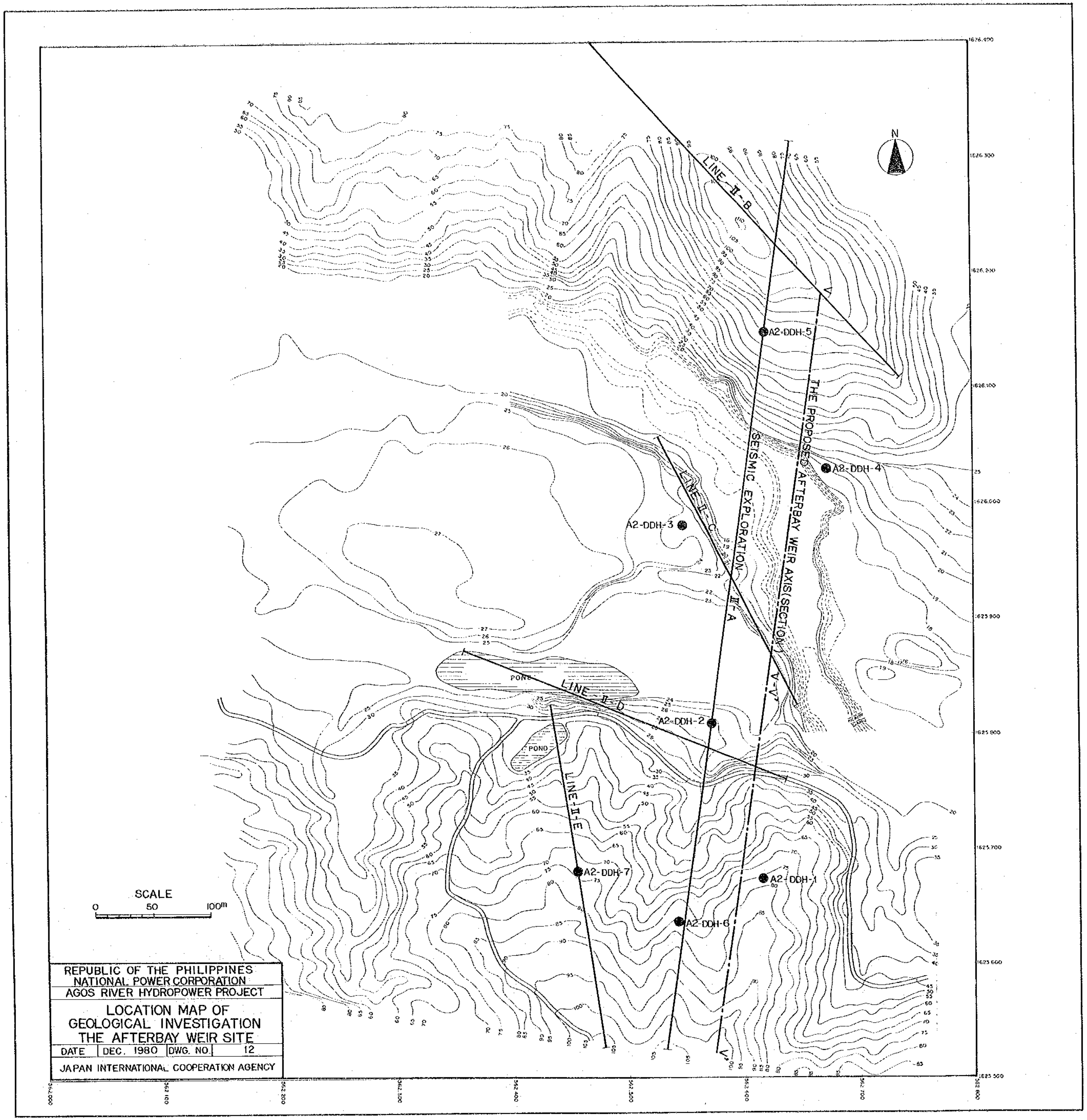
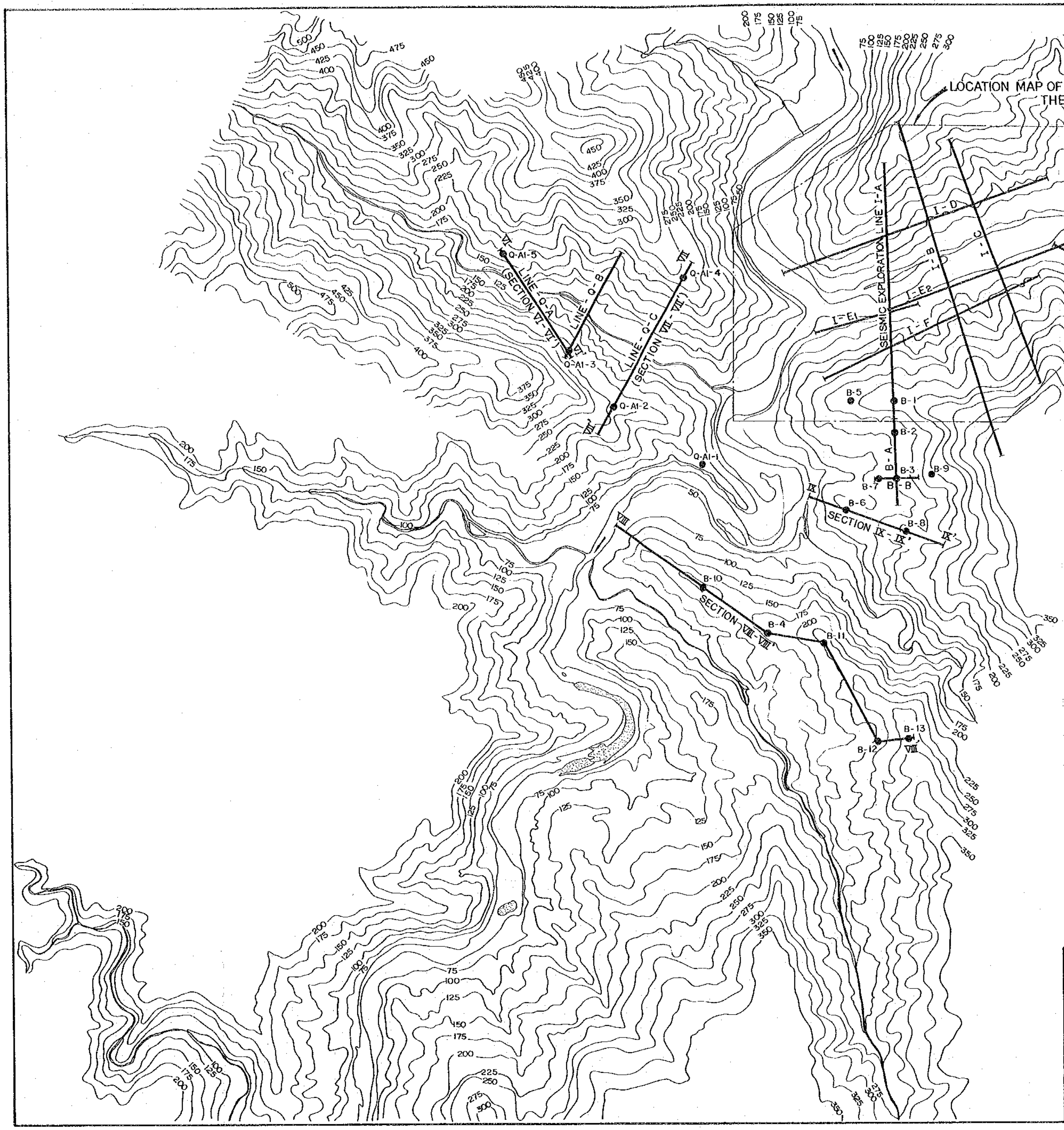


