REPUBLIC OF KENYA

MINISTRY OF WATER DEVELOPMENT

NATIONAL WATER CONSERVATION AND PIPELINE CORPORATION

STUDY ON CONSTRUCTION OF DAM IN MALEWA RIVER SYSTEM FOR GREATER NAKURU WATER SUPPLY PROJECT

FINAL REPORT

VOLUME IV SUPPORTING REPORT (III)

ANNEX C Construction Material Survey

ANNEX D Hydrological Investigation

ANNEX E Water Demand Forecast and Questionnaire Survey on Willingness-to-Pay

ANNEX F Water Resources Development Planning

[illegible] 1990

JAPAN INTERNATIONAL COOPERATION AGENCY

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DECEMBER 1990

JAPAN INTERNATIONAL COOPERATION AGENCY

CONSTRUCTION OF DAM IN MALEWA RIVER SYSTEM
FEASIBILITY STUDY REPORT

ANNEX C

CONSTRUCTION MATERIAL SURVEY

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Abbreviation and Local Terms

1. Abbreviation of Measures

1.1 Length

mm	=	millimeter
cm	=	centimeter
m	=	meter
km	=	kilometer

1.2 Area

m^2, sq.m	=	square meter
ha	=	hectare
km^2, sq.km	=	square kilometer

1.3 Volume

lit, l	=	liter
lcd	=	liter per capita per day
cu.m, m^3	=	cubic meter
cu.m/day, m^3/day	=	cubic meter per day
MCM	=	million cubic meter

1.4 Weight

mg	=	milligram
mg/l	=	milligram per liter
g	=	gramme
kg	=	kilogram
t	=	ton

1.5 Time

s, sec	=	second
min	=	minute
h, hr	=	hour
d	=	day
yr	=	year

1.6 Money

Kshs.	=	Kenya Shilling(unit of Kenya currency, US$1.00 = Ksh 23.0 = ¥ 150)
US$, $	=	US dollar
¥	=	Japanese Yen

1.7 Electric Measures

kV	=	kilovolt
kW	=	kilowatt
MW	=	megawatt
kWh	=	kilowatt hour
kVA	=	kilovolt ampere

1.8 Other Measures

mmho	=	micromho = conductance
ppm	=	parts per million
ppb	=	parts per billion
MPN	=	most probable number
‰	=	mill
%	=	per cent
PS	=	0.736 kW
°	=	degree
'	=	minute
"	=	second
℃	=	degree centigrade
n.a.	=	not available
COD	=	Chemical Oxygen Demand
T-N	=	Total Nitrogen
I -	=	Inorganic -
O -	=	Organic -
T-P	=	Total - Phosphorus
DO	=	Dissolved Oxygen
pH	=	Exponent of hydrogen ion concentration

1.9 Derived Measures Based on the Same Symbols

cu.m/sec, m^3/s	=	cubic meter per second
cu.m/day, m^3/day	=	cubic meter per day
t/ha	=	ton per hectare
lpcd	=	liter per capita per day

2. Other Abbreviations

BS	=	British Standards
JIS	=	Japanese Industrial Standards
ASTM	=	American Society for Testing and Material
GNP	=	gross national products

GDP	=	gross domestic product
GRDP	=	gross regional domestic product
El.	=	elevation
FWL	=	flood water level
FSL	=	full supply level
MSL	=	minimum supply level
HWL	=	normal operation level
LWL	=	minimum operation level
f.o.b	=	free on board
c.i.f.	=	cost, insurance and freight
ICB	=	international competitive bid
LCB	=	local competitive bid

3. Abbreviation of Organizations

MOA	=	Ministry of Agriculture
MENR	=	Ministry of Environment & Natural Resources
MOF	=	Ministry of Finance
MOLD	=	Ministry of Livestock Development
MOLG	=	Ministry of Local Government
MOTW	=	Ministry of Tourism & Wildlife
MOTC	=	Ministry of Transport & Communication
MORD	=	Ministry of Regional Development
MOWD	=	Ministry of Water Development
NES	=	National Environmental Secretariat
NWCPC	=	National Water Conservation & Pipeline Corporation
SOK	=	Survey of Kenya
KWS	=	Kenya Wildlife Service
NMC	=	Nakuru Municipal Council
NTC	=	Naivasha Town Council

ASTU	=	Anti-Stock Theft Unit
KYSTC	=	National Youth Service Training Center
GMB	=	Gilgil Military Barracks
KMB	=	Kenyatta Military Barracks
WWF	=	World Wide Fund for Nature
JICA	=	Japan International Cooperation Agency
OECF	=	Overseas Economic Cooperation Fund, Japan

I. INTRODUCTION

The construction material survey was programmed for execution in two phases. The preliminary survey in the Phase 1Study aimed at selecting the most suitable borrow areas for earthfill material and quarry sites for concrete aggregate, filter material and rockfill materials. The supplementary survey in the Phase 2 Study was to clarify in detail the physical and mechanical properties of the materials available from the selected borrow areas and quarry sites for the preliminary design of the dam.

The field works of the preliminary survey consisted of identification of alternative borrow areas and quarry sites, and physical and mechanical tests of the materials sampled from the alternative sites and areas. It was carried out during the period from February to June, 1989.

The field works of the detailed survey consisted of physical and mechanical tests of the materials sampled from the site and area selected through the preliminary study.Findings of the preliminary survey and the detailed survey will be presented chiefly in Chapter II and Chapter III of this report, respectively.

All the physical and mechanical tests have been performed in a laboratory in Nairobi, in accordance with the Technical Specifications and Contract Documents which was prepared by the JICA Study Team.A part of the rock materials was tested in Japan to confirm the test result.

For the completion of this materials study, the Study Team is much obliged to Mr. Mwai, Chief Geologist of the NWCPC, and Mr. Waweru, Geologist of the MOWD, who have provided great support and assistance to the Study Team.

II. PRELIMINARY SURVEY

2.1 Borrow Area for Earthfill Materials

2.1.1 Identification of Borrow Areas

Through the field reconnaissance survey around the dam sites in both the Malewa and Turasha rivers, three borrow areas have been selected for earth embankment materials as shown in Fig.C.2.1.

(1) Borrow Area "Gilgil"

It is located adjacent to the Gilgil railway station in the town of Gilgil. The area with approximate altitude of El. 2,020 m covers approximately 25 ha and had once used as borrow area in the past. A distance to the Malewa dam site is approximately 19 km through the existing Kipipiri road (D390) and rural road. Access to the Turasha dam site can easily be made through the Kipipiri road, D391 road and rural road, approximately 18 km.

(2) Borrow Area "East Road"

The selected area is situated close to the Gilgil golf course, about 3.5 km east from the town of Gilgil and covers an area of approximately 150 ha. The ground elevation of the area is around El. 2,100 m. A distance to the Malewa dam site is approximately 17 km through the existing Kipipiri road and a rural road and to the Turasha dam site approximately 16 km through the Kipipiri road, D391 road and rural road.

(3) Borrow Area "Mahindu"

The selected area is situated in the vicinity of Mahindu village to the northeast of the Malewa and Turasha dam sites and extends over approximately 150 ha. The area has ground elevation of approximately El. 2,360 m and is in the shortest distance to the dam sites among the others; approximately 11 km to the Malewa dam site and about 8 km to the Turasha dam site, both through the Kipipiri road and rural road.

2.1.2 Test Pittings

In order to assess quantity and properties of earth materials available, test pittings were made in each of the borrow areas. Two test pits, each 2 m in depth, were dug at every borrow area and their soil conditions have been observed. Profiles of the test pits are presented in Figs.C.2.2 through C.2.4.

Both residual and lateritic soils, originated from tuffaceous bedrocks, are the predominant type of soil in every borrow area and are overlain by top humic soil with thickness of 0.5 to 1 m. Thickness of the residual and lateritic soils is in the range of 1 to 2 m.

2.1.3 Laboratory Test

The representative soil samples were obtained from the test pits as listed below:

Borrow Area	Test Pit No.	Sample No.
Gilgil	GP-1	GP-1U, GP-1L, GP-1M,
	GP-2	GP-2U, GP-2L, GP-2M
East Road	EP-1	EP-1U, EP-1L, EP-1M
	EP-2	EP-2U, EP-2L, EP-2M
Mahindu	MP-1	MP-1U, MP-1L, MP-1M
	MP-2	MP-2U, MP-2L, MP-2M

All the samples were tested in the laboratory in Nairobi for their physical and mechanical properties. The testing items and quantities are as shown in Table C.2.1.

Test results are presented in Table C.3.3 through C.3.4.

2.1.4 Properties of Earthfill Material

(1) Physical Test

(a) Gradation analysis

The test was carried out in a combined sieve and hydrometer analysis method. Gradation curves, as shown in Figs C.2.5 to C.2.7, have been drawn smooth, disregarding discrepancies at connections of the sieving test and the hydrometer test around 0.074 millimeters of particle size. The tests indicate low contents of clay (less than 0.005 mm) in the samples form Gilgil (GP) and Mahindu (MP).

(b) Moisture content

The moisture content falls under a range between 15.6% of MP-2U and 45.5% of MP-1L. The moisture contents of six samples, GP-1M, GP-2M, EP-1M, EP-2M, MP-1M and MP-2M were lower than optimum moisture contents by 3 % (MP-1M) to 14.8% (GP-2M).

(c) Atterberg limits

Atterberg tests were carried out using the test samples under 0.42 mm in diameter for determination of liquid limit, plastic limit and plasticity index. Almost all materials in the borrow areas, being classified as ML to MH as shown in Figs. C.2.8, are medium to high plasticity soils suitable for impervious earthfill.

(d) Specific gravity

The specific gravity falls within a range between 2.47 of GP-2M and 2.79 of GP-2L.

(e) Classification of soil

Almost all materials in the borrow areas are classified into SM (silty sand) or S-M (sand mixed silt) according to the classification of soils of ASTM. MH (silt with high liquid limit) and CH (clay), however, are occasionally observed in the samples MP-IU, EP-IU and EP-2U. Soil of SM or S-M is more suitable for impervious earthfill than MH or CH.

2) Mechanical Test

(a) Moisture-density relations of soils and soil-aggregate mixtures, using rammer (standard compaction tests).

Standard compaction tests were carried out for maximum dry density and optimum moisture content. The moisture content - dry density curves obtained are shown in Figs. C.2.9 to C.2.12. As indicated in the table of test results, the natural moisture contents of all samples are on the dry side of the optimum moisture content, so that the materials may have to be wetted by sprinkling.

(b) Pearmeability

Pearmeability tests were carried out by the variable head method, on the samples which were prepared principally under the corresponding optimum moisture content. As indicated in the table of test results and in Figs. C.2.13, the coefficient of permeability is mostly less than 3 x 10^{-7} cm/sec, if the material is compacted well at the optimum moisture content.

(c) Triaxial strength

The test results have been presented in the graphs to show:

- the relation between the difference in principal stresses and compressive strain,
- Mohr circles, and
- the relation between the difference in principal stresses and lateral pressure ($\overline{CU}$ test).

The results are also presented in Figs. C.2.14 to C.2.28.

The triaxial tests show a variation in shearing strength parameters, ranging from 0.0 to 1.4 kgf/sq.cm for cohesion and 10.5° to 29° for internal friction angle in UU tests, and 0.0 to 0.5 kgf/sq.cm for cohesion and 22.5° to 37.5° for internal friction angle in $\overline{CU}$ tests.

2.2 Quarry Site for Fine Concrete Aggregate

2.2.1 Identification of Quarry Site

There is no suitable sand and gravel deposits in the vicinity of the dam sites. It has been noted that, for construction of Grain Silo in Nakuru municipality, fine aggregate was transported from Kisumu, approximately 180 km west of Nakuru, and coarse aggregate was produced by means of crushing the quarried rocks. Within the Nakuru municipality, a fine aggregate quarry site is under operation by local miners. This quarry site covers an area of approximately 24 ha.

2.2.2 Test Pittings

Test pitting was not required for fine concrete aggregate since the sand deposit could be found at the quarry operation site. Sand in the quarry site is a member of lake deposits which is probably of volcanic ash origin and contains a lot of fragments of taffaceous rocks.

2.2.3 Laboratory Test

Six representative samples (Sample number SS-1 through SS-6) were collected from the Nakuru fine aggregate quarry site were tested in laboratory in Nairobi to clarify their properties. The testing items and quantities are as presented in Table C.2.1.

The test results are summarized as shown below.

Sample No.	+5 mm (%)	5-2mm (%)	2-0.425 mm (%)	0.425-0.075 mm (%)	-0.075 mm (%)	Specific gravity	Absorption (%)
SS-1	10.1	28.0	53.9	8.0	-	2.42	7.64
SS-2	5.3	24.7	47.1	12.8	10.1	2.39	6.76
SS-3	11.3	18.2	18.7	9.1	42.7	2.49	7.48
SS-4	11.3	19.6	59.4	9.8	-	2.89	7.56
SS-5	5.0	20.5	57.5	13.2	3.8	2.40	12.60
SS-6	11.0	19.7	38.2	10.7	20.4	2.39	9.11

2.2.4 Properties of Fine Concrete Aggregate

(1) Sieving analysis

The tests were carried out by mechanical analysis. The gradation curves are shown in Figs. C.2.29 to Figs. C.2.30. The proportion of fine particles under 0.075 mm in diameter is generally very high for fine concrete aggregate.

(2) Specific gravity and absorption

The tests were carried out by pychnometer method. Specific gravities show the values around 2.40, low values for fine concrete aggregate. Absorptions show the values around 7.50 indicating generally high.

2.3 Quarry Sites for Rockfill Materials and Concrete Aggregates

2.3.1 Identification of Quarry Sites

Since no sand and gravel deposits are available within reasonable hauling distances from the dam sites, rock quarrying is the only way to obtain rockfill material, filter material and coarse concrete aggregate. Two prospective sites have been identified through the surface geological exploration in the vicinity of the dam sites as shown in Fig. C.2.1.

(1) Quarry site "South Gilgil "

This site is located in the southwest rim of the Gilgil town and presently rock quarrying is operated by the Ministry of Public Works. The site is formed with steep cliff of trachytes. The cliff with a height of about 20 m has the north-south direction and has the ground height of El. 2,200 m at its top. Distances to the Malewa and Turasha dam sites are approximately 23 km and 20 km, respectively, through the Kipipiri and rural roads.

(2) Quarry site "Kipipiri Road"

The site covers conspicuous hills formed by welded tuff and high degree welded tuff in its upper and lower part about five meters thick, respectively located along the Kipipiri road. The hills have their ground height of approximately El. 2,200 m at their top. This quarry site is more closely located to the dam sites than the Site "South Gilgil";

i.e., approximately 5 km and 10 km to the Malewa and Turasha dam sites respectively. The high degree welded tuff is deemed to be suitable as concrete aggregates.

2.3.2 Laboratory Tests

The representative rock fragments were sampled from the respective quarry sites and tested in the laboratory in Nairobi to grasp their properties for concrete aggregates, filter materials and rockfill materials.

Quarry Site	Sample Number
(1) For coarse concrete aggregate test	
South Gilgil	TG-1 through TG-3
Kipipiri	WG-1 through WG-3
(2) For rockfill material test	
South Gilgil	TR-1 through TR-5
Kipipiri Road	WR-1 through WR-5

The testing items and quantities are as presented in Table C.2.1.

2.3.3 Properties of Rockfill Materials and Concrete Aggregate

(1) Rockfill materials

(a) Specific gravity and absorption

The tests were carried out by suspension method. Specific gravities show an average of 2.50 for trachyte (TR) and 2.45 for welded tuff (WR). Absorptions show an average of 1.72 % for trachyte and 1.80 % for welded tuff.

(b) Unconfined compressive strength

The tests were carried out on samples trimmed columnar, of which the proportion of length to diameter is two to one in principle. The test results ranges from 41.1 to 66.3 kgf/sq.cm for the trachyte and from 76.4 to 122.0 kgf/sq.cm for the welded tuff. The test results of all samples, however, seem to be smaller than that of empirical estimation. Some range of testing errors may have been involved.

(2) Concrete aggregates

(a) Specific gravity and absorption

The tests were carried out by suspension method. Specific gravities show an average of 2.53 for the trachyte (TG) and 2.46 for the welded tuff(WG) in saturated surface-dry condition. Absorptions show an average of 2.8% for the trachyte and 4.2% for the welded tuff neglecting unreasonably high values.

(b) Unit weight

The test results show an average of 1,404 kg/cu.m for the trachyte and 1,312 kg/cu.m for the welded tuff.

(c) Soundness

The tests were carried out by chemical method. The test results show an average of 0.2% for trachyte and 0.3% for the welded tuff. The values are satisfactory for concrete aggregate.

(d) Abrasion

The tests were carried out by Los Angeles method. The test results show an average of 35.9% for the trachyte and 28.8% for the welded tuff.

(e) Potential reactivity

The tests were carried out by chemical method to check the potential alkali reactivity of aggregate. Values for Dissolved Silica (Sc) and Reduction in Alkalinity (Rc) were determined and plotted in Figs. C.2.31 which showed that all samples were plotted in the potentially deleterious field, except one (WG-3) in the deleterious field. Therefore, additional testing by chemical method and mortar-bar method should be considered at the pre-construction investigation stage.

Other two samples has fallen under the innocuous field in the later stage of detailed survey.

2.4 Evaluation of Borrow Areas and Quarry Sites

(1) Borrow area for earthfill materials

The evaluation for each borrow area for earthfill materials is summarized as follows:

Description	Gilgil	East Road	Mahindu
Hauling Distance to Dam site (km)	19 km (Malewa) 18 km (Turasha)	17 km (Malewa) 16 km (Turasha)	11 km (Malewa) 8 km (Turasha)
Soil Classification	Residual Soil (SM) ~ (S-M)	Residual Soil & Upper Part ~ (SM)	Lateritic Soil (MH) ~ (SM)
Quality	Good	Good	Good
Geological Condition	Soil is thin partially.	Depth to bedrock is over two meters.	Soil is very thin generally.
Others	Houses and railway station are close to the site.	Site is grass land.	Site is cultivated land.

Judging from the comparison above, the East Road is the preferable site for earthfill material source.

(2) Quarry site for fine concrete aggregate

Only one site was surveyed for fine concrete aggregate because there is no suitable sand and gravel deposits in the vicinity of the dam sites.

The site is within the Nakuru municipality and the distance to the dam sites is about 60 km. The quality of the sand collected from the site is sub-standard as described in

Sub-section 2.2.4. It is recommendable to produce fine concrete aggregate by means of crushing the quarried rock together with the coarse aggregate.

(3) Quarry site for rockfill materials and concrete aggregates

Comparison of alternative quarry sites for rockfill material and concrete aggregate is summarized as follows:

Site	Hauling Distance to Dam site	Rock Facies	Quality	Geological Condition	Others
South Gilgil	23 km (Malewa) 20 km (Turasha)	Trachyte	Moderate	Weathered zone is 5 m or more.	Presently rock quarrying is operated.
Kipipiri Road	5 km (Malewa) 10 km (Turasha)	High degree welded tuff	Moderate	Weathered zone is thin. Upper part 5 m is welded tuff. The bed is 5 m thick.	Welded tuff of upper part is probably suitable for rockfill material.

III. SUPPLEMENTARY SURVEY

3.1 General

This chapter will present mainly findings of the supplementary survey in the Phase 2 Study.

Through the Phase 1 Study, a borrow area at "East Road", about 17 km southwest of the damsite and a quarry site of "Kipipiri Road, 5 km south of the damsite have finally been selected as shown in Fig. C.3.1.

The detailed survey in the Phase 2 Study was concentrated on these borrow area and quarry site.

Survey items and their quantities are presented in Table C.3.1.

3.2 Earthfill Materials

3.2.1 Borrow Area

Earthfill material survey was carried out for "East Road" borrow area covering an area of approximately 150 ha and at ground elevation is around El. 2,100 m. A distance to the Malewa damsite is approximately 17 km through the existing Kipipiri Road and rural road as shown in Fig. C.3.1.

3.2.2 Test Pittings

In order to assess quantity and properties of earth materials available from the borrow area, test pitting were carried out. Five test pits, each two meters in depth, were dug for in-situ observation and sampling of soil. The locations of the test pits are shown in Fig. C.3.2 and profile of the respective test pit is presented in Figs. C.3.3 through C.3.5.

Both residual soils and lateritic soils, originated from taffaceous bedrocks are the predominant type of soil and are overlain by top humic soil which is 0.3 to 0.8 m thick. Thickness of the residual and lateritic soils is in the range of one to two meters.

3.2.3 Laboratory Test

The representative soil samples were obtained from the test pits as listed below.

Borrow Area	Test Pit No.	Sample No.
East Road	EP-3	EP-3
	EP-4	EP-4
	EP-5	EP-5
	EP-6	EP-6
	EP-7	EP-7

All the samples were tested in the laboratory in Nairobi for their physical and mechanical properties. The testing items and quantities are as shown in Table C.3.2.

The test results are summarized as presented in Tables C.3.5 and C.3.6.

3.2.4 Properties of Earthfill Materials

(1) Physical Test

(a) Gradation analysis
The test was carried out in a combined sieve and hydrometer analysis method. Gradation curves are as shown in Figures C.3.6 to C.3.7.

Uniformity Coefficient (Uc) and Coefficient of Curvature (Uc') show that EP-1M, EP-2M (in Phase 1) and EP-4 (in Phase 2) are well-graded in distribution of soil particles, but others are not.

(b) Moisture content
The moisture content falls under a range between 24.0 % of EP-7 and 36.4 % of EP-6. The moisture content of three samples out of five are higher than optimum moisture content, while all six samples in the Phase 1 Study are lower than optimum moisture content. This is probably because sampling in Phase 2 Study was carried out immediately after the rainy season and that in Phase 1 Study immediately after the dry season.

(c) Atterberg limits

Atterberg tests were carried out using the samples under 0.42 mm in particle size for determination of liquid limit, plastic limit and plasticity index. All samples except EP-2U in the borrow area in the Phase 1 Study, being classified as ML to MH as shown in Fig. C.3.8, are medium to high plasticity soils usable for impervious earthfill.

(d) Specific gravity

The specific gravity falls within a range between 2.37 of EP-7 and 2.59 of EP-6. Average through the Phase 1 and Phase 2 Studies are 2.52.

(e) Classification of soil

The tested materials in the borrow area are classified into ML (Silt with low liquid limit) of EP-3 and EP-7, MH (Silt with high liquid limit) of EP-5 and EP-6, and GM (Gravel with silt) of EP-4 according to the classification of soils in ASTM, while all materials tested in the Phase 1 Study are classified into SM (Silty Sand) with some exceptions of CH (Clay) in the upper part of pits.

SM, ML and GM are suitable for impervious earthfill materials, while CH and MH have disadvantage in shearing strength and trafficability.

(2) Mechanical Test

(a) Compaction test

Compaction tests were carried out for maximum dry density and optimum moisture content. The moisture content - dry density curves obtained are shown in Figs. C.3.9 to C.3.14.

Moisture contents of samples tend to be on the wet side of the optimum moisture content, if the sampling is carried out just after rainy season, and to be on dry side, if sampled just after dry season.

(b) Permeability

Permeability tests were carried out by the variable head method, on the samples which were prepared principally under the corresponding optimum moisture content.

As indicated in Table C.3.4 and in Fig. C.3.15, the coefficients of permeability are less than 7 x 10^{-8} cm/sec, if the material is compacted well at the optimum moisture content.

The coefficients of permeability in the Phase 1 Study show larger value than that in the Phase 2 Study, because the former contains less fine-grained soil than the later.

Average of the coefficients of permeability is 7 x 10^{-8} cm/sec through the Phase 1 and Phase 2 Studies.

(c) Triaxial strength

The test results are presented in the graphs in Figs. C3.16 to C3.25 to show:

- the relation between the difference in principal stresses and compressive strain,
- Mohr circles, and
- the relation between the difference in principal stresses and principal pressure ($\overline{CU}$ test)

Test results show 0.06 to 0.20 kgf/cm2 for cohesion and 17.5° to 21.4° for internal friction angle in UU tests and 0.0 to 0.16 kgf/cm2 for cohesion and 25.3° to 30.4° for internal friction angle in $\overline{CU}$ tests.

Average is 0.35 kgf/sq.cm for cohesion and 19.8° for internal friction angle in UU test, and 0.10 kgf/sq.cm for cohesion and 31.2° for internal friction angle in $\overline{CU}$ test through the Phase 1 and Phase 2 Studies.

3.2.5 Estimate of Available Quantity

The proposed borrow area is bounded by small streams on the west and east. According to the observation of the test pits and the supplementary surface geological reconnaissance, bedrock crops out on the slopes of the eastern limit and depth to the bedrock gradually increases toward the west. The average thickness of top humid soil and available soil so far confirmed are 0.5 m and 1.5 m, respectively. The quantity of the available soil is estimated at approximately 300,000 cu.m, assuming 1.5 m for thickness and 200 m x 1,000 m for area, while the required core volume is 200,000 cu.m and top soil volume to be excavated is 100,000 cu.m. Further extension of the area will be possible toward the north.

According to the results of the laboratory test, there is a little local or seasonal variation especially in the gradation (soil classification) and moisture content. The problem of the gradation will be solved by trying to mix materials. The problem of moisture content may require elaborate control to the optimum moisture content.

As a whole, soils in the proposed borrow area are judged suitable as a core material of fill dam.

3.3 Rockfill Materials and Concrete Aggregates

3.3.1 Quarry Sites

Rock and concrete aggregate material survey was carried out at "Kipipiri Road" quarry site. The site covers conspicuous hills formed by welded tuff and high degree welded tuff, located along the Kipipiri Road as shown in Fig. C.3.1. The hills have their ground height of approximately El.2,200 m at their top. A distance to the Malewa damsite is approximately 5 km. According to the results of the preliminary survey, the welded tuff is suitable for rockfill material and the high degree welded tuff for concrete aggregates and filter material. Investigation including core drillings was further carried out during the Phase 2 Study to confirm the quantity and quality.

3.3.2 Core Drillings

Core drillings was carried out at four locations as shown in Fig. C.3.26. Drilling logs of the test drillings are presented in Fig. C.3.27.

3.3.3 Laboratory Test

The representative rock fragments have been sampled from the quarry site as listed below and were tested in the laboratories in Nairobi and Tokyo to assess their properties for the concrete aggregates, filter materials and rockfill materials.

	Sample	Sample No.
Kipipiri Road Quarry Site	For concrete aggregate (from out crops)	WG-4 through WG-6
	For rockfill material (from drilled core)	WR-6 through WR-10 (High degree welded tuff)
		WRC-1 through WRC-5 (Welded tuff)
Malewa Dam Site	For rockfill material (flom drilled core)	WRC-6 throgh WRC-11 (Welded tuff)

Testing items and quantities are presented in Table C.3.2.

The test results are summarized as presented in Table C.3.5.and C.3.6

3.3.4 Properties of Rockfill Materials and Concrete Aggregates

(1) Rockfill materials (Welded tuff)

(a) Specific gravity and absorption

The tests were carried out by suspension method. Specific gravities of the welded tuff fall under a range between 1.67 and 2.27, and show an average of 1.96. Absorptions of the welded tuff fall under a range between 4.7 and 28.6 %, and show an average of 18.4 %.

According to the Table C.3.6, absorptions in all the samples show considerably larger value than that of Table C.3.5. It is probably because that the test in Japan was conducted on untrimmed fragmental sample, which had considerably larger specific surface than the samples tested in Kenya.

(b) Unconfined compressive strength

The tests were carried out using drilled core samples trimmed columnar, of which the proportion of length to diameter is two to one in principle.

The test results of welded tuff range 54.4 to 393.6 kgf/sq.cm and show an average of 121.1 kgf/sq.cm.

(c) Compaction test

Compaction tests were made to obtain density of rockfill material. Since the volume of sample was little, the tests were conducted applying a procedure similar to the compaction test method of soil using under 38.1 mm diameter, three layered sample, mold of 15 cm diameter, and rammer of 2.5 kg weight, drop height of 30 cm and blow number of 55.

Obtained values of density are very small, which, to some extent, seems to have been affected by scale effect of the mold and the maximum diameter of sample. It is deemed, however, that any considerably larger values of density would not be expected, even if larger mold and larger diameter of sample are used.

(d) X-ray diffraction analysis

Results of X-ray diffraction analysis show that deleterious minerals to accelerate weathering and fragmentation of rock, like analcime and monmorillonite are included rather in minor proportions.

(e) P,S-wave velocity

P and S wave velocity was measured for supplements P-wave velocity ranges 1.42 to 2.25 km/sec and show an average of 2.03 km/sec.On the other hand,S-wave velocity ranges 0.81 to 1.39 km/sec and show an average of 1.18 km/sec.

(2) Concrete aggregates (high degree welded tuff)

(a) Specific gravity and absorption

The tests were carried out by suspension method. Specific gravities (SSD: Saturated Surface Dry) range 2.34 to 2.56 and show an average of 2.40 through Phase 1 and Phase 2 Studies. Absorptions range 2.6 to 7.5 % and show an average of 5.6 %.

The average value of 2.40 for specific gravity is a little less and that of 5.6 for absorption is a little larger than a standard requirement, respectively.

(b) Unit weight

The test results range 1,286 to 1,307 kg/cu.m and show an average of 1,293 kg/cu.m through the Phase 1 and Phase 2 Studies.

The average of 1,293 kg/cu.m seems to be low for concrete aggregate.

(c) Soundness

The tests were carried out by chemical method. The test results range 1.0 to 3.0 % and show an average of 1.0 % with the Phase 1 and Phase 2 Studies.

The values are satisfactory for concrete aggregate.

(d) Abrasion

The tests were carried out by Los Angeles method. The tests results range 22.0 to 25.0 % and show an average of 25.8 % through the Phase 1 and Phase 2 Study.

The average of 25.8 % is generally satisfactory for concrete aggregate.

(e) Potential reactivity

The tests were carried out by chemical method to check the potential alkali reactivity of aggregate. Values for Dissolved Silica (Sc) and Reduction in Alkalinity (Rc) were determined and plotted in Fig. C.3.28 which shows that all samples were plotted in the innocuous or the potentially deleterious field, except one (WG-3) in the deleterious field. No immediate harm is seen in materials plotted in the innocuous or in the potentially deleterious field. Additional testing, however, by mortar-bar method is recommended at the pre-construction investigation stage.

3.3.5 Selection of Quarry Site

Initially the high degree welded tuff unit in the Kipipiri Quarry site was contemplated for concrete aggregates and filter material and the welded tuff unit for rockfill material. It was, however, clarified through the test drillings and supplementary surface reconnaissance that the high degree welded tuff unit is found only in a very limited area with thickness less than three meters. Although the estimated exploitable quantity of about 110,000 cu.m assuming 1.0 m of thickness and 200 m x 300 m plus 150 m x 350 m for area, is equal to required concrete aggregates and filter material of about 110,000 cu.m, the quarry operation will actually be difficult because of the little thickness of the rock. In the other hand, the exploitable quantity of the welded tuff, associated with the high degree welded tuff, is estimated about 1,000,000 cu.m, assuming five meters for thickness and 800 m x 250 m for area, for required rockfill material of about 710,000 cu.m.

It is said that the welded tuff has general problems as rockfill material in specific gravity, absorption and weakness against weathering, especially repetition of dry and wet conditions. Several samples of welded tuff have been supplementarily tested in Japan.

The welded tuff is not an excellent rock material, and may involve possibility of rapid weathering. This sort of rock may, for a large part, be crushed and disintegrated into fine fragments and particles in a process of quarring, loading, unloading and embanking with compaction. It should be regarded as this sort of material in designing the dam embankment. It should be embanked in a condition with so high contents of fine material and to the highest density it can attain. A test embankment and a large-scale shearing test are recommended to be made in the stage of detailed design.

Since the high degree welded tuff which was initially considered for concrete aggregate and filter material, is turned out to be of a very limited occurrence with minor thickness, the concrete aggregates will be produced quarrying Trachyte from the "South Gilgil" quarry site, which is located in the western outskirts of Gilgil town and has long been under operation by the Ministry of Public Works for production of asphalt concrete. Trachyte is widespread with thickness sufficient for quarrying operation. The test results of trachyte are presented in Table C3.7. The trachyte is satisfactory for concrete aggregate and filter material in spite of a drawback in abrasion.

3.4 Design Parameters for Embankment Materials

Design parameters for embankment materials are presented in Table C.3.8. These parameters were estimated based on the test results or based on the empirical judgement, if not tested. Further testing in laboratory and in the site in the stage of detailed design is recommended for final determination of reliable parameters.

Although some of excavated rocks at the damsite will be usable for inner shell material, soft rocks as the lake sediments should not be accepted.

TABLES

Table C2.1 Laboratory Testing Items and Quantities

Testing Items		Unit	Quantity	Sample No.
A. Sand and Gravel Materials				
(1)	Screen analysis of sand and coarse aggregate	no.	6	SS-1 through SS-6
(2)	Specific gravity and absorption of sand by pychnometer method	no.	6	SS-1 through SS-6
(3)	Specific gravity and absorption of coarse aggregate by suspension method	no.	6	TG-1 through TG-3,& WG-1 through WG-3
(4)	Unit weight of aggregate for concrete	no.	6	TG-1 through TG-3,& WG-1 through WG-3
(5)	Soundness of aggregate (Sodium sulphate method)	no.	6	TG-1 through TG-3,& WG-1 through WG-3
(6)	Abrasion of coarse aggregate by Los Angels machines	no.	6	TG-1 through TG-3,& WG-1 through WG-3
(7)	Potential reactivity of aggregate (chemical method)	no.	6	TG-1 through TG-3,& WG-1 through WG-3
B. Earthfill Materials				
(B.1)	Physical Test			
(1)	Screen analysis	no.	18	GP-1U, GP-1L ,GP-1M, GP-2U, GP-2L, GP-2M EP-1U, EP-1L,.EP-1M MP-1U, MP-1L, MP-1M MP-2U, MP-2L, MP-2M
(2)	Moisture content	no.	18	Same as above
(3)	Liquid limit, plastic limit and plasticity index	no	18	Same as above
(4)	Specific gravity	no.	18	Same as above
(B.2)	Mechanical Test			
(1)	Moisture-density relations of soils and soil-aggregate mixtures,using 5.5 lb rammer and 12 in drop	no.	6	GP-1M, GP-2M, EP-1M EP-2M, MP-1M, MP-2M
(2)	Permeability	no.	6	Same as above
(3)	Triaxial, UU	no.	18	Same as above
(4)	Triaxial, CU	no.	18	Same as above
C. Rockfill Material				
(1)	Specific gravity and absorption by suspension method	no.	10	TR-1 through TR-5, WR-1 through WR-5
(2)	Unconfined compressive strength of intact rock specimen	no.	10	Same as above

Table C.3.1 Survey Items and Quantities

Survey Items		Unit	Quantity
(1)	Earth material		
(1.a)	Test pitting	nos.	5
(1.b)	Physical test		
	Screen analysis	nos.	5
	Moisture content	nos.	5
	Liquid and plastic limit and plastic index	nos.	5
	Specific gravity	nos.	5
(1.c)	Mechanical test		
	Compacting test	nos.	5
	Permeability test	nos.	5
	Triaxial test, UU	nos.	9
	" , $\overline{CU}$	nos.	9
(2)	Rock and Concrete aggregate		
(2.a)	Test drilling*	Loc.	4
(2.b)	Laboratory test		
	Specific gravity and absorption	nos.	3
	Unit weight	nos.	3
	Soundness	nos.	3
	Abrasion	nos.	3
	Potential reactivity	nos.	3
(3)	Rock material		
	Specific gravity and absorption	nos.	18
	Unconfined compressive strength of intact rock specimen	nos.	18
	Compaction test	nos.	2
	P.S-Wave velocity	nos	8
	X-ray diffraction analysis	nos	6

*: Test drilling conducted at the Kipipiri Road Quarry Site

Boreholes	Elevation (El.m)	Depth (m)
KB-1	2,223.58	30
KB-2	2,207.87	20
KB-3	2,191.00	20
KB-4	2,179.59	30

Table C.3.2 Testing Items and Quantity for Construction Materials Survey

	Testing Items	Unit	Quantity	Sample
1.	Earth material			
1.1	Physical test			EP-3 through EP-7
(a)	Screen analysis	no.	5	
(b)	Moisture content	no.	5	
(c)	Liquid limit and	no.	5	
(d)	Plastic limit and plasticity index	no.	5	
(e)	Specific gravity	no.	5	
1.2	Mechanical test			
(a)	Compaction	no.	5	EP-3 through EP-7
(b)	Permeability test	no.	5	
(c)	Triaxial test, UU	no.	9	EP-3, EP-6, EP-7
(d)	Triaxial test, CU	no.	9	
2.	Concrete aggregates			WG-4 through WG-6
(a)	Specific gravity and absorption by pychnometer method	no.	3	
(b)	Specific gravity and absorption by suspension method	no.	3	
(c)	Unit weight	no.	3	
(d)	Soundness by sodium sulphate method	no.	3	
(e)	Abrasion by Los Angels machine	no.	3	
(f)	Potential reactivity by chemical method	no.	3	
3.	Rock material			
(a)	Specific gravity and absorption by suspension test	no.	18	WR-6 through WR-10
(b)	Unconfined compressive strength of intract rock specimen	no.	18	WRC-1 through WRC-13
(c)	Compaction test	no.	2	Welded tuff of Quarry Site & Dam Site
(d)	P.S-Wave velocity	no.	8	WRC-6 through WRC-13
(e)	X-ray diffraction analysis	no.	6	WRC-6 through WRC-11

Note : Testing items, 3-(c), (d), (e) and eight sample of Testing items, 3-(a), (b) were conducted in Japan.

Table C.3.3 Results of Laboratory Test (Earthfill Materials, Physical Test)

Testing Items / Sample No.	Moisture Content Wn (%)	Specific Gravity (Gs)	Gradation Analysis							Atterberg Limits		
			+2 mm (%)	2 - 0.074 mm (%)	0.074 - 0.005 mm (%)	-0.005 mm (%)	Uniformity coefficient UC	Coefficient of Curvature Uc'	Classifi-cation	Liquid Limit WL%	Plastic LImig WP%	Plasticitiy Index IP%
GP-1U	22.0	2.53	34	35	25	6	155.6	0.39	(SM)	60.8	30.9	29.9
GP-1L	19.8	2.68	28	62	9	1	14.7	0.35	(S-M)	75.5	54.9	20.6
GP-1M	23.6	2.53	25	65	9	1	8.0	0.44	(S-M)	65.4	53.0	12.4
GP-2U	20.0	2.63	22	45	25	8	84.6	0.79	(SM)	56.4	39.1	17.3
GP-2L	23.3	2.79	16	54	27	3	16.7	2.34	(SM)	56.2	51.7	4.3
GP-2M	21.0	2.47	16	58	25	1	8.3	1.56	(SM)	66.0	61.4	4.6
EP-1U	22.1	2.48	2	20	48	30	11.1	0.69	(CH)	54.4	28.9	25.5
EP-1L	18.0	2.55	7	53	32	8	116.7	0.16	(SM)	49.7	45.5	4.2
EP-1M	22.2	2.77	9	46	33	12	52.5	1.54	(SM)	48.3	41.4	6.9
EP-2U	23.2	2.51	9	37	30	24	52.8	0.33	(CH)	57.3	13.0	44.3
EP-2L	25.6	2.56	6	45	29	20	43.2	0.69	(SM)	52.4	31.9	20.5
EP-2M	22.0	2.64	17	51	29	3	30.0	1.41	(SM)	57.0	32.3	24.7
MP-1U	20.2	2.62	12	24	39	25	-	-	(MH)	52.3	35.4	16.9
MP-1L	45.5	2.72	34	36	26	4	81.2	0.27	(SM)	62.3	45.0	17.3
MP-1M	28.0	2.72	29	37	33	1	50.0	0.21	(SM)	56.5	26.6	29.9
MP-2U	15.6	2.51	26	43	30	1	30.0	0.35	(SM)	35.0	23.4	11.6
MP-2L	34.7	2.56	24	41	32	3	38.9	0.79	(SM)	39.2	28.1	11.1
MP-2M	23.5	2.65	26	30	39	5	15.4	0.56	(SM)	46.8	37.8	9.0

Table C.3.4 Results of Laboratory Test (Earthfill Materials, Mechanical Test)

Testing Items	Compaction Tests			Permeability Tests		Triaxial Tests					
						UU			$\overline{CU}$		
Sample No.	Optimum Moisture Content Wopt (%)	Maximum Dry Density γd max (t/m^3)	Wn-Wopt (%)	Coeff. of Permeability K (cm/sec)	Water Content (W)	C (kgf/cm^2)	ø (°)	Water Content (W)	C' (kgf/cm^2)	ø (°)	Water Content (W)
GP-1M	36.4	1.218	-12.2	2×10^{-6}	Wopt	0.2	29	Wopt	0.5	37.5	Wopt
GP-2M	35.8	1.211	-14.8	3×10^{-7}	Wopt	1.2	28.5	Wopt	0.6	33	Wopt
EP-1M	27.2	1.370	-5.0	2×10^{-7}	Wopt	1.4	21	Wopt	0.0	37.5	Wopt
EP-2M	31.5	1.330	-9.5	3×10^{-7}	Wopt	0.8	17.5	Wopt	0.2	33.5	Wopt
MP-1M	31.0	1.305	-3.0	9×10^{-7}	Wopt	0	28	Wopt	0.3	34.5	Wopt
MP-2M	28.0	1.440	-4.5	3×10^{-7}	Wopt	0.2	10.5	Wopt	0.3	22	Wopt

Table C.3.5 Results of Laboratory Test (Earthfill Materials, Physical Test)

	Testing Items / Sample No.	Moisture Content Wn (%)	Specific Gravity (Gs)	Gradation Analysis							Atterberg Limits		
				+2 mm (%)	2 - 0.0074 mm (%)	0.074 - 0.005 mm (%)	- 0.005 mm (%)	Uniformity Coefficcient UC	Coefficient of Curvature UC	Classification	Liquid Limit WL%	Plastic Limit WP%	Plasticity Index IP%
Phase 1	EP - 1U	22.1	2.48	2	20	48	30	11.1	0.69	(CH)	54.4	28.9	25.5
	EP - 1L	18.0	2.55	7	53	32	8	116.7	0.16	(SM)	49.7	45.5	4.2
	EP - 1M	22.2	2.77	9	46	33	12	52.5	1.54	(SM)	48.3	41.4	6.9
	EP - 2U	23.2	2.51	9	37	30	24	52.8	0.33	(CH)	57.3	13.0	44.3
	EP - 2L	25.6	2.56	6	45	29	20	43.2	0.69	(SM)	52.4	31.9	20.5
	EP - 2M	22.0	2.64	17	51	29	3	30.0	1.41	(SM)	57.0	32.3	24.7
Phase 2	EP - 3	29.2	2.48	13	37	31	19	142.3	0.60	(ML)	42.0	31.0	11.0
	EP - 4	35.0	2.42	55	19	16	10	1469.4	1.92	(GM)	55.0	43.0	12.0
	EP - 5	29.7	2.49	1	20	45	34	—	—	(MH)	56.0	42.0	14.0
	EP - 6	36.4	2.59	17	19	28	36	—	—	(MH)	65.0	43.0	22.0
	EP - 7	24.0	2.37	16	28	30	26	97.9	0.29	(ML)	49.0	36.0	13.0
Ave. 1		26.1	2.53	13.8	34.1	31.9	20.2	224.0	0.85		53.3	35.3	18.0
Ave. 2		25.9	2.52	10.7	33.7	31.0	20.3	76.5	0.85		53.2	36.6	18.7

Ave. 1 : Average of all
Ave. 2 : Average excluding max. & min.

Table C.3.6 Results of Laboratory Test (Earthfill Materials, Mechanical Test)

	Testing Items / Sample No.	Compaction Tests			Permeability Tests		Triaxial Tests					
							UU			$\overline{CU}$		
		Optimum Moisture Content Wopt (%)	Maximum Dry Density rd max. (t/m3)	Wn-Wopt (%)	Coeff. of Permeability K (cm/sec)	Water Content (W)	C (kgf/cm2)	ø (°)	Water Content (W)	C (kgf/cm2)	ø (°)	Water Content (W)
Phase 1	EP - 1M	27.2	1,370	-5.0	2×10^{-7}	Wopt	1.4	21	Wopt	0.0	37.5	Wopt
	EP - 2M	31.5	1,330	-9.5	3×10^{-7}	Wopt	0.8	17.5	Wopt	0.2	33.5	Wopt
Phase 2	EP - 3	26.9	1,440	2.3	3×10^{-8}	Wopt	0.06	21	Wopt	0.16	29.8	Wopt
	EP - 4	32.5	1,270	2.5	7×10^{-8}	Wopt	—	—	—	—	—	—
	EP - 5	38.3	1,228	-8.6	2×10^{-8}	Wopt	—	—	—	—	—	—
	EP - 6	29.2	1,376	7.2	8×10^{-9}	Wopt	0.06	21.4	Wopt	0.13	25.3	Wopt
	EP - 7	26.2	1,452	-2.2	4×10^{-9}	Wopt	0.20	17.5	Wopt	0.0	30.4	Wopt
Ave. 1		30.3	1,352	-1.9	9×10^{-8}		0.50	19.7		0.10	31.3	
Ave. 2		29.5	1,357	-2.2	7×10^{-8}		0.35	29.8		0.10	31.2	

Ave. 1 : Average of all
Ave. 2 : Average excluding max. & min.

Table C.3.7 Results of Laboratory Tests (Rockfill Materials & Concrete Aggregates)

Phase	Material	Sample No.	Location	Specific Gravity (S.S.D)	Absorption (%)	Unit Weight (kg/cu.m)	Soundness (Sodium sulphate) (%)	Abrasion (Los Angeles) (%)	Potential Reactivity (Chemical) (m mol/lit)	Unconfined Compressive Strength (kgf/sq.m)
	Rockfill Materials									
Phase 1	High degree Welded tuff	WR-1	Outcrop	2.50	1.3	—	—	—	—	76.4
		WR-2		2.56	1.0					76.0
		WR-3		2.37	1.8					122.0
		WR-4		2.42	2.7					92.8
		WR-5		2.40	2.2					112.7
Phase 2		WR-6	KB-3 6.74	2.46	2.9	—	—	—	—	899.4
		WR-7	KB-3 7.12	2.36	5.3					583.3
		WR-8	KB-3 7.32	2.38	6.4					636.3
		WR-9	KB-3 7.52	2.38	6.3					689.3
		WR-10	KB-3 7.77	2.34	5.6					477.2
	Ave. 1			2.42	3.55					*657.1
	Ave. 2			2.41	3.51					*636.3
	Welded tuff	WRC-1	KB-2 5.88	2.20	4.7	—	—	—	—	106.1
		WRC-2	KB-2 10.65	2.23	10.7					263.1
		WRC-3	KB-3 3.77	2.00	14.3					106.1
		WRC-4	KB-3 9.60	1.96	20.9					159.1
		WRC-5	KB-4 5.55	1.95	16.8					212.1
	Ave. 1			2.02	13.5					169.3
	Ave. 2			2.05	13.9					159.1
	Concrete Aggregates									
Phase 1	High degree Welded tuff	WG-1	Outcrop	2.41	4.2	1,278	0.4	28.2	RC:210 SC:409.4 RC:435 RC:433.4 RC:100 SC:586	—
		WG-2		2.41	4.2	1,270	0.2	27.8		
		WG-3		2.56	9.1	1,388	0.3	30.5		
Phase 2		WG-4		2.34	6.4	1,286	2.4	22.0	RC:300 SC:138 RC:460 SC:126 RC:350 SC:666	—
		WG-5		2.34	7.5	1,299	3.0	25.0		
		WG-6		2.45	2.6	1,307	1.0	25.0		
	Ave. 1			2.42	5.7	1,305	1.2	26.4		
	Ave. 2			2.40	5.6	1,293	1.0	25.8		

Ave. 1 : Average of all
Ave. 2 : Average excluding max. & min.
* Excluding Phase / Study

Table C.3.8 Result of Home Laboratory Tests (Welded tuff) (1/2)

Simple No.	Rock Name	Location	Specific Gravity (S.S.O)	Absorption (%)	Unconfined Compressive Strength (kgf/sq.cm)	Compaction Test Density (g/cu.cm)	P-Wave Velocity (km/sec)	S-Wave Velocity (km/sec)
WRC-6	Welded tuff	KB-2 4.00 m	1.86	25.4	95.8	Wet γ t = 1.25 Dry γ d = 1.21 Moisture Content w = 2.6% Void Raitio e = 0.56	2.11	1.20
WRC-7		KB-2 10.30 m	2.27	9.8	393.6		2.18	1.28
WRC-8		KB-3 3.60 m	2.00	15.0	120.4		2.25	1.39
WRC-9		KB-3 10.00 m	1.80	28.6	122.3		1.74	0.97
WRC-10		KB-4 5.80 m	1.90	22.1	164.7		2.21	1.35
WRC-11		KB-4 6.15 m	1.83	23.3	74.7		1.81	1.13
WRC-12		MB-8 12.70 m	1.83	23.6	54.4	γ t = 1.25 γ d = 1.23 w = 1.4% e = 0.46	2.11	1.12
WRC-13		MB-9 11.25 m	1.67	24.0	86.2		1.42	0.81
Ave. 1			1.90	21.5	139.0	γ t = 1.25 γ d = 1.22	1.98	1.16
Ave. 2			1.87	22.8	83.0		2.03	1.18
Ave. 3			1.96	18.4	121.1		—	—

Ave. 1 : Average of all, Ave. 2 : Average excluding max. & min.
Ave. 3 : Average of Ave. 2 in Table C3.7 and C3.8

— continue —

Table C.3.8 Results of Home Laboratory Tests (Welded tuff) (2/2)
Results of X-ray Diffraction Analysis

Sample			Detected Minerals					
			Feldspar	Quartz	Amphibole	Analcime	Montmorillo-nite	Glass
WRC-6	KB-2	4.0	◎	○	∘		∘	∘
WRC-7	"	10.3	◎	∘	∘		∘	∘
WRC-8	KB-3	3.6	◎	∘	∘		∘	○
WRC-9	"	10.0	○	∘		∘	○	○
WRC-10	KB-4	5.8	○	∘		∘	∘	○
WRC-11	"	6.15	○	∘		∘	∘	○

Size of the circles indicates magnitude of the mineral contents, and the multipul circles represent far higher mineral contents.

