2

THE FEASIBILITY STUDY
ON
PORT LOUIS WATER SUPPLY PROJECT
IN MAURITIUS

SUPPORTING REPORT (II)

APPENDIX C
APPENDIX D

JUNE 1989

JAPAN INTERNATIONAL COOPERATION AGENCY

APPENDIX - C
CONSTRUCTION MATERIAL

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1. Introduction

The objectives of construction material investigation are (1) to find adequate material sources of fill material for rockfill dam and concrete aggregate, (2) to estimate available quantity, and (3) to evaluate quality of the construction materials for Port Louis Water Supply Project.

Prior to the commencement of construction material investigation, reconnaissance was carried out to get information about topographic and geologic conditions in the vicinity of the proposed damsite.

2. Construction Material Requirement

The requirement of construction materials for the dam and related structures is estimated as follows:

(A) Fill Material		
1) Core	230,000 m3	
2) Filter	100,000 m3	
3) Rock	1,200,000 m3	
(B) Concrete Aggregate		
1) Fine	15,000 m3	
2) Coarse	20,000 m3	

3. Construction Material Sources

3.1 General

Taking into account the material requirement mentioned above, material investigation on fill material and concrete aggregate was carried out in the surrounding areas of the proposed damsite The investigation areas are shown on Fig. C.1.

3.2 Earth Borrow Area

Earth borrow areas S-3,5,7,8,9 and 10 were investigated for the possibility of core material sources by reconnaissance, test pitting and laboratory tests. Location and obtainable material of each borrow area is described below.

(1) Earth Borrow Area S-3
It is located at 0.8km east from proposed damsite. The material consists of silty clay, and it is of a dark brown to reddish brown color.

(2) Earth Borrow Area S-5
It is located at 1.2km southeast from proposed damsite. The material consists of clayey soil encountered with rock, and it is of a dark brown to reddish brown color.

(3) Earth Borrow Area S-7
It is located at 1km south from proposed damsite. The material consists of clayey soil, and it is of a dark brown to reddish brown color.

(4) Earth Borrow Area S-8
It is located at 1.7km south from proposed damsite. The material consists of almost same material as earth borrow area S-7.

(5) Earth Borrow Area S-9
It is located at 2.6km southeast from proposed damsite. The material consists of clayey soil, and it is of a dark brown color.

(6) Earth Borrow Area S-10
It is located at 3km southeast from proposed damsite. The material consists of clayey soil, and it is of a dark brown color.

All the materials mentioned above are composed of residual soil originated from deteriorated basalt and agglomerate, and usable depth of those borrow areas are estimated about 3 to 4m in average.

3.3 Quarry Site

Natural sand and gravel material is not available in the surrounding areas of the proposed damsite, therefore filter material and concrete aggregate are necessary to produce from quarried rock of massive basalt in the quarry site, which is located at 1km north of the proposed damsite.

Rock material in the shell zone of the rockfill dam is obtainable from this quarry site, available quantity is much larger than its requirement. Quality of the rock was confirmed by core drilling at 2 sites of Q-(1) and Q-(2) (refer to Fig. C.1) and laboratory test. The rock in the quarry site is hard, fresh and durable. Boring logs at those sites are shown in Appendix B; Geology.

4. Laboratory Test

All samples taken at prospective borrow areas and quarry site were tested in the Laboratory of University of Mauritius School of Industrial Technology during the period from October 1988 to January 1989.

4.1 Test Method

In principle, the laboratory test was carried out in the aforementioned loaboratory in accordance with American Society for Testing and Materials (ASTM).

4.2 Test Results

The test results of the core material and rock material are summarized in the Tables 1 to 3 and shown on Figs. C.2 to C.6.

(1) Core Material

Table 1 indicates that the materials of all borrow areas are basically suitable for core material of the rockfill dam, because their soil properties satisfy the criteria of core material such as plasticity index(>13%) except some samples, imperviousness(K<5x10 -5cm/sec) etc.

Outline of test results of the core material is as follows.

Specific gravity	:2.8 to 2.9, *(2.9)
Plasticity index	:13 to 17%, *(16%)
Natural moisture content	:37 to 50%, *(41%)
Optimum moisture content	:29 to 36%, *(32%)
Maximum dry density	:1.3 to 1.5tf/m3, *(1.4tf/m3)
Cohesion	
(Total stress)	:0.8 to 1.4kgf/cm2, *(1.1kgf/cm2)
(Effective stress)	:0.4kgf/cm2, *(0.4kgf/cm2)
Angle of internal friction	
(Total)	:7 to 22deg., *(13deg.)
(Effective stress)	:31 to 33deg., *(32deg.)
Coefficient of permeability	:1x10 -5 to 5x10 -7cm/sec, *(1x10 -5 to 1x10 -7cm/sec)

*( ):shows test results of material sampled at S-3 and S-5.

Detailed test results are shown in Table 1 and Figs. C.2 to C.5.

(2) Filter and Concrete Aggregate

Four samples of sand and gravel materials were purchased from local supplier. Laboratory test such as specific gravity and absorption, unit weight, particle size, abrasion loss by Los Angels machine etc. were carried out in the said laboratory. Test results of them are shown in Table 2 and Fig. C.6.

(3) Rock Material

Laboratory test of rock materials taken at said quarry site by core drilling Q-(1) was carried out. Test results are summarized in Table 3. This table suggests that hard rock can be obtained from massive basalt lava and comparatively hard rock can be obtaied from agglomerate strata in the quarry site.

5. Conclusion and Recommendation

5.1 Fill Material

Based on the field investigation and laboratory test results, quality, available quantity and effective utilization of construction materials such as core, filter, shell materials and concrete aggregate were studied. The conclusion and recommendation are mentioned hereinafter.

(1) Core Material

Adequate core material is obtainable qualitatively and quantitatively at the earth borrow areas S-3,5,7,8,9 and 10.

Out of these 6 borrow areas, S-3 and S-5 are considered to be the most suitable borrow areas, because they are very close to the damsite, and adequate material can be obtaied and its available quantity is assumed to be much more than required quantity of the core material.

Natural moisture content is about 3 to 15% wet side of the optimum moisture content on the whole borrow area. Therefore, drying up is necessary to obtain suitable properties as a core material such as high dry density and high shear strength, low coefficient of permeability and sufficient trafficability.

To reduce moisture content of the residual soil, seepage water and capillarity of the ground water shall be stopped by deep trench cutting or other methods.

It is recommended that fill work of the core material shall be carried out during dry season to keep adequate moisture content.

(2) Filter Material

Sand and gravel materials taken from local supplier were tested in the said laboratory, Test results are shown in Table 2 and Fig.C.6. These sand and gravel material can be used for filter material and concrete aggregate. However, supplying capacity of the material by the supplier is judged to be insufficient. Consequently, it is recommended that all filter material and concrete aggregate must be obtained from said quarry site with crushing process.

Suitable filter material and concrete aggregate can be obtained from massive basalt in the quarry site, because the massive basalt is hard, fresh and durable enough.

(3) Rock Material

Bulk density, specific gravity, absorption, uniaxial compressive strength were obtained by the laboratory test. These test results are shown in Table 3. This table indicates that the rock taken in the borehole Q-(1) is suitable for rock material for shell zone of the rockfill dam, because compressive strength, specific gravity and bulk density is comparatively high except some portions of the drilled core.

5.2 Concrete Aggregate

As aforementioned, all concrete aggreagte are obtainable from quarried rock in the said quarry site. Judging from the laboratory test results, suitable fine and coarse aggregates are obtainable from the quarry site with crushing process. Since a huge quantity of rock material is obtained at the quarry site, high quality rock only should be used as concrete agregate.

5.3 Design Values of Fill Materials

Design values of fill materials are assumed based on the construction material investigation. These are shown in Table 4.

6. Further Investigation

Following further investigation should be carried out to clarify the physical and mechanical properties of construction materials during detailed design stage.

(a) Core drilling at proposed quarry site

(Number of core drilling : 2 holes)
(Total length of boreholes : 60m)

(b) Test pitting at earth borrow area S-3 andS-5

(Number of test pitting : 5 sites)
(Depth of test pit : 4m)
(Material sampling : 5 disturbed samples)

(c) Laboratory test

Fill material

(Core material)

-Moisture content test	5 samples
-Atterberg limits test	do
-Gradation analysis	do
-Specific gravity test	do
-Unit weight test	do
-Compaction test	do
-Triaxial compression test	3 samples
-Permeability test	do
-Consolidation test	do
(Rock material)	
-Uniaxial compression test	do

Concrete aggregate

-Specific gravity and absorption test	6 samples
-Durability test	do
-Alkali-aggregate reaction test	3 samples

TABLES

TABLE C.1 SUMMARY OF SOIL PROPERTIES

Item	3-1	3-2	5-1	5-2	7-1	7-2	8-1	8-2	9-1	9-2	10-1	10-2
Sampling depth (m)	2.0	4.0	2.0	4.0	2.0	4.0	2.0	4.0	2.0	4.0	2.0	4.0
Natural Moisture Content W (%)	43.0	39.2	42.6	37.9	42.3	44.5	41.5	49.2	37.0	46.1	41.1	49.6
Specific Gravity GS	2.91	2.84	2.93	2.91	2.85	2.86	2.84	2.79	2.91	2.90	2.83	2.82
Grain Size Analysis												
Maximum Particle Size (mm)												
Gravel (4.76 - 76.2 mm) (%)	-	2	2	2	12	2	3	8	-	1	1	1
Sand (0.074 - 4.76 mm) (%)	30	15	20	36	20	26	26	38	15	30	35	43
Silt (0.002 - 0.074 mm) (%)	30	47	45	46	42	55	45	49	65	53	39	42
Clay (< 0.002 mm) (%)	40	36	33	16	26	17	27	5	20	16	25	14
Unit Weight (tf/m^3)												
Unified Soil Classification System	MH	MH	MH	MH	MH	MH	MH	ML	MH	MH	MH	MH
Consistency												
Liquid Limit WL (%)	74.2	72.3	68.0	52.0	55.9	54.8	56.0	48.4	58.2	64.0	60.0	50.5
Plastic Limit WP (%)	36.4	55.8	54.6	36.4	42.1	39.1	40.3	NP	41.2	NP	46.5	NP
Plasticity Index IP (%)	37.8	16.5	13.4	15.6	13.8	15.7	15.7	NP	17.0	NP	13.5	NP
Optimum Moisture Content (%)		36.0		28.5	34.0							34.5
Maximum Dry Density Dd (tf/m^3)		1.36		1.53	1.41							1.35
Triaxial Compression Test												
Unconsolidated Undrained Test												
95% of Dd max, dry side		c:0.5,φ:28		c:0.8,φ:23								c:0.2,φ:32
Dd max		c:1.4,φ:7		c:0.8,φ:18								c:1.0,φ:22
95% of Dd max, dry side		c:0.4,φ:9		c:0.8,φ:5								c:0.3,φ:16
Consolidated Undrained Test												
95% of Dd max, dry side		c':0.9,φ':28		c':1.0,φ':30								c':0.5,φ':29
Dd max		c':0,φ':26		c':0.4,φ':31								c':0.8,φ':32
95% of Dd max, dry side		c':0.4,φ':31		c':0.4,φ':33								c':0.4,φ':33
Coefficient of Permeability K (cm/s)												
95% of Dd max, dry side		2.0×10^{-4}		2.2×10^{-5}								8.8×10^{-6}
Dd max		7.3×10^{-7}		1.4×10^{-5}								4.9×10^{-7}
95% of Dd max, dry side		2.1×10^{-6}		8.2×10^{-7}								5.6×10^{-7}