REPUBLIC OF THE PHILIPPINES
NATIONAL POWER CORPORATION
AGOS RIVER HYDROPOWER PROJECT

LOCATION MAP OF GEOLOGICAL INVESTIGATION THE AFTERBAY WEIR SITE

DATE	DEC. 1980	DWG. NO.	12

JAPAN INTERNATIONAL COOPERATION AGENCY



REPUBLIC OF THE PHILIPPINES
NATIONAL POWER CORPORATION

AGOS RIVER HYDROPOWER PROJECT

LOCATION OF INVESTIGATIONS
QUARRY SITE & BORROW PIT

DATE	DEC. 1980	DWG. NO.	13

JAPAN INTERNATIONAL COOPERATION AGENCY

PART II CONSTRUCTION MATERIALS

CHAPTER 1

INTRODUCTION

The field work for construction material investigation was carried out from July 1979 to April 1980.

As the fundamental conception of dam is to utilize local materials available in the project area as much as possible, the type of Agos dam is conceived to be of rockfill. Therefore, the ground reconnaissance nearby the site has been conducted for the prospective quarry site and borrow areas.

The field investigation is divided into 2 stages. The first stage was aimed to select the sites and to grasp characteristics of materials available. The second stage, based on the results of the first stage investigation and test carried out by NAPOCOR's laboratory in Metro Manila, was aimed to determine the most favourable sites for material sources from the viewpoints of quality and quantity.

The Agos Hydropower Project includes the construction of rockfill dam with center core of 130 m in height (above the river bed) and other appurtenant structures. Therefore, it is needed to exploit the construction materials such as soil, sand and gravel and rock materials which are used for dam embankment. Among them, sand and gravel will be also used for concrete aggregates. Based on the results of above field survey, this report intends to assess the quality, suitability and available quantity of these construction materials in detail.

The field investigation was performed in cooperation with the staff of NAPOCOR, and the soil test was done at NAPOCOR laboratory in accordance with the specification prepared by JICA Team.

CHAPTER 2

GENERAL DESCRIPTION OF CONSTRUCTION MATERIALS

2.1 Soil Material

(1) Heavily Weathered Material

The upper portion of hill area located on the right bank of the Agos river is covered with superficial material which is weathered to clayey soil due to the tropical weather condition while it is not clear whether it is residual or creeping soil. It shows generally reddish brown color which is a characteristic of lateritic soil but sometimes exhibits milky gray or yellowish gray color.

These clayey soils are characterized by high water content and low dry density and shows an elastic wave velocity of 0.3 to 0.6 km/sec (belongs to the superficial lowest velocity layer) in seismic exploration and also the value of 2 to 10 in standard penetration test.

According to the results of sub-surface observation by digging test pits, geological survey of core drilling and seismic exploration, the mean thickness of this layer is estimated to be around 5 to 6 m. In general, it is thicker on the gentle slope and mountain ridge, while thin on the steep slope.

(2) Weathered Material

The weathered material underlies the highly weathered clayey soil mentioned above with mean layer thickness of 4 to 5 m. In some places, however, the thickness of this layer is more than 10 m. The material showing dark brown color is fragile and easily transformed to small fragments or sandy material.

On the other hand, the N value in the standard penetration test and the velocity of elastic wave in seismic exploration are around 10 to 50 and 1 km/sec, respectively. It is considered that this layer can be excavated by the ripper.

(3) Silty Fine Sand Layer of Terrace Deposits

The terrace deposits spread on the both banks along the Agos river are utilized for farming.

According to its particle size distribution, the terrace deposits can be classified into two portions. One is an upper portion of terrace deposit composed of grayish silty fine sand and the other one is a lower portion composed of sand and gravel. The thickness of the upper silty fine sand layer is estimated to be around 4 m in an average and this material ranges from silty or clayey layer with high water content (in lower part) to fine sand layer (in upper part).

(4) Sand and Gravel Layer of Terrace Deposits

As mentioned in the above paragraph (3), the lower portion of the terrace deposit is composed of sand and gravel layer and clearly distinguished from the upper silty layer.

This sand and gravel layer is also classified into two kinds. One is a well graded mixture ranging from boulder of 30 cm diameter in maximum to sand, sometimes to silt. The other is a compacted mixture of subangular fragment cemented with sand, sometimes containing boulder more than 50 cm in diameter. They are both well compacted and the boulders or pebbles are hard enough.

Exploitable depth of these sand and gravel layer is estimated to be 5 m on an average.

2.2 Sand and Gravel Material

(1) River Deposit

It is envisaged to use the sand and gravel deposited in the river bed of the Agos as the filter material. This material is originated from graywacke, conglomerate, sandstone, shale, and limestone, of which the majority is graywacke. In the upstream reach of the hamlet Magsai-sai, it contains big boulders of graywacke and conglomerate. They are considered to be supplied from steep slope on both sides of the river and from the terrace deposit. In the downstream reach of Magsai-sai, the maximum gravel size is smaller than the upstream's ones. As the river bed slope of the Agos is rather steep, even the river bed deposits at the estuary contain cobbles of around 15 to 20 cm in diameter.

As the sand deposits are scattered at the downstream portion of every elbow of the river channel, they cannot be economically explored.

(2) Beach Sand

In the estuary of the Agos river and the adjacent beach, the sand dune widely spreads. The grain size of sand in and around the estuary is coarse while that at the beach far from the estuary is rather fine.

(3) Conglomerate

The Marcos Highway connecting Metropolitan Manila to Infanta is under construction. The construction site is located around 7 km downstream from damsite where the cut slopes of fresh or slightly weathered rock are exposed.

As these excavated rocks are well graded and the maximum grain size is around 10 cm, it is considered that the rock material composed of conglomerate is usable for filter material.

2.3 Quarried Rock

The quarry site to be exploited for shell zone of main dam is located just upstream of the confluence of the Kaliwa and Kanan rivers. They are considered to be hard and massive enough for rock material.

2.4 Deposit Quantity

2.4.1 Soil Material

(1) Heavily Weathered Material and Weathered Material

Based on the N value of the standard penetration test, heavily weathered material is defined as $N \leq 10$ and weathered material is 10 to 50.

The available quantity ratio of heavily weathered to weathered material in the proposed borrow area is estimated to be 6:4 on the basis of typical geological profile as shown in Fig. 2-1.

The available quantity is calculated in the following table, estimating the excavation depth of 10 m on an average.

Proposed borrow area	Area ($\times 10^3 m^2$)	Deposit quantity ($\times 10^3$ m^3)	
		Heavily weathered material	Weathered material
I Upstream	2,625	15,750	10,500
I Midstream	1,512	9,075	6,050
I Downstream	537	3,225	2,150
II Borrow area	1,200	7,200	4,800
Total	5,874	35,250	23,500

(2) Silty Fine Sand Layer and Sand and Gravel Layer of the Terrace Deposit

Based on the topographic map of the terrace deposit area and the results of subsurface investigation including test pitting, the deposit quantity is estimated as shown below.

	Deposit quantity (x10^3 m^3)
Silty fine sand layer	1,950
Sand and gravel layer	3,110

The above quantities are estimated excluding the boulder of more than 20 cm in diameter. The calculation procedure applied is shown in Table 2-1.

2.4.2 Sand and Gravel

(1) Sand and Gravel Layer in the River Bed

The obtainable quantity from the river bed is estimated to be 2 million cubic meters and the calculation method is the same as that of soil materials.

(2) Beach Sand

As the required quantity of sand is around 200 thousand cubic meters, there is the sufficient amount of sand at the beach.

CHAPTER 3

LOCATION OF SAMPLING AND LABORATORY TEST

3.1 Location of Sampling

Five (5) borrow areas for soil materials were selected by the investigation and named, from upstream, Agos I upstream area, Agos I middle area, Agos I downstream area, Agos II upstream area and Agos II downstream area. Fifty six (56) borrow pits were excavated at these areas and 93 soil samples collected from different depth were tested at the laboratory. In the borrow area Agos I upstream, 8 test drillings and seismic exploration of 500 m in length have been done to investigate the geological stratum of the borrow areas.

As for the filter material of the embankment as well as the concrete aggregates, alluvial deposits scattered from the confluence to the estuary were surveyed. Fifteen (15) borrow pits were explored and 32 samples from different depth were collected and tested.

The location of sampling for the above-mentioned construction materials is shown in the Table 3-1 to 3-4 and Fig. 2-2 to 3-1.

3.2 Laboratory Test

The following tests were carried out for soil materials,

a) Specific gravity
b) Particle size analysis
c) Natural moisture content
d) Natural density test
e) Plastic limit test
f) Liquid limit test
g) Compaction test
h) Tri-axial compression test UU
   CU
i) Permeability test

The following tests were carried out on the sand samples collected,

a) Specific gravity test and water absorption test
b) Density test
c) Chemical durability test
d) Mortar strength test
e) Washing test

In addition to those listed above, the alkali reaction tests were carried out for the beach sand.

As for the gravel, following tests were carried out,

a) Specific gravity test and water absorption test
b) Density test
c) Standard abrasion test
d) Washing test
e) Chemical durability test
f) Concrete test (7 days and 28 days strength test with the sand samples used for tests)

With respect to the chemical durability test, samples were brought to Japan and X-ray analysis was carried out together with the chemical durability test.

The compressive strength test on the core samples extracted from the core drilling at quarry site was carried out.

The items of laboratory test performed are summarized in the Table 3-5 to 3-12. Samples collected from each material site were tested in NAPOCOR laboratory in accordance with Japanese Industrial Standard (JIS) and ASTM. The results of laboratory test are shown in Data Book IV.

CHAPTER 4

GEOLOGY OF THE PROJECT SITES

4.1 Agos Damsite

4.1.1 General

The proposed Agos damsite is situated immediately downstream of confluence of the Kanan and the Kaliwa rivers, and the conceived dam axis is laid at 500 m of distance from the confluence.

Within about 1 kilometer's reach downstream from the confluence, the Agos river runs almost straightly east-northeastward through the channel with 120 m to 160 m of width. The river bed is at EL.40 m on the dam axis, and shows approximately 1/300 of gradient. Both banks rise at 1/1.85 to 1/2.30 (28° to 24° from horizontal) of average slope toward the ridges higher than EL.300 m.

On the slopes of both banks, several narrow gullies are incised at nearly right angle to the river channel. These gullies have steep gradients of 1/3.3 to 1/2.5 and a little perennial flow less than 100 litres/sec.

Bed rock in the damsite is composed of sedimentary rocks of greywacke group of Cretaceous to Paleogene age, comprising most prevailing greywackes, conglomerates, fine sandstones and shales, which have been metamorphosed in low grade. The general feature is alternating greywackes and conglomerates, with occasional intercalations of fine sandstone and shale layers. Greywacke and conglomerate form massive beds with little cleavages on bedding planes. In the other word, the bedding planes are generally obscure and is often distinguished only by the help of intercalating layers of fine sandstone and shale. The strata, showing average strike and dip of N30° - 35°E/30°-45°SE, develop across the river channel obliquely from upstream right bank to downstream left bank and dip toward right bank and downstream.

Joints and minor dislocation planes are developed dominantly in the direction of N70° - 80°W/60° - 90°NE.

Bed rocks are weathered in surfacial zone, and, in the uppermost zone, they are, for the most part, decomposed into residual soil. Organic top soil is rather thin, say less than 1 m.

Talus deposits composed of rock fragments and creeped residual soil are developed at the foot of the slopes along the river. Terrace of flood deposits are rather obscure in shape and very limited in locations on the said 1 km course of river around the damsite. River

Soils having these physical properties are classified into MH, CH, SC and SM in the Unified Soil Classification System. Most of them, however, may be classified into MH and CH because of high content ratio of fine material under 74μ.

The plasticity index (PI) generally ranges from 19.7 to 62.5, 32.6 on an average and the highest frequency value is 25 to 30. It can be said that the material is highly plastic and resistible against piping action.

(2) Compaction and Permeability

The compaction tests were performed in accordance with the method in JIS A 1210, 1-1. The results are shown in the following table.

Borrow area	Max. dry density γd max (g/cm^3)	Optimum moisture content Wopt (%)	Natural moisture content - Optimum moisture content Wf - Wopt (%)
Agos I Upstream	1.07 to 1.43 (1.21)	27.3 to 45.0 (38.5)	4.8 to 33.8 (21.2)
Agos I Downstream	1.22 to 1.31 (1.28)	24.5 to 38.3 (34.3)	10.8 to 33.4 (18.9)
Agos II	1.17 to 1.34 (1.21)	31.2 to 40.0 (36.3)	2.5 to 24.4 (12.8)
General	1.07 to 1.43 (1.22)	24.5 to 45.0 (37.1)	2.5 to 33.8 (18.5)

Figures in parentheses are the mean value.

As ssen from the results, the heavily weathered materials have low density, and the difference between natural and optimum moisture contents are very wide. It suggests that those materials have a characteristic of inefficiency in construction.

The permeability were tested under "optimum moisture content" condition. The coefficient of permeability (k) is in the order of 1×10^{-7} cm/sec, which is sufficiently impervious as core material of rockfill dam.

(3) Consolidation Tests

The consolidation tests were done under maximum dry density (γd max) condition for the sample in Agos I upstream borrow area and under wet side of γd max x 95% for the sample in Agos II borrow area. The maximum pressure (P max) applied was 20 kg/cm^2.

The maximum consolidation pressure were determined by using Casagrande's method, as listed in the Table 4-5. The table shows that maximum consolidation pressure Py is:

$3.0 < Py < 7.0$ kg/cm^2, under wet side of γd max x 95%,

$5.0 < Py \leq 20.0$ kg/cm^2 or more, under γd max condition (mostly $Py < 10$ kg/cm^2)

It suggests that those materials have some problems in their compressibility. However, the materials of $\gamma d > 1.4$ gr/cm^3 can be expected to have the maximum consolidation pressure of $Py > 20$ kg/cm^2. Optimum moisture content of this material of $\gamma d > 1.4$ gr/cm^3 is $Wopt \leq 30\%$. Maximum compressive pressure of the Agos dam is estimated at 25 kg/cm^2 (140 m x 1.8 t/m^3).

(4) Shear Strength

The results of triaxial compression tests under the Unconsolidated and Undrained (UU) condition and the Consolidated and Undrained (CU) conditions are as follows.

Sample name	U - U			C - U		
	ø (degree)	c (kg/cm^2)	Initial condition	ø (degree)	c (kg/cm^2)	Initial condition
I-TP-3 (2.5-3 m)	14°-00'	0.9	$\bar{W}$ = 35.7 γd = 1.22	15°-00'	0.4	$\bar{W}$ = 35.7 γd = 1.23
I-TP-5 (3.0 m)	15°-00'	1.2	$\bar{W}$ = 23.9 γd = 1.45	21°-30'	0.2	$\bar{W}$ = 24.7 γd = 1.44
I-TP-12 (2.5-3 m)	17°-00'	1.0	$\bar{W}$ = 24.1 γd = 1.47	14°-30'	0.7	$\bar{W}$ = 24.4 γd = 1.46
I-TP-13 (3.0 m)	6°-00'	0.8	$\bar{W}$ = 45.0 γd = 1.12	10°-00'	1.5	$\bar{W}$ = 41.9 γd = 1.14
II-TP-4 (3.0 m)	3°-00'	1.2	$\bar{W}$ = 37.2 γd = 1.25	12°-00'	0.9	$\bar{W}$ = 35.9 γd = 1.26
"	9°-00'	1.2	$\bar{W}$ = 39.9 γd = 1.20	15°-30'	0.6	$\bar{W}$ = 40.1 γd = 1.20

ϕ U-U = 3^o - 1.7^o C U-U = 0.8 - 1.2 kg/cm^2

ϕ C-U = 10^o - 21.5^o C C-U = 0.2 - 1.5 kg/cm^2

The relations between internal friction and density and between cohesion and density are shown in Fig.4-4, in which the internal friction angle increases and cohesion is constant or slightly decreases when the density increases. However, internal friction angle and cohesion cannot be clearly correlated with density. Mohr's circles are drawn separately in lower density group (γd = 1.2) and higher density group (γd >1.4), to get two kinds of envelopes as shown below and in Fig.4-4 and 4-5.

The low density group (γd = 1.13 to 1.25 gr/cm^3)

ϕ U-U = 12^o C U-U = 0.8 kg/cm^2

ϕ C-U = 13^o C C-U = 0.8 kg/cm^2

The high density group (γd = 1.45 to 1.47 gr/cm^3)

ϕ U-U = 16^o C U-U = 1.2 kg/cm^2

ϕ C-U = 19^o C C-U = 0.5 kg/cm^2

4.2 Weathered Materials

The test samples are WR-1 and WR-2.

(1) Physical Properties

The weathered materials have saturated surface-dry density of G' = 2.42 and an average absorption of W' = 9.0%. Compared with fresh rock whose G' and W' are generally 2.6 and less than 1.0% respectively, the weathered rock, therefore, is decomposed to some extent and can be excavated easily by a pick, being classified into SM or SW.

The natural moisture contents (Wf) were 11.5 to 18% and 14.8% on an average. However, these values may be increased by 5%, because the test samples were taken from outcrops of slope surface.

The content ratio of silt and clay components (less than 74μ) is 4 to 8% and 6% on an average. However, they may increase after compaction because the material is broken into finer components.

The plasticity index (Ip) of the material is rather low, less than 13.

(2) Mechanical Properties

The compaction tests were carried out in accordance with JIS A 1210. The results are tabulated in the following table.

Sample name	d max (g/cm^3)	Wopt (%)	Wf-Wopt
WR-1	1.62	13.6	-2.1
WR-2	1.69	20.9	-2.9
Average	1.66	17.3	-2.5

The natural moisture content is in a dry side of 2.5% (on an average) than the optimum moisture content. The real natural moisture content is nearly the optimum moisture content as the samples were taken from outcrop. Therefore, those materials may have good efficiency for construction.

The permeability tests were done under Wopt condition, and the results are as follows:

WR-1 $K = 8.5 \times 10^{-5}$ cm/sec

WR-2 $K = 8.5 \times 10^{-7}$ cm/sec

These materials are semipervious or impervious, and they would be suitable for core materials, if they are well compacted by sufficient compaction energy under the control of moisture content.

4.3 Silty Fine Sand Material in Terrace Deposit

The test samples are F-0 (h = 5 m), F-1, D-6 (h = 0.3 and 3.0 m) and D-8 (h = 0.3 and 2.5 m).

(1) Physical Properties

The results of physical test are summarized in the following table.

The lower layer of terrace deposits which is represented by sample F-0 shows nearly the same values of natural moisture contents and finer (-74) component contents as those of the heavily weathered soil material. However, it has the lower coefficient of uniformity and lower plasticity index. It seems to be less resistable against piping in general. But high composition of finer component and higher value of plasticity index shows that piping effect may not be occurred under sufficient moisture control.

On the other hand, materials in the upper layer of terrace deposit, represented by F-1, D-6, D-8 shows that the coefficients of uniformity are less than 10, plasticity index is 12 on an average and natural water content is possibly less than Wopt. Therefore it is considered that these material may be less resistable against piping effect.

Sample name	Wf (%)	Gs	Unified soil classi-fication system	Contain ratio of silt and clay	Uniformity coefficient	PI	Note
F-0 (h=5 m)	49.7	2.99	CL	62.0	18	19.0	Lower portion
F-1 (Surface layer)	-	2.77	SM	6.0	6	21.6	Upper portion
D-6 (h=0.3 m)	-	2.94	"	21.0	9	14.8	"
" (h=3 m)	-	2.87	"	7.0	3	NP	"
D-8 (h=0.3 m)	-	2.83	"	19.0	21	13.1	"
" (h=2.5 m)	-	2.78	"	18.0	12	10.6	"
Average	-	2.86 (2.84)	-	22.2 (14.2)	11.5 (9.6)	13.2 (12.0)	-

Figures in parentheses are the average value of upper portion of this deposit.

(2) Mechanical Properties

The compaction test and permeability tests are made only for the sample F-0 (h = 5 m). The results are as follows:

d max = 1.33, Wf - Wopt = 13.4%

$k = 2.6 \times 10^{-8}$ cm/sec

The dry density is as low as that of the heavily weathered materials. The coefficient of permeability is quite low.

4.4 Sand and Gravel Materials in Terrace Deposit

These materials correspond to the samples marked as DA. The physical properties are studied from in-situ density test and field observation.

(1) Physical Properties

All terrace deposits contain many big boulders of more than 50 cm. In case the maximum grain size is 15 cm, the content ratio of more than 15 cm of grain size may be in range of 0 to 60%, 40% on an average in weight and 20% on an average in volume.

The content ratio of silt and clay (less than 74μ) is 5 to 15% in case that the maximum size is less than 15 cm. Accordingly, those materials are classified in GC and partly in GW.

In-situ sieve analysis on 14 samples were made and the results of sieve analysis were shown together with the range of gradation curves for core materials in large fill dams in Japan (refer to Fig.4-7 and 4-8). Among them, 3 samples are within the above grain size classification, 7 samples including the above 3 samples, are nearly on the boundary of coarse side and the other 7 samples are far from this range.

If the material is mixed with soil, the material will have sufficient shearing stress and low compressibility and is used for core.

4.5 Mixed Materials

The heavily weathered materials are widely distributed in and around the project area. However, those materials seem to be unsuitable as core materials of high dam because of their high moisture content and low density. Therefore, a laboratory test was carried out on the mixed sample with coarse material to improve their physical and mechanical properties.

The mixing materials are as follows:

Heavily weathered material —— (Soil A and B)-- Agos I upstream borrow area

Coarse material ——┬—— Sand (F sand) -- River bed deposit
└—— Weathered rock (WR-1) ---- Agos I upstream borrow area

Physical properties of these materials are as follows:

Sample name	Wf	Unified soil classification system	Content ratio of silt and clay	Wopt	d max g/cm^3
Soil A	76.2	MH	72%	43.0%	1.085
Soil B	61.7	MH	52	54.0	1.012
F sand	-		1		
WR-1	11.5		4	13.6	1.620

The combinations of mixing are as follows:

Soil A with F sand .... Mix 1
Soil A with WR-1 .... Mix 2
Soil B with F sand .... Mix 3
Soil B with WR-1 .... Mix 4

The mixing ratio (P') in dry weight of coarse materials are as follows:

$$P' = 33\% \ (\frac{\text{heavily weathered materials}}{\text{coarse material}} = 2/1)$$

$$P' = 50\% \ (\frac{\text{heavily weathered materials}}{\text{coarse material}} = 1/1)$$

$$P' = 67\% \ (\frac{\text{heavily weathered materials}}{\text{coarse material}} = 1/2)$$

(1) Physical Properties

The maximum ratio of coarse materials is P' = 67% and that of finer component (-74 μ) is 18 to 27%. Plastic index of all the samples is more than 10, being sufficiently resistible against piping effect.

P' = 33% —— PI = 12.0 to 22.5 (18.9 on an average)
P' = 50% —— PI = 10.8 to 27.1 (17.7 on an average)
P' = 67% —— PI = 11.5 to 21.2 (15.3 on an average)

(2) Mechanical Properties

Compaction, permeability, consolidation and triaxial compression tests were conducted.

The compaction tests were made under the standard compaction energy (Ec) and the relation between mixing ratio of the coarse material P' and maximum density γd max, optimum moisture content Wopt is shown in Fig. 4-9. Maximum dry density increases and optimum moisture content decreases as mixing ratio of coarse material increases.

Assuming that γd is bigger than 1.4 gr/cm^3 and W is less than 30% and Py is more than 20 kg/cm^2 for desirable core material conditions, the mixing ratio of coarse material (P') shall be more than 50% as shown in Table 4-5.

Though the permeability was intended to be tested under the condition of Wopt, it was actually carried out under the dry side. The coefficient of permeability obtained was rather high than expected, due to low degree of saturated (Sr). The relation between permeability k and degree of saturation Sr is shown in Fig.4-10. From this relation, it is assumed that impermeability can be obtained even the mixture rate is 67% if the degree of saturation is more than 80%. In general, the condition of γd max and Wopt corresponds to the range of Sr = 80 to 90%. Therefore, the mixing materials which contain coarse materials of 50 to 67% can be used for the core materials of the Agos dam. In this case, required reduction of the moisture content (W) of the heavily weathered materials is as follows in order to obtain the optimum moisture content (W) of the mixed material.

Agos I upstream borrow area	W = 12 to 7%
Agos I downstream borrow area	W = 5 to 1%

Provided that the moisture content ratio of coarse materials is 10%.

4.6 Discussion on Soil Materials

Comments on soil materials as the core of the Agos dam are summarized as follows.

(1) Heavily Weathered Materials

These materials spread widely over the project area and their estimated volume is about 35 million m^3. They show higher plasticities of PI = 32.6 on an average, high resistance against piping effect and high impermeability of $k \doteqdot 10^{-9}$ cm/sec. But there are some defects in their workability during construction.

i) The natural moisture content Wf is very high, of 58% and the difference from the optimum moisture content is about 18%. The low efficiency in trafficability and treatment are expected in the course of embankment.

ii) The wide difference between the natural and optimum moisture contents is beyond moisture control in the actual condition.

iii) Maximum dry density γd max = 1.22 gr/cm^3 (mean) is low, the maximum consolidation pressure Py is also very low in most cases compared with maximum load of the dam body P max = 25 kg/cm^2. The settlement is rather big as 10.1% and 15%, corresponding to P = 10 kg/cm^2 and 20 kg/cm^2 respectively. This will cause deformation of the embanked body, accompanying cracks in the core body as well as along contact plane between core and adjacent zone.

From the above reasons, these materials themselves are inadequate to use in embankment of core zone. But they can be used as contact clay over the bedrock. In the contact zone between core body and rough surface of bedrock, high impermeability and resistance against piping is the most important for water tightness.

(2) Weathered Materials

These materials have no problem in their availability. The natural moisture content is also near the optimum one. The materials are well graded. They correspond to SM and SW in soil classification and their workability during construction is also seemed to be good.

They show γd max = 1.66 gr/cm^3 and contain 6% of 74 μ. If the embankment is executed under the sufficient compaction and moisture control, coarse component will be crashed to finer size.

They always underlie the heavily weathered soil. To exploit them, large amount of overlying heavily weathered material has to be removed. Lower layer of the weathered soil will become harder to the extent of N=50 and expected to be unsuitable for impervious material.

In these situation , it is advisable that the weathered material is used as mixing material with the heavily weathered soil for core but not used as a single material. Thus, by applying the mixing method, the defect of heavily weathered material such as high compressibility and that of weathered material such as low plasticity can be compensated each other.

(3) Sand and Gravel Materials of Terrace Deposit

These materials are mostly composed of well-graded sand and gravel, with high density (γd >1.8) and low compressibility. This is the most suitable material for the core of the Agos dam if the materials satisfy the impermeability.

So far as the results of field gradation test, their grain size is too coarse, 50% of the material is beyond maximum grain size of standard core material of fill dam. They may be used as core material by mixing with finer material. In this case the content of silt and

The bedding plane is obscure in general, except for the bedding of the intercalated thin layer of fine sandstones, showing WNW-ESE to ENE-WSW of strikes and 35^{o} to $45^{o}S$ of dips.

River bed deposit together with flood terrace deposit has thickness of about 50 m in the maximum, consisting of sand and gravels with the maximum diameter of more than 50 cm, which are originated mainly from greywacke and other rocks such as volcanic rocks, limestones, sandstones and conglomerates.

4.2.2 Zoning of the Foundation

Seismic exploration in the afterbay weir site was carried out with five exploration lines totalling 2,100 m in length, devided the ground into five zones by velocity of elastic wave propagation following the same procedure as in the Agos damsite. These zones are classified as follows:

Zone I	0.2 - 0.3 km/sec	Top soil and talus
Zone II	0.7 - 0.8 km/sec/ 0.9 - 1.0 km/sec	Residual soil/decomposed rock
	1.2 km/sec	Partly upper zone of river deposit
Zone III	1.7 - 1.9 km/sec/ 1.8 - 2.0 km/sec	Weathered or cracky rocks Partly lower zone of river deposit
Zone IV	2.3 - 2.5 km/sec	Lower zone of river deposit Partly weathered or cracky rocks
Zone V	3.5 km/sec/4.5 km/sec	Fresh and solid bed rock

The foundation, consisting of the almost same geological units as the Agos damsite, is divided into the following categories.

(1) Quarternary Deposit

River deposit

The recent deposit of sand and gravel layer shows about 50 m of maximum thickness and more than 250 m of width along the proposed weir axis. Gravels are composed of andesite and basaltic rocks, limestones, conglomerates and greywacke as the most abundant component. The size of gravel is more than 50 cm in maximum diameter. Superficial deposits are relatively loose, showing 0.7 - 0.8 km/sec of velocity in seismic exploration. The lower zone with 1.7 - 1.9 km/sec of the velocity seems to be compacted more densely.

Therefore, the mixed materials of the heavily weathered material with the weathered one are used as the core material.

Stock piling for mixing requires,

i) For thorough mixing of material, at least three kinds of stock-yards should be prepared

- Yard for stock piling of excavated heavily weathered material
- Yard for squeezing excess moisture out of the material
- Yard for mixing and ready-to-transporting

ii) Each material, heavily weathered and weathered, is spread in 20 cm compacted thickness (P' = 58%).

iii) Ultimate thickness of the pile will be around 5 m, corresponding to digging height of power shovels to be used.

iv) Judging from the quality of soils and land available for stock pile yard, the Agos I downstream borrow area is selected.

4.7 Design Value

(1) Core Material

a) Density (Unit weight)

Dry density $\gamma d = 1.43\ t/m^3$ (Fig.4-9 P' = 60%)

Water content $W = Wopt = 27\%$ (Fig.4-9 P' = 60%)

Specific gravity Heavily weathered material

$Gs_1 = 2.82$

Weathered material

$Gs_2 = 2.77$ (average)

Modified specific gravity

$Gs = 2.82 \times 0.4 + 2.77 \times 0.6 = 2.79$

Void ratio $e = \frac{Gs \times \gamma w}{\gamma d} - 1 = \frac{2.79 \times 1.0}{1.43} - 1 = 0.95$

Wet density $\gamma t = \gamma d \times (1 + \frac{W}{100}) = 1.43 \times 1.27 \fallingdotseq 1.82\ t/m^3$

Saturation density $\gamma sat = \frac{(Gs + e) \times \gamma w}{1 + e} = \frac{(2.77 + 0.95) \times 1.0}{1 + 0.95}$

$= 1.91\ t/m^3$

Submerged density $\gamma sub = \gamma sat - \gamma w = 1.91 - 1.0 = 0.91\ t/m^3$

b) Shearing strength

Considering the result of triaxial compression test of the heavily weathered material (γd = 1.44 to 1.47 t/m^3) and also the mixing of the coarse material the following shearing strength is proposed

Immediately after completion	$\phi = 18^0$ $c = 5\ t/m^2$
After completion	$\phi = 20^0$ $c = 5\ t/m^2$

c) Permeability coefficient

$k = 1 \times 10^{-5}$ cm/sec

d) Criteria for control of embankment

Water content	$W = Wopt \pm 3\%$
Density	$\gamma d \geqq \gamma d\ max$
Saturation	$Sr \geqq 80\%$

(2) Rock Material

a) Density

Specific gravity of rock material G' = 2.60 (estimated)
e = 0.4 (estimated)

$$\gamma t = \frac{G'}{1 + e} \times \gamma w = \frac{2.6 \times 1.0}{1 + 0.4} = 1.86\ t/m^3$$

$$\gamma sat = \frac{(G' + e) \times \gamma w}{1 + e} = \frac{(2.60 + 0.4)}{1 + 0.4} = 2.14\ t/m^3$$

b) Shearing strength

ϕ = 42 to 45 degrees

$c = 0\ t/m^2$

(3) Crashed Rock Material

a) Density

$G' = 2.55$

$e = 0.35$

$$\gamma t = \frac{2.55 \times 1.0}{1 + 0.35} = 1.89 \ t/m^3$$

$$\gamma sat = \frac{(2.55 + 0.35) \times 1.0}{1 + 0.35} = 2.15 \ t/m^3$$

b) Shearing strength

$\phi = 38$ to 40 degrees

$c = 0 \ t/m^2$

(4) Filter Material

a) Density

$$G' = 2.60 \ (\frac{\text{average of river bed sand and gravel + conglomerate}}{2}$$

$$= \frac{2.62 + 2.59}{2} \doteqdot 2.60)$$

$e = 0.30$ (well-graded)

$$\gamma t = \frac{2.60 \times 1.0}{1 + 0.3} = 2.00 \ t/m^3$$

$$\gamma sat = \frac{(2.60 + 0.3) \times 1.0}{1 + 0.3} = 2.23 \ t/m^3$$

$\gamma sub = 1.23 \ t/m^3$

b) Shearing strength

$\phi = 35$ to 37 degrees

$c = 0 \ t/m^2$

CHAPTER 5

RESULT OF LABORATORY TEST ON SAND AND GRAVEL MATERIAL

5.1 Materials for Concrete Aggregates

5.1.1 Quality

To confirm the quality of sand and gravel sampled from the river bed of the Agos and beach sand, the laboratory test for coarse and fine aggregates were carried out.

The results of them are summarized below.

	Specific gravity (surface dry)	Absorption (%)	Durability (%)
Fine aggr.			
a) River sand (Mean)	2.19 to 2.53 (2.45)	4.2 to 7.11 (7.2)	13.0 to 16.3 (14.1)
b) Beach sand (Mean)	2.49 to 2.81 (2.60)	3.5 to 5.2 (4.5)	10.1 to 13.0 (12.0)
Coarse aggr.			
c) Sand & gravel (Mean)	2.54 to 2.77 (2.62)	0.4 to 4.3 (1.5)	(1.7)

	Decantation test (%)	Los Angels (%)	Compressive strength/2 of mortar (%) 7-day	28-day
Fine aggr.				
a) River sand (Mean)	1.4 to 23.0 (6.1)		88.4 to 100/1 (94.0)	98.7 to 99.5/1 (99.0)
b) Beach sand. (Mean)	1.9 to 4.0 (2.8)		(96.1)	(95.3)
Coarse aggr.				
c) Sand & gravel (Mean)	0.6 to 8.2 (2.0)	13.3 to 19.8 (16.5)		

Note: /1 Test values in 1979 are excluded.
/2 The percentage shows a ratio of compressive strength after washing to that before washing.

(1) Fine Aggregate

The results of laboratory test show that the beach sand is superior to the river sand in every item of laboratory test as shown in the table. The durability test was carried out by using solution of sodium sulfate. An allowable limit of durability is said to be 10%. Those values of beach sand and river sand obtained this time are 12% and 14.4% respectively and they exceed the allowable limit by 2 and 4.4%. In general, however, it is not always prohibited to apply them to the fine aggregates.

The silt and clay content affects the compressive strength, durability and shrinkage of concrete. The mean silt and clay content ratio of river sand and beach sand are 6.1% and 2.8% respectively. As its allowable limit of reinforced concrete is 3% in general, the river sand should be washed to remove these fine components. On the other hand, the beach sand should be also washed to remove the salt component.

The results in reduction in alkality Rc for alkali reactivity tests of beach sand were satisfactory to following the provisions of ASTM.

(2) Coarse Aggregates

Required quality of coarse aggregates may be defined as follows according to the guide line of JSCE,

Specific gravity	- more than 2.5
Water absorption	- less than 3%
Chemical durability	- less than 12%
Washing	- less than 1%
Abraision	- less than 40%

Judging from the results of laboratory test, the sand and gravel from the Agos river deposit is sufficiently usable as the coarse aggregate in quality except silt and clay content ratio.

The sand and gravel of the river deposit is composed mainly of graywacke, sandstone, shale and limestone.

In relation to rather high value of chemical durability of fine aggregates, several tests on rock fragments of graywacke, sandstone and limestone had been carried out to find out the characteristic as to what component is the most reactive, in particular the chemical durability and Los Angels tests. The results are shown below.

It has been recognized that graywacke is the most reactive component to sodium sulphate among them and weak in Los Angels test.

	Specific gravity	Water absorption (%)	Chemical durability (%)	Los Angels (%)
Graywacke	2.58	1.40	3.29	1.10
Sandstone	2.59	1.07	1.96	0.65
Limestone	2.66	0.68	0.02	0.01

Therefore two pieces of graywacke have been brought to Japan and tested on chemical durability and X-ray analysis in Nippon Koei Engineering Laboratory. According to the result, the loss by chemical durability is 1.6 and 1.2% almost the same as the test in NAPOCOR laboratory. X-ray analysis revealed that the graywacke is composed of mainly quartz, albite, pyrophyllite and includes a small amount of clay mineral. Though it cannot be judged because of one test, it is possible that pyrophyllite may react with the solution of sodium sulphate. It is recommended to carry out more tests in the detailed design stage.

5.1.2 Gradation

(1) Fine Aggregates

The results of grain size analysis are shown in Table 5-1 to Table 5-7.

The fineness modulas (F.M) is one of the factor to evaluate the distribution of grain size.

The calculation formula of F.M is:

$$F.M. = P_1 + P_2 + P_3 + \ldots\ldots + P_n$$

where, P_1 - P_n is the passing ratio of each sieve, 0.075 to 5.0 mm for fine aggregate and 5 to 40 mm for coarse aggregate. According to the standard of JSCE, it is recommended that the values of F.M. for fine and coarse aggregate are between 2.3 and 3.1 and between 6 and 8 respectively. The results of F.M. analysis are also shown in Table 5-1 to Table 5-7 and summarized below. The results show that the mean values of F.M. for the river sand are nearly close to upper and lower limits of fine aggregate. Therefore, it is expected that the fine aggregate having a favorable grain size distribution can be obtained by mixing them in an appropriate proportion.

	River sand					Beach
	Zone A	Zone F	Zone D	Zone B	Total	
F.M. (Mean)	3.1~3.9 (3.4)	3.1~3.9 (3.6)	1.5~3.4 (2.7)	3.1~3.9 (3.5)	1.5~3.2 (3.1)	1.6~3.2 (2.4)
Sample Nos.	5	8	19	2	34	8
Passing ratio for stand. size	0/5 = 0%	1/8 = 13%	10/19=53%	1/2 = 50%	12/34=35%	3/8 = 38%

The values of F.M. in the various kinds of mixing ratio are calculated in the following table.

Sieve size (mm)	Mixing ratio (River sand : Beach sand)			Standard of grain size distribution
	1:1	2:1	1:2	
5	100.0	100.0	100.0	95-100
2.5	88.3	86.4	90.2	80-100
1.2	69.9	65.6	74.2	50-85
0.6	48.2	43.9	52.4	25-60
0.3	19.2	17.7	20.7	10-30
0.15	3.8	4.1	3.5	2-10
0.075	0.8	1.1	0.6	
F.M.	2.72	2.82	2.59	2.3-3.1
Decision	OK	OK	OK	

From the above calculation, the most favourable mixing ratio of river sand and beach sand is determined to be 1:1.

(2) Coarse Aggregate

The results of F.M. analysis for sand and gravel of river deposit are summarized in the following table.

The exceeding ratio from the standard grain size distribution is 52% as a whole, and this is rather high. However, as the F.M. value of these material distributes within the standard of JSCE, no processing to adjust the grain size is needed.

	Sand and gravel of river deposit				Total	F.M. in JSCE standard
	Zone A	Zone F	Zone D	Zone B		
F.M. (Average)	6.0~7.4 (6.6)	6.2~7.1 (6.7)	6.4~7.5 (7.0)	6.8~7.3 (7.0)	6.0~7.5 (6.9)	6~8
Nos. of sample	5	6	18	4	33	
Exceeding Nos. (from standard grain size distribution)	2	3	11	1	11	
Exceeding ratio (%)	40	50	61	25	52	

5.1.3 Compression Test

The compression test was carried out by using the concrete produced under the following conditions.

Slump value	3 inch ± 0.5 inch
W/C ratio	40 to 50%
Coarse aggregate	Gravel of river deposit
Fine aggregate	River sand and beach sand with mixing ratio of 1:1

The results of compression test are summarized as follows.

W/C (%)	σ_7 (kg/cm^2)	σ_{28} (kg/cm^2)	Slump (mm)
47.0	187	284	89
41.3	217	309	89
39.1	256	338	76

The relation between 28-day strength and C/W is shown in Fig.5-2. Although those values show some irregularity, the average values of 28-day compressive strength of concrete made of the above material is within a range of JSCE formula, $\sigma_{28} = -210 + 215$ C/W.

Therefore, it is judged that sand and gravel material obtained from the Agos river bed and beach sand is sufficiently usable for concrete aggregates.

5.2 Filter Material

The criteria for filter material is given by the following descriptions from the relation with core material used.

i) $\dfrac{\text{15\% grain size of filter material}}{\text{15\% grain size of core material}} > 5$

ii) $\dfrac{\text{15\% grain size of filter material}}{\text{85\% grain size of core material}} < 5$

iii) It is desirable that gradation curve of filter materials is approximately parallel to that of the core materials.

iv) If the core material contains coarse material, i) and ii) shall be applied to the materials under 25 mm size.

v) Filter materials shall not be cohesive and not contain more than 5% fine passing No.200 (0.074 mm) sieve.

The limits of grain size distribution meeting the above criteria is shown in Fig.5-4, where the gradation curve of core material mixed with heavily weathered and weathered material in 60% and 40% respectively is used.

The results of gradation test of river deposits and heavily weathered material are shown in Fig 5-3. As these gradation are almost within the above limit, river deposits can be used for filter material.

5.3 Source of Sand and Gravel Materials

The obtainable quantity of sand and gravel from river deposit is estimated to be around 2,000 x 10^3 m^3.

According to the preliminary design, the required quantity of sand and gravel is calculated at 1,200 x 10^3 m^3 and 400 x 10^3 m^3 for filter material and concrete aggregates respectively, totalling 1,600 x 10^3 m^3. It is recommended that the sand and gravel for concrete aggregates should be supplied from river deposit and beach.

T A B L E S

Table 2-1 List of the Available Amount of Sand and Gravel

* No.	Sand and gravel in the river bed: Sand and gravel (Includ- ing big boulder	The ratio of big boulder	Sand and gravel (Exclud- ing big boulder)	Terrace deposit: Sand and gravel (Exclud- ing big boulder)	Silty fine sand	Remarks
1	94,500	0.1	85,050	16,800	2,800	
2	14,110	0.1	12,700			
3	60,000	0.15	51,000			
4	13,000	0	13,000	229,050	152,700	
5	5,000	0.3	3,500	365,550	304,630	
6	1,000	0	1,000			
7	27,500	0.2	22,000	306,000	306,000	
8	4,810	0.2	3,850			
9	54,750	0.1	49,280	420,000	300,000	
10	390	0.2	310	315,000	105,000	
11	19,130	0.2	15,300	123,750	82,500	
12	1,200,000	0.2	27,740	240,500	360,750	
13		0.15	1,000,000	110,000	44,000	
14	38,580	0.2	30,860	742,500		
15	10,500	0.2	8,400	232,000	290,000	
16	4,280	0.1	3,850			
17	31,500	0.05	29,930	12,750		
18	64,000	0.1	57,600			
19	25,200	0.05	23,940			
20	14,000	0	14,000			
21	95,400	0	95,400			
22	57,450	0	57,450			
23	429,000	0	429,000			
24	112,130	0	112,130			
25	46,500	0	46,500			
26	23,050	0	23,050			
Total	1,381,770		1,254,170	3,113,900	1,948,380	

* Locations of barrow area referrs to Fig. 2-3

Table 3-1 Soil Material (No.1)

YEAR	Sample No.	Location of Sample		Pit or Slope	Excavation depth (m)	Material
1979	I-TP- 1	I Upstream borrow area	EL. 135	P	3.0	Strong weathered materials
	" 2	"	180	"	1.0	"
	" 3	"	215	"	3.0	"
	" 4	"	235	"	3.0	"
	" 5	"	245	"	3.0	"
	" 6	"	210	"	3.0	"
	" 7	"	160	"	3.0	"
	" 8	"	225	"	3.0	"
	" 9	"	185	"	3.0	"
	" 10	"	140	"	3.0	"
	" 11	"	70	"	3.0	"
	" 12	"	215	S	(6.0)	"
	" 13	"	180	"	(6.0)	"
	" 14	"	115	"	(6.0)	"
	" 15	"	250	"	(4.0)	"
	" 16	"	305	P	4.0	"
	" 17	"	140	"	3.0	"
	F - 0	Terrace deposit on the Agos river		P	5.0	Terrace deposit silty fine sand layer
	F - 1	"		P	1.5	"
	II-TP-1	I Borrow Pit	EL. -70	S	(6.0)	Strong weathered materials
	" 2	"		P	3.0	"
	" 3	"		"	3.0	"
	" 4	"		"	3.0	"
	" 5	"		"	3.0	"
	" 6	"		"	3.0	"
	" 7	"		S	(3.0)	"

* Excavation dapth: ( ) shows the depth on slope outcrop

Table 3-2 Soil Material (No.2)

Year	Sample No.	Location of Sample		Pit or Slope	Excavation depth (m)	Material
1979	S - 1	I Downstream borrow area		S	-	Strong weathered materials
	2	"		S	-	"
	TP - 1	"	EL.	P	4.0	"
	" 2	"	EL. 230	"	4.0	"
	" 3	"	" 350	"	4.0	"
1980	Soil A	I Upstream borrow area (Same as I-TP-13)	EL. 180	S	(6.0)	"
	" B	" (Same as I-TP-9)	185	P	(3.0)	"
	WR - 1	"	120	S	(10.0)	Weathered material
	" 2	Along Marcoss highway	250	S	(15.0)	"
	M-TP- 1	I Midstream borrow area	120	P	3.0	Strong Weathered Material
	" 2	"	160	"	3.0	"
	" 3	"	120	"	3.0	"
	Marcos 3	Along Marcos highway	380	S		"
	4	"	380	"		"
	5	"	300	"		"
	DA - 1	Terrace facet along the Agos river		S		Terrace deposit
	2	"		"		"
	3	"		"		"
	4	"		"		"
	5	"		"		"
	6	"		"		"
	7	"		"		"
	8	"		"		"
	9	"		"		"
	10	"		"		"
	11	"		"		"
	12	"		"		"
	13	"		"		"
	14	"		"		"
	15	"		"		"

Table 3-3 Sand and Gravel Material and Rock Material

Year	Sample No.	Location of Sample	Pit or Slope	Depth	Material
1979	F - 2	River bed between Agos dam and afterbay weir	P	1.0	Sand and gravel layer
	F - 3	"	"	0.5	"
	F - 4	"	S	(3.0)	"
	F - 5	"	"	(5.0)	"
	A - 1	River bed at Agos damsite	P	1.0	"
	A - 2	"	"	1.0	"
	D - 1	River bed at afterbay weir	S	(5.0)	"
	D - 2	"	"	(6.0)	"
	D - 3	"	"	(5.0)	"
	D - 4	"	"	(5.0)	"
	D - 5	"	"	(4.0)	"
	D - 6	"	"	(3.0)	Between terrace deposit and sand and gravel layer
	D - 7	"	P	1.0	Sand and gravel layer in the river bed
	D - 8	"	"	2.5	Same as D-6
	D - 9	"	S	(2.0)	Sand and gravel in the riverbed
	Santa Monica A	Beach	P		Beach sand
	" B	"	"		"
	" C	"	"		"
	" D	"	"		"
	Abiawin Different rocktype	Agos damsite	–	–	Sand and gravel in the river bed
	$G_{S}1$ - 1	Along Marcos highway EL 100	S	–	
	G_{S} - 2	" EL 380	"	–	

Table 3-4 Aggregate, Filter Material

Year	Sample No.	Location of Sample	Pit or Slope	Depth	Material
1980	A	In the riverbed at Agos damsite	P	0.5	Sand and gravel layer in the riverbed
	D	In the riverbed at afterbay weir, D-2	S	(6.0)	"
	F	The riverbed between Agos dam and afterbay weir, F-2	P	0.5	"
	S.T.M	Beach, Santa Monica A	P	1.0	Beach sand
	Different rock type	Agos damsite	-	-	Sand and gravel layer in the riverbed
	B - 1	In the riverbed after-bay weir	P	0.5	"
	B - 2	"	"	0.5	"
	B - 3	"	"	0.5	"
	B - 4	"	"	0.5	"
	B - 5	"	"	0.5	"

Year	Sample number	Depth of sampling (m)	Mechanical tests: Compaction test	Mechanical tests: Triaxial compression UU	Mechanical tests: Triaxial compression CU	Mechanical tests: Permeability	Mechanical tests: