TECHNOTEST, INC.
SOIL TESTING LABORATORY
893 E. delos SANTOS AVENUE
QUEZON CITY, PHILIPPINES



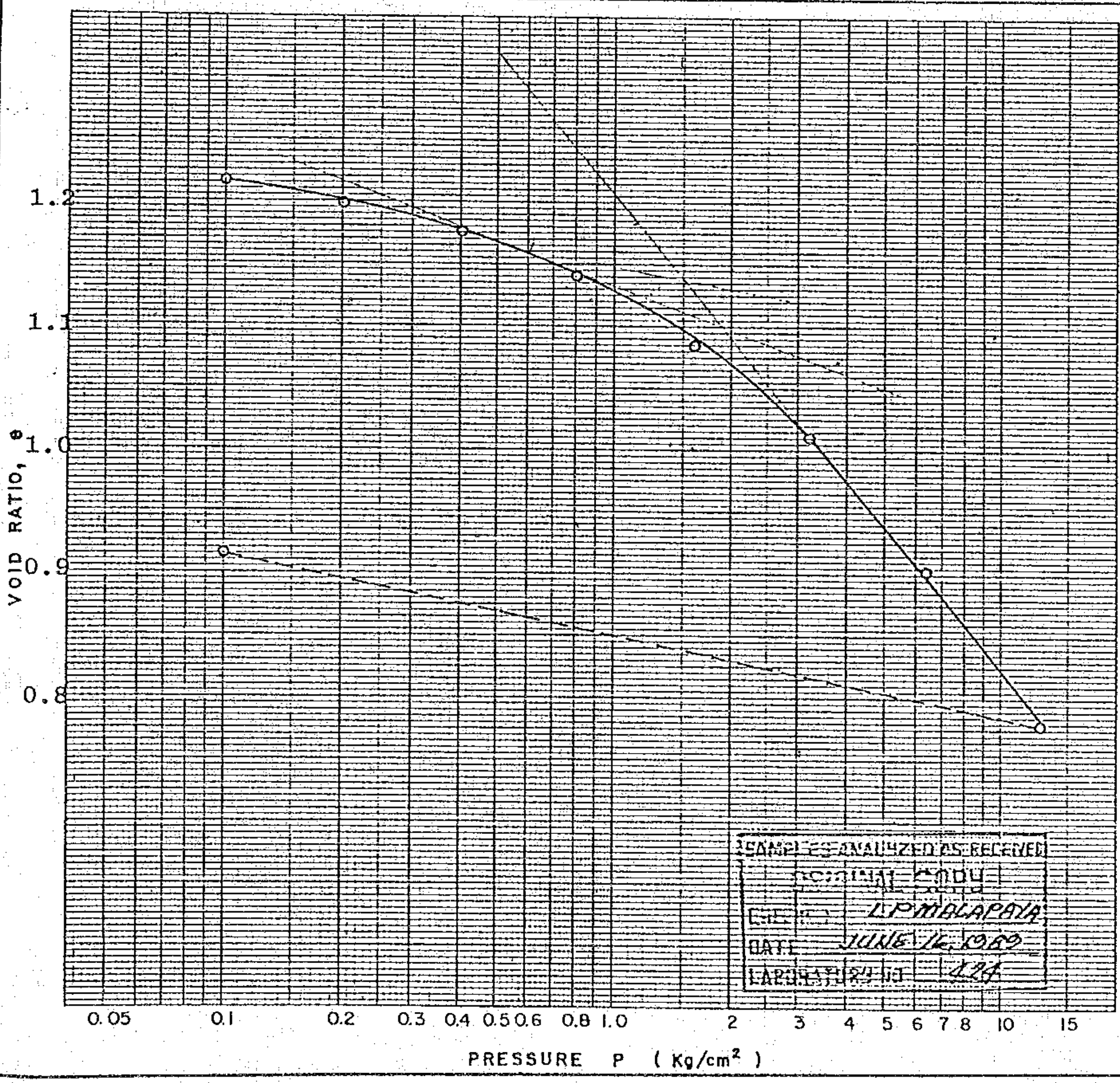
# CONSOLIDATION TEST e-log p CURVES

PROJECT: Flood Control and Drainage Project DATE: 6-16-89

BOREHOLE No: JB-8 (TP) DEPTH: 0.5-1.00 m TESTED BY: L. SANTIAGO

| DRY DENSITY g/cc | WET DENSITY $\gamma_t$ g/cm³ | SPECIFIC GRAVITY $G_s$ | MOISTURE CONTENT $W_o$ % | INITIAL DEGREE of SATURATION $S_o$ % | INITIAL VOID RATIO $e_o$ | COMPRESSION INDEX $C_c$ | PRECONSOLIDATION PRESSURE $P_c$ Kg/cm² |
|---|---|---|---|---|---|---|---|
| 1.16 | 1.69 | 2.61 | 45.86 | 95.99 | 1.247 | 0.383 | 1.102 |

REMARKS:




DPC / RN M-79

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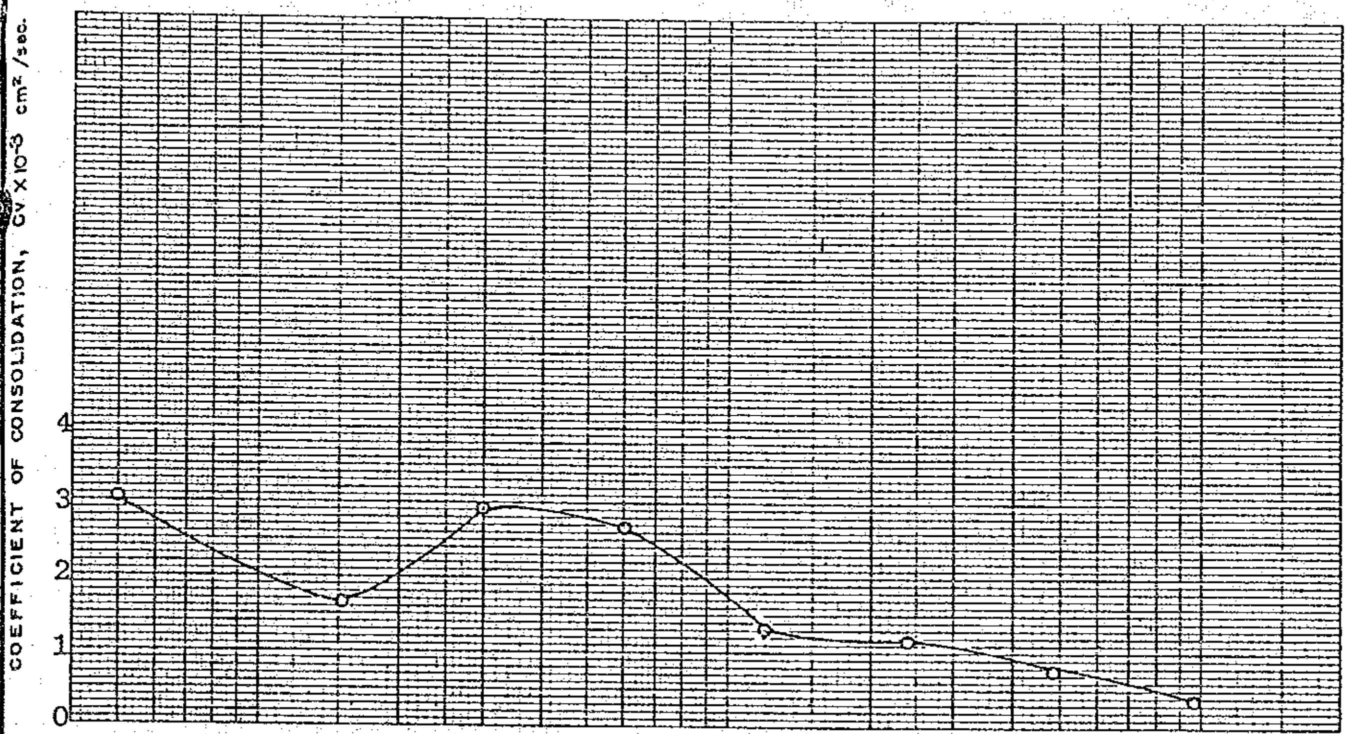
893 E. delos SANTOS AVENUE
QUEZON CITY, PHILIPPINES

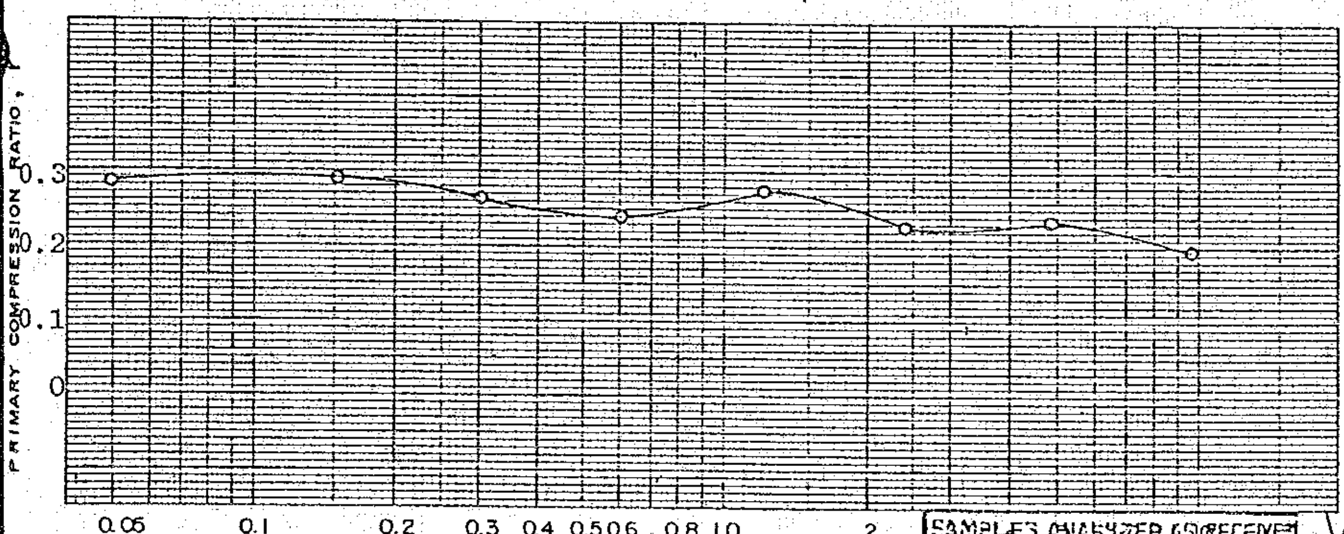


# CONSOLIDATION TEST Cv, r~ log $\overline{P}$ CURVES

PROJECT: Flood Control and Drainage Project

BOREHOLE No: JB-8 (TP) DEPTH: 0.5-1.00 m DATE: 6-15-89




PRESSURE $\overline{P} = \frac{1}{2}(P_{n-1} + P)$

REMARKS:

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DPC / RN M-79

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SOIL TESTING LABORATORY
893 E. delos SANTOS AVENUE
QUEZON CITY, PHILIPPINES



