CHAPTER VI

ENGINEERING AND INDUSTRIAL RESOURCES

The available material resources of the study area, are soils, river sands, crushed stones, buildingstones, industrial clays, silica sand, coal, cherty limestone, and Kankar. Their occurrences are given in Table VI.1 and are shown on Map VI.1.

ENGINEERING MATERIAL RESOURCES

They include fine aggregate, coarse aggregate, and buildingstones.

(A) FINE AGGREGATE:

It consists of soils and river sand.

SOIL: Samples were collected from five openpits at different depths depending on the variation in colour and texture of soil. The field observations are given in Table VI.2. Soil samples were tested in the laboratory for their index and engineering properties (IS:2720 - Methods of Test for Soils). Formulae used for calculations of these properties are given in Appendix VI.1 p. 258.

LABORATORY METHODS:

(1) Specific Gravity (IS:2720 P.III, 1969): The specific gravity at room temperature, of each soil sample

TABLE VI.1

ENGINEERING AND INDUSTRIAL RESOURCES

(A) ENGINEERING MATERIAL RESOURCES

Sr. No.	Location	Taluka	District	Eingineering Material	Use
1.	W of Mahika	Wankaner	Rajkot	White & Yellow sandstone	Building stone
2.	S of Bhaduka	Sayla	Surendra-nagar	- do -	- do -
3.	N of Palasadi	Wankaner	Rajkot	Feruginous sandstone	- do -
4.	SE of Jodhpur	"	"	- do -	- do -
5.	W of Songadh	Chotila	Surendra-nagar	- do -	- do -
6.	Ranipat	Muli	"	- do -	Crushed aggregate
7.	N of Bhet	"	"	- do -	Building stone
8.	SW of Sudamda Nava	Sayla	"	- do -	- do -
9.	W of Dudhai	Muli	"	White sandstone	- do -
10.	Sarla	"	"	- do -	-do -
11.	SSE of Aya Dagdagia	Sayla	"	- do -	- do -
12.	Vagadia	Muli	"	Quartzitic sandstone	Crushed aggregate
13.	Vanalia	Sayla	"	- do -	- do -
14.	NW of Daldi	Wankaner	Rajkot	Trap rock	- do -
15.	NE of Than	Chotila	Surendra-nagar	Dyke rock	- do -
16.	NE of Monthala	"	"	- do -	- do -
17.	N of Somasar	Sayla	"	- do -	- do -
18.	N of Devpara	Chotila	"	Maha River sand	Fine aggregate
19.	E of Kashia-gala	Wankaner	Rajkot	- do -	- do -
20.	Sagadhra	Muli	Surendra-nagar	Balal River sand	- do -
21.	Raisangpar	"	"	Bambhan River sand	- do -
22.	W of Bhaduka	Sayla	"	Bhagavo River sand	- do -
23.	SW of Digha-lia	Wankaner	Rajkot	Kharodia Nala (Machhu River sand)	- do -

contd...

TABLE VI.1 (contd.)

(B) INDUSTRIAL MATERIAL RESOURCES

1	2	3	4	5	6
1.	S of Samatpar	Sayla	Surendra-nagar	Friable White Sandstone	Glass
2.	W of Bhasol	"	"	- do -	-do-
3.	W of Waori	Chotila	"	- do -	-do-
4.	W of Gugaliane	"	"	- do -	-do-
5.	Lunsar	Wankaner	Rajkot	Fire Clay	Ceramics
6.	Khakhrathal	Muli	Surendra-nagar	- do -	-do-
7.	Velala	"	"	- do -	-do-
8.	Chandrelia	"	"	- do -	-do-
9.	W of Palasan	"	"	- do -	-do-
10.	Gadhada	"	"	- do -	-do-
11.	Songadh	Chotila	"	- do -	-do-
12.	Amarapar	"	"	- do -	-do-
13.	Than	"	"	- do -	-do-
14.	Ranipat	Muli	"	White Clay	Cement
15.	NE of Navagam	Chotila	"	- do -	-do-
16.	SE of Jodhpur (River bank)	Wankaner	Rajkot	- do -	-do-
17.	NE of Khakhra-thal	Muli	Surendra-nagar	Coal Seam	Fuel
18.	Tarnetar	"	"	- do -	-do-
19.	Songadh	Chotila	"	- do -	-do-
20.	W of Aya Dagdagia	Sayla	"	Cherty limestone	Lime
21.	N of Muli (on river bank)	Muli	"	Kankar	Lime

TABLE VI.2

FIELD OBSERVATIONS OF OPENPIT SOIL SAMPLES

Location	Open-pit No.	Soil Sample No.	Sampling Depth (cm)	Soil Colour
SE of Sarsana	1	/1	0 - 50	Reddish brown
(E of Than-Murthala Road)		/2	50 -100	Yellowish brown
SE of Than	2	/1	0 - 80	Greyish black
(S of Than-Vagadia Road)		/2	80 -120	Yellowish black
N of Sidsar	3	/1	0 - 70	Grey
(E of Muli-Sayla Road)		/2	70 - 90	Brownish grey
W of Sayla	4	/1	0 - 50	Brownish black
(Opp to N Sudamda)		/2	50 -135	Greyish black
S of Sayla	5	/1	0 - 15	Greyish black
		/2	15 - 30	Greyish black

passing 10 mesh BS sieve, was determined by using the formula given in Appendix VI.1 p. 256. The variation in specific gravity ranges from 2.58 to 2.81.

(2) Atterberg Limits (IS:2720 P.V, 1970): These limits are to be determined generally for fine grained soils and are related to the amount of water. Air dry soils passing 40 mesh BS sieve was used for the determination of liquid limit and plastic limit.

(a) Liquid limit: It was determined at different water contents, by number of blows varying from 20 to 40. Liquid limit at 25 blows for each soil sample, was calculated by using the formula given in Appendix VI.1 p. 256. The variation in liquid limit ranges from non-plastic to plastic (upto 43 percent).

(b) Plastic limit: A thread having 3 mm (1/8") diameter was prepared on a glass plate, for each soil sample and the crumbled pieces of each thread were kept in oven, to determine the water content which is the indication of plastic limit. The variation in plastic limit ranges from non-plastic to plastic (upto 25 per cent).

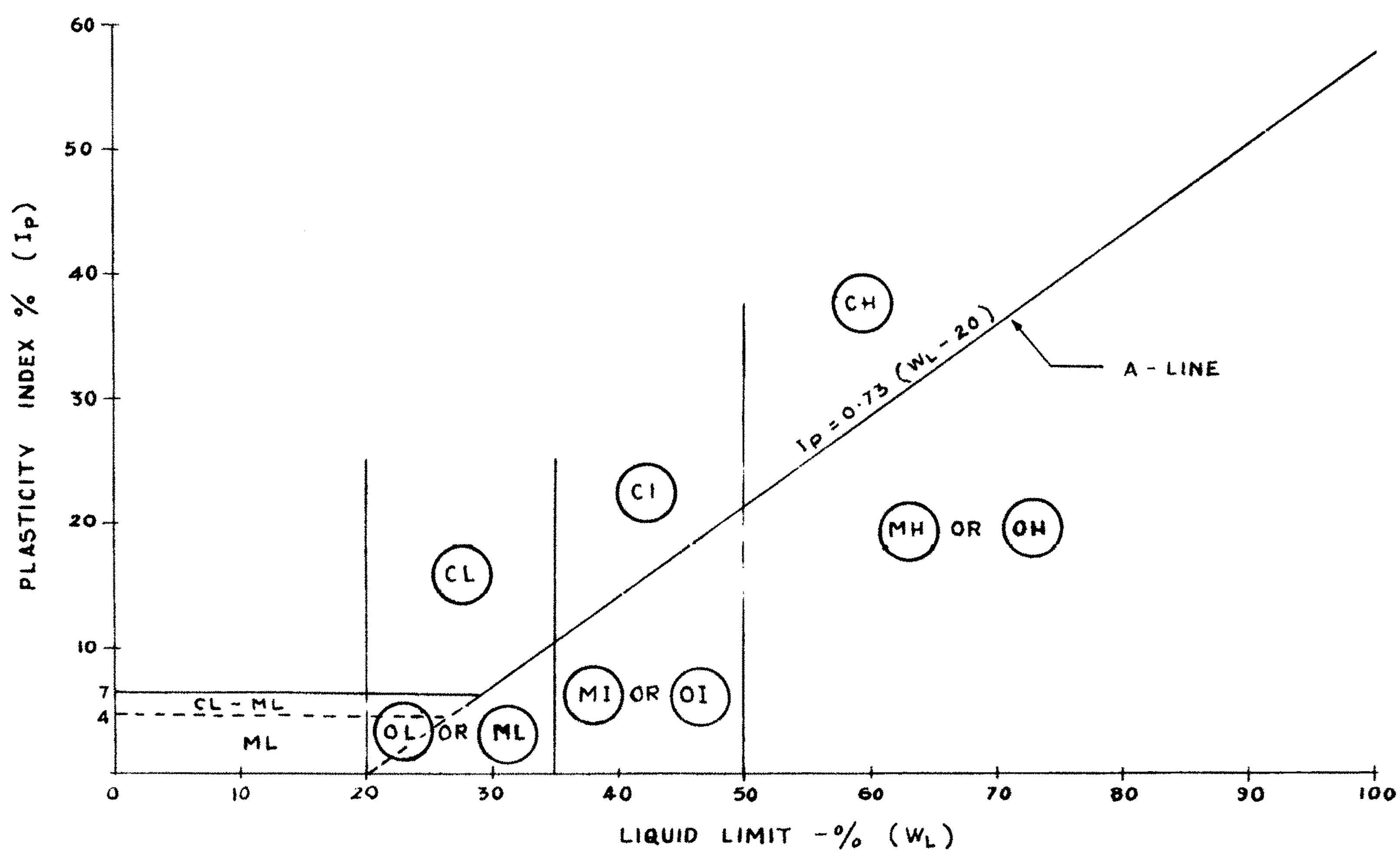
(c) Plasticity index: The difference between the liquid limit at 25 blows and plastic limit of 3 mm diameter thread at breaking point gave plasticity index. The variation in plasticity index ranges from 0 to 18 per cent. The relationship between liquid limit and plasticity index (IS:1498, 1970) is shown in the plasticity chart (Fig.VI.1).

(3) Grain Size Analysis (IS:2720 P.IV, 1965): It consists of dry sieve analysis and sedimentation analysis.

(a) Dry Sieve analysis: Each openpit soil sample was sieved through a set of BS sieves(3/4", 3/8", 3/16" and 10 mesh). The soil fractions coarser than 2.00 mm diameter, retained on each sieve were weighed and their cumulative per cent and per cent passing through each sieve were calculated.

(b) Sedimentation analysis: It includes wet sieving and hydrometer analysis. Soil sample, passing from 10 mesh BS sieve was treated with hydrogen peroxide and sodium hexametaphosphate (4% solution). Wet sieving was then carried out using 200 mesh BS sieve. Fraction retained on the sieve, was oven dried and was sieved through a set of BS sieves (mesh nos: 10,16,30,60,100 and 200). The cumulative percentages retained on each sieve and their per cent finer were calculated. The material passing through 200 mesh BS sieve, was used for

FIG. VI. 1



PLASTICITY CHART

hydrometer analysis. Hydrometer readings were taken at different time intervals, viz. 1/2, 1, 4, 19, 60, 120 and 240 minutes and 24 hours. Their percentage finer was calculated. The per cent finer than the size and their corresponding equivalent particle diameter in mm, were used to draw a grain size distribution curve (Graph VI.1). From this curve, the percentages of sand, silt and clay were determined. The variation in the percentage of components (Appendix VI.2 p.259) of each soil sample is shown in the histogram (Graph VI.2).

The soil classification for engineering purposes (IS:1498, 1970) of each openpit soil sample was made from grain size distribution curve, and plasticity chart (Appendix VI.3 p.260). SM and SC are silty sands and clayey sands respectively. CI is inorganic clays with medium plasticity. Soil profile of each openpit soil is shown in Fig. VI.2.

(4) Compaction Test (IS:2720 P.VII, 1965): In the laboratory, Standard Proctor Test was carried out on the soil passing 3/4 inch BS sieve to determine the relationship between the per cent water content and the dry density of soil after compaction at the energy

GRAIN SIZE ANALYSIS

Sample No. 1/1

A. SIEVE ANALYSIS:

BS Sieve (Mesh No.)	Particle Diameter (mm)	Per cent Finer
10	2.0000	96
16	1.2000	90
30	0.5900	65
60	0.3000	58
100	0.1500	34
120	0.0760	28

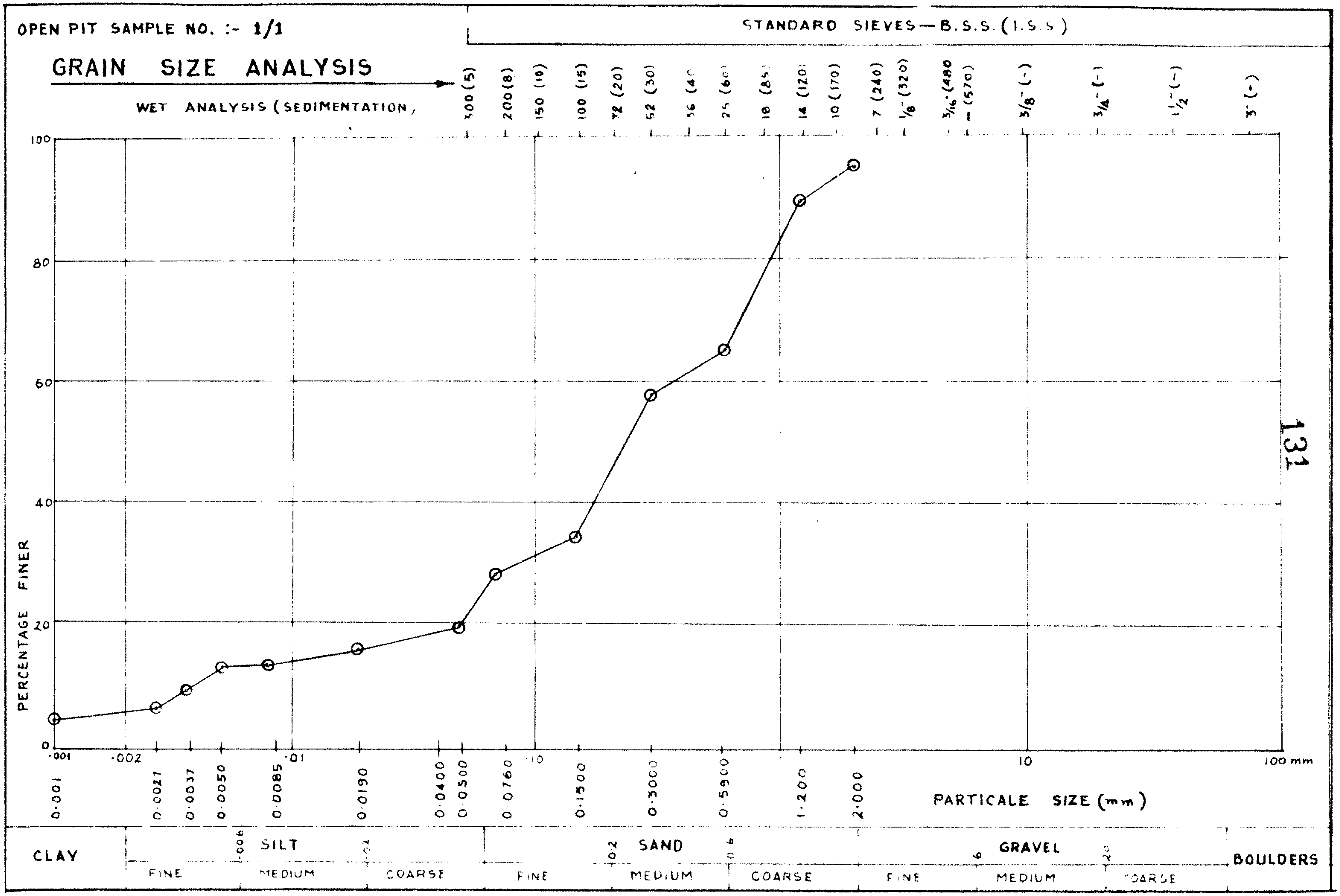
B. HYDROMETER ANALYSIS:

Time Interval (minute)	Particle Diameter (mm)	Per cent Finer
1/2	0.0500	19
1	0.0400	15
4	0.0190	15
19	0.0085	12
60	0.0050	12
120	0.0037	8
240	0.0027	5
24 hrs	0.0010	3

C. RESULTS OBTAINED FROM GRAIN SIZE DISTRIBUTION CURVE:

Soil Fractions	Coarse %	Medium %	Fine %	Total %
Gravel	-	-	4	4
Sand	31	22	15	68
Silt	13	3	8	24
Clay	-	-	4	4

GRAPH VI . 1


OPEN PIT SAMPLE NO. :- 1/1
GRAIN SIZE ANALYSIS
WET ANALYSIS (SEDIMENTATION)
STANDARD SIEVES — B.S.S. (I.S.S.)
300 (5)
200 (8)
150 (10)
100 (15)
72 (20)
52 (30)
25 (60)
18 (85)
14 (120)
10 (170)
7 (240)
1/8" (320)
3/16" (480
— (570)
3/8" (-)
3/4" (-)
1 1/2" (-)
3" (-)
PERCENTAGE FINER
0
20
40
60
80
100
·001
·002
·01
·10
10
100 mm
0·001
0·0027
0·0037
0·0050
0·0085
0·0190
0·0400
0·0500
0·0760
0·1500
0·3000
0·5900
1·200
2·000
PARTICALE SIZE (mm)
CLAY
SILT
FINE
MEDIUM
COARSE
SAND
FINE
MEDIUM
COARSE
GRAVEL
FINE
MEDIUM
COARSE
BOULDERS

GRAIN SIZE ANALYSIS

Sample No. 1/2

A. SIEVE ANALYSIS:

BS Sieve (Mesh No.)	Particle Diameter (mm)	Per cent Finer
10	2.0000	97
16	1.2000	93
30	0.5900	79
60	0.3000	60
100	0.1500	41
200	0.0760	32

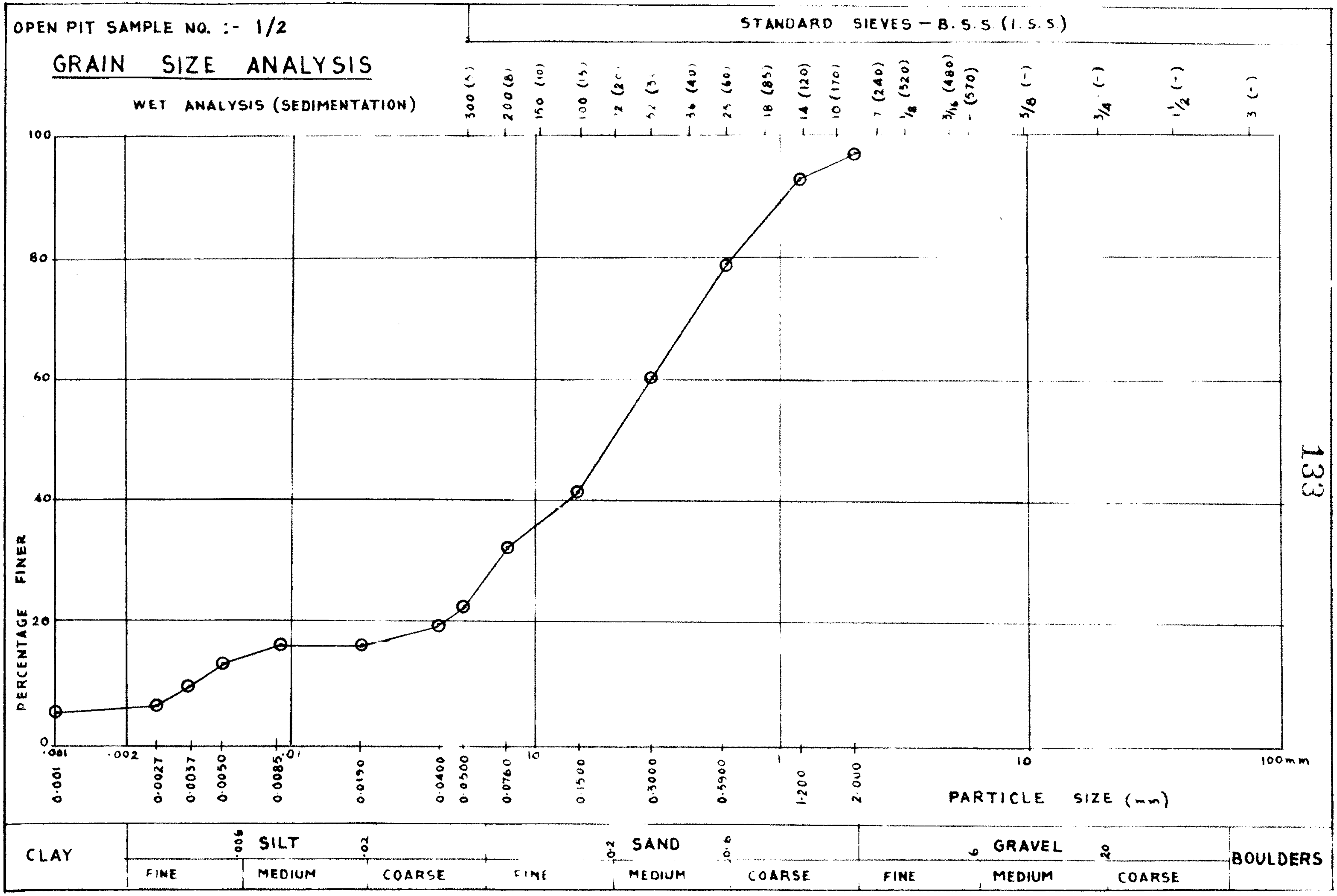
B. HYDROMETER ANALYSIS:

Time Interval	Particle Diameter (mm)	Per cent Finer
1/2 m	0.0500	22
1 m	0.0400	19
4 m	0.0190	16
19 m	0.0085	16
60 m	0.0050	13
120 m	0.0037	9.5
240 m	0.0027	6
24 hrs	0.0010	5

C. RESULTS OBTAINED FROM GRAIN SIZE DISTRIBUTION CURVE:

Soil Fractions	Coarse %	Medium %	Fine %	Total %
Gravel	-	-	3	3
Sand	18	31	20	69
Silt	12	2	8	22
Clay	-	-	6	6

GRAPH VI. 1



GRAIN SIZE DISTRIBUTION CURVE

GRAIN SIZE ANALYSIS

Sample No. 2/1

A. SIEVE ANALYSIS:

BS Sieve (Mesh No.)	Particle Diameter (mm)	Per cent Finer
10	2.0000	97
16	1.2000	96
30	0.5900	91
60	0.3000	76
100	0.1500	59
200	0.0760	53

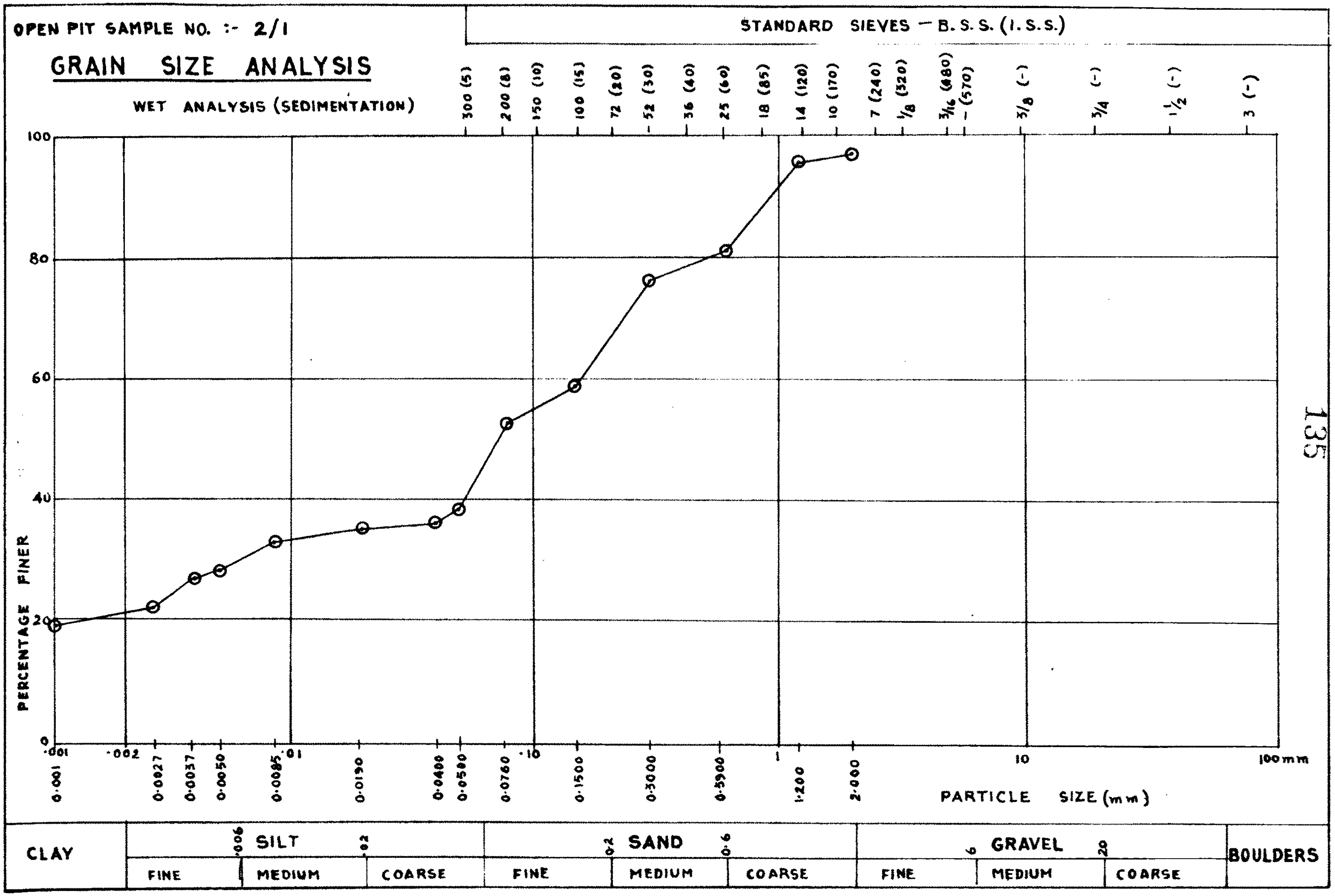
B. HYDROMETER ANALYSIS:

Time Interval	Particle Diameter (mm)	Per cent Finer
1/2 m	0.0500	38
1 m	0.0400	36
4 m	0.0190	35
19 m	0.0085	33
60 m	0.0050	28
120 m	0.0037	27
240 m	0.0027	22
24 hrs	0.0010	19

C. RESULTS OBTAINED FROM GRAIN SIZE DISTRIBUTION CURVE:

Soil Fractions	Coarse %	Medium %	Fine %	Total %
Gravel	-	-	3	3
Sand	6	25	13	44
Silt	18	5	9	32
Clay	-	-	21	21

GRAPH VI. 1


OPEN PIT SAMPLE NO. :- 2/1
GRAIN SIZE ANALYSIS
WET ANALYSIS (SEDIMENTATION)
STANDARD SIEVES — B.S.S. (I.S.S.)
300 (5)
200 (8)
150 (10)
100 (15)
72 (20)
52 (30)
36 (40)
25 (60)
18 (85)
14 (120)
10 (170)
7 (240)
1/8 (320)
3/16 (480)
– (570)
3/8 (-)
3/4 (-)
1 1/2 (-)
3 (-)
PERCENTAGE FINER
100
80
60
40
20
0
·001
·002
·01
·10
1
10
100 mm
0·001
0·0027
0·0037
0·0050
0·0085
0·0190
0·0400
0·0580
0·0760
0·1500
0·3000
0·5900
1·200
2·000
PARTICLE SIZE (mm)
CLAY
SILT
·006
·02
SAND
0·2
0·6
GRAVEL
6
20
BOULDERS
FINE
MEDIUM
COARSE
FINE
MEDIUM
COARSE
FINE
MEDIUM
COARSE

GRAIN SIZE ANALYSIS

Sample No. 2/2

A. SIEVE ANALYSIS:

BS Sieve (Mesh No.)	Particle Diameter (mm)	Per cent Finer
10	2.0000	96
16	1.2000	95
30	0.5900	86
60	0.3000	61
100	0.1500	43
200	0.0760	36

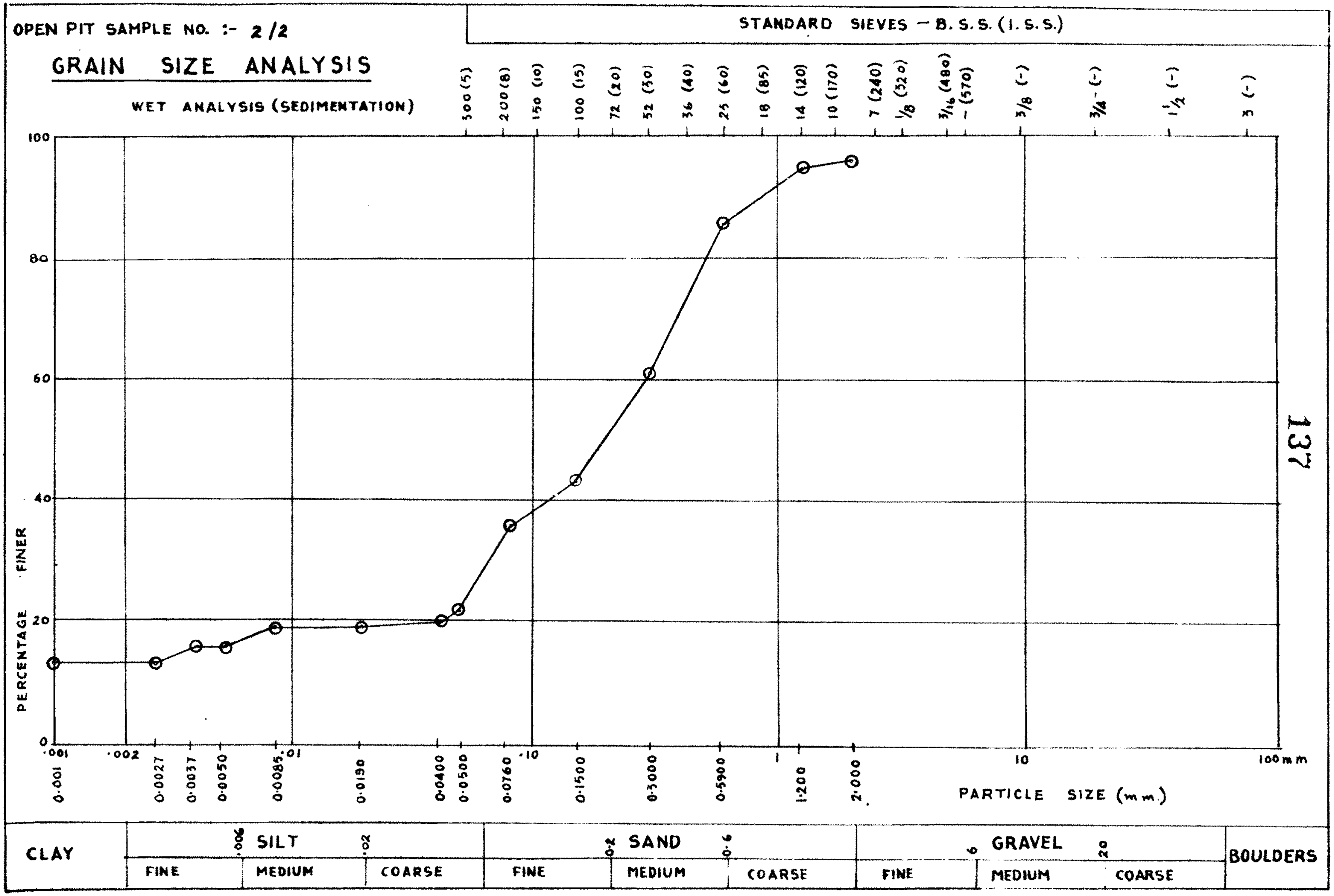
B. HYDROMETER ANALYSIS:

Time Interval	Particle Diameter (mm)	Per cent Finer
1/2 m	0.0500	22
1 m	0.0400	20
4 m	0.0190	19
19 m	0.0085	19
60 m	0.0050	16
120 m	0.0037	16
240 m	0.0027	13
24 hrs	0.0010	13

C. RESULTS OBTAINED FROM GRAIN SIZE DISTRIBUTION CURVE:

Soil Fractions	Coarse %	Medium %	Fine %	Total %
Gravel	-	-	4	4
Sand	10	36	14	60
Silt	17	2	4	23
Clay	-	-	13	13

GRAPH VI. 1


OPEN PIT SAMPLE NO. :- 2/2
GRAIN SIZE ANALYSIS
WET ANALYSIS (SEDIMENTATION)
STANDARD SIEVES — B. S. S. (I. S. S.)
300 (5)
200 (8)
150 (10)
100 (15)
72 (20)
52 (30)
36 (40)
25 (60)
18 (85)
14 (120)
10 (170)
7 (240)
1/8 (320)
3/16 (480)
- (570)
3/8 (-)
3/4 (-)
1 1/2 (-)
3 (-)
PERCENTAGE FINER
100
80
60
40
20
0
·001
·002
·01
·10
1
10
100 mm
0·001
0·0027
0·0037
0·0050
0·0085
0·0190
0·0400
0·0500
0·0760
0·1500
0·3000
0·5900
1·200
2·000
PARTICLE SIZE (mm)
CLAY
SILT
·006
·02
FINE
MEDIUM
COARSE
SAND
0·2
0·6
FINE
MEDIUM
COARSE
GRAVEL
6
20
FINE
MEDIUM
COARSE
BOULDERS

GRAIN SIZE ANALYSIS

Sample No. 3/1

A. SIEVE ANALYSIS:

BS sieve (Mesh No.)	Particle Diameter (mm)	Per cent Finer
10	2.0000	85
16	1.2000	84
30	0.5900	77
60	0.3000	67
100	0.1500	59
200	0.0760	55

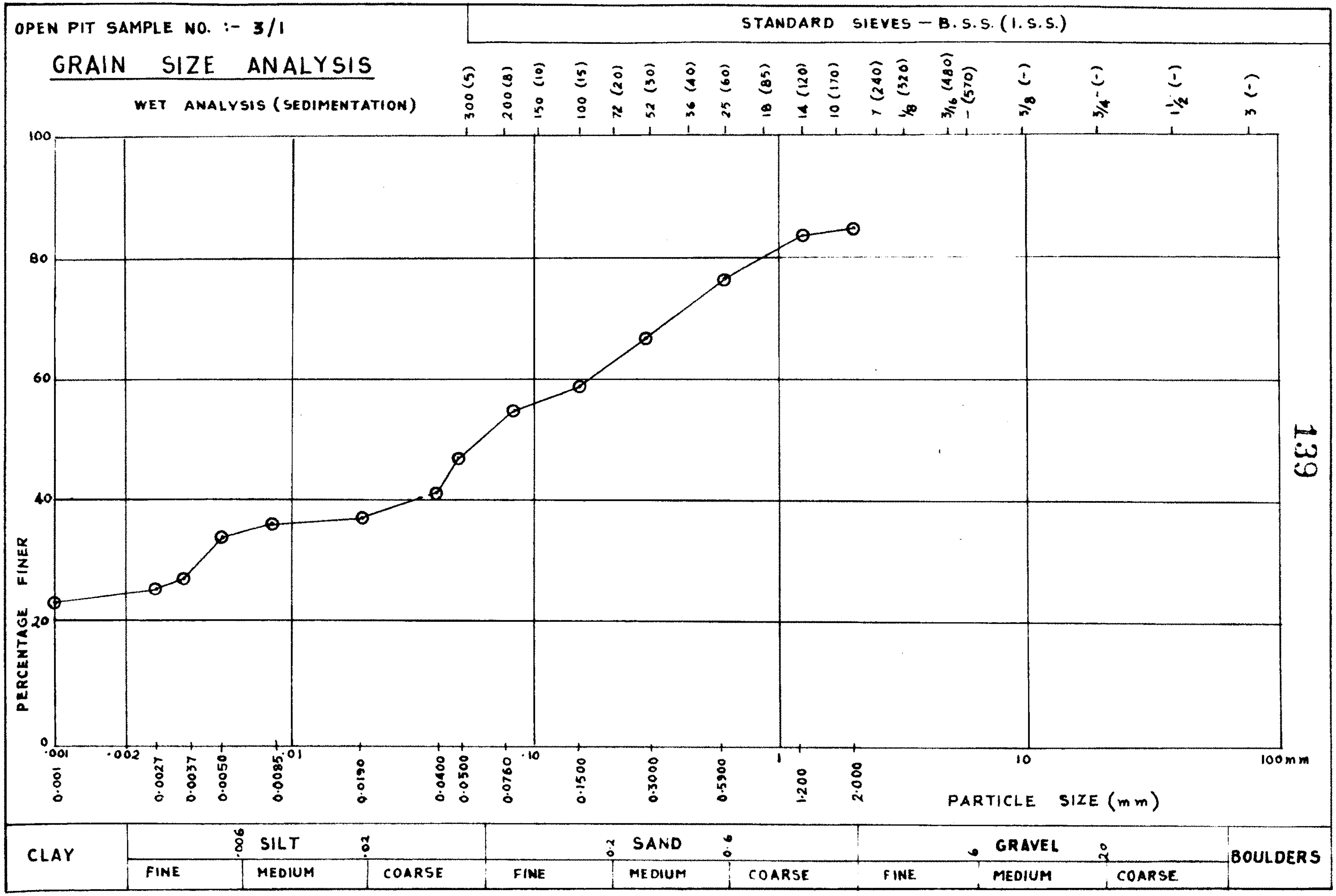
B. HYDROMETER ANALYSIS:

Time Interval	Particle Diameter (mm)	Per cent Finer
1/2 m	0.0500	47
1 m	0.0400	41
4 m	0.0190	37
19 m	0.0085	36
60 m	0.0050	34
120 m	0.0037	27
240 m	0.0027	25
24 hrs	0.0010	23

C. RESULTS OBTAINED FROM GRAIN SIZE DISTRIBUTION CURVE:

Soil Fractions	Coarse %	Medium %	Fine %	Total %
Gravel	-	-	15	15
Sand	8	15	10	33
Silt	15	2	11	28
Clay	-	-	24	24

GRAPH VI. 1


OPEN PIT SAMPLE NO. :- 3/1
GRAIN SIZE ANALYSIS
WET ANALYSIS (SEDIMENTATION)
STANDARD SIEVES — B.S.S. (I.S.S.)
300 (5)
200 (8)
150 (10)
100 (15)
72 (20)
52 (30)
36 (40)
25 (60)
18 (85)
14 (120)
10 (170)
7 (240)
1/8 (320)
3/16 (480)
— (570)
3/8 (-)
3/4 (-)
1 1/2 (-)
3 (-)
PERCENTAGE FINER
100
80
60
40
20
0
·001
·002
·01
·10
1
10
100mm
0·001
0·0027
0·0037
0·0050
0·0085
0·0190
0·0400
0·0500
0·0760
0·1500
0·3000
0·5900
1·200
2·000
PARTICLE SIZE (mm)
CLAY
SILT
·006
·02
SAND
0·2
0·6
GRAVEL
6
20
BOULDERS
FINE
MEDIUM
COARSE
FINE
MEDIUM
COARSE
FINE
MEDIUM
COARSE

GRAIN SIZE ANALYSIS

Sample No. 3/2

A. SIEVE ANALYSIS:

BS Sieve (Mesh No.)	Particle Diameter (mm)	Per cent Finer
10	2.0000	78
16	1.2000	73
30	0.5900	59
60	0.3000	48
100	0.1500	41
200	0.0760	38

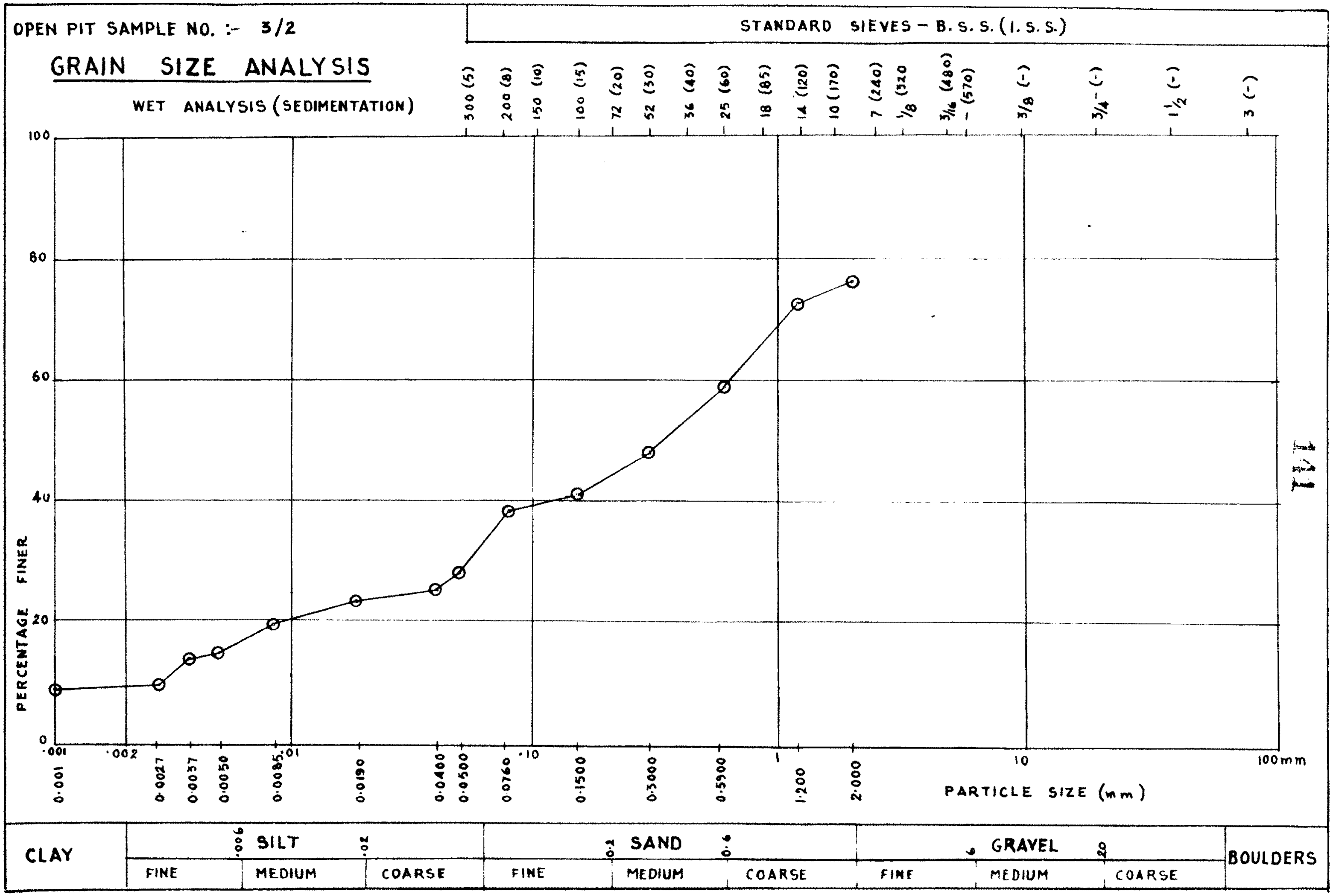
B. HYDROMETER ANALYSIS:

