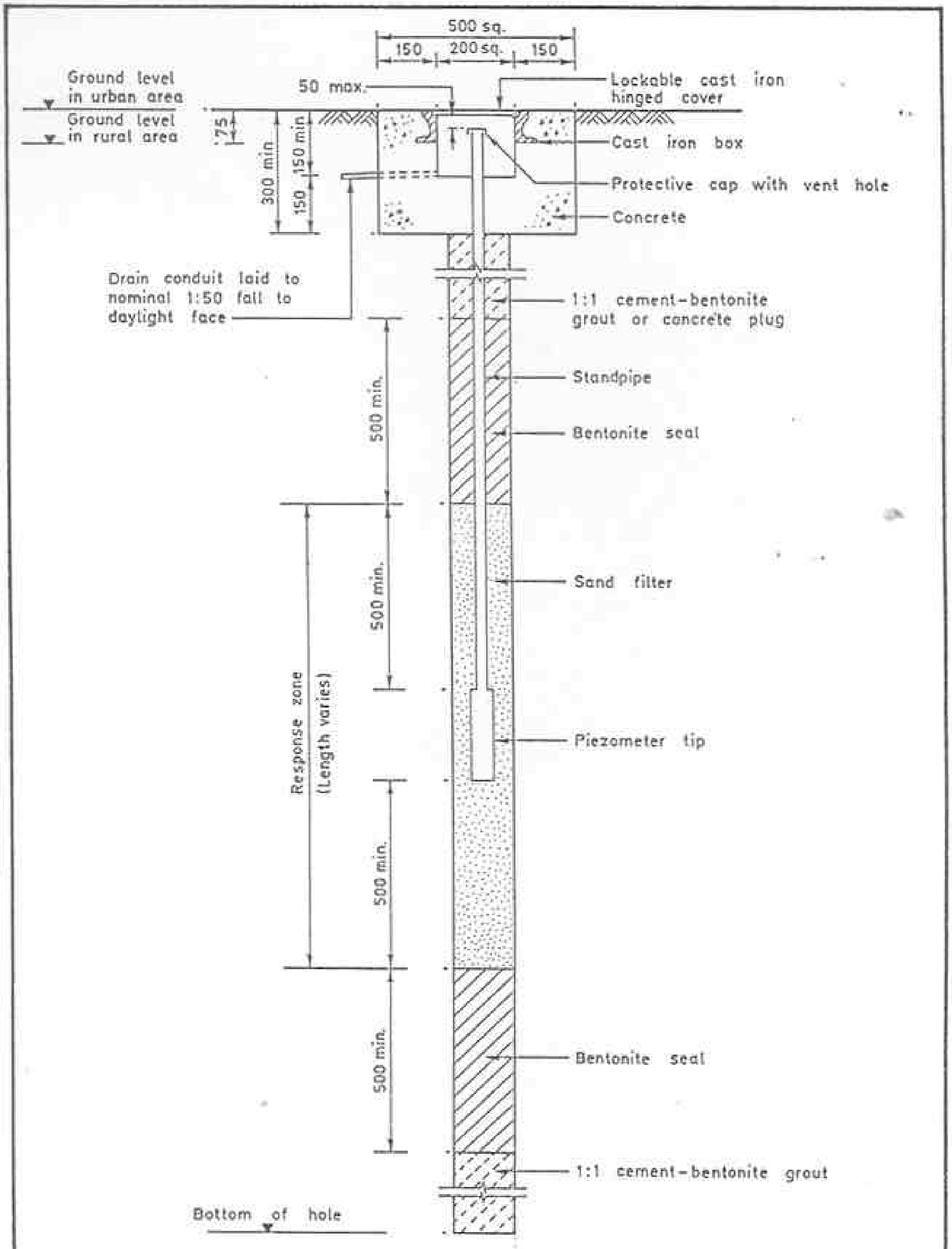
- Water samples must be properly sealed and labelled

- Care in Installation
  - de-airing
  - sealing
  - read guideline and specification

- Good practice to lower the water in the borehole by a few metres from the expected groundwater level and then allow it to rise to its original level and collect the water samples

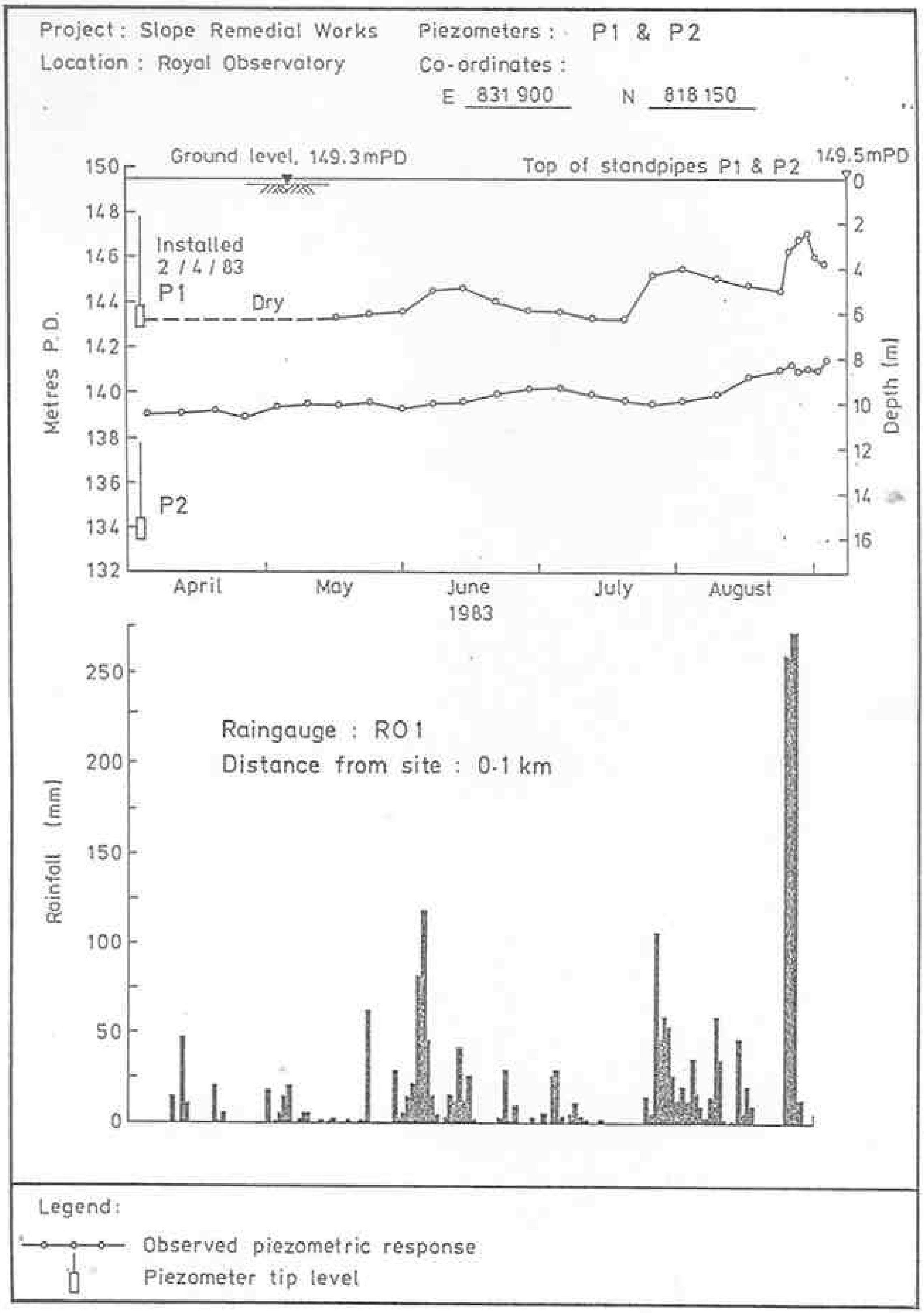
Care in Installation

- Porous element must be fully saturated and fill with de-aired water
- If two piezometers are placed in a single borehole, proper seal is the key to success
- Response test is required by falling head type



Notes: (1) Scale is diagrammatic.
(2) All dimensions are in millimetres.

Typical Installation Details of a Piezometer in a Borehole



Example of Piezometer Record

<u>Standard Penetration Test (SPT)</u>

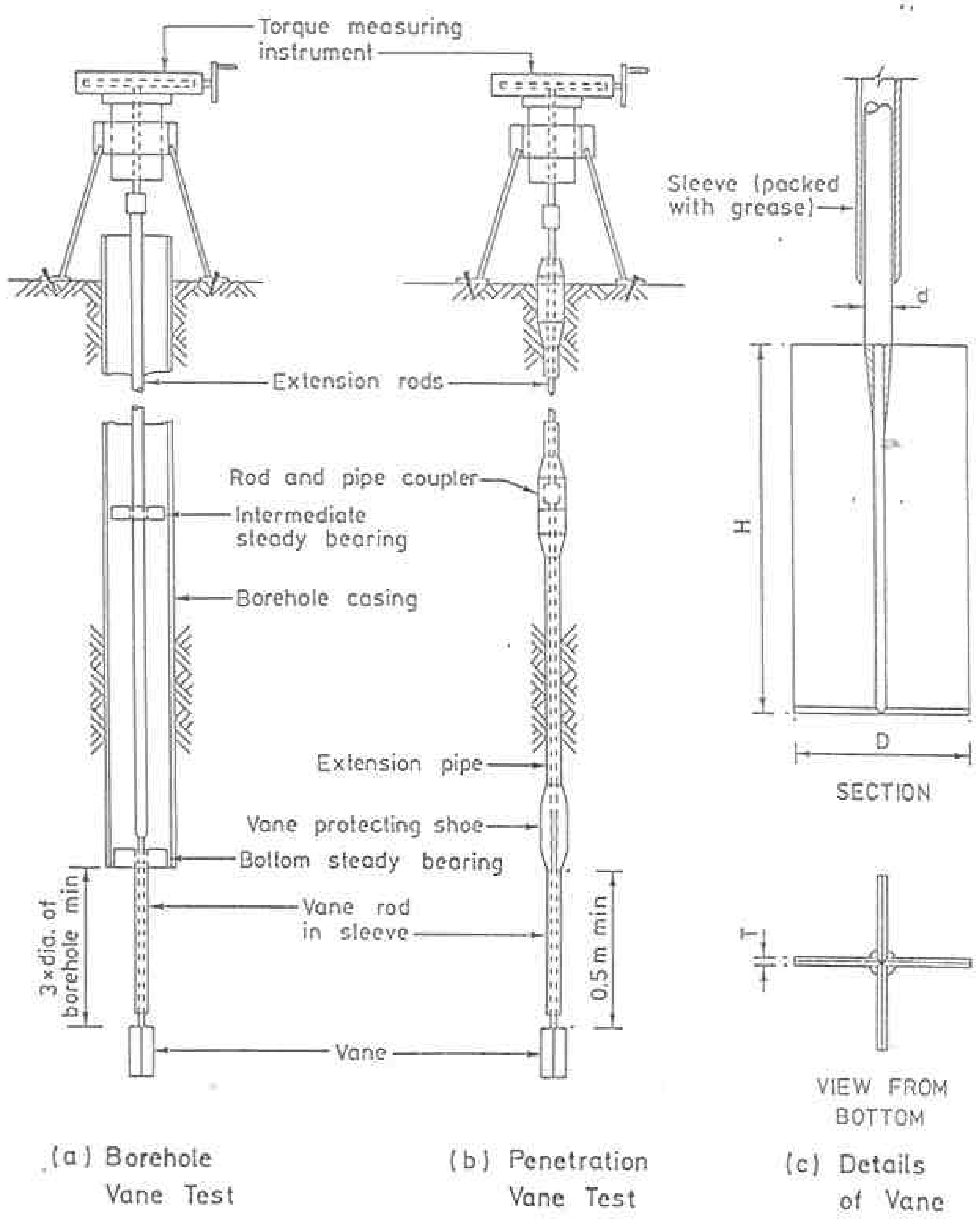
- **BS 1377**
  - *Hammer weight = 65kg*
  - *Drop height =760mm*
  - *Sampler is driven a total of 450mm into the soils and the number of blows for the last 300mm of penetration is the SPT, N value*
  - *Simple and rugged*

- **<u>Care in the test</u>**
  - *dented driving shoe should not be used*
  - *depth of test is very important. No test above the base of casing*
  - *base of borehole must be properly cleaned*
  - *use counter to prevent counting error*
  - *mark the penetration depth clearly*
  - *always keep borehole water level as close to the natural ground as possible (if the approximate ground water level is known) or else keep the borehole full of water. Water level in the borehole drops too fast and below ground water table during changing of assembly for SPT in silty and sandy soils can cause boiling in the sandy and silty soils*
  - *close supervision*

<u>Vane Shear Test</u>

- **BS 1377**
  - *Equipment must be calibrated*
  - *Various vane shear (vane constant varies with size for computation)*
  - *Cohesive soil only*
  - *Influence of rootlets and coarse particles may lead to misleading results*

<u>Self Penetration Vane</u>



Note : Figure based on BS 1377 (BSI, 1975b).

Vane Shear Devices

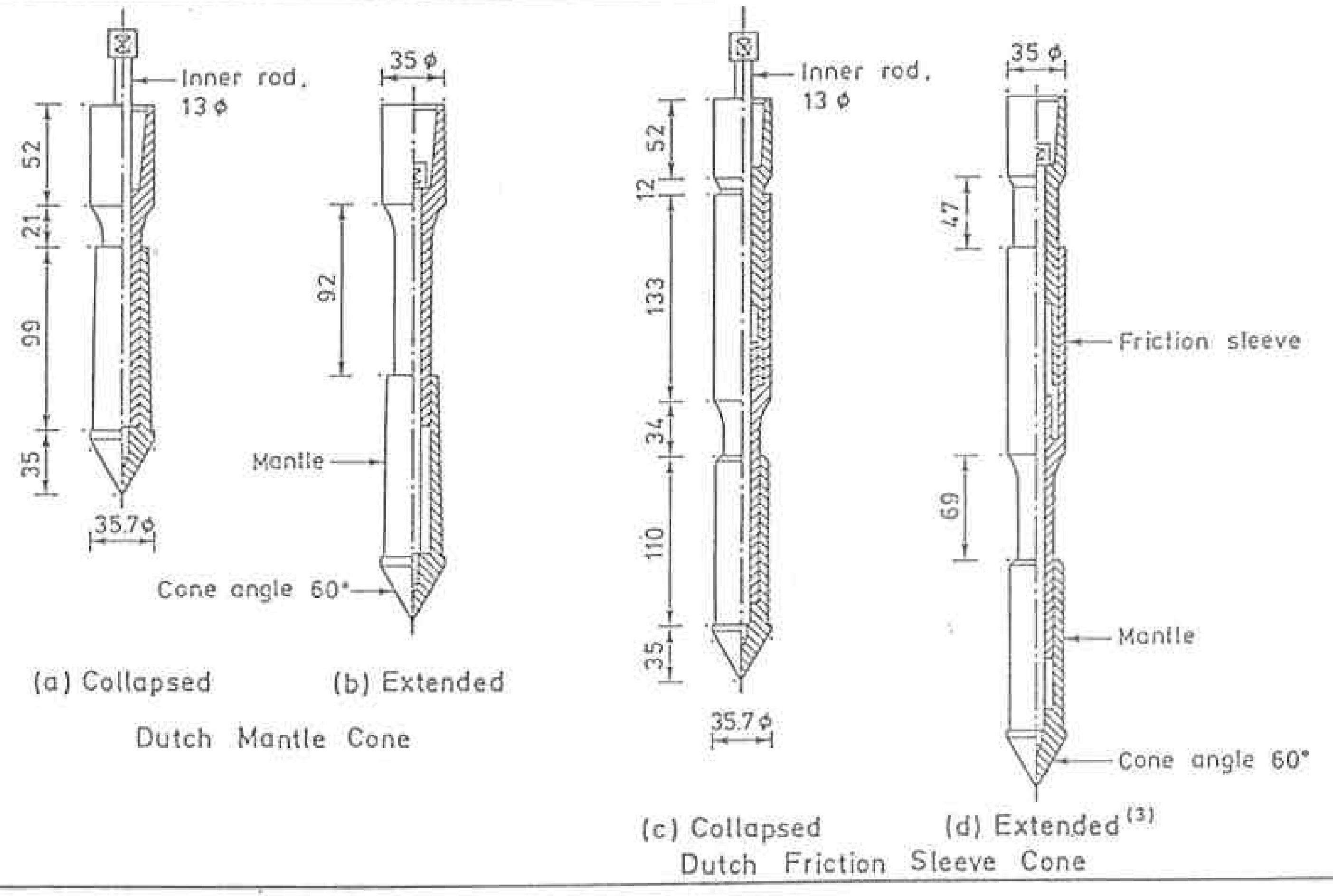
Static Cone Penetrometer

- **BS 5930**
  - *Provide skin friction and end-bearing resistance*
  - *Continuous soil profile and identification*
  - *Not suitable for soil having boulders or core stones or hard driving expected*

Piezocone (CPTU)

Advanced static cone penetration test with facility to measure pore water pressure during insertion of the cone. Data are captured electronically on computer.

Allow dissipation test to be carried out in the subsoil to determine the horizontal coefficient of consolidation, C_h which is important for vertical drains design.



Notes :

(1) All dimensions are in millimetres.
(2) Details shown follow the ISSMFE (1977).
(3) The friction sleeve cone extends in two increments to reach the position shown in (d). The mantle is first extended 35 mm, then the mantle and friction sleeve together are extended another 35 mm.

Mechanical Cone Penetrometers

PLANNING OF GROUND INVESTIGATION

In most projects, ground investigation should be carried out in two stages.
In limestone formation, another stage is required i.e. proof drilling to detect and treat cavities and slump zones.

Stage 1 – Preliminary

- General subsoil profile
  - *Estimate earthwork and rock excavation*
  - *Typical soft areas, cut or fill*
- Preliminary or confirmation of layout and formation levels
- For conceptual designs and preliminary cost estimates

Stage 2 – Detailed Investigation

Optimum building layout selected or confirmed, detailed ground investigation can be planned for the critical areas of concern.

- Refine subsoil profile
- Soil parameters for detailed designs of foundations, platforms, slopes and excavations
- Soft soil fill area
- Major cut and slope
- Structures
  - *retaining wall*
  - *loading areas especially large column load area*

Additional ground investigation
- Permeability
- Pressuremeter
- Piezometer
- Piezocone
- Plate bearing test

Selection of Ground Investigation Methods

- **Boreholes**
  - *all soils*

- **Piezocone**
  - *sedimentary material or alluvial deposits without core stones*
  - *need of strength and consolidation characteristic of soils*
  - *rapid continuous logging of soil profile*

- **Vane shear test in boreholes and penetration vane tests**
  - *on cohesive soil*
  - *obtain in-situ strength for bearing capacity prediction*

- **Slope and cut area**
  - *use boreholes*
  - *SPT and Mazier samples for triaxial tests to obtain effective strength parameters like C’ and ƒ‘*
  - *Install piezometers to measure ground water level*

- **Fill area/ soft ground**
  - *use boreholes and piezocones*
  - *vane shear tests for soft cohesive soil and Mackintosh probe*
  - *Undisturbed soil sampling using thin wall or piston sampler for laboratory strength and consolidation tests*

Ground Investigation Over Water

- Stable working platform is very important particularly for piezocone and collecting undisturbed samples in boreholes
  - Staging (scaffold stagings)
  - Barge or ship with proper anchors
  - Jack-up platform (water depth $\leq$ 15m)

Extent of Ground Investigation

It depends on:

- available information
- geological formation and features
- variability of subsoil and ground water
- proposed structures and platforms
- adjacent property

Preliminary Ground Investigation

- **Number/ Spacing (Minimum)**
  - *Boreholes in a fill area of a formation*
  - *Boreholes in a line for one of a typical X-Section of similar topography (large area; a few lines are needed)*

- o **Depth**

  Fill Area

  - *Compressible (SPT N-value $\simeq$ 30)*

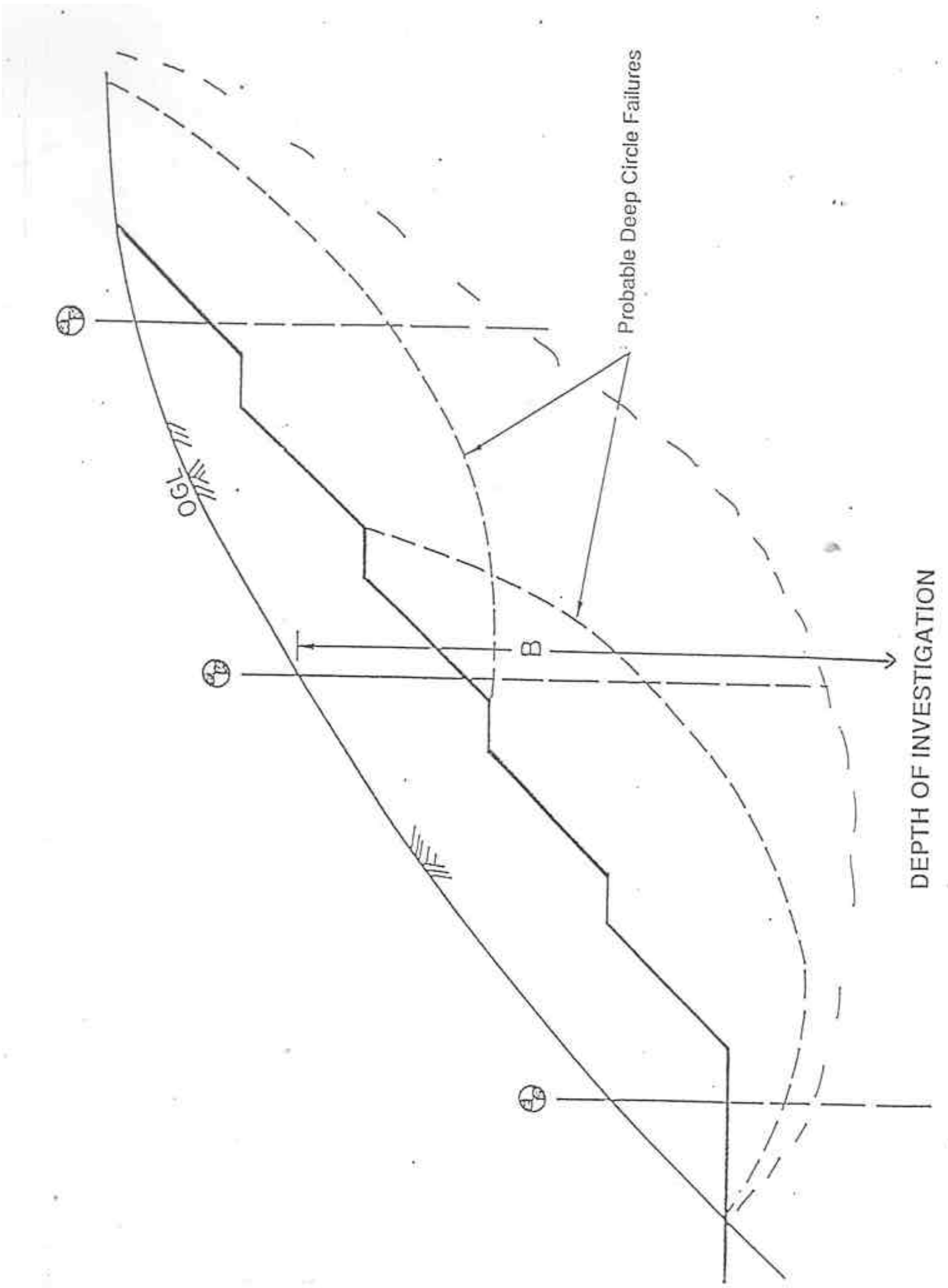
- o **Cut Area**

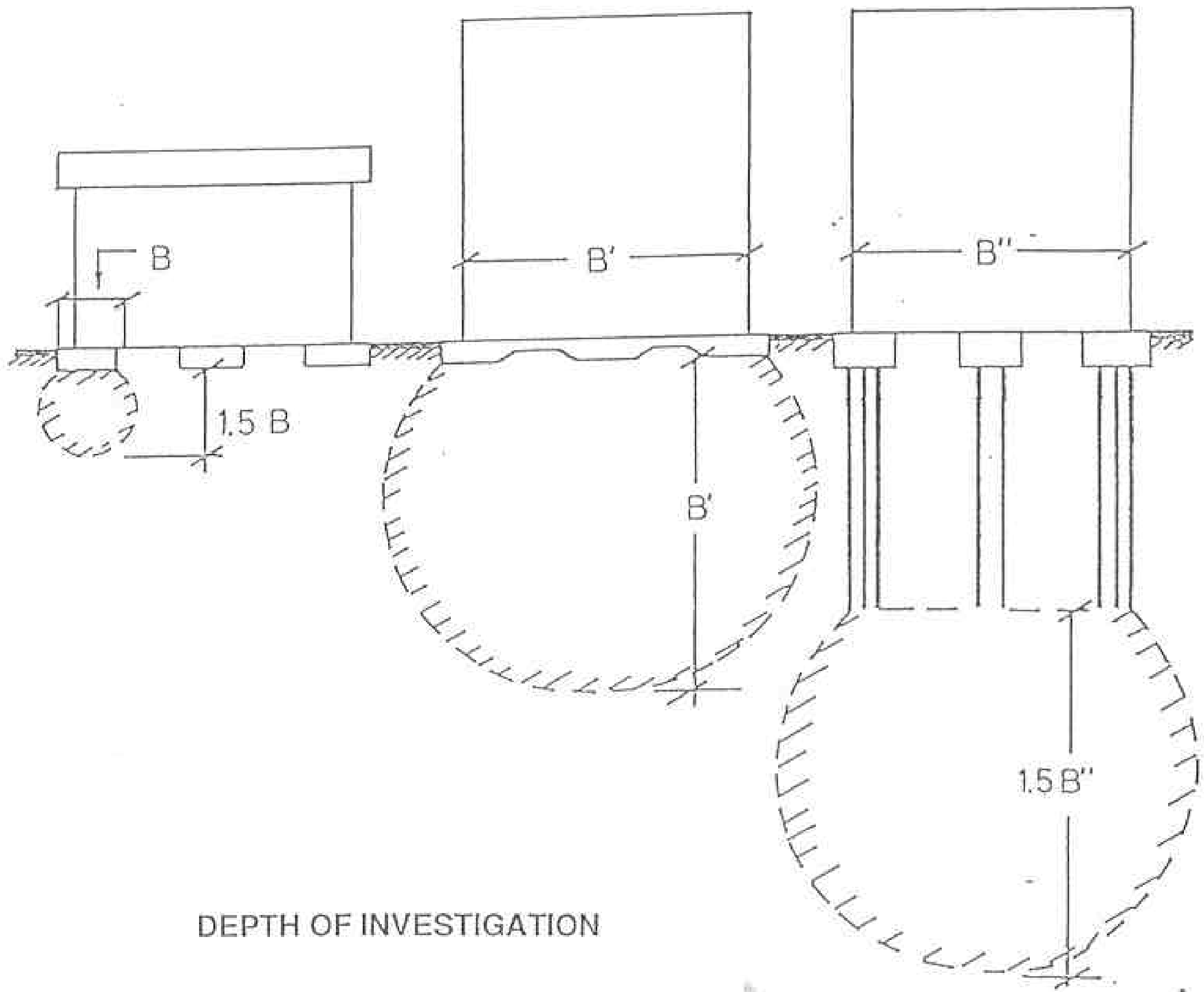
  - *Depth of potential slips*

- o **Structures**

  - *Up to depth of soils where the pressure induced by structure has little influence.*

- o **Geophysical survey for large area and to determine bedrock profile and characteristics**





DEPTH OF INVESTIGATION

Detailed Ground Investigation

- **Spacing**
  - No hard and fast rules generally 10m to 30m for structures. The spacing can be increased if geophysical survey is used to interpolate or identify problem areas.
  - Intensified ground investigation for problem areas and structures for safe and economical designs
  - Bridges
    - Generally one at every pier and abutment

- **Depth of Rock Coring**

Rock type	Minimum core length
a. Igneous rock	- 3m 6m for areas with expected boulders
b. Sedimentary other than limestone	3m – 6m
c. Limestone with no cavity	10m
d. Limestone with cavities	10m cavities free

Field Test and Sampling

- SPT generally at 1.5m interval or larger interval depending on undisturbed sampling schedule to depth up to 30m. The interval can be increased at greater depth. Undisturbed samples should be taken between SPT and staggered between boreholes

- Vane shear tests
  - *Top 10m at 1m intervals*
  - *> 10m at 1m – 2m intervals. Undisturbed samples should be taken between vane shear tests and staggered between boreholes*

Laboratory Test and Sampling

a) Classification
  - Sieve Analysis
  - Atterberg Limits
  - Moisture Content
  - Unit Weight
  - Specific Gravity

b) Compressibility
  - Consolidation
  - Swelling

c) Shear Strength

Total

- Laboratory Vane
- UCT
- UU
- Shear Box

Effective

- CIU
- CID

d) Compaction

e) Chemical

- SO_4
- Cl
- Ph
- Resistivity
- Redox Potential

SSP GEOTECHNICS SDN BHD
(Geotechnical Consultants)

LABORATORY SOIL TEST SCHEDULE

JOB NO : .... DATE : .... DATE RECEIVED : .... REQUESTED BY : ....

PROJECT : .... DATE REQUIRED : .... LOCATION : ....

PRIORITY : ....

SAMPLING LOCATION	SAMPLE NO.	DEPTH m	M/C %	A.L.	B.D. Mg/m3	S.G. gm/c.c	VOID RATIO	SIEVE ANALYSIS		CONSOLIDATION			TRIAXIAL		UCT	CHEMICAL ANALYSIS			
								Mech.	Hydro.	Std.	Rapid	S.S.	CIU	UU		ORGANIC CONTENT	pH	SULPHATE CONTENT	CHLORIDE CONTENT
TOTAL	Requested																		
	Performed																		

NOTE :

CIU
- Isotropicaly Consolidated undrained test with pore pressure measurements
- Use 70mm diameter sample (i.e. untrimmed Mazier sample)
- Sample should not have side filter during consolidation
- Shearing strain should be calculated using C values calculated during consolidation stage
- Multi-stage testing not allowed

UU
- Unconsolidated undrained test (at total overburden pressure of the sample)

UCT
- Unconfined compression test (untrimmed sample)

Form/LSTF

SUMMARY ON THE COMMON TYPES OF GROUND INVESTIGATION, FIELD TESTS, SAMPLING & LABORATORY TESTS

Description	Types of Ground Investigation						Field Test					Laboratory Test							
	JP	HA	TP	BH	PZ	GS	SPT	PM	PLT	VS	PW	C	M/C	γ	Con	UU	UCT	CIU	Chem
1) Soft ground treatment	m	m	m	y	y	m	-	-	-	y	m	y	y	y	y	y	y	m	m
2) Shallow foundation																			
cohesive soil	y	m	m	y	-	-	y	m	y	m	-	y	y	y	y	y	y	m	m
non cohesive soil	y	m	m	y	m	-	y	-	y	-	-	y	y	y	-	-	-	-	m
3) Pile Foundation																			
Fill ground	m	m	m	y	m	m	y	m	-	m	-	y	y	y	y	y	y	-	m
Cut ground	-	-	m	y	-	m	y	-	-	-	-	y	y	y	-	-	-	-	m
4) Slope																			
Cut	-	-	m	y	-	y	y	-	-	-	y	y	y	y	-	y	y	y	-
Fill	m	m	m	y	m	m	y	-	-	y	m	y	y	y	y	y	y	y	m

Legend:

JP	: JKR Probe	SPT	: Standard Penetration Test	C	: Classification
HA	: Hand Auger	PM	: Pressuremeter	M/C	: Moisture Content
TP	: Trial Pit	PLT	: Plated Bearing Test	γ	: Unit Weight
BH	: Borehole	VS	: Vane Shear Test	Con	: Consolidation
PZ	: Piezocone	K	: Permeability Test	UU	: Unconsolidated Undrained
GS	: Geophysical Survey	Y	: Yes should be done	UCT	: Unconfined Compression
		M	: May be added	CIU	: Triaxial with Pore Water Pressure
		-	: Not relevant/necessary	Chem	: Chemical Test

SPECIAL ATTENTION

Triaxial Compression Test

- No/ Minimum Trimming
- No Side Drains
- No Multistage

SITE SUPERVISION

- Full Time Engineering Geologists, Engineers or Experienced Technicians
- Briefing (Supervision Checklist)
- Communication
- Checklist

Interpretation of Field and Laboratory Tests Field

- JKR/ Mackintosh
- SPT (Standard Penetration Test)
- Field Vane Shear

Laboratory Tests

- Unconfined Compression
- Consolidation
- Triaxial Test (UU, CU & CD with pore pressure measurement)

科兔

料免

JKR Probes

- Primitive tool
- Limited use
    - Shallow bedrock profile
    - Weak zone at shallow depth
    - Shallow foundation
        - No recent fill and future settlement,
        - Structure of low risk
        - If in doubt – use borehole

Interpretation

JKR Chart

Correlation with SPT ‘N’

Mackintosh Sounding Record Sheet

Project : NORTH-SOUTH EXPRESSWAY SIMPANG PULAI TO GOPENG SI/8A-2
Supervisor : DANIEL   Date: 7-9-1989