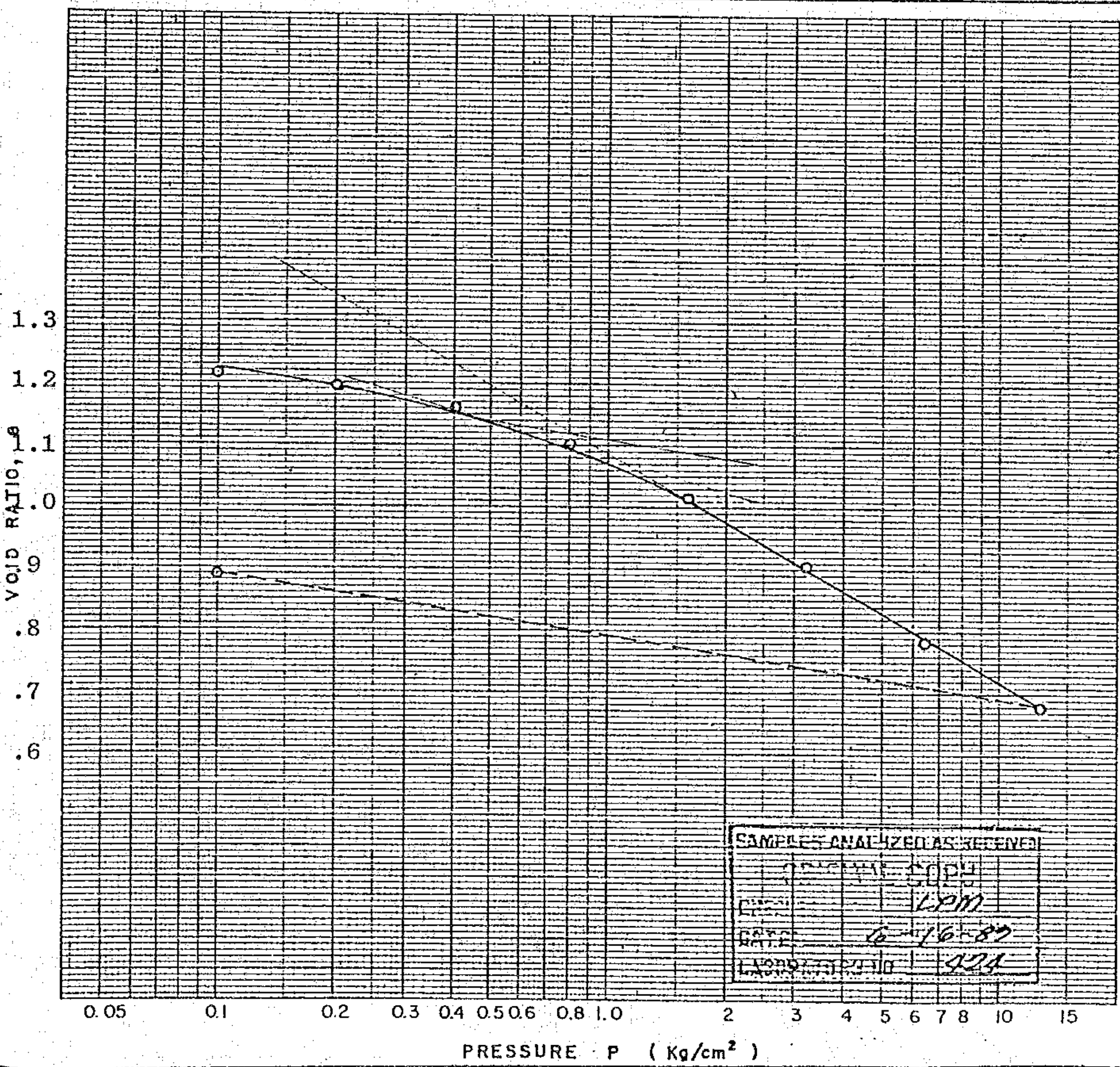
# CONSOLIDATION TEST e - log p CURVES

PROJECT: Flood Control and Drainage Project DATE: 6-15-89

BOREHOLE No: JB-9 (TP) DEPTH: 0.5-1.00 m TESTED BY: L. SANTIAGO

| DRY DENSITY g/cc | WET DENSITY $\gamma_t$ g/cm³ | SPECIFIC GRAVITY $G_s$ | MOISTURE CONTENT $W_o$ % | INITIAL DEGREE of SATURATION $S_o$ % | INITIAL VOID RATIO $e_o$ | COMPRESSION INDEX $C_c$ | PRECONSOLIDATION PRESSURE $P_c$ Kg/cm² |
|---|---|---|---|---|---|---|---|
| 1.17 | 1.72 | 2.62 | 47.30 | 99.38 | 1.247 | 0.368 | 0.83 |

REMARKS:

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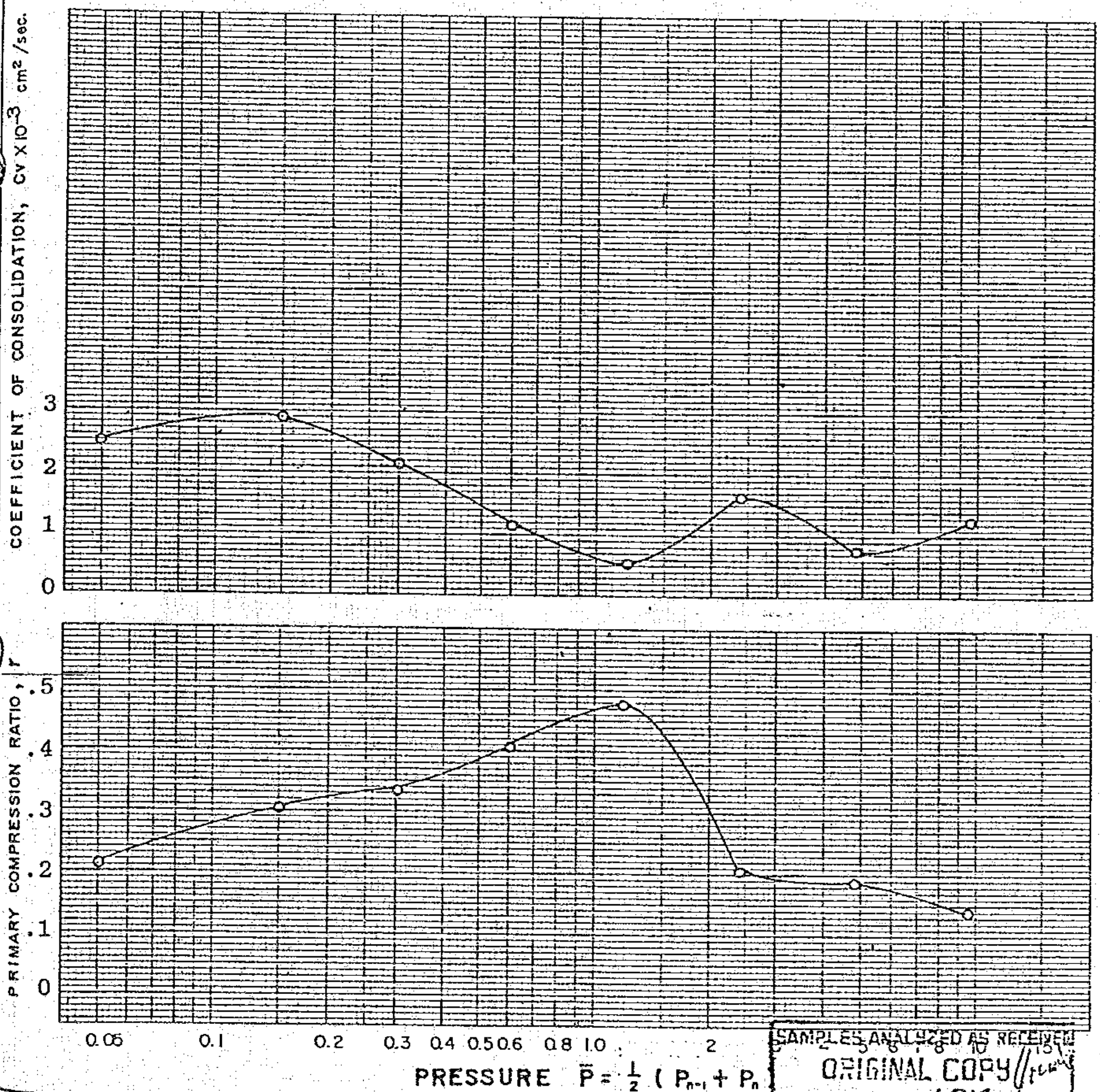
893 E. delos SANTOS AVENUE
QUEZON CITY, PHILIPPINES

# CONSOLIDATION TEST Cv, r ~ log $\overline{P}$ CURVES

PROJECT: Flood Control and Drainage Project

BOREHOLE No: JB-9 (TP) DEPTH: 0.5-1.00m DATE: 6-15-89

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DATE: 6-16-89
LABORATORY NO

REMARKS:

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SOIL TESTING LABORATORY
TECHNOTEST BLDG., 893 EDSA, QUEZON CITY
METRO MANILA, PHILIPPINES

J-1

Standard
Volume=926 cc

# PROCTOR COMPACTION TEST

PROJECT: Flood Control and Drainage Project

TYPE OF MATERIAL:

SAMPLE No. JB-3 (TP) DEPTH (m): DATE: 6-30-89

| DETERMINATIONS | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | RUN NUMBER | | 1 | 2 | 3 | 4 | 5 |
| DENSITY | WATER ADDED | cc | 400 | 500 | 600 | 700 | 800 |
| | WT. CYLINDER + W SOIL | g | 5114 | 5438 | 5660 | 5595 | 5447 |
| | WT. OF CYLINDER | g | 3938 | 3938 | 3938 | 3938 | 3938 |
| | WT. OF W SOIL | g | 1176 | 1500 | 1722 | 1657 | 1509 |
| | WET DENSITY | g/cc | 1.27 | 1.62 | 1.86 | 1.79 | 1.63 |
| WATER CONTENT | CONTAINER NUMBER | | 1 | 2 | 3 | 4 | 5 |
| | WT. DISH + W SOIL | g | 134.52 | 142.73 | 152.65 | 163.23 | 167.52 |
| | WT. DISH + D SOIL | g | 119.24 | 121.97 | 125.09 | 123.97 | 121.14 |
| | WT. OF DISH | g | 16.41 | 16.56 | 16.75 | 16.32 | 16.60 |
| | WT. OF WATER | g | 15.28 | 20.76 | 27.56 | 39.26 | 46.38 |
| | WT. OF D SOIL | g | 102.83 | 105.41 | 108.34 | 107.65 | 104.54 |
| | WATER CONTENT/D SOIL | % | 14.86 | 19.69 | 25.44 | 36.47 | 44.37 |
| | DRY DENSITY | g/cc | 1.11 | 1.35 | 1.48 | 1.31 | 1.13 |
| PENETRATION RESISTANCE | NEEDLE NUMBER | | 1 | 2 | 3 | 4 | 5 |
| | NEEDLE AREA, sq. in. | | 1/20 | 1/20 | 1/20 | 1/20 | 1/20 |
| | AVERAGE READING, lbs. | | 96.45 | 80.80 | 62.00 | 42.80 | 31.64 |
| | RESISTANCE | psi | 1929 | 1616 | 1240 | 817 | 632.80 |
| | (psi / 70.3) | g/cm² | 27.44 | 23.00 | 17.64 | 11.63 | 9.00 |

DENSITY / PENETRATION RESISTANCE CURVE

MAXIMUM DRY DENSITY, g/cc = 1.48

OPTIMUM MOISTURE CONTENT, % = 25.44

NATURAL MOISTURE CONTENT, % =

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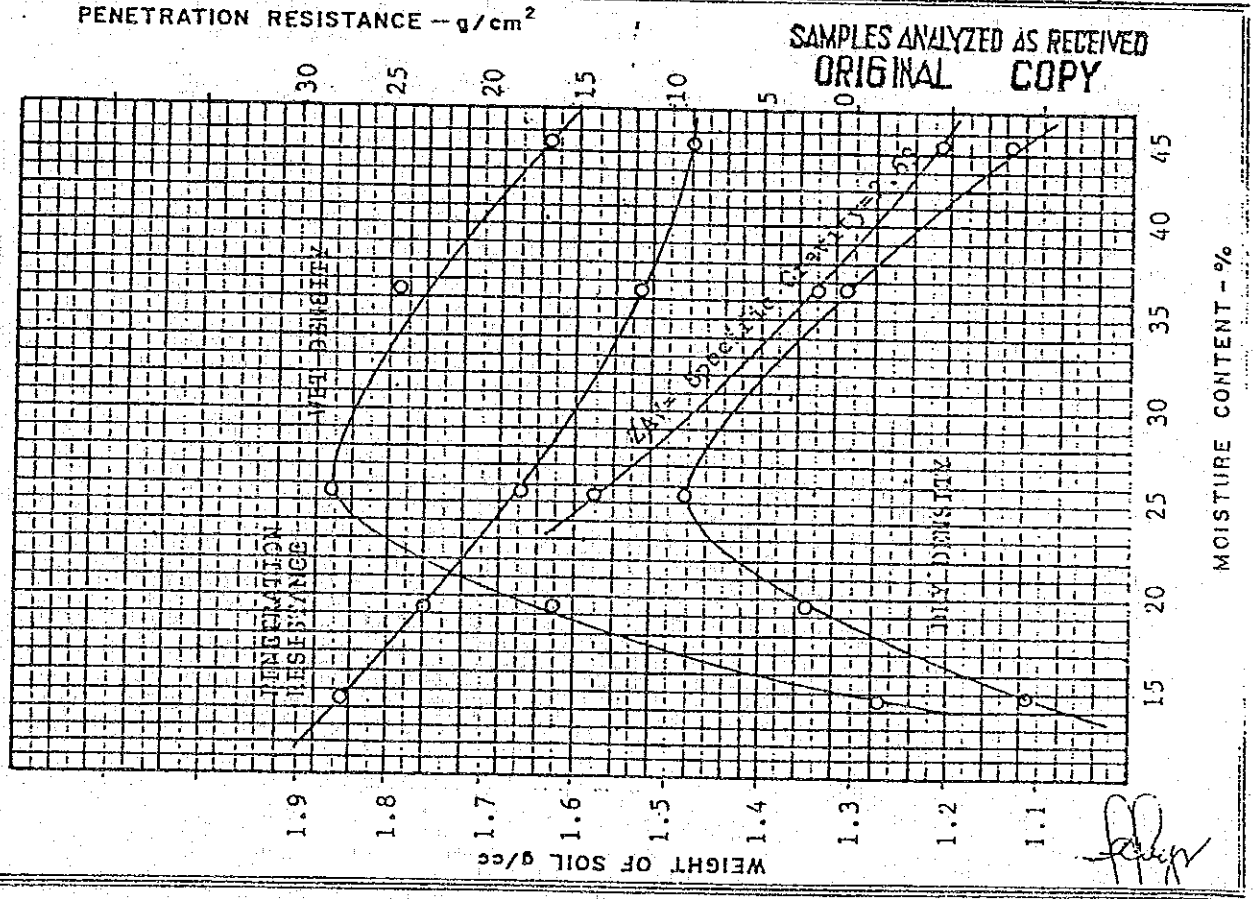


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# TECHNOTEST, INC.