Time Interval	Particle Diameter (mm)	Per cent Finer
1/2 m	0.0500	28
1 m	0.0400	25
4 m	0.0190	24
19 m	0.0085	20
60 m	0.0050	15
120 m	0.0037	14
240 m	0.0027	10
24 hrs	0.0010	9

C. RESULTS OBTAINED FROM GRAIN SIZE DISTRIBUTION CURVE:

Soil Fractions	Coarse %	Medium %	Fine %	Total %
Gravel	-	-	22	22
Sand	19	15	10	44
Silt	10	7	7	24
Clay	-	-	10	10

GRAPH VI. 1


OPEN PIT SAMPLE NO. :- 3/2
GRAIN SIZE ANALYSIS
WET ANALYSIS (SEDIMENTATION)
STANDARD SIEVES - B. S. S. (I. S. S.)
300 (5)
200 (8)
150 (10)
100 (15)
72 (20)
52 (30)
36 (40)
25 (60)
18 (85)
14 (120)
10 (170)
7 (240)
1/8 (320
3/16 (480)
- (570)
3/8 (-)
3/4 (-)
1 1/2 (-)
3 (-)
PERCENTAGE FINER
100
80
60
40
20
0
·001
·002
·01
·10
1
10
100mm
0·001
0·0027
0·0037
0·0050
0·0085
0·0190
0·0400
0·0500
0·0760
0·1500
0·3000
0·5900
1·200
2·000
PARTICLE SIZE (mm)
CLAY
SILT
·006
·02
FINE
MEDIUM
COARSE
SAND
0·2
0·6
FINE
MEDIUM
COARSE
GRAVEL
6
20
FINE
MEDIUM
COARSE
BOULDERS

GRAIN SIZE ANALYSIS

Sample No. 4/1

A. SIEVE ANALYSIS:

BS Sieve (Mesh No.)	Particle Diameter (mm)	Per cent Finer
10	2.0000	99
16	1.2000	98
30	0.5900	75
60	0.3000	64
100	0.1500	52
200	0.0760	46

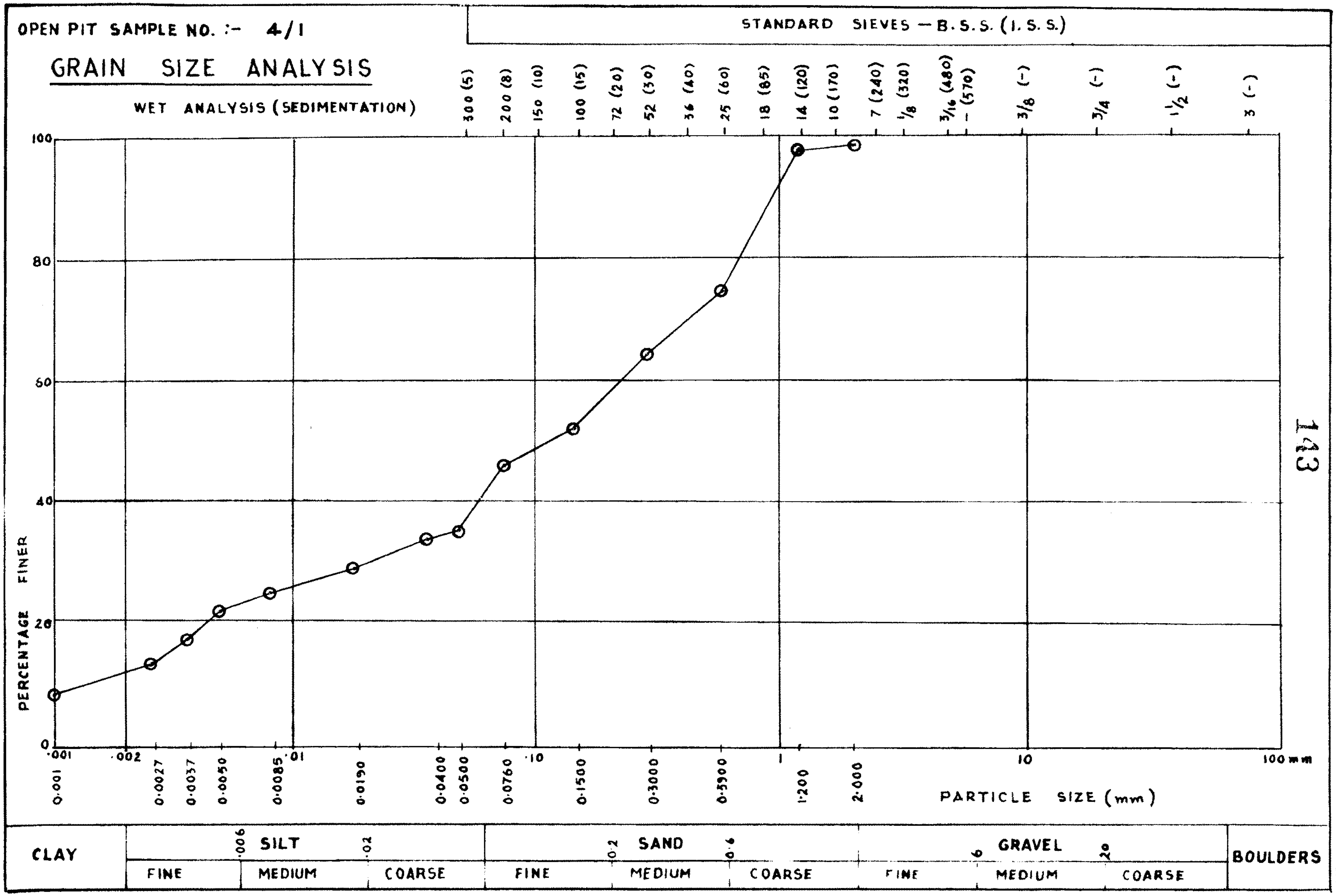
B. HYDROMETER ANALYSIS:

Time Interval	Particle Diameter (mm)	Per cent Finer
1/2 m	0.0500	35
1 m	0.0400	34
4 m	0.0190	29
19 m	0.0085	25
60 m	0.0050	22
120 m	0.0037	17
240 m	0.0027	13
24 hrs	0.0010	8

C. RESULTS OBTAINED FROM GRAIN SIZE DISTRIBUTION CURVE:

Soil Fractions	Coarse %	Medium %	Fine %	Total %
Gravel	-	-	1	1
Sand	23	18	17	58
Silt	11	7	12	30
Clay	-	-	11	11

GRAPH VI. 1


OPEN PIT SAMPLE NO. :- 4/1
GRAIN SIZE ANALYSIS
WET ANALYSIS (SEDIMENTATION)
STANDARD SIEVES — B.S.S. (I.S.S.)
300 (5)
200 (8)
150 (10)
100 (15)
72 (20)
52 (30)
36 (40)
25 (60)
18 (85)
14 (120)
10 (170)
7 (240)
1/8 (320)
3/16 (480)
– (570)
3/8 (-)
3/4 (-)
1 1/2 (-)
3 (-)
PERCENTAGE FINER
100
80
60
40
20
0
·001
·002
·01
·10
1
10
100 mm
0·001
0·0027
0·0037
0·0050
0·0085
0·0190
0·0400
0·0500
0·0760
0·1500
0·3000
0·5900
1·200
2·000
PARTICLE SIZE (mm)
CLAY
SILT
·006
·02
FINE
MEDIUM
COARSE
SAND
0·2
0·6
FINE
MEDIUM
COARSE
GRAVEL
6
20
FINE
MEDIUM
COARSE
BOULDERS

GRAIN SIZE ANALYSIS

Sample No. 4/2

A. SIEVE ANALYSIS:

BS Sieve (Mesh No.)	Particle Diameter (mm)	Per cent Finer
10	2.0000	95
16	1.2000	94
30	0.5900	88
60	0.3000	65
100	0.1500	45
200	0.0760	40

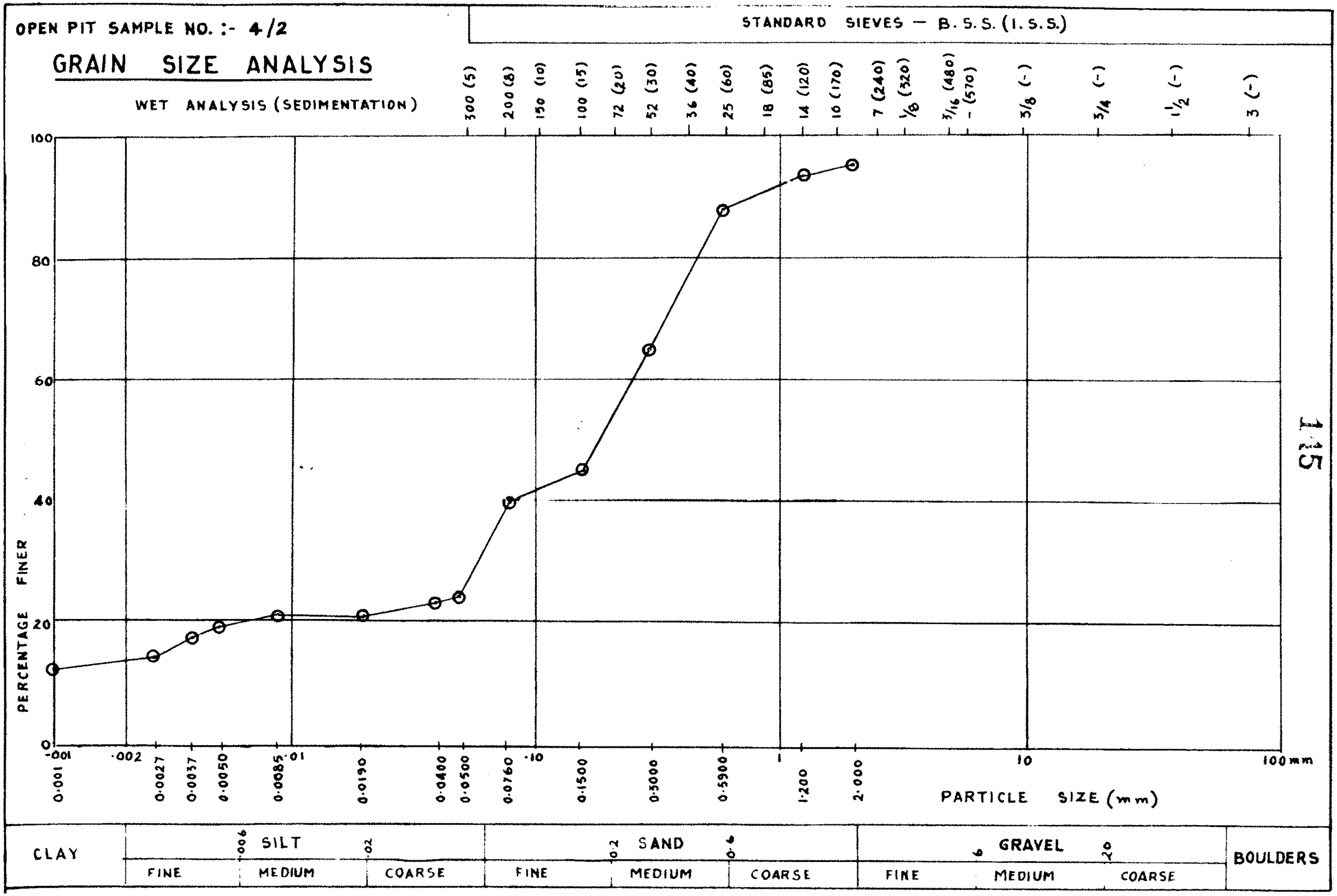
B. HYDROMETER ANALYSIS:

Time Interval	Particle Diameter (mm)	Per cent Finer
1/2 m	0.0500	24
1 m	0.0400	23
4 m	0.0190	21
19 m	0.0085	21
60 m	0.0050	19
120 m	0.0037	17
240 m	0.0027	14
24 hrs	0.0010	12

C. RESULTS OBTAINED FROM GRAIN SIZE DISTRIBUTION CURVE:

Soil Fractions	Coarse %	Medium %	Fine %	Total %
Gravel	-	-	5	5
Sand	7	35	21	63
Silt	11	1	7	19
Clay	-	-	13	13

GRAPH VI. 1



GR IN IZE DI TRI TION E

GRAIN SIZE ANALYSIS

Sample No. 5/1

A. SIEVE ANALYSIS:

BS Sieve (Mesh No.)	Particle Diameter (mm)	Per cent Finer
10	2.0000	65
16	1.2000	61
30	0.5900	53
60	0.3000	48
100	0.1500	41
200	0.0760	38

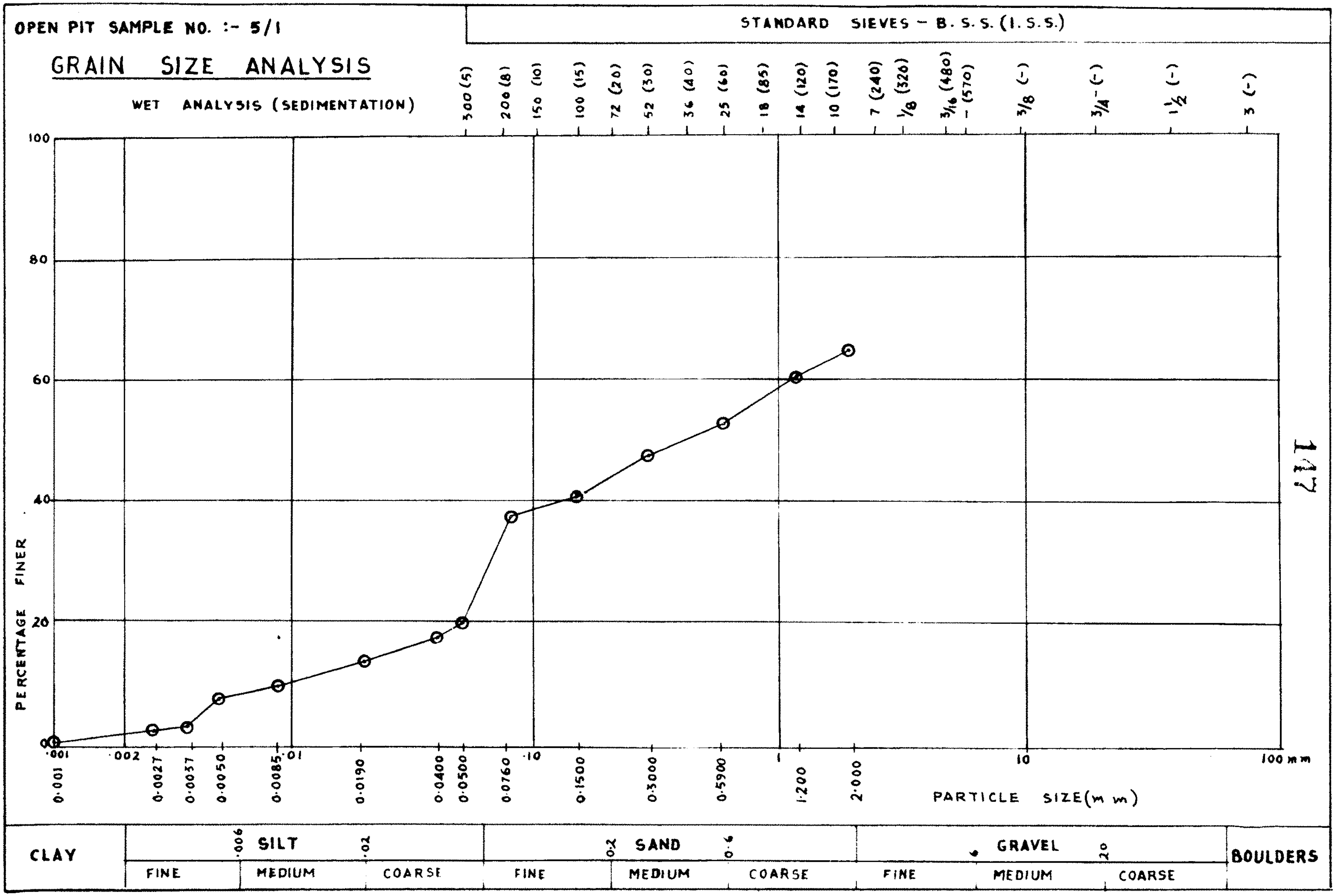
B. HYDROMETER ANALYSIS:

Time Interval	Particle Diameter (mm)	Per cent Finer
1/2 m	0.0500	20
1 m	0.0400	18
4 m	0.0190	14
19 m	0.0085	10
60 m	0.0050	8
120 m	0.0037	3
240 m	0.0027	2.5
24 hrs	0.0010	1.5

C. RESULTS OBTAINED FROM GRAIN SIZE DISTRIBUTION CURVE:

Soil Fractions	Coarse %	Medium %	Fine %	Total %
Gravel	-	-	35	35
Sand	12	9	12	33
Silt	18	5	7	30
Clay	-	-	2	2

GRAPH VI. 1


OPEN PIT SAMPLE NO. :- 5/1
GRAIN SIZE ANALYSIS
WET ANALYSIS (SEDIMENTATION)
STANDARD SIEVES – B.S.S. (I.S.S.)
300 (5)
200 (8)
150 (10)
100 (15)
72 (20)
52 (30)
36 (40)
25 (60)
18 (85)
14 (120)
10 (170)
7 (240)
1/8 (326)
3/16 (480)
– (570)
3/8 (-)
3/4 (-)
1 1/2 (-)
3 (-)
100
80
60
40
20
0
PERCENTAGE FINER
·001
·002
·01
·10
1
10
100 mm
0·001
0·0027
0·0037
0·0050
0·0085
0·0190
0·0400
0·0500
0·0760
0·1500
0·3000
0·5900
1·200
2·000
PARTICLE SIZE (m m)
CLAY
SILT
·006
·02
SAND
0·2
0·6
GRAVEL
20
BOULDERS
FINE
MEDIUM
COARSE
FINE
MEDIUM
COARSE
FINE
MEDIUM
COARSE

GRAIN SIZE ANALYSIS

Sample No. 5/2

A. SIEVE ANALYSIS:

BS Sieve (Mesh No.)	Particle Diameter (mm)	Per cent Finer
10	2.0000	60
16	1.2000	59
30	0.5900	50
60	0.3000	37
100	0.1500	28
200	0.0760	25

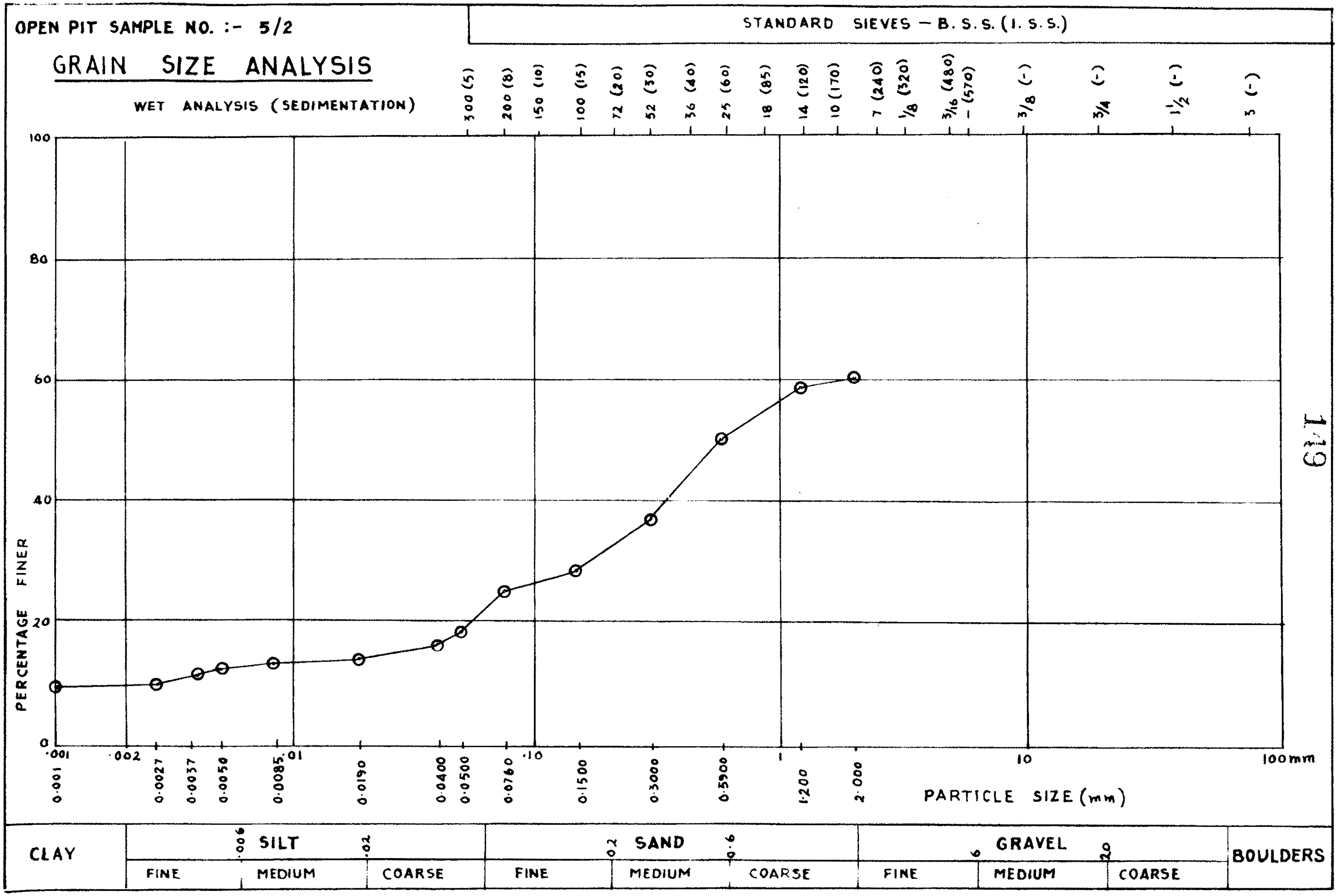
B. HYDROMETER ANALYSIS:

Time Interval	Particle Diameter (mm)	Per cent Finer
1/2 m	0.0500	18
1 m	0.0400	16
4 m	0.0190	14
19 m	0.0085	13
60 m	0.0050	12
120 m	0.0037	11
240 m	0.0027	10
24 hrs	0.0010	9

C. RESULTS OBTAINED FROM GRAIN SIZE DISTRIBUTION CURVE:

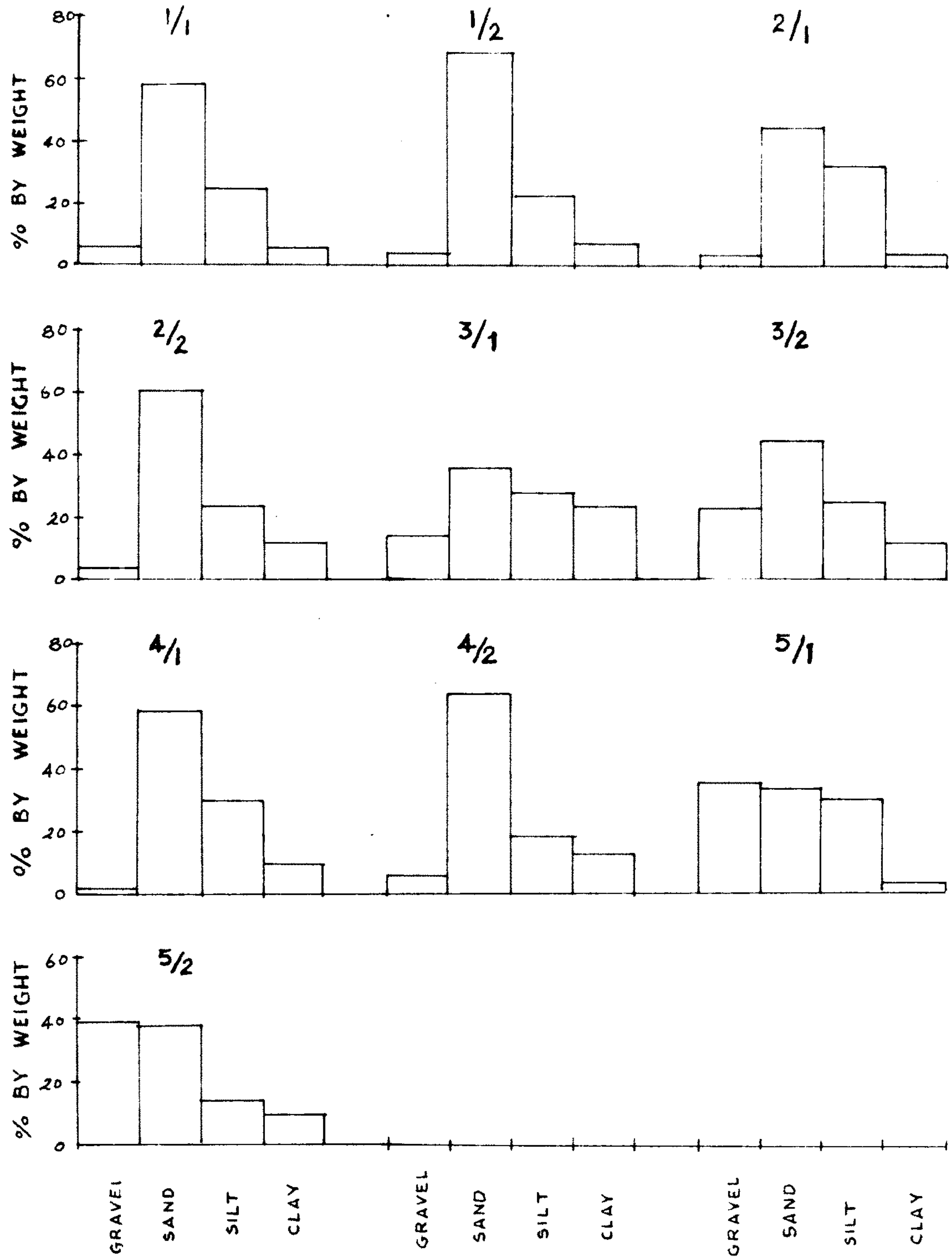
Soil Fractions	Course %	Medium %	Fine %	Total %
Gravel	-	-	40	40
Sand	10	18	10	38
Silt	8	1	3	12
Clay	-	-	10	10

GRAPH VI. 1



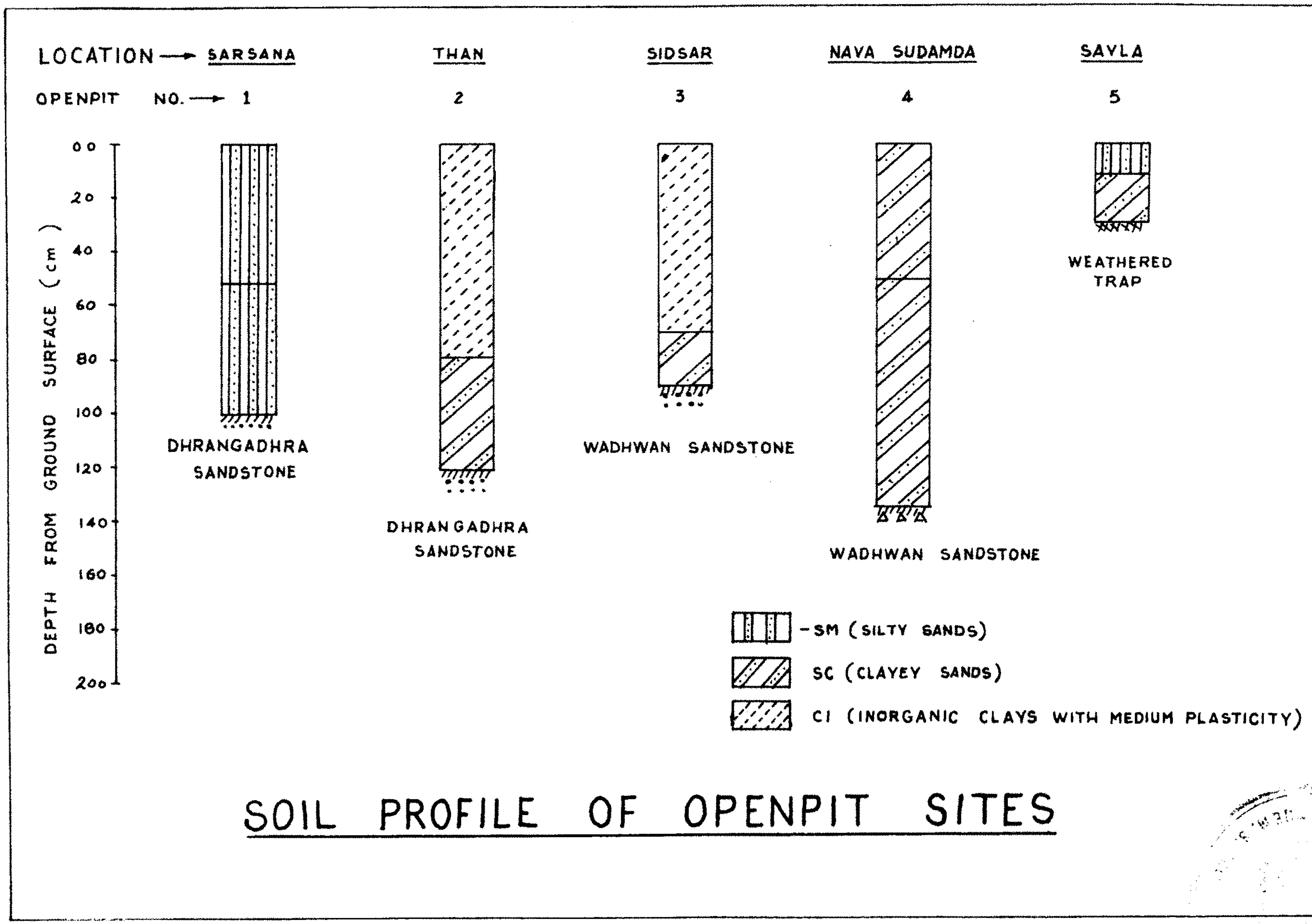
I R BUTION CURVE

GRAPH VI. 2



HISTOGRAMS OF SOIL SAMPLES FROM OPEN PITS

FIG. VI.2



SOIL PROFILE OF OPENPIT SITES

specified as per test. Dry densities at different water contents, were calculated by using the formula given in Appendix VI.1 p.256.

The maximum dry density (MDD) and optimum moisture content (OMC) of each openpit soil sample, were determined from Graph VI.3 in which dry density (Unit weight of soil) was plotted against moisture content. The results of compaction test are used in earth construction, viz. dams, retaining walls, highways and airports, where dry density of soil is an important factor.

(5) Penetration Resistance (IS:2720 P.XVI, 1965): It is a measure of the firmness of the soil and is expressed in pounds per square inch. It is also known as California Bearing Ratio. In the laboratory, this test was carried out on soil passing 3/4 inch BS sieve. Wet soil sample, prepared by using the results of Proctor compaction test, was filled in mould. The mould, along with the sample was used to find out the required loads at different penetration values. Penetration in inch, verses load in pound, were plotted on the Graph VI.4. The CBR value percentages for 0.1 and 0.2 inch penetrations in unsoaked conditions, were calculated with the help of standard loads for the above penetrations. CBR value percentages in soaked condition,

STANDARD PROCTOR TEST

Sample No. 1/1

Lab. No.	Water added %	Moisture content %	Dry Density lb/cft	Dry Density gm/cm^3
1	3.0	3.9	104.00	1.666
2	3.0	5.9	116.00	1.858
3	3.0	8.6	123.00	1.970
4	3.0	11.8	119.00	1.906

Results obtained from Graph:

Maximum dry density (MDD) 123.0 lb/cft (1.970 gm/cm^3)

Optimum moisture content (OMC) 8.6%

Sample No. 1/2

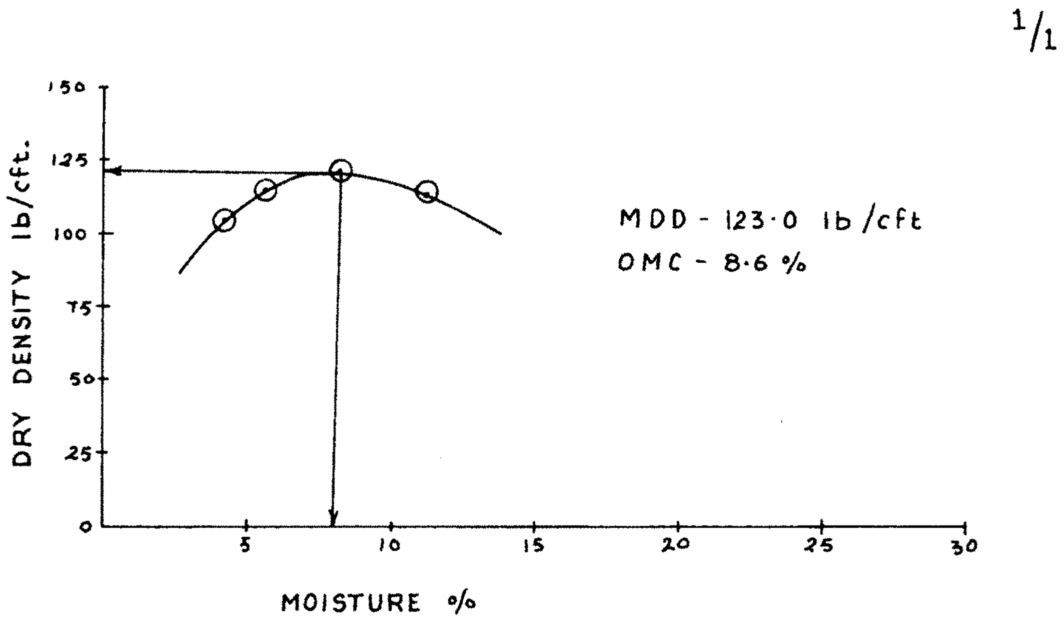
Lab.No.	Water added %	Moisture content %	Dry Density lb/cft	Dry Density gm/cm^3
1	4	4.2	113.0	1.778
2	4	8.9	122.0	1.954
3	4	11.0	121.0	1.938
4	4	14.6	115.0	1.842

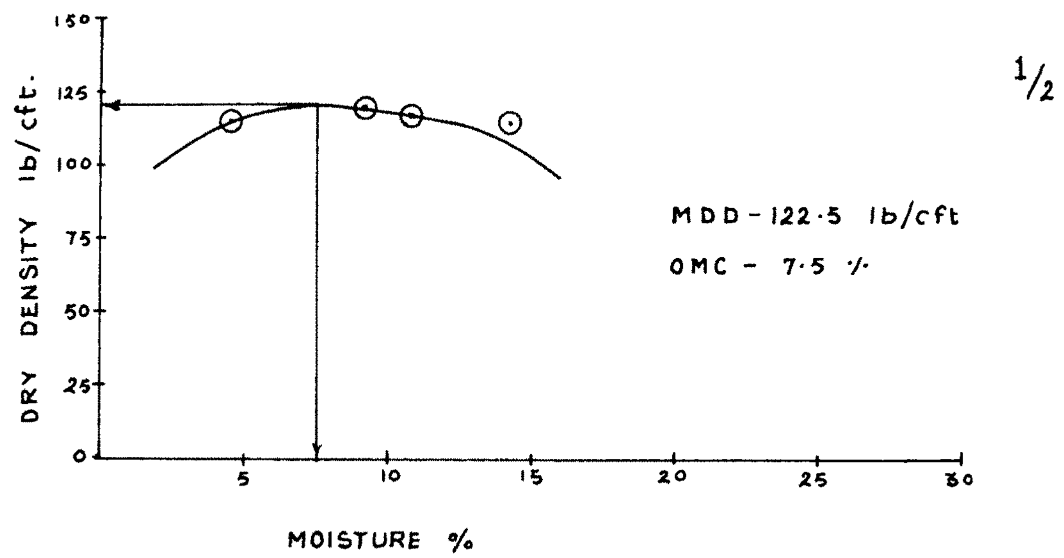
Results obtained from Graph:

Maximum dry density (MDD) 122.50 (1.962 gm/cm^3)

Optimum moisture content (OMC) 7.5%

GRAPH VI. 3





MOISTURE PERCENT - DRY DENSITY RELATIONSHIP
(STANDARD PROCTOR TEST)

STANDARD PROCTOR TEST

Sample No. 2/1

Lab. No.	Water added %	Moisture content %	Dry Density lb/cft	Dry Density gm/cm^3
1	3.0	8.7	99.0	1.586
2	3.0	11.8	106.0	1.698
3	3.0	14.6	110.0	1.762
4	3.0	17.8	107.0	1.714

Results obtained from Graph:

Maximum dry density (MDD) 110 lb/cft (1.762 gm/cm^3)

Optimum moisture content (OMC) 14.60%

Sample No. 2/2

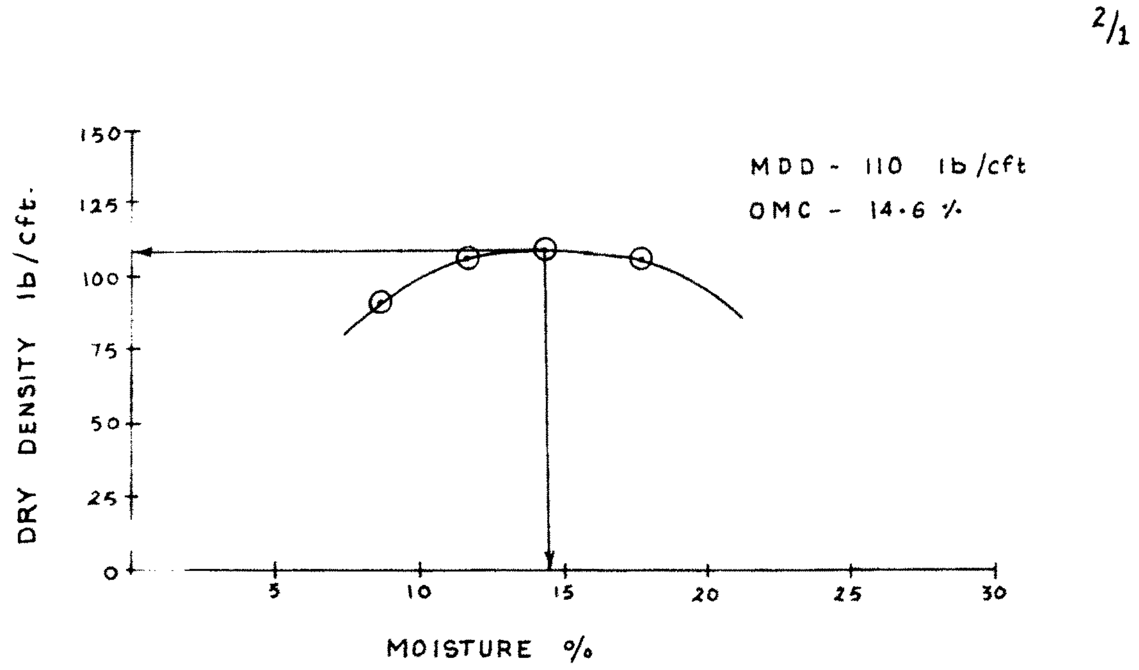
Lab. No.	Water added %	Moisture content %	Dry Density lb/cft	Dry Density gm/cm^3
1	3	5.1	104.0	1.666
2	3	8.8	115.0	1.842
3	3	11.5	120.0	1.922
4	3	14.0	111.0	1.778

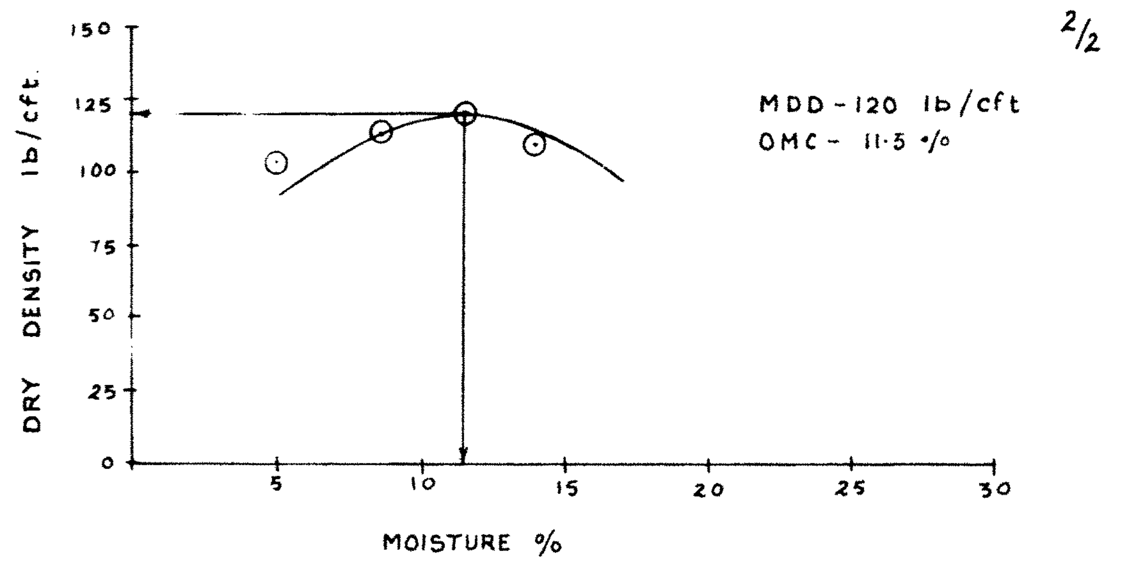
Results obtained from Graph:

Maximum dry density (MDD) 120.0 lb/cft (1.922 gm/cm^3)

Optimum moisture content (OMC) 11.5%

GRAPH VI. 3





MOISTURE PERCENT - DRY DENSITY RELATIONSHIP

(STANDARD PROCTOR TEST)

STANDARD PROCTOR TEST

Sample No. 3/1

Lab. No.	Water added %	Moisture content %	Dry density lb/cft	Dry density gm/cm^3
1	4	12.3	96.0	1.538
2	4	16.1	101.0	1.618
3	4	21.4	103.0	1.650
4	4	26.4	93.0	1.490

Results obtained from Graph:

Maximum dry density (MDD) 107.5 lb/cft (1.722 gm/cm^3)