Note : c,c' (Unit:kgf/cm^2) ; Cohesion
: φ,φ' (Unit:degree) ; Angle of Interim Friction

TABLE C.2 SUMMARY OF CONCRETE AGGREGATE

	Test Sample Purchased from Supplier			
	Rocksand	(b)	(c)(i)	(c)(ii)
Specific Gravity				
Oven dry	3.14	2.74	2.96	2.48
Surface dry	3.07	2.68	2.94	2.27
Absorption (%)	1.08	1.92	0.78	9.35
Unit Weight (tf/m3)	1.818	1.385	1.550	1.428
Abrasion Loss (Los Angeles)				
100 revolutions (%)	-	5.9	4.1	13.4
500 revolutions (%)	-	23.3	13.3	34.1

TABLE C.3 LABORATORY TEST RESULTS OF ROCK MATERIAL

Sample No. Depth	Bulk Density (tf/m3)	Compressive Strength (kgf/cm2)	Specific Gravity Dry	Specific Gravity ***Satu.	Absorption (%)
*Q(1) 7.5-7.8m	2.90	1370	2.94	2.96	0.8
*Q(1) 11.5-11.7m	2.93	710	2.96	2.97	0.6
**Q(1) 12.3-12.5m	2.70	580	2.57	2.70	4.9
**Q(1) 15.2-15.3m	2.42	320	2.19	2.43	11.0

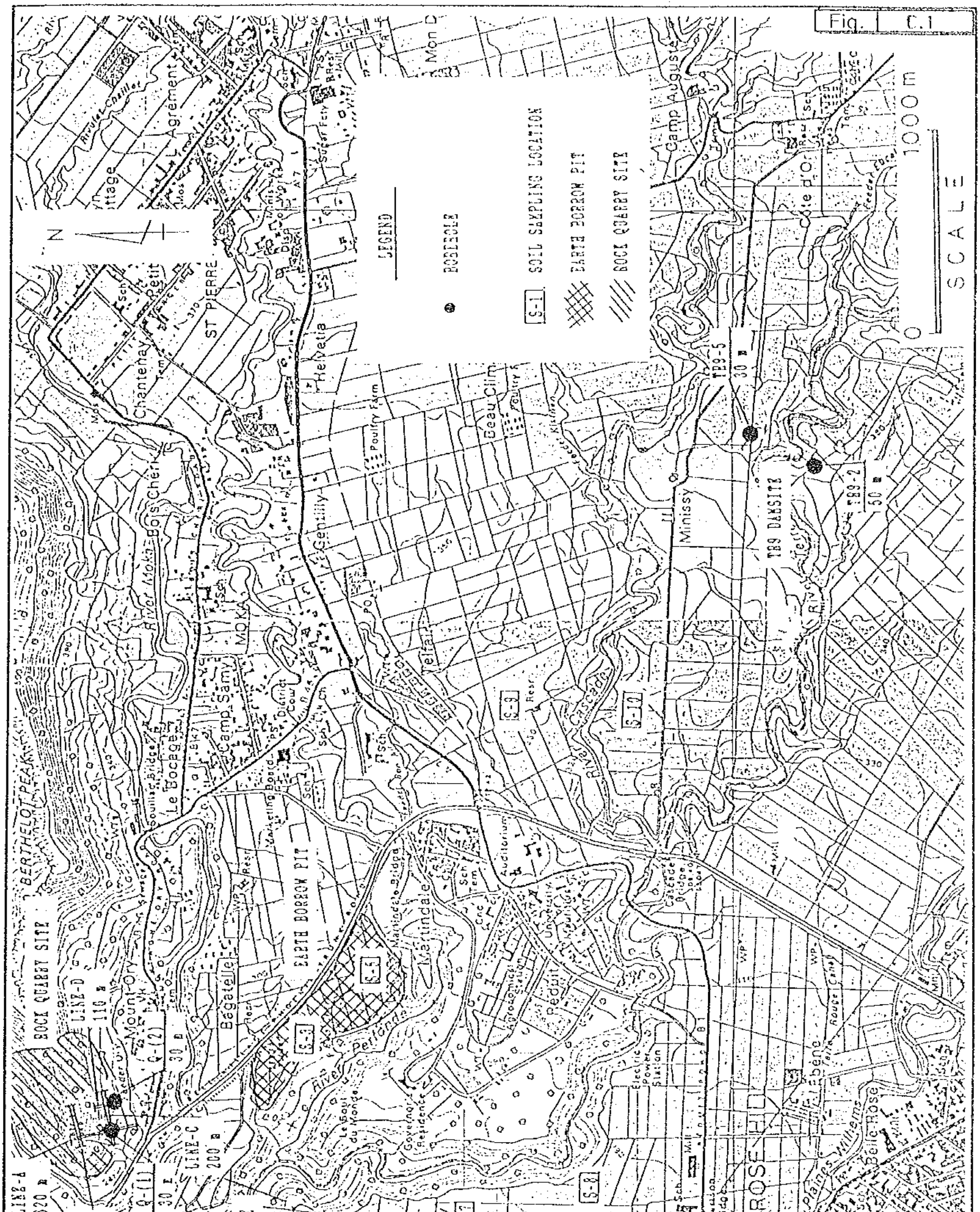
Remarks: * Massive basalt
** Agglomerate
*** Saturation

TABLE C.4 ASSUMED DESIGN VALUES OF FILL MATERIALS

	Core Material	Filter Material	Rock Material
Wet Density Dt (tf/m3)	1.80	2.00	1.95
Saturated Density Dsat (tf/m3)	1.90	2.15	2.10
Cohesion C (tf/m2)	2.0	0	0
Angle of Internal Friction / (degree)	25	35	41
Coefficient of Permeability Permeability K (cm/sec)	1x10 -5	1x10 -3	1x10 -1

FIGURES

Fig. C.1



LOCATION MAP OF CONSTRUCTION MATERIAL SOURCES

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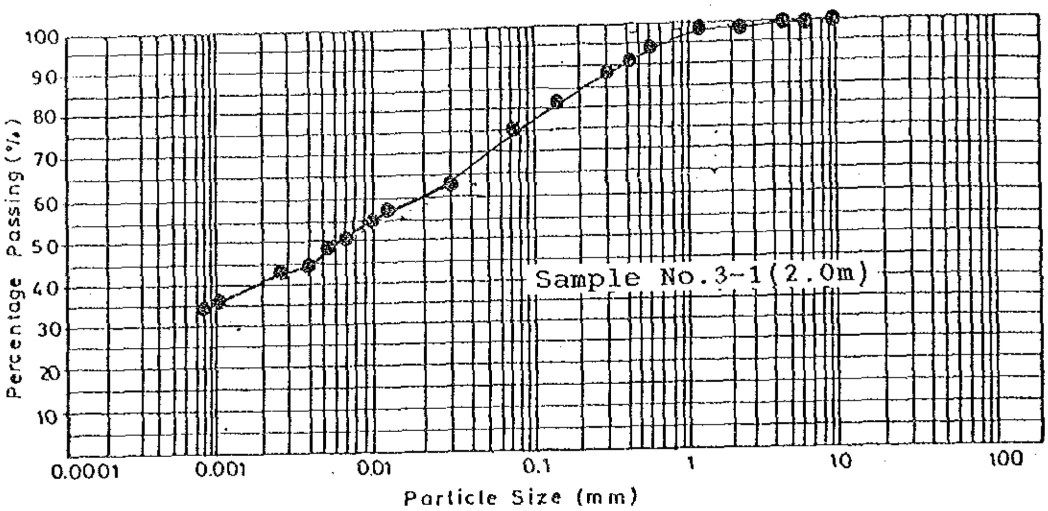
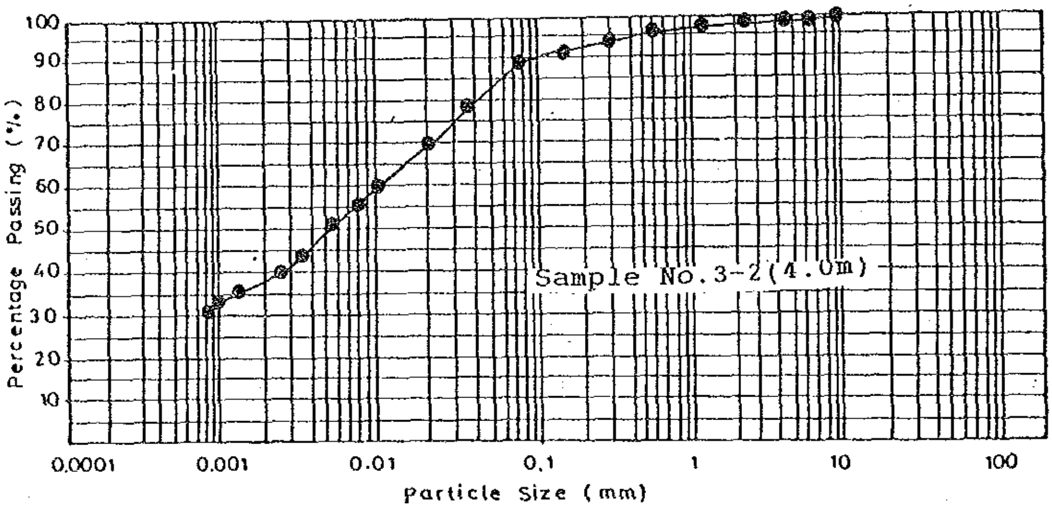
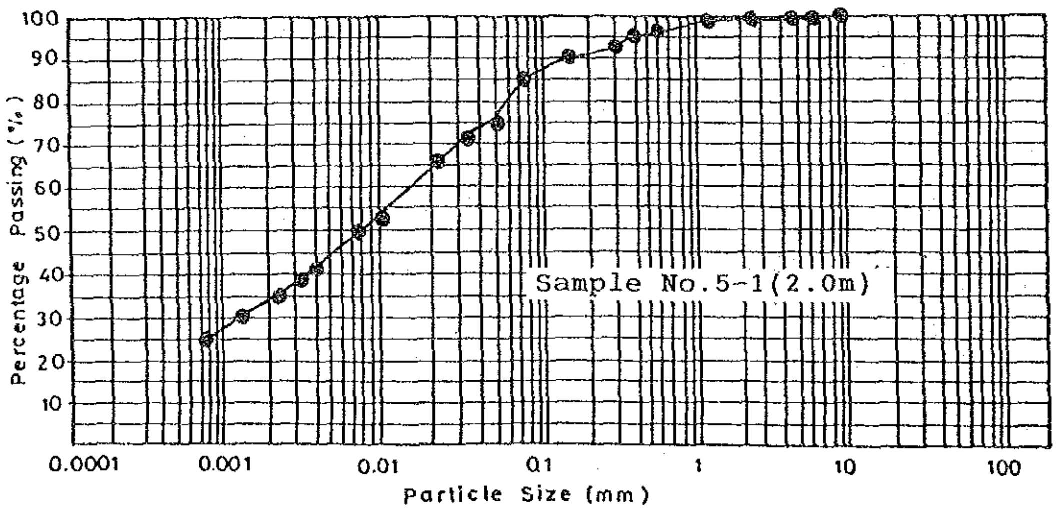
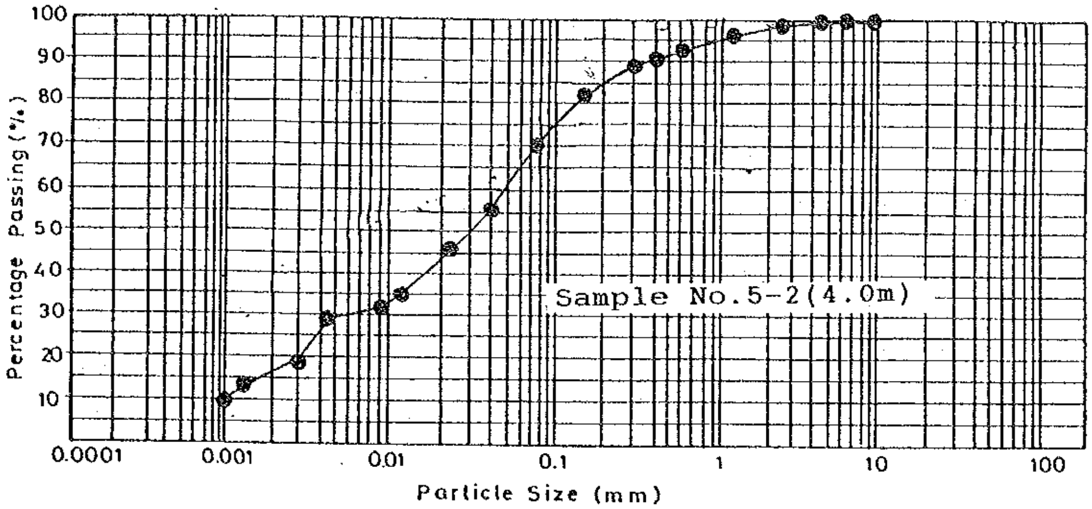


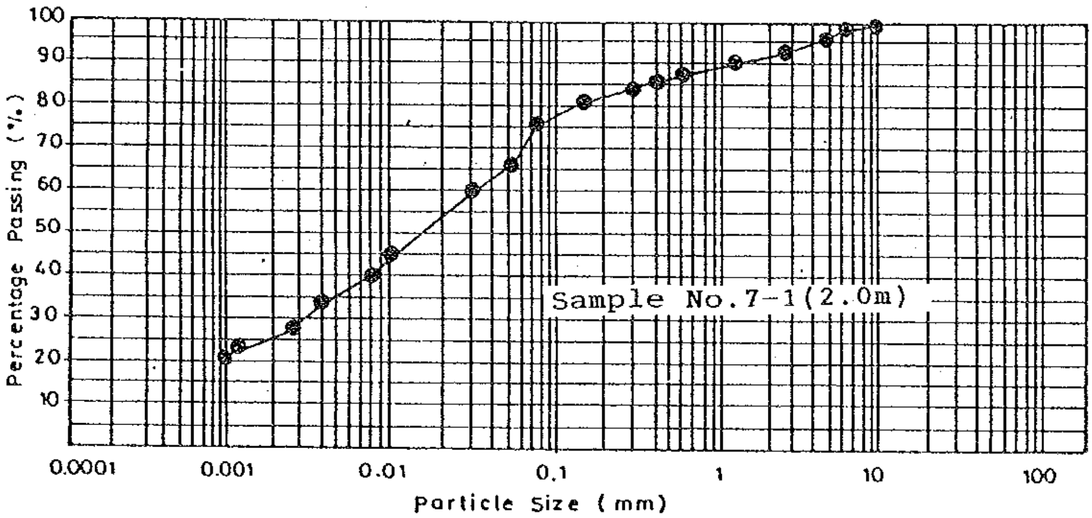


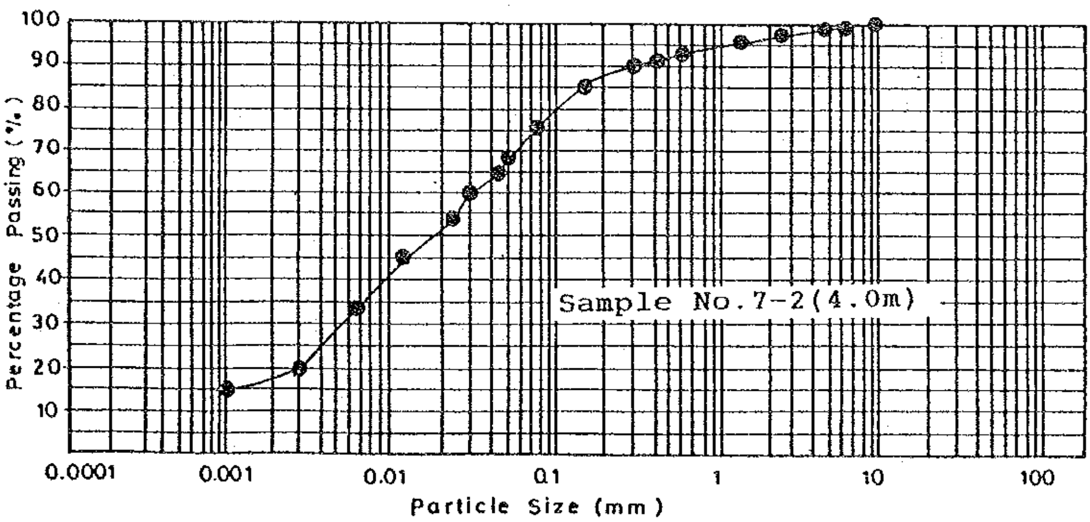


GRAIN SIZE ACCUMULATION CURVE OF CORE MATERIAL (1/4)	GOVERNMENT OF MAURITIUS PORT LOUIS WATER SUPPLY PROJECT JAPAN INTERNATIONAL COOPERATION AGENCY

Fig. C.2







GRAIN SIZE ACCUMULATION
CURVE OF CORE MATERIAL (2/4)

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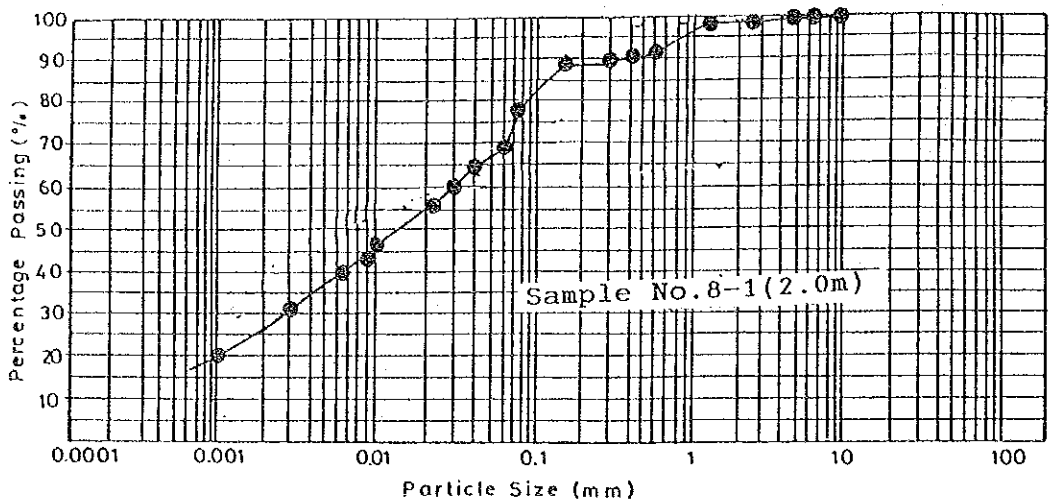
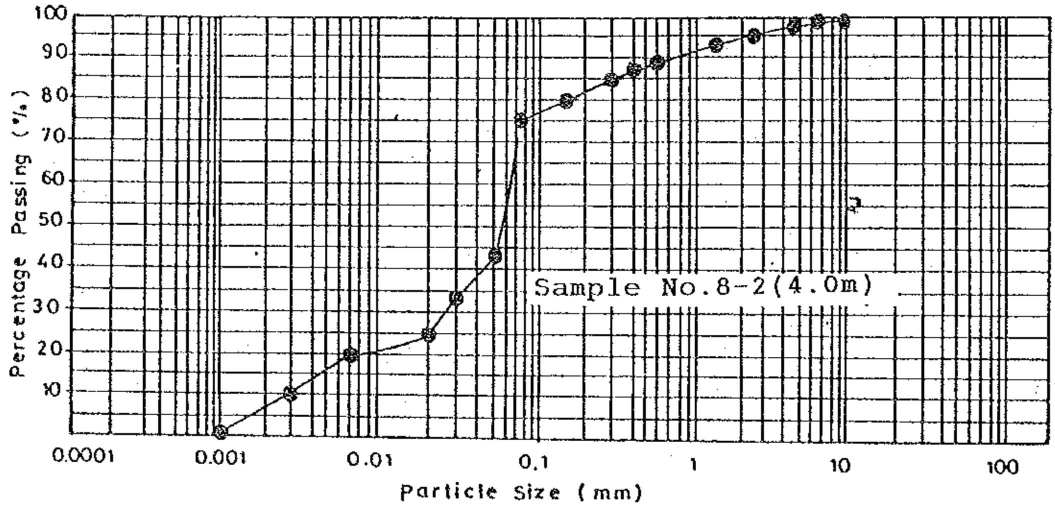
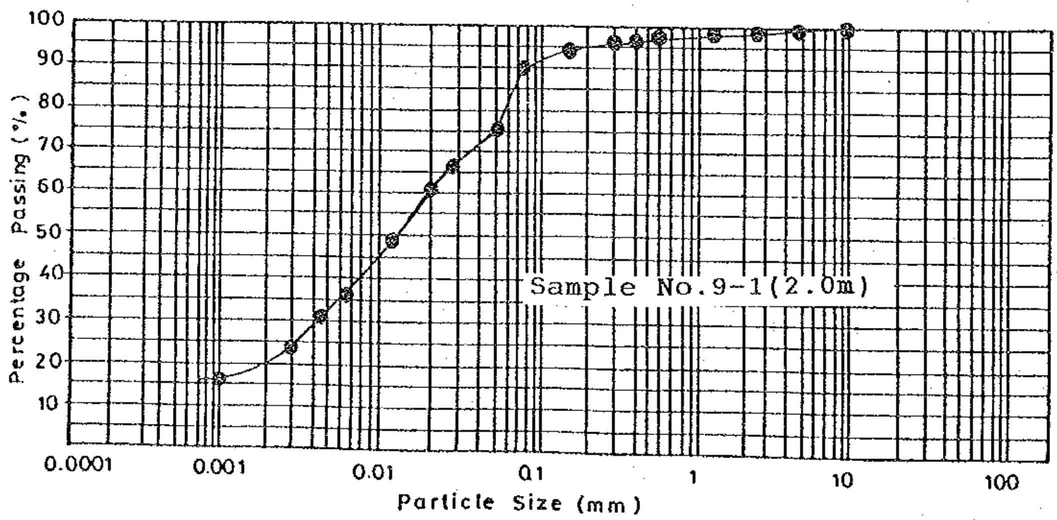
Fig. C.2







GRAIN SIZE ACCUMULATION CURVE OF CORE MATERIAL (3/4)

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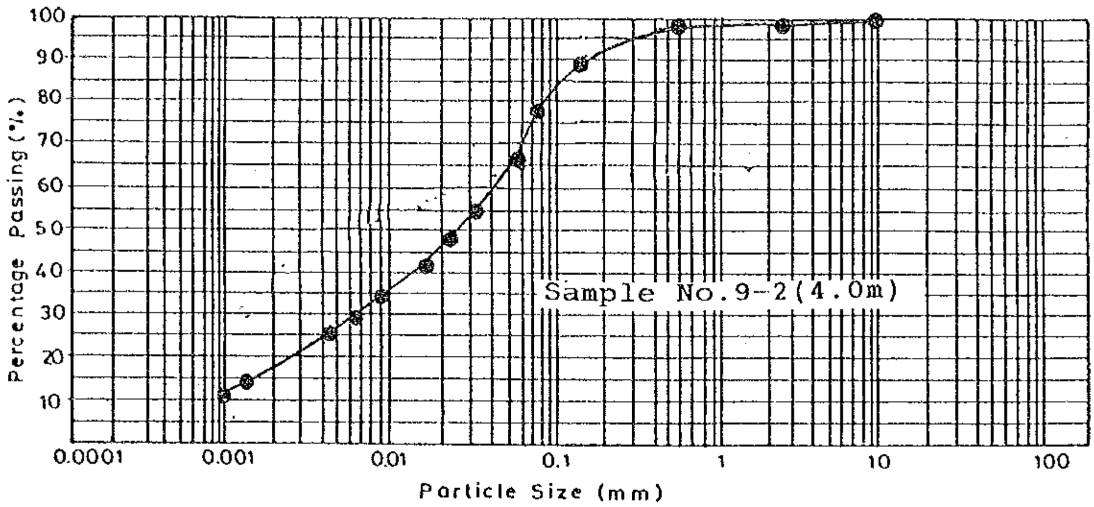

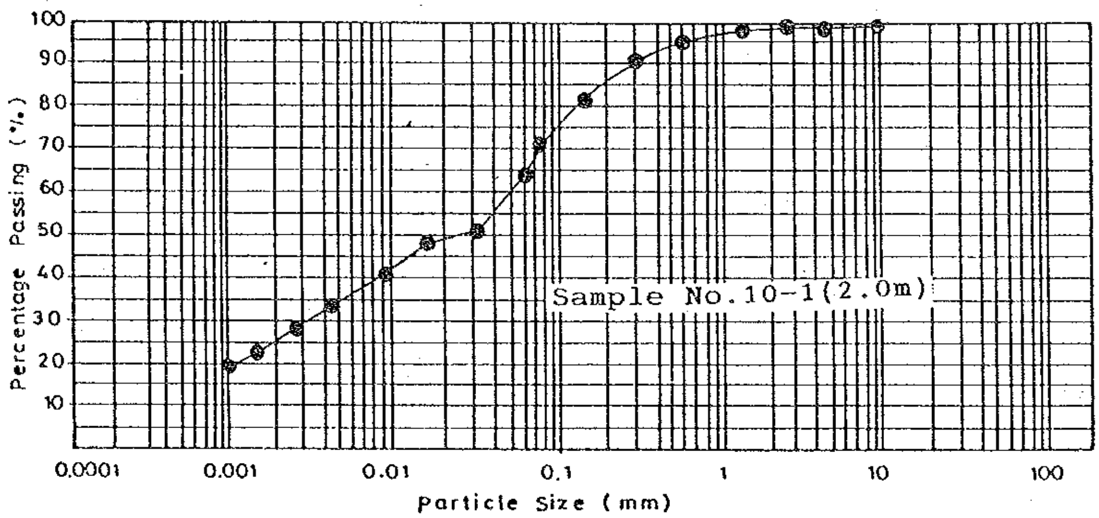

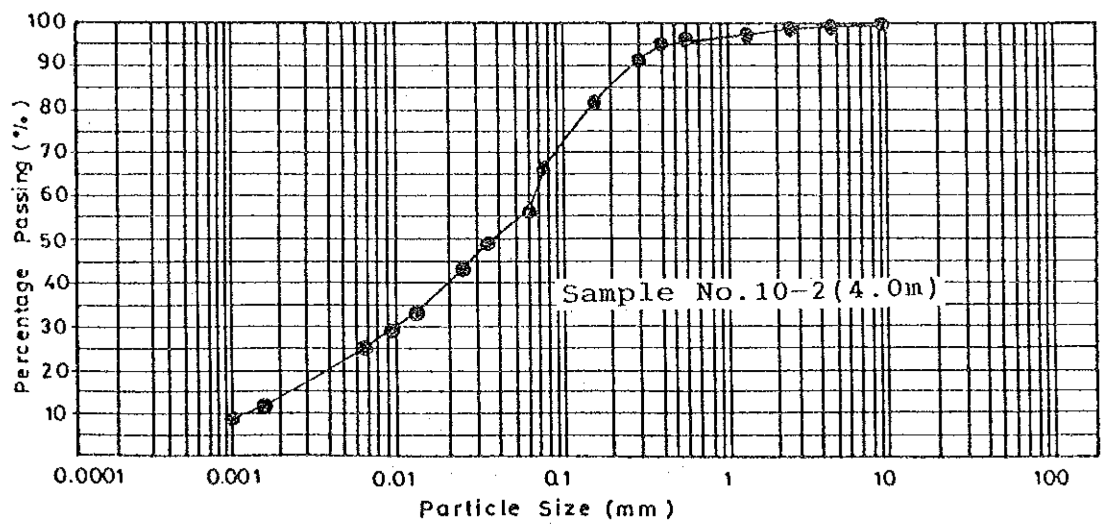

GRAIN SIZE ACCUMULATION CURVE OF CORE MATERIAL (4/4)

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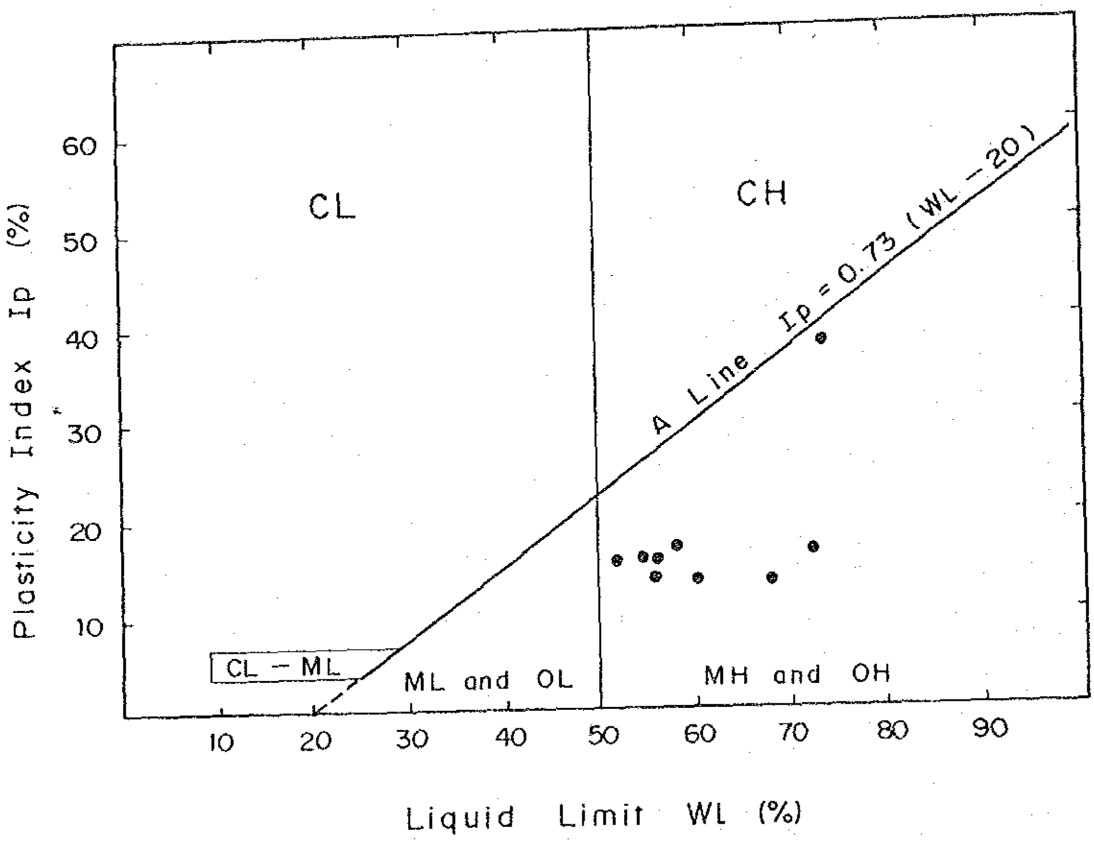
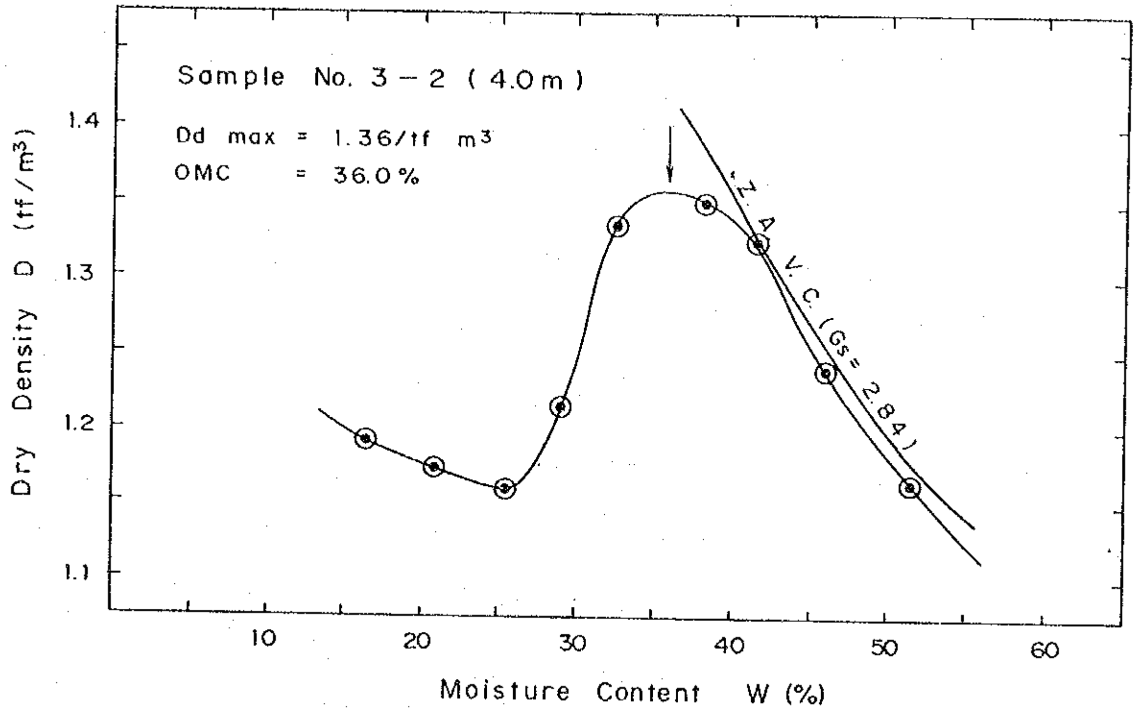
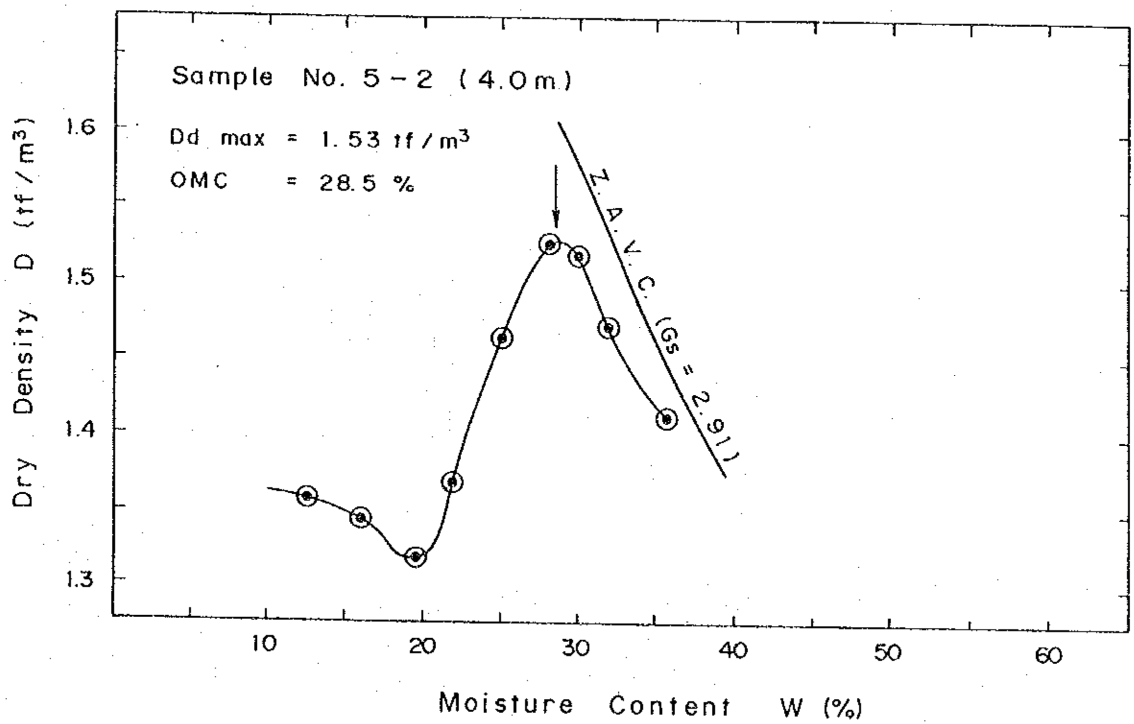


PLASTICITY CHART (CORE MATERIAL)	GOVERNMENT OF MAURITIUS PORT LOUIS WATER SUPPLY PROJECT JAPAN INTERNATIONAL COOPERATION AGENCY

Fig. C.4





MOISTURE–DENSITY RELATIONSHIP OF CORE MATERIAL (1/2)

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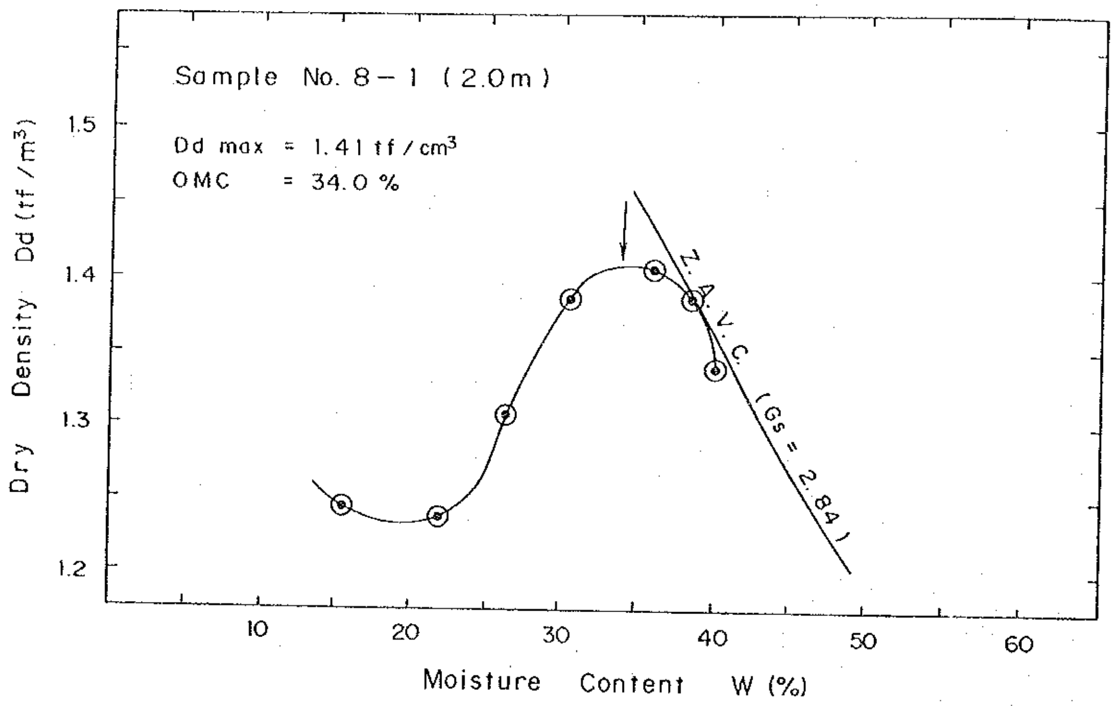

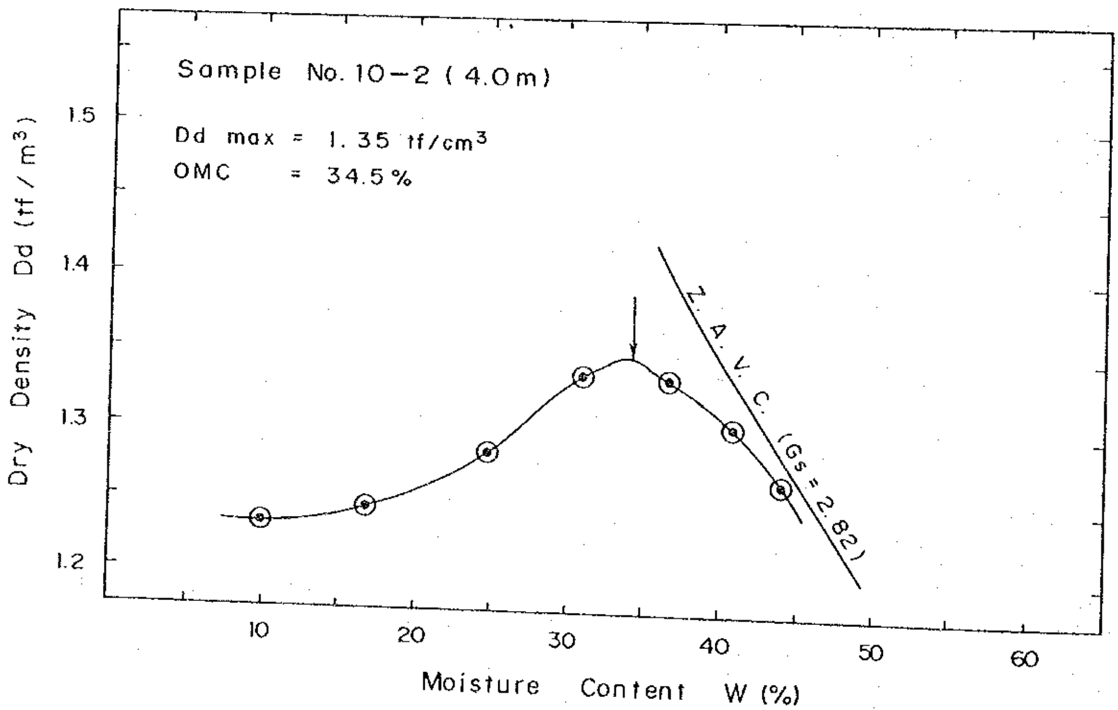

MOISTURE-DENSITY RELATIONSHIP OF CORE MATERIAL (2/2)