SOIL TESTING LABORATORY
TECHNOTEST BLDG., 893 EDSA, QUEZON CITY
METRO MANILA, PHILIPPINES



Standard

Volume=926 cc

## PROCTOR COMPACTION TEST

PROJECT: Flood Control and Drainage Project

TYPE OF MATERIAL:

SAMPLE No. JB-4 (TP) DEPTH (m): DATE: 6-30-89

**DETERMINATIONS**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| DENSITY | RUN NUMBER | | 1 | 2 | 3 | 4 | 5 |
| | WATER ADDED | cc | 400 | 500 | 600 | 700 | 800 |
| | WT. CYLINDER + W SOIL | g | 5188 | 5401 | 5641 | 5604 | 5484 |
| | WT. OF CYLINDER | g | 3938 | 3938 | 3938 | 3938 | 3938 |
| | WT. OF W SOIL | g | 1250 | 1463 | 1703 | 1666 | 1546 |
| | WET DENSITY | g/cc | 1.35 | 1.58 | 1.84 | 1.80 | 1.67 |
| WATER CONTENT | CONTAINER NUMBER | | 1 | 2 | 3 | 4 | 5 |
| | WT. DISH + W SOIL | g | 138.74 | 152.56 | 168.39 | 207.98 | 257.07 |
| | WT. DISH + D SOIL | g | 121.54 | 128.55 | 134.37 | 157.17 | 185.02 |
| | WT. OF DISH | g | 16.78 | 16.37 | 15.11 | 16.22 | 15.61 |
| | WT. OF WATER | g | 17.20 | 43.88 | 34.02 | 50.81 | 72.05 |
| | WT. OF D SOIL | g | 104.76 | 112.18 | 119.26 | 140.95 | 169.41 |
| | WATER CONTENT / D SOIL | % | 16.42 | 21.40 | 28.53 | 36.05 | 42.53 |
| | DRY DENSITY | g/cc | 1.16 | 1.30 | 1.43 | 1.32 | 1.17 |
| PENETRATION RESISTANCE | NEEDLE NUMBER | | 1 | 2 | 3 | 4 | 5 |
| | NEEDLE AREA, sq. in. | | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 |
| | AVERAGE READING, lbs. | | 102.60 | 92.15 | 68.25 | 43.55 | 28.15 |
| | RESISTANCE | psi | 2052 | 1843 | 1365 | 871 | 563 |
| | ( psi / 70.3 ) | $g/cm^2$ | 29.19 | 26.22 | 19.43 | 12.40 | 8.02 |

DENSITY / PENETRATION RESISTANCE CURVE

MAXIMUM DRY DENSITY, g/cc = 1.43

OPTIMUM MOISTURE CONTENT, % = 28.53

NATURAL MOISTURE CONTENT, % =

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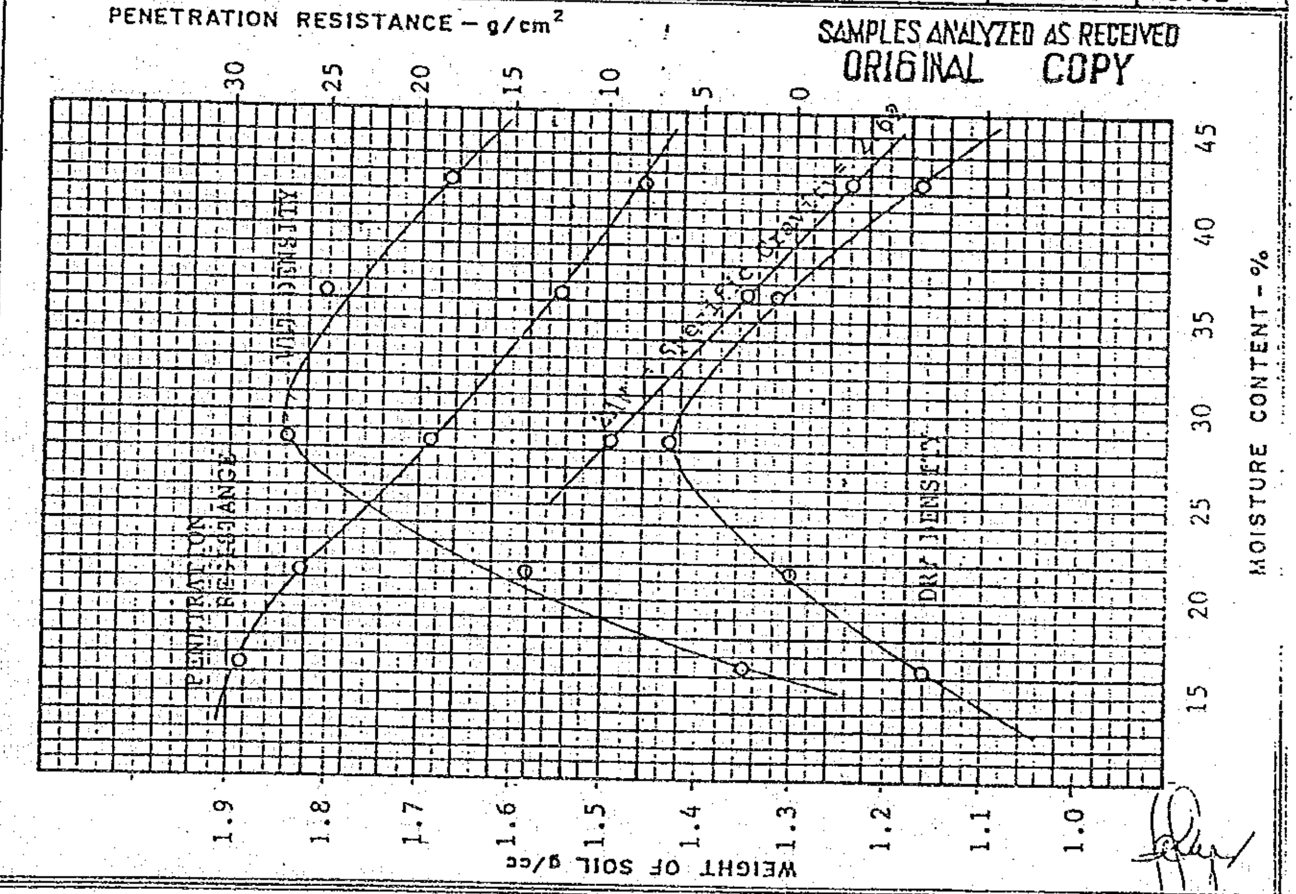




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TECHNOTEST BLDG., 893 EDSA, QUEZON CITY
METRO MANILA, PHILIPPINES

# PROCTOR COMPACTION TEST

Standard
Volume = 926 cc

PROJECT: Flood Control and Drainage Project

TYPE OF MATERIAL:

SAMPLE No. JB-7 (TP) DEPTH (m): DATE: 6-29-89

| | | | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|---|
| DENSITY | RUN NUMBER | | 1 | 2 | 3 | 4 | 5 |
| | WATER ADDED | cc | 400 | 500 | 600 | 700 | 800 |
| | WT. CYLINDER + W SOIL | g | 5095 | 5364 | 5651 | 5577 | 5465 |
| | WT. OF CYLINDER | g | 3938 | 3938 | 3938 | 3938 | 3938 |
| | WT. OF W SOIL | g | 1157 | 1426 | 1713 | 1639 | 1527 |
| | WET DENSITY | g/cc | 1.25 | 1.54 | 1.85 | 1.77 | 1.65 |
| WATER CONTENT | CONTAINER NUMBER | | 1 | 2 | 3 | 4 | 5 |
| | WT. DISH + W SOIL | g | 136.16 | 142.87 | 132.32 | 168.37 | 188.50 |
| | WT. DISH + D SOIL | g | 117.36 | 119.57 | 105.84 | 126.71 | 135.88 |
| | WT. OF DISH | g | 14.60 | 16.11 | 15.21 | 15.40 | 14.55 |
| | WT. OF WATER | g | 18.80 | 23.30 | 26.48 | 41.66 | 52.62 |
| | WT. OF D SOIL | g | 102.76 | 103.46 | 90.63 | 111.31 | 121.33 |
| | WATER CONTENT / D SOIL | % | 18.30 | 22.52 | 29.22 | 37.43 | 43.37 |
| | DRY DENSITY | g/cc | 1.06 | 1.26 | 1.43 | 1.29 | 1.15 |
| PENETRATION RESISTANCE | NEEDLE NUMBER | | 1 | 2 | 3 | 4 | 5 |
| | NEEDLE AREA, sq. in. | | 1/20 | 1/20 | 1/20 | 1/20 | 1/20 |
| | AVERAGE READING, lbs. | | 69.00 | 52.50 | 36.00 | 20.45 | 12.70 |
| | RESISTANCE | psi | 1380 | 1050 | 720 | 409 | 254 |
| | (psi / 70.3) | g/cm² | 19.63 | 14.95 | 10.24 | 5.83 | 3.62 |

DETERMINATIONS

DENSITY / PENETRATION RESISTANCE CURVE

MAXIMUM DRY DENSITY, g/cc = 1.43
OPTIMUM MOISTURE CONTENT, % = 29.22
NATURAL MOISTURE CONTENT, % =

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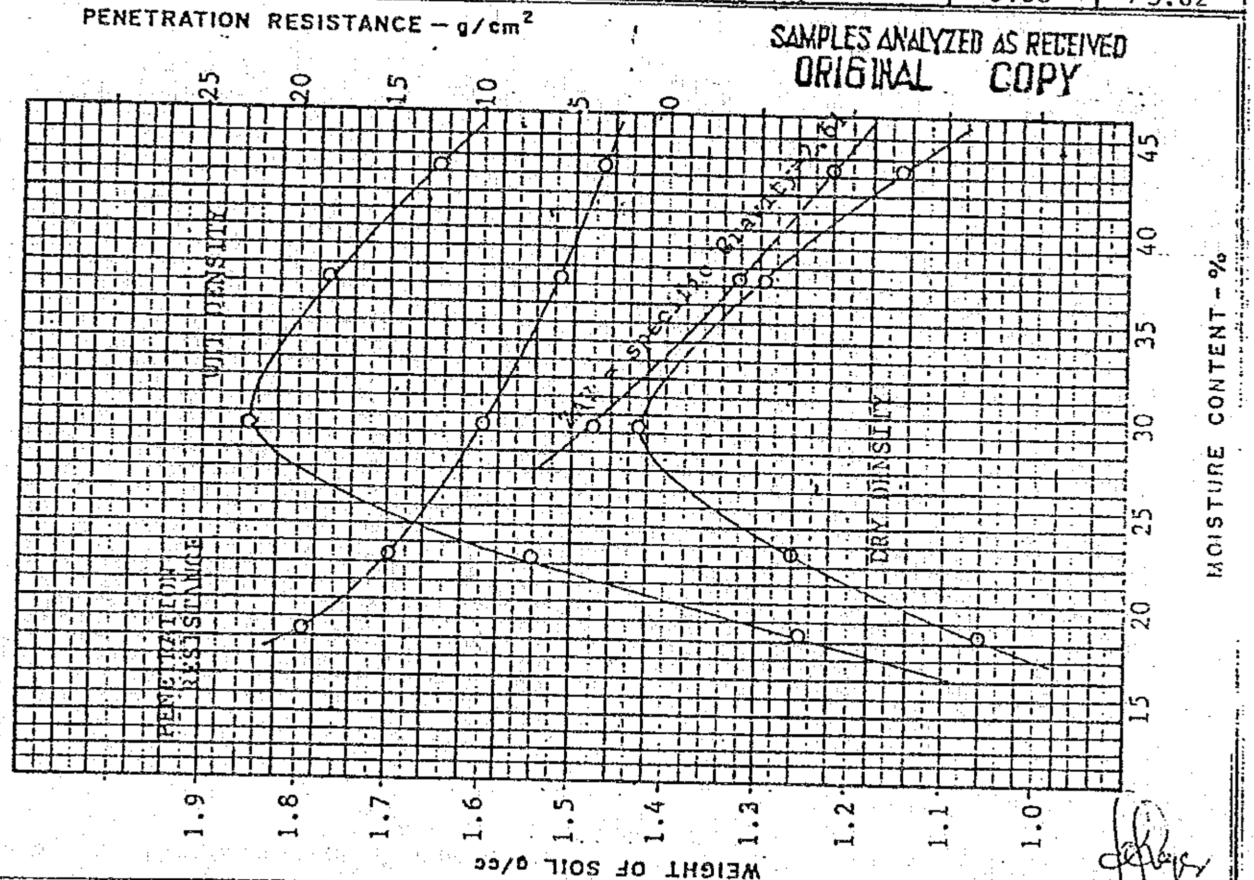


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TECHNOTEST BLDG., 893 EDSA, QUEZON CITY
METRO MANILA, PHILIPPINES



# PROCTOR COMPACTION TEST

Standard
Volume=926 cc

PROJECT: Flood Control and Drainage Project

TYPE OF MATERIAL:

SAMPLE No. JB-8 (TP) DEPTH (m): 0.5-1.00 m DATE: 6-30-89

| DETERMINATIONS | | Unit | | | | | |
|---|---|---|---|---|---|---|---|
| DENSITY | RUN NUMBER | | 1 | 2 | 3 | 4 | 5 |
| | WATER ADDED | cc | 400 | 500 | 600 | 700 | 800 |
| | WT. CYLINDER + W SOIL | g | 5178 | 5438 | 5632 | 5632 | 5604 |
| | WT. OF CYLINDER | g | 3938 | 3938 | 3938 | 3938 | 3938 |
| | WT. OF W SOIL | g | 1240 | 1500 | 1694 | 1694 | 1666 |
| | WET DENSITY | g/cc | 1.34 | 1.62 | 1.83 | 1.83 | 1.80 |
| WATER CONTENT | CONTAINER NUMBER | | 1 | 2 | 3 | 4 | 5 |
| | WT. DISH + W SOIL | g | 94.74 | 154.50 | 123.99 | 147.75 | 149.03 |
| | WT. DISH + D SOIL | g | 84.27 | 131.24 | 101.92 | 115.59 | 113.89 |
| | WT. OF DISH | g | 16.85 | 14.64 | 16.87 | 16.62 | 14.71 |
| | WT. OF WATER | g | 10.47 | 23.26 | 22.07 | 32.16 | 35.14 |
| | WT. OF D SOIL | g | 67.62 | 116.60 | 85.05 | 98.97 | 99.18 |
| | WATER CONTENT/D SOIL | % | 15.48 | 19.95 | 25.95 | 32.49 | 35.43 |
| | DRY DENSITY | g/cc | 1.16 | 1.35 | 1.45 | 1.38 | 1.33 |
| PENETRATION RESISTANCE | NEEDLE NUMBER | | 1 | 2 | 3 | 4 | 5 |
| | NEEDLE AREA, sq. in. | | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 |
| | AVERAGE READING, lbs. | | 58.95 | 52.75 | 43.40 | 34.25 | 25.40 |
| | RESISTANCE | psi | 1179 | 1055 | 868 | 685 | 508 |
| | (psi / 70.3) | g/cm² | 16.78 | 15.00 | 12.35 | 9.75 | 7.23 |

DENSITY / PENETRATION RESISTANCE CURVE
MAXIMUM DRY DENSITY, g/cc = 1.45
OPTIMUM MOISTURE CONTENT, % = 25.95
NATURAL MOISTURE CONTENT, % =

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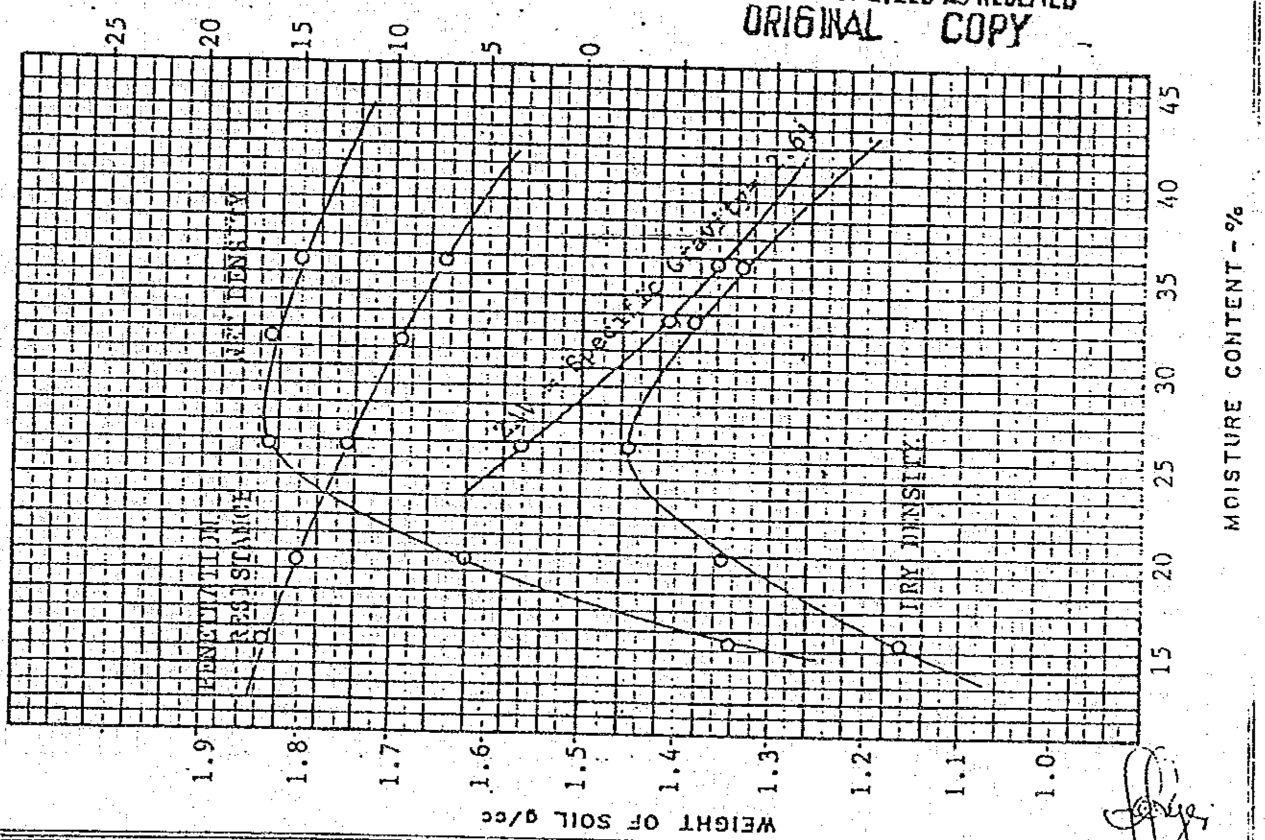


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SOIL TESTING LABORATORY
TECHNOTEST BLDG., 893 EDSA, QUEZON CITY
METRO MANILA, PHILIPPINES



# PROCTOR COMPACTION TEST

Standard
Volume = 926 cc

PROJECT: Flood Control and Drainage Project

TYPE OF MATERIAL:

SAMPLE No. JB-9 (TP) DEPTH (m): 0.5-1.00 m DATE: 6-29-89

| DETERMINATIONS | | | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|---|
| | RUN NUMBER | | 1 | 2 | 3 | 4 | 5 |
| DENSITY | WATER ADDED | cc | 400 | 500 | 600 | 700 | 800 |
| DENSITY | WT. CYLINDER + W SOIL | g | 5133 | 5346 | 5577 | 5539 | 5447 |
| DENSITY | WT. OF CYLINDER | g | 3938 | 3938 | 3938 | 3938 | 3938 |
| DENSITY | WT. OF W SOIL | g | 1195 | 1408 | 1639 | 1601 | 1509 |
| DENSITY | WET DENSITY | g/cc | 1.29 | 1.52 | 1.77 | 1.73 | 1.63 |
| WATER CONTENT | CONTAINER NUMBER | | 1 | 2 | 3 | 4 | 5 |
| WATER CONTENT | WT. DISH + W SOIL | g | 143.75 | 174.82 | 156.59 | 178.93 | 191.06 |
| WATER CONTENT | WT. DISH + D SOIL | g | 120.29 | 143.85 | 124.79 | 135.95 | 140.86 |
| WATER CONTENT | WT. OF DISH | g | 16.01 | 16.92 | 16.99 | 14.87 | 16.90 |
| WATER CONTENT | WT. OF WATER | g | 23.46 | 30.97 | 31.80 | 42.98 | 50.20 |
| WATER CONTENT | WT. OF D SOIL | g | 104.28 | 126.93 | 107.80 | 121.08 | 123.96 |
| WATER CONTENT | WATER CONTENT/D SOIL | % | 22.50 | 24.40 | 29.50 | 35.50 | 40.50 |
| | DRY DENSITY | g/cc | 1.05 | 1.22 | 1.37 | 1.28 | 1.16 |
| PENETRATION RESISTANCE | NEEDLE NUMBER | | 1 | 2 | 3 | 4 | 5 |
| PENETRATION RESISTANCE | NEEDLE AREA, sq. in. | | 1/20 | 1/20 | 1/20 | 1/20 | 1/20 |
| PENETRATION RESISTANCE | AVERAGE READING, lbs. | | 83.05 | 74.55 | 64.25 | 47.15 | 28.12 |
| PENETRATION RESISTANCE | RESISTANCE | psi | 1661 | 1491 | 1285 | 943 | 562.4 |
| PENETRATION RESISTANCE | (psi / 70.3) | g/cm² | 23.63 | 21.21 | 18.29 | 13.42 | 8.00 |

DENSITY/PENETRATION RESISTANCE CURVE

MAXIMUM DRY DENSITY, g/cc = 1.37
OPTIMUM MOISTURE CONTENT, % = 29.50
NATURAL MOISTURE CONTENT, % =

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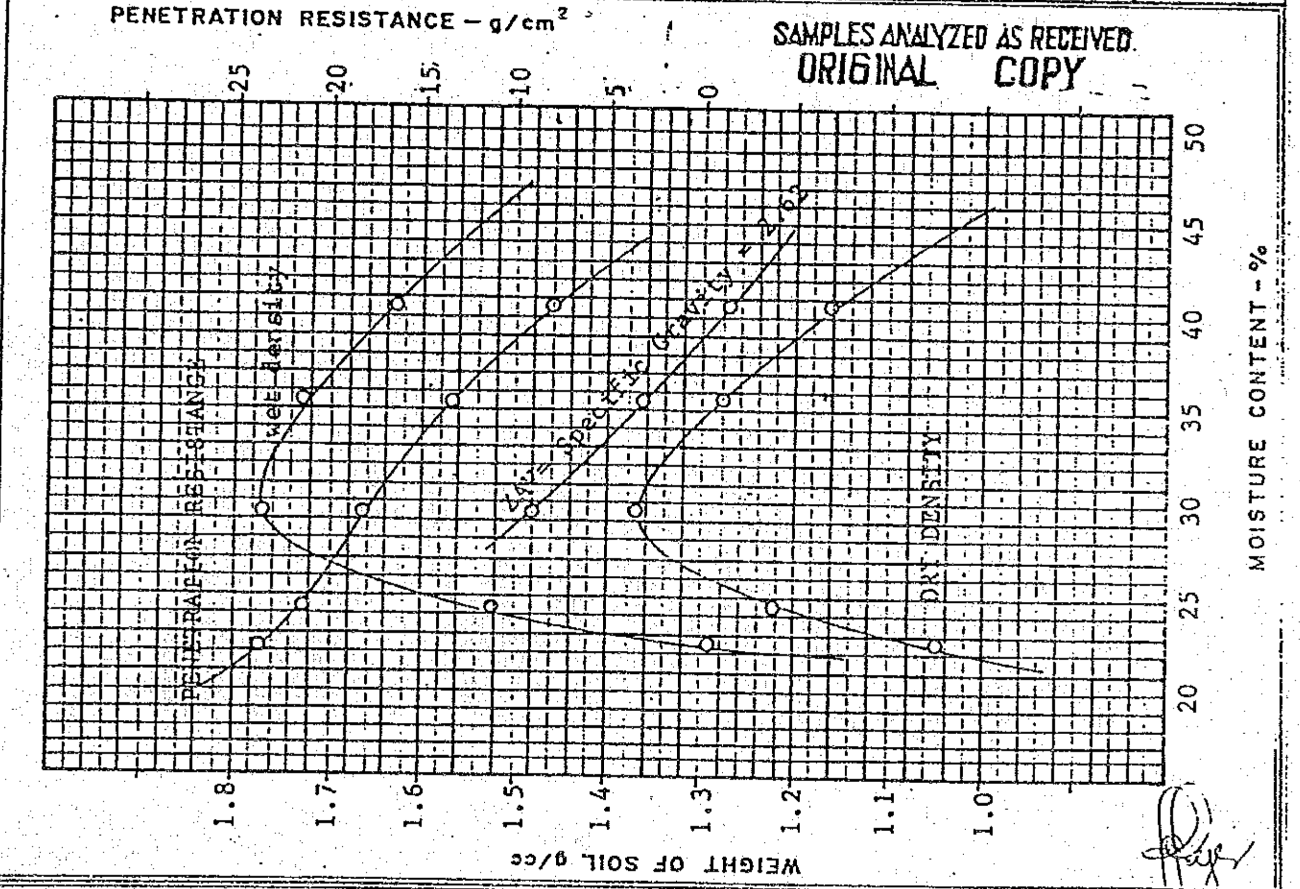




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# C. PRELIMINARY STUDY ON THE OPTIMUM SHAPE FOR THE LAKESHORE DIKE

# PRELIMINARY STUDY ON THE OPTIMUM SHAPE FOR THE LAKESHORE DIKE

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## PRELIMINARY STUDY ON THE OPTIMUM SHAPE FOR THE LAKESHORE DIKE

Lakeshore dike is designed by the following procedure.

First step : To examine the wave effect of the Laguna lake to the top elevation of the dike varying its bank slope,

Second step: To examine the shape of the dike varying its embankment material and method,

Third step : To determine the optimum shape of the dike by construction cost comparison, and

Fourth step: Study the consolidation settlement of foundation.

### 1. Top Elevation of the Lakeshore Dike

Top elevation of the lakeshore dike is determined by the following equation.

$$\text{TOP EL.} = \text{HWL} + \Delta H + 0.50 \text{ m} \quad \text{.................... ①}$$

where, TOP EL.; Top elevation of the lakeshore dike

HWL ; Design high water level of the Laguna lake (EL. 13.80 m)

$\Delta H$ ; Wave setup to the dike

#### (1) Shallow wave (Bretschneider's method)

The lakeshore dike is planned to be located at the north shoreline. The biggest wind wave to the dike is supposed to be caused by the south wind of a typhoon. In this case, its fetch length is about 20 km and its wind speed is supposed to be 20 m/s.

The shallow wave can be calculated by Bretschneider's Method using Fig. 1, Fig. 2 and Table 1 for wave height, its period and length respectively.

Now, h=2.3 m, $U_{10}$=20 m/s and F=20,000 m,

$$gh/U_{10}^2=0.056$$
$$gF/U_{10}^2=490$$

From Fig. 1,

$$gH_{1/3}/U_{10}^2=0.019$$
$$H_{1/3}=0.019 \times 20^2/9.8=0.78 \text{ m}$$

From Fig. 2,

$$T_{1/3}=2.7 \text{ sec}$$
$$t=1.0 \text{ hr}$$

From Table 1,

$$L_{1/3}=9.89 \text{ m}$$

where, h; water depth of the Laguna lake (=2.3 m)
$U_{10}$; wind speed at 10 m above water surface (=20 m/s)
F; fetch length (=20 km)
g; acceleration of gravity (=9.8 m/s$^2$)
$H_{1/3}$; wave height of one-third significant wave
$T_{1/3}$; wave period of one-third significant wave
t; required minimum wind duration
$L_{1/3}$; wave length of one-third significant wave

The design wave in front of the dike becomes as follows;

Wave height; H=0.78 m
Wave length; L=9.89 m
Wave period; T=2.7 sec.

(2) Wave setup (ΔH)

Wave setup to the dike can be calculated by Fig. 3 of Savielle's diagram which is a function of bank slope and H/L.

(3) Top elevation of the dike

Top elevation of the lakeshore dike is calculated by equation ① as follows:

| Bank slope | HWL | ΔH | TOP. EL. |
|---|---|---|---|
| 1:2 | EL. 13.80 m | 1.20 m | EL. 15.50 m |
| 1:3 | EL. 13.80 m | 0.80 m | EL. 15.10 m |
| 1:4 | EL. 13.80 m | 0.60 m | EL. 14.90 m |
| 1:5 | EL. 13.80 m | 0.50 m | EL. 14.80 m |
| 1:6 | EL. 13.80 m | 0.50 m | EL. 14.80 m |
| 1:7 | EL. 13.80 m | 0.50 m | EL. 14.80 m |
| 1:8 | EL. 13.80 m | 0.40 m | EL. 14.70 m |
| 1:9 | EL. 13.80 m | 0.40 m | EL. 14.70 m |
| 1:10 | EL. 13.80 m | 0.30 m | EL. 14.60 m |

2. Alternative Shape of the Lakeshore Dike

Five alternative embankment methods ~~are~~ considered in relation to the embankment material and its method as follows;

Case 1: Embankment by dredged material from the bottom or lakeshore of the Laguna lake

Case 2: Embankment by mixed soil of dredged material with borrowed material

Case 3: Embankment by dredged material for the center part and borrowed material for the outer part

Case 4: Embankment by borrowed material

Case 5: Embankment by mixed soil of dredged material with cement or lime powder

As the soil along the lakeshore dike and the embankment material of the dike are generally soft, stability analysis of slip circle method is conducted to determine the dike's shape. The typical soil profile of the original ground is supposed to be as follows;

| Depth | Soil Property | | N-value |
|---|---|---|---|
| Ground surface to EL. 9.00m | : Clay | $\gamma_t = \gamma_s = 1.64$ t/m$^3$<br>$C' = 1.10$ t/m$^2$<br>$\phi' = 22.0°$ | 10 |
| EL. 9.00 m to EL. 6.50 m | : Sand | $\gamma_t = \gamma_s = 1.75$ t/m$^3$<br>$C' = 1.80$ t/m$^2$<br>$\phi' = 36.0°$ | 5 |
| EL. 6.50 m to EL. -5.50 m | : Clay | $\gamma_t = \gamma_s = 1.50$ t/m$^3$<br>$C' = 1.90$ t/m$^2$<br>$\phi' = 20°$ | 2 |
| EL. -5.50 m to EL. -10.50 m | : Clay | $\gamma_t = \gamma_s = 1.70$ t/m$^3$<br>$C' = 3.20$ t/m$^2$<br>$\phi' = 18.5°$ | 20 - 50 |

where, $\gamma_t$; wet unit weight (t/m$^3$)
$\gamma_s$; saturated unit weight (t/m$^3$)
$C'$; cohesion (t/m$^2$)
$\phi'$; angle of internal friction (°)

Embankment materials are supposed to be as follows;

| Case No. | Soil Property |
|---|---|
| Case 1 : dredged material | $\gamma_t = \gamma_s = 1.60\ t/m^3$<br>$C' = 0.90\ t/m^2$<br>$\phi' = 11.0°$ |
| Case 2 : mixed clay | $\gamma_t = \gamma_s = 1.60\ t/m^3$<br>$C' = 1.10\ t/m^2$<br>$\phi' = 22.0°$ |
| Case 3 : borrowed material | $\gamma_t = \gamma_s = 1.70\ t/m^3$<br>$C' = 3.00\ t/m^2$<br>$\phi' = 22.0°$ |
| dredged material | $\gamma_t = \gamma_s = 1.60\ t/m^3$<br>$C' = 0.90\ t/m^2$<br>$\phi' = 11.0°$ |
| Case 4 : borrowed material | $\gamma_t = \gamma_s = 1.70\ t/m^3$<br>$C' = 3.00\ t/m^2$<br>$\phi' = 22.0°$ |
| Case 5 : soil material | strongest in these 5 cases |

In the stability analysis, coefficient of earthquake is set to be 0.2. The required safety factors for normal and seismic conditions are 1.5 and 1.2 respectively. The top width of the lakeshore dike is set to be 9.10 m from the requirement of maintenance road. The ground elevation is supposed to be EL. 12.00 m.

Stability analysis of Case 4, which will be the optimum case as shown in sub-section 3 is shown in Fig. 4.

From the stability analysis, typical shapes of the lakeshore dike for these 5 alternatives are determined as follows (ref. to Fig. 5);

| Case | Bank Slope | Top. EL. |
|---|---|---|
| 1 | 1:10 | EL. 14.60 |
| 2 | 1:3 | EL. 15.10 |
| 3 | 1:4 | EL. 14.90 |
| 4 | 1:2 | EL. 15.50 |
| 5 | 1:2 | EL. 15.50 |

## 3. Optimum Shape of the Lakeshore Dike

Optimum Shape of the lakeshore dike is determined by comparing the construction costs for these 5 alternatives.

### (1) Construction method

Construction methods for these alternatives are supposed to be as follows;

Case 1: First step is excavating the soft soil around the lakeshore dike by dredger etc. Second step is pre-loading it to proceed consolidation of the foundation of the dike. Third step is embanking the dike with compaction.

Case 2: First and second steps are the same as Case 1. Third step is transporting the borrowed material from the borrowed area. Fourth step is mixing the soft soil and the borrowed material with a proportion of 60% and 40% respectively. Fifth step is embanking the dike with compaction by the mixed material.

Case 3: First, second and third steps are the same as Case 2. Fourth step is embanking the dike with compaction using the soft soil for the center part and borrowed material for the outer part with a proportion of 60% and 40% respectively.

Case 4: First step is transporting the borrowed material from the borowed area. Second step is embanking the dike with compaction.

Case 5: First and second steps are the same as Case 1. Third step is embanking the dike with compaction by the soil cement which is made by mixing the soft soil with cement or lime powder during embankment. In the case of cement powder, the mixing ratio is supposed to be about 5% of weight of the soil that is 0.08 $t/m^3$ from the economical view point.

(2) Cost comparison

Cost comparison of the construction cost of the lakeshore dike per unit length is made considering the above embankment method. The embankment volume is set to be 1.2 times of the design volume considering the consolidation settlement of the foundation as shown in sub-section 4. The summary of the construction costs becomes as follows (ref. to Table 2);

| Case No. | Construction Cost (P/m) |
|---|---|
| 1 | 34,880 |
| 2 | 21,910 |
| 3 | 20,980 |
| 4 | 17,590 |
| 5 | 29,210 |

(3) Optimum shape of the dike

From the above result, it is shown that the Case 4 is the most economical. This reason is that the Case 4 can avoid double handling of excavated material and become the simplest construction method.

Costs of Case 2 and 3 are high because of this double handling. Cost of Case 1 is the highest because of its high revetment cost. Cost of Case 5 is high because of its cement cost.

As a result, Case 4 of embankment by the borrowed material is the optimum embankment method.

## 4. Consolidation Settlement

Consolidation settlement of the foundation of the lakeshore dike for the Case 4 is calculated using the model shown in Fig. 6. In this calculation, it is supposed that consolidation settlement does not occur for the dike itself because compaction is provided.

(1) Total quantity of settlement

Total quantity of settlement of the foundation is 0.70 m as shown in the following table:

| Layer | H (m) | $P_E$ (t/m$^2$) | $P_F$ (t/m$^2$) | $P_E+P_F$ (t/m$^2$) | e | $C_c$ | $\Delta H$ (m) |
|---|---|---|---|---|---|---|---|
| 1 | - | - | - | - | - | - | - |
| 2 | 3.00 | 2.46 | 6.08 | 8.54 | 1.19 | 0.37 | 0.27 |
| 3 | - | - | - | - | - | - | - |
| 4 | 12.00 | 18.30 | 4.38 | 22.68 | 1.34 | 0.80 | 0.38 |
| 5 | 5.00 | 31.55 | 3.54 | 35.09 | 1.30 | 0.48 | 0.05 |
| 6 | - | - | - | - | - | - | - |
| | | | | | | Total | 0.70 |

Notes:

H : Height of a layer

$P_E$: Earth pressure arting at the center part of a layer

$P_F$: Load acting at the center part of a layer by the weight of the embankment

e : Void ratio of a layer

$C_c$: Compression index of a layer

$\Delta H$: Consolidation settlement

$\Delta H = H \cdot Cc/(1+e) \cdot \log_{10}((P_E+P_F)/P_E)$

(2) Consolidation-time curve

Consolidation-time curve of the foundation is calculated as shown in Fig. 7 by summing up those of clay layers as shown in the following table.

| U (%) | Tv | Layer 2 ΔH (m) | Layer 2 t (day) | Layer 4 ΔH (m) | Layer 4 t (day) | Layer 5 ΔH (m) | Layer 5 t (day) |
|---|---|---|---|---|---|---|---|
| 10 | 0.008 | 0.03 | 1.0 | 0.04 | 19.6 | 0.01 | 2.9 |
| 20 | 0.031 | 0.05 | 3.8 | 0.08 | 76.0 | 0.01 | 11.2 |
| 30 | 0.071 | 0.08 | 8.8 | 0.11 | 174.0 | 0.02 | 25.7 |
| 40 | 0.126 | 0.11 | 15.6 | 0.15 | 308.8 | 0.02 | 45.6 |
| 50 | 0.197 | 0.14 | 24.4 | 0.19 | 482.8 | 0.03 | 71.3 |
| 60 | 0.287 | 0.16 | 35.6 | 0.23 | 703.4 | 0.03 | 103.8 |
| 70 | 0.403 | 0.19 | 50.0 | 0.27 | 987.7 | 0.04 | 145.8 |
| 80 | 0.567 | 0.22 | 70.3 | 0.30 | 1,389.7 | 0.04 | 205.1 |
| 90 | 0.848 | 0.24 | 105.2 | 0.34 | 2,078.4 | 0.05 | 306.7 |
| 100 | | 0.27 | | 0.38 | | 0.05 | |

Notes: U; degree of consolidation
Tv; time factor
ΔH; consolidation settlement
t; consolidation time
$t = Tv \cdot (H/2)^2 / Cv$
H; height of a clay layer
Cv; coefficient of consolidation

As a result, consolidation times of 70% and 80% of the foundation are about 1.5 years and 2.8 years respectively.

(3) Extra-embankment

Percentage of the extra-embankment due to consolidation settlement is 20% as shown in Fig. 8.

## 5. Remarks

As the lakeshore dike is designed based on the data collected in the investigation conducted in this study, there are some inadequate data which are used by estimation as follows;

- Wave and wind data of the Laguna lake
- Water depth data of the Laguna lake
- Geotechnical data of the disturbed samble of the soil along the lakeshore dike and the borrowed material

It is necessary to collect these data in the detailed design stage.

*Table 1*

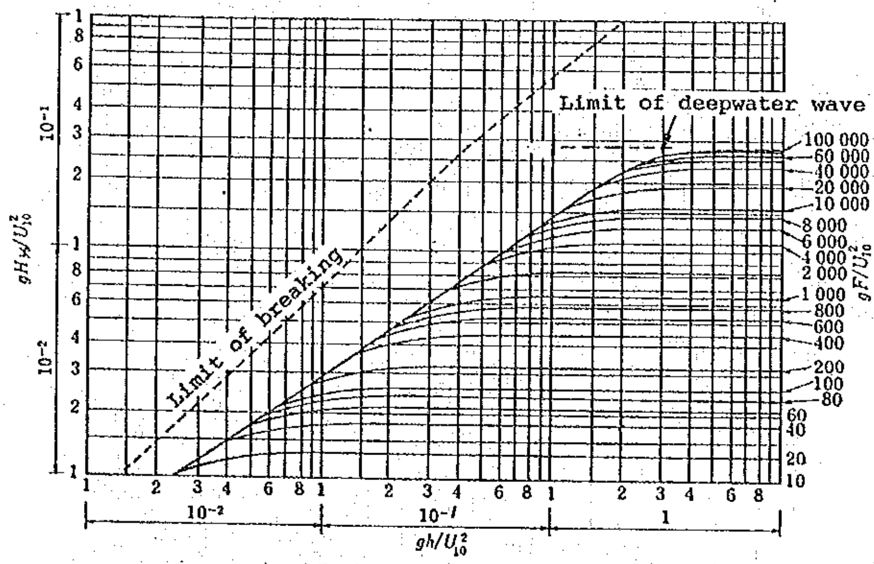
List of wavelengh and celerity for a given wave period and water depth ($g$ = 9.8m/s²).

| Wave period (s) / Water depth (m) | 2.0 | | 2.5 | | 3.0 | | 4.0 | | 5.0 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Wave-length (m) | Celerity (m/s) | Wave-length (m) | Celerity (m/s) | Wave-length (m) | Celerity (m/s) | Wave-length (m) | Celerity (m/s) | Wave-length (m) | Celerity (m/s) |
| 0.1 | 1.95 | 0.97 | 2.45 | 0.98 | 2.95 | 0.98 | 3.94 | 0.99 | 4.94 | 0.99 |
| 0.2 | 2.71 | 1.35 | 3.42 | 1.37 | 4.14 | 1.38 | 5.55 | 1.39 | 6.96 | 1.39 |
| 0.3 | 3.26 | 1.63 | 4.15 | 1.66 | 5.03 | 1.68 | 6.77 | 1.69 | 8.50 | 1.70 |
| 0.4 | 3.69 | 1.85 | 4.74 | 1.89 | 5.76 | 1.92 | 7.79 | 1.95 | 9.79 | 1.96 |
| 0.5 | 4.05 | 2.03 | 5.24 | 2.09 | 6.39 | 2.13 | 8.67 | 2.17 | 10.92 | 2.18 |
| 0.6 | 4.36 | 2.18 | 5.67 | 2.27 | 6.95 | 2.32 | 9.45 | 2.36 | 11.93 | 2.39 |
| 0.7 | 4.62 | 2.31 | 6.05 | 2.42 | 7.45 | 2.48 | 10.17 | 2.54 | 12.85 | 2.57 |
| 0.8 | 4.85 | 2.42 | 6.40 | 2.56 | 7.90 | 2.63 | 10.82 | 2.71 | 13.70 | 2.74 |
| 0.9 | 5.04 | 2.52 | 6.70 | 2.68 | 8.31 | 2.77 | 11.43 | 2.86 | 14.49 | 2.90 |
| 1.0 | 5.21 | 2.61 | 6.98 | 2.79 | 8.69 | 2.90 | 11.99 | 3.00 | 15.23 | 3.05 |
| 1.1 | 5.36 | 2.68 | 7.23 | 2.89 | 9.04 | 3.01 | 12.52 | 3.13 | 15.93 | 3.19 |
| 1.2 | 5.49 | 2.74 | 7.46 | 2.99 | 9.36 | 3.12 | 13.02 | 3.26 | 16.59 | 3.32 |
| 1.3 | 5.60 | 2.80 | 7.67 | 3.07 | 9.66 | 3.22 | 13.50 | 3.37 | 17.22 | 3.44 |
| 1.4 | 5.70 | 2.85 | 7.87 | 3.15 | 9.95 | 3.32 | 13.94 | 3.49 | 17.82 | 3.56 |
| 1.5 | 5.78 | 2.89 | 8.04 | 3.22 | 10.21 | 3.40 | 14.37 | 3.59 | 18.40 | 3.68 |
| 1.6 | 5.85 | 2.93 | 8.20 | 3.28 | 10.46 | 3.49 | 14.77 | 3.69 | 18.95 | 3.79 |
| 1.8 | 5.96 | 2.98 | 8.48 | 3.39 | 10.90 | 3.63 | 15.53 | 3.88 | 19.98 | 4.00 |
| 2.0 | 6.05 | 3.02 | 8.72 | 3.49 | 11.30 | 3.77 | 16.22 | 4.05 | 20.94 | 4.19 |
| 2.2 | 6.11 | 3.05 | 8.91 | 3.56 | 11.65 | 3.88 | 16.85 | 4.21 | 21.84 | 4.37 |
| 2.5 | 6.16 | 3.08 | 9.14 | 3.66 | 12.09 | 4.03 | 17.71 | 4.43 | 23.08 | 4.62 |
| 3.0 | 6.21 | 3.11 | 9.40 | 3.76 | 12.67 | 4.22 | 18.95 | 4.74 | 24.92 | 4.98 |
| 3.5 | 6.23 | 3.11 | 9.55 | 3.82 | 13.09 | 4.36 | 19.98 | 5.00 | 26.52 | 5.30 |
| 4.0 | 6.23 | 3.12 | 9.64 | 3.86 | 13.39 | 4.46 | 20.85 | 5.21 | 27.93 | 5.59 |
| 4.5 | 6.24 | 3.12 | 9.69 | 3.88 | 13.60 | 4.53 | 21.57 | 5.39 | 29.18 | 5.84 |
| 5.0 | 6.24 | 3.12 | 9.72 | 3.89 | 13.75 | 4.58 | 22.18 | 5.55 | 30.29 | 6.06 |
| 6.0 | 6.24 | 3.12 | 9.74 | 3.90 | 13.91 | 4.64 | 23.11 | 5.78 | 32.17 | 6.43 |
| 7.0 | 6.24 | 3.12 | 9.75 | 3.90 | 13.99 | 4.66 | 23.75 | 5.94 | 33.67 | 6.73 |
| 8.0 | 6.24 | 3.12 | 9.75 | 3.90 | 14.02 | 4.67 | 24.19 | 6.05 | 34.86 | 6.97 |
| 9.0 | 6.24 | 3.12 | 9.75 | 3.90 | 14.03 | 4.68 | 24.47 | 6.12 | 35.81 | 7.16 |
| 10.0 | 6.24 | 3.12 | 9.75 | 3.90 | 14.03 | 4.68 | 24.65 | 6.16 | 36.56 | 7.31 |
| 11.0 | 6.24 | 3.12 | 9.75 | 3.90 | 14.04 | 4.68 | 24.77 | 6.19 | 37.15 | 7.43 |
| 12.0 | 6.24 | 3.12 | 9.75 | 3.90 | 14.04 | 4.68 | 24.84 | 6.21 | 37.60 | 7.52 |
| 13.0 | 6.24 | 3.12 | 9.75 | 3.90 | 14.04 | 4.68 | 24.89 | 6.22 | 37.95 | 7.59 |
| 14.0 | 6.24 | 3.12 | 9.75 | 3.90 | 14.04 | 4.68 | 24.91 | 6.23 | 38.22 | 7.64 |
| 15.0 | 6.24 | 3.12 | 9.75 | 3.90 | 14.04 | 4.68 | 24.93 | 6.23 | 38.42 | 7.68 |
| 16.0 | 6.24 | 3.12 | 9.75 | 3.90 | 14.04 | 4.68 | 24.94 | 6.23 | 38.57 | 7.71 |
| 17.0 | 6.24 | 3.12 | 9.75 | 3.90 | 14.04 | 4.68 | 24.95 | 6.24 | 38.68 | 7.74 |
| 18.0 | 6.24 | 3.12 | 9.75 | 3.90 | 14.04 | 4.68 | 24.95 | 6.24 | 38.77 | 7.75 |
| 19.0 | 6.24 | 3.12 | 9.75 | 3.90 | 14.04 | 4.68 | 24.95 | 6.24 | 38.83 | 7.77 |
| 20.0 | 6.24 | 3.12 | 9.75 | 3.90 | 14.04 | 4.68 | 24.95 | 6.24 | 38.87 | 7.77 |
| Deepwater waves | 6.24 | 3.12 | 9.75 | 3.90 | 14.04 | 4.68 | 24.96 | 6.24 | 38.99 | 7.80 |

Table 2 Cost Comparison of Embankment Method of Lakeshore Dike (Per Unit Length)

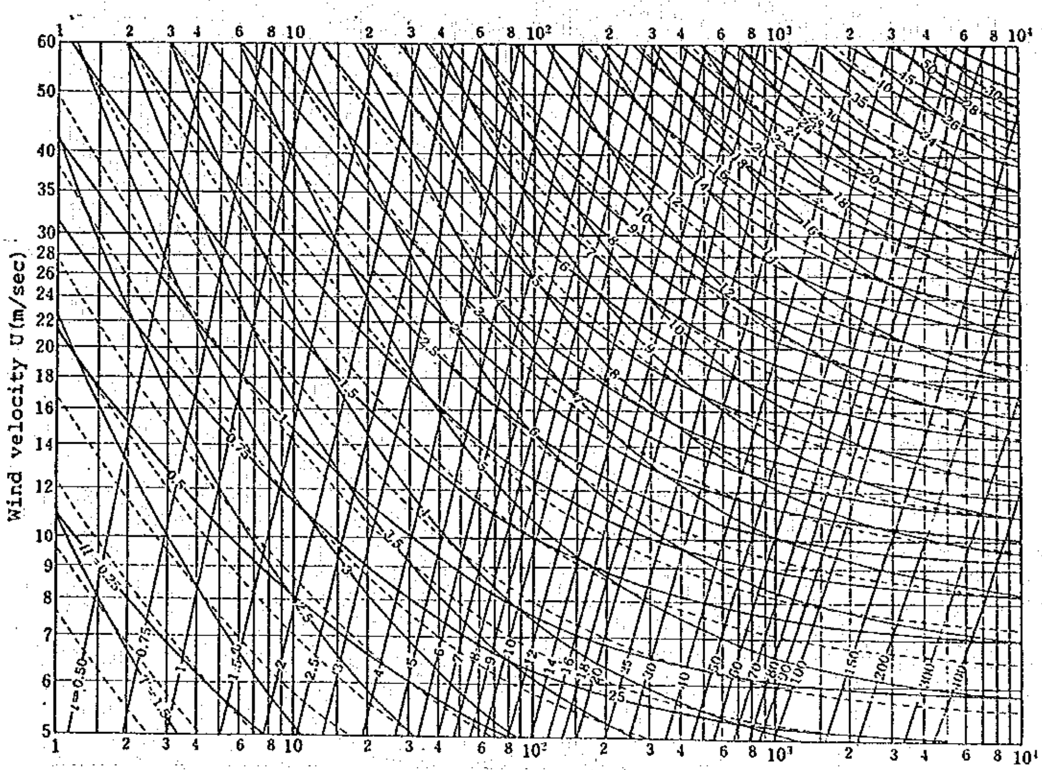
(unit ;P/m)

| Work Item | Unit | Unit Cost (P) | Case 1 | | Case 2 | | Case 3 | | Case 4 | | Case 5 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Quantity | Amount | Quantity | Amount | Quantity | Amount | Quantity | Amount | Quantity | Amount |
| 1. Excavation, dredger | $m^3$ | 50 | 149 | 7,450 | 57 | 2,850 | 61 | 3,050 | - | - | 91 | 4,550 |
| 2. Excavation, dredged material incl. loading hauling & spreading | $m^3$ | 30 | - | - | 57 | 1,710 | - | - | - | - | - | - |
| 3. Excavation, borrowed material incl. loading hauling & spreading | $m^3$ | 100 | - | - | 37 | 3,700 | 41 | 4,100 | 91 | 9,100 | - | - |
| 4. Embankment, dredged material | $m^3$ | 40 | 149 | 5,960 | - | - | 61 | 2,440 | - | - | - | - |
| 5. Compacting, borrowed material | $m^3$ | 5 | - | - | - | - | 41 | 210 | 91 | 460 | - | - |
| 6. Embankment, mixed soil with dredged material & borrowed material incl. mixing | $m^3$ | 40 | - | - | 94 | 3,760 | - | - | - | - | - | - |
| 7. Embankment, soil cement incl. mixing | $m^3$ | 45 | - | - | - | - | - | - | - | - | 91 | 4,100 |
| 8. Cement (0.08 $t/m^3$) | ton | 1,450 | - | - | - | - | - | - | - | - | 7.3 | 10,590 |
| 9. Revetment | $m^2$ | 600 | 26.1 | 15,660 | 10.4 | 6,240 | 12.8 | 7,680 | 8.5 | 5,100 | 8.5 | 5,100 |
| 10. Preparatory works (20%) | L.S. | | | 5,810 | | 3,650 | | 3,500 | | 2,930 | | 4,870 |
| Total | | | | 34,880 | | 21,910 | | 20,980 | | 17,590 | | 29,210 |




$H_{1/3}$:wave height of one-third significant wave
$U_{10}$ :wind velocity (10 m above water surface)
F :fetch length
h :water depth
Coefficient of roughness f is 0.01.

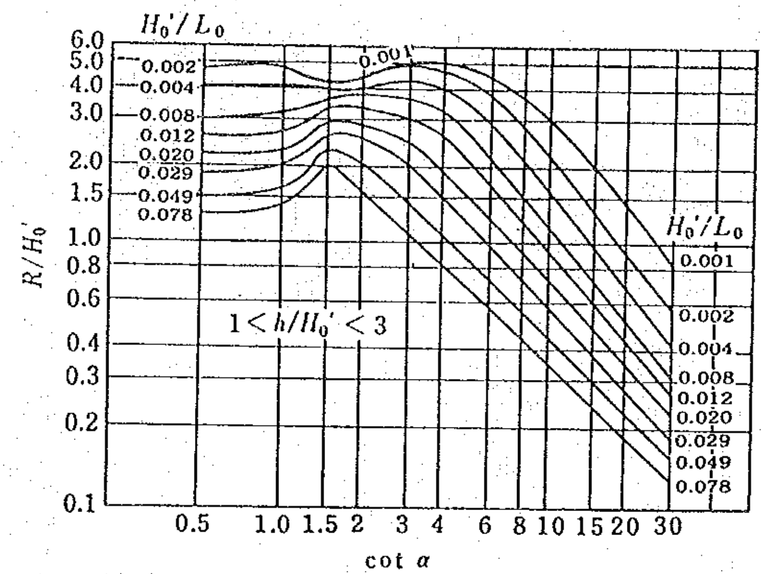
Fig. 1 Relation between Wave Height,Wind Velocity,and Fetch Length of Shallow Wave under Constant Water Depth (Bretchneider's Curve)




—— Wave height $H_{1/3}$ (m) —— Minimum wind duration t(h)

—— Period $T_{1/3}$ (s) ------ Iso-energy line $(H_{1/3}\ T_{1/3})^2$ = constant

Fig.2 Wind Wave Prediction Curves (corrected by Wilson's formula, 1956)

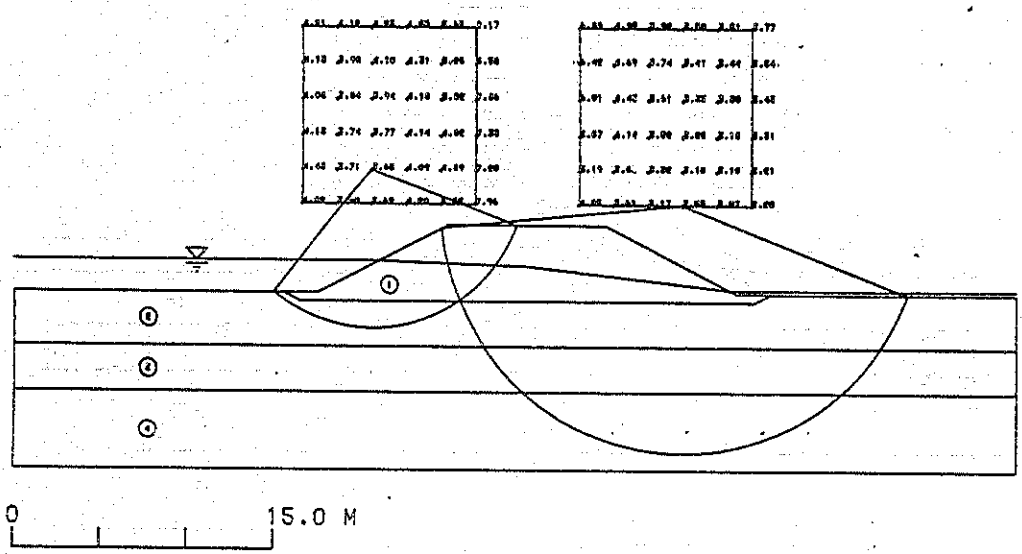



α :angle of slope between holizontal plane
$H_0'$ :height of wave
$L_0$ :length of wave
h :water depth
R :wave setup

Fig.3 Wave Setup to Tidal Dike
(Saville's Curve)

LAKESHORE DIKE .CASE 4-1 (SLOPE=1:2,C=3.0,PAI=22.0,HWL,B=9.10)

S T A B I L I T Y   A N A L Y S I S



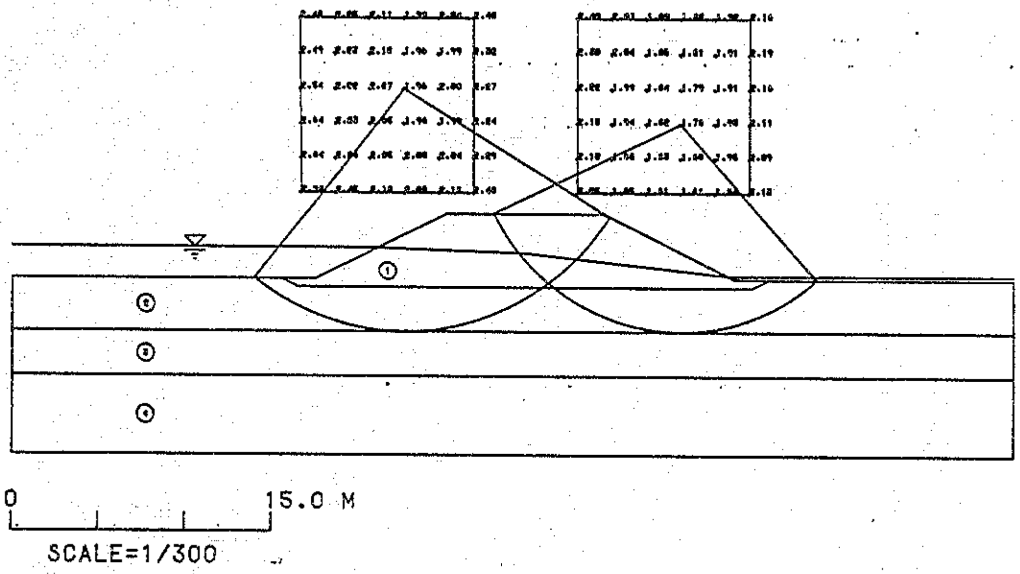

| MATERIAL | COHESION ($T/M^2$) | FRICTION (DEG) | W(WET) ($T/M^3$) | W(SAT) ($T/M^3$) | W(SUB) ($T/M^3$) |
|---|---|---|---|---|---|
| 1 | 3.00 | 22.00 | 1.70 | 1.70 | 0.70 |
| 2 | 1.10 | 22.00 | 1.64 | 1.64 | 0.64 |
| 3 | 1.80 | 36.00 | 1.75 | 1.75 | 0.75 |
| 4 | 1.90 | 20.00 | 1.50 | 1.50 | 0.50 |
| ACCELERATION OF EARTHQUAKE | | | | 0.200 | |

| MINIMUM SAFETY FACTOR (NORMAL) | | |
|---|---|---|
| | UP STREAM SIDE | DOWN STREAM SIDE |
| NORMAL | 3.648 | 3.034 |
| SEISMIC | 2.062 | 1.871 |

Fig.4 Stability Analysis of the Lakeshore Dike (1/2)
(Case 4,Normal Condition)

LAKESHORE DIKE ,CASE 4 (SLOPE=1:2,C=3.0,PAI=22.0,HWL,B=9.10)

S T A B I L I T Y A N A L Y S I S




| MATERIAL | COHESION (T/M²) | FRICTION (DEG) | W(WET) (T/M³) | W(SAT) (T/M³) | W(SUB) (T/M³) |
| --- | --- | --- | --- | --- | --- |
| 1 | 3.00 | 22.00 | 1.70 | 1.70 | 0.70 |
| 2 | 1.10 | 22.00 | 1.64 | 1.64 | 0.64 |
| 3 | 1.60 | 36.00 | 1.75 | 1.75 | 0.75 |
| 4 | 1.90 | 20.00 | 1.50 | 1.50 | 0.50 |
| ACCELERATION OF EARTHQUAKE | | | | 0.200 | |

| MINIMUM SAFETY FACTOR (SEISMIC) | | |
| --- | --- | --- |
| | UP STREAM SIDE | DOWN STREAM SIDE |
| NORMAL | 4.184 | 3.265 |
| SEISMIC | 1.964 | 1.783 |

Fig.4 Stability Analysis of the Lakeshore Dike (2/2)
(Case 4,Seismic Condition)