Table C.3.9 Results of Laboratory Tests (Trachyte)

	Sample No. \ Testing Item	Specific Gravity (S.S.D)	Absorption (%)	Unit Weight (kg/cu.m)	Soundness (Sodium sulphate) (%)	Abrasion (Los Angeles) (%)	Potential Reactivity (Chemical) (m mol/lit)	Unconfined Compressive Strength (kgf/sq.cm)
	Rockfill Materials							
Phase 1	Outcrop TR-1	2.56	1.0	—	—	—	—	62.0
Phase 1	Outcrop TR-2	2.33	1.1					42.0
Phase 1	Outcrop TR-3	2.52	2.8					41.1
Phase 1	Outcrop TR-4	2.55	1.8					66.3
Phase 1	Outcrop TR-5	2.56	1.9					49.1
Phase 2	Outcrop TG-4	2.57	2.1	—	—	—	—	569.0
Phase 2	Outcrop TG-5	2.58	2.1					597.6
Phase 2	Outcrop TG-6	2.57	2.3					599.6
Phase 2	Outcrop TG-7	2.58	2.1					623.0
Phase 2	Outcrop TG-8	2.57	2.3					555.7
Ave. 1		2.54	2.0					* 589.0
Ave. 2		2.56	2.0					* 588.7
	Concrete Aggregates							
Phase 1	TG-1	2.54	2.8	1,380	0.2	36.6	RC:115 SC:466.4	—
Phase 1	TG-2	2.55	2.7	1,390	0.1	35.0	RC:310 RC:459.4	
Phase 1	TG-3	2.51	9.1	1,442	0.2	36.0	RC:350 SC:586	
Ave. 1		2.53	4.9	1,404	0.2	35.9		
Ave. 2		2.54	2.8	1,390	0.2	36.0		

Ave. 1 : Average of all
Ave. 2 : Average excluding max. & min.
* Excluding Phase 1 Study

Table C3.10 Design Parameters for Embankment Materials

		Material	Specific Gravity	Dry Density (t/m^3)	Wet Density (t/m^3)	Cohesion (Effective) (t/m^3)	Int.Fric.An (Effective) (o)	Coeff. of Permeability (cm/sec)
①	Impervious Core	Soil	2.52	1.29	1.60 (Saturated)	0.95	29.5	1×10^{-5}
②	Filter	Trachyte	2.56	1.85	1.90	0.0	35.0	5×10^{-4}
③	Inner Shell	Welded Tuff & Others	1.90	1.22	1.25	0.0	35.0	1×10^{-3}
④	Outer Shell	Welded Tuff & High Degree Welded Tuff	1.96	1.22	1.25	0.0	38.0	5×10^{-3}
⑤	Riprap	Trachyte	2.56	1.85	1.90	0.0	40.0	Free Draining

Note : Underlined is estimated

FIGURES

Fig. C.2.1

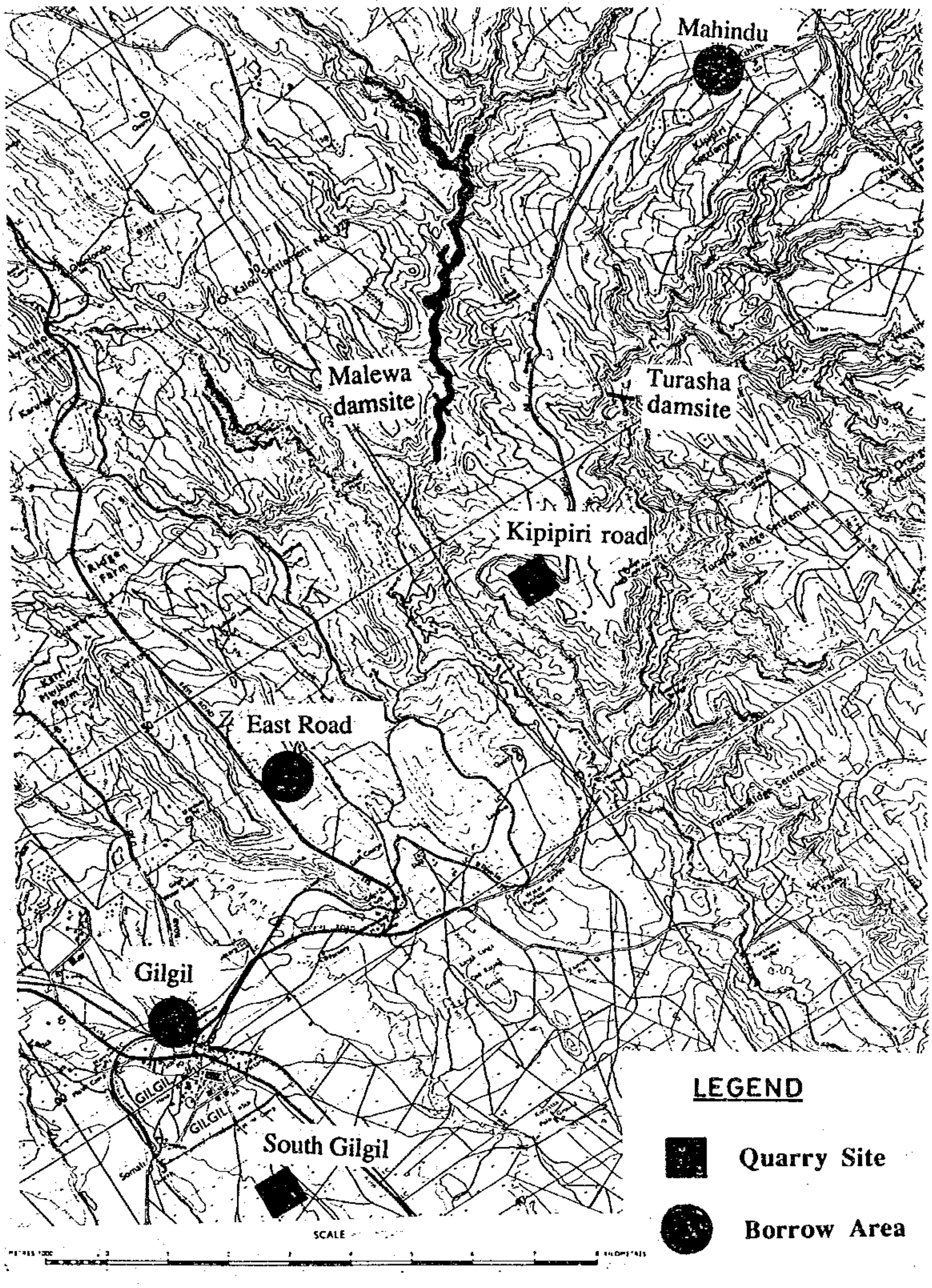

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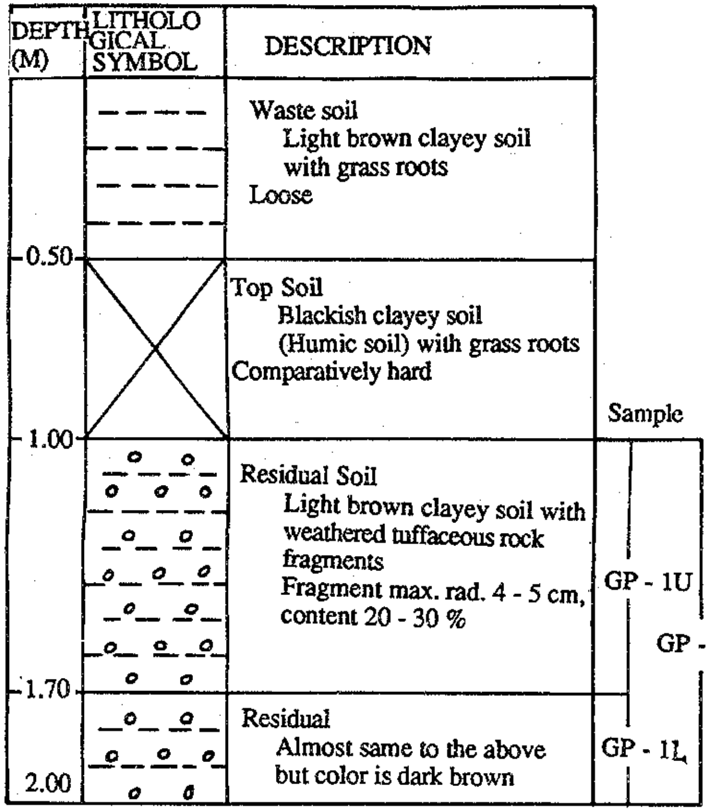
Fig. C.2.2

TEST PIT GP - 1



TEST PIT GP - 2

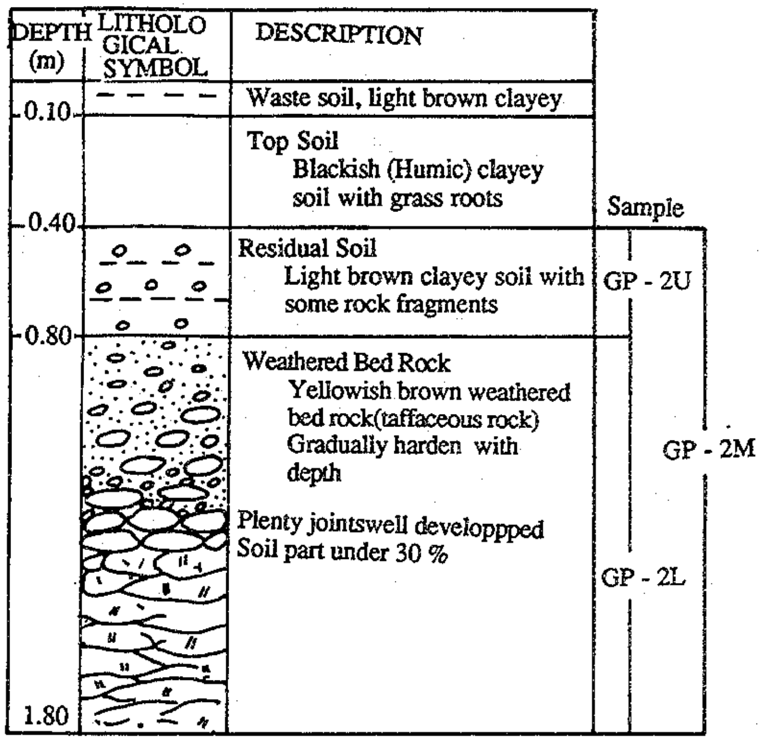


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Fig. C.2.3

TEST PIT EP - 1

DEPTH (m)	LITHOLOGICAL SYMBOL	DESCRPTION	Sample
0 – 1.00		Top Soil Blackish humic clayey soil with grass roots Comparatively compact	
1.00 – 1.50		Lateritic Soil Dark brown lateritic granular soil with grass roots	EP - 1U / EP - 1M
1.50 – 2.00		Lateritic Soil Light brown lateritic granular soil, compact	EP - 1L / EP - 1M

TEST PIT EP - 2

DEPTH (m)	LITHOLOGICAL SYMBOL	DESCRIPTION	Sample
0 – 0.80		Top Soil Blackish humic clayey soil with grass roots Comparatively compact	
0.80 – 1.20		Moved Residual Soil Light brown clayey soil with some rock fragments	EP - 2U / EP - 2M
1.20 – 1.70		Moved Residual Soil Light brown clayey soil Compact	EP - 2U / EP - 2M
1.70 – 2.00		Lateritic Soil Dark brown lateritic soil Loose	EP - 2L / EP - 2M

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JAPAN INTERNATIONAL COOPERATION AGENCY

TITLE

Plofiles of Test Pits in East Road Borrow Area (2/3)

Fig. C.2.4

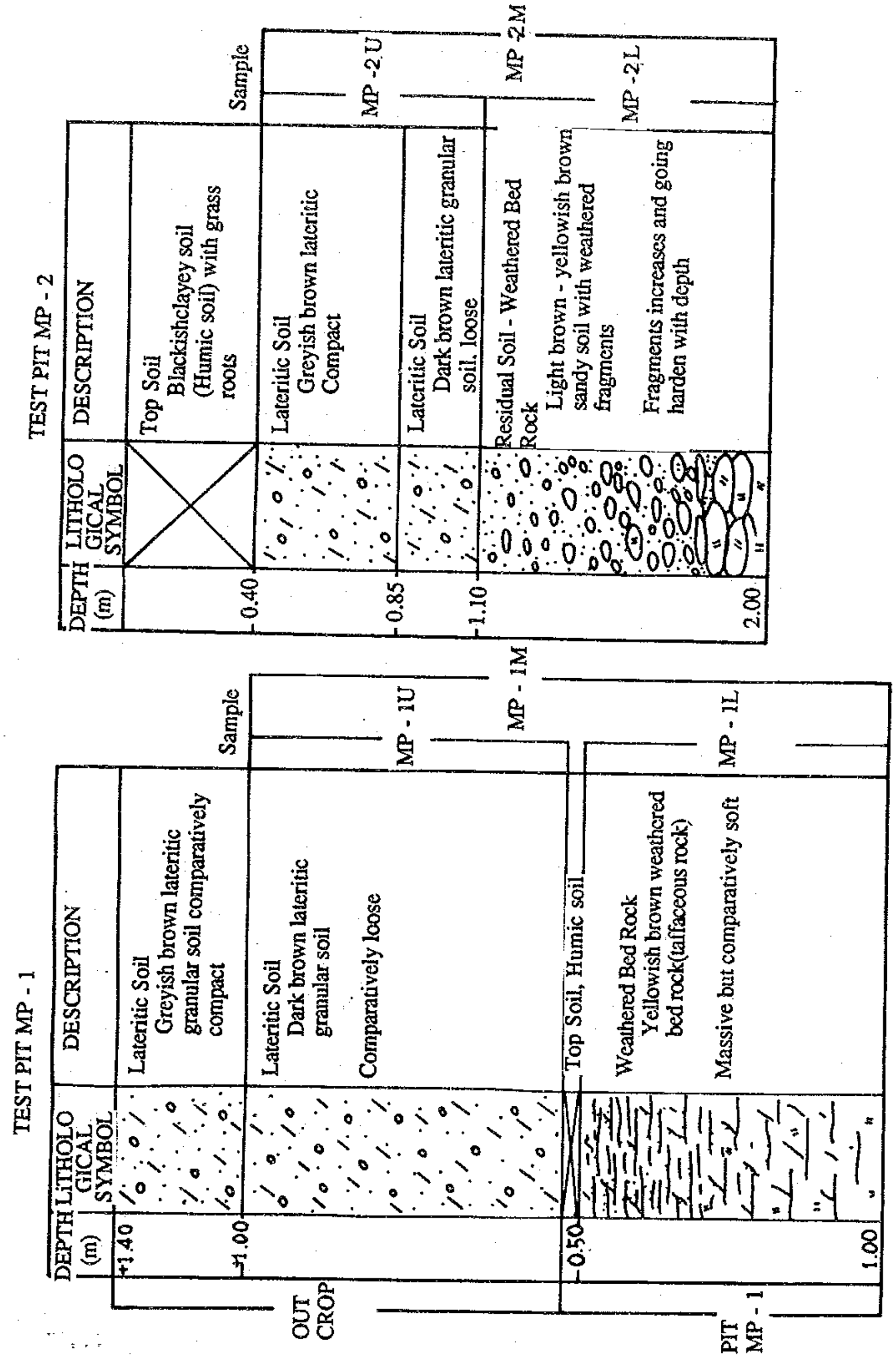

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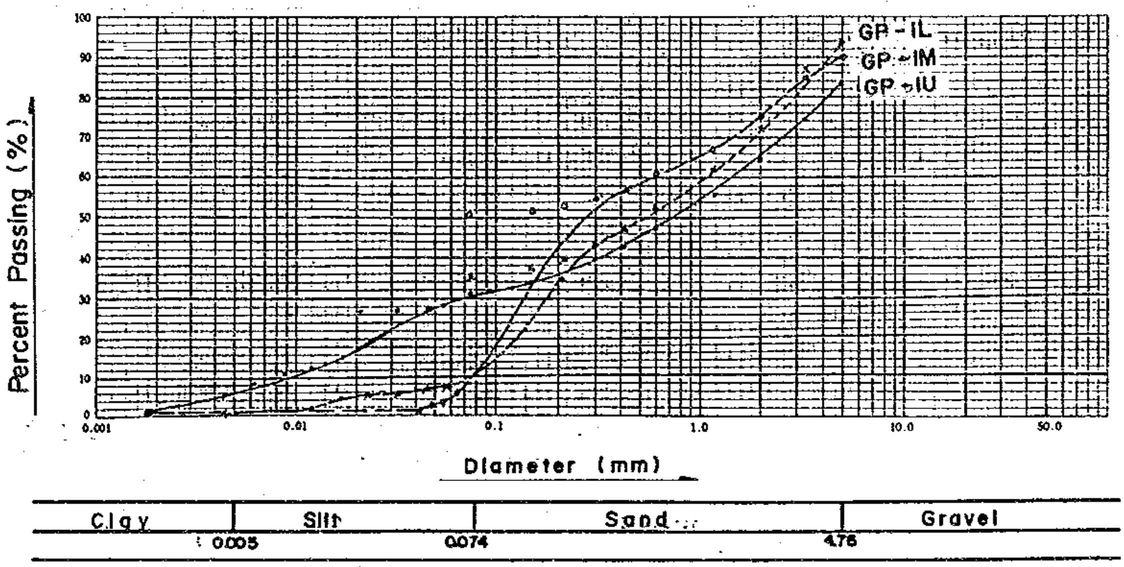
Fig. C.2.5

Gradation Curves of Soil (GP-1)



Gradation Curves of Soil (GP-2)

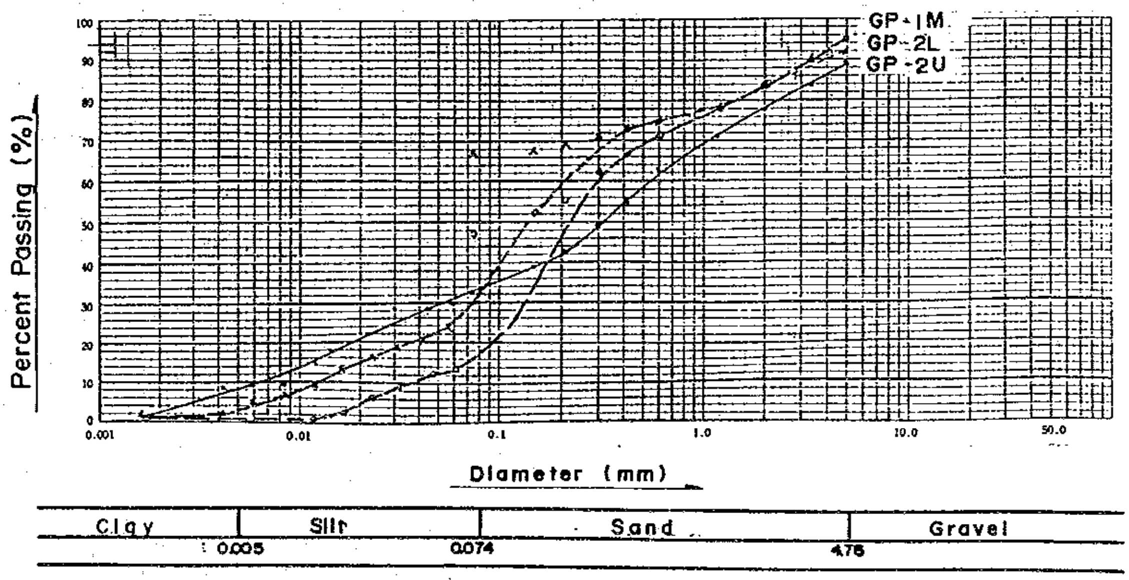


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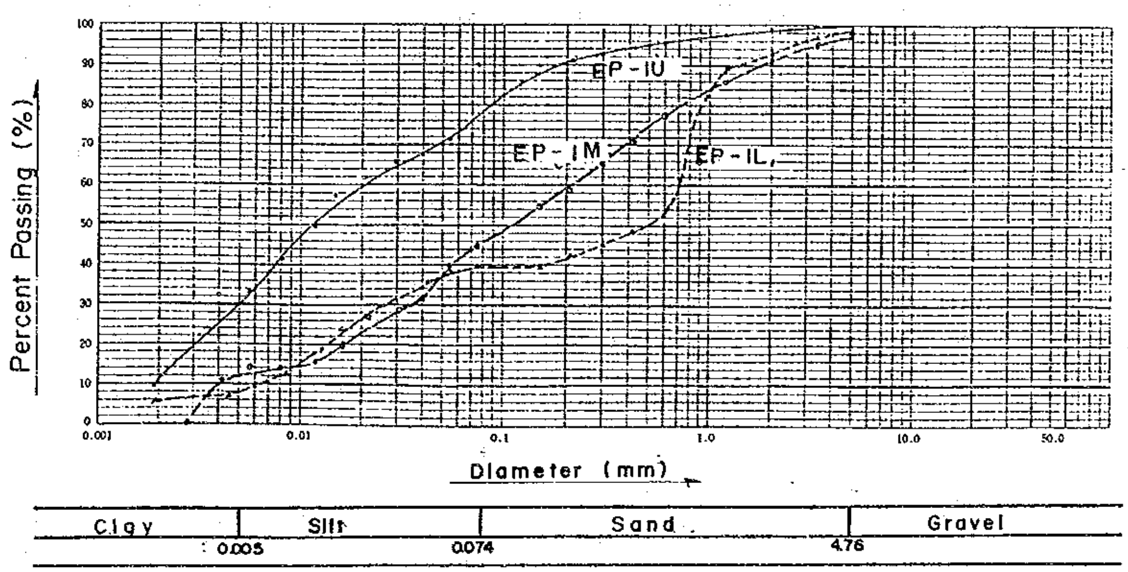
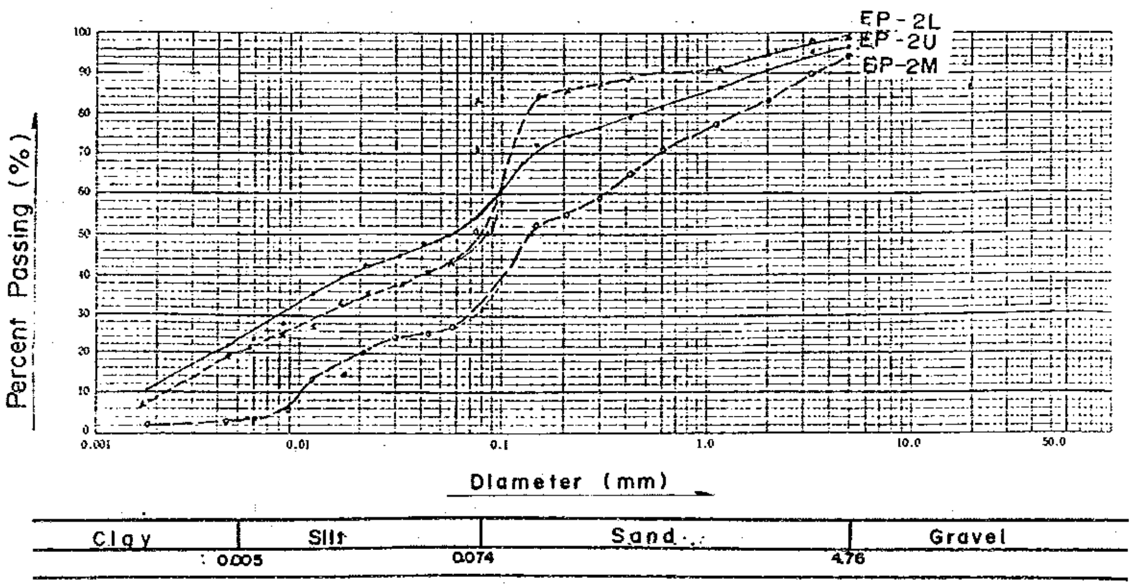
Fig. C.2.6

Gradation Curves of Soil (EP-1)



Gradation Curves of Soil (EP-2)



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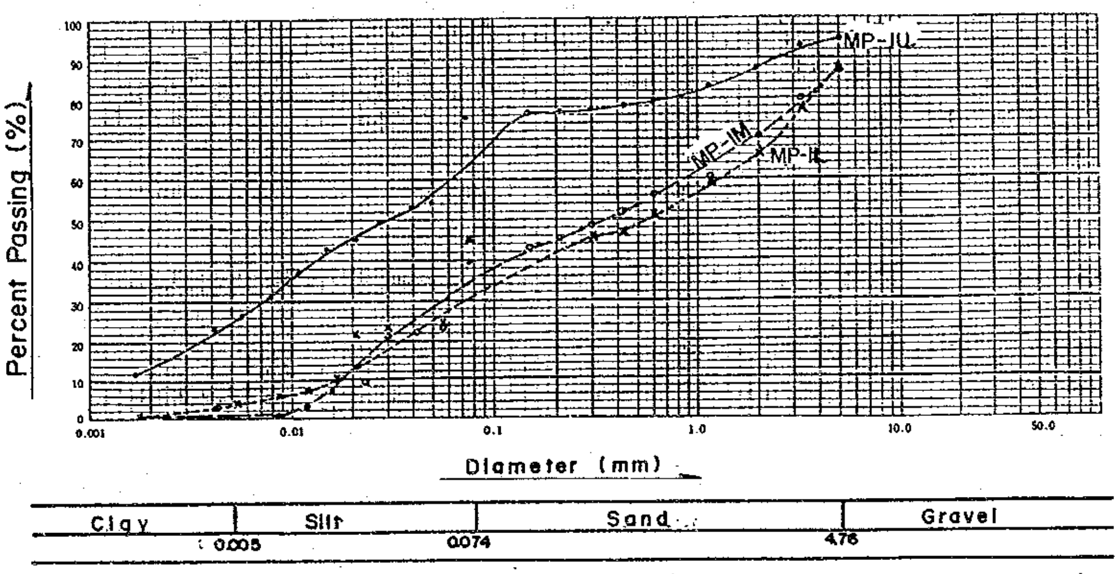
Gradation Curves of Soil (MP-1)