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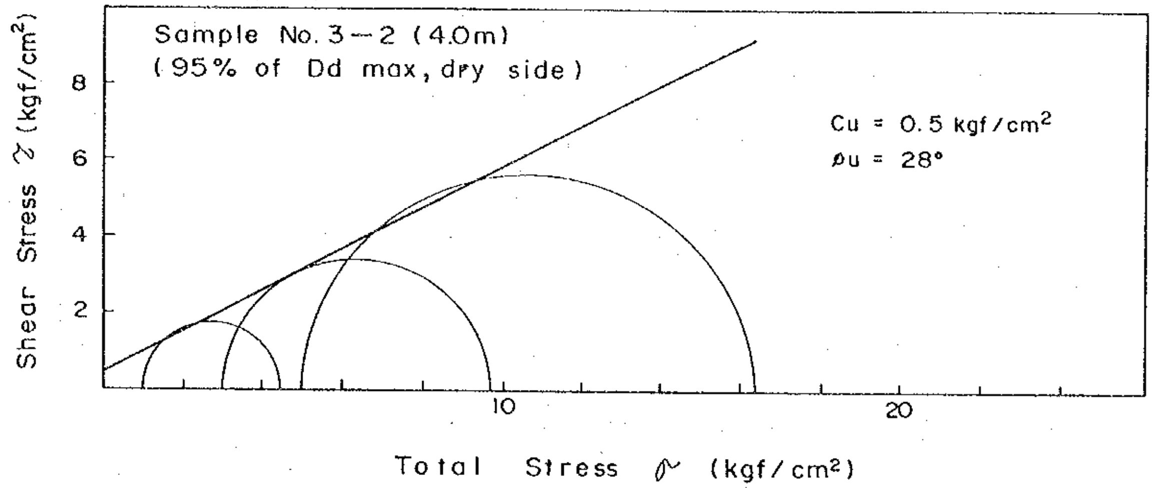
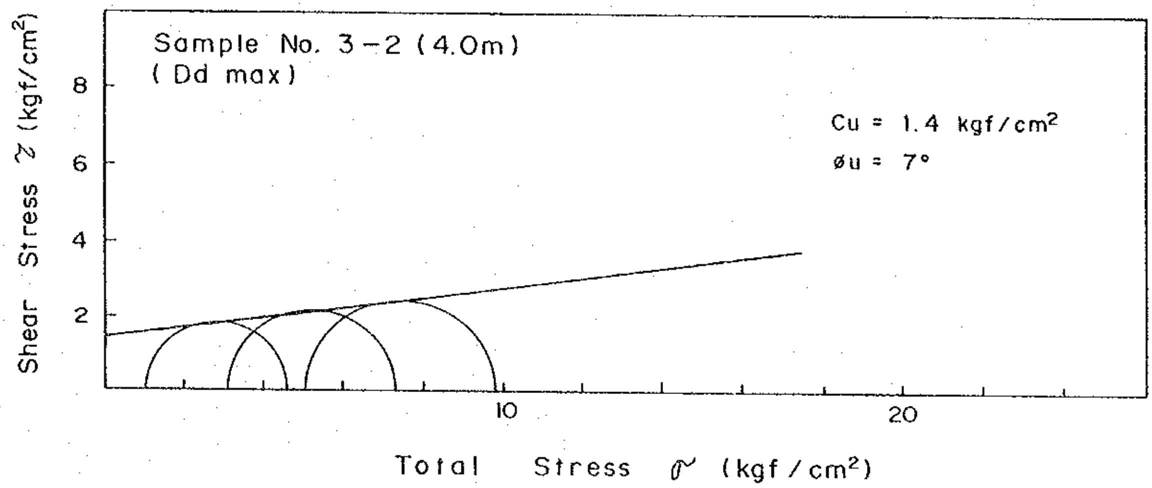
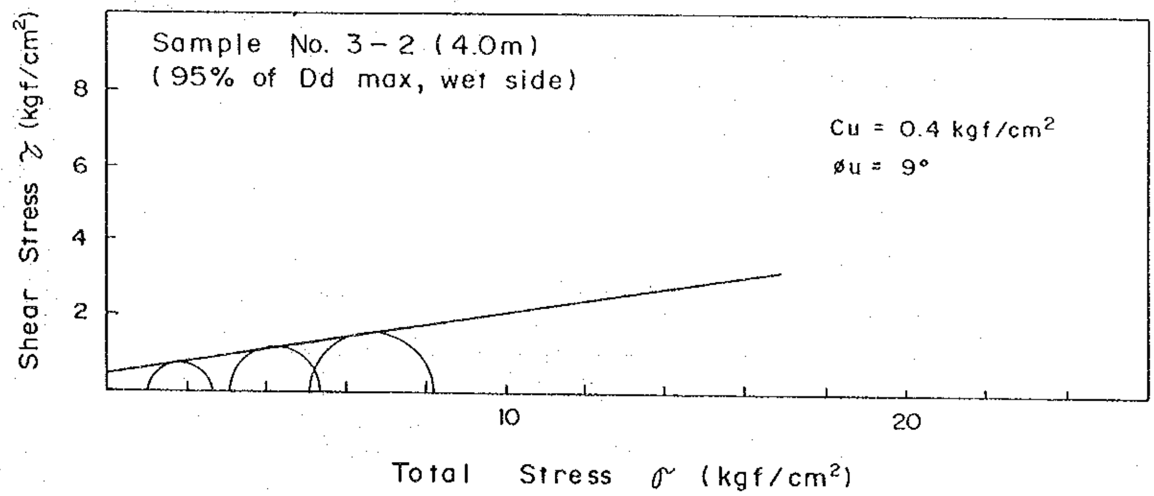
Fig. C.5

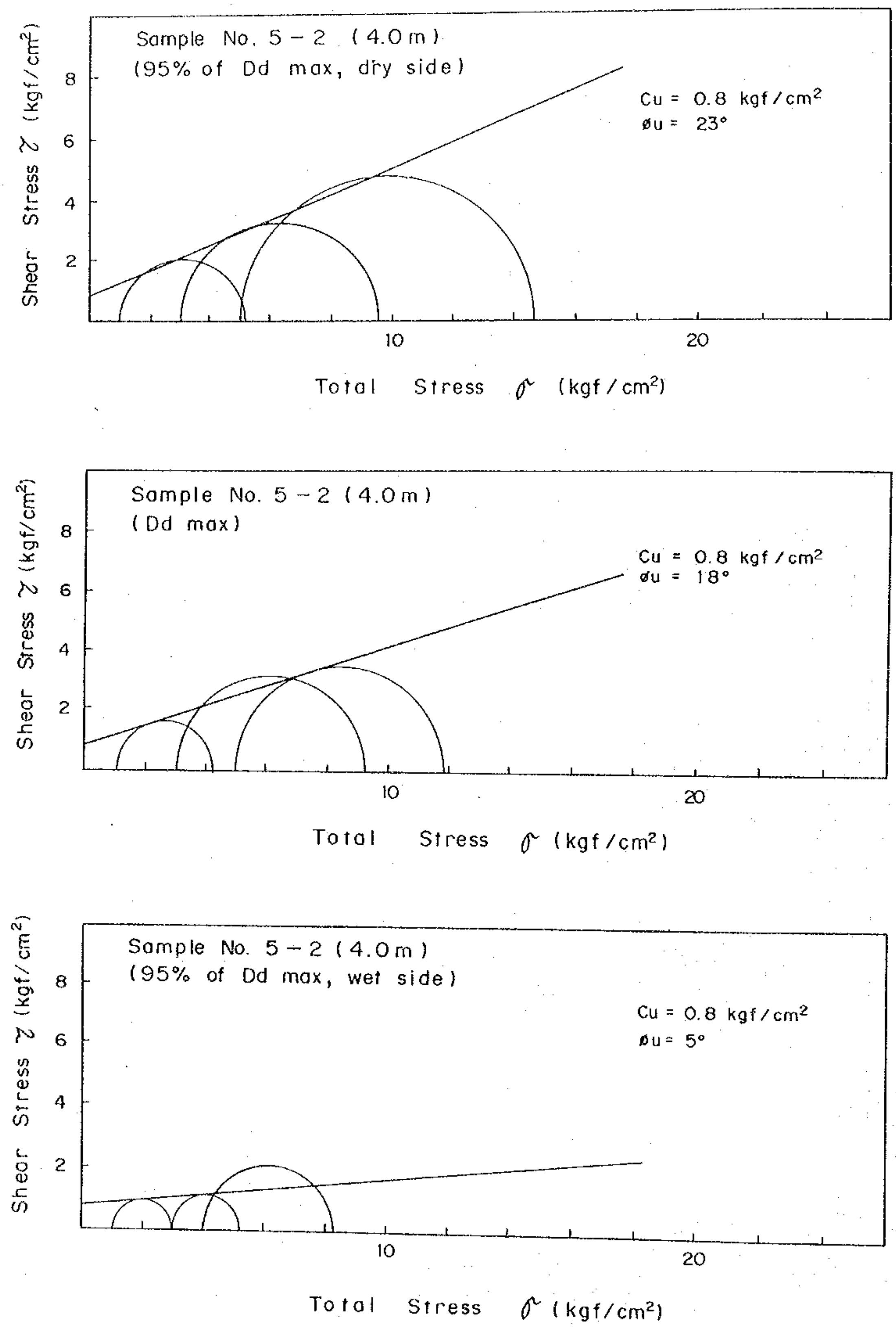




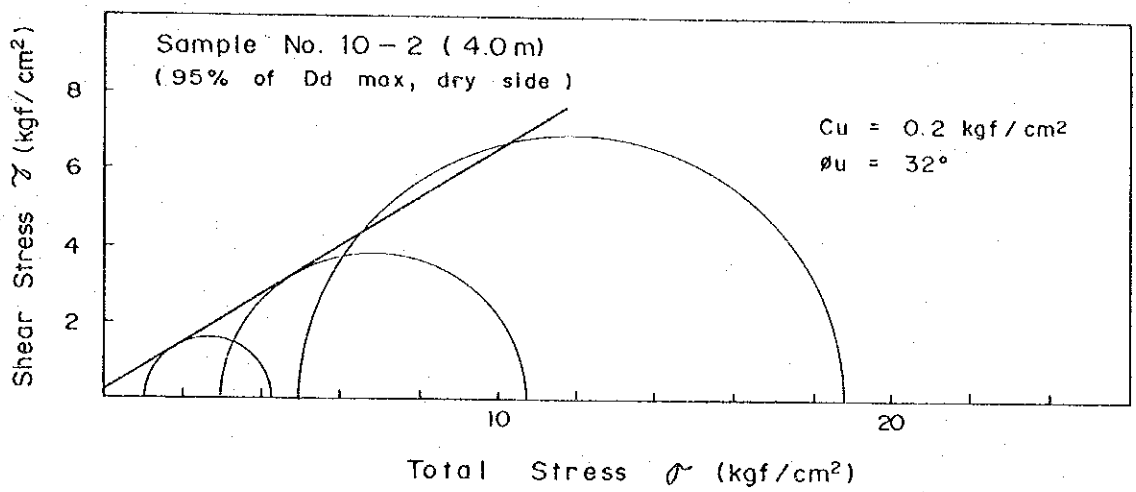


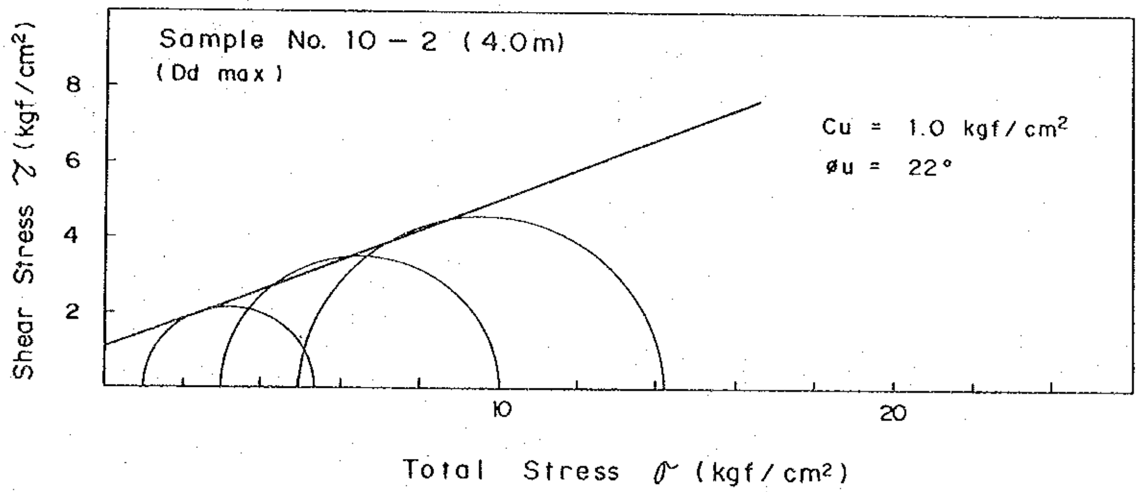
TRIAXIAL COMPRESSION TEST RESULTS CORE MATERIAL (1/6)	GOVERNMENT OF MAURITIUS PORT LOUIS WATER SUPPLY PROJECT JAPAN INTERNATIONAL COOPERATION AGENCY

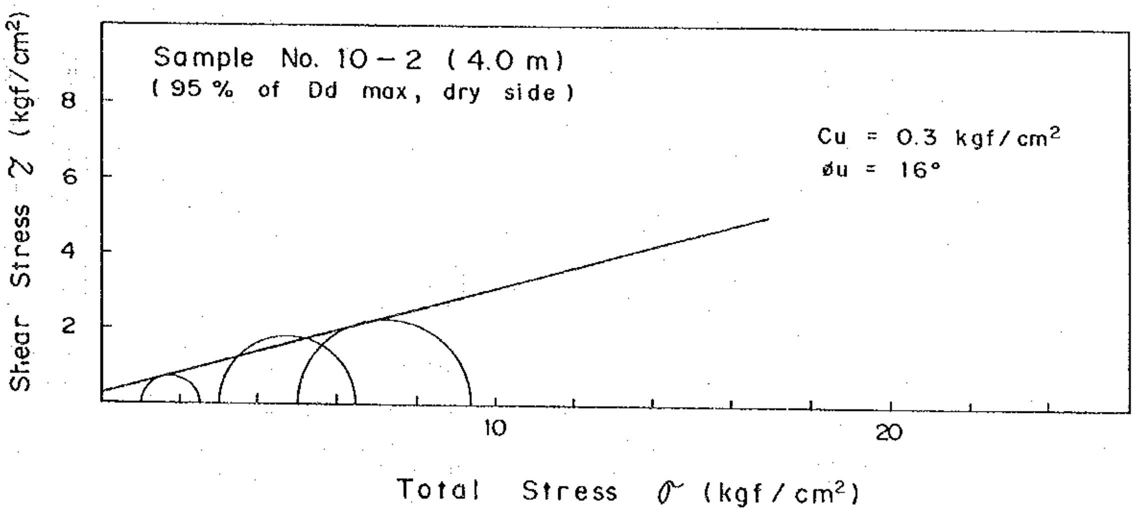
Fig. C.5



TRIAXIAL COMPRESSION TEST RESULTS CORE MATERIAL (2/6)	GOVERNMENT OF MAURITIUS PORT LOUIS WATER SUPPLY PROJECT JAPAN INTERNATIONAL COOPERATION AGENCY







TRIAXIAL COMPRESSION TEST
RESULTS CORE MATERIAL (3/6)

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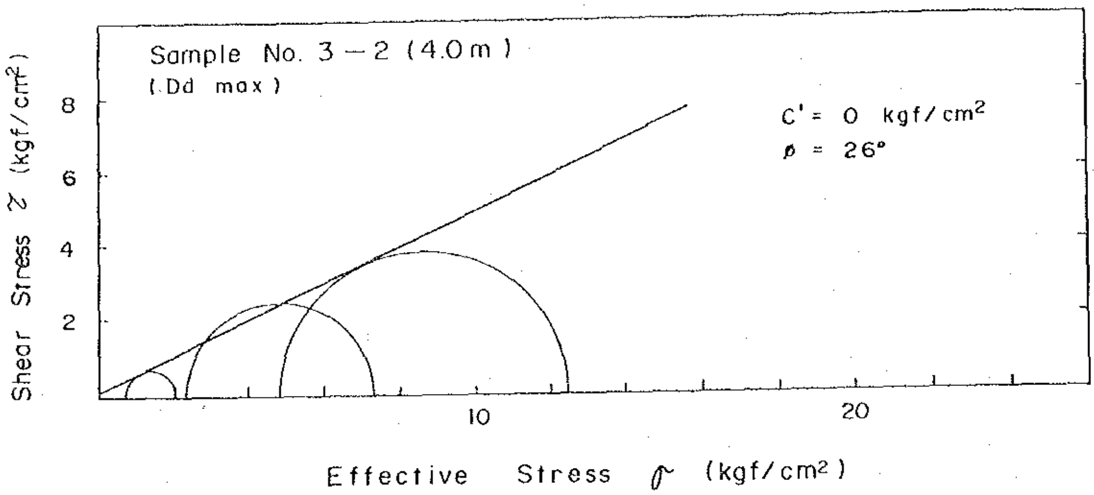
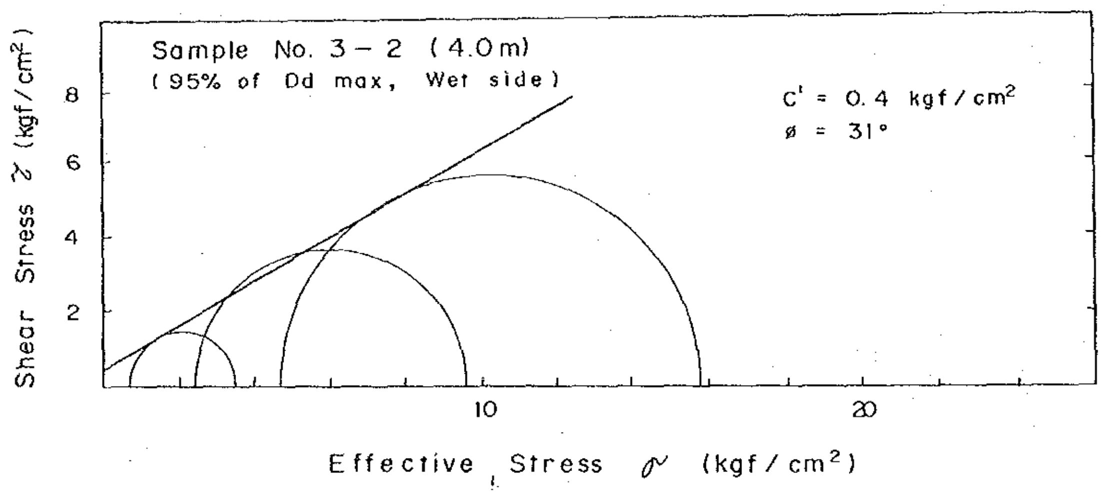
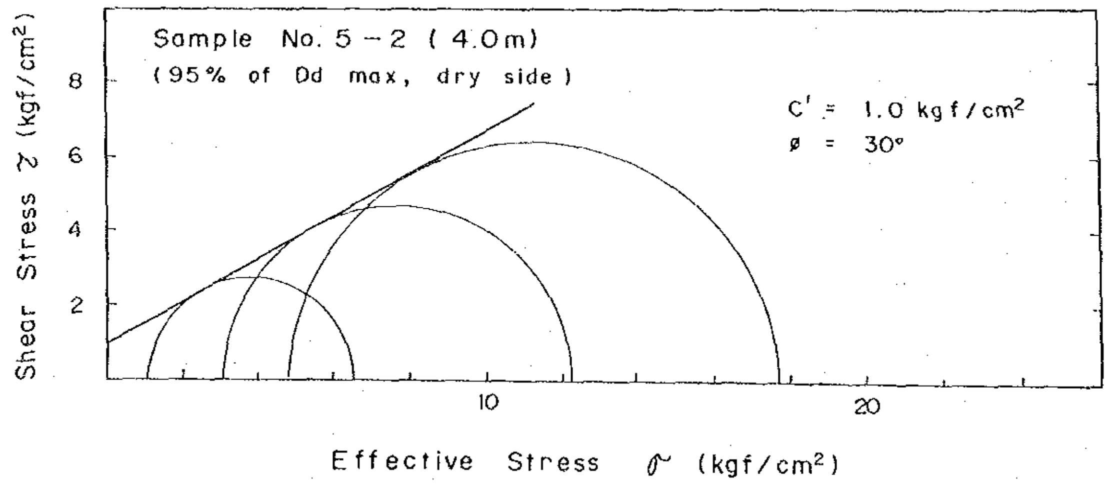
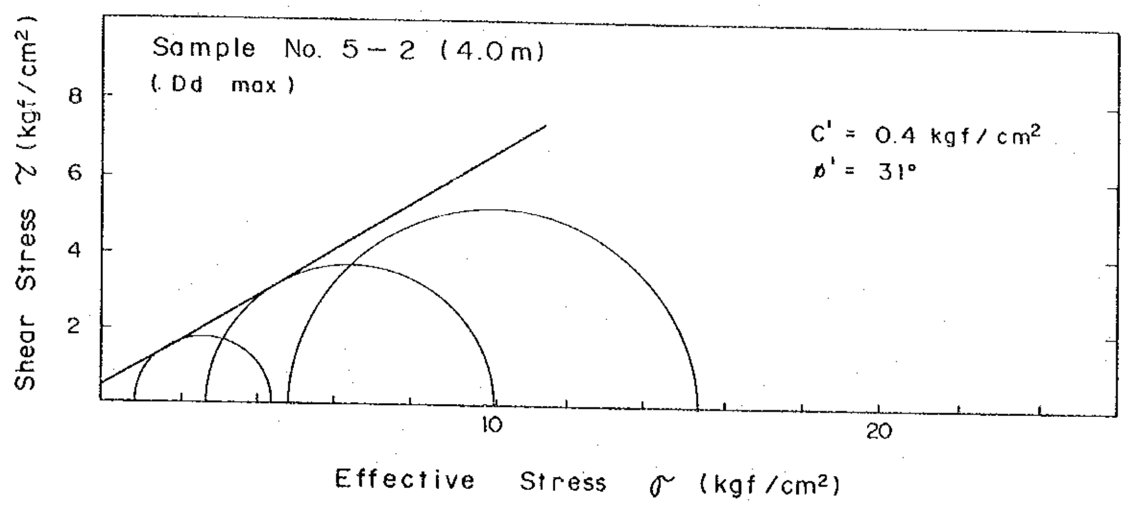