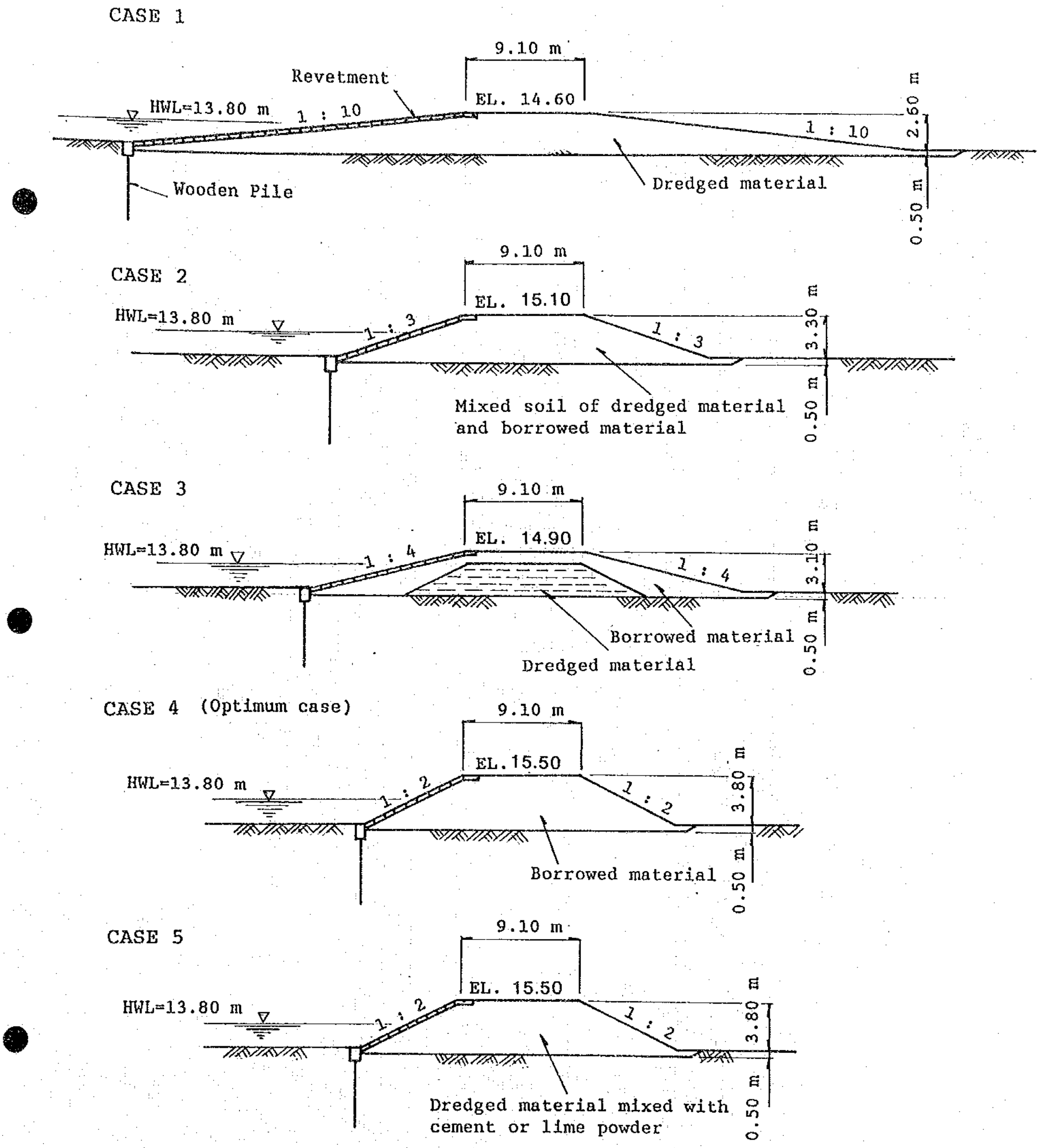
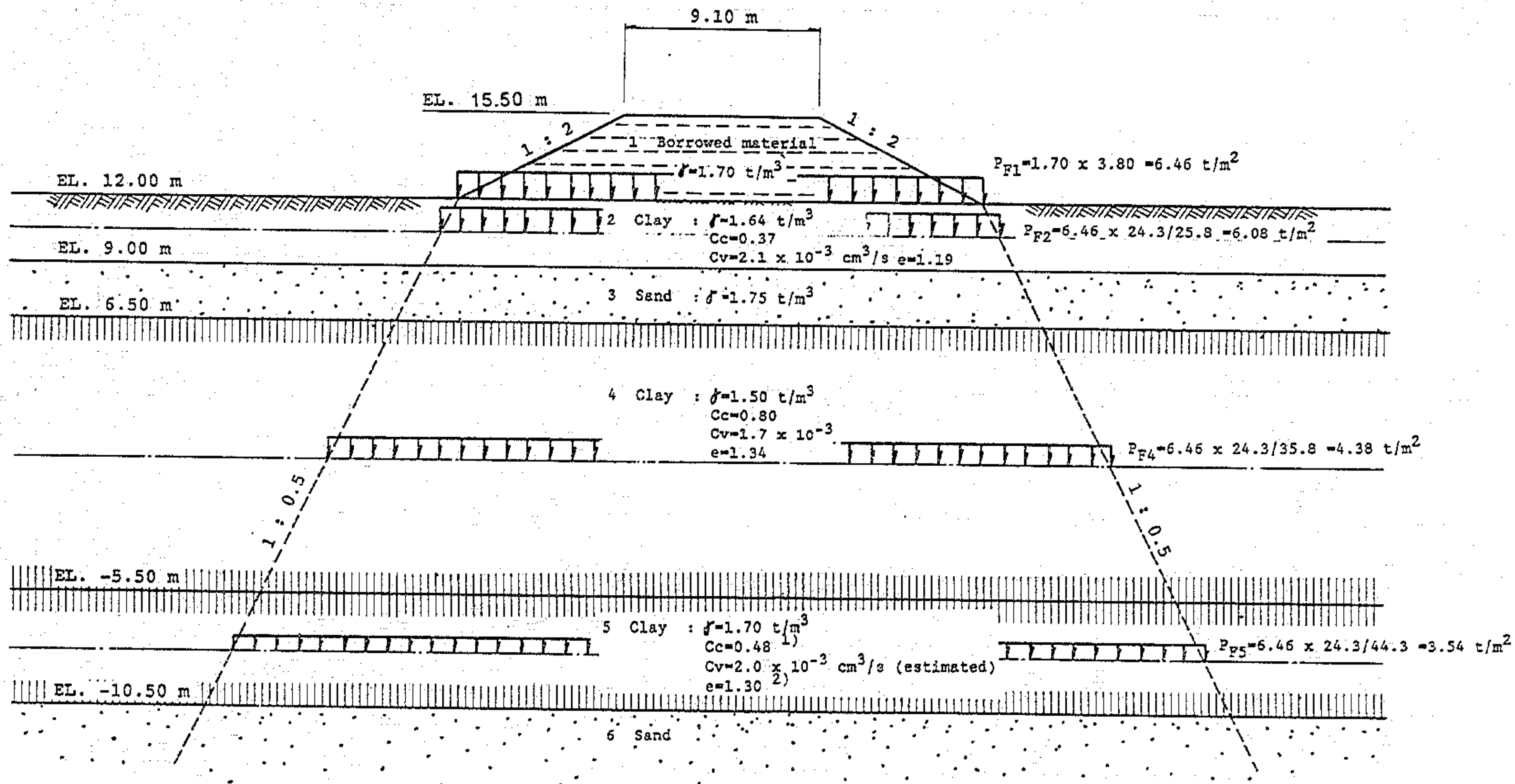



Fig. 5 Typical Sections for the Lakeshore Dike
for Alternatives

Notes;

- $\gamma$ :unit weight ($t/m^3$)
- Cc :compression index
- Cv :Coefficient of consolidation ($cm^3/s$)
- e :void-ratio
- LL :liquid limit (%)
- Gs :specific gravity of soil substance
- G :specific gravity of soil




Remarks ;

1) $Cc=0.009(LL-10)$
$=0.009 \times (63-10)$
$=0.48$

2) $e=(Gs-G)/(G-1)$
$=(2.61-1.70)/(1.70-1)$
$=1.30$

Fig.6 Typical Model for Consolidation Settlement of Foundation of the Lakeshore Dike

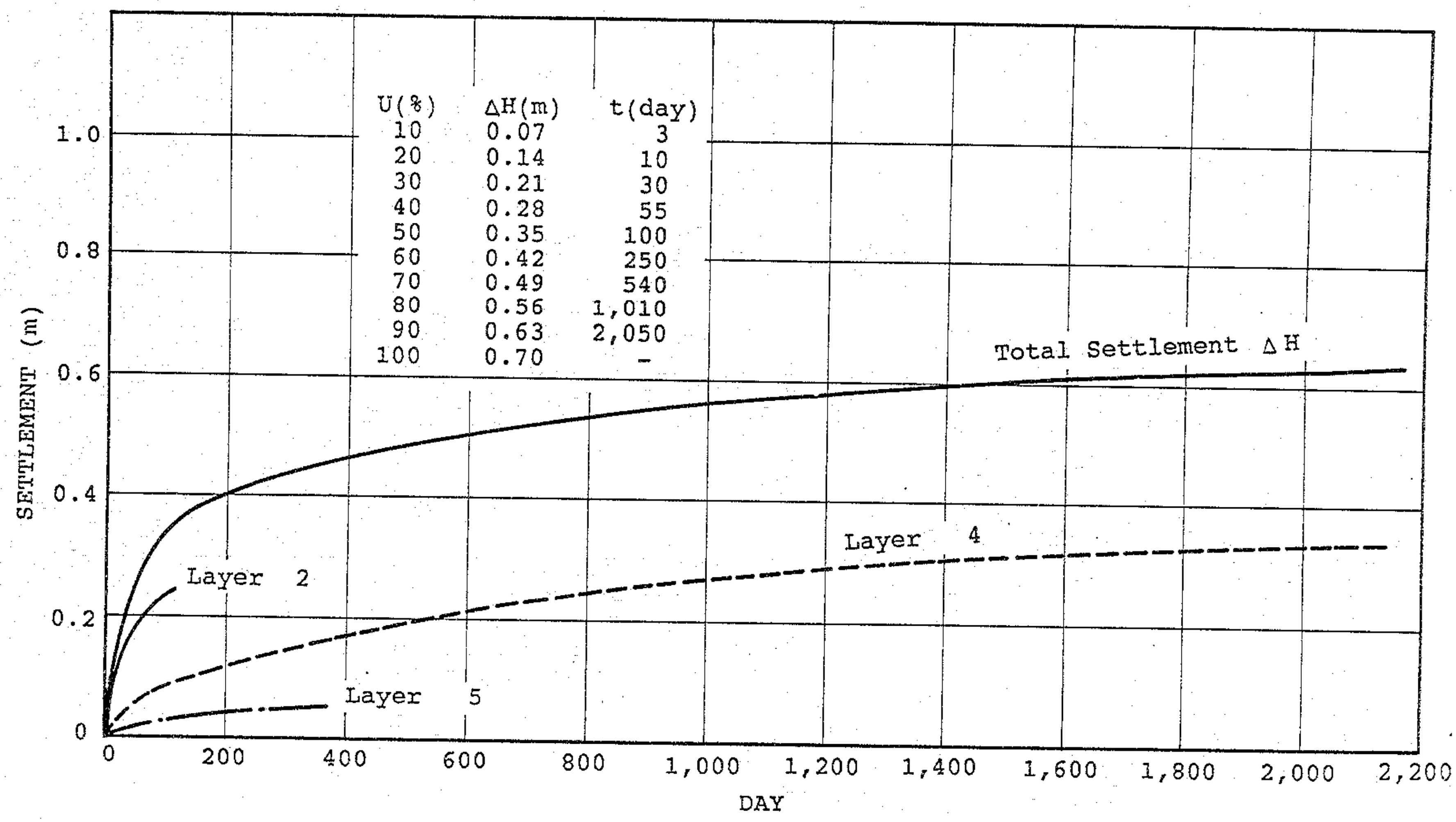
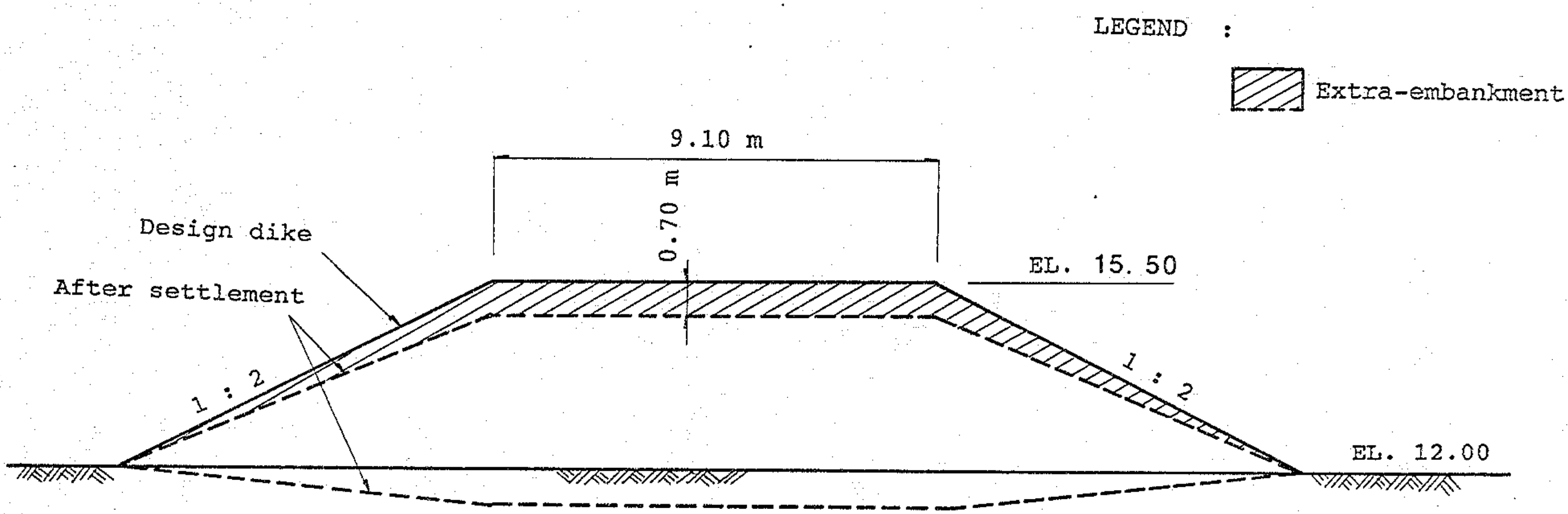



Fig.7 Consolidation -Time Curve of Foundation of the Lakeshore Dike




1). Design embankment : 63.5 $m^2$
2). Extra-embankment : 11.7 $m^2$
11.7/63.5=18.4 %——20 %

Fig.8 Volume of Extra-Embankment of the Lakeshore Dike

JICA