Optimum moisture content (OMC) 18.0%

Sample No. 3/2

Lab. No.	Water added %	Moisture content %	Dry density lb/cft	Dry density gm/cm^3
1	3	12.25	109.25	1.750
2	3	14.75	114.75	1.834
3	3	17.40	114.35	1.832
4	3	20.10	110.00	1.762

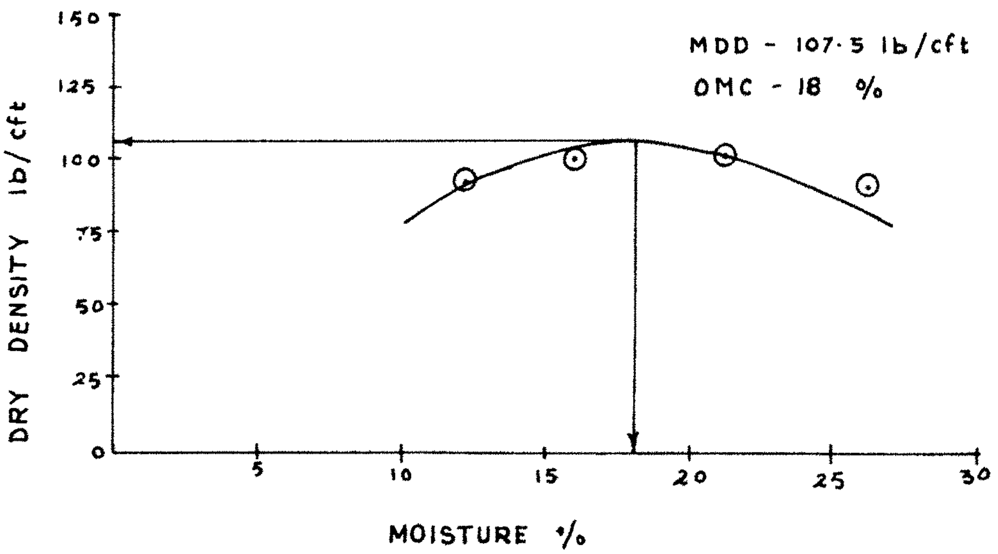
Results obtained from Graph:

Maximum dry density (MDD) 117.50 lb/cft (1.882 gm/cm^3)

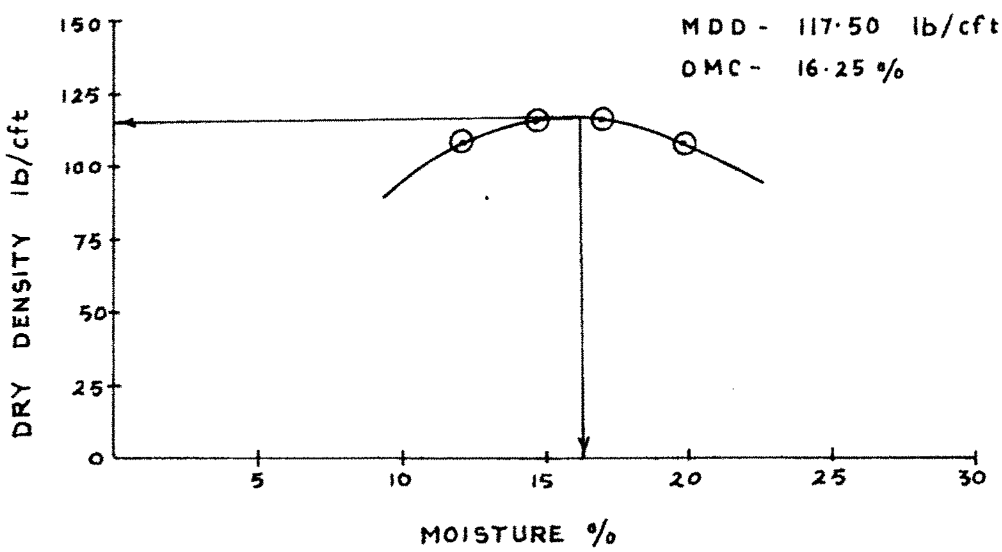
Optimum moisture content (OMC) 16.25%.

GRAPH VI.3

3/1



3/2



MOISTURE PERCENT - DRY DENSITY RELATIONSHIP
(STANDARD PROCTOR TEST)

STANDARD PROCTOR TEST

Sample No. 4/1

Lab. No.	Water added %	Moisture content %	Dry density lb/cft	Dry density gm/cm^3
1	5	3.40	104.0	1.666
2	5	8.20	111.0	1.778
3	5	13.50	113.0	1.810
4	5	14.50	105.0	1.682

Results obtained from Graph:

Maximum dry density (MDD) 117.50 lb/cft (1.882 gm/cm^3)

Optimum moisture content (OMC) 11.25%

Sample No.4/2

Lab. No.	Water added %	Moisture content %	Dry density lb/cft	Dry density gm/cm^3
1	3	6.4	110.0	1.762
2	3	9.2	113.0	1.810
3	3	13.4	115.0	1.842
4	3	17.5	108.0	1.730

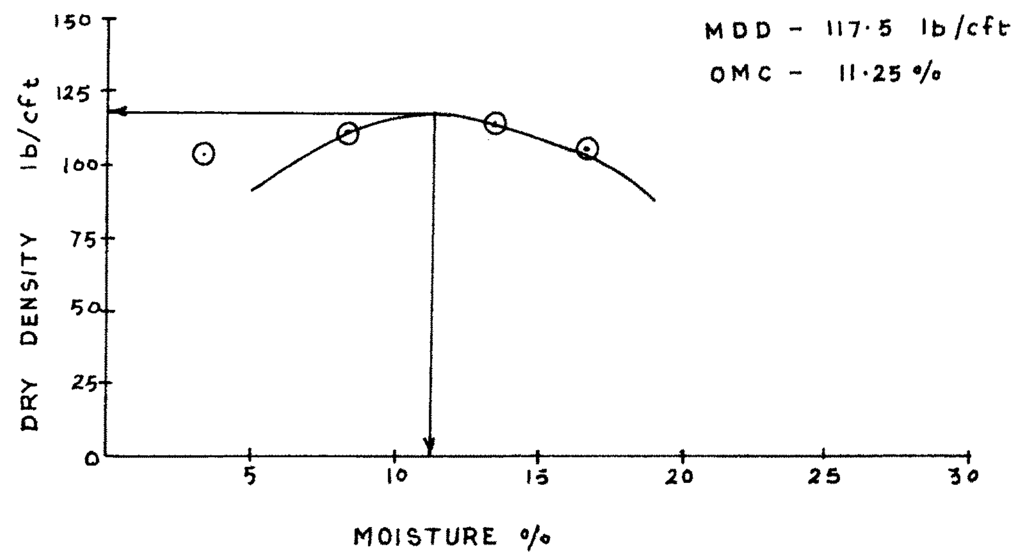
Results obtained from Graph:

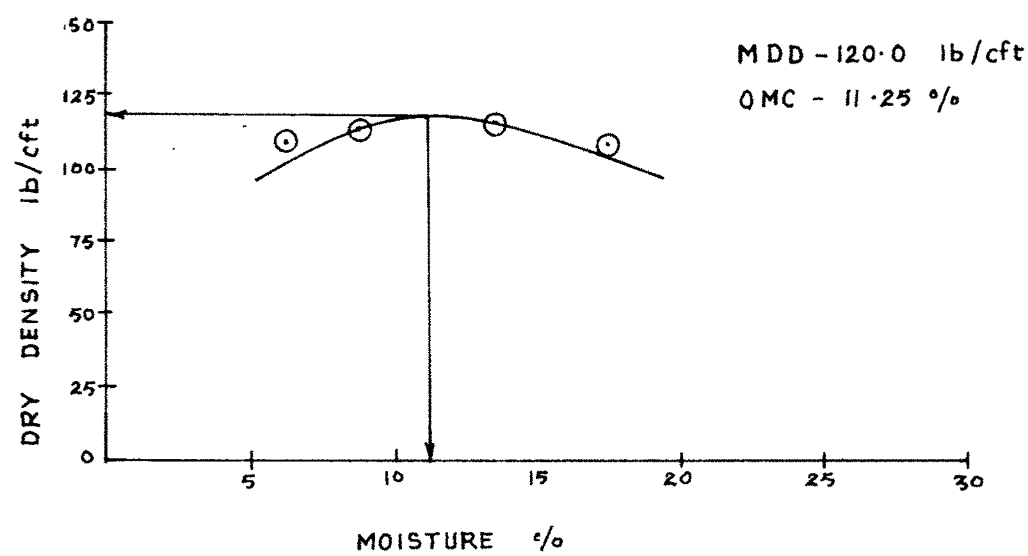
Maximum dry density (MDD) 120.0 lb/cft (1.922 gm/cm^3)

Optimum moisture content (OMC) 11.25%

GRAPH VI.3

4/1





MOISTURE PERCENT - DRY DENSITY RELATIONSHIP
(STANDARD PRCCTOR TEST)

STANDARD PROCTOR TEST

Sample No. 5/1

Maximum dry density 132.25 lb/cft (2.118 gm/cm^3)
Minimum dry density 114.50 lb/cft (1.834 gm/cm^3)

Sample No. 5/2

Lab. No.	Water added	Moisture content %	Dry density lb/cft	Dry density gm/cm^3
1	3	5.6	119.0	1.906
2	3	7.6	120.0	1.922
3	3	8.9	122.0	1.954
4	3	13.9	125.0	2.002

Results obtained from Graph:

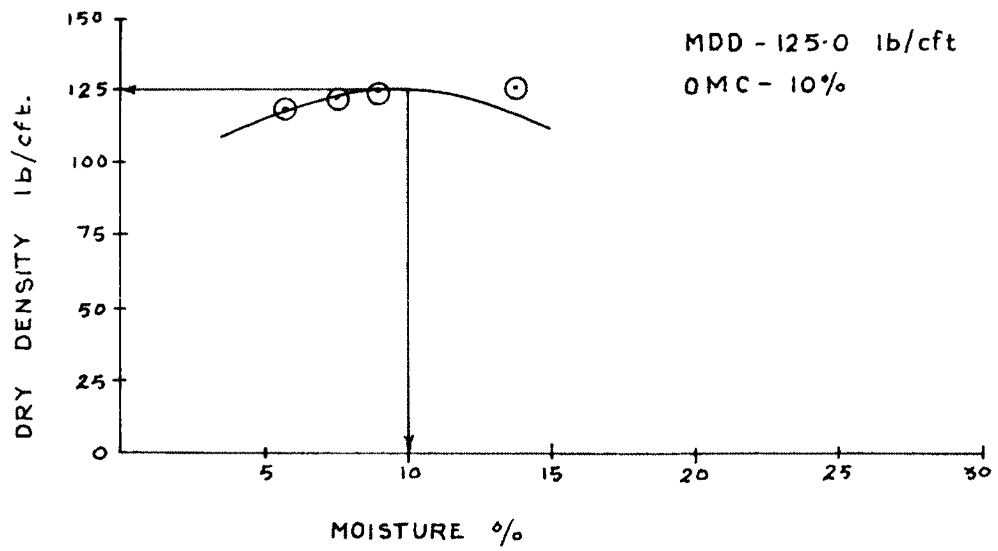
Maximum dry dnesity (MDD) 125.0 lb/cft (2.002 gm/cm^3)
Optimum moisture content (OMC) 10.0%

GRAPH VI. 3

5/1

MAXIMUM DRY DENSITY - 132·25 lb/cft
MINIMUM DRY DENSITY - 114·50 lb/cft

5/2



MOISTURE PERCENT - DRY DENSITY RELATIONSHIP
(STANDARD PROCTOR TEST)

CALIFORNIA BEARING RATIO TEST
(PENETRATION RESISTANCE)

Sample No. 1/1

Penetration of Plunger		Load on Plunger				Load on Plunger for 100% CBR	
		Before soaking		After soaking			
Inch	mm	lb	kg	lb	kg	lb	kg
0.000	0.000	0	0	0	0		
0.025	0.625	238.00	107.96	68.00	30.84		
0.050	1.250	326.00	147.87	95.00	43.09		
0.075	1.875	487.00	220.90	122.00	55.34		
0.100	2.500	715.00	324.32	144.00	65.32	3000	1370
0.150	3.750	910.00	412.78	181.00	82.10		
0.200	5.000	1080.00	489.89	222.00	100.70	4500	2055

Results: CBR % for

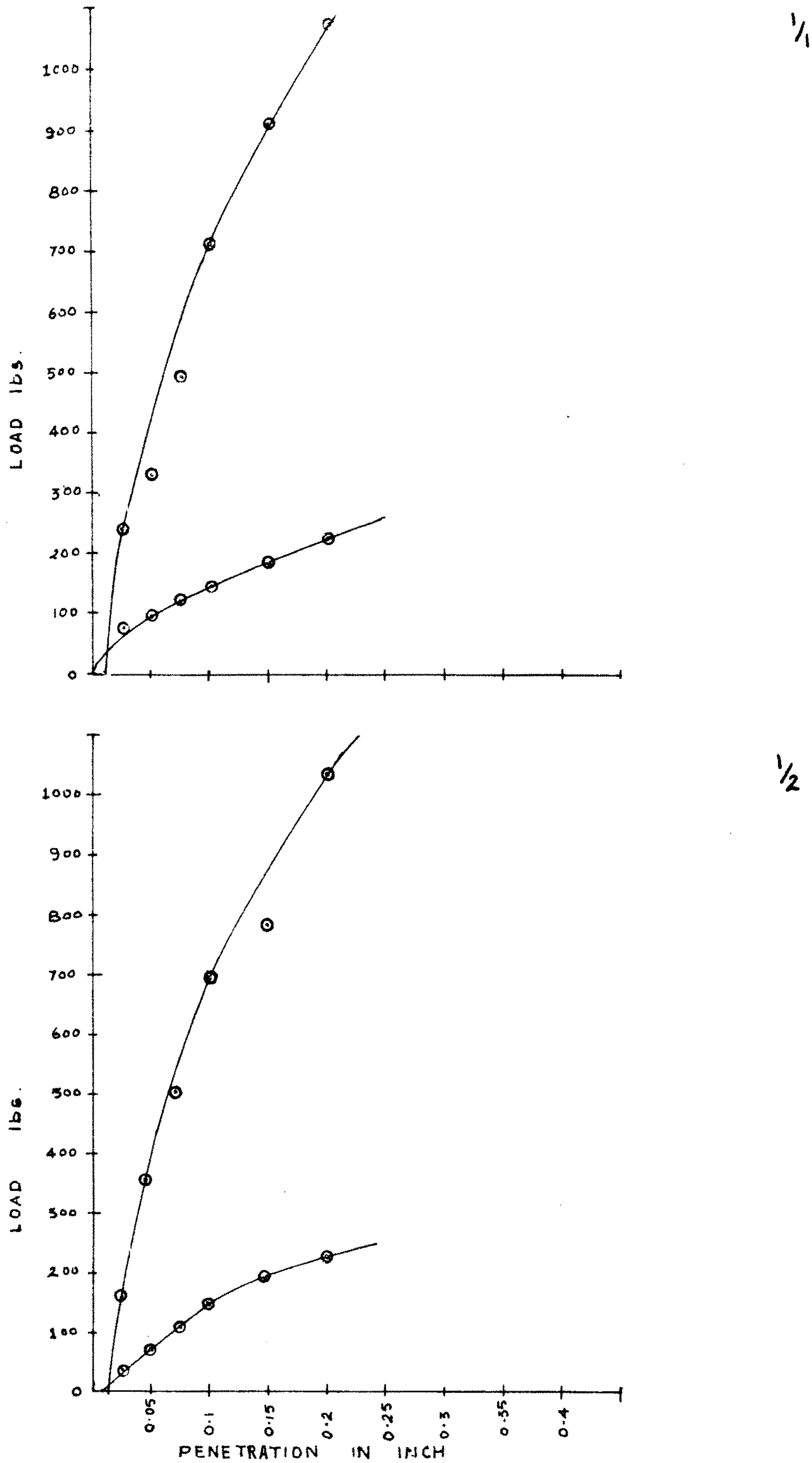
0.1	2.5	23.76	4.77
0.2	5.0	24.00	4.92
Final CBR %		24.00	5.00

Sample No. 1/2

Penetration of Plunger		Load on Plunger				Load on Plunger for 100% CBR	
		Before soaking		After soaking			
Inch	mm	lb	kg	lb	kg	lb	kg
0.000	0.000	0	0	0	0		
0.025	0.625	168.02	76.21	43.36	19.67		
0.050	1.250	357.72	162.26	78.59	35.65		
0.075	1.875	506.77	229.87	111.11	50.40		
0.100	2.500	691.05	313.46	157.18	71.30	3000	1370
0.150	3.750	780.48	354.02	195.12	88.51		
0.200	5.000	1035.22	469.57	233.06	105.72	4500	2055

Results: CBR % for

0.1	2.5	22.95	5.22
0.2	5.0	22.92	5.16
Final CBR %		23.00	5.00



CALIFORNIA BEARING RATIO TEST

(PENETRATION TEST)

CALIFORNIA BEARING RATIO TEST
(PENETRATION RESISTANCE)

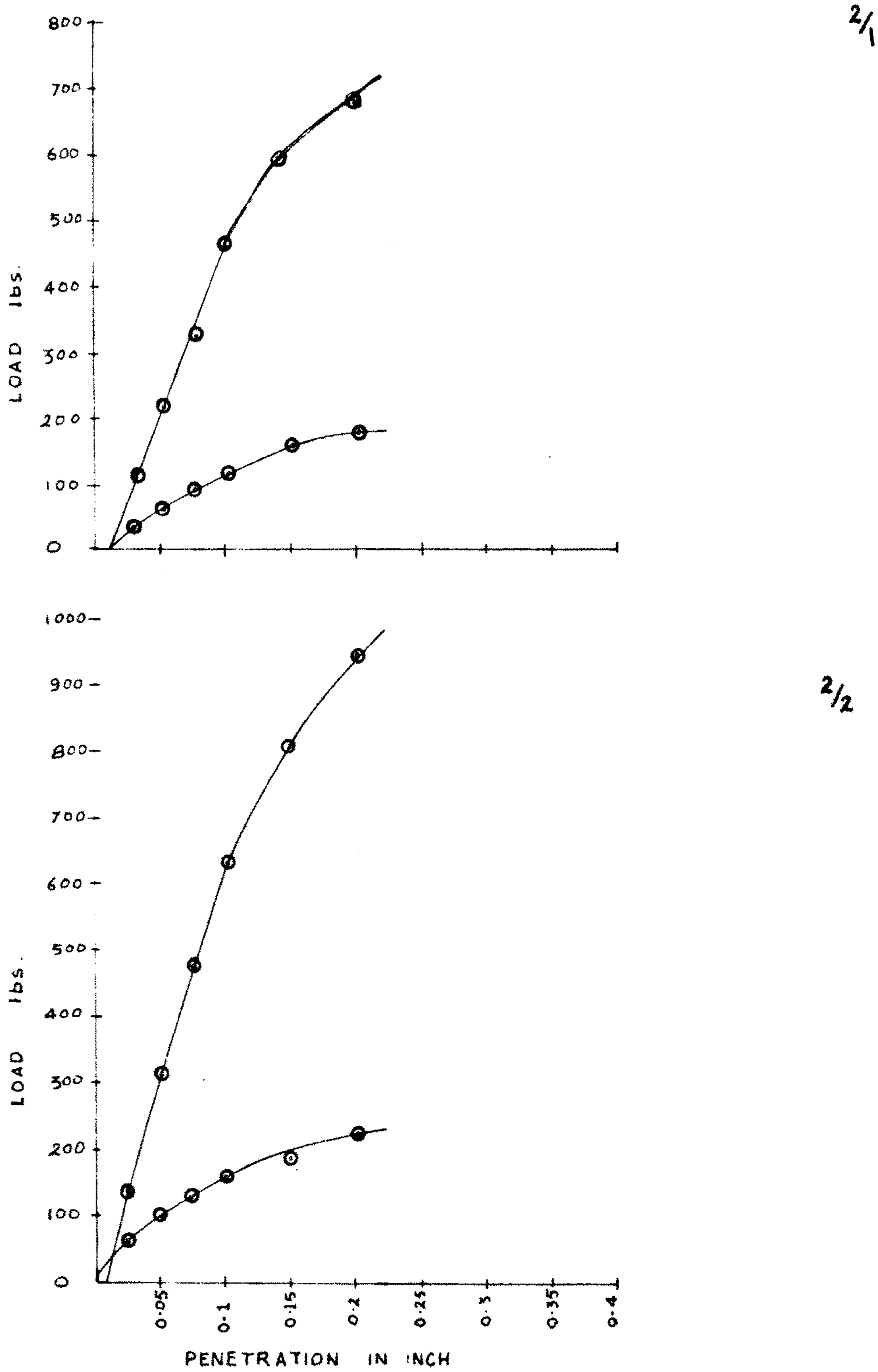
Sample No. 2/1

Penetration of Plunger		Load on Plunger				Load on Plunger for 100% CBR	
		Before soaking		After soaking			
Inch	mm	lb	kg	lb	kg	Lb	kg
0.000	0.000	0	0	0	0		
0.025	0.625	121.95	55.32	32.52	14.75		
0.050	1.250	216.80	98.34	59.62	27.04		
0.075	1.875	330.62	149.97	94.85	43.02	3000	1370
0.100	2.500	460.70	208.97	121.95	55.32		
0.150	3.750	585.36	263.62	151.76	68.84		
0.200	5.000	677.50	307.31	178.86	81.13	4500	2055
Results CBR % for							
0.1	2.5	15.30		4.05			
0.2	5.0	15.00		3.96			
Final CBR %		15.00		4.00			

Sample No. 2/2

Penetration of Plunger		Load on Plunger				Load on Plunger for 100% CBR	
		Before soaking		After soaking			
Inch	mm	lb	kg	lb	kg	lb	kg
0.000	0.000	0	0	0	0		
0.025	0.625	130.00	58.97	57.00	25.85		
0.050	1.250	311.65	141.36	95.00	43.09		
0.075	1.875	469.00	212.74	127.00	57.61		
0.100	2.500	629.00	285.31	152.00	68.95	3000	1370
0.150	3.750	802.00	363.79	190.00	86.18		
0.200	5.000	943.00	427.74	225.00	102.06	4500	2055
Results CBR % for							
0.1	2.5	20.88		5.04			
0.2	5.0	20.88		4.98			
Final CBR %		21.00		5.00			

GRAPH VI.4



CALIFORNIA BEARING RATIO TEST

(PENETRATION TEST)

CALIFORNIA BEARING RATIO TEST
(PENETRATION RESISTANCE)

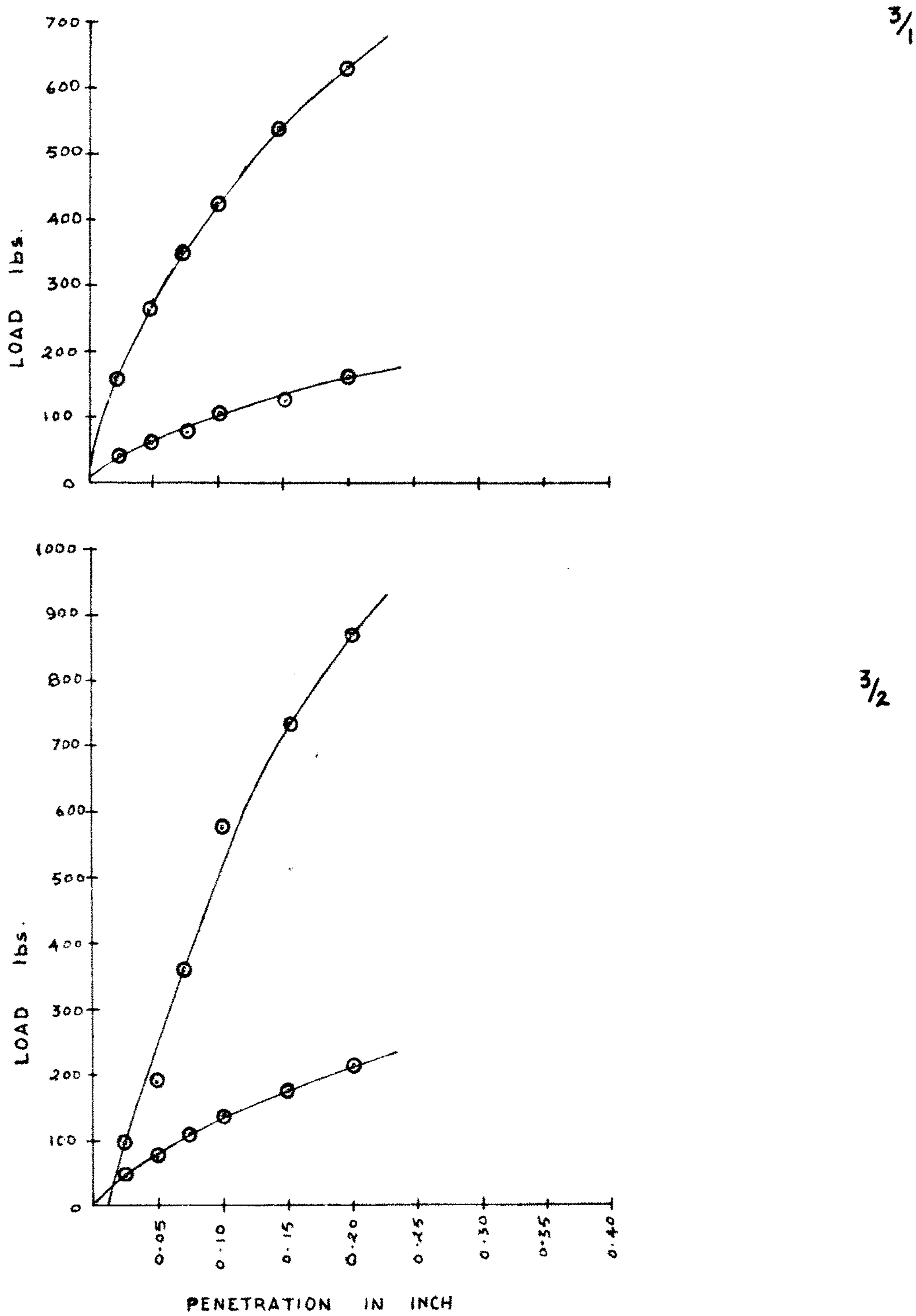
Sample No. 3/1

Penetration of Plunger		Load on Plunger				Load on Plunger for 100% CBR	
		Before soaking		After soaking			
Inch	mm	lb	kg	lb	kg	lb	kg
0.000	0.000	0	0	0	0		
0.025	0.625	160.00	72.58	32.50	14.74		
0.050	1.250	284.00	128.82	59.06	26.79		
0.075	1.875	355.00	161.02	84.00	38.10		
0.100	2.500	420.00	190.51	108.00	48.99	3000	1370
0.150	3.750	534.00	242.22	138.00	62.60		
0.200	5.000	631.00	286.22	163.00	73.78	4500	2055
Results CBR % for							
0.1	2.5	13.95		3.60			
0.2	5.0	13.98		3.60			
Final CBR %		14.00		3.60			

Sample No. 3/2

Penetration of Plunger		Load on Plunger				Load on Plunger for 100% CBR	
		Before soaking		After soaking			
Inch	mm	lb	kg	lb	kg	lb	kg
0.000	0.000	0	0	0	0		
0.025	0.625	92.00	41.73	41.00	18.60		
0.050	1.250	189.70	86.05	73.00	33.11		
0.075	1.875	358.00	162.39	105.50	47.63		
0.100	2.500	574.50	260.59	138.00	62.60	3000	1370
0.150	3.750	732.00	322.03	171.00	77.56		
0.200	5.000	867.00	393.27	306.00	138.80	4500	2055
Results CBR % for							
0.1	2.5	19.08		4.54			
0.2	5.0	19.20		5.56			
Final CBR %		19.00		4.50			

GRAPH VI. 4



CALIFORNIA BEARING RATIO TEST

(PENETRATION TEST)

CALIFORNIA BEARING RATIO TEST
(PENETRATION RESISTANCE)

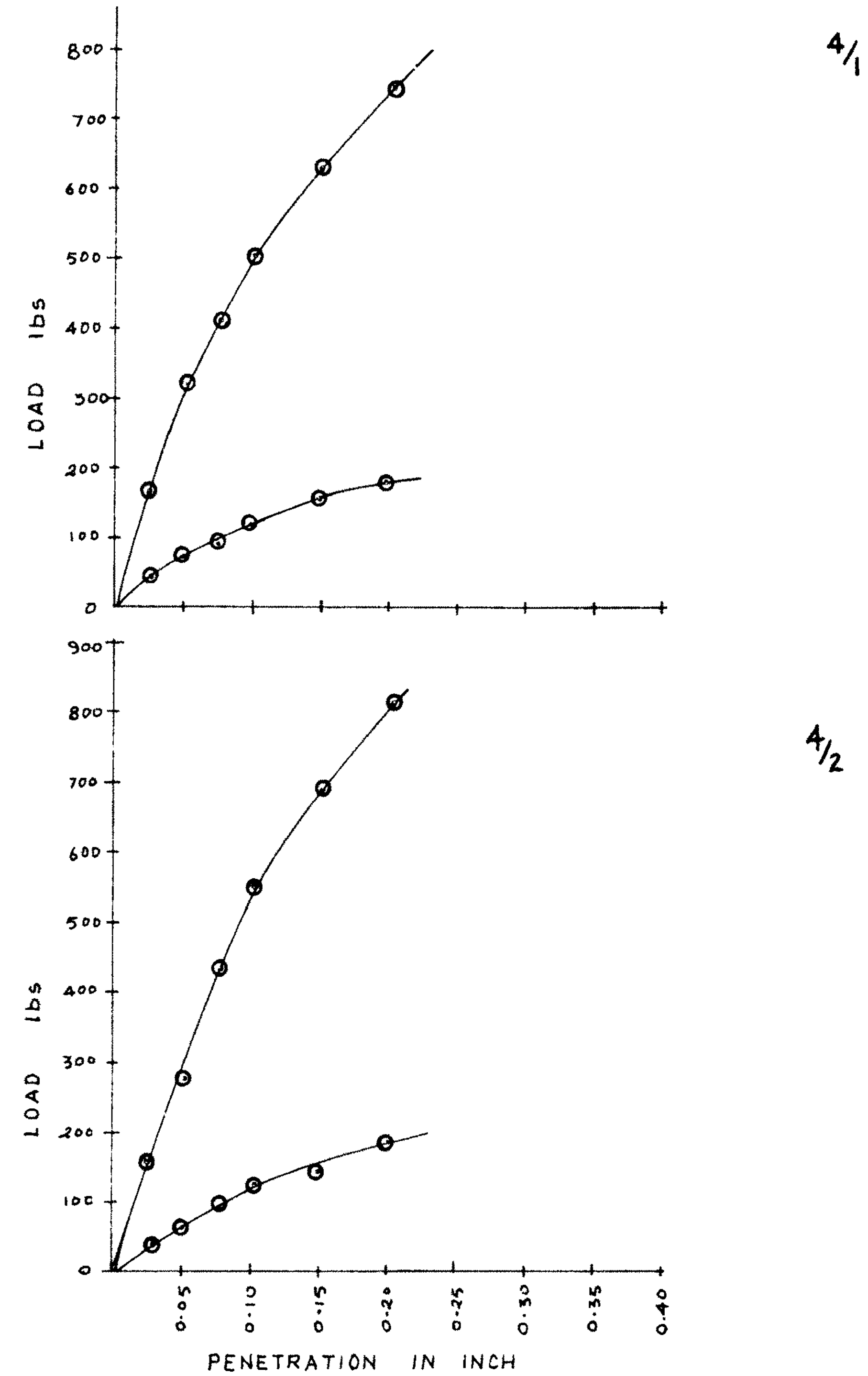
Sample No. 4/1

Penetration Plunger		Load on Plunger				Load on Plunger for 100% CBR	
		Before soaking		After soaking			
Inch	mm	lb	kg	lb	kg	lb	kg
0.000	0.000	0	0	0	0		
0.025	0.625	162.50	73.71	40.50	18.37		
0.050	1.250	319.70	145.02	70.50	31.98		
0.075	1.875	412.00	186.88	89.43	40.56		
0.100	2.500	507.00	229.97	119.00	53.98	3000	1370
0.150	3.750	634.00	287.58	157.00	71.21		
0.200	5.000	748.00	339.29	181.50	82.33	4500	2055
Results CBR % for							
0.1	2.5	16.83		3.96			
0.2	5.0	16.56		4.02			
Final CBR %		17.00		4.00			

Sample No. 4/2

Penetration Plunger		Load on Plunger				Load on Plunger for 100% CBR	
		Before soaking		After soaking			
Inch	mm	lb	kg	lb	kg	lb	kg
0.000	0.000	0	0	0	0	0	
0.025	0.625	149.00	67.59	32.50	14.74		
0.050	1.250	165.50	120.43	54.00	24.49		
0.075	1.875	420.00	190.51	86.70	39.33		
0.100	2.500	542.00	245.85	119.00	53.98	3000	1370
0.150	3.750	677.50	307.31	135.50	60.56		
0.200	5.000	807.70	366.37	176.00	79.83	4500	2055
Results CBR % for							
0.1	2.5	18.00		3.96			
0.2	5.0	17.88		3.90			
Final CBR %		18.00		4.00			

GRAPH VI. 4



CALIFORNIA BEARING RATIO TEST

(PENETRATION TEST)

CALIFORNIA BEARING RATIO TEST
(PENETRATION RESISTANCE)

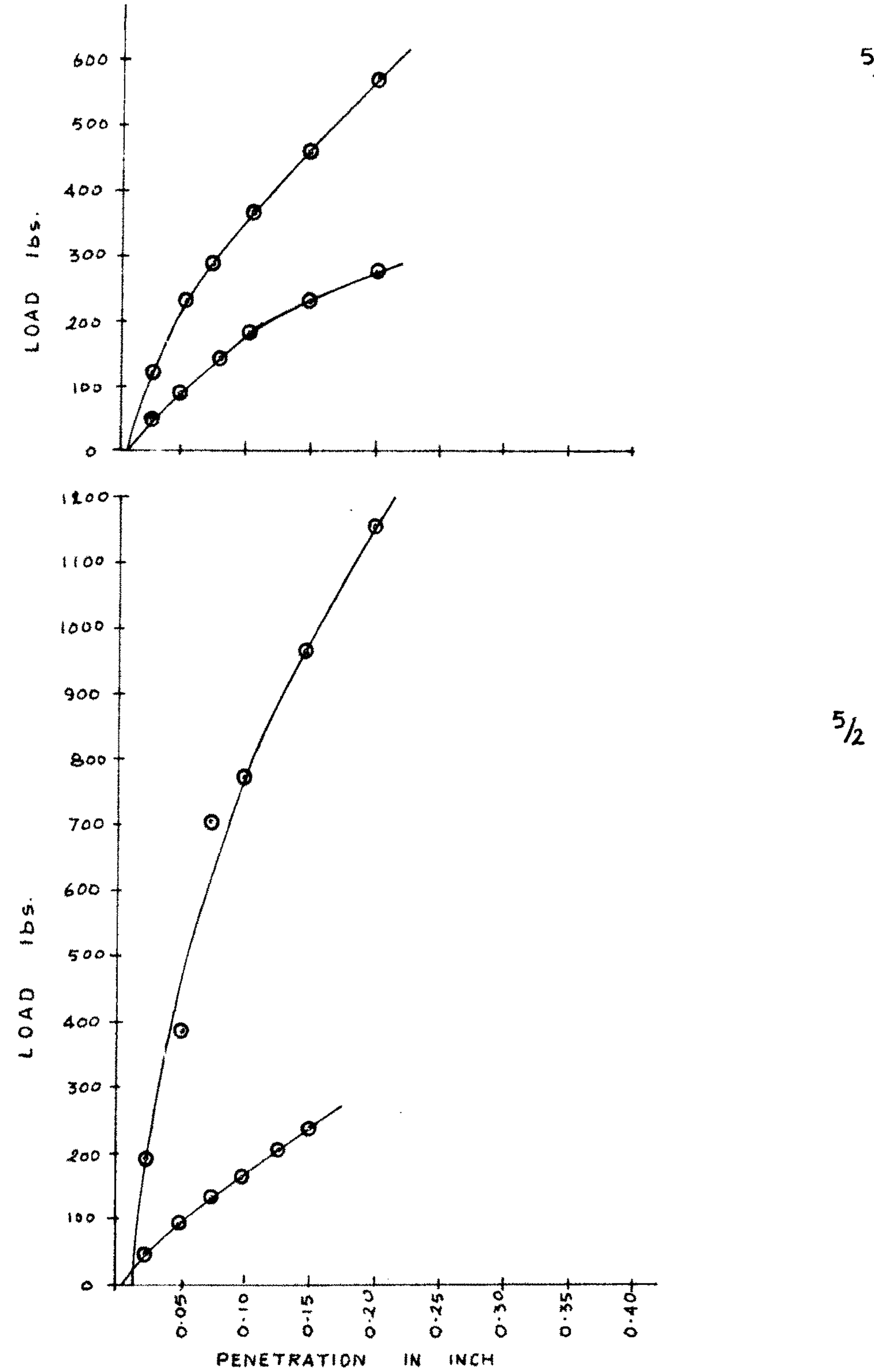
Sample No. 5/1

Penetration Plunger		Load on Plunger				Load on Plunger for 100% CBR	
		Before soaking		After soaking			
Inch	mm	lb	kg	lb	kg	lb	kg
0.000	0.000	0	0	0	0		
0.025	0.625	125.00	56.70	57.00	25.85		
0.050	1.250	235.50	101.38	92.00	41.73		
0.075	1.875	284.50	129.05	115.50	52.39		
0.100	2.500	379.50	172.14	189.50	85.96	3000	1370
0.150	3.750	460.50	208.88	235.00	106.60		
0.200	5.000	567.00	257.19	271.00	122.93	4500	2055
Results CBR % for							
0.1	2.5	12.60		6.30			
0.2	5.0	12.60		6.00			
Final CBR %		12.60		6.00			

Sample No. 5/2

Penetration Plunger		Load on Plunger				Load on Plunger for 100% CBR	
		Before soaking		After soaking			
Inch	mm	lb	kg	lb	kg	lb	kg
0.000	0.000	0	0	0	0		
0.025	0.625	195.00	88.45	48.50	22.00		
0.050	1.250	393.00	178.26	86.50	39.24		
0.075	1.875	704.50	319.56	124.50	56.47		
0.100	2.500	775.00	351.54	162.50	73.71	3000	1370
0.150	3.750	962.00	436.36	203.00	92.08		
0.200	5.000	1165.00	528.44	246.50	111.81	4500	2055
Results CBR % for							
0.1	2.5	25.74		5.40			
0.2	5.0	25.80		5.46			
Final CBR %		26.00		5.50			

GRAPH VI.4



CALIFORNIA BEARING RATIO TEST

(PENETRATION TEST)

were also determined for the same soil samples, after making saturated with water for 4 days. The results of penetration test, are used in the design of highway and railway embankment where CBR value is an important factor.

(6) Permeability Test (IS:2720 P.XVII, 1966): It was carried out on soil passing 3/4 inch BS sieve. Wet soil sample, prepared by using the results of Proctor compaction test, was filled in the permeability mould. It was then kept under water for 3 days. The saturated soil sample was tested for constant discharge cc/sec under constant head permeameter. The coefficient of permeability at 27°C was calculated for each openpit soil sample by using the formula given in Appendix VI.1 p.256.

(7) Shearing Strength (IS:2720 P.XIII, 1965): Stress and strain were determined with the help of Box-shear equipment. This test is known as Direct Shear test or undrained (quick) test. The soil passing 3/16 inch BS sieve was used. Wet soil, prepared by using the results of Proctor compaction test, was used to prepare samples which were filled in shear boxes. After immersing them in water till saturation, normal load was applied to each soil sample for about 45 minutes. This sample was moved

horizontally when the unit was operated. The load equivalent was obtained from dial reading. Dividing the load equivalent by the area of sample the shear stress was calculated. The cohesion (c) and the internal friction angle (ø) were obtained from Graph VI.5 in which normal stress was plotted against shear stress.

The test results of each openpit soil samples are given in Table VI.3.

The characteristic properties for SM, SC and CI Soil types are given in the following table:

Characteristics Properties	Soil Type		
	SM	SC	CI
Atterberg limits:			
Liquid limits (%)	Non plastic	27 - 38	41 - 43
Plastic limit (%)	"	14 - 22	23 - 25
Plastic Index (%)	"	10 - 16	18
Maximum Dry Density (lb/cft)	122 - 132	117.5 - 127.0	107.5 - 110.0
Optimum Moisture Content (%)	7.5 - 8.6	11.5 - 16.2	14.6 - 18.0
Permeability(cm/sec)	9.5 x 10^{-4} - 6.0 x 10^{-5} (Pervious to Semi-pervious)	2.0 x 10^{-6} - 8.0 x 10^{-6} (Impervious to Semi-pervious)	Impervious
Specific Gravity	2.76 - 2.81	2.64 - 2.66	2.58 - 2.60
Soaked CBR Value(%)	5 - 6	4 - 5.5	3.6 - 4.0
Shear Strength:			
Cohesion(lb/sq in)	0.0	0.5	1.0
Internal friction	34° - 35°	31° - 33°	25.0° - 25.5°

The suitability of openpit soils for general engineering purposes based on the results of index and engineering properties is determined with reference to Appendix VI.4 p.262.