Gradation Curves of Soil (MP-2)

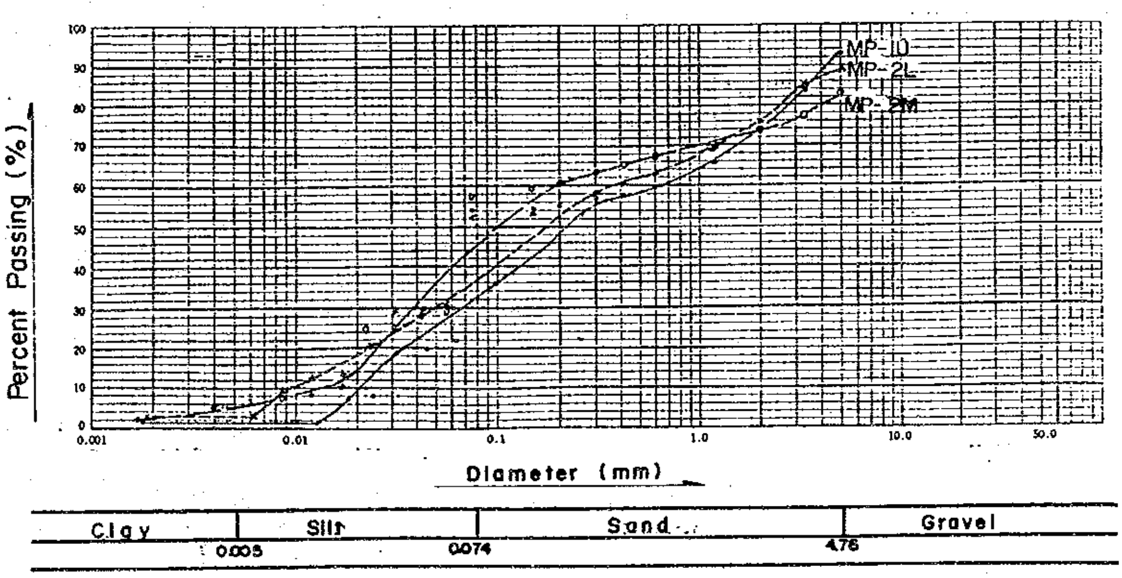


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Fig. C.2.8

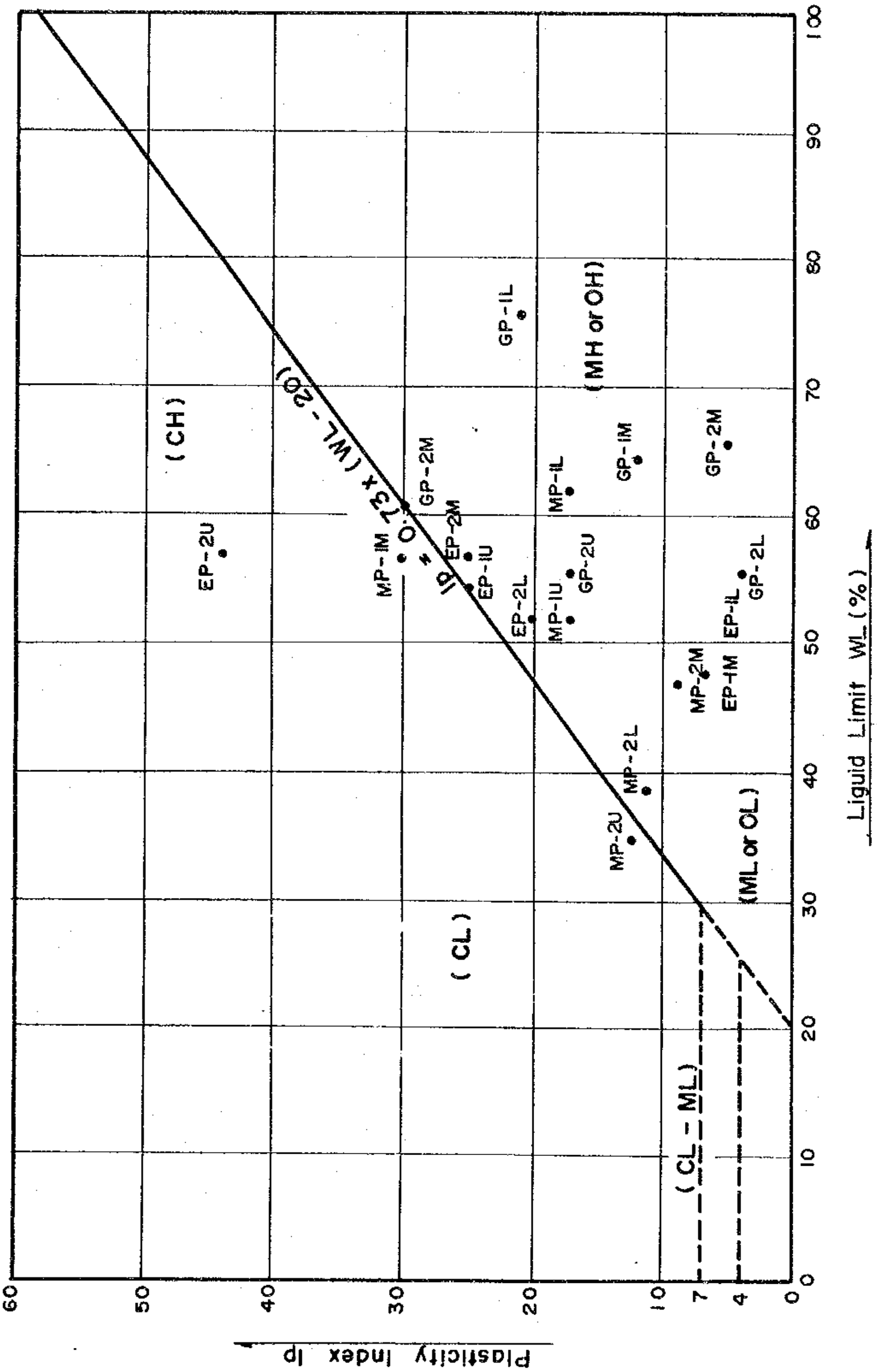

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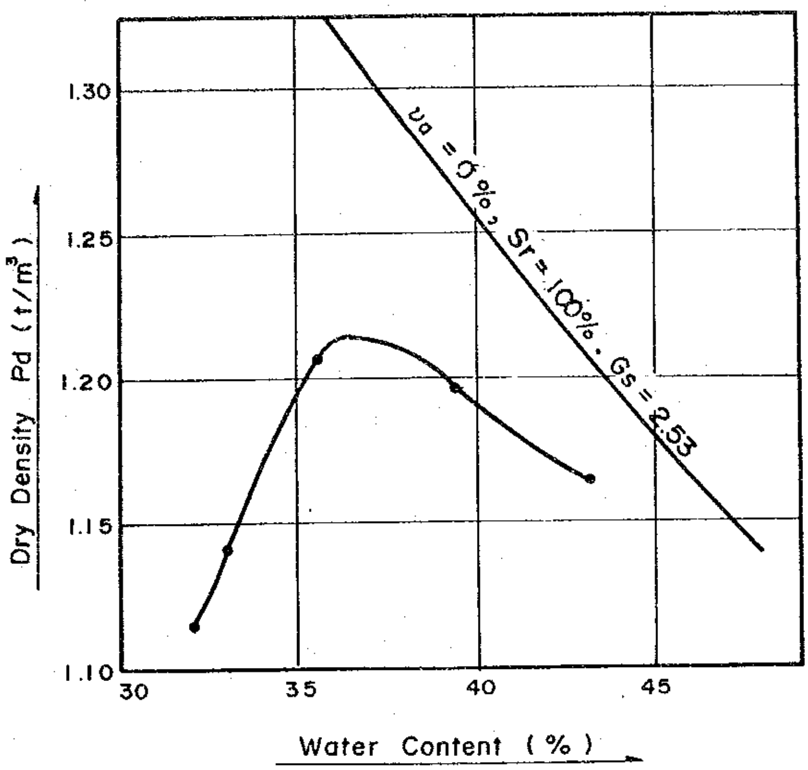
Fig. C.2.9

Compaction Characteristics of Soil (GP-1M)



Compaction Characteristics of Soil (GP-2M)

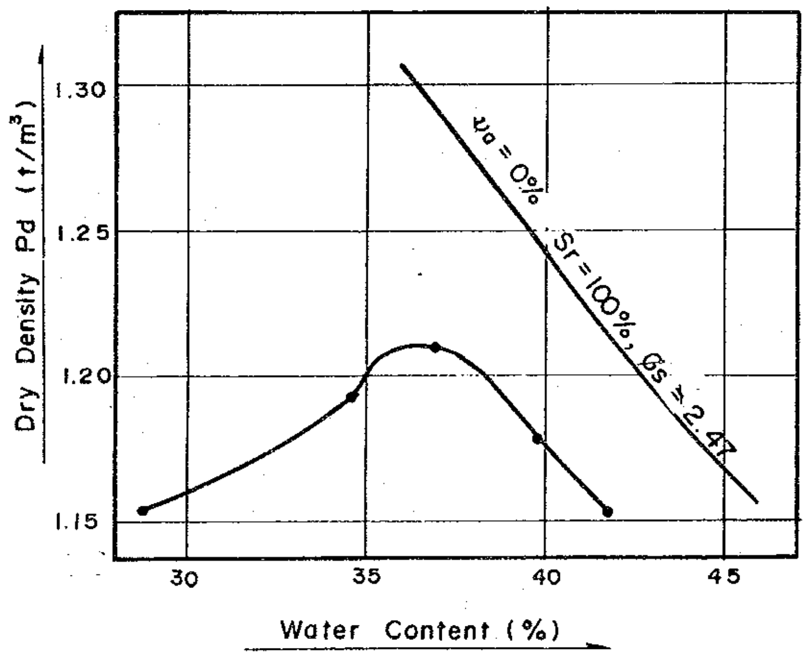


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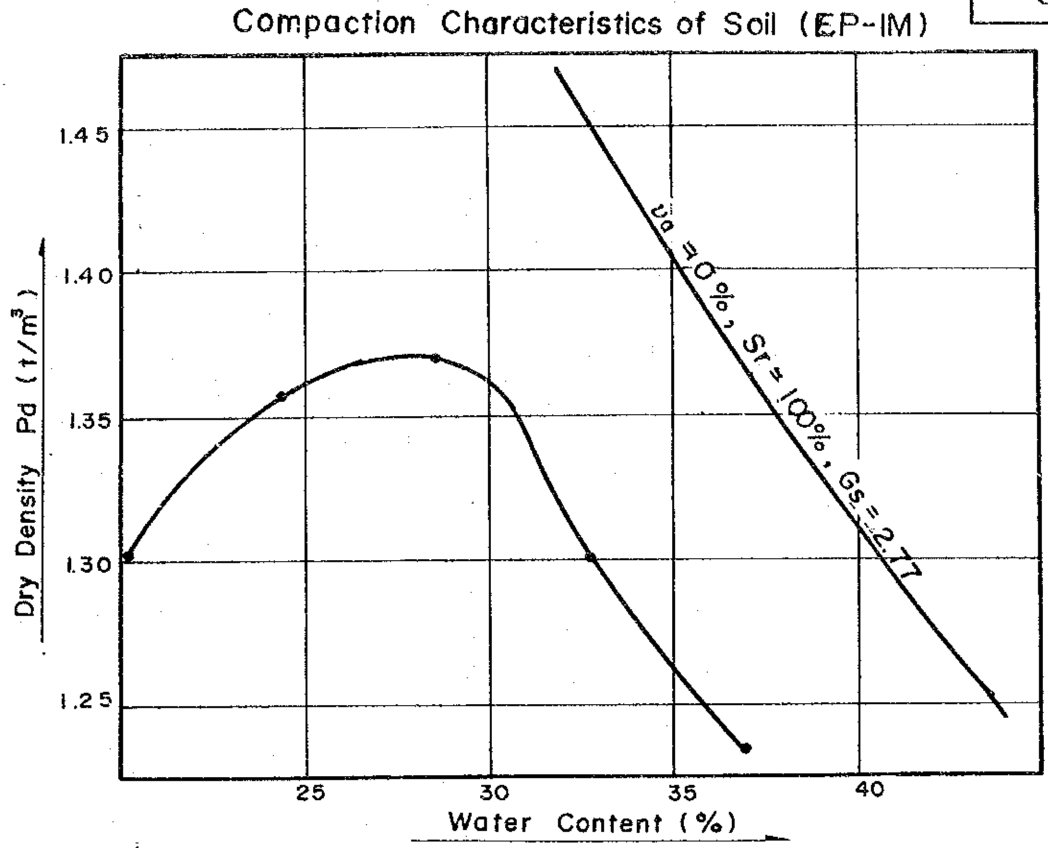
Fig. C.2.10



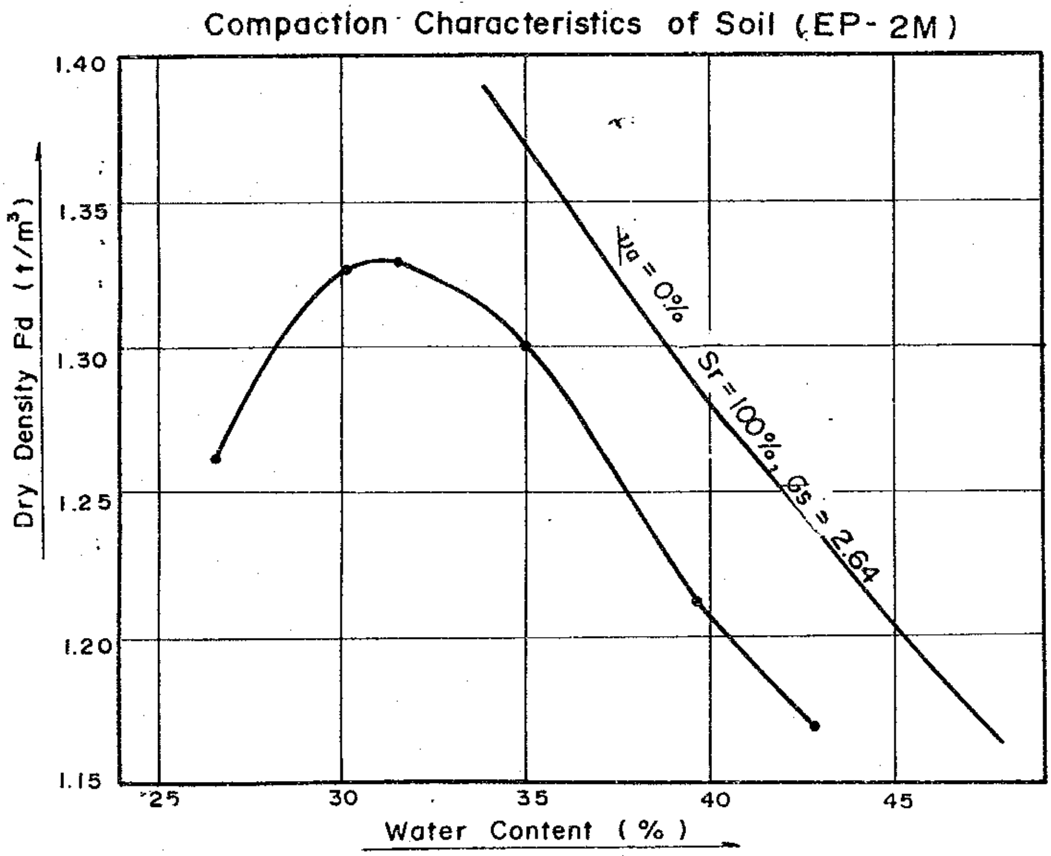


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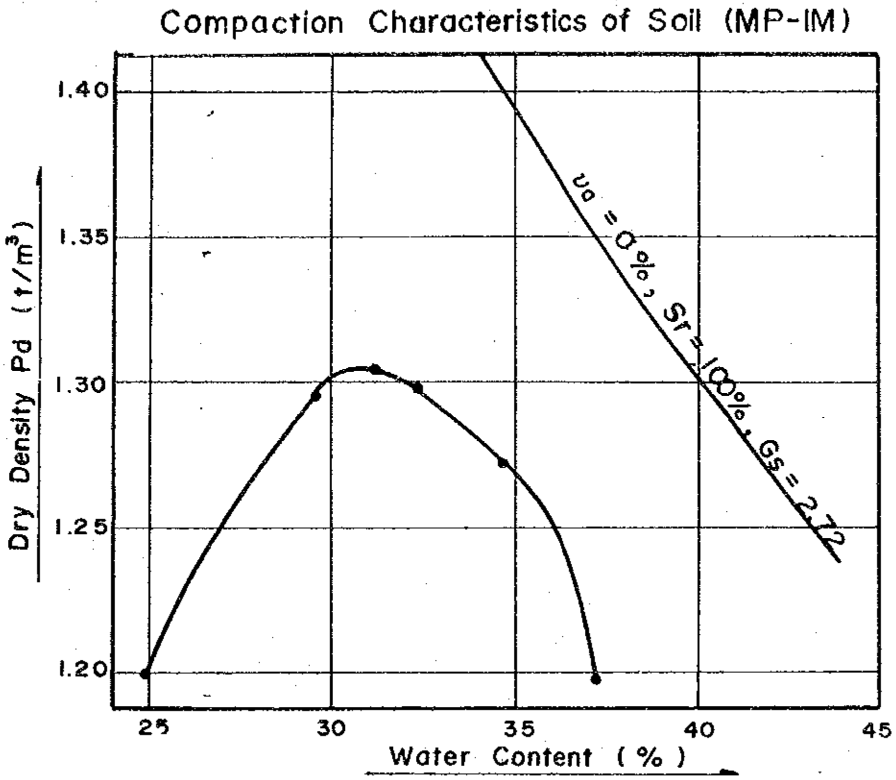
Fig. C.2.11



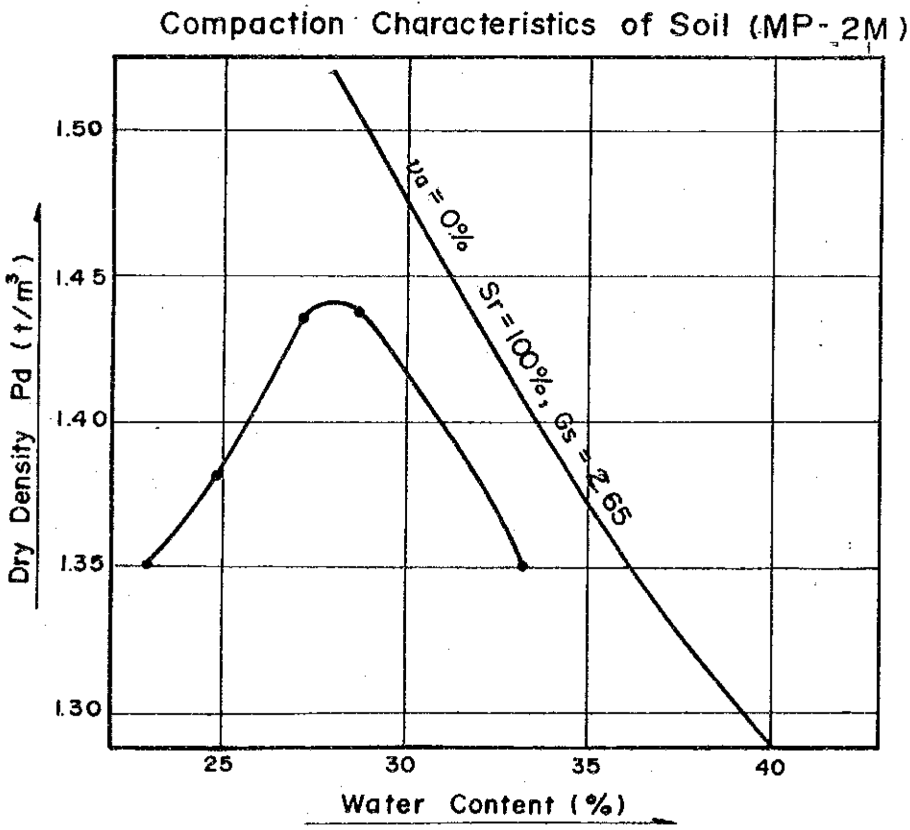


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Fig. C.2.12

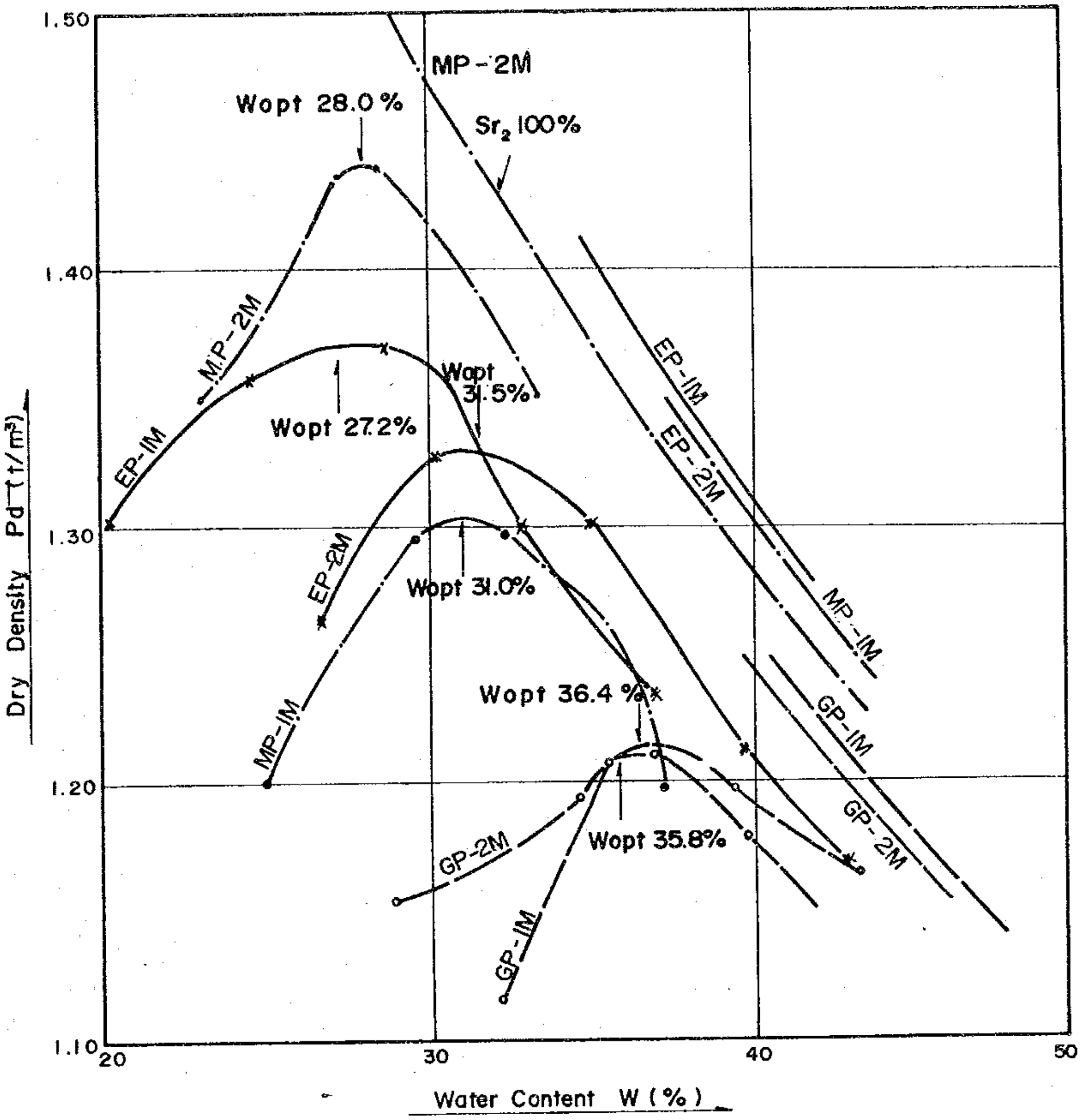

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Fig. C.2.13

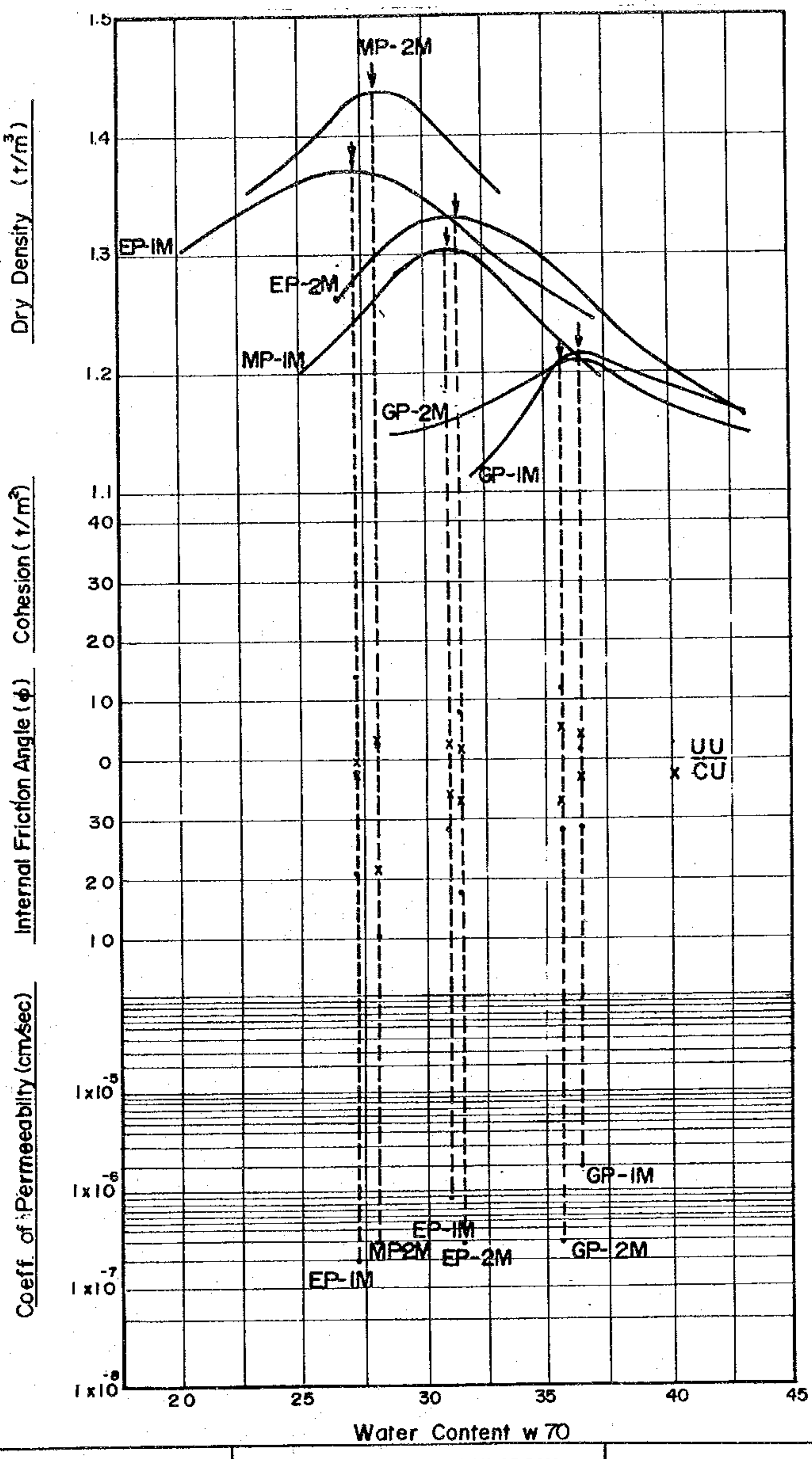

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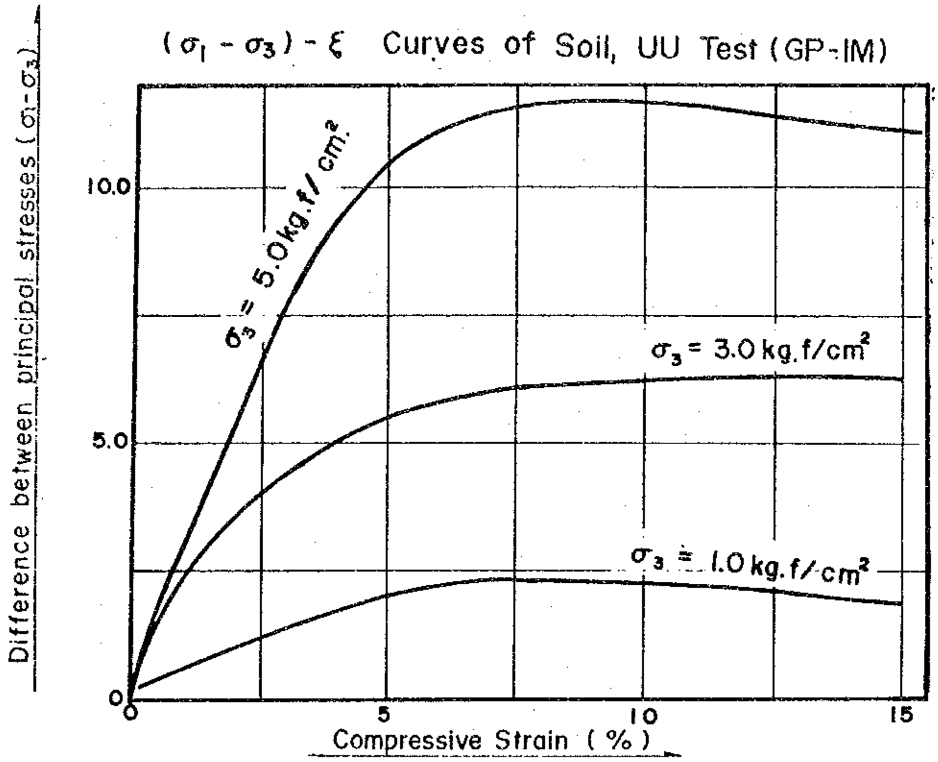
Fig. C.2.14



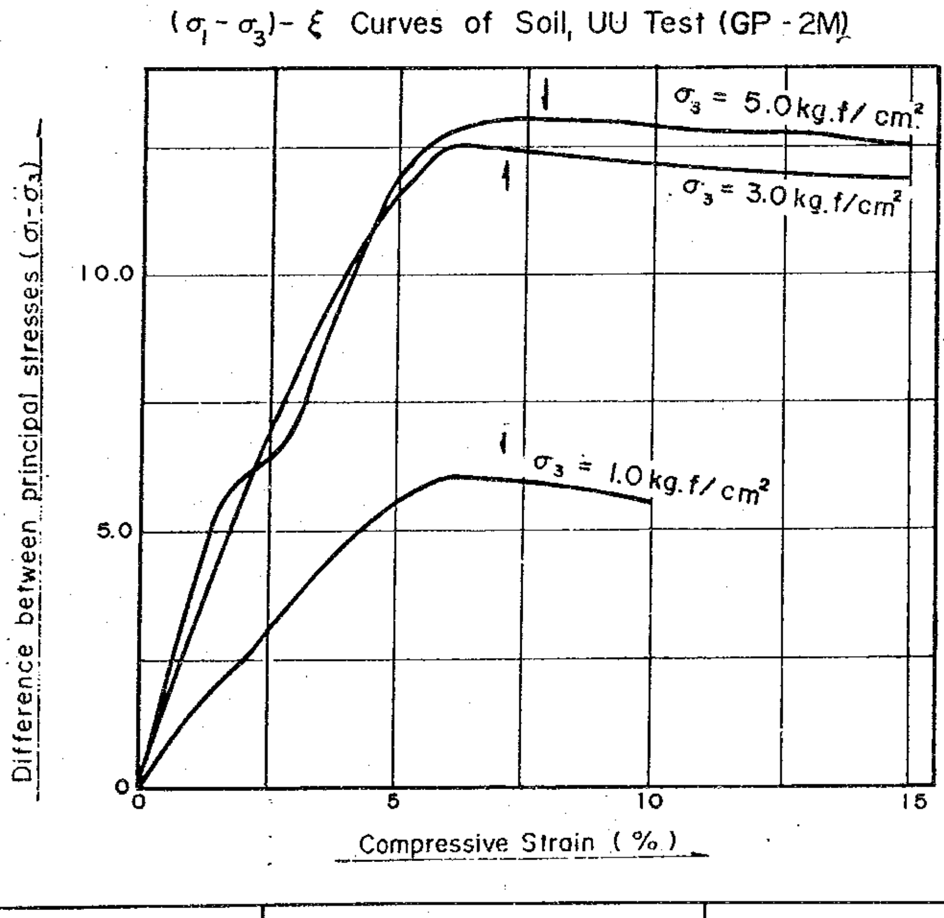


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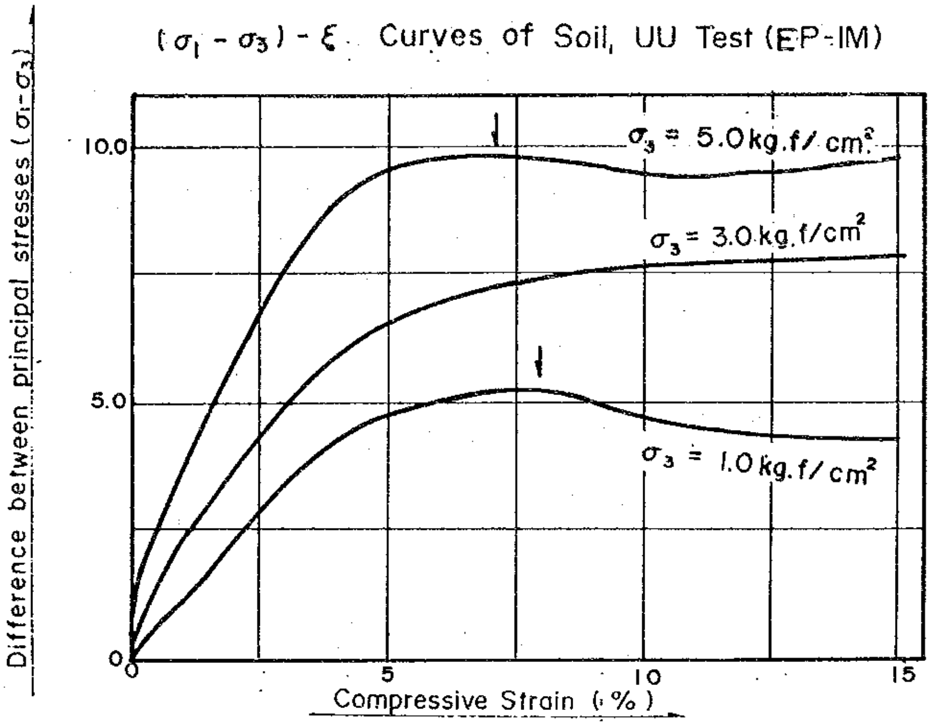
Fig. C.2.15



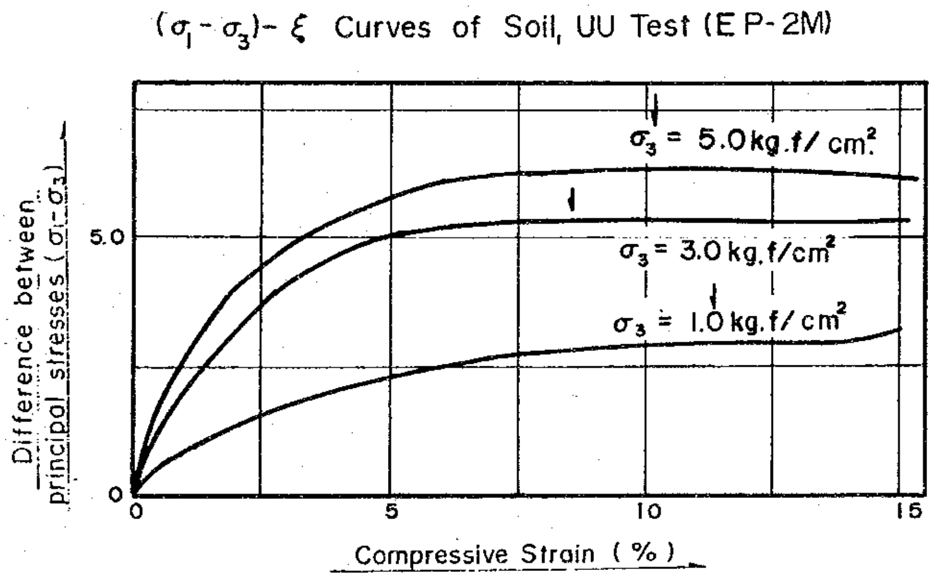


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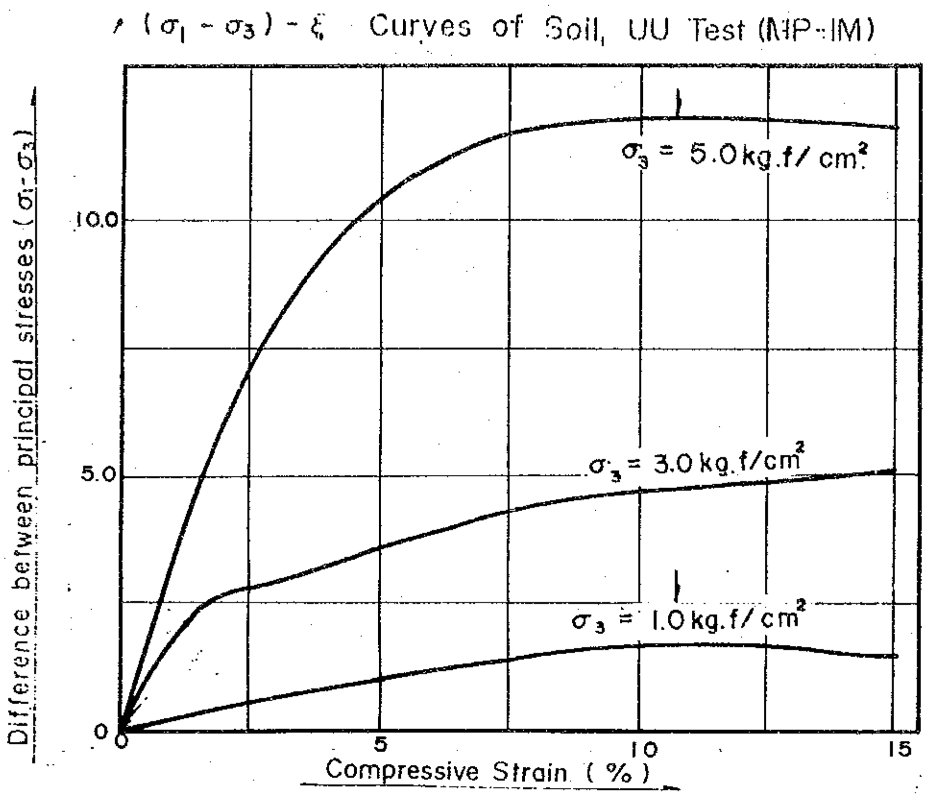
Fig. C.2.16



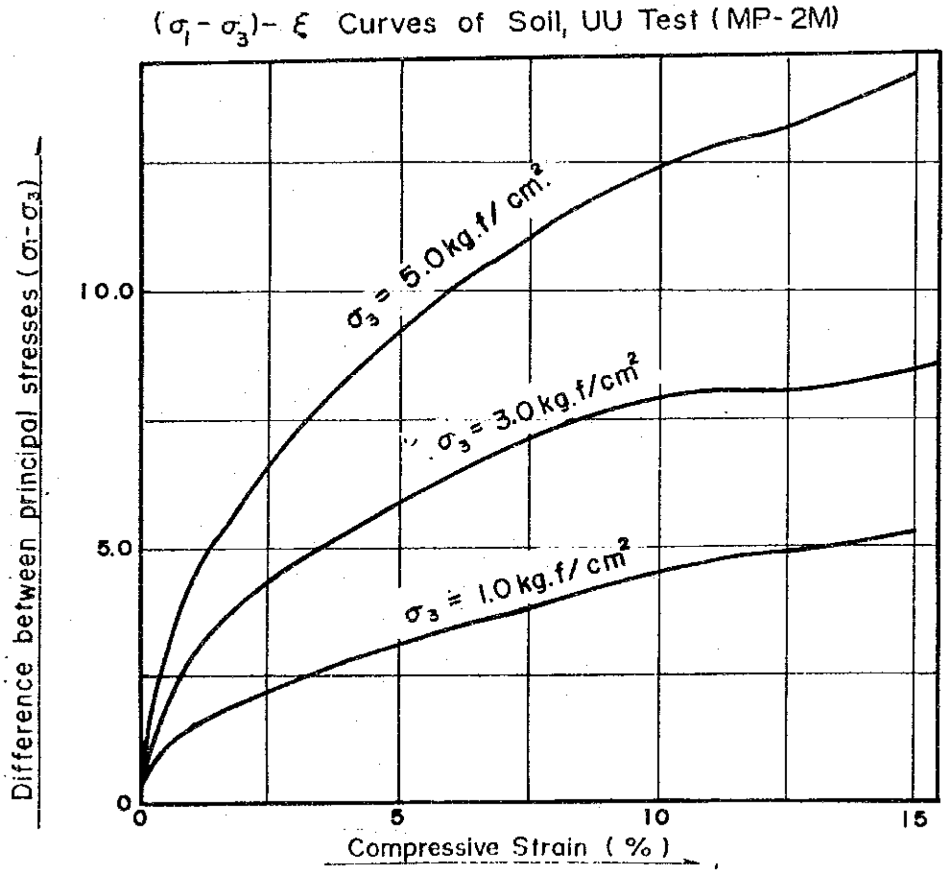


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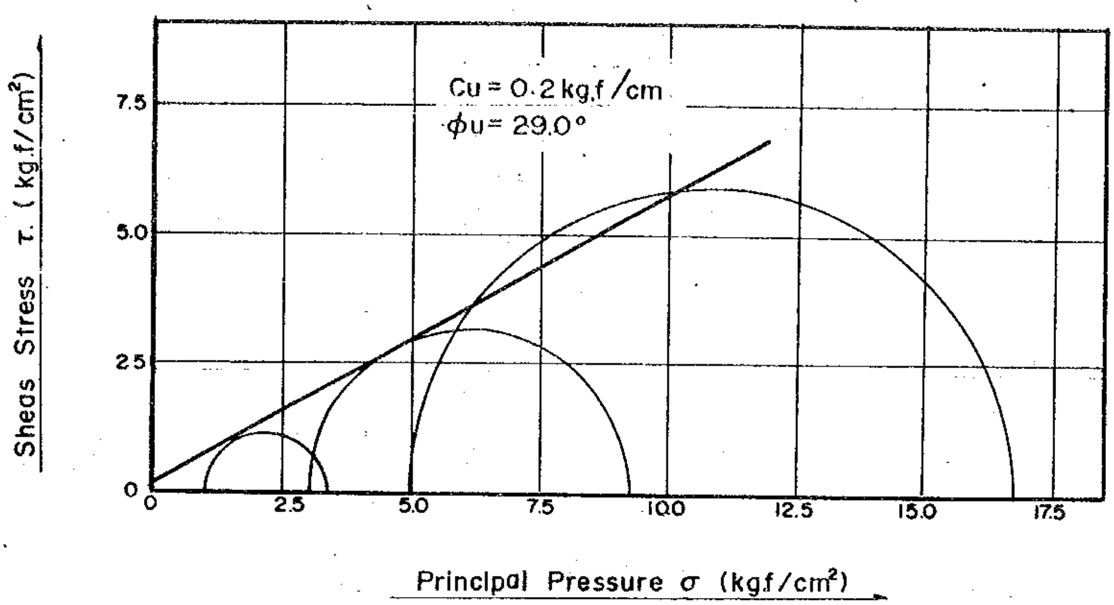
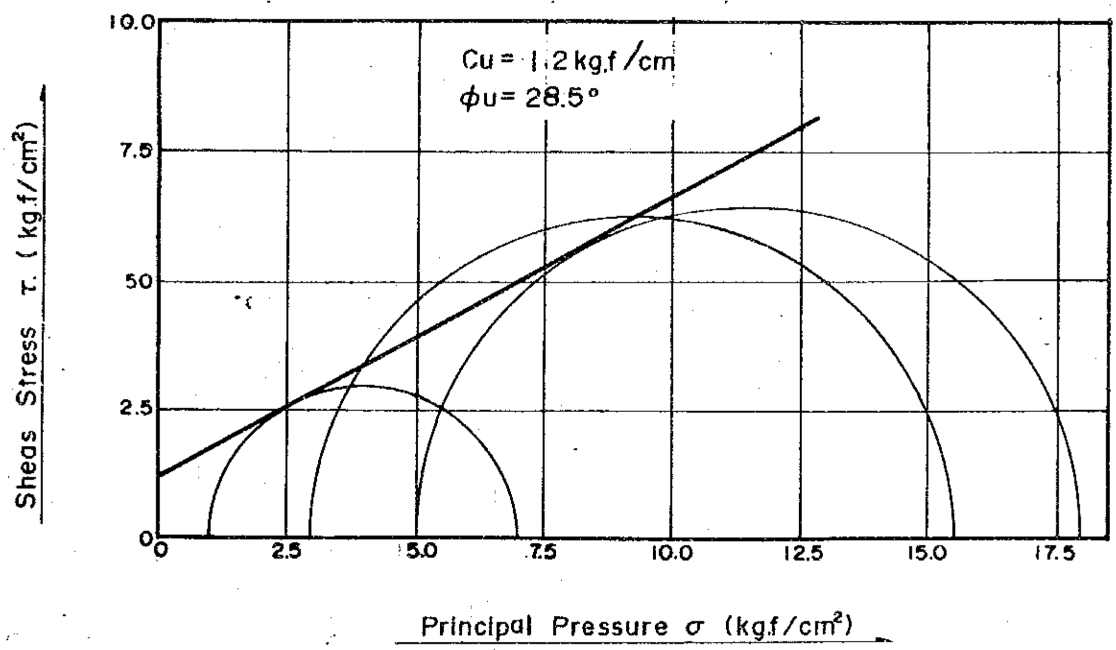
Fig. C.2.17

Mohr - Circle Diagram of Soil, UU Test (GP-1M)



Mohr - Circle Diagram of Soil, UU Test (GP-2M)



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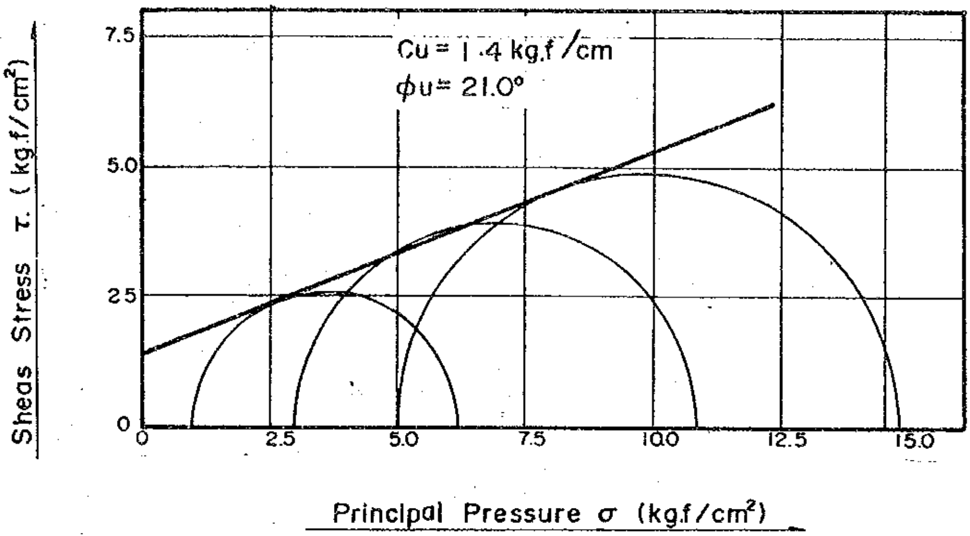
Mohr - Circle Diagram of Soil, UU Test (EP-1M)



Mohr - Circle Diagram of Soil, UU Test (EP-2M)

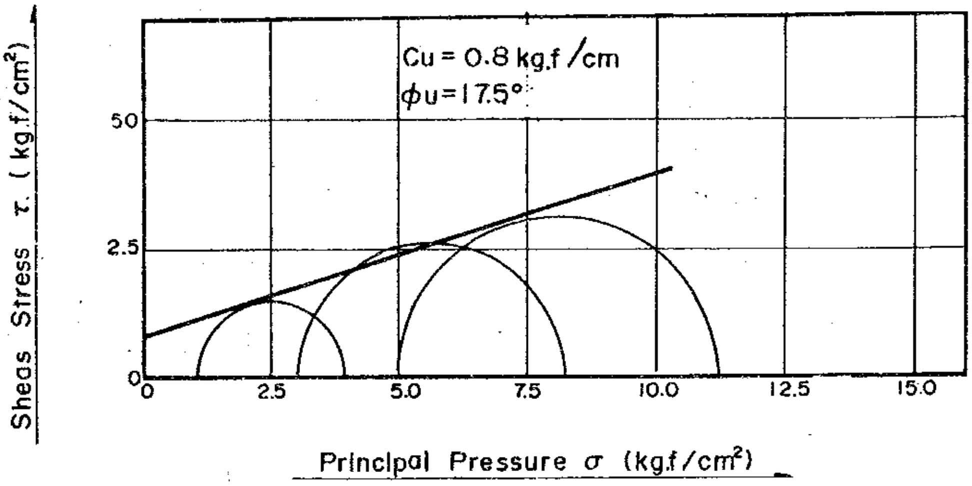


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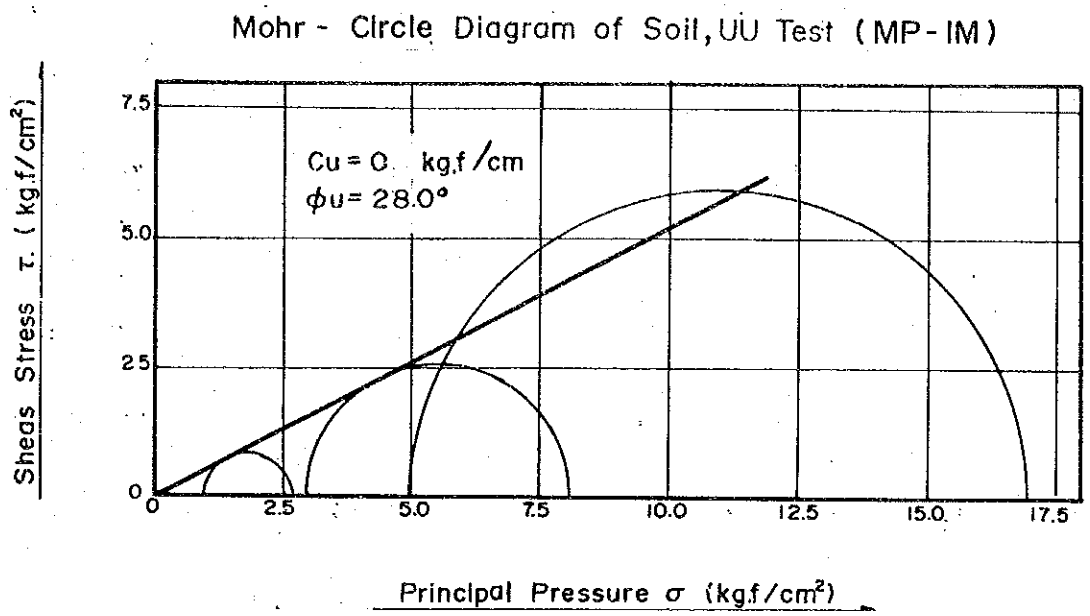
Fig. C.2.19



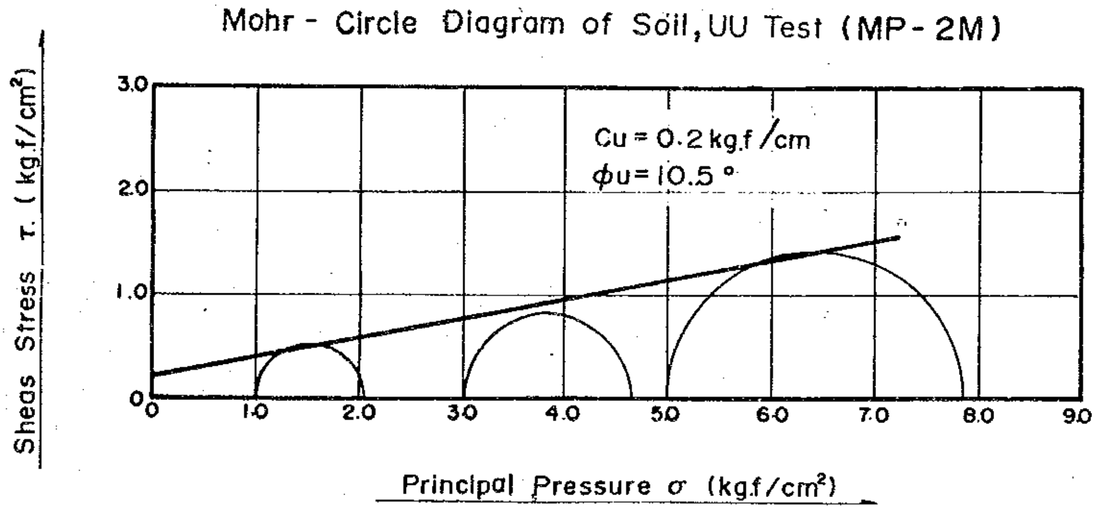


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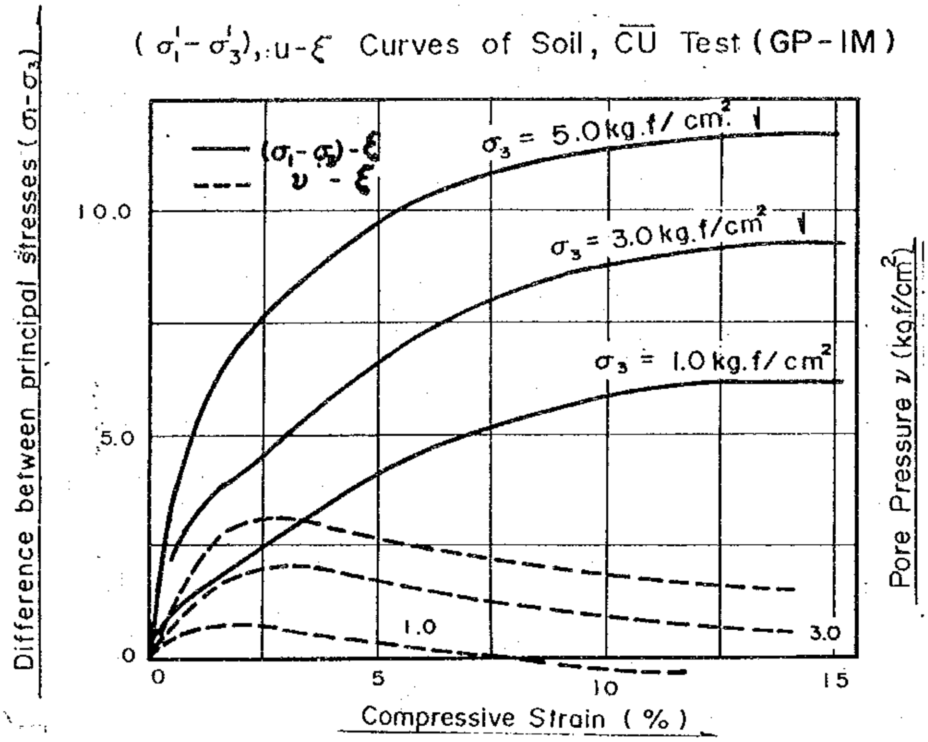
Fig. C.2.20



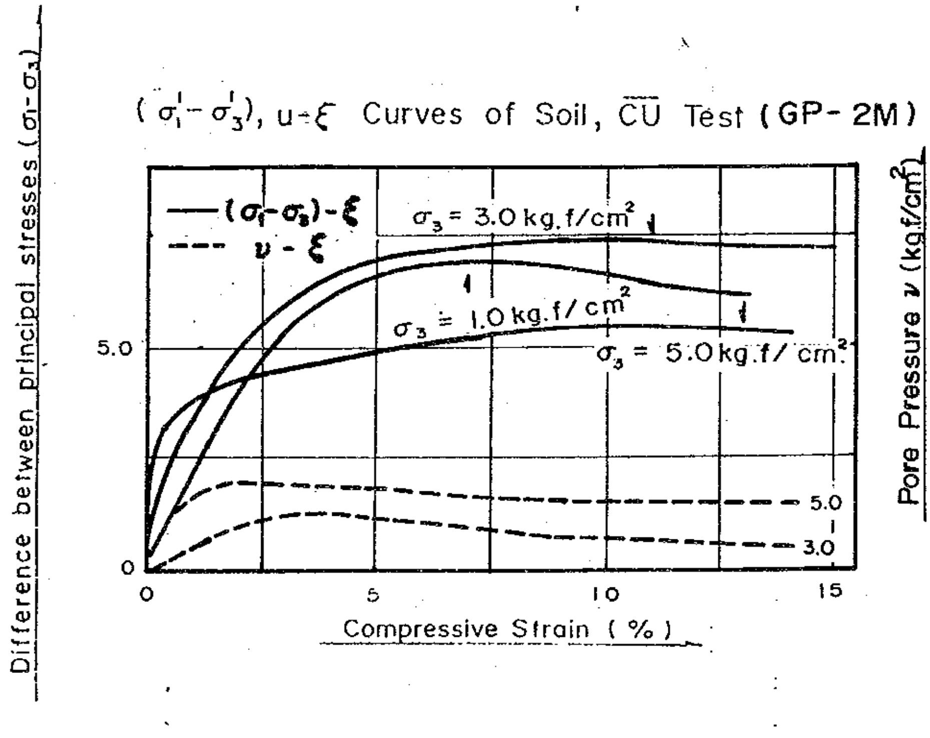


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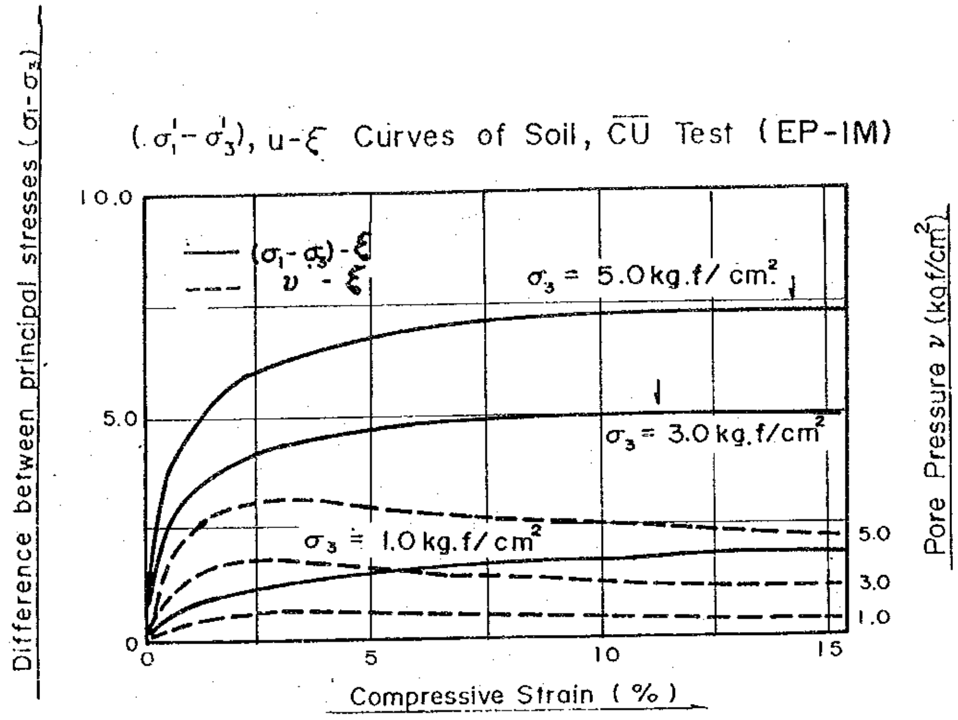
Fig. C.2.21



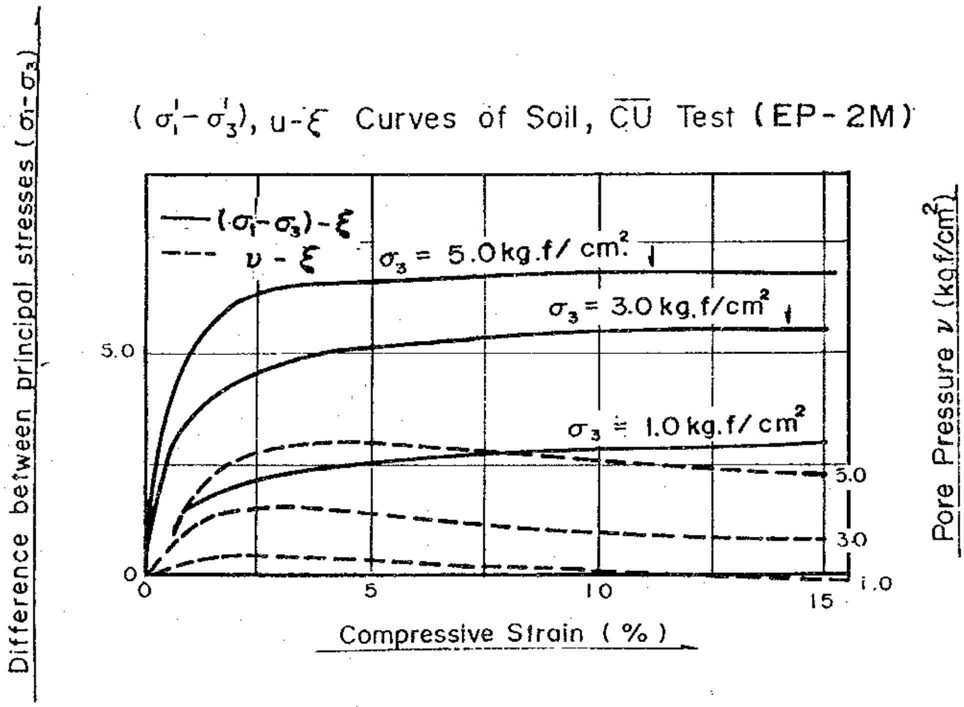


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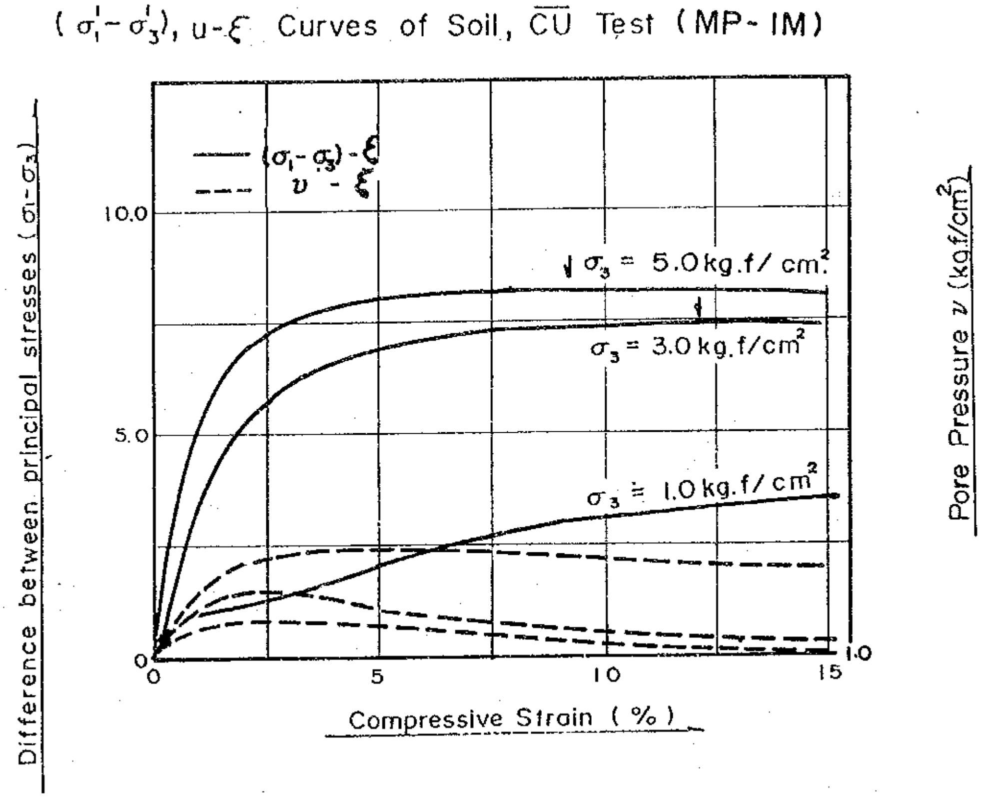
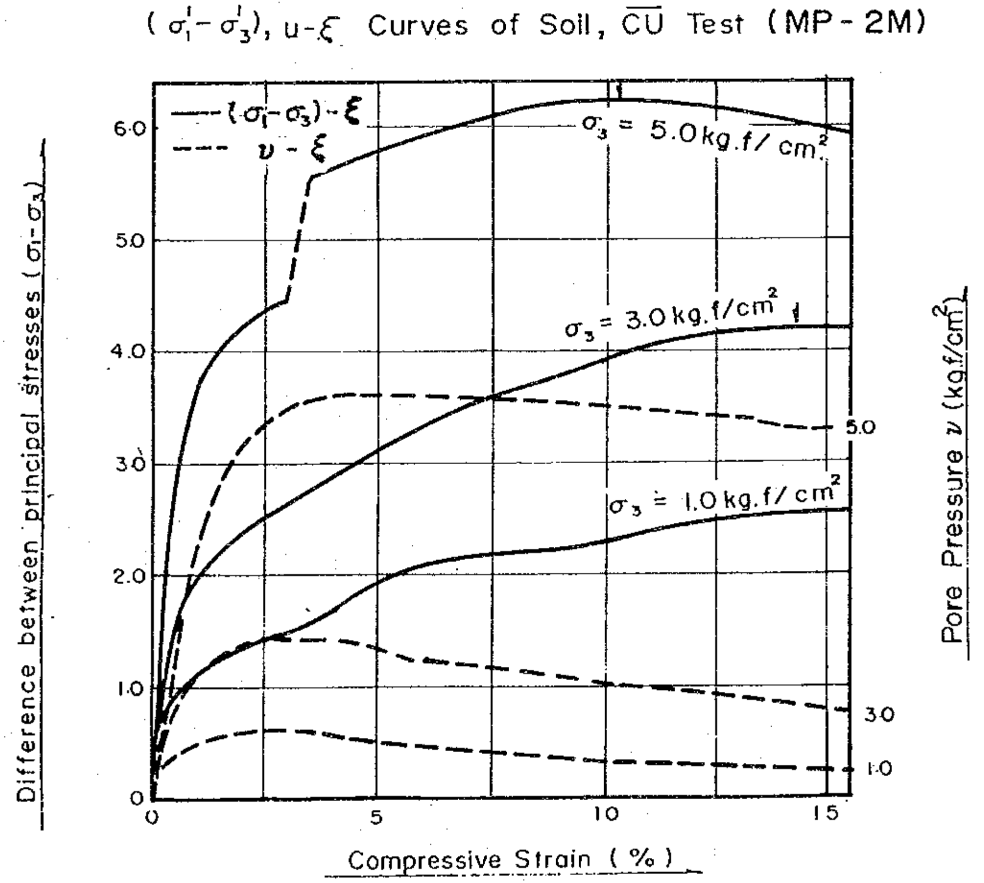
Fig. C.2.22





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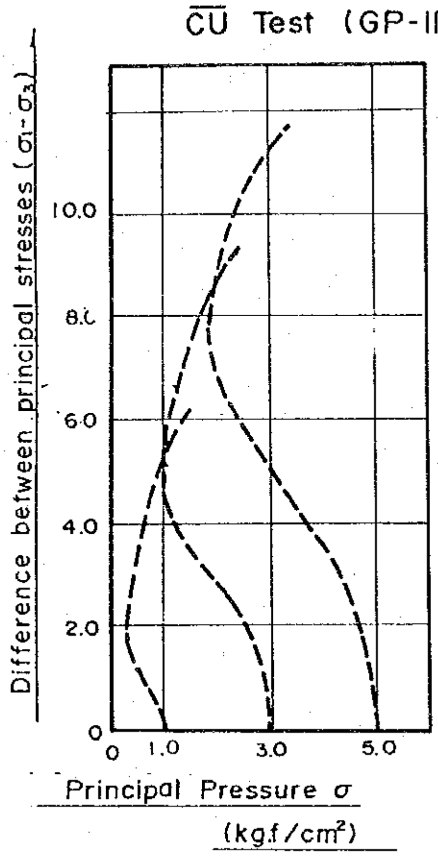
$(\sigma_1' - \sigma_3') - \sigma_3'$ Curves of Soil, $\overline{CU}$ Test (GP-1M)



$(\sigma_1' - \sigma_3') - \sigma_3'$ Curves of Soil, $\overline{CU}$ Test (GP-2M)

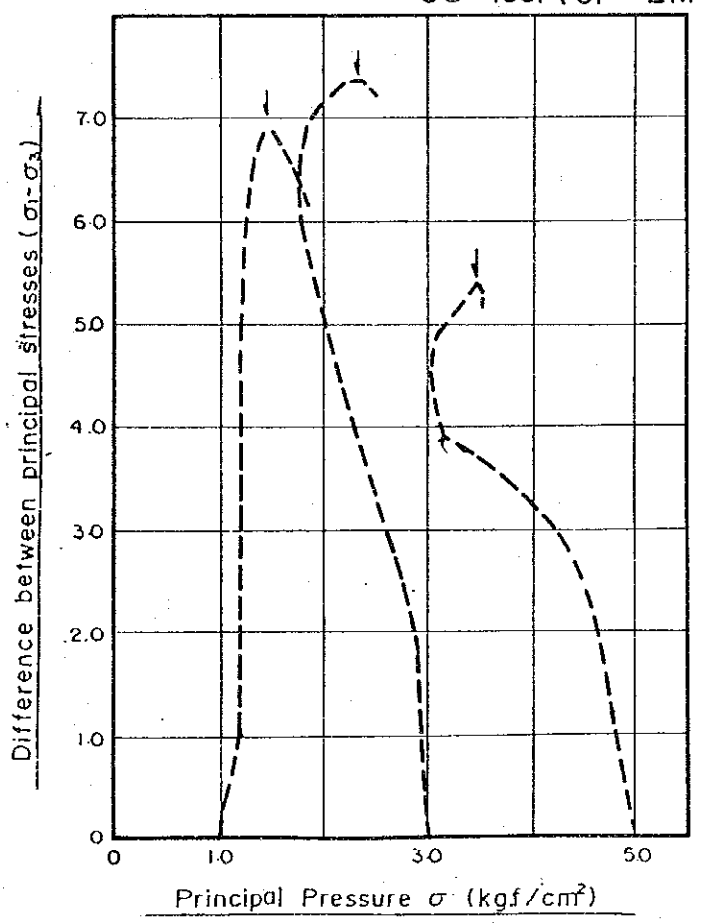


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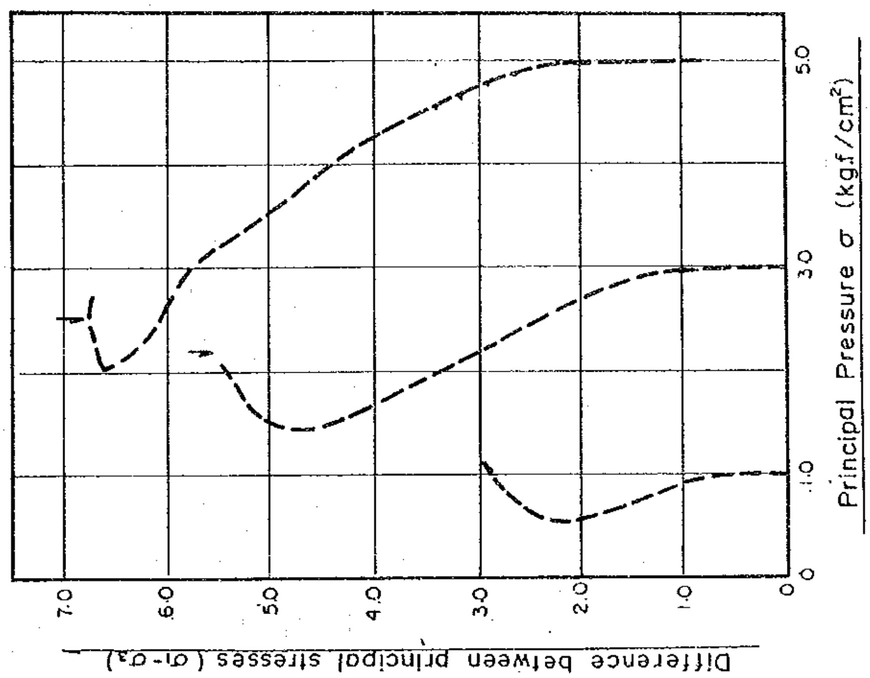
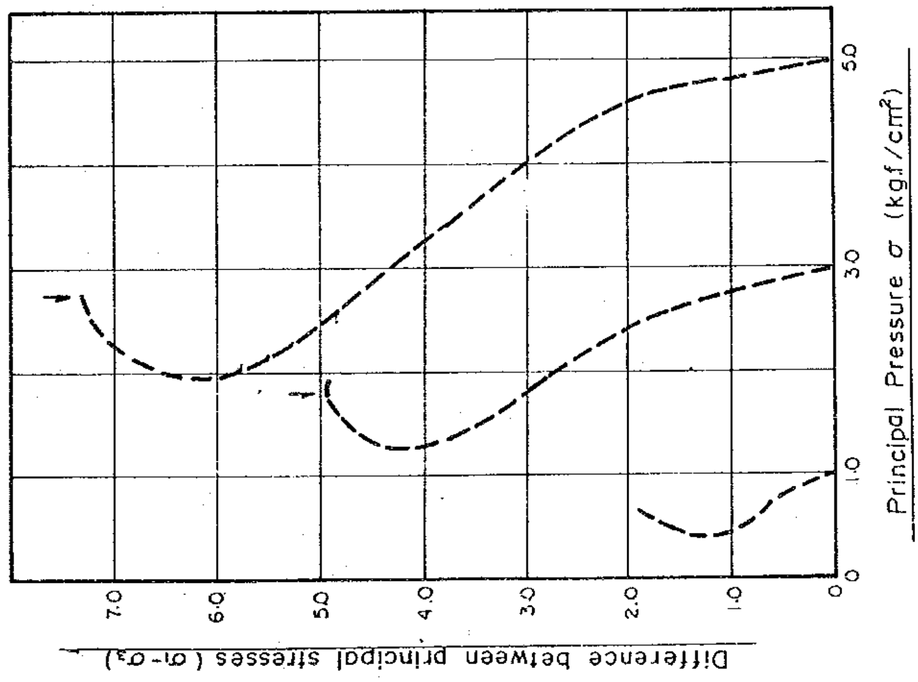
Fig. C.2.24

$(\sigma_1' - \sigma_3') - \sigma_3'$ Curves of Soil, $\overline{CU}$ Test (EP-2M)

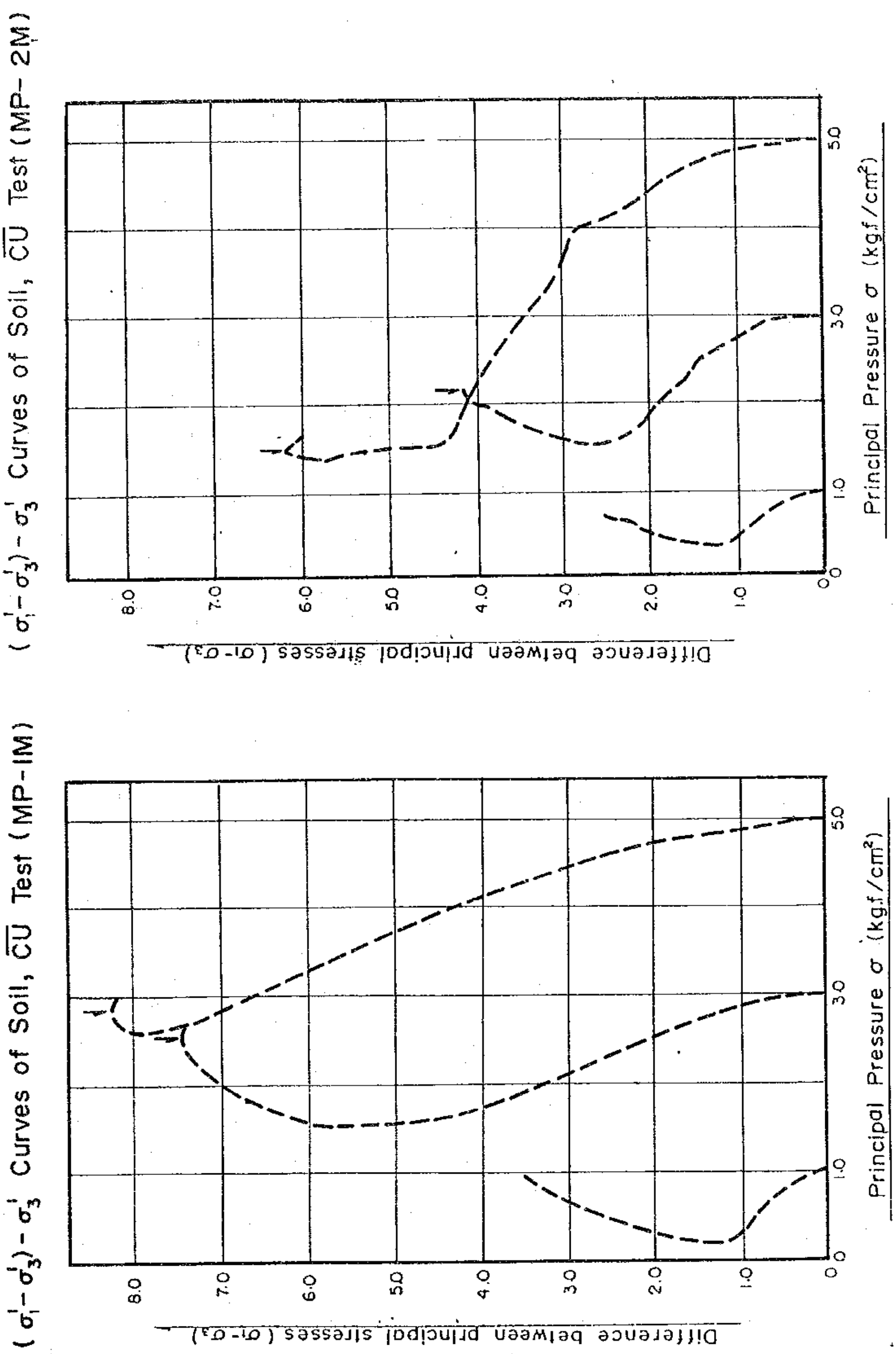


$(\sigma_1' - \sigma_3') - \sigma_3'$ Curves of Soil, $\overline{CU}$ Test (EP-1M)



THE REPUBLIC OF KENYA MINISTRY OF WATER DEVELOPMENT NATIONAL WATER CONSERVATION AND PIPELINE CORPORATION	THE STUDY FOR CONSTRUCTION OF DAM IN MALEWA RIVER SYSTEM GREATER NAKURU WATER SUPPLY PROJECT EASTERN DIVISION JAPAN INTERNATIONAL COOPERATION AGENCY	TITLE $(\sigma_1' - \sigma_3') - \sigma_3'$ Curves of Soil, CU Test(EP)

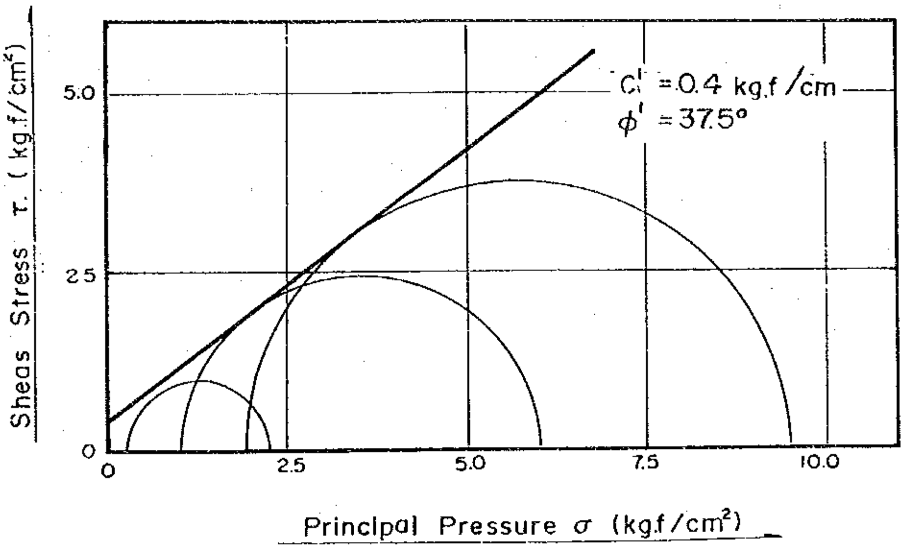
Fig. C.2.25



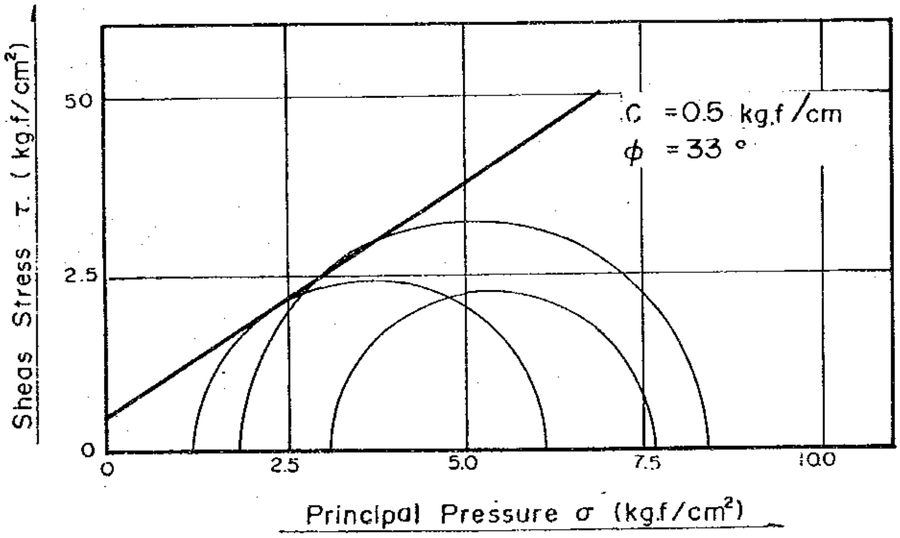
THE REPUBLIC OF KENYA MINISTRY OF WATER DEVELOPMENT NATIONAL WATER CONSERVATION AND PIPELINE CORPORATION	THE STUDY FOR CONSTRUCTION OF DAM IN MALEWA RIVER SYSTEM GREATER NAKURU WATER SUPPLY PROJECT EASTERN DIVISION JAPAN INTERNATIONAL COOPERATION AGENCY	TITLE (σ1'−σ3')−σ3' Curves of Soil, CU Test(MP)

Fig. C.2.26

Mohr - Circle Diagram of Soil, $\overline{CU}$ Test (GP-1M)



Mohr - Circle Diagram of Soil, $\overline{CU}$ Test (GP- 2M)



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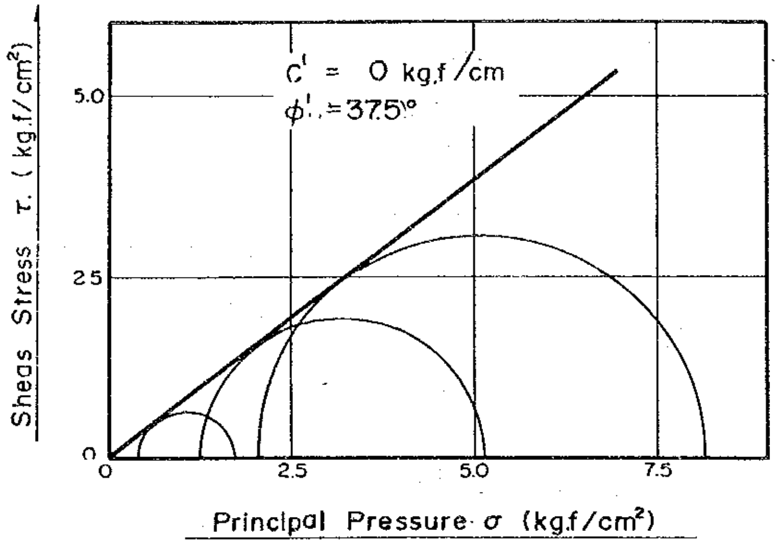
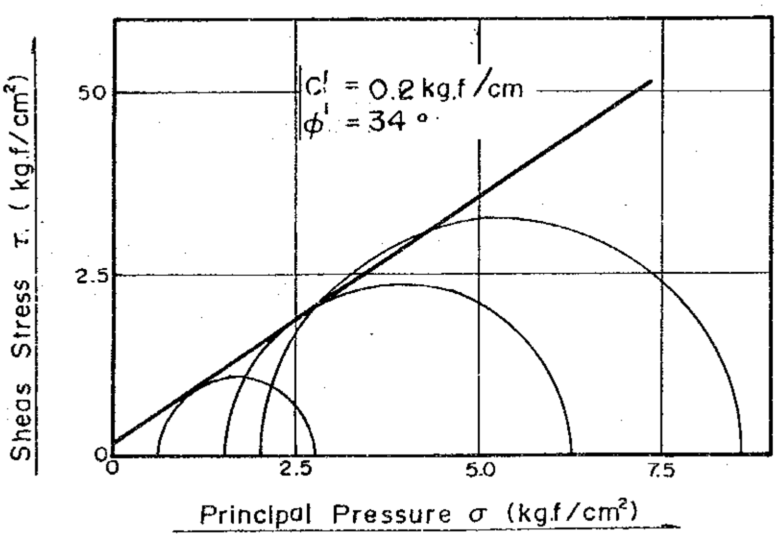
Mohr - Circle Diagram of Soil, $\overline{CU}$ Test (EP-1M)



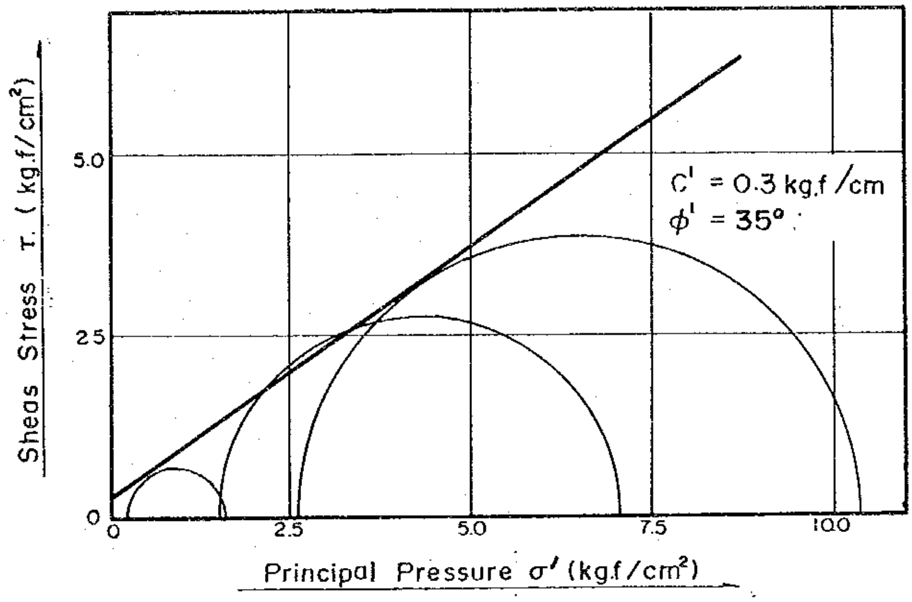
Mohr - Circle Diagram of Soil, $\overline{CU}$ Test (EP-2M)



THE REPUBLIC OF KENYA MINISTRY OF WATER DEVELOPMENT NATIONAL WATER CONSERVATION AND PIPELINE CORPORATION	*THE STUDY FOR CONSTRUCTION OF DAM IN MALEWA RIVER SYSTEM GREATER NAKURU WATER SUPPLY PROJECT EASTERN DIVISION* JAPAN INTERNATIONAL COOPERATION AGENCY	TITLE Mohr-Circle Diagram of Soil, CU Test(EP)

Fig. C.2.28

Mohr - Circle Diagram of Soil, $\overline{CU}$ Test (MP-1M)



Mohr - Circle Diagram of Soil, $\overline{CU}$ Test (MP-2M)

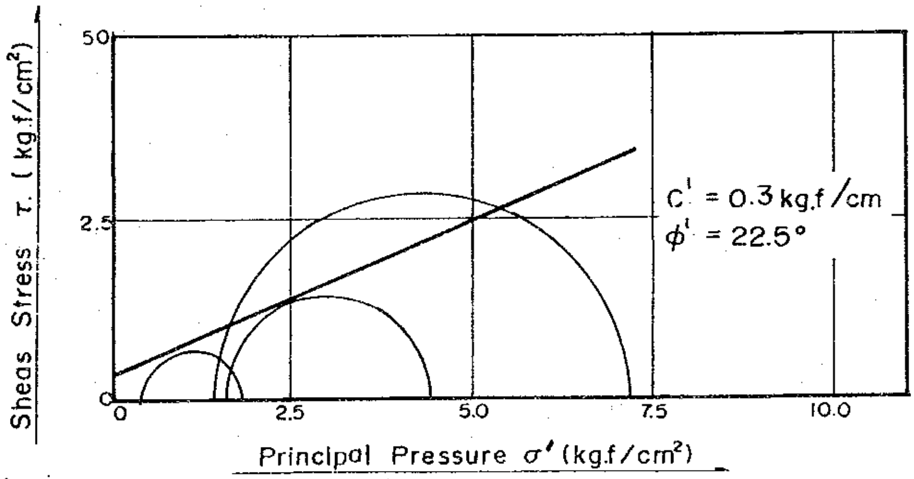


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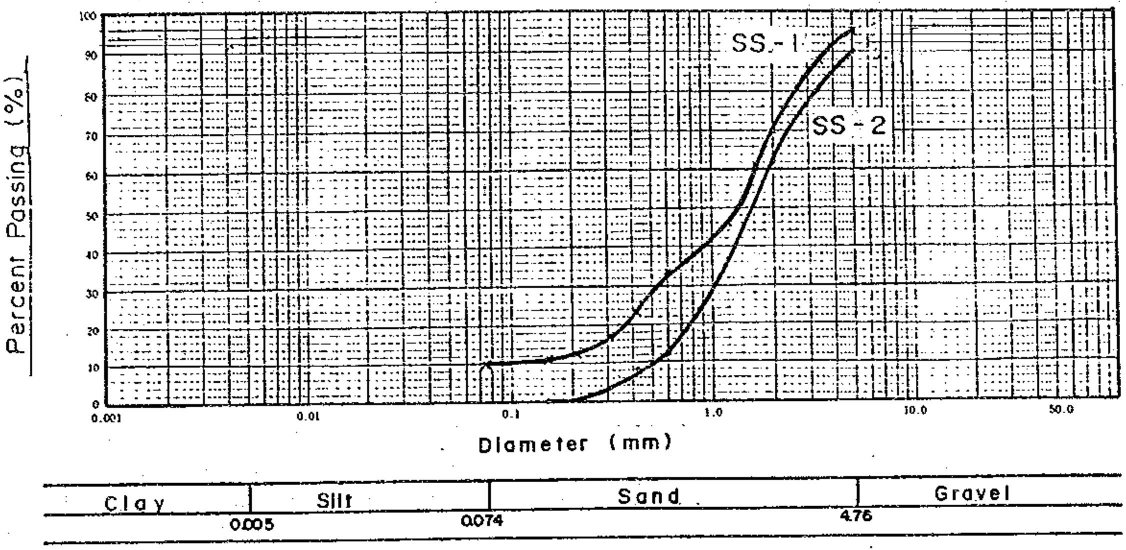
Fig. C.2.29

Gradation Curves of Sand (SS-1, 2)



Gradation Curves of Sand (SS-3, 4)

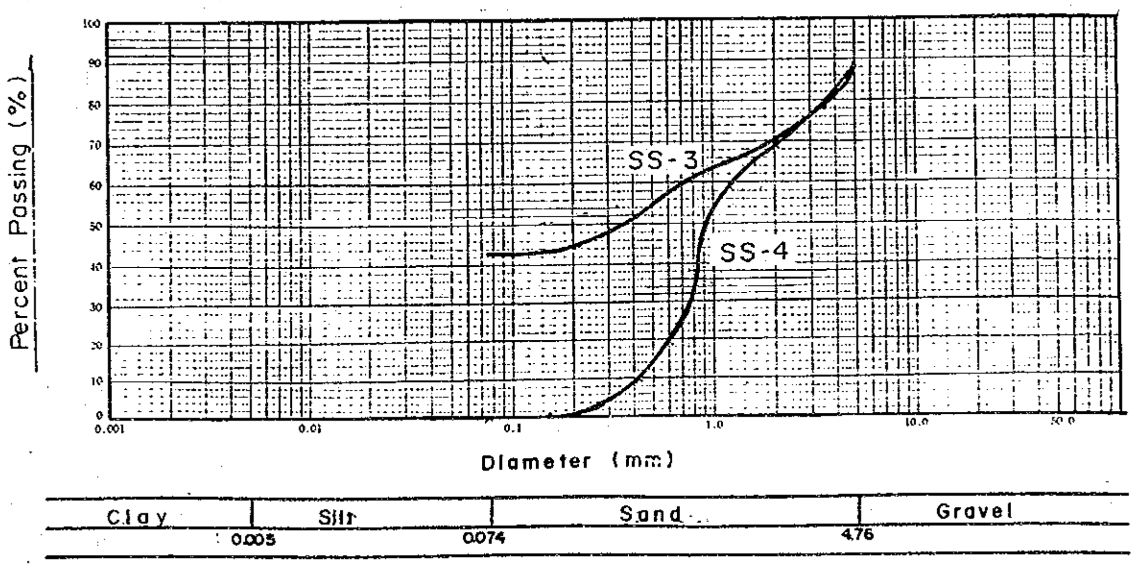


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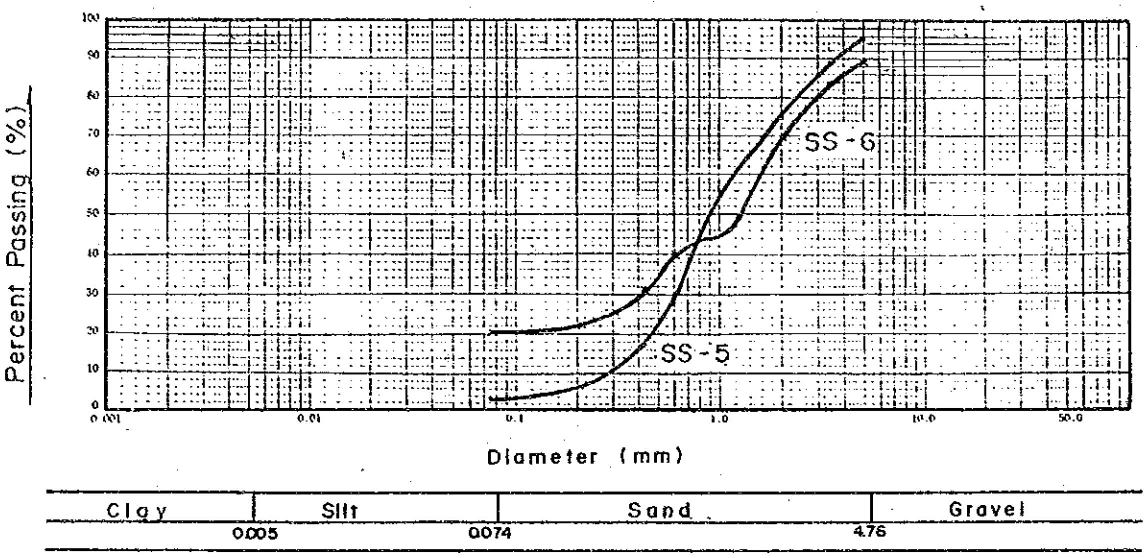
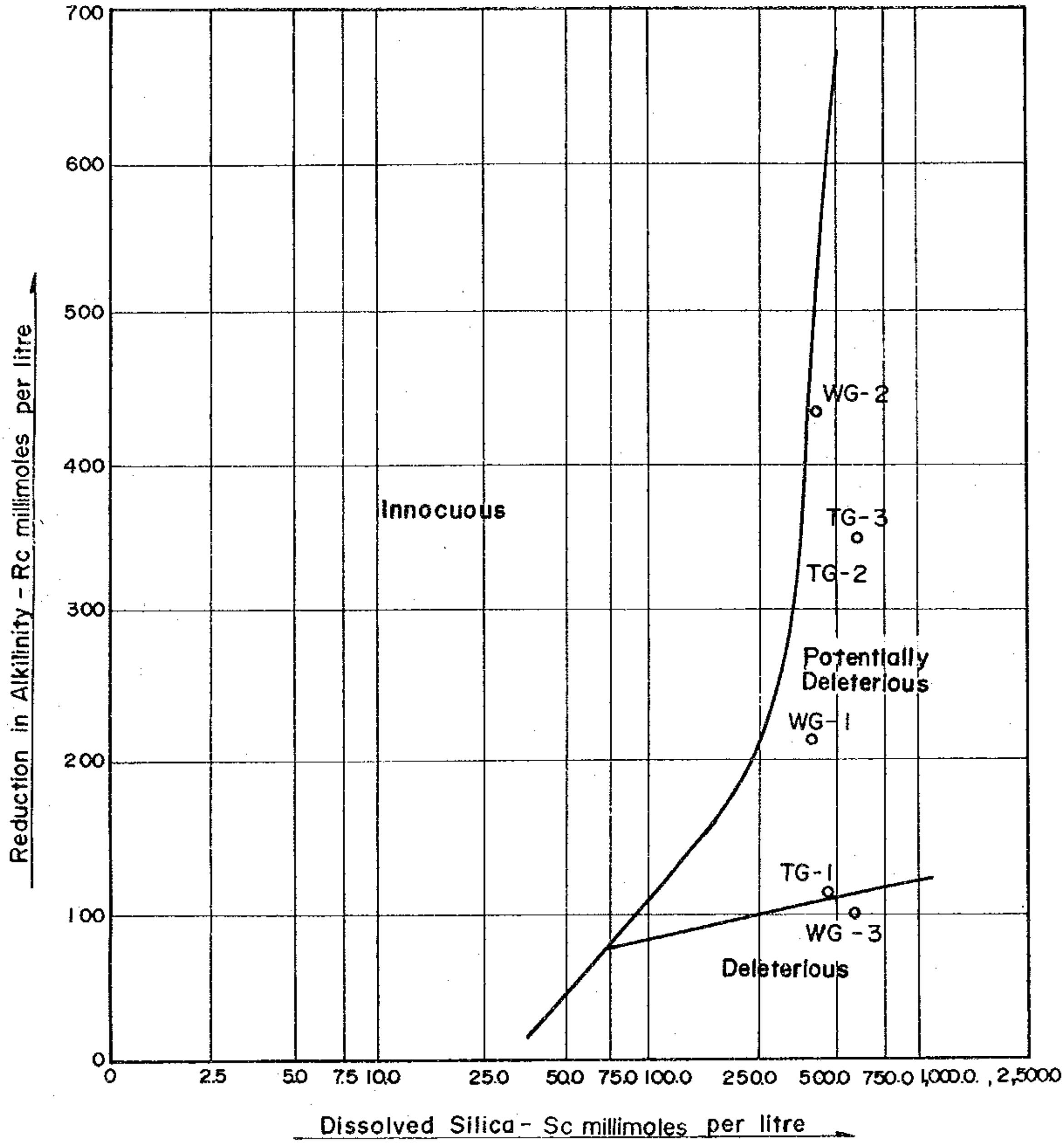
Fig. C.2.30

Gradation Curves of Sand (SS-5, 6)



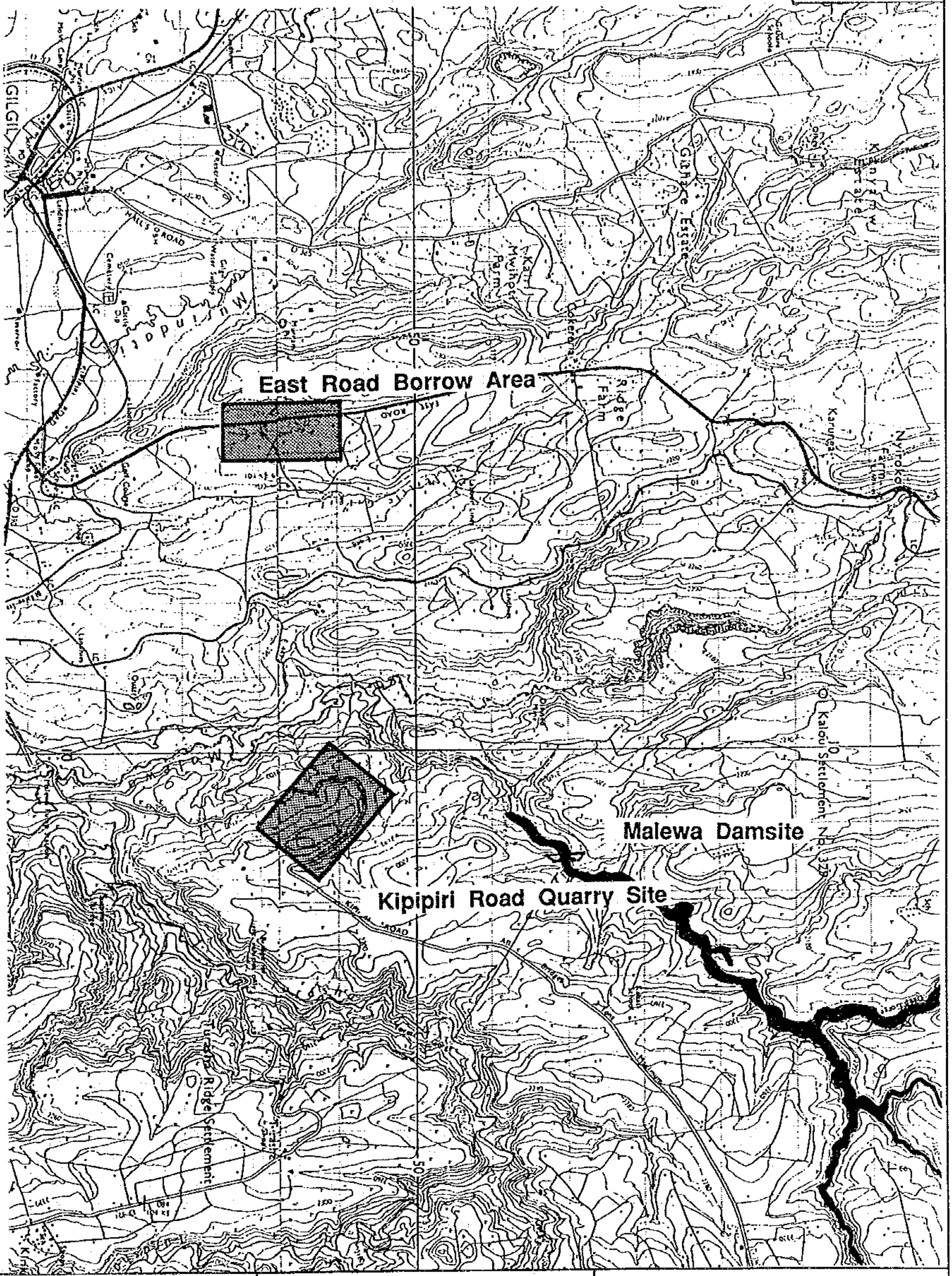
THE REPUBLIC OF KENYA MINISTRY OF WATER DEVELOPMENT NATIONAL WATER CONSERVATION AND PIPELINE CORPORATION	THE STUDY FOR CONSTRUCTION OF DAM IN MALEWA RIVER SYSTEM GREATER NAKURU WATER SUPPLY PROJECT EASTERN DIVISION JAPAN INTERNATIONAL COOPERATION AGENCY	TITLE Gradation Curves of Sand

Fig. C.2.31



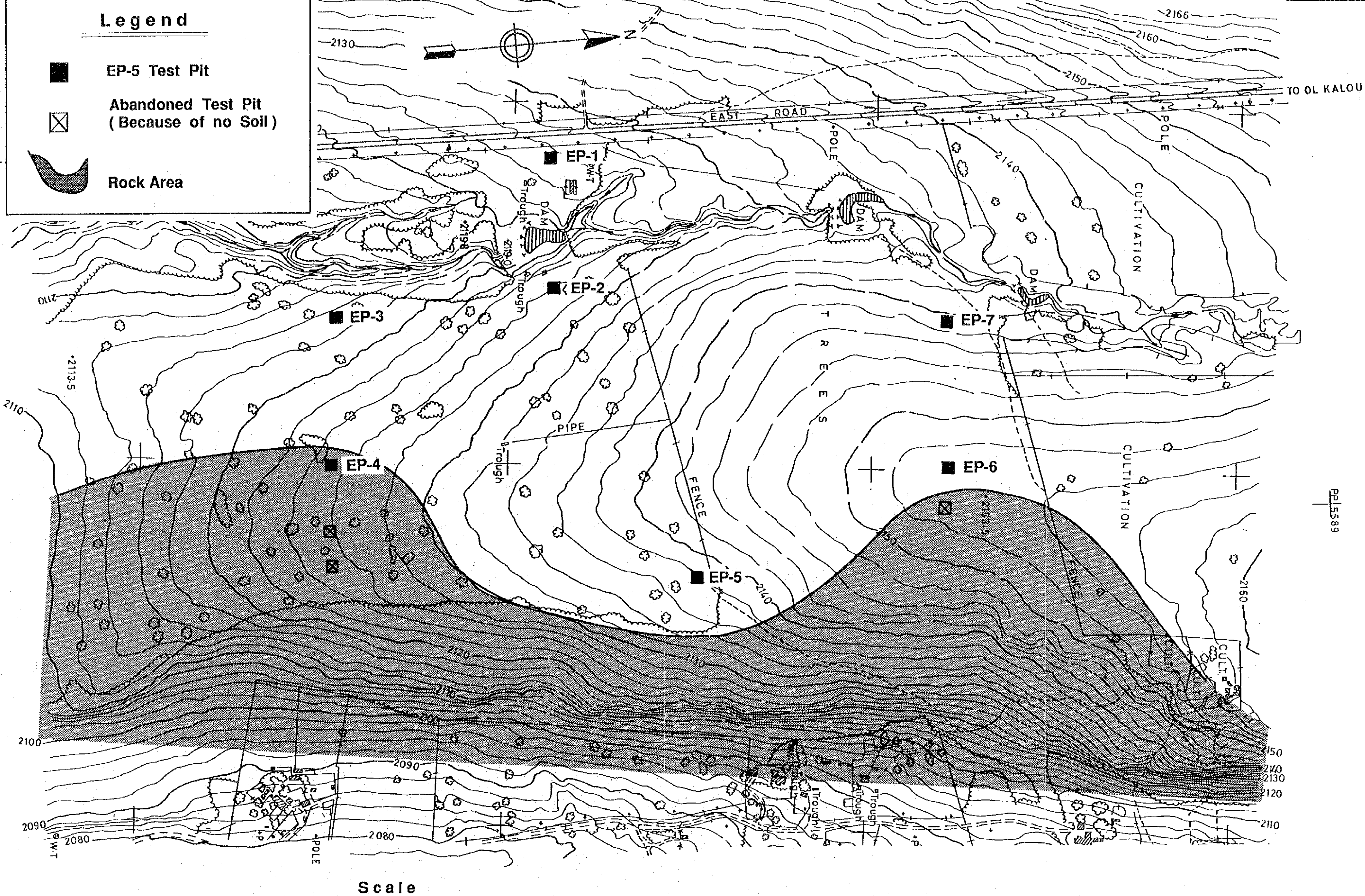
THE REPUBLIC OF KENYA MINISTRY OF WATER DEVELOPMENT NATIONAL WATER CONSERVATION AND PIPELINE CORPORATION	THE STUDY FOR CONSTRUCTION OF DAM IN MALEWA RIVER SYSTEM GREATER NAKURU WATER SUPPLY PROJECT EASTERN DIVISION JAPAN INTERNATIONAL COOPERATION AGENCY	TITLE Potential Reactivity of Concrete Aggregate(Chemical Method)

Fig. C.3.1



THE REPUBLIC OF KENYA MINISTRY OF WATER DEVELOPMENT NATIONAL WATER CONSERVATION AND PIPELINE CORPORATION	THE STUDY FOR CONSTRUCTION OF DAM IN MALEWA RIVER SYSTEM GREATER NAKURU WATER SUPPLY PROJECT EASTERN DIVISION JAPAN INTERNATIONAL COOPERATION AGENCY	TITLE **Locations of Kipipiri Road Quarry Site and East Road Borrow Area**

Fig. C.3.2



THE REPUBLIC OF KENYA MINISTRY OF WATER DEVELOPMENT NATIONAL WATER CONSERVATION AND PIPELINE CORPORATION	THE STUDY FOR CONSTRUCTION OF DAM IN MALEWA RIVER SYSTEM GREATER NAKURU WATER SUPPLY PROJECT EASTERN DIVISION JAPAN INTERNATIONAL COOPERATION AGENCY	TITLE Locations Map of Test Pittings in East Road Borrow Area

Fig. C.3.3

TEST PIT EP-3

Depth (m)	Lithological Symbol	Description	Sample
0.00 – 0.80		Top soil ; moist black humic clayey soiln with numerous grass roots. relatively loose.	
0.80 – 1.40		Moved residua soil ; Dark brown clayey soil with occasional roots. relatively compact. Dark brown stained rock fragment (Max. 5cm) encountered.	EP-3
1.40 – 2.00		Lateritic Soil ; Light brown, relatively loose and without organic contents	

TEST PIT EP-4

Depth (M)	Lithological Symbol	Description	Sample
0.00 – 0.30		Top ssoil ; Black moist humic caly soil with numerous grass roots. Loose.	
0.30 –		Residual soil-weathered bed rock. light brown, slightly moist and relatively compact soil. contains less roots. sand and gravel percentages Increase with depth. Max.size of taffeceous rock ragments are 36cm and most Them are swlightly friable to hard.	EP-4

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Fig. C.3.4

TEST PIT EP-5

Depth (M)	Lithological Symbol	Description	Sample
0.00 – 0.80		Top Soil ; Black humic clay soil. Slighly moist and relaativelycompacts. Few rootse extensding to a depth of 0.4m.	
0.80 – 1.80 – 2.00		Lateritic Soil ; Light brown Slightly moist Soil. Few roots. Less compact up to 1.4m from where the soil hardens downwards. Highly weathered dark brown stained tuffaceous rock fragments of Max. size of 6cm encountered below 1.8m. The soil is apparently dry below 1.4m.	EP-3

TEST PIT EP-6

Depth (M)	Lithological Symbol	Description	Sample
0.00 – 0.60		Top soil ; Black moist humic clay soil with numerous grass roots. Relatively loose.	
0.60 – 2.00		Residual soil ; Light brown. slightly moist soil. Very hard whitish silica nodules and dark brown stained Taffaceous rock fragments of a Max. sixe of 10cm were encountered. The soil is relatively loose with occasional roots.	EP-6

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Fig. C.3.5

TEST PIT EP-7

Depth (M)	Lithological Symbol	Description	Sample
0.00 – 0.30		Top soil ; Black moist humic clay soil with numerous grass roots.	
0.30 – 1.30		Lateritic granular soil ; greyish brown, dry and compact. Occasional roots. Max.size of the few rock fragments encountered was 4cm.	EP-7
1.30 – 2.00		Residual Soil ; Light brown. slightly moist soil. Hard silica nodules and dark brown stained taffaceous rocks (Max.6cm) encountered relatively loose.	

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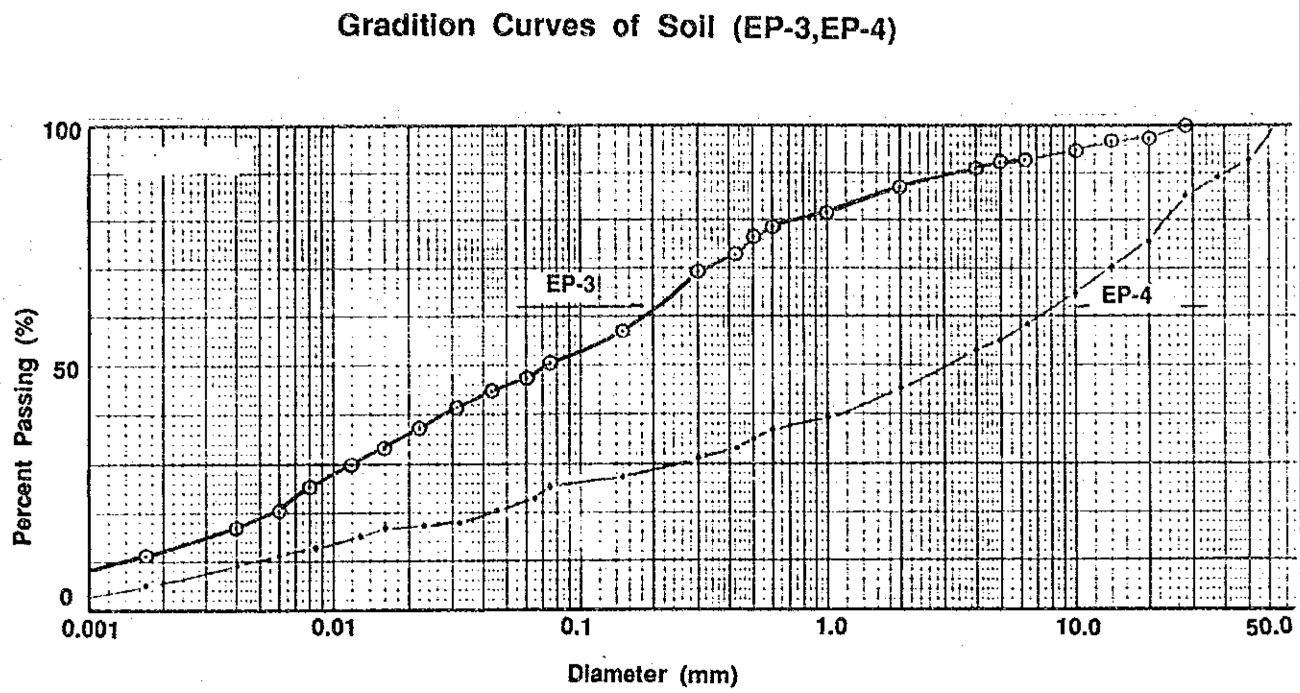
JAPAN INTERNATIONAL COOPERATION AGENCY

TITLE

Profiles of Test Pits in East Road Borrw Area (3/3)

Fig. C.3.6



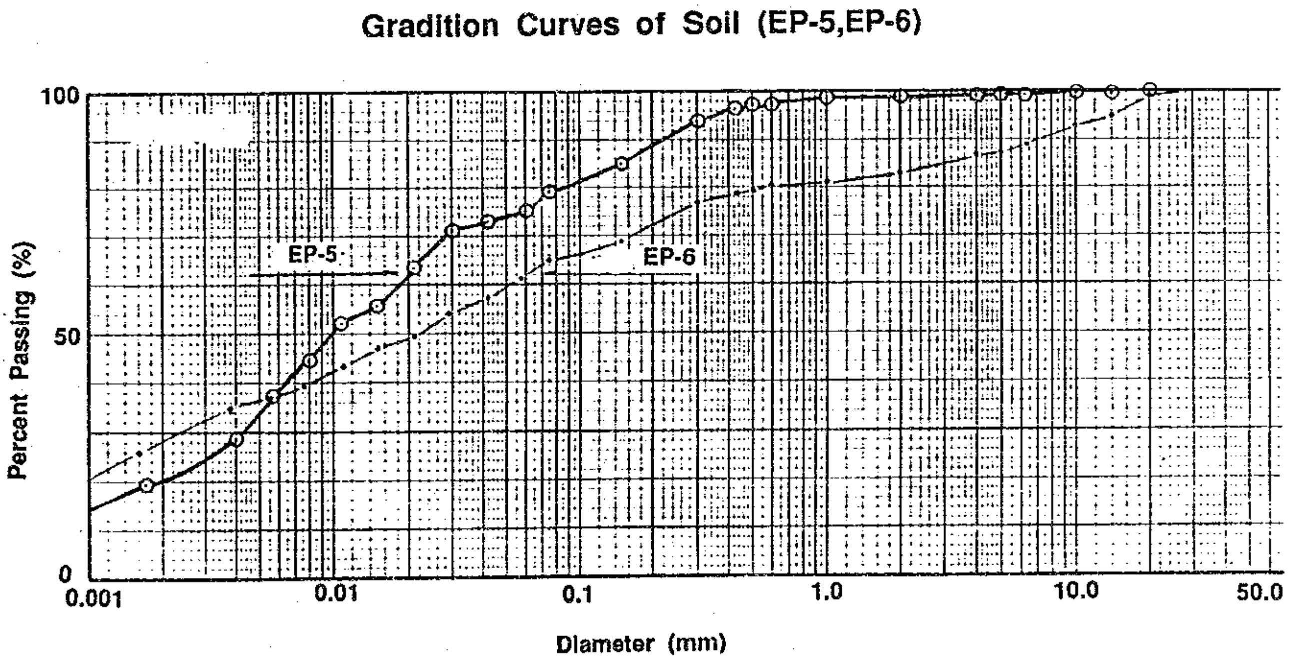


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Fig. C.3.7

Gradition Curves of Soil (EP-7)

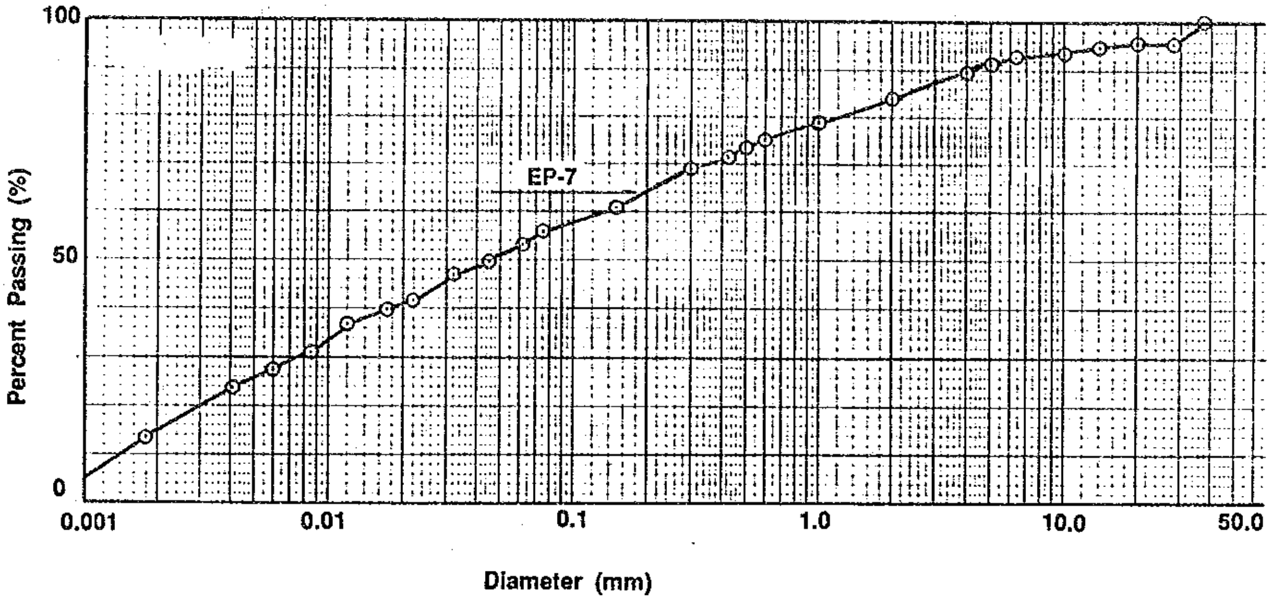

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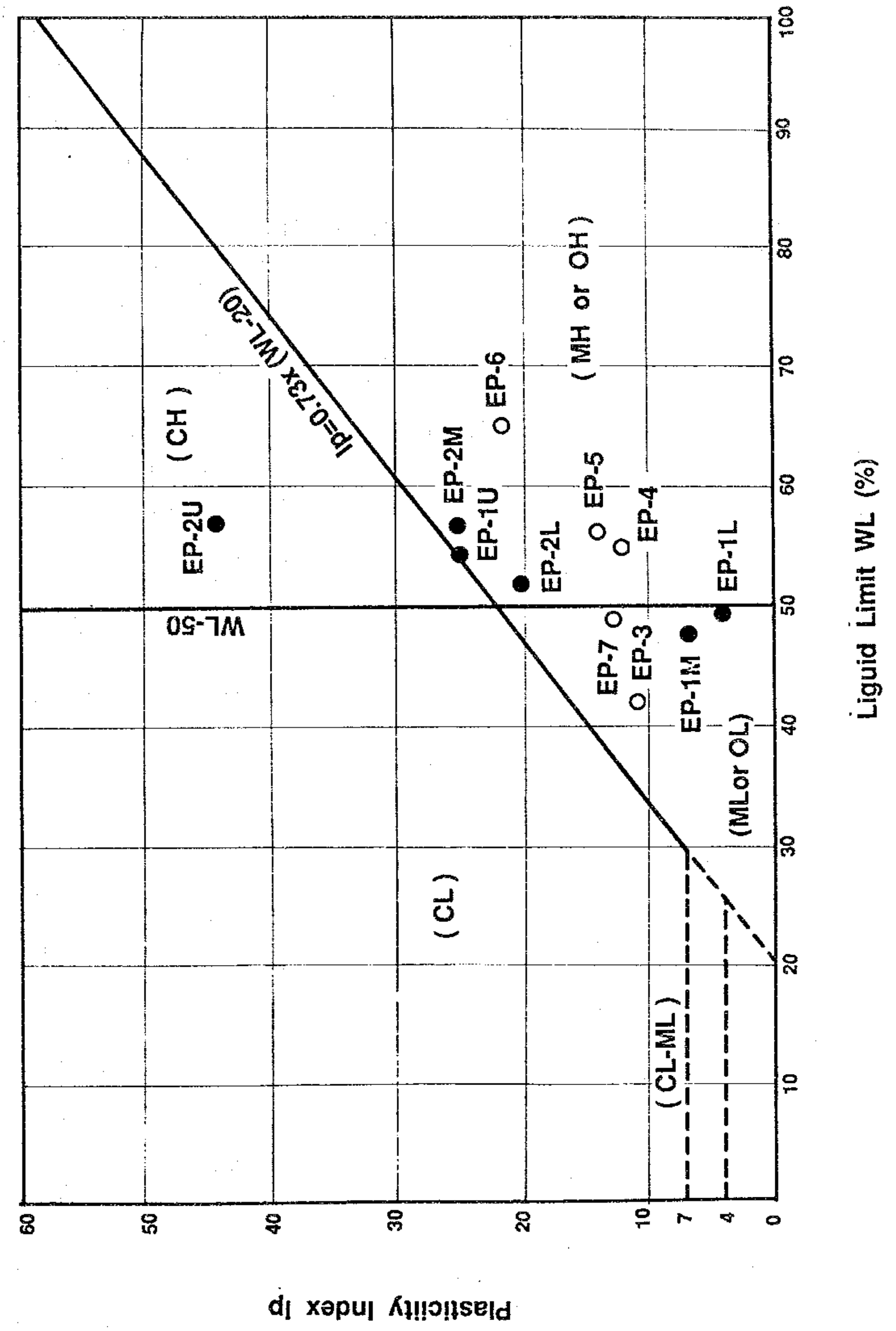
Fig. C.3.8



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