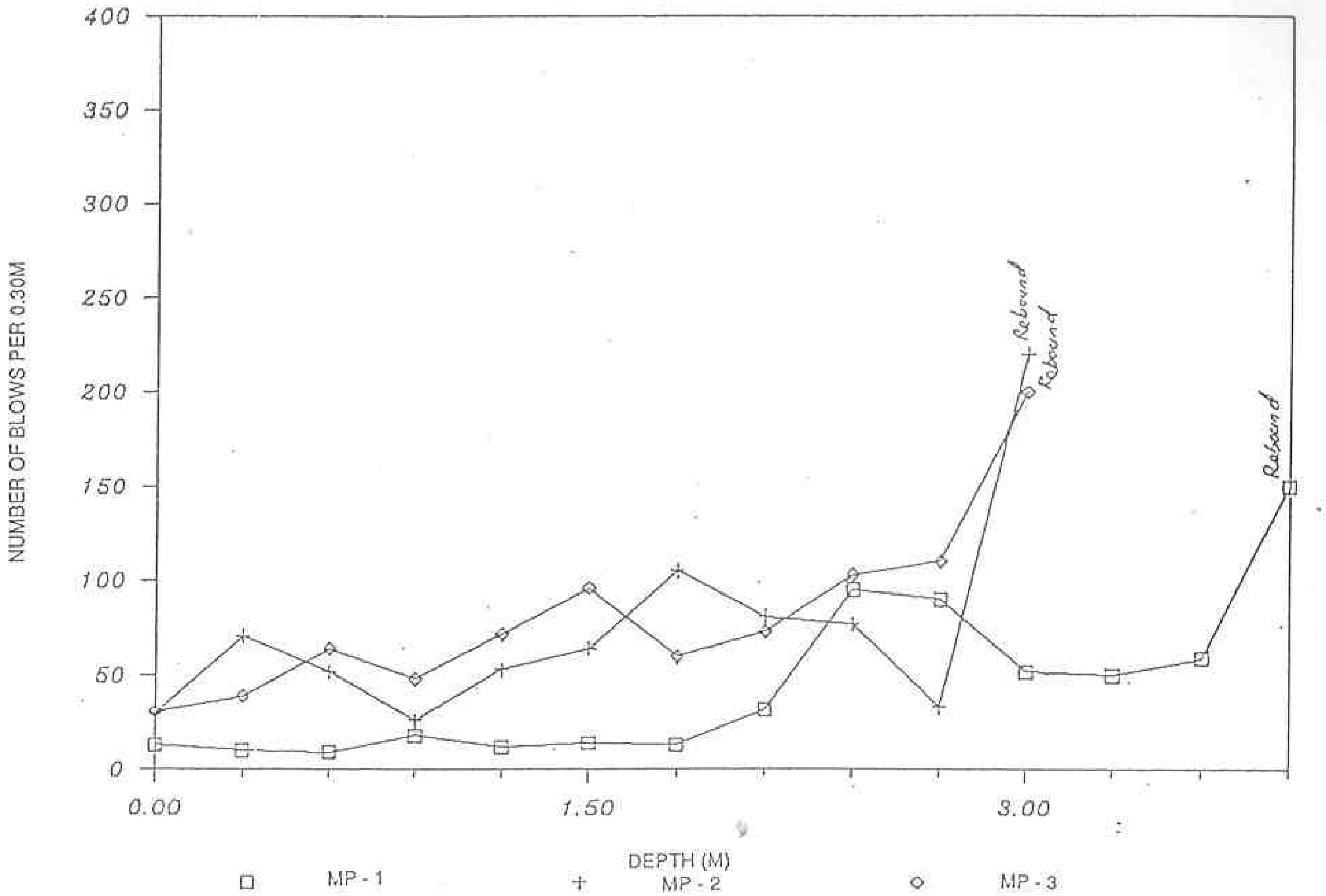
Position No	MP - 1	MP - 2	MP - 3	MP - 4	MP - 5
Chainage	22 340M	22 320M	22 322M	22 172M	21 128M
R. Level	45.489M	46.529M	47.779M	63.618M	64.823M
Depth (M)	NUMBER OF BLOWS PER 0.30 METRE				
0.0 - 0.3	13	30	31	7	8
0.3 - 0.6	10	71	39	19	16
0.6 - 0.9	9	52	64	15	21
0.9 - 1.2	18	26	48	16	26
1.2 - 1.5	12	*53	*72	21	35
1.5 - 1.8	14	64	96	33	26
1.8 - 2.1	13	105	60	27	32
2.1 - 2.4	32	81	73	21	30
2.4 - 2.7	95*	77	103	28	35
2.7 - 3.0	90	33	110	19	25
3.0 - 3.3	52	220	200	20	20
3.3 - 3.6	50	Rebound	Rebound	71	29
3.6 - 3.9	59			147	25
3.9 - 4.2	150			114	28
4.2 - 4.5	Rebound			97	35
4.5 - 4.8				103	40
4.8 - 5.1				78	42
5.1 - 5.4				123	45
5.4 - 5.7				133	54
5.7 - 6.0				118	82
6.0 - 6.3				110	250
6.3 - 6.6				134	207
6.6 - 6.9				130	400
6.9 - 7.2				174	0.20m
7.2 - 7.5				121	
7.5 - 7.8				116	
8.7 - 8.1				198	
8.1 - 8.4				238	
8.4 - 8.7				140	
8.7 - 9.0				116	
9.0 - 9.3				121	
9.3 - 9.6				80	
9.6 - 9.9				65	
9.9 - 10.2				87	
10.2 - 10.5				80	
10.5 - 10.8				100	
10.8 - 11.1				74	
11.1 - 11.4				106	
11.4 - 11.7				110	
11.7 - 12.0				121	
12.0 - 12.3				400	
12.3 - 12.6				0.20m	
12.6 - 12.9					
12.9 - 13.2					
13.2 - 13.5					
13.5 - 13.8					
13.8 - 14.1					
14.1 - 14.4					
14.4 - 14.7					
14.7 - 15.0					
REMARKS	WT=FULL	WT=FULL	WT=FULL	WT=NIL	WT=NIL

MP - 1: Depth of water = 2.40m; Platform " = 0.35m

MP - 2: Depth of water = 2.40m; Platform " = 0.40m

MP - 3: Depth of water = 1.15m; Platform " = 0.40m

MACKINTOSH PROBE GRAPHS



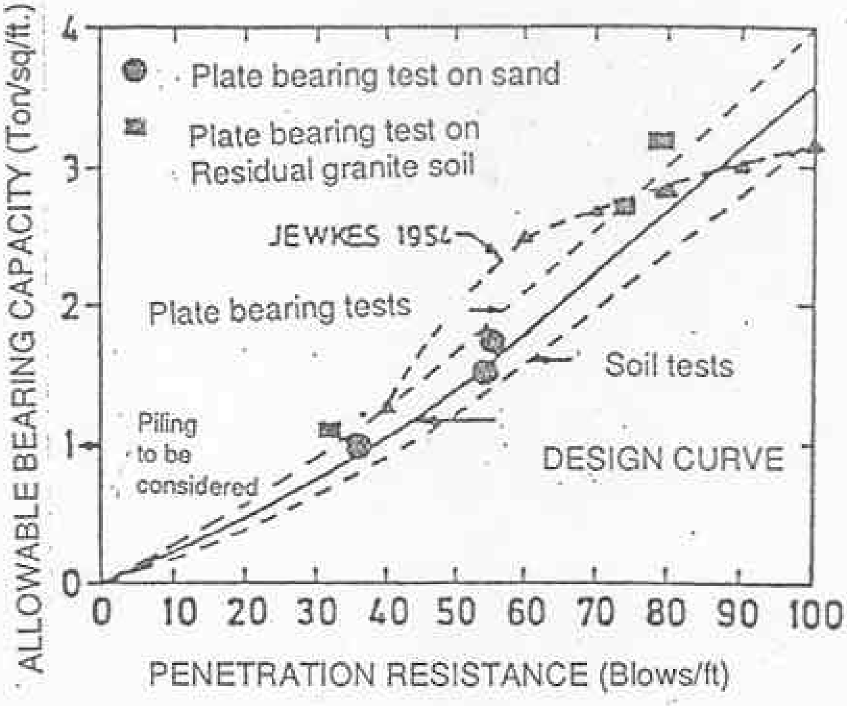


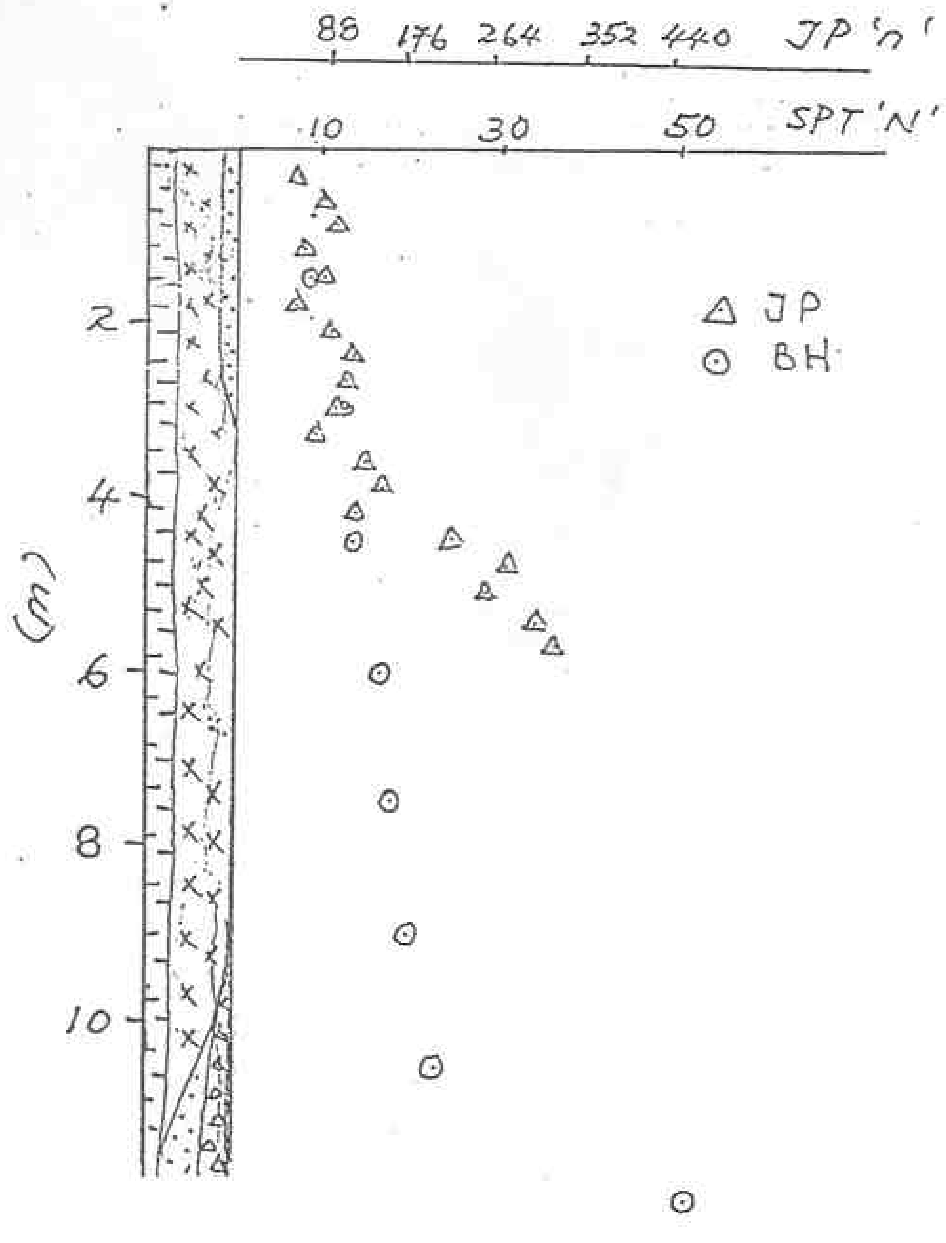
FIG. S2 ALLOWABLE BEARING CAPACITY V.S. J.K.R. DYNAMIC CONE PENETRATION RESISTANCE (AFTER OOI AND TING, 1975)

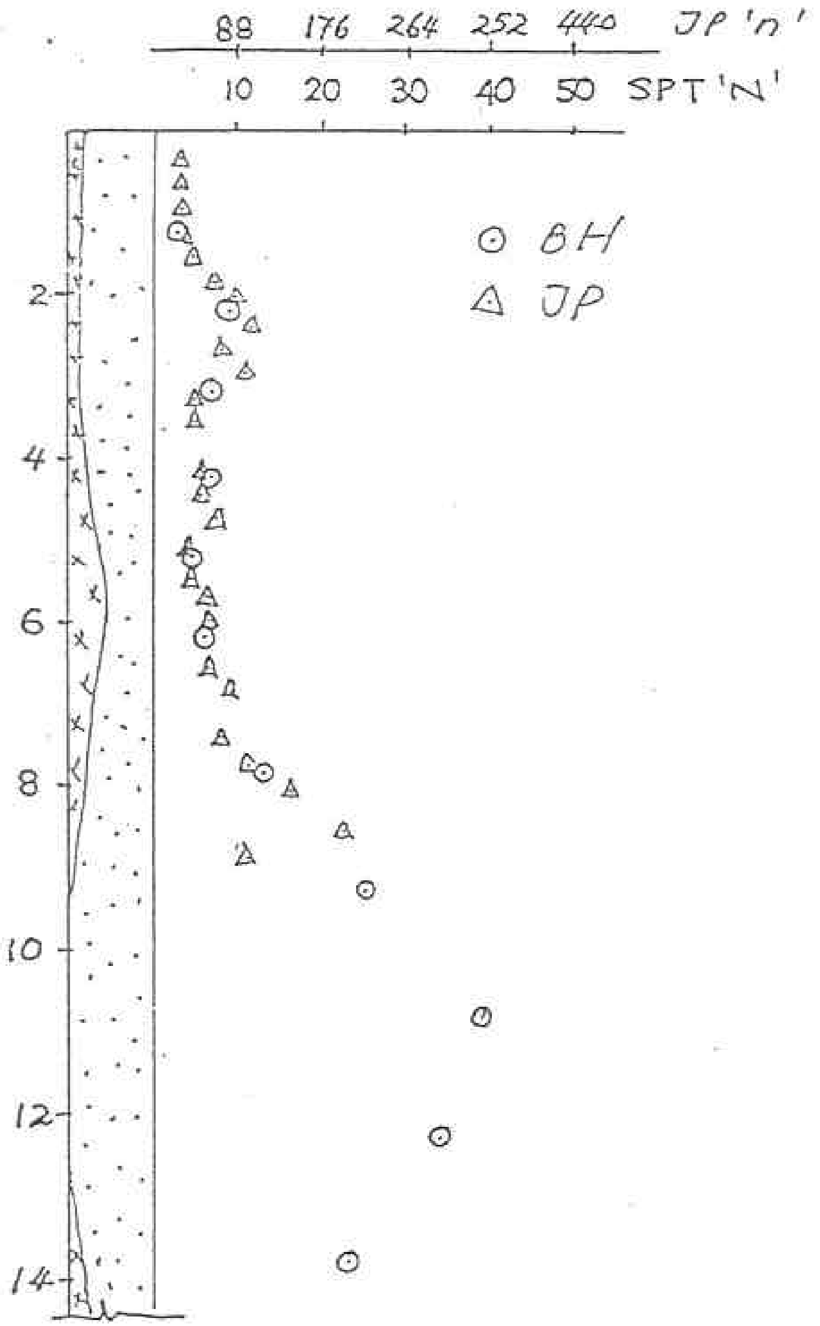
COMPARISON BETWEEN JKR PROBE AND SPT

Type of Penetrometer	Cone		Weight of amme (kg)	Height of fall (mm)	Energy per unit area Nm/m2
	Dia (mm)	Area (mm2)			
JKR probe	25	491	5	280	27970
SPT	50	1963	65	760	246736

Ratio of Energy of SPT to JKR Probe

$$\frac{246,736}{27970} = 8.8$$


88 176 264 352 440 JP 'n'
10 30 50 SPT 'N'
2
4
6
8
10
(m)
△ JP
⊙ BH


88 176 264 252 440 JP 'n'
10 20 30 40 50 SPT 'N'
2
4
6
8
10
12
14
BH
JP

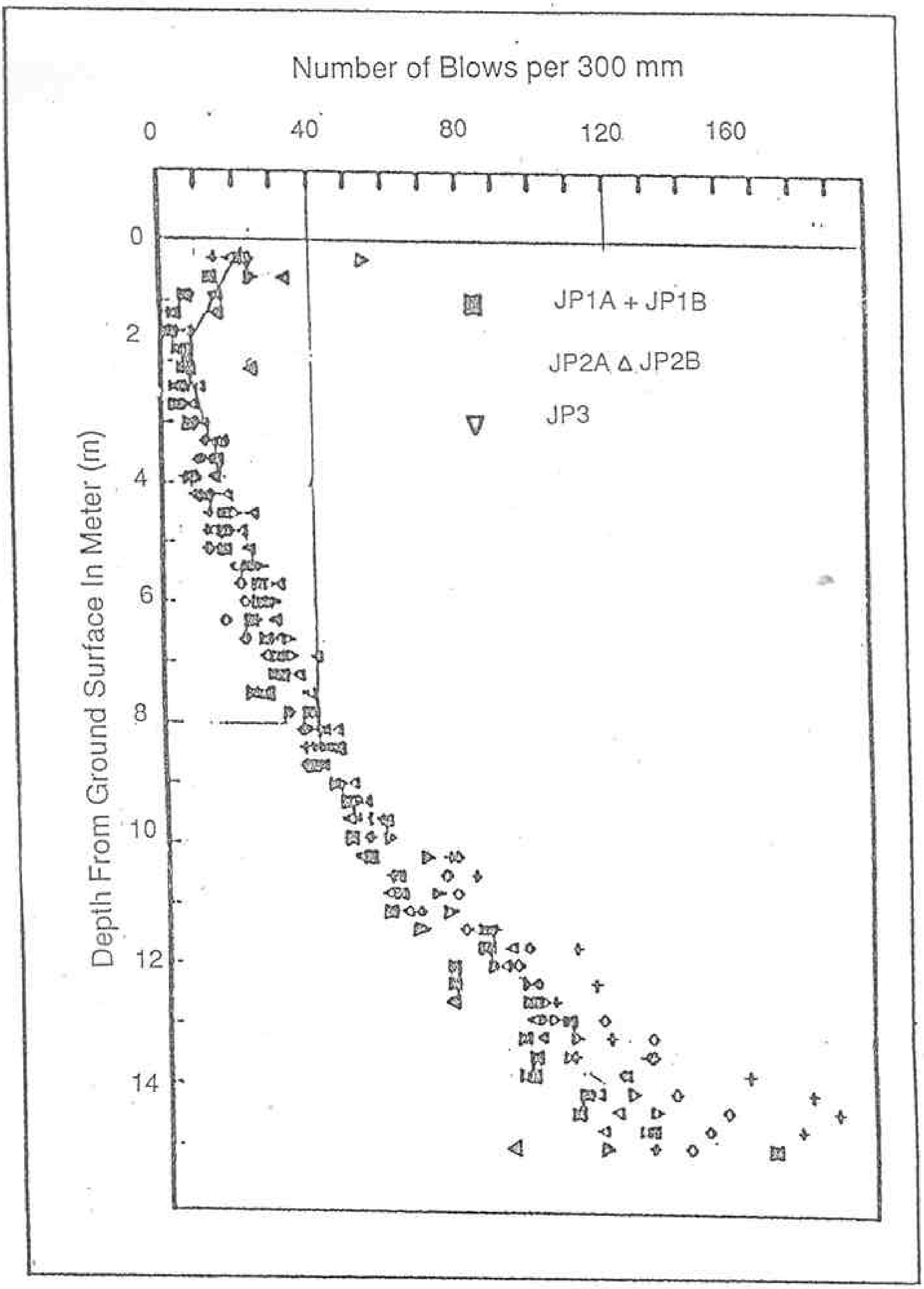


FIG. S3a JKR PROBE PROFILES

Standard Penetration Test (SPT)

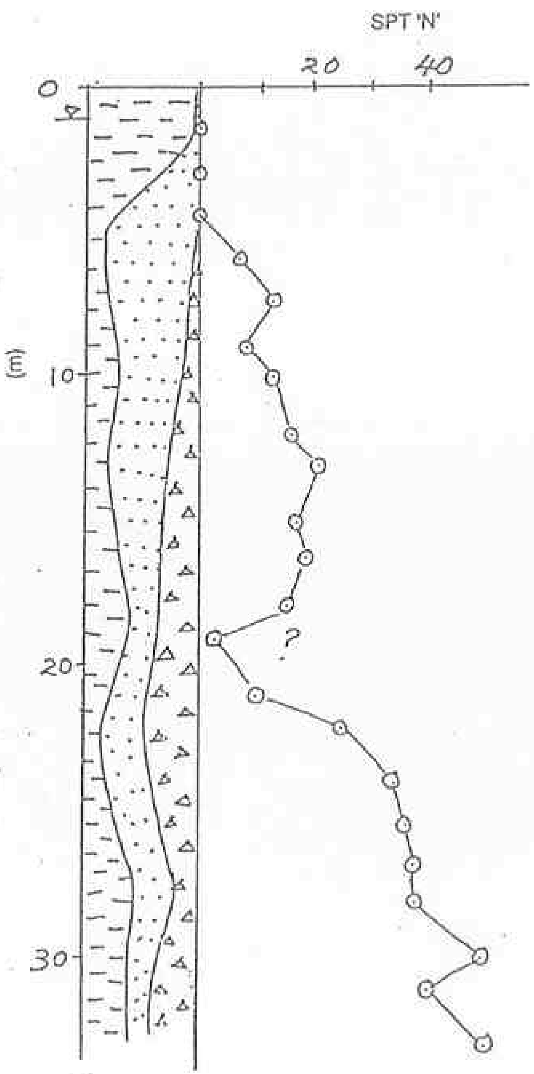
A popular test

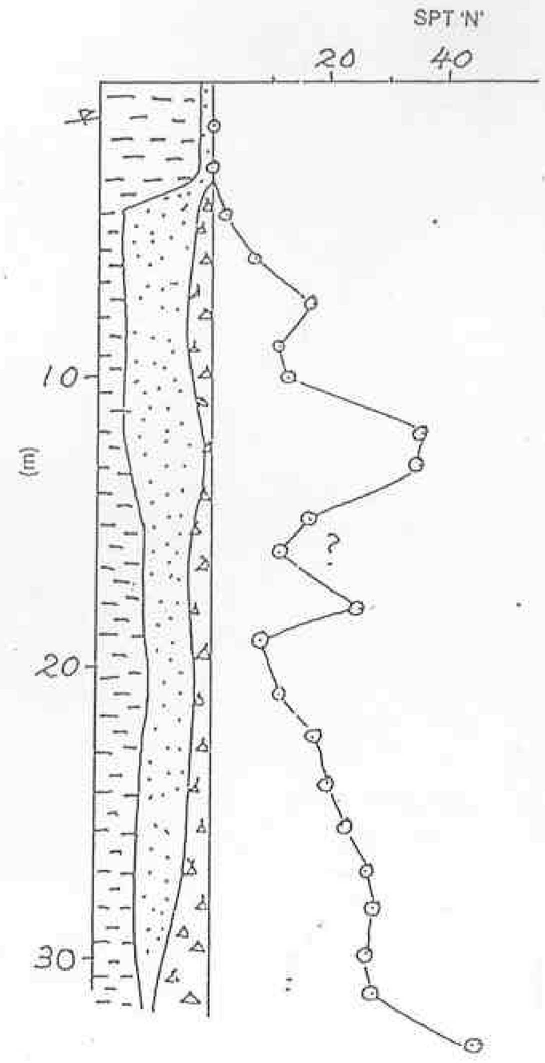
- useful for pile foundation designs

Common errors

Factors affecting SPT (N) values

✗ Inadequate cleaning of borehole	☒ N, sludge trapped in sampler
✗ casing driven bottom of borehole	⇧ N in sand ⇩ N in clay
✗ damage tip of sampling spoons	⇧ N
✗ loose joints on connecting rods	⇧ N
✗ not using guide rod	⇧ N, eccentric blows
✗ water level in borehole below ground water level	⇩ N esp sand at bottom of borehole, piping effect
✗ free fall not attainable	⇩ N, using >1 1/2 turns of rope


SPT 'N'
20
40
0
10
20
30
(m)
?


SPT 'N'
20
40
10
20
30
(m)
?

DEEP BORING LOG

PROJEK	Sekolah Menengah Vokasional Besut, Terengganu

Borehole No: DB/1	Reduced Level: 14.12 ft (m)	Type of Drill: Acker 5
Sheet No: 5 of: DB/1	Water Level: (m)	Date: 26.2.85

DEPTH (metre)	DESCRIPTION OF SOIL: COLOUR, CONSISTENCY, RELATIVE DENSITY GRAIN SIZE, TEXTURE ETC.	SAMPLE DEPTH (metre)	No.	Field Test 75 mm	75 mm	75 mm	75 mm	75 mm	75 mm	REMARKS
6	- ditto -	36.0m & 36.45m	D.22	1	2	2	2	3	4	N = 11 Rec = 30%
	END OF BORE									
	Water level.									
	0.5m — 24.2.85 Casing depth 21.0m.									
	0.45m — 27.2.85 Without Casing.									
	0.45m — 28.2.85 — Same —									

NOTES

N - Standard Penetration Test (S.P.T)
U/2 - 50 Ø undisturbed sample
PS - 50 Ø undisturbed piston sample
D - Disturbed sample
VS - Vane Shear & Test
W - Water sample
C - Core Sample
RQD - Rock Quality Designation

R/r - Recovery Ratio (%)
V - Water Level (W.L.) (Water level observations during boring should be given on the last sheet of log)

COHESIVE SOIL (N)
0-2 : VERY SOFT
2-4 : SOFT
4-8 : MEDIUM STIFF
8-15 : STIFF
15-30 : VERY STIFF
30 : HARD

NON COHESIVE SOIL (N)
0-4 : VERY LOOSE
4-10 : LOOSE
10-30 : MEDIUM DENSE
30-50 : DENSE
50 : VERY DENSE

V. Lsiew
(Penyelia)

(Jurutera P/T)

DEEP BORING LOG

PROJEK	Sekolah Menengah Vokasional Besut, Trengganu.		
Borehole No: DB/1	Reduced Level: 14.12 ft (m)	Type of Drill: Acker 1	
Sheet No: 1 of: DB/1	Water Level: 0.45m. (m)	Date: 19.2.85	

DEPTH (metre)	DESCRIPTION OF SOIL: COLOUR, CONSISTENCY, RELATIVE DENSITY GRAIN SIZE, TEXTURE ETC.	SAMPLE DEPTH (metre)	SAMPLE No:	Field Test 75 mm	75 mm	75 mm	75 mm	75 mm	75 mm	REMARKS
0.0m	Dark grey graded medium to fine loose sand with organic matter.									
0.3m 0.8m	Black graded medium to fine compact sand with organic matter.									
	Light grey graded medium to fine loose SAND	1.5m to 1.95m	D.1	1	1	2	2	2	4	N= 10 R/r= 60%.
2.8M	Greenish grey graded medium to fine loose SAND	3.0m to 3.45m	D.2	1	2	2	2	2	2	N= 8 R/r= 70%
4.5m	Greenish grey graded medium to fine very loose SAND with little CLAY and seashells.	4.5m to 4.95m	D.3	1	1	0	1	0	1	N= 2 R/r= 70%.
6.0m	Greenish grey graded coarse to fine very loose silty clayey SAND with seashells and decayed wood	6.0m to 6.45m	D.4	0	1	0	1	0	1	N= 2 R/r= 100%
7.5m	Greenish grey very soft sandy silty CLAY with traces of seashells and decayed wood	7.5m to 7.95m	D.5	wt of hammer						N= 0 R/r= 100%
8.5M										

NOTES

N - Standard Penetration Test (S.P.T)
U/2 - 50 Ø undisturbed sample
PS - 50 Ø undisturbed piston sample
D - Disturbed sample
VS - Vane Shear & Test
W - Water sample
C - Core Sample
RQD - Rock Quality Designation

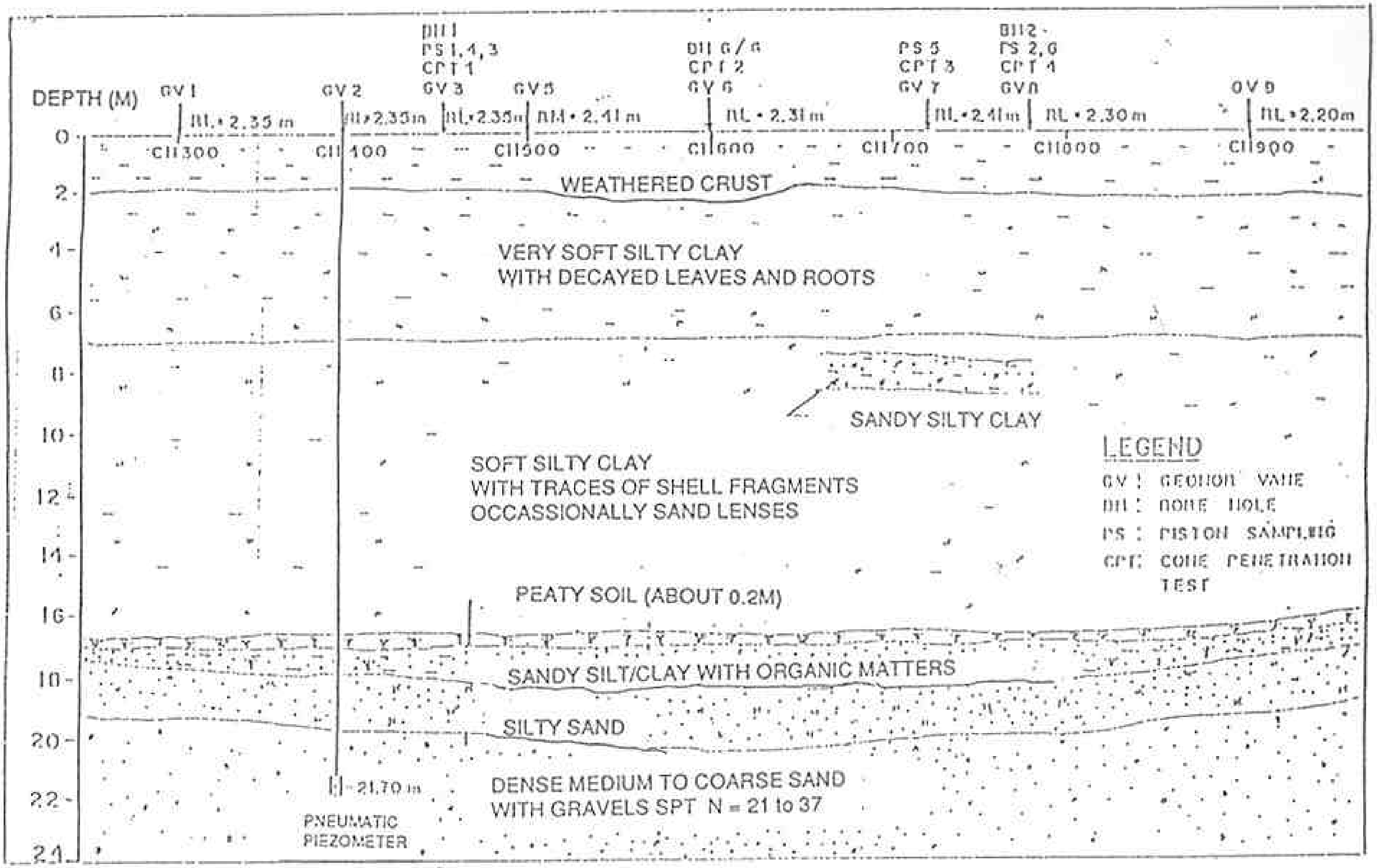
R/r - Recovery Ratio (%)
V - Water Level (W.L.) (Water level observations during boring should be given on the last sheet of log)

COHESIVE SOIL (N)
0-2 : VERY SOFT
2-4 : SOFT
4-8 : MEDIUM STIFF
8-15 : STIFF
15-30 : VERY STIFF
30 : HARD

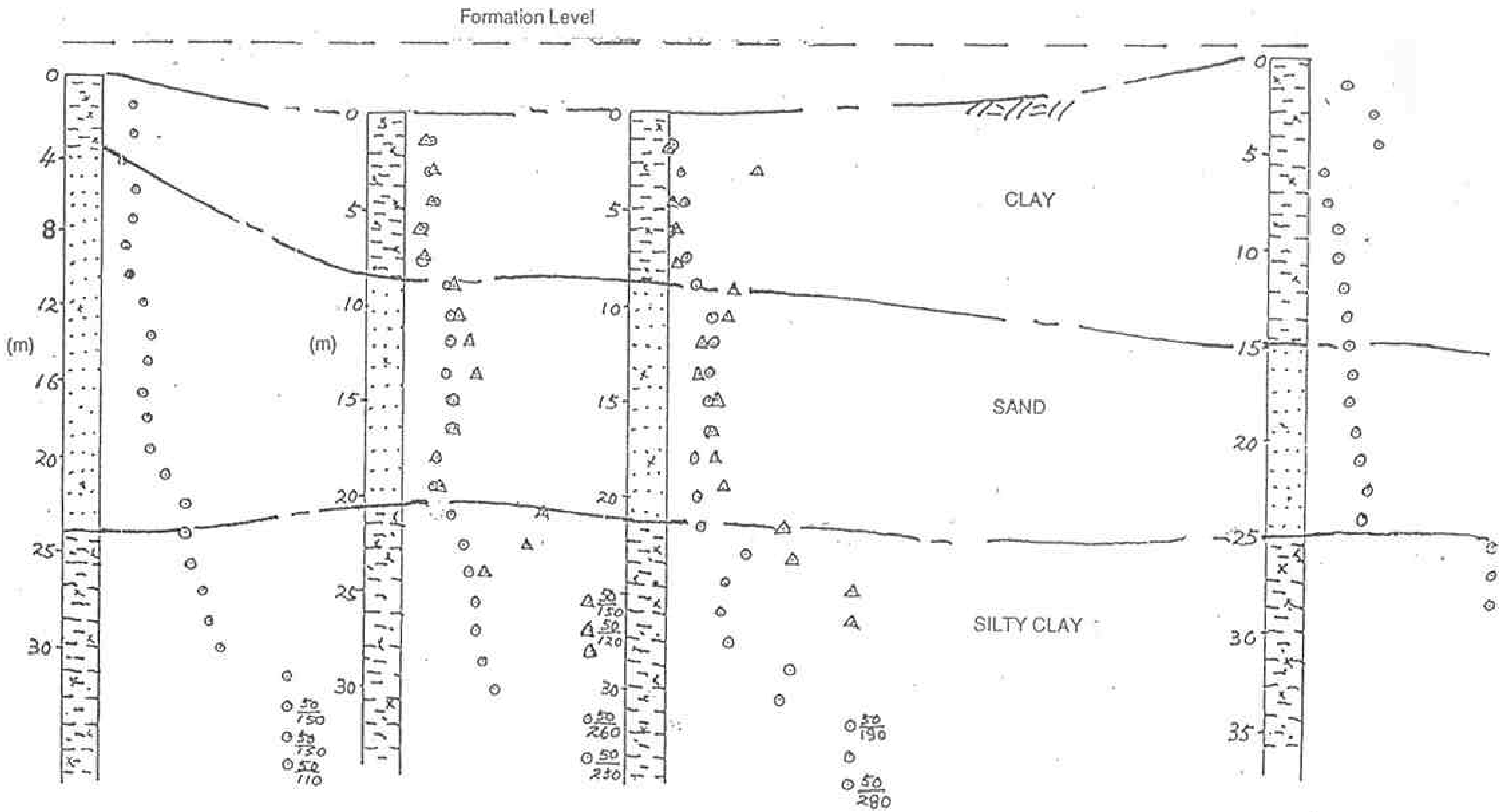
NON COHESIVE SOIL (N)
0-4 : VERY LOOSE
4-10 : LOOSE
10-30 : MEDIUM DENSE
30-50 : DENSE
50 : VERY DENSE

Y. Lisman
(Penyelia)

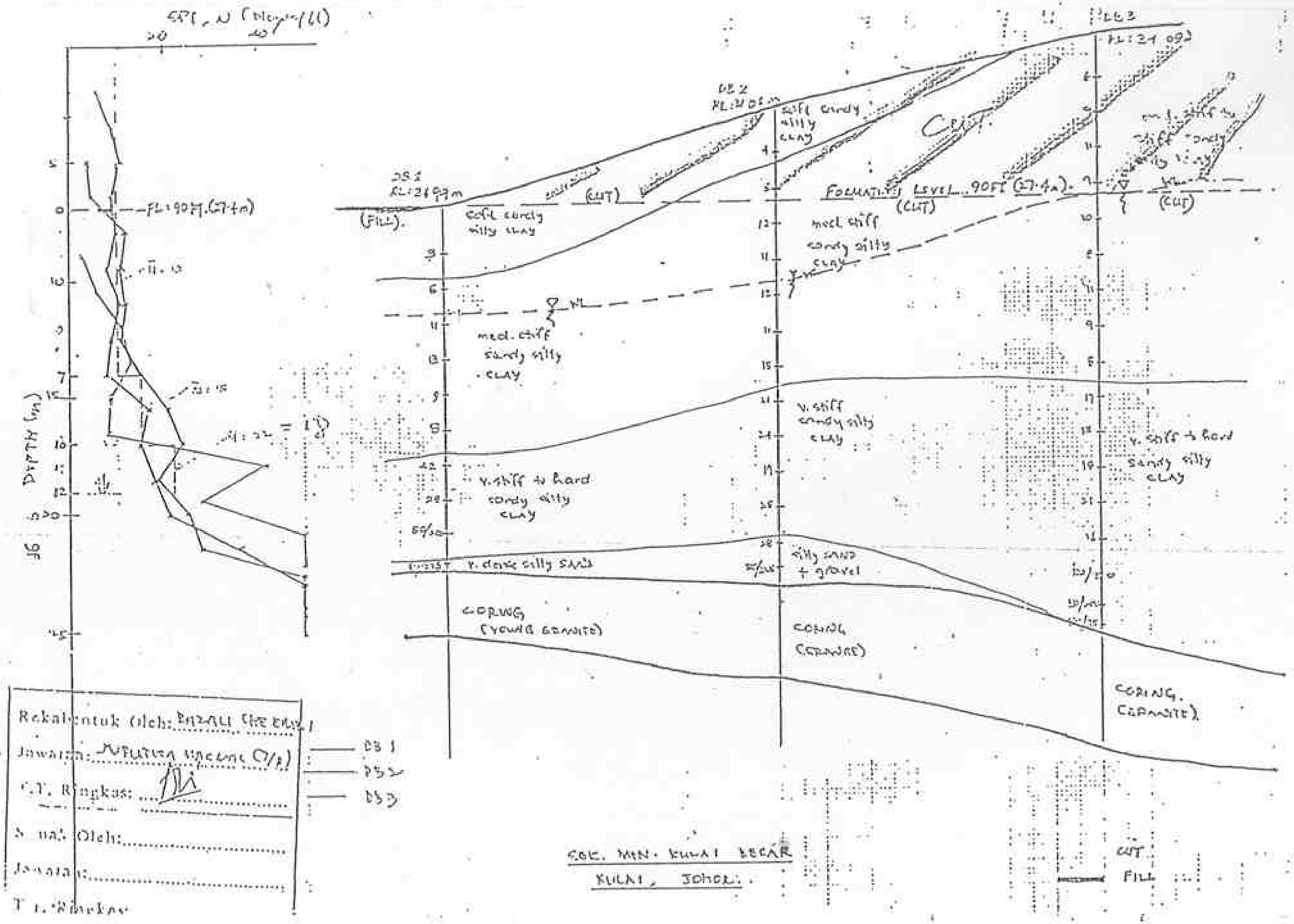
(Jurutera P/T)



SIMPLIFIED SOIL PROFILE (After Mha 1986)

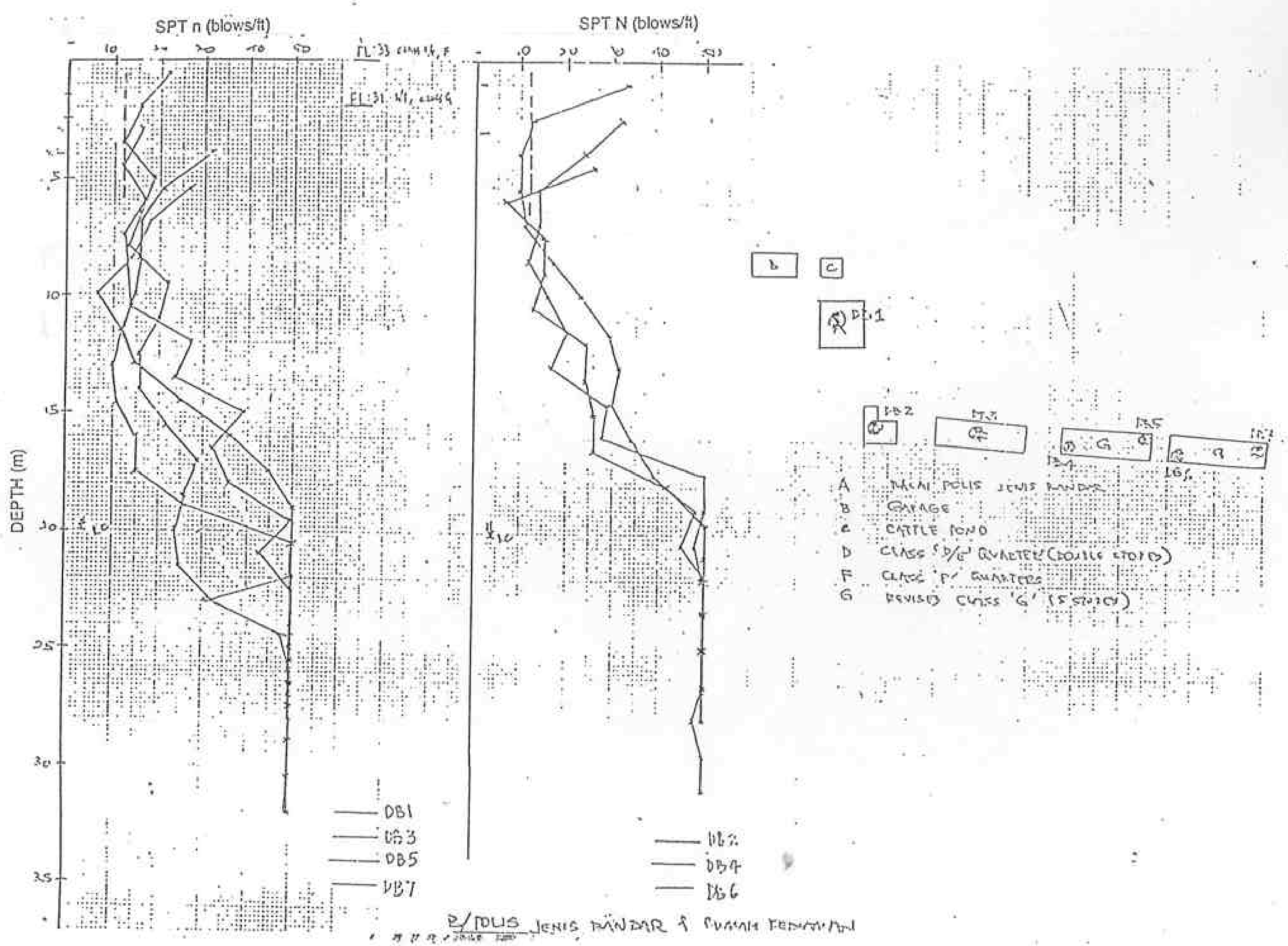


Soil Profile

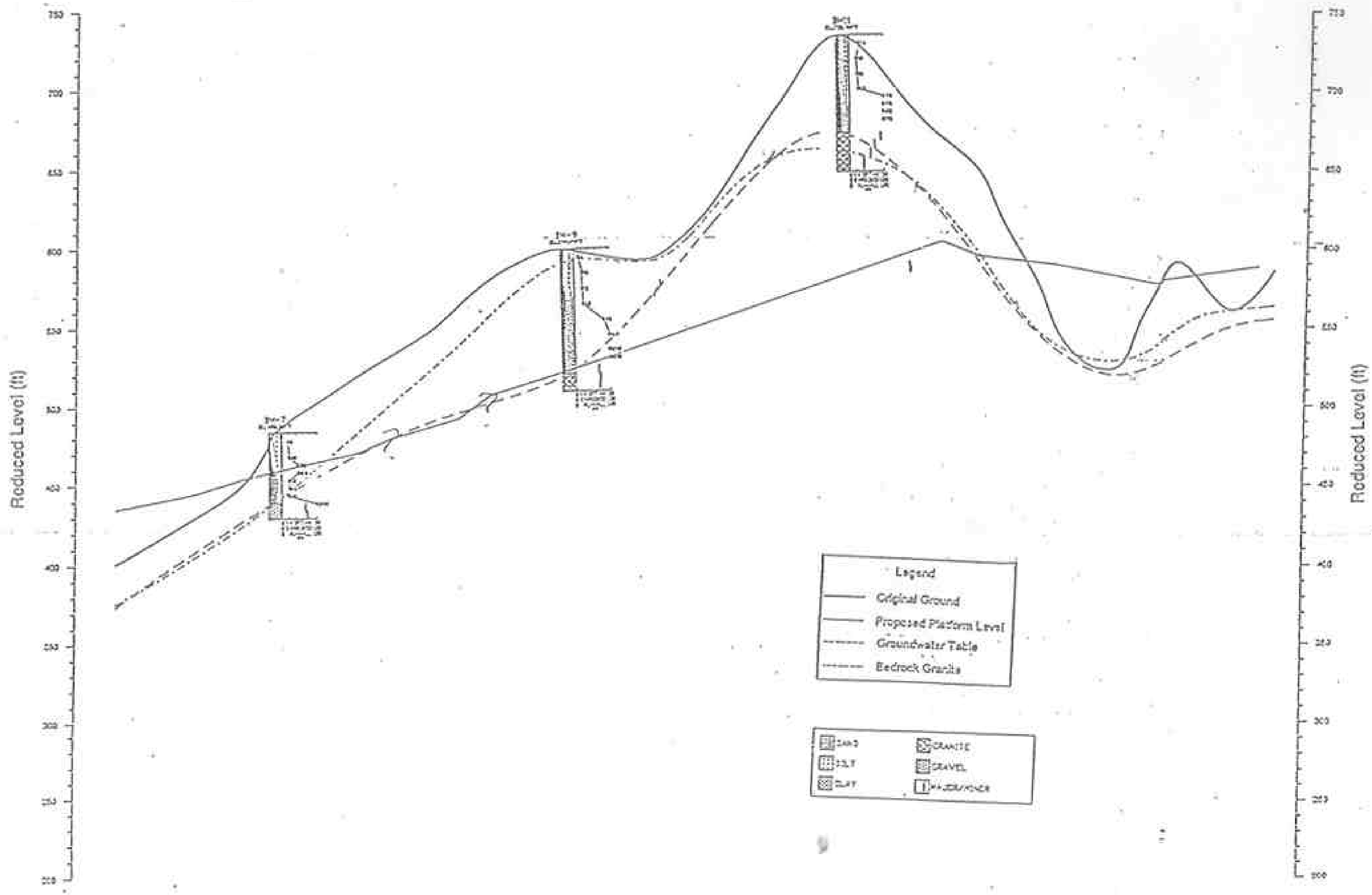


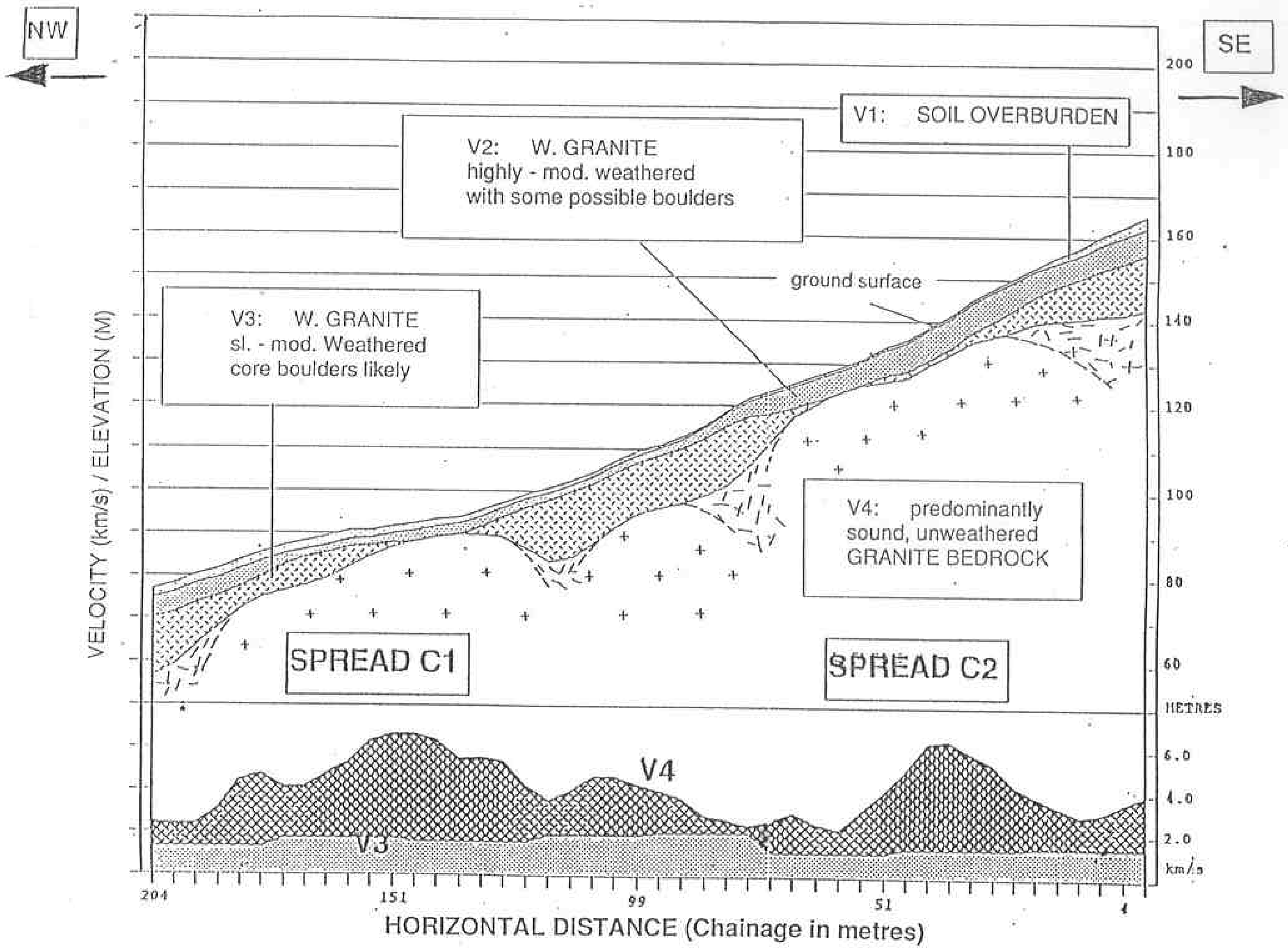
Rekabentuk Oleh: BAZALI CHE ENA?
Jawatan: JURUTERA KANAN (J/K)
T.T. Ringkas:
Semak Oleh: ....
Jawatan: ....
T.T. Ringkas

SEK. MEN. KULAI BESAR
KULAI, JOHOR.



SPT n (blows/ft)
SPT N (blows/ft)
DEPTH (m)
DB1
DB3
DB5
DB7
DB2
DB4
DB6
A
B
C
D
F
G
GARAGE
CATTLE POND
CLASS 'D/E' QUARTERS (DOUBLE STOREY)
CLASS 'F' QUARTERS
REVISED CLASS 'G' (5 STOREY)


Reduced Level (ft)
750
700
650
600
550
500
450
400
350
300
250
200
Reduced Level (ft)
Legend
Original Ground
Proposed Platform Level
Groundwater Table
Bedrock Granite
SAND
SILT
CLAY
GRANITE
GRAVEL

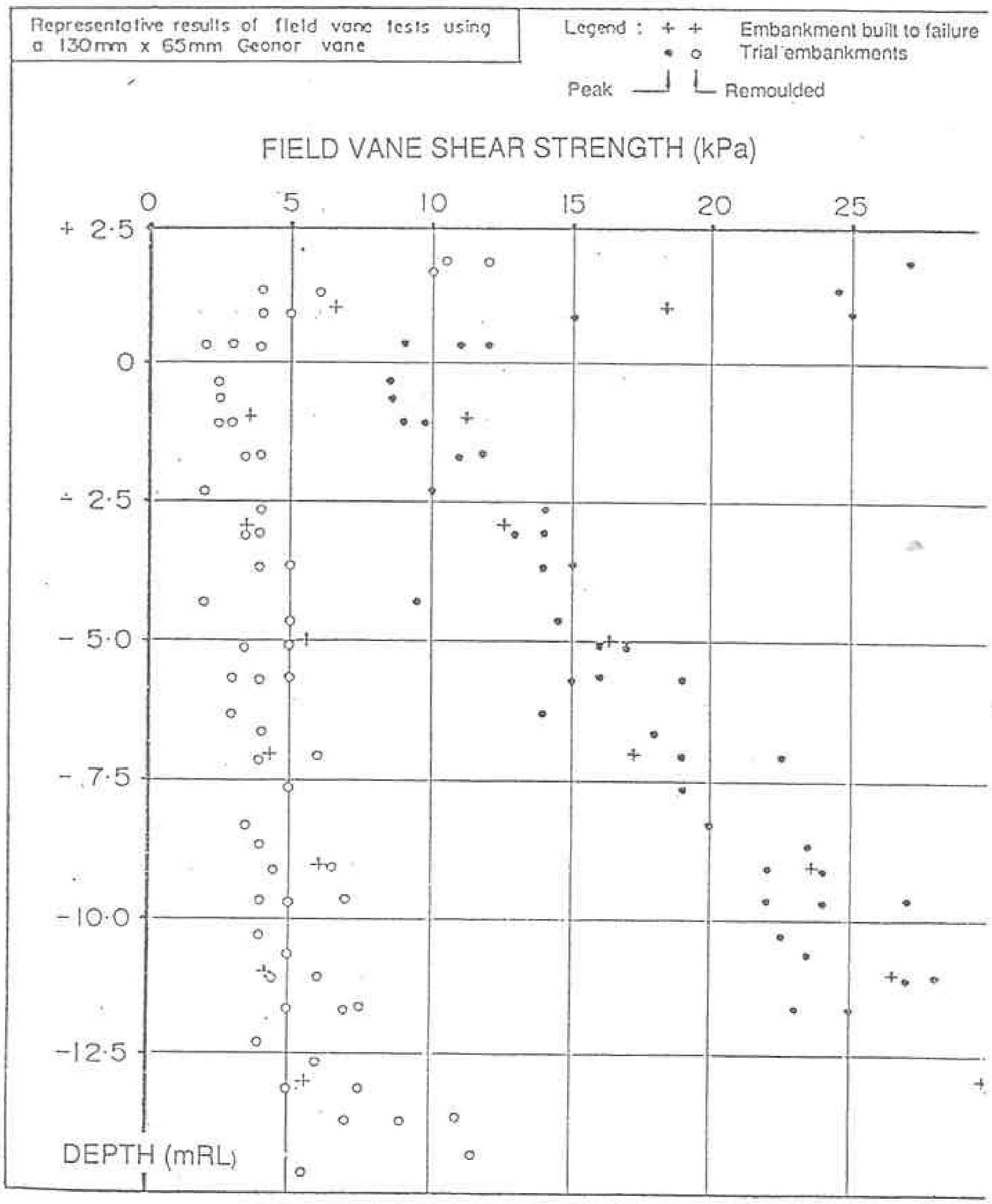

NW
SE
V1: SOIL OVERBURDEN
V2: W. GRANITE
highly - mod. weathered
with some possible boulders
V3: W. GRANITE
sl. - mod. Weathered
core boulders likely
V4: predominantly
sound, unweathered
GRANITE BEDROCK
ground surface
SPREAD C1
SPREAD C2
V4
V3
200
180
160
140
120
100
80
60
METRES
6.0
4.0
2.0
km/s
204
151
99
51
4
VELOCITY (km/s) / ELEVATION (M)
HORIZONTAL DISTANCE (Chainage in metres)

Vane Shear Test

1) Vane test in borehole
2) Geonor vane
3) Lab vane

Use

- To determine in-situ undrained shear strength (S_{uv}) of soft clayey soils



Most common errors

– Computation - spring factor
– clay with organic materials

Recognise errors

Summarise results with s_u from unconfined compression, UU and lab vane superimposed

Plot $\frac{s_{uv}}{P_o'}$ against PI

or s_{uv} against P_o' then find $\frac{s_{uv}}{P_o'}$

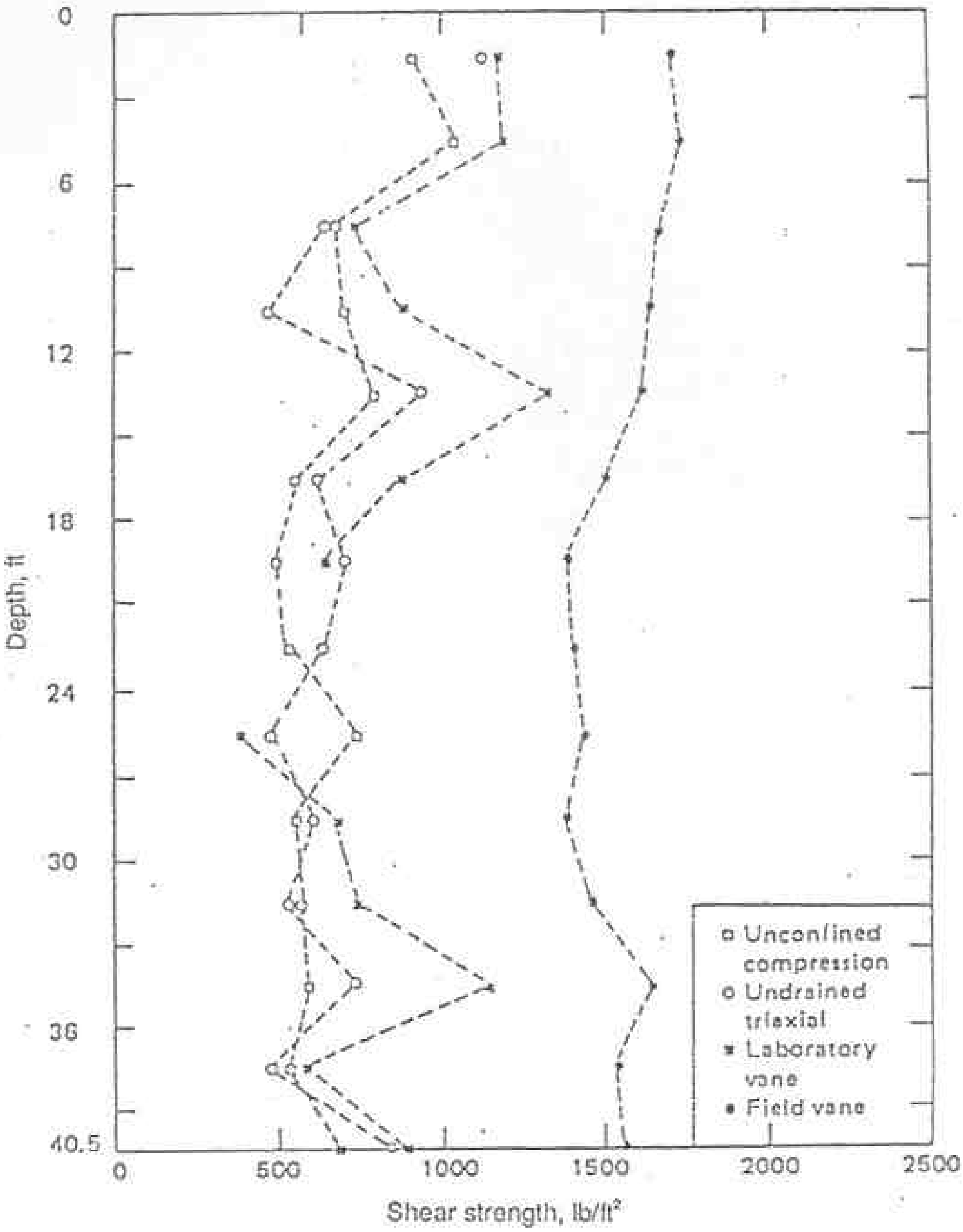
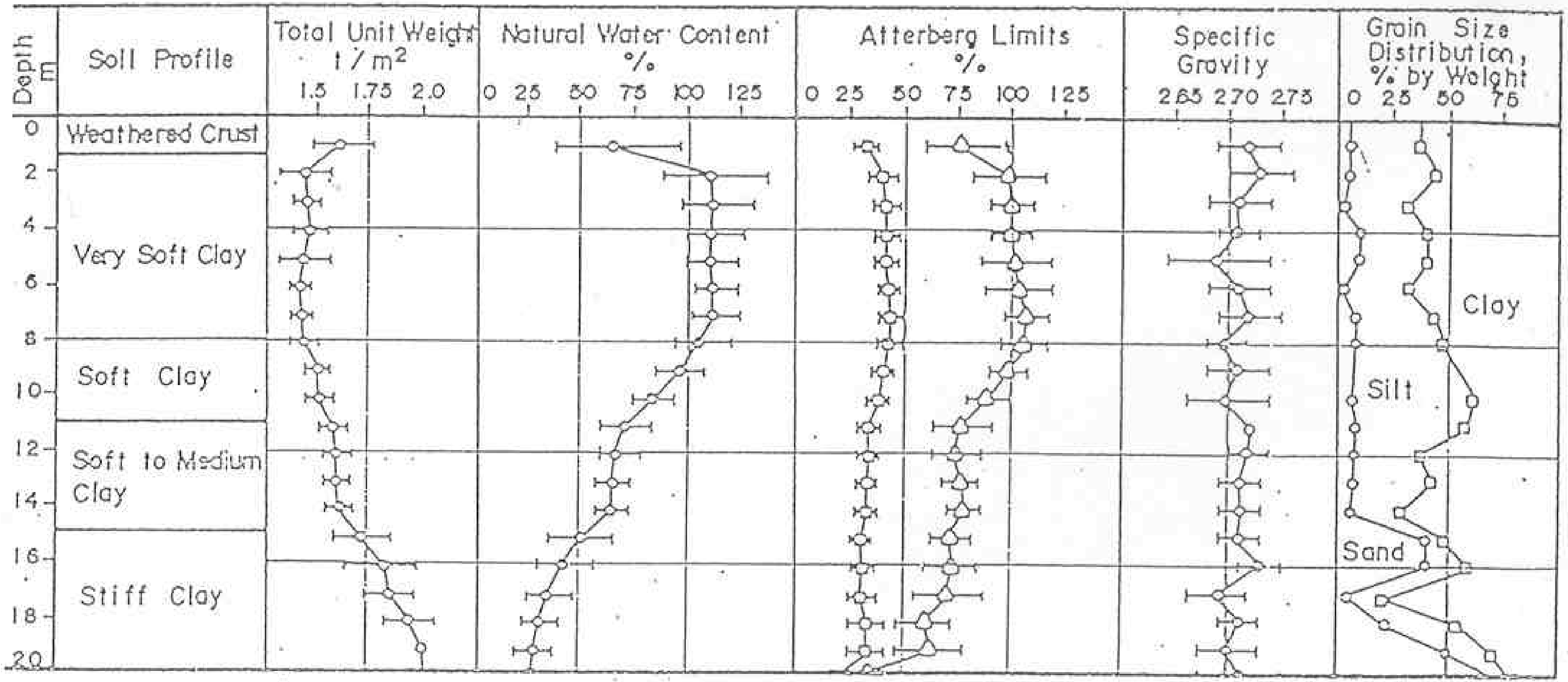
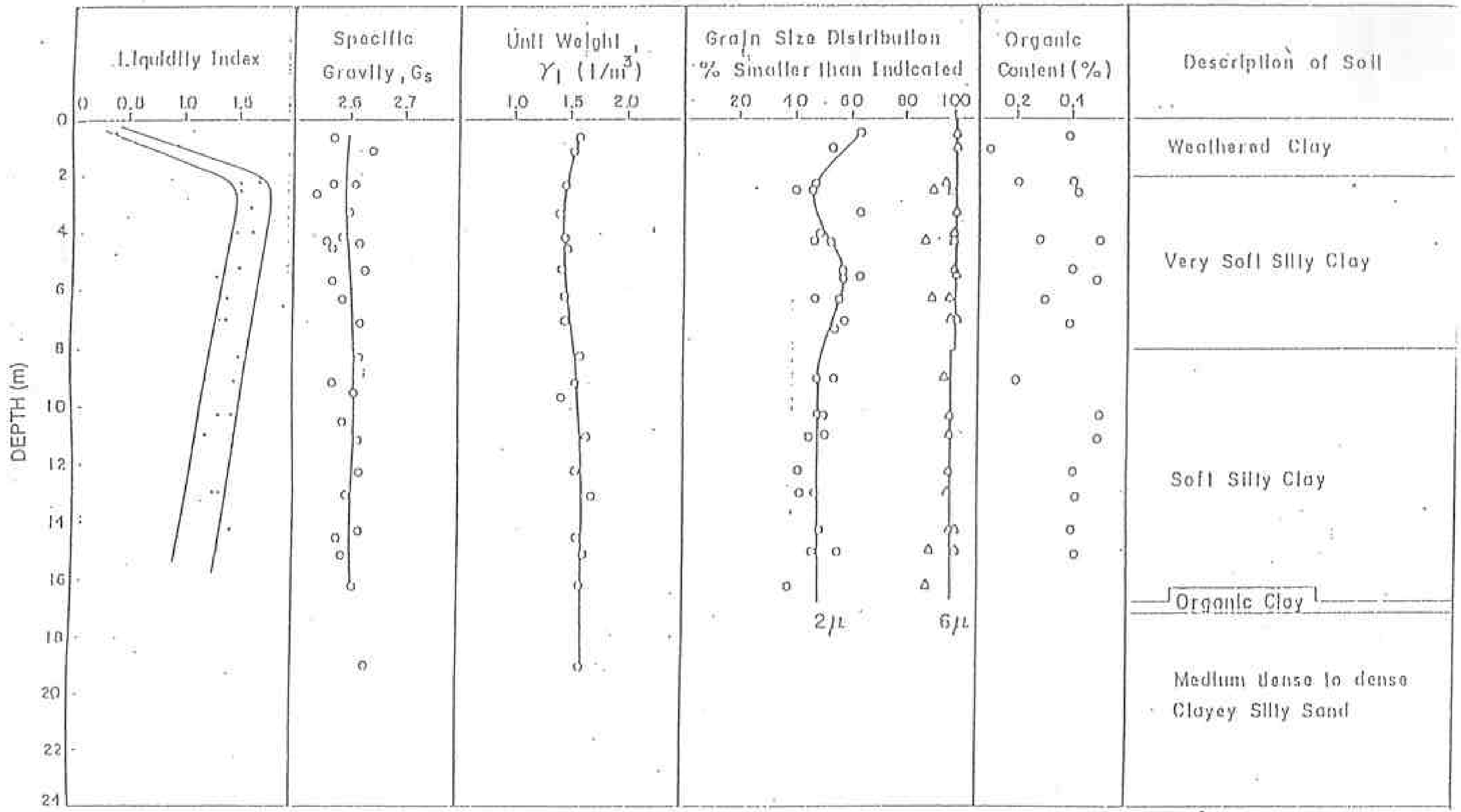


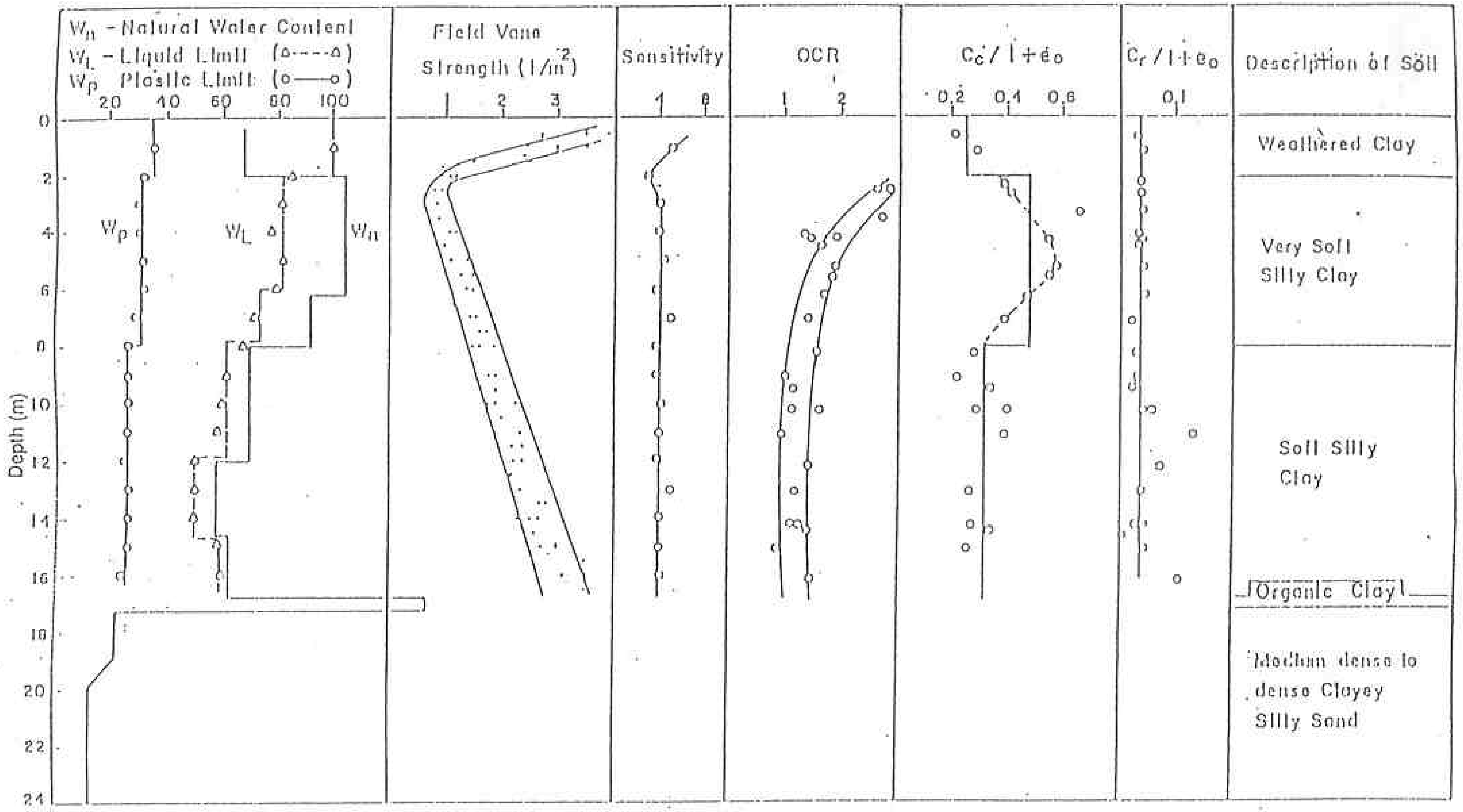
Fig. 7.60 Depth vs. Typical undrained shear strength by various test methods for Morgan City recent alluvium. (Note: 1ft = 0.3048m; 1 lb/ft^2 = 47.88 N/m^2.) *(Redrawn after A. Arman, J.K. Poplin, and N. Ahmad, Study of Vane Shear, Proc. Conference on In Situ Measurement of Soil Properties, ASCE, vol. 1, 1975).*



TYPICAL SOIL PROFILE AND SOIL PROPERTIES



GEOTECHNICAL PROPERTIES OF SUNGEI MUAR FLOOD PLAN, MALAYSIA (AIT, 1988)



GEOTECHNICAL PROPERTIES OF SUNGEI MUAR FLOOD PLAN, MALAYSIA (AIT, 1988)

LABORATORY TESTS

- Why?
- Types of Tests!
- How?
- Specifications?
  (Load, Pressure, Time)

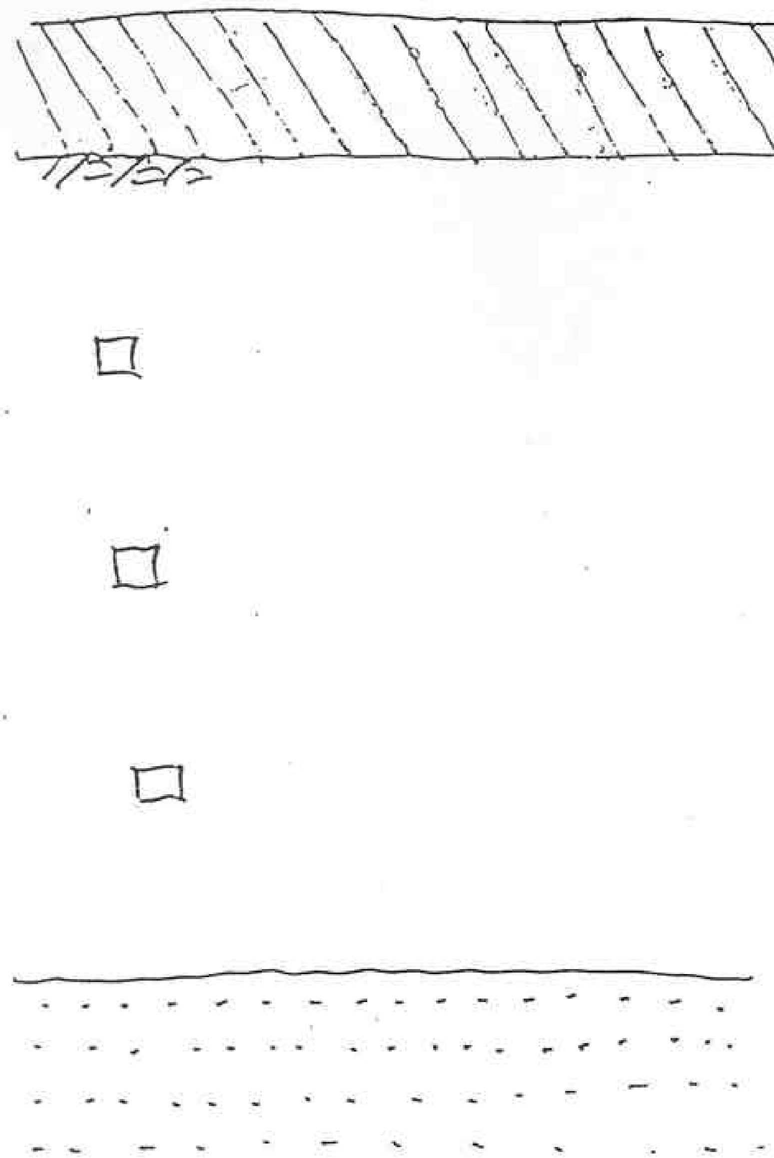
Specifications

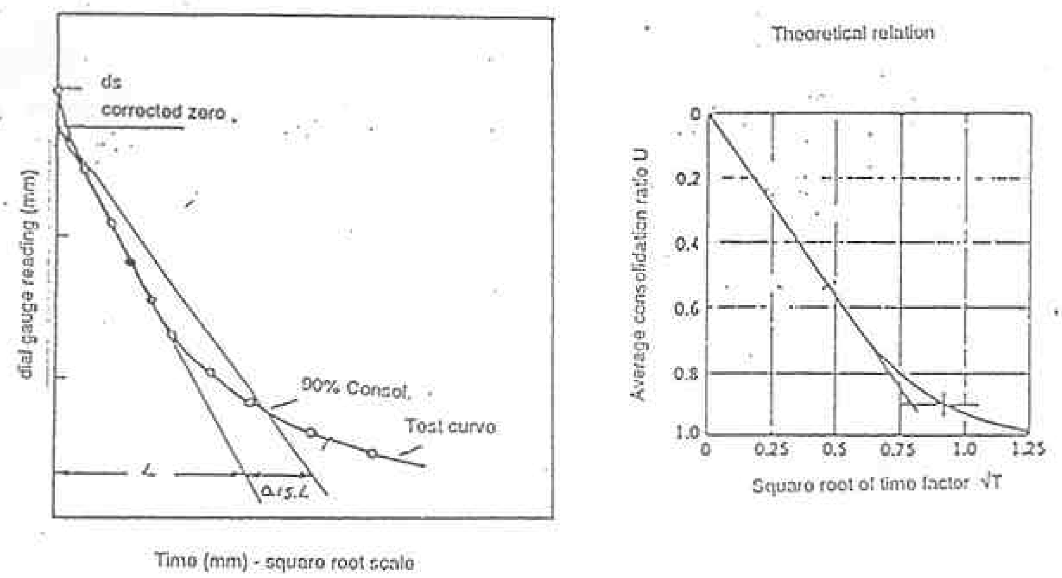
1) Which samples are appropriate and suitable for these test?

2) For consolidation test

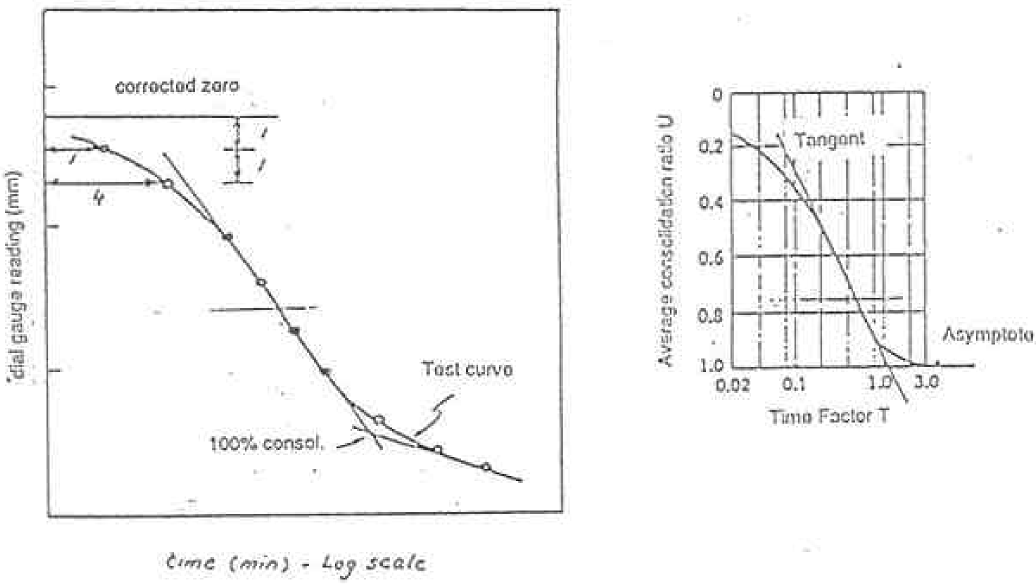
– Load increment	}	$0.5\ P_o' - 8P_o'$
	}	or to
– Pressure	}	$e \approx 0.42e_o$

3) For triaxial tests
   - Strain rate
   - Back pressure





Square - root of time fitting method



Logarithm of time fitting method

Test to obtain s_u, c', Ø'

s_u (direct)

- UC
- Triaxial Tests (UU)
- Lab. Vane Shear
- Shear Box

s_u (indirect)

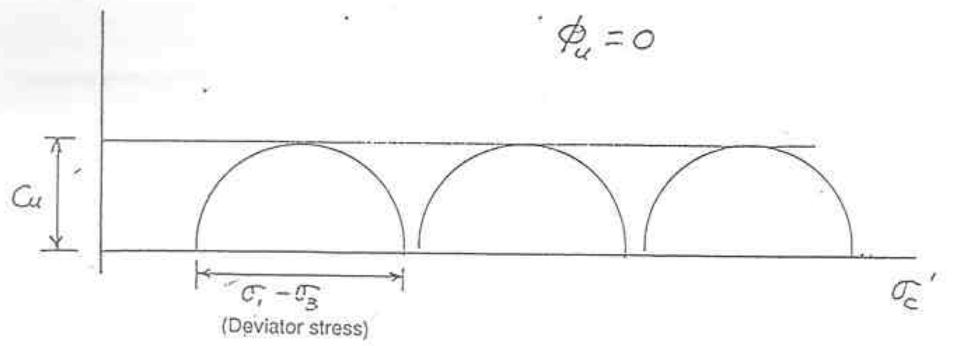
$$\frac{s_u}{P'} = 0.11 + 0.0037\, Ip$$ (Skempton, 1957)

$$Ip = LL - PL$$
$$= PI$$

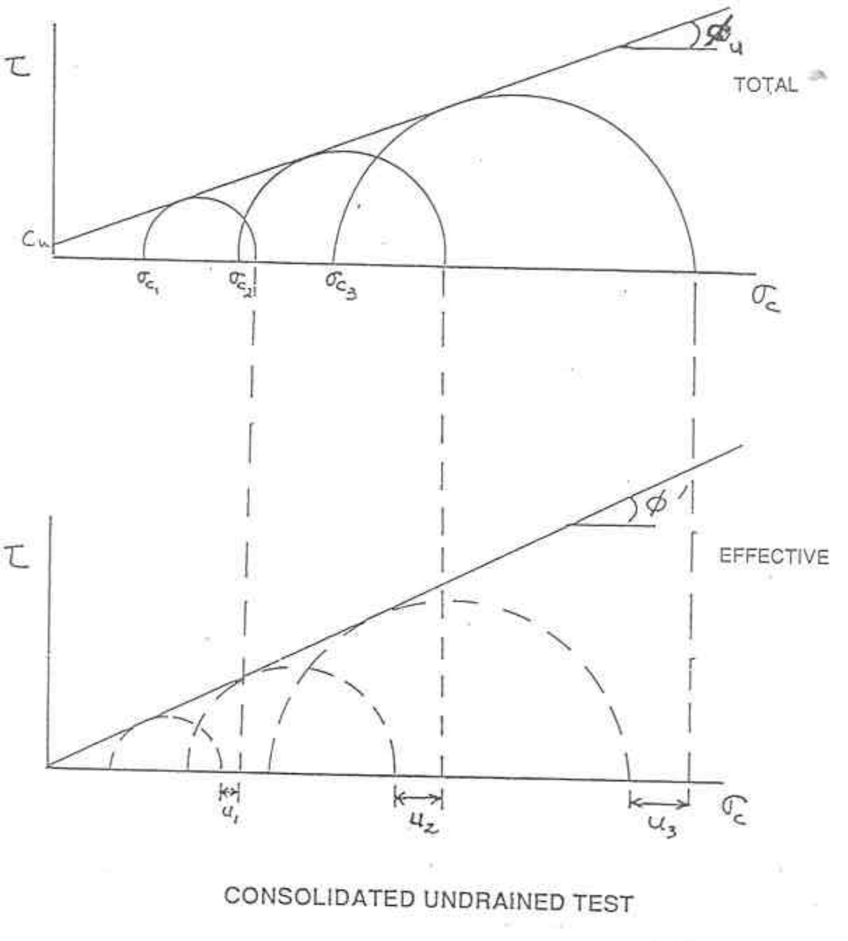
$$s_{ur} = 170 \exp(-4.5\, LI)\ kN/m^2$$

(Wroth + Wood 1978)

$$LI = \frac{W - PL}{PI}$$

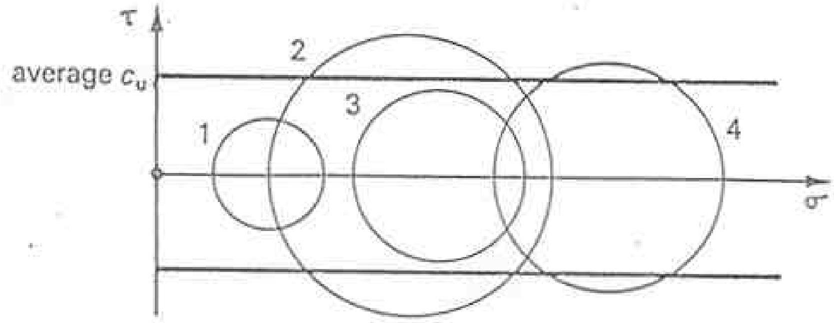


UNCONSOLIDATED UNDRAINED TEST

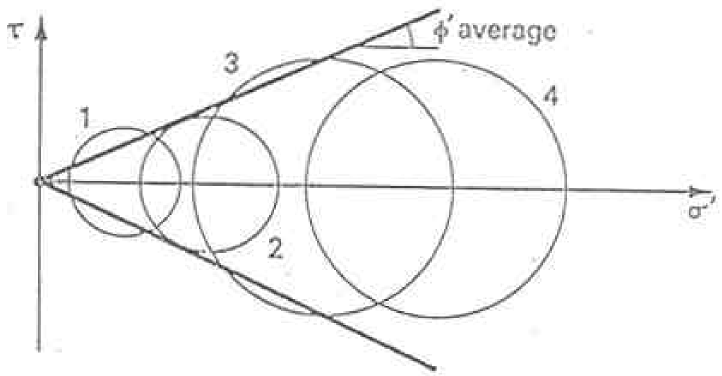


CONSOLIDATED UNDRAINED TEST

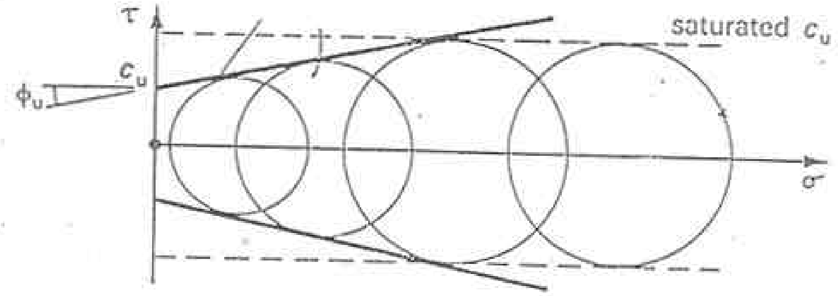
THE DEFORMATION OF SOIL ELEMENT



Undrained tests on independent samples of undisturbed clayey soil



Drained tests on independent samples of undisturbed clayey soil



Nominally undrained tests on samples of clayey soil compacted at a unique moisture content

Interpretation of CIU

Advantages of interpreting from Stress Paths

- Enables the field stress changes to be presented more realistically indicating the characteristic of subsoils.

- Generally plotted in Total Stress (Total Stress Path, TSP) and effective stress (Effective Stress Path, ESP).

Types of Plot

A) MIT Stress Path Plot

- developed by professor T. W. Lambe of the Massachusetts Institute of Technology (1967), USA

- Horizontal axis

$$s = \frac{\sigma_1 + \sigma_3}{2} \quad \& \quad s' = \frac{\sigma_1' + \sigma_3'}{2}$$

- Vertical axis

$$t = \frac{\sigma_1 - \sigma_3}{2} = \frac{\sigma_1' - \sigma_3'}{2}$$

B) Cambridge Stress Path Plot

- Developed by Roscoe, Schofield and Wroth (1958) at the University of Cambridge, England

- Horizontal axis

$$p = \frac{\sigma_1 + \sigma_2 + \sigma_3}{3} \quad \& \quad p' = \frac{\sigma_1' + \sigma_2' + \sigma_3'}{3}$$

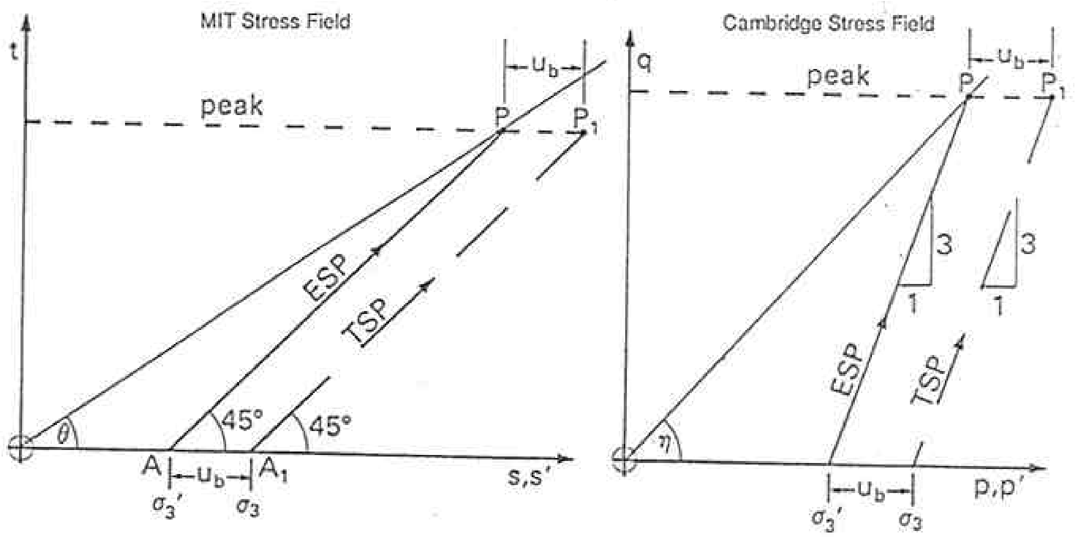
For triaxial test, two of the principal effective stress are equal to the horizontal effective stress, therefore can be expressed as

$$p = \frac{\sigma_1 + 2\sigma_2}{3} \quad \& \quad p' = \frac{\sigma_1' + 2\sigma_2'}{3}$$

- Vertical axis

$$q = \sigma_1 - \sigma_3 = \sigma_1' - \sigma_3'$$

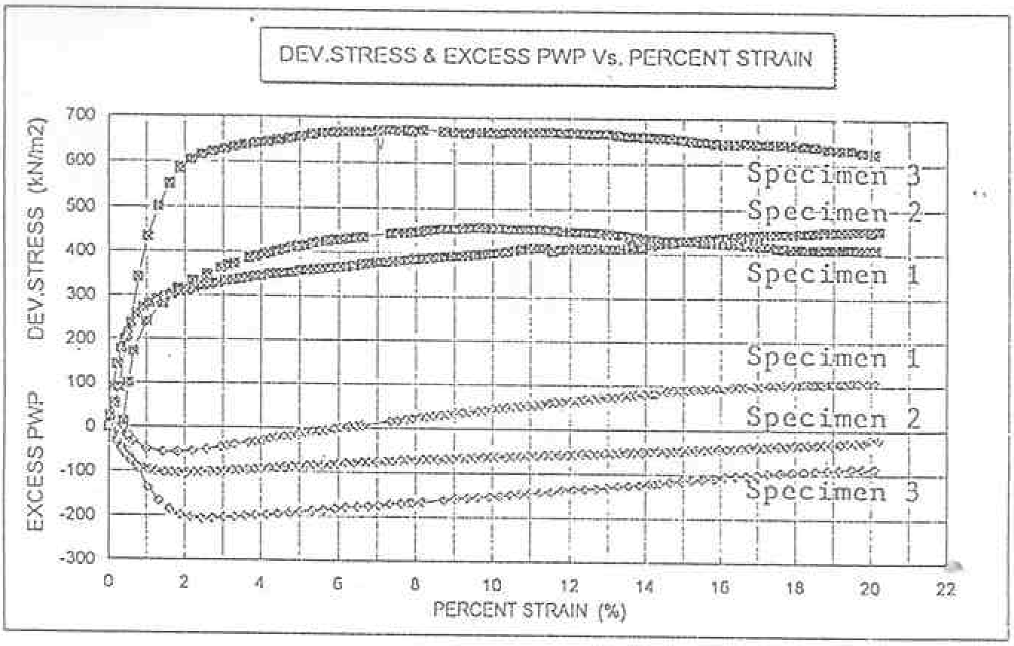
STRESS PATHS IN TRIXIAL TESTING

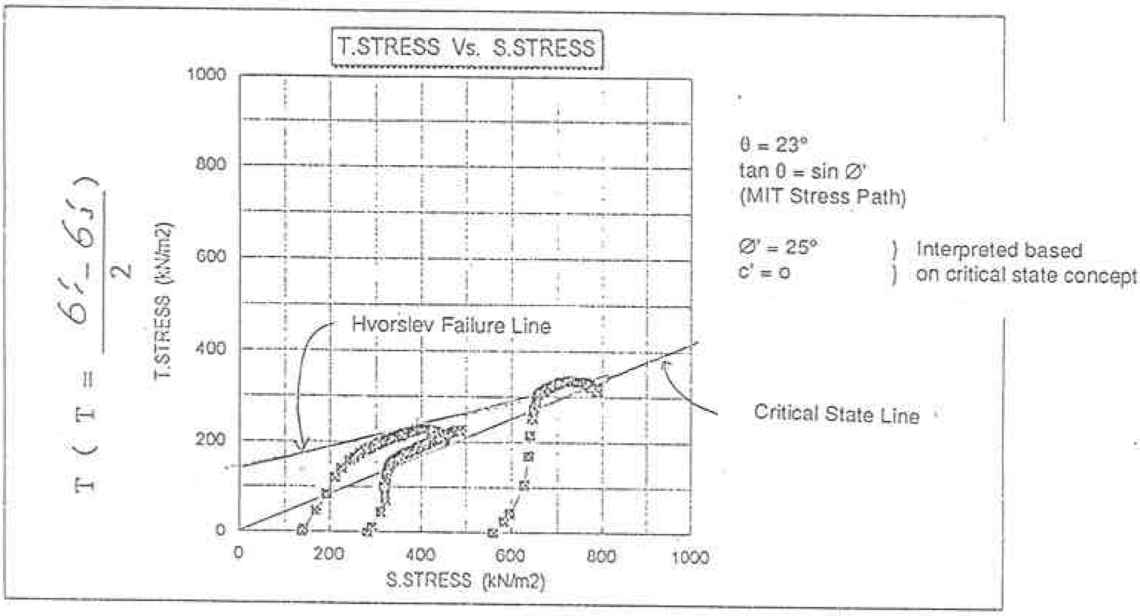


Stress paths of total and effective stresses for a drained triaxial compression test

Where:

ESP = Effective Stress Path
TSP = Total Stress Path
U_b = Back Pressure

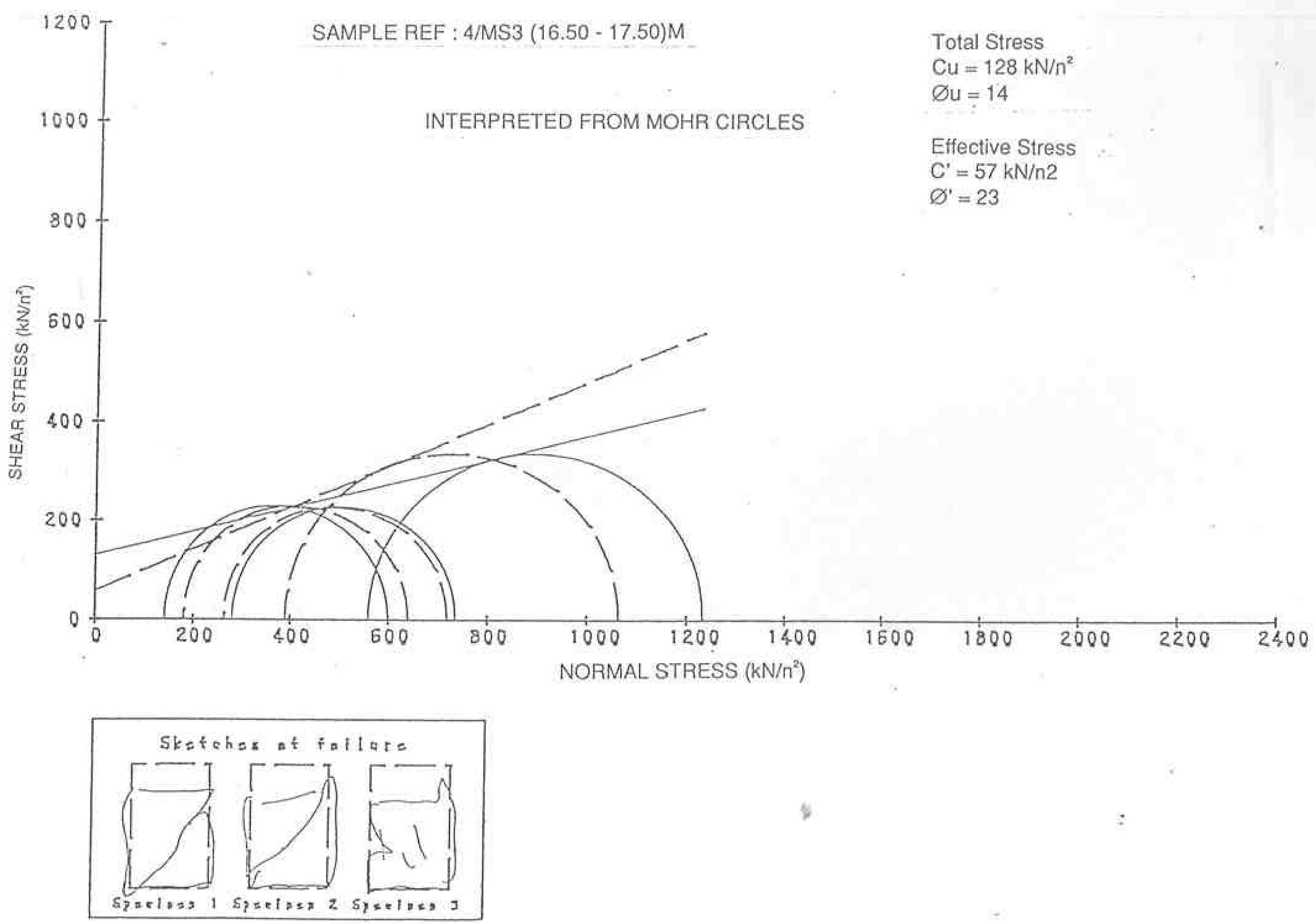


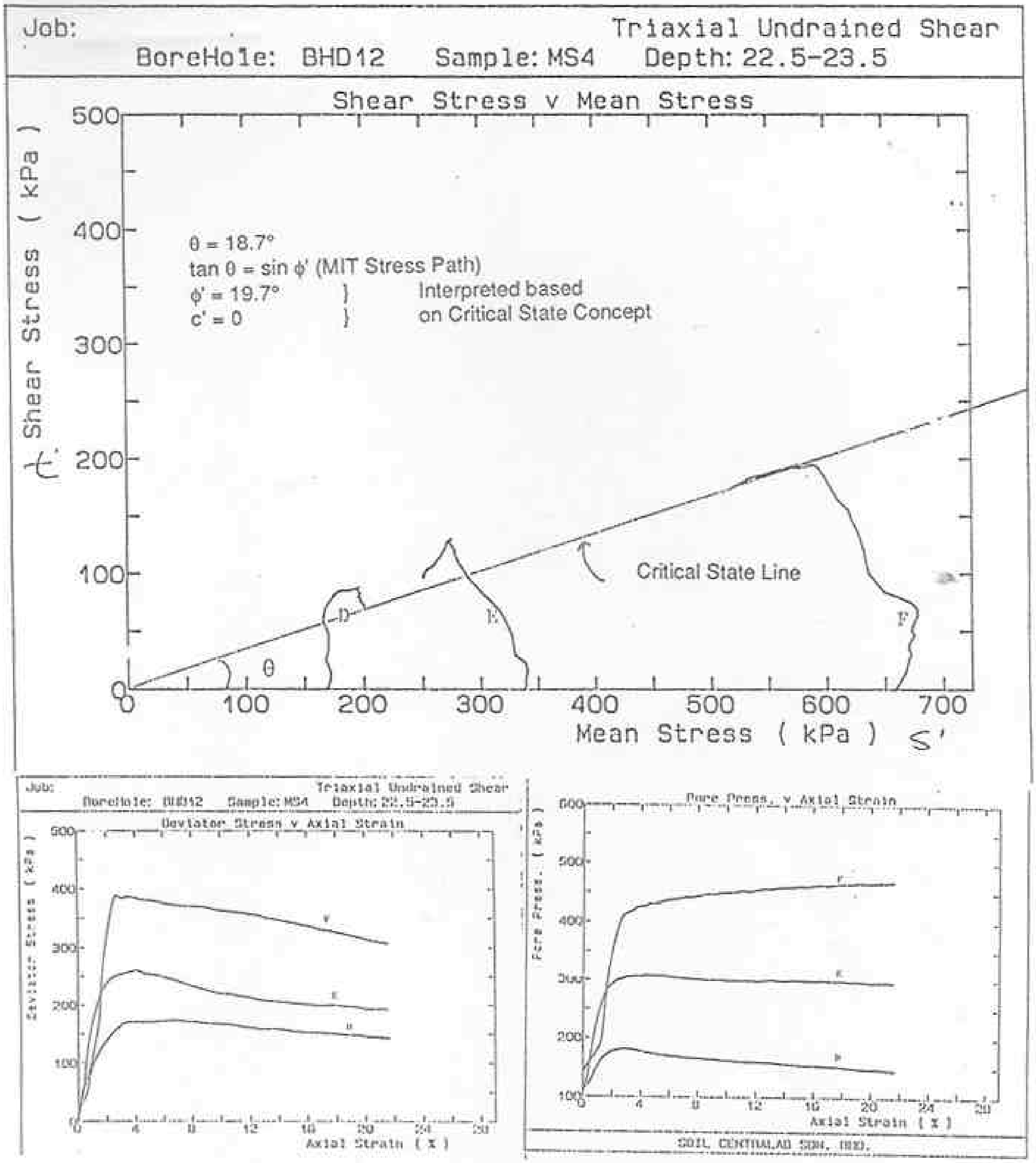


S ($S = \frac{\sigma_1' + \sigma_3'}{2}$)

NOTE: Samples showed overconsolidated Characteristics

EXAMPLE 1


SAMPLE REF : 4/MS3 (16.50 - 17.50)M
INTERPRETED FROM MOHR CIRCLES
Total Stress
Cu = 128 kN/n²
Øu = 14
Effective Stress
C' = 57 kN/n2
Ø' = 23
SHEAR STRESS (kN/n²)
0
200
400
600
800
1000
1200
NORMAL STRESS (kN/n²)
1400
1600
1800
2000
2200
2400
Sketches at failure
Specimen 1
Specimen 2
Specimen 3


Job:
Triaxial Undrained Shear
BoreHole: BHD12
Sample: MS4
Depth: 22.5-23.5
Shear Stress v Mean Stress
Shear Stress (kPa)
θ = 18.7°
tan θ = sin ϕ' (MIT Stress Path)
ϕ' = 19.7°
c' = 0
Interpreted based on Critical State Concept
Critical State Line
D
E
F
θ
Mean Stress (kPa)
Triaxial Undrained Shear
Deviator Stress v Axial Strain
Axial Strain (%)
Pore Press. v Axial Strain
Axial Strain (%)
SOIL CENTRALAB SDN. BHD.

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