SHEAR PARAMETERS

Sample No. 1/1

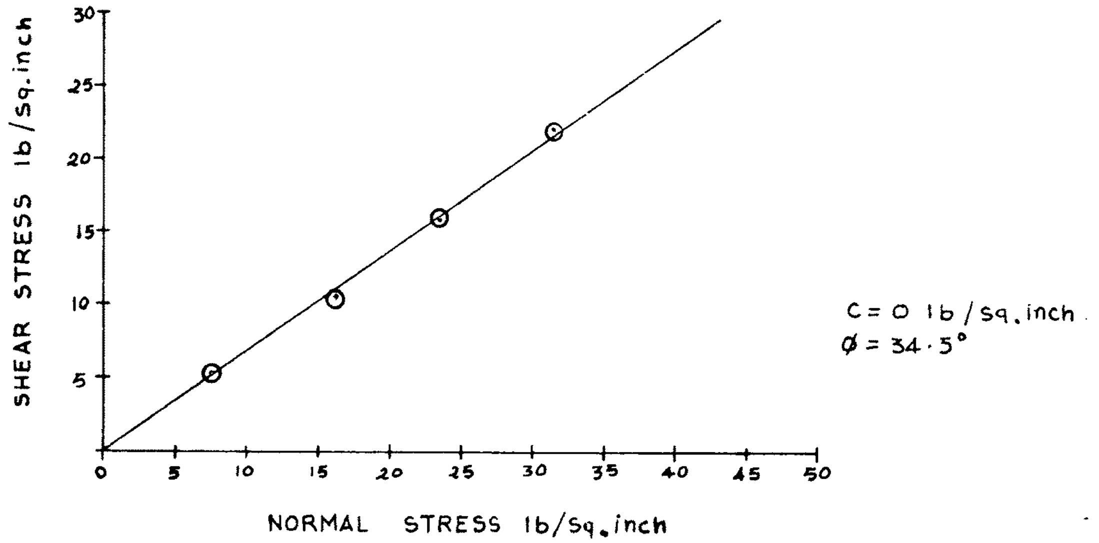
Lab. No.	Normal stress lb/sq in	(kg/cm^2)	Maximum shear stress lb/sq in	(kg/cm^2)	Cohesion lb/sq in	(kg/cm^2)	Internal friction (ø in degree)
1	7.78	(0.545)	5.45	(0.381)			
2	15.55	(1.088)	10.78	(0.755)	0.0	(0.0)	34.5
3	23.33	(1.633)	16.53	(1.157)			
4	31.11	(2.178)	21.98	(1.539)			

Sample No.1/2

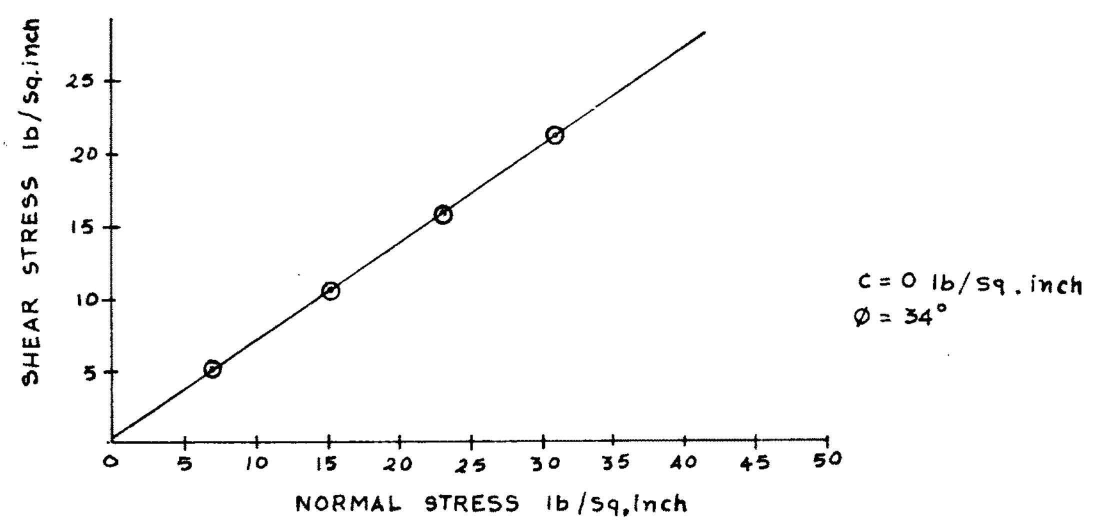
Lab. No.	Normal stress lb/sq in	(kg/cm^2)	Maximum shear stress lb/sq in	(kg/cm^2)	Cohesion lb/sq in	(kg/cm^2)	Internal friction (ø in degree)
1	7.78	(0.545)	5.35	(0.374)			
2	15.55	(1.088)	10.78	(0.755)	0.0	(0.0)	34.0
3	23.33	(1.633)	16.11	(1.128)			
4	31.11	(2.178)	21.43	(1.500)			

GRAPH VI. 5

1/1



1/2



SHEAR PARAMETERS (DIRECT-SHEAR TEST)

SHEAR PARAMATERS

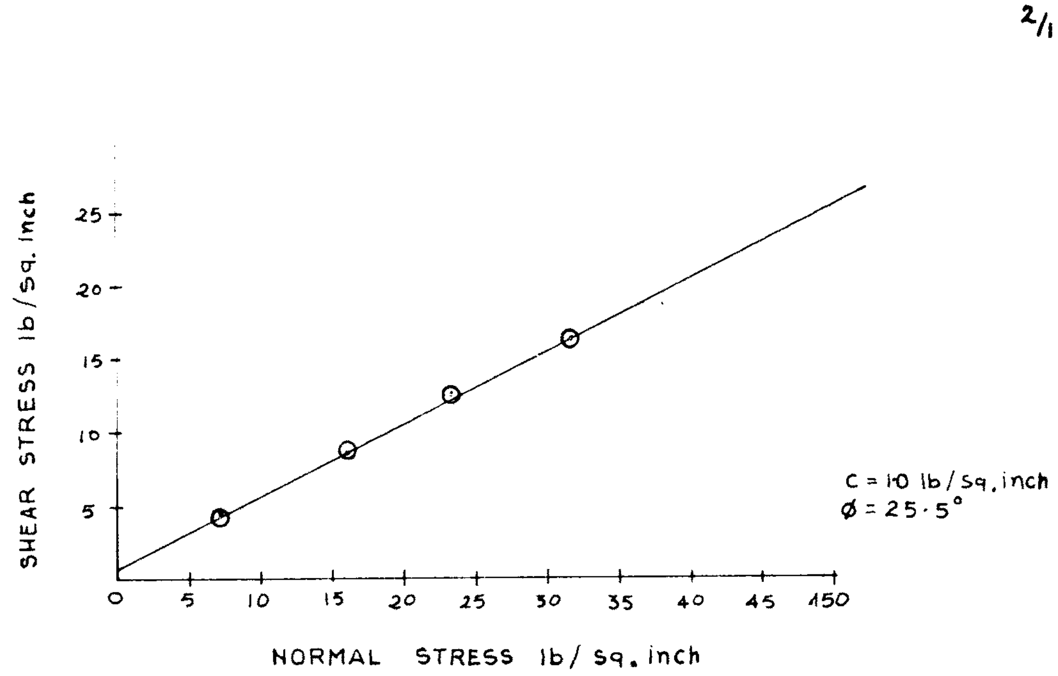
Sample No.2/1

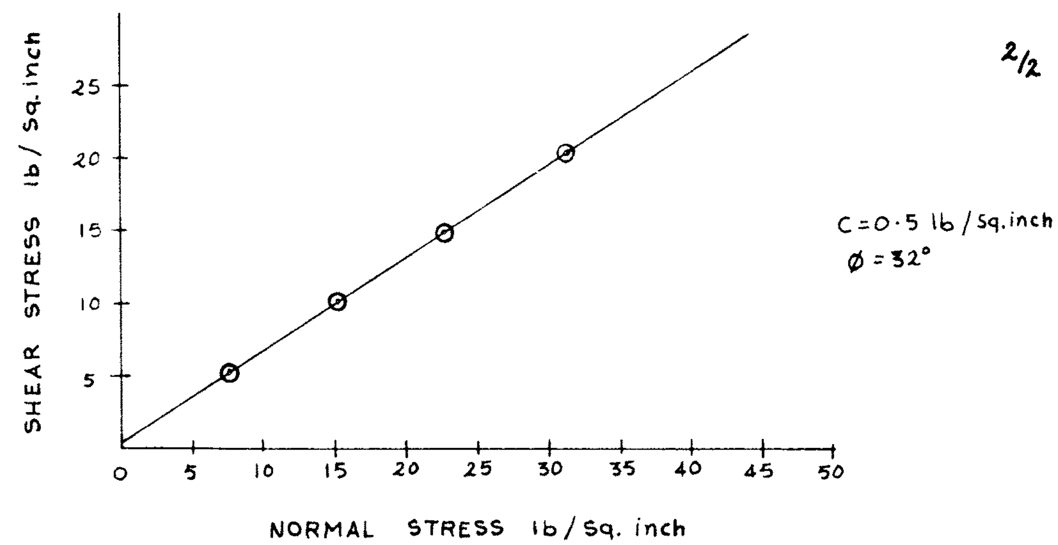
Lab. No.	Normal stress lb/sq in	Normal stress (kg/cm²)	Maximum shear stress lb/sq in	Maximum shear stress (kg/cm²)	Cohesion lb/sq in	Cohesion (kg/cm²)	Internal friction (ø in degree)
1	7.78	(0.545)	4.84	(0.339)			
2	15.55	(1.088)	8.72	(0.610)	1.0	(0.07)	25.5
3	23.33	(1.633)	12.47	(0.873)			
4	31.11	(2.178)	16.67	(1.167)			

Sample No.2/2

Lab. No.	Normal stress lb/sq in	Normal stress (kg/cm²)	Maximum shear stress lb/sq in	Maximum shear stress (kg/cm²)	Cohesion lb/sq in	Cohesion (kg/cm²)	Internal friction (ø in degree)
1	7.78	(0.545)	5.30	(0.371)			
2	15.55	(1.088)	10.30	(0.721)	0.5	(0.035)	32.0
3	23.33	(1.633)	15.28	(1.070)			
4	31.11	(2.178)	20.27	(1.419)			

GRAPH VI. 5





SHEAR PARAMETERS (DIRECT-SHEAR TEST)

SHEAR PARAMETERS

Sample No. 3/1

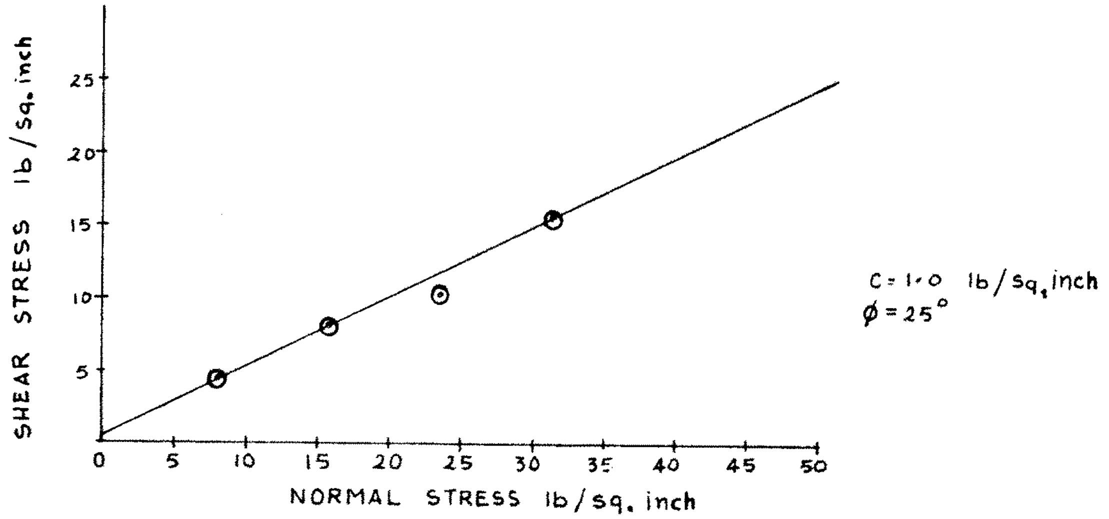
Lab. No.	Normal stress lb/sq in	(kg/cm^2)	Maximum shear stress lb/sq in	(kg/cm^2)	Cohesion lb/sq in	(kg/cm^2)	Internal friction (ø in degree)
1	7.78	(0.545)	4.68	(0.328)			
2	15.55	(1.088)	8.42	(0.590)	1.0	(0.07)	25.0
3	23.33	(1.633)	10.01	(0.701)			
4	31.11	(2.178)	15.75	(1.102)			

Sample No. 3/2

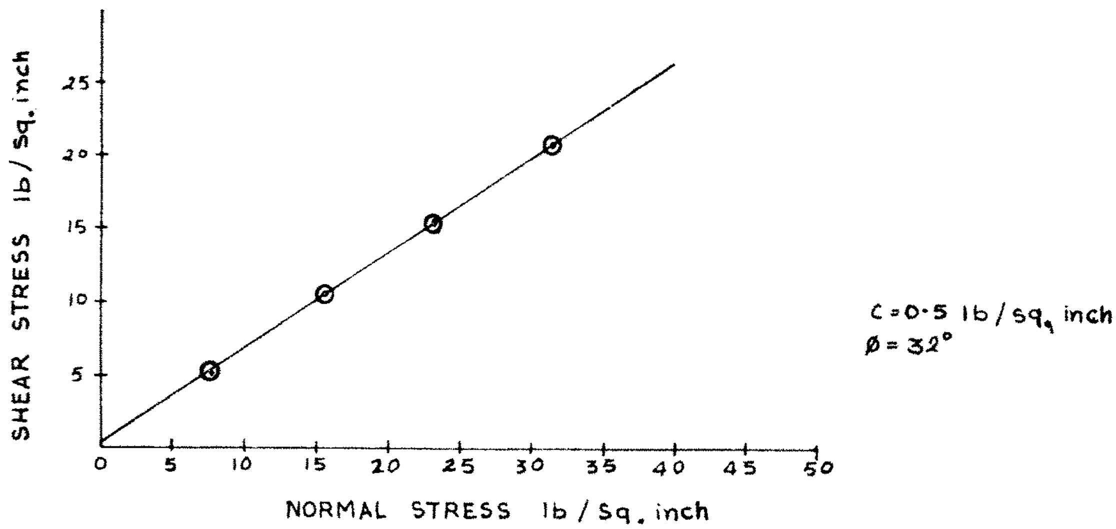
Lab. No.	Normal stress lb/sq in	(kg/cm^2)	Maximum shear stress lb/sq in	(kg/cm^2)	Cohesion lb/sq in	(kg/cm^2)	Internal friction (ø in degree)
1	7.78	(0.545)	5.32	(0.372)			
2	15.55	(1.088)	10.48	(0.734)	0.5	(0.035)	32.0
3	23.33	(1.633)	15.45	(1.081)			
4	31.11	(2.178)	20.68	(1.448)			

GRAPH VI. 5

3/1



3/2



SHEAR PARAMETERS (DIRECT-SHEAR TEST)

SHEAR PARAMETERS

Sample No. 4/1

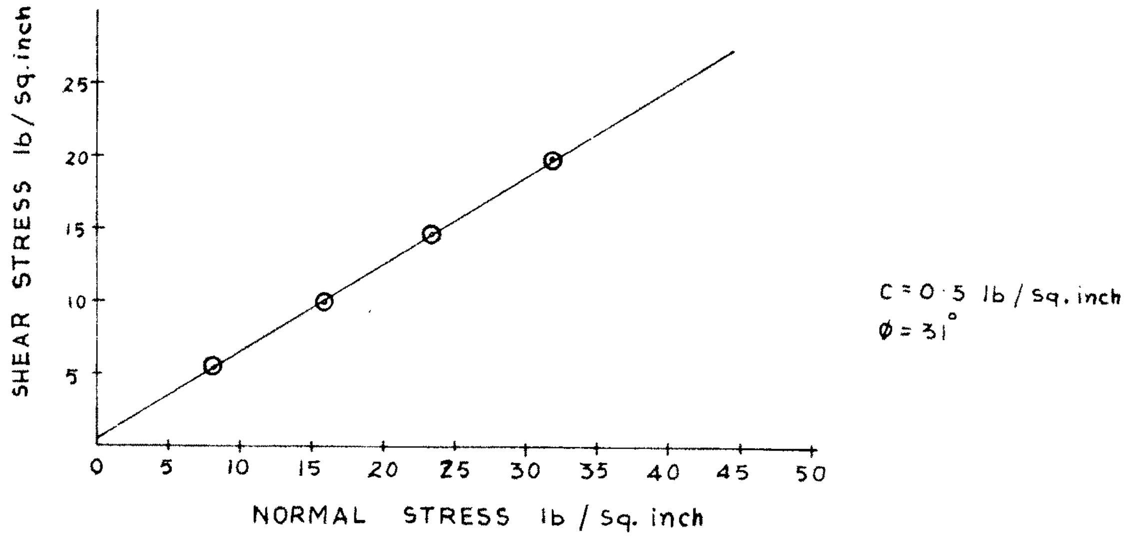
Lab. No.	Normal stress lb/sq in	Normal stress (kg/cm^2)	Maximum shear stress lb/sq in	Maximum shear stress (kg/cm^2)	Cohesion lb/sq in	Cohesion (kg/cm^2)	Internal friction (ø in degree)
1	7.78	(0.545)	5.30	(0.371)			
2	15.55	(1.088)	9.68	(0.678)	0.5	(0.035)	31.0
3	23.33	(1.633)	14.82	(1.037)			
4	31.11	(2.178)	19.33	(1.353)			

Sample No. 4/2

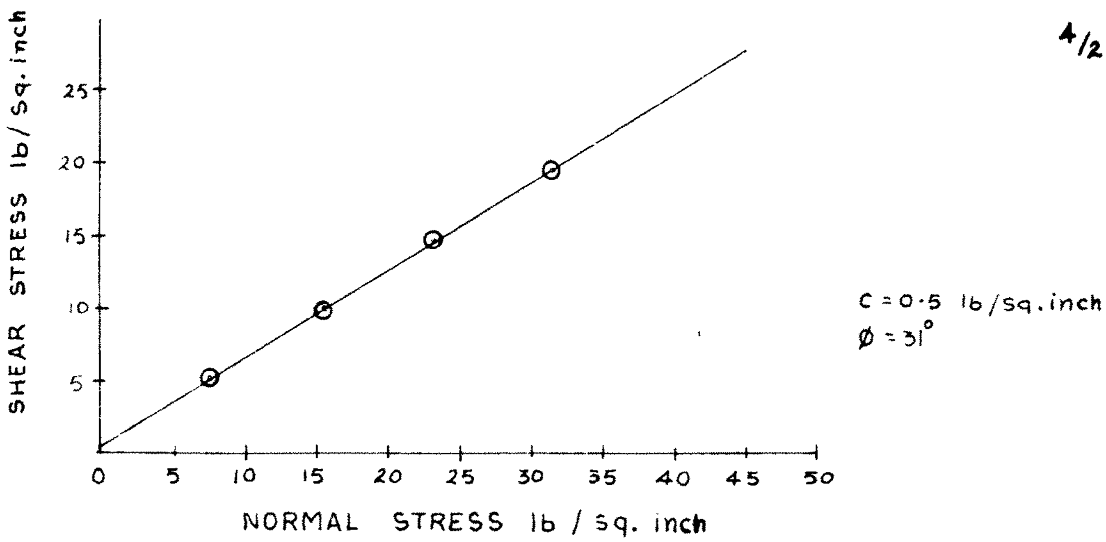
Lab. No.	Normal stress lb/sq in	Normal stress (kg/cm^2)	Maximum shear stress lb/sq in	Maximum shear stress (kg/cm^2)	Cohesion lb/sq in	Cohesion (kg/cm^2)	Internal friction (ø in degree)
1	7.78	(0.545)	5.16	(0.361)			
2	15.55	(1.088)	9.83	(0.688)	0.5	(0.035)	31.0
3	23.33	(1.633)	14.51	(1.016)			
4	31.11	(2.178)	19.35	(1.354)			

GRAPH VI. 5

4/1



4/2



SHEAR PARAMETERS (DIRECT-SHEAR TEST)

SHEAR PARAMETERS

Sample No. 5/1

Lab. No.	Normal stress		Maximum shear stress		Cohesion		Internal friction
	lb/sq in	(kg/cm^2)	lb/sq in	(kg/cm^2)	lb/sq in	(kg/cm^2)	(ø in degree)
1	7.78	(0.545)	5.80	(0.406)			
2	15.55	(1.088)	11.29	(0.790)	0.0	(0.0)	35.0
3	23.33	(1.633)	16.92	(1.184)			
4	31.11	(2.178)	22.72	(1.590)			

Sample No. 5/2

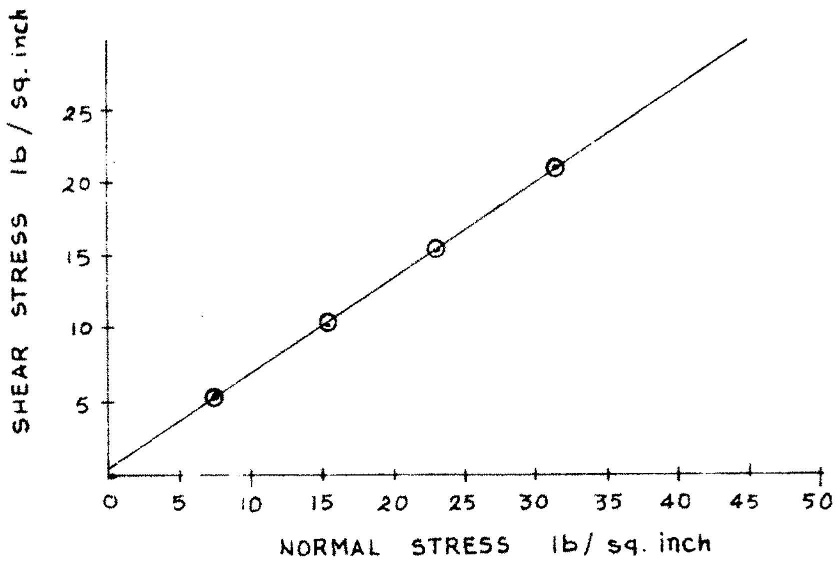
Lab. No.	Normal stress		Maximum shear stress		Cohesion		Internal friction
	lb/sq in	(kg/cm^2)	lb/sq in	(kg/cm^2)	lb/sq in	(kg/cm^2)	(ø in degree)
1	7.78	(0.545)	5.48	(0.384)			
2	15.55	(1.088)	10.18	(0.713)	0.5	(0.035)	33.0
3	23.33	(1.633)	15.80	(1.106)			
4	31.11	(2.178)	20.95	(1.466)			

GRAPH VI. 5

5/1

C = 0·0 lb / Sq. inch
ø = 35°

5/2



C = 0·5 lb/sq. inch
O = 33°

SHEAR PARAMETERS (DIRECT-SHEAR TEST)

PETROGRAPHIC STUDY: Each openpit soil sample was treated with dilute hydrochloric acid and washed by water. These samples were sieved through a set of BS sieves (mesh Nos. 5, 7, 14,25 and 52). The soil fractions retained on the sieves were analysed for their constituents given in the following table:

Location	Open-pit Soil Sample No.	Sampling Depth (cm)	Constituents
Sarsana	1/1	0 - 50	Quartz, Sandstone
	/2	50 - 100	Quartz,Calcareous sandstone
Than	2/1	0 - 80	Quartz, Clay lump, Shale
	/2	80 - 120	Quartz, Clay lump,Sandstone
Sidsar	3/1	0 - 70	Trap, Quartz
	/2	70 - 90	Trap, Quartz
Sudamda Nava	4/1	0 - 50	Quartz, Clay lump
	/2	50 - 135	Calcareous sandstone, Ferruginous sandstone, Clay lump, Quartz
Sayla	5/1	0 - 15	Trap, Quartz
	/2	15 - 30	Trap, Quartz

HEAVY MINERAL STUDY: Soil fraction, passing 52 mesh BS sieve was sieved through 80 and 120 mesh ASTM sieves

(85 and 125 mesh BS sieves). The soil fraction retained on 120 mesh ASTM sieve was treated by bromoform (Sp. gravity 2.89) for heavy mineral separation. The heavy mineral grains of each soil sample, were identified under the binocular microscope (Milner, 1962). The results are given in the following table:

Location	Open-pit No.	Sampling Depth (cm)	Description of Heavy Minerals
Sarsana	1	0 - 100	Poor yield, Augite and basaltine (hornblende basalt) dominant. Zircon, rutile, tourmaline and garnet-rare. Grains are rounded without sharp edges and fracturing
Than	2	0 - 120	- do -
Sidsar	3	0 - 90	Augite and basaltine grains abundant, Grains are angular with sharp edges and fracturing.
Sudamda Nava	4	0 - 135	Poor yield, Augite dominant with basaltine as a secondary mineral. Grains are rounded to subangular without sharp edges and fracturing.
Sayla	5	0 - 30	Augite and basaltine grains abundant. Grains are angular with sharp edges and fracturing.

CLAY MINERAL STUDY: Coarser fragments and organic matter were removed from each openpit soil sample. Clay fraction, having 0.002 mm or less diameter was separated by sedimentation and was used to determine their base exchange capacity and Silica sesquioxide ratio ($SiO_2:Al_2O_3$).

(a) Base exchange capacity: Wet clay fraction, weighing 2 to 3 grams, was used for making uniform suspension in distilled water. Fifty millilitre portion from this suspension was taken in a preweighed beaker to determine the weight of clay in it. Another 50 ml portion from the same suspension was taken in a conical flask. Ten millilitre of saturated potassium chloride solution was added to it. After 24 hours, this solution was titrated with standard alkali, using phenolphthalein as an indicator. One litre 1 N alkali corresponds to one equivalent of base exchange capacity. Base exchange capacity of each openpit soil sample, was calculated and was expressed as milliequivalent per 100 gram clay (IS:2720 P.XXIV, 1967).

(b) Silica sesquioxide ratio: From known weight of clay fraction SiO_2 and R_2O_3 were determined in the laboratory for eachopenpit soil sample (IS:2720 P.XXV,1967).

The test results are given in the following table:

Location	Open-pit No.	Soil Sample No.	Silica Sesquoxide			BEC (meq/100 gm clay)	Clay mineral inference
			Wt.of clay (gm)	SiO_2 (%)	R_2O_3 (%)		
Sarsana	1	/1	1.858	50.20	50.37	33.3	Illite
		/2	1.823	46.56	48.41	95.0	Montmorillonite
Than	2	/1	2.060	59.01	42.51	83.0	Montmorillonite
		/2	2.059	48.78	53.95	45.0	Beidellite
Sidsar	3	/1	2.780	46.23	49.90	59.0	Beidellite
		/2	1.240	34.35	62.74	31.5	Illite
Sudamda Nava	4	/1	1.103	38.44	49.13	42.3	Beidellite
		/2	1.409	28.90	65.10	84.6	Montmorillonite
Sayla	5	/1	0.662	51.80	44.92	107.0	Montmorillonite
		/2	1.006	57.75	43.16	62.6	Beidellite

The variation in base exchange capacity of standard clay minerals (Grim, 1968) is given in the following table.

Name of clay mineral	BEC(meq/100 gm clay)
Kaolinite	3 - 15
Montmorillonite	80 - 150
Illite	10 - 40
Beidellite	Mixture of illite & Montmorillonite.

The results of petrographic studies including constituents, heavy minerals and clay minerals and clay minerals with the parent materials and soil types for each openpit soils are given in the following table:

Location	Soil depth	Engineering Soil classi.	Constituents (+52 mesh BS sieve)	Heavy Minerals (-80+120 mesh ASTM sieve)	Clay Minerals	Parent Material
Sarsna	0- 50	SM	Quartz sandstone	Augite & basaltine; Rounded grains without sharp edges & fracturing	Illite	Dhrangadhra sandstone
	50-100	SM	Quartz, calcareous sandstone		Montomorillonite	
Than	0- 80	CI	Quartz, shale, clay lump	- do -	- do -	- do -
	80-120	SC	Quartz, clay lump sandstone		Beidellite	
Sidsar	0- 70	CI	Quartz, Trap	Augite & basaltine; Grains (Angular) with sharp edges & fracturing	- do -	Deccan trap
	70- 90	SC	Quartz, Trap		Illite	
Sudamla Nava	0- 50	SC	Quartz, clay lump	Augite and basaltine; grains rounded without sharp edges & fracturing	Beidellite	Wadhwan sandstone
	50-135	SC	Quartz, clay lump, calcareous sandstone, Fer. sandstone		Montmorillonite	
Sayla	0-15	SM	Trap, Quartz	Augite and basaltine	Montmorillonite	Deccan Trap
	15-30	SC	Trap, Quartz	Grains angular with sharp edges & fracturing	Beidellite	

RIVER SAND (IS:2386 Parts II & VIII, 1963): Sand samples from six river beds were collected for the determination of their fineness modulii and deleterious materials present in them. Sand sample passing 3/16 inch BS sieve, was sieved through a set of 7, 14, 25, 52 and 100 mesh BS sieves. Cumulative per cent of fraction retained on each sieve, was calculated to determine the fineness modulus given in the following table:

Location	Name of river or nala	Fineness Modulus 1	Fineness Modulus 2	Fineness Modulus 3	Average Fineness Modulus
Kashiagala	Maha	1.98	2.07	2.08	2.04
Bet. Morthala & Devpara	Maha	2.35	2.28	2.39	2.34
Sagadhra	Balal	1.68	1.68	1.74	1.70
Raisangpar	Bambhan	2.21	2.24	2.30	2.25
Bhaduka	Bhogavo-I	2.05	2.11	2.15	2.10
Bet. Paj & Dighalia	Kharodia nala (Machhu)	2.92	2.94	2.93	2.93

The fineness modulii of river sands range from 1.7 to 2.9. In common practice sand having 1.5 to 3.3 fm is used in construction work but sand having 2.5 to 3.3 fm is used in mass work. The best quality of sand has 2.4 to 2.7 fm.

Petrographic Study: Sand samples were also examined for the deleterious materials which were identified as Cryptocrystalline silica and clay lump. Sands of the Bhogavo river and Kharodia nala have more than 3 per cent deleterious materials.

(B) CRUSHED AGGREGATE (IS:2386, 1963):

Crushed aggregates of basalt (trap rock) from crusher plants located at Daldi and Muli, quartzitic sandstone from Ranipat and white sandstone from Sara, were tested for their engineering properties. The test results are given in the following table:

Location	Rock type	Impact value (%)	Crushing value (%)	Abrasion value Los Angles(%)	Specific gravity	Water Absorption (%)
Daldi	Basalt	14.20	16.66	17.70	2.85	1.45
Muli	Basalt	12.50	19.30	13.60	2.80	1.30
Sara	White sandstone	32.25	38.63	52.10	2.20	4.40
Ranipat	Quartzitic sandstone	26.22	30.64	29.00	2.40	2.80

All the above crushed aggregates except that of white sandstone from Sara quarry meet the required specification (Appendix VI.5 p. 264 ; IS:383, 1970). These aggregates according to the specified size, are used as follows:

Aggregate Size (inch)	Use
$1\frac{1}{2}$	As railway ballast
$\frac{1}{2}$ to $\frac{3}{4}$	For roads
$\frac{1}{4}$ to 1/8	For road surfacing

(C) BUILDINGSTONES (IS:1121-1957; 1122 & 1124-1974 & 1123-1975):

SANDSTONE: White, yellow and light brown Dhrangadhra sandstones of medium to fine grain texture are quarried in the study area. White sandstone quarries are located near Samatpar, Sara, Aya Dagdagia, Waori and Bhasol (Plate VI.1). White, yellow and light brown sandstone quarries are located near Mahika, Sudamda Nava, Bhaduka, Dudhai and Than (Plate VI.2).

Mahika Sandstone quarry is located NE of Mahika on the eastern bank of Machhu river. During quarry operations by blasting, blocks of various sizes are available due to stratifications and joints in this sandstone. The various products of quarry viz. Window sill (150 cm x 30 xm x 15 cm), Plinth (90 cm x 45 cm x 15 cm), rectangular blocks, and rubbles, dressed by hammer and chisel are used locally as building materials. The medium grained white and yellow

PLATE NO. VI.1

Dhrangadhra sandstone quarry near Aya Dagdagia.

PLATE No.VI.2

Dhrangadhra sandstone quarry near Sudamda Nava (N of Chotila-Limdi NHW No.8).

sandstone from Waori, and Songadh quarries are also used locally as building material. The test results of sandstones are given in the following table:

Salient features	Waori Quarry	Mahika Quarry
Rock type	White Sandstone	Yellow Sandstone
Specific Gravity	2.27	2.18
Water Absorption	4.39	5.5
Dry Crushing Strength (kg/cm^2)		
Parallel to bedding plane	40 - 160	260 - 300
Perpendicular to bedding plane	180 - 200	280 - 320

On the basis of strength classification given by Winkler (1973) these sandstones are weak to medium strong rocks.

BASALT: The rock from Deccan trap lavaflows is basaltic in composition. It is greyish black to black in clour and fine to medium grain in texture. It is hard, compact and tough. The columnar joints when present are taken advantage of in quarry operations as is the case at the quarry near Daldi. Blocks (30 cm x 20 cm) are used in the construction of culverts and for foundation purposes.

Classification of buildingstones, viz. sandstone and basalt, is given in Appendix VI.6 p. 265 (IS:1123,1975).

INDUSTRIAL MATERIAL RESOURCES

It includes industrial clays, silica sand, coal and raw materials for lime:

(A) INDUSTRIAL CLAYS:

FIRECLAY: The fireclay in the form of grey and black shales, occur in Than Formation of Dhrangadhra Group. The fireclay deposits form an eastwest belt lying between 22°35' to 22°45' N and 71°00' to 71°20' E. The quarries are located near Than, Songadh, Lunsar, Velala, Chandrelia, Palasan, Khakhrathal, and Gadhada (Plates VI.3 & VI.4). The chemical analysis of fireclays from various quarries are compiled in the following table:

Chemical composition (%)	Than Quarry	Songadh Quarry	Velala Quarry	Khakhrathal Quarry
SiO_2	61.14	52.44	60.07	57.79
Al_2O_3	22.66	26.55	24.71	21.23
Fe_2O_3	0.57	1.85	1.24	0.90
TiO_2	1.58	0.98	1.80	1.42
CaO	0.36	2.76	1.00	0.57
MgO	0.31	0.27	1.01	Trace
SO_3	-	0.07	-	-
Alkalies	-	-	0.58	0.77
Loss on Ignition	12.78	15.08	10.08	17.64

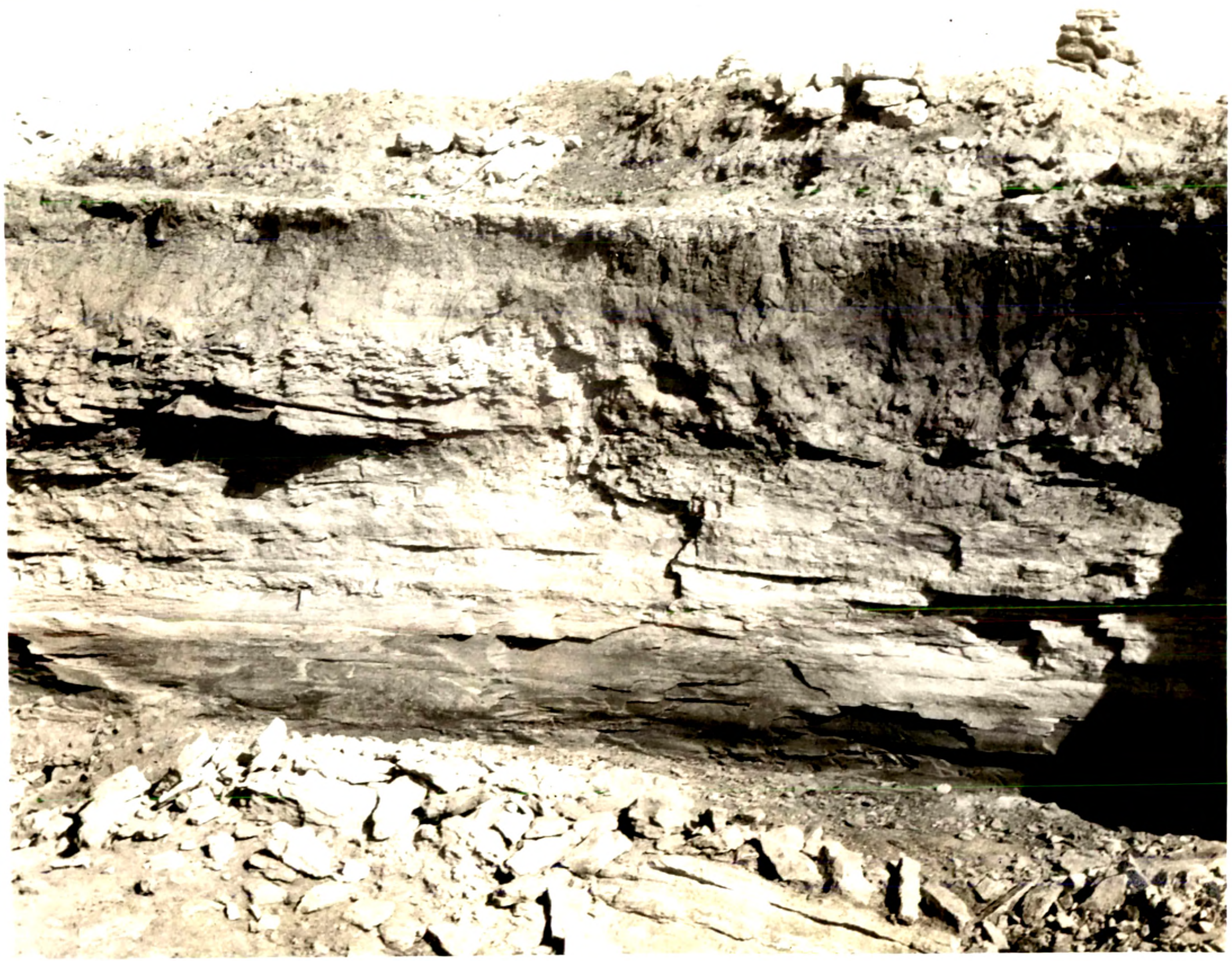


PLATE NO. VI.3 Fireclay, opencast mine near Lunsar

PLATE NO.VI.4

Fireclay, opencast mine, W of Palasan

Fireclay is worked by cut and fill method of open cast mining. The overburden varies from 1 to 5 meter. Fireclay is used as a raw material in ceramic industries for manufacturing porcelains, sanitarywares, refractories, toys and tiles (roofing and flooring). The potteries viz. Parshuram Pottery Works at Than, Digvijay Pottery Works at Vagadia and Nalia Factory at Muli are located in the study area.

WHITE CLAY : It occurs west of Tarnetar as well as north of Ranipat. Cement factory uses this clay as a raw material for making white cement. Another small occurrence of this clay is located on eastern bank of the Machhu river south-east of Jodhpur. The chemical analysis of white clay from Ranipat (as given by supplier) is as follows:

SiO_2	68.8 %
Al_2O_3	21.9 %
CaO	1.2 %
Loss on ignition	7.3 %

(B) SILICA SAND:

White friable sandstone of Surajdeval Formation of Dhrangadhra Group is used for making silicasand (Plate VI.5). The chemical analysis of this sandstone (as given by quarry owners) is as follows:

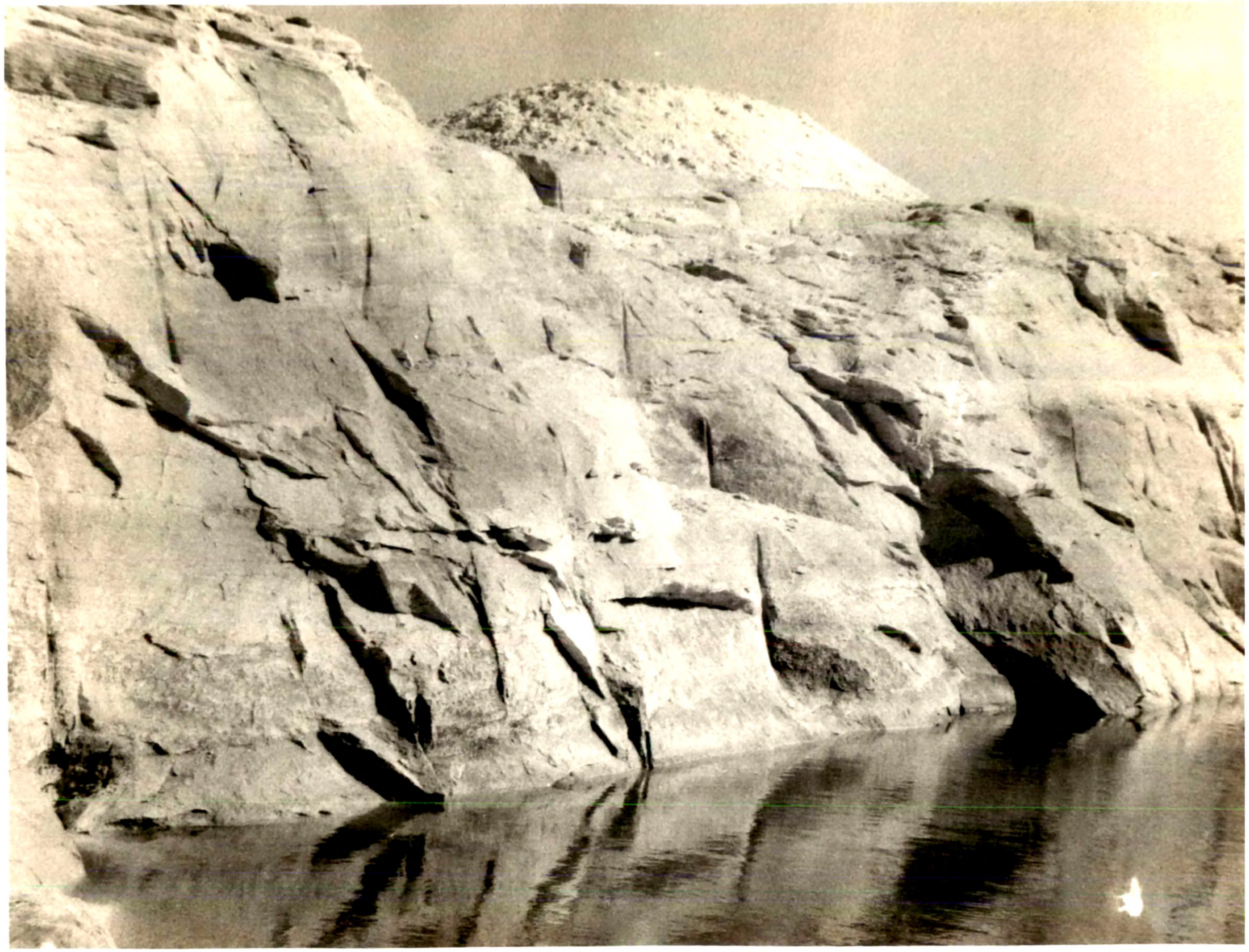


PLATE NO. VI.5   Sandstone quarry Surajdeval Formation near Bhasol

Chemical Composition (%)	Gujarat Mineral Development Corporation	Sompura and Co.
SiO_2	97.44	98.22
Al_2O_3	1.21	1.15
Fe_2O_3	0.58	0.33

The quarries are located near Waori, Bhasol, Samatpar and Gugaliana. The white friable sandstone is disintegrated with the help of crushers. The following mesh sizes of silica sand are obtained by screening:

Grading of Sand (BS mesh size)	Use
10 - 16	Foundary
30 - 80	Glass
80 - 120	Waste product
120 - 180	Pottery.

(C) COAL:

Thin seams of sub-bituminous coal are observed in the open cast mine near Khakhrathal (Plate VI.6) and in open well section near Songadh and Tarnetar. The average proximate analysis of ten samples of the coal seams (Kathiara et al., 1970) is as follows:

PLATE NO. VI.6 Coalseam, opencast mine, S of Khakhrathal

Moisture	2.13 %
Volatile matter	10.02 %
Fixed carbon	50.49 %
Ash	36.96 %
Calorific value	5571 K cal/kg (10,129 B.T.U.)

(D) RAW MATERIALS FOR LIME:

Cherty limestone near Aya Deriwala and Kankar deposits from the bank of Bhogavo-I river opposite to Muli are locally used for making lime.