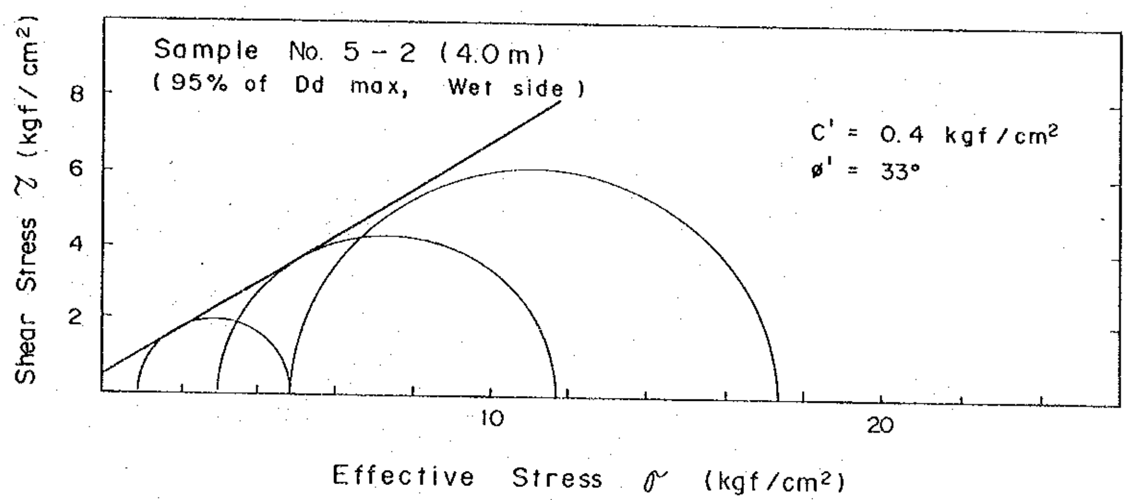


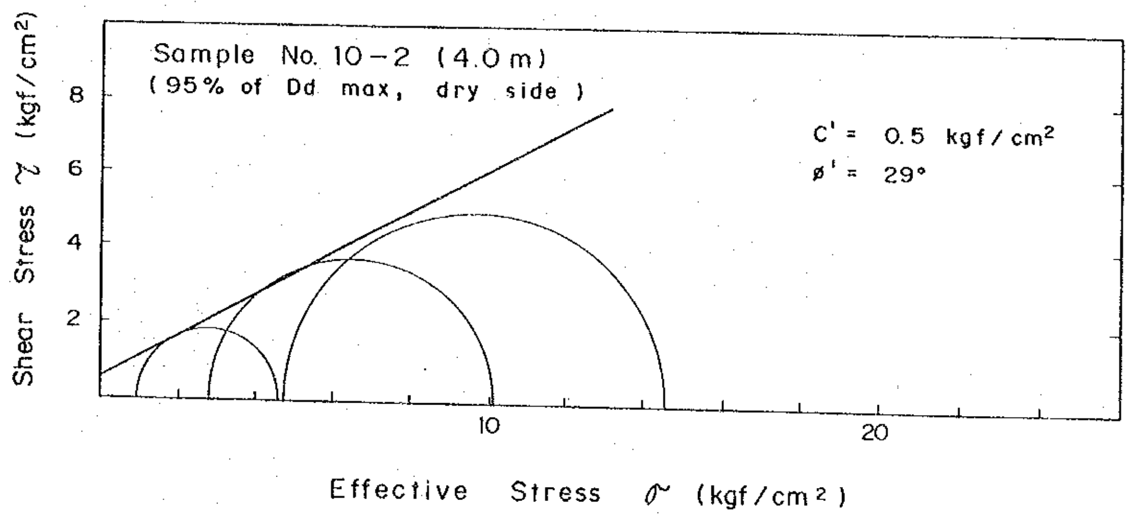


TRIAXIAL COMPRESSION TEST RESULTS CORE MATERIAL (4/6)	GOVERNMENT OF MAURITIUS PORT LOUIS WATER SUPPLY PROJECT JAPAN INTERNATIONAL COOPERATION AGENCY

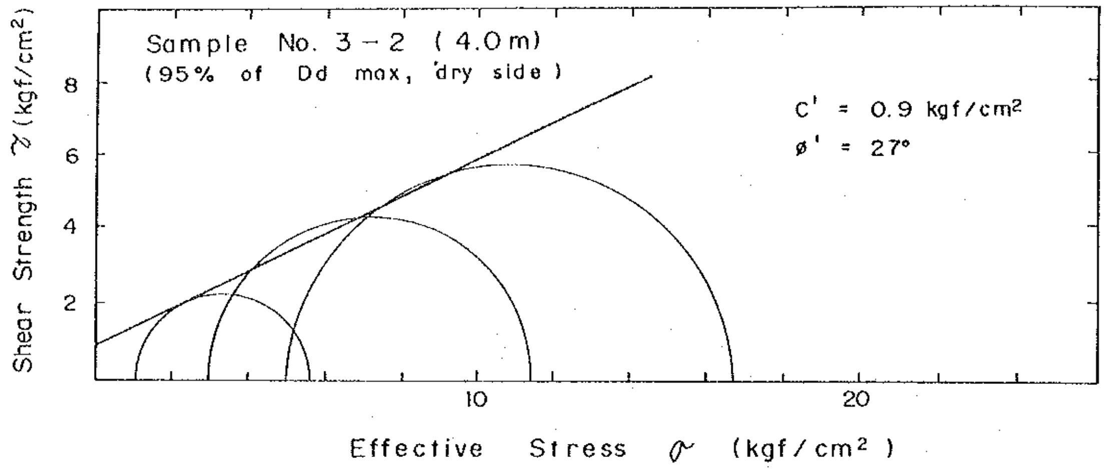
Fig. C.5

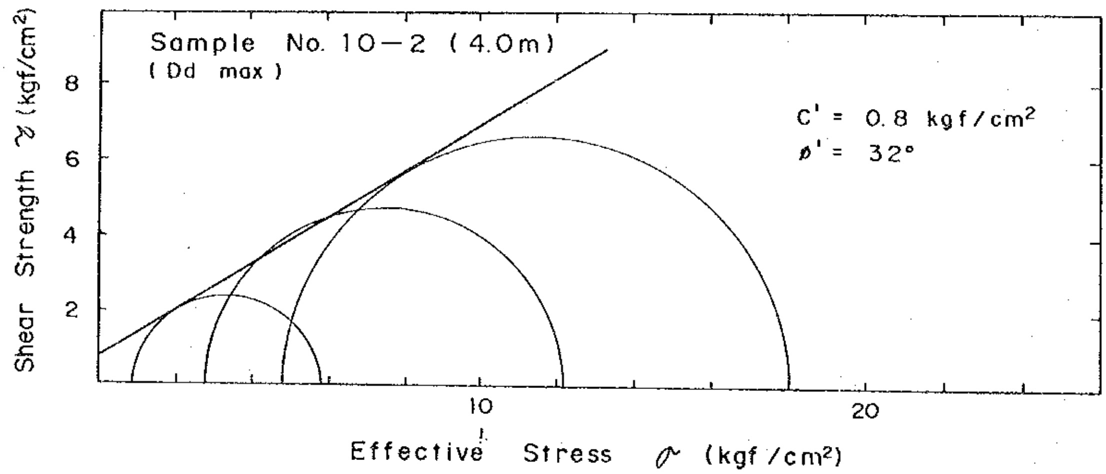


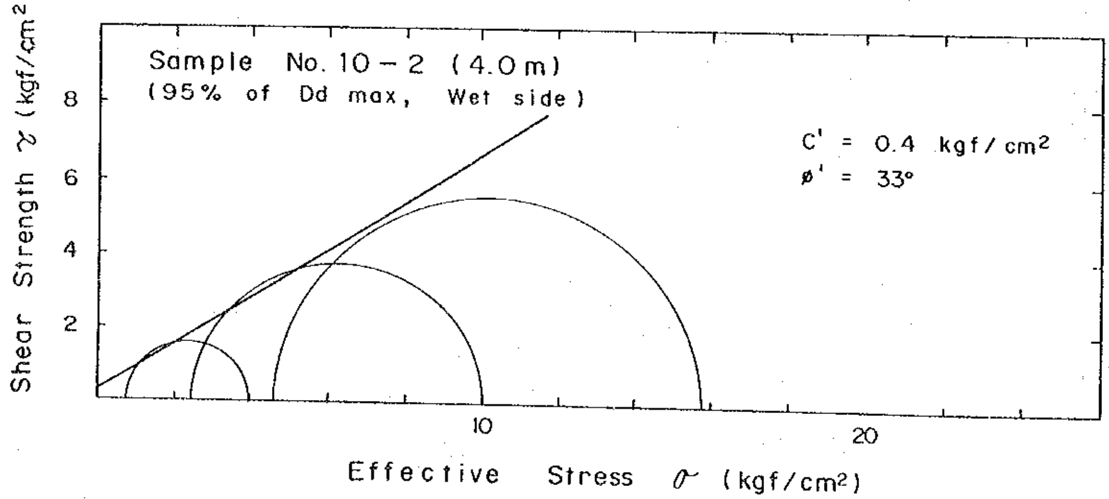




TRIAXIAL COMPRESSION TEST TEST RESULTS MATERIAL (5/6)	GOVERNMENT OF MAURITIUS PORT LOUIS WATER SUPPLY PROJECT JAPAN INTERNATIONAL COOPERATION AGENCY







TRIAXIAL COMPRESSION TEST
TEST RESULTS MATERIAL (6/6)

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