3 Determination of Design Soil Values

3.1 General

The soils analysed for embankment and foundation design are Alluvial and Diluvial deposits of which a total of 178 samples were taken by undisturbed and disturbed sampling. The following samples were analysed:

Undisturbed Samples	Alluvium (Ac).....	145 Samples
Disturbed Samples	Alluvium (Ac).....	79 Samples
"	(As).....	9 Samples
"	Diluvium (Dc).....	41 Samples
"	(Ds).....	55 Samples
Total.....		329 Samples

The type and quantity of tests and applicable standards are shown in Table 1.2

Based on the results of these soil tests, physical and mechanical properties of the Ac, As, Dc and Ds soils were determined and suitable bearing strata for bridge foundations identified.

3.2 Laboratory Soil Test Results

3.2.1 Physical Properties

(1) Particle Size Grading

The grading of four soil categories are shown in the following table 3.2.1

Cohesive deposits (Ac and Dc) contain fines fraction, silt (40.6) and clay (49.8%) total 90.2～91.2% by weight.

Sandy soil (As and Ds-deposit) contains coarse sand and gravel over 90.6～90.7% by weight.

Table 3.2.1 Soil Grading Results

Soil Fraction / Stratum	Gravel (%)	Sand (%)	Silt (%)	Clay (%)	No.10 (2.00) (%)	No.40 (0.425) (%)	No.200 (0.075) (%)
	Average Range of recorded values	Average Range of recorded values	Average Range of recorded values	Average Range of recorded values	Average Range of recorded values	Average Range of recorded values	Average Range of recorded values
Ac-cohesive	1.1	8.1	45.6	45.2	98.8	96.3	90.8
Soil	0-3.6	0.1~18.0	33.8~57.3	34.2~56.2	96.3~100	91.2~100	80.2~100
As-Sandy	4.9	85.7	9.3	0	95.1	32.5	9.4
Soil	0.0~9.0	81.5~90.0	6.8~11.7	0	91.0~99.1	22.2~42.7	7.2~11.6
Dc-Cohesive	0.7	11.7	40.6	49.8	99.2	94.2	87.4
Soil	0~2.0	0.8~24.6	28.3-52.9	35.1-64.5	97.8~100	86.5~100	74.0~100
Ds-Sandy	8.0	82.6	9.4	0	92.0	38.9	9.4
Soil	0.9~19.8	70.6~94.7	4.2~13.6	0	80.2~100.0	24.1~53.7	5.2~13.6

(2) Consistency Test Results

The moisture content and index test results are summarized in table 3.2.2 and graphs in Figure 3.2.1.

Ac Soil

- Ac soil: No variation in strength, moisture content or plasticity with depth was observed.
- According to the classification chart, Ac-soil is classified as CH: 67.7 % MH-OH: 25.8 % CL: 6.5 %
- Colloidal activity

  Ac-soil is classified as follows:

- Non-active clay (mainly Kaolinite) A< 0.75.....14.0 %

- Ordinary clay (mainly Illite) A=0.75~1.25..... 46.2%

- Active-clay (including organic colloid) A= 1.25~ 2.00.....39.8 %

Ac soil is classified as being in an unstable to stable condition since Wn=<Wl, Ic= -0.2~1.4 and average Ic= 0.8

Dc Soil

Dc soil: No variation in strength, moisture content or plasticity with depth was observed.

- According to the classification chart, Dc soil is classified as CH: 63.4 %, MH or OH 22.0 % and CL 9.8 %
- Colloidal activity: A < 7.5 : 22.0 % A=0.75~1.25: 51.2 % A>1.25: 26.8 %
- Dc soil is classified as being in a stable condition with Wn< Wl, Ic=0.6~1.5 and average Ic=1.0

Table 3.2.2 Moisture Content and Plasticity Test Results

Test Index / Stratum	Wn (%)	Wl (%)	Ip	If	It	Ic	Activity Ratio
	Average	Average	Average	Average	Average	Average	Average
	Range of recorded values	Range of recorded values	Range of recorded values	Range of recorded values	Range of recorded values	Range of recorded values	Range of recorded values
Ac-Cohesive Soil	51.3	76.8	44.5	23.8	2.2	0.8	1.2
	39.4~63.1	59.3~94.3	29.5~59.5	11.9~35.8	0.7~3.8	- 0.2~1.4	0.8~1.7
Dc-Cohesive Soil	38.7	68.4	41.2	-26.1	1.7	1.0	1.0
	31.5~45.8	53.8~83.0	28.3~54.0	14.4~37.9	1.1~2.4-	0.6~1.5	0.7~1.3

Note

ML: Inorganic silt, very fine sand, rock flour, silty or clayey fine sand

CL: Inorganic clay of low to medium plasticity, gravely clay, sandy clay, silty clay, low cohesive clay

OL: Organic silt and organic silty-clay of low plasticity

MH: Inorganic silt, micaceous or diatomaceous fine sand or silt and plastic silt

CH: Inorganic clay of high plasticity, high cohesive clay

OH: Organic clay of medium to high plasticity

Wn: Natural water content

Wl: Liquid limit

Ip: Plasticity index

If: Flow index

It: Toughness index (It = Ip/If)

Degree of shear strength at plastic limit

Ic: Consistency index (toughness and stability of cohesive soil)

$$Ic = (Wl-Wn)/Ip$$

$Ic \geq 1$: Stable condition

$Ic = 0$: Unstable condition (liquefies when disturbed)

Colloidal activity: Colloidal activity has strong relationship with clay mineral and geological condition of sediment, and is defined by Skempton.

Clay is classified into four groups from non-active clay to high-activity clay (activity >2). It is shown as the following formula.

$$\text{Colloidal activity} = \frac{\text{Plasticity index Ip}}{\text{Soil particle (\%) of less than 2 } \mu}$$

Table 3.2.3 Classifications by Colloidal Activity

Activity Ratio	Description	Main Clay Mineral	Deposition Conditions
A < 0.75	Non-active clay	Kaolinite	• Fresh water sediments • Marine deposits which have been leached
A=0.75 - 1.25	Ordinary clay	Illite	Marine and estuarine deposits
A > 1.25	Active clay	•Including organic colloid • A ≥ 2 includes Montmorillonite	

c) Specific Gravity, Bulk Density and Voids Ratio

Measured values of specific gravity, bulk density and voids ratio are summarized in table 3.2.4 and shown on graphs in Figure 3.2.2 and Figure 3.2.3.

· Specific Gravity (Gs)

The test results yield consistent values with a standard deviation of 0.042~0.016

· Wet Density (γt)

The tests show consistent values. The relationship between γt and other parameters is shown by the following formula:

$$\gamma t = \frac{1 + \frac{Wn}{100}}{\frac{1}{Gs} + \frac{\frac{Wn}{100}}{\frac{Sr}{100}}} * \gamma w$$

Where:

γt : Bulk density of soil (t/m^3)

Wn : Natural moisture content (%)

Sr : Degree of saturation (%)

Gs : Specific gravity

If the soil samples are fully saturated by high ground water at the project site, Sr=100% is applied to the above formula. The formula becomes the function of natural moisture content (Gs= constant).

$$\gamma t = \frac{1 + \frac{Wn}{100}}{\frac{1}{Gs} + \frac{Wn}{100}}$$

Table 3.2.4 Results of Gs, γt and e

Soil Properties / Stratum	Specific Gravity Gs	Wet Density γt	Voids Ratio e
	Average	Average	Average
	Range of recorded values	Range of recorded values	Range of recorded values
Ac- Cohesive Soil	2.650	1.6604	1.409
	2.608~ 2.693	1.551~1.767	1.087~1.730
As-Sandy Soil	2.673	-	-
	2.668~ 2.679	-	-
Dc-Cohesive Soil	2.665	-	-
	2.626~ 2.703	-	-
Ds-Sandy Soil	2.674	-	-
	2.658~2.690	-	-

The values of Gs and Wn are plotted and given in the Appendix- .The values of wet density adopted for design are:

Ac $\gamma t = 1.660 \text{ t / m}^3$

As $\gamma t = 1.700 \text{ t / m}^3$

Dc $\gamma t = 1.800\ t / m^3$

Ds $\gamma t = 1.900\ t / m^3$

- Voids Ratio (e)

The voids ratio of the Ac soils has a strong correlation with the natural moisture content:

Ac- soil

$e = 0.025Wn + 0.148$

Variance = 3.338

Correlation coefficient = 0.941

3.2.2 Mechanical Properties

Mechanical tests (Unconfined compression and consolidation tests) were carried out on undisturbed samples of soils along the railway alignment.

(1) Unconfined Compression Test

Unconfined compressive test results are shown in table 3.2.5 and Figure 3.2.4 and Figure 3.2.5. The relationships between qu (kg/cm^2) and E_{50} (kg/cm^2) for the Ac soils are shown by:

Ac soil

$E_{50} = 22.925qu + 1.253$

Variance = 3.713

Correlation coefficient = 0.660

Again, the relationships between qu (kg/cm^2) and the natural moisture content (Wn) for the Ac soils are shown by:

Ac soil

$qu = - 0.0155Wn + 1.588$

Variance = -2.083

Correlation coefficient = -0.331

(2) Triaxial Compressive Strength

The triaxial compressive strength as shown in table 3.2.5 were executed under unconsolidated and undrained condition

Table 3.2.5 Result of Soil Mechanical Properties

Item of Mechanical Soil Property / Deposit	Unconfined Compression qu , E50 and ε			Triaxial Compression Cuu, Φuu	
	qu (kg/cm^2)	E50 (kg/cm^2)	ε (%)	Cuu (kg/cm^2)	Φuu (Degree)
	Average	Average	Average	Average	Average
	Represen -tative range	Represen -tative range	Represen -tative range	Represen -tative range	Represen -tative range
Ac-Cohesive Soil	0.795	19.8	7.5	0.259	6.3
	0.361-1.229	6.6-33.0	2.0-11.1	0.089-0.420	4.0 ~ 8.5

(3) Consolidation

The test of consolidation are shown in table 3-2-6 and in the following figure

Figure 3.3.1 e- log p Curve (Ac)

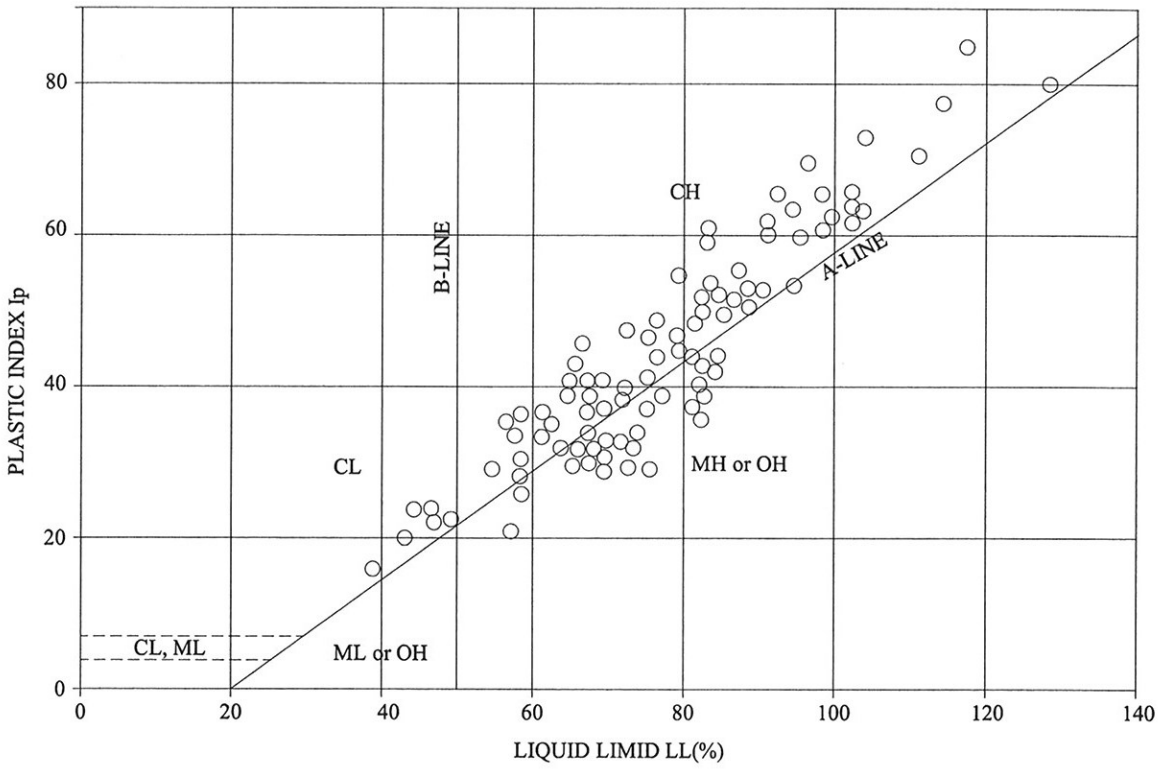
Figure 3.3.2 log Cv- log p Curve (Ac)

Since the test result, the Ac-deposit do not appear to significantly gain strength with increasing depth below ground, these deposits are considered to be unconsolidation

Table 3.2.6 Result of Consolidation

Item of Mechanical Soil Property / Deposit	Yield Stress of Consolidation Pc (kg/cm^2)	Compression Index Cc
	Average Value	Average Value
	Represen -tative range	Represen -tative range
Ac-Cohesive Soil	0.866	0.516
	0.649-1.083	0.142-0.890

PLASTICITY CHART



COLLOIDIAL ACTIVITY

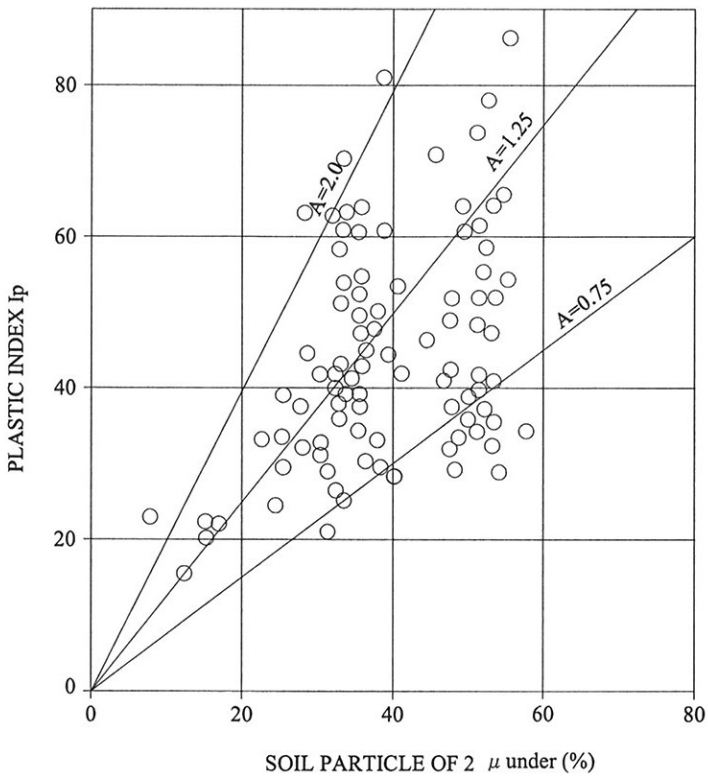
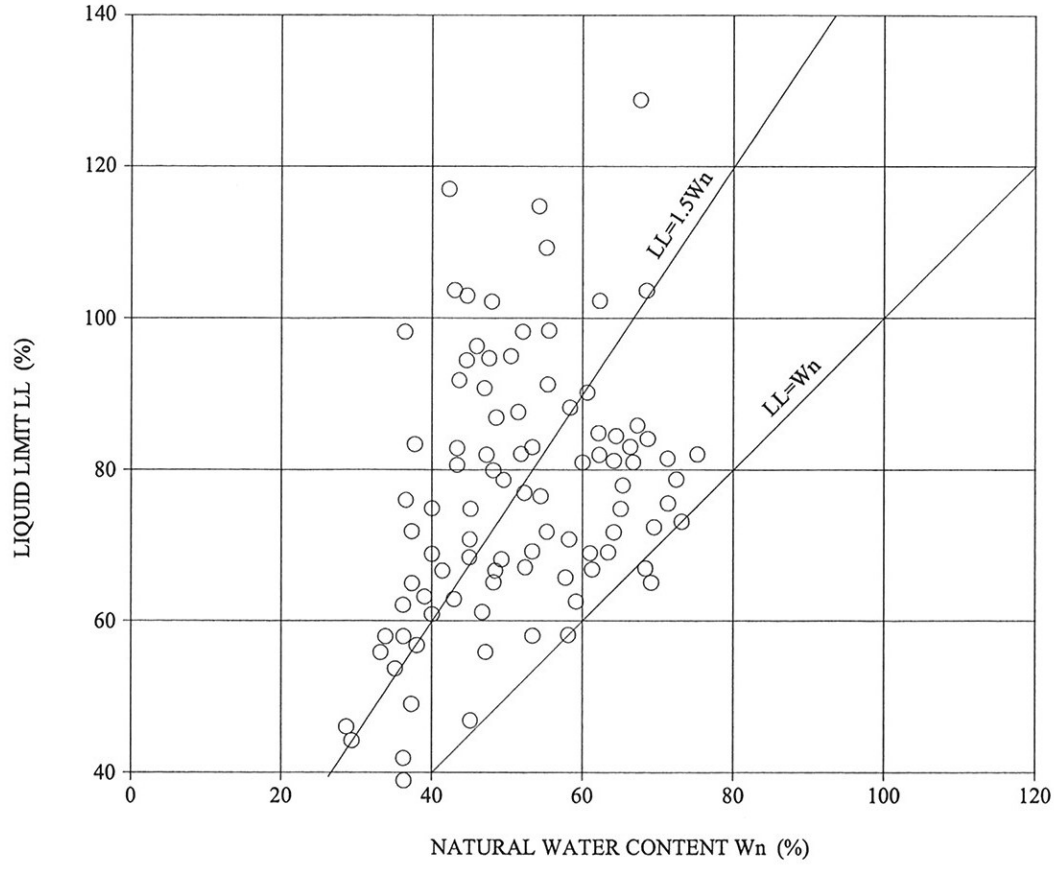


Figure 3.2.1

THE DETAILED DESIGN STUDY OF RAILWAY ELECTRIFICATION AND DOUBLE-DOUBULE TRACKING OF THE JAVA MAIN LINE PROJECT
(STAGE 2)

CONSISTENCY CHART



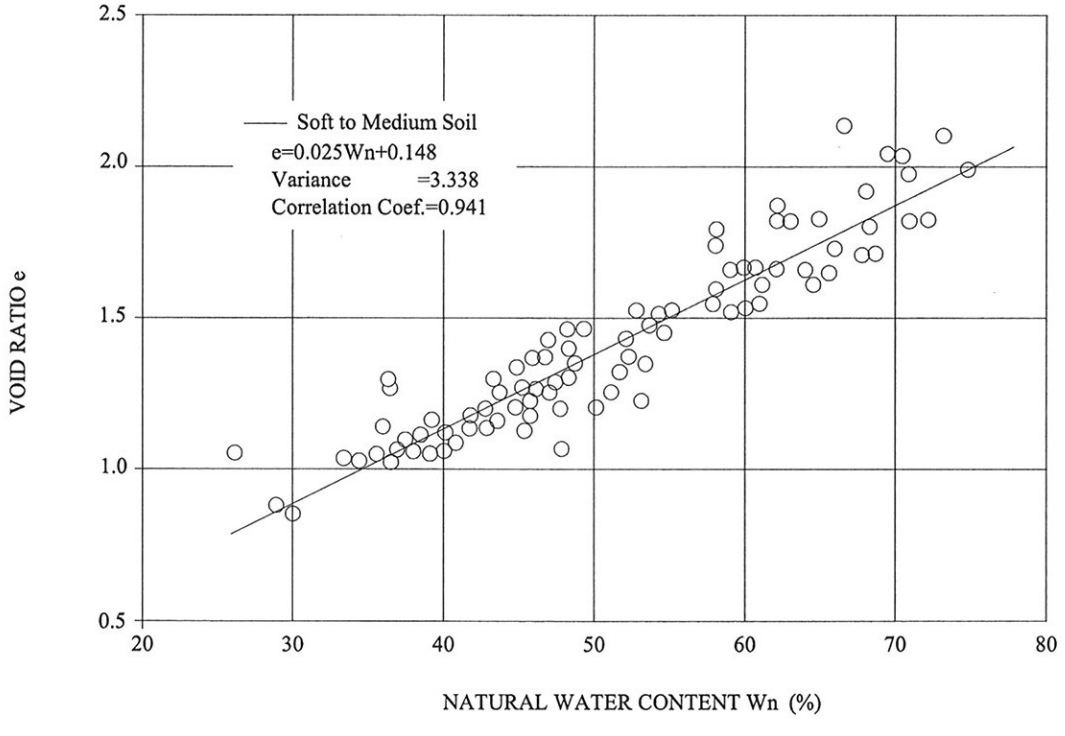
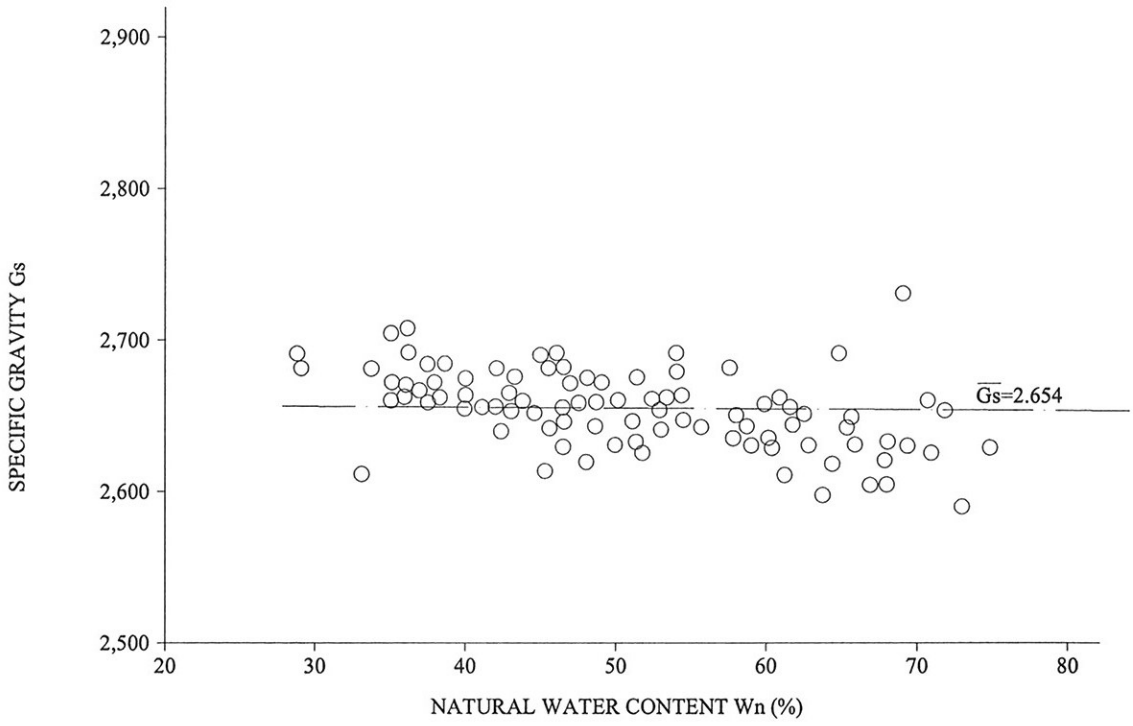


Figure 3.2.2

THE DETAILED DESIGN STUDY OF RAILWAY ELECTRIFICATION AND DOUBLE-DOUBULE TRACKING OF THE JAVA MAIN LINE PROJECT (STAGE 2)

RELATIVE CHART OF NATURAL WATER CONTENT (Wn)AND LIQUID LIMIT (LL%), VOID RATIO(e)



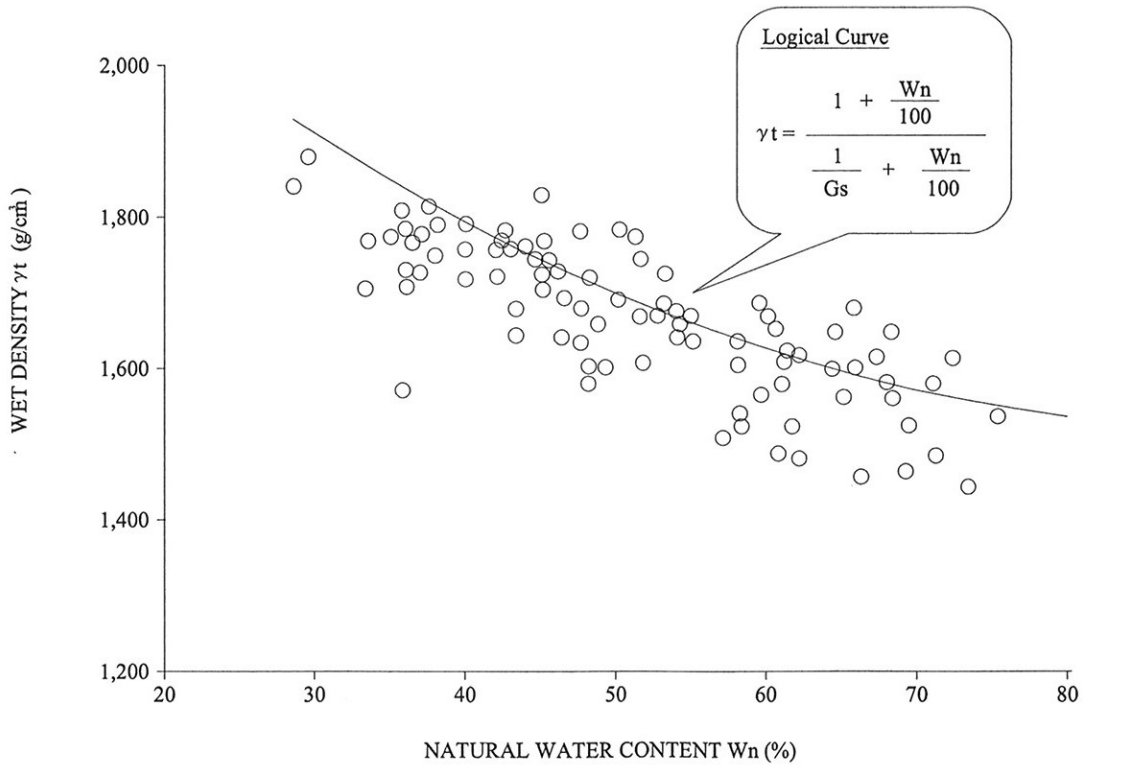
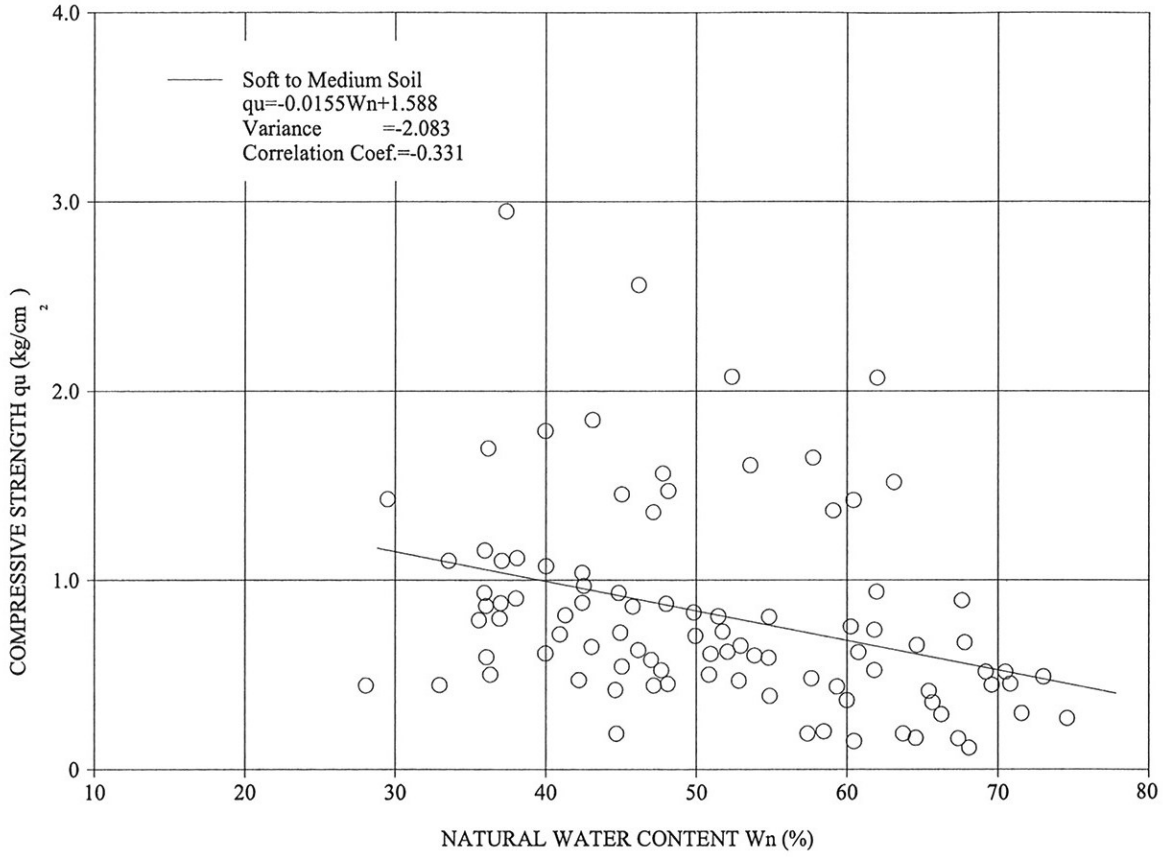


Figure 3.2.3

THE DETAILED DESIGN STUDY OF RAILWAY ELECTRIFICATION AND DOUBLE-DOUBULE TRACKING OF THE JAVA MAIN LINE PROJECT
(STAGE 2)

RELATIVE CHART OF
NATURAL WATER CONTENT (Wn)AND
SPECIFIC GRAVITY(Gs),WET DENSITY(γt)



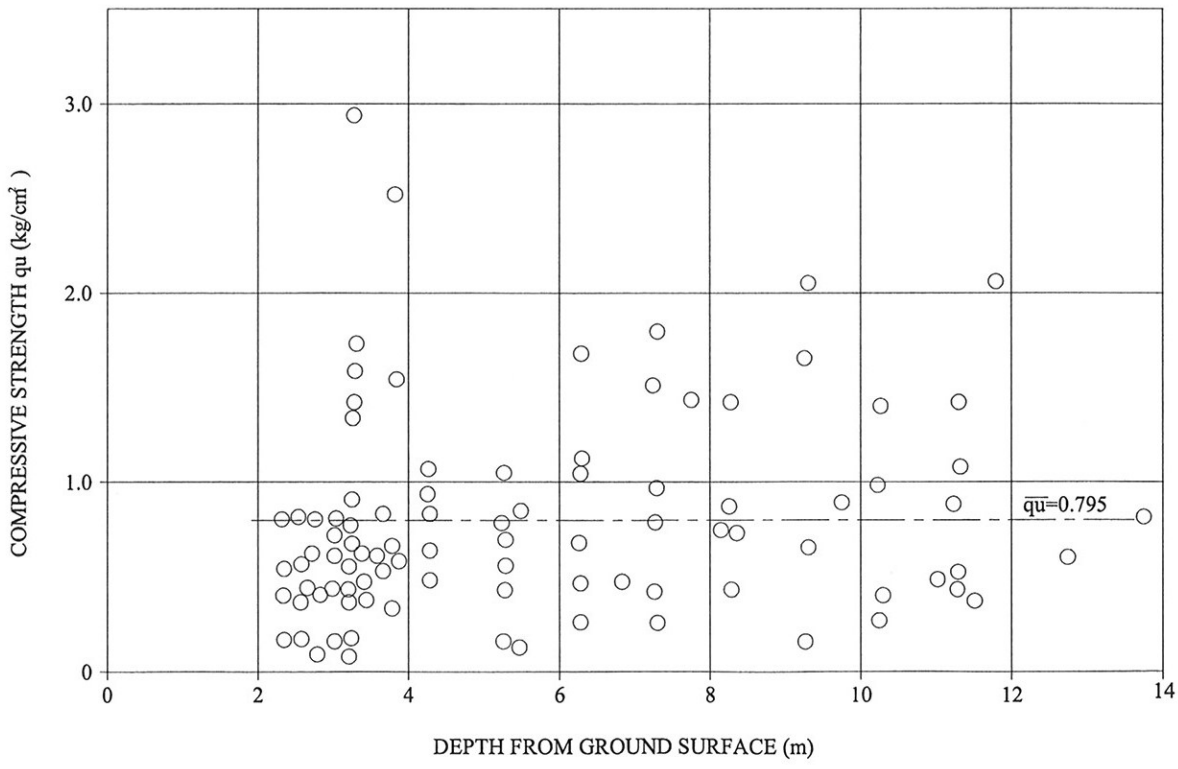
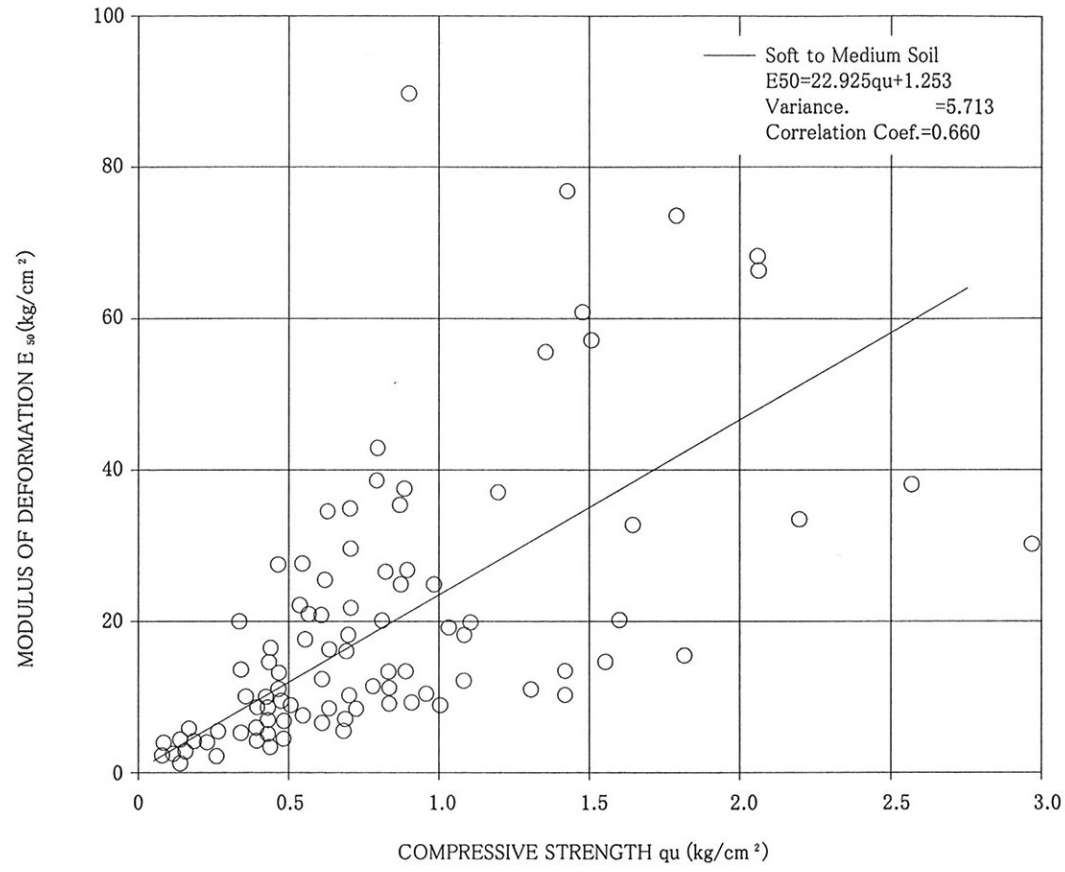


Figure 3.2.4

THE DETAILED DESIGN STUDY OF RAILWAY ELECTRIFICATION AND DOUBLE-DOUBULE TRACKING OF THE JAVA MAIN LINE PROJECT
(STAGE 2)

RELATIVE CHART OF NATURAL WATER CONTENT (Wn)AND (qu), DEPHT AND (qu)



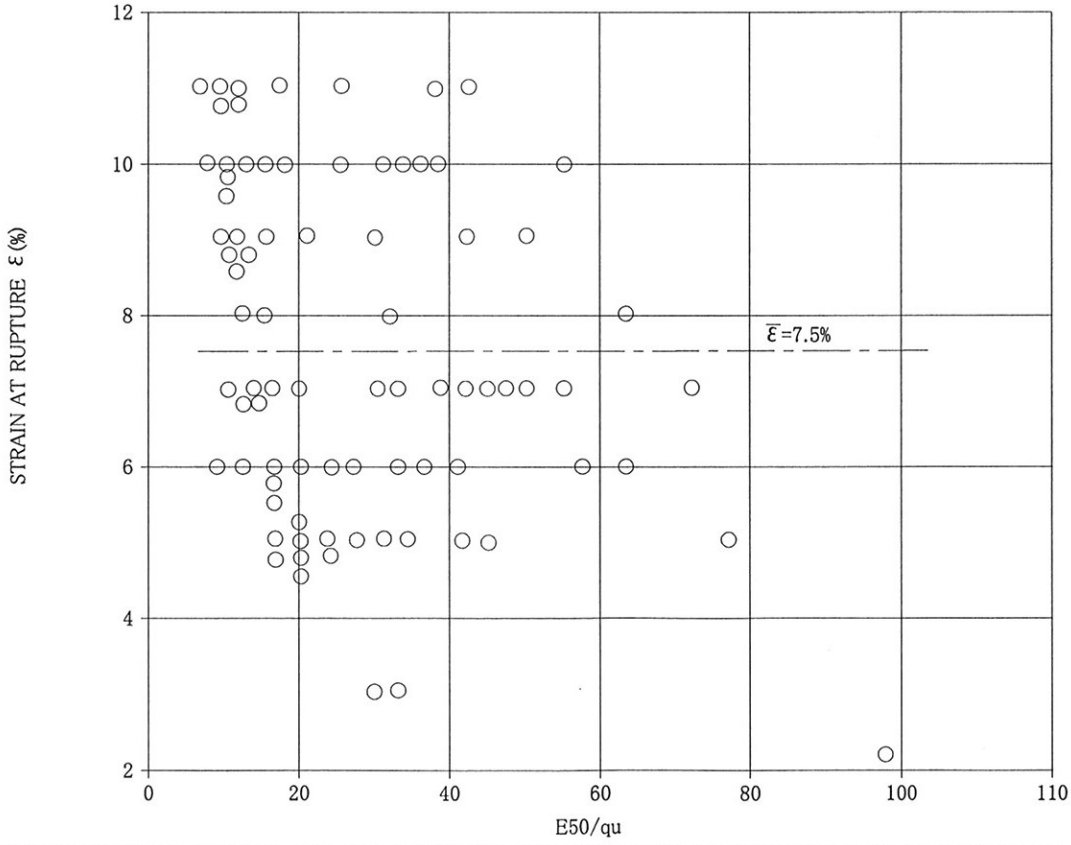


Figure 3.2.5

THE DETAILED DESIGN STUDY OF RAILWAY ELECTRIFICATION AND DOUBLE-DOUBULE TRACKING OF THE JAVA MAIN LINE PROJECT
(STAGE 2)

RELATIVE CHART OF
qu AND E50,
E50/qu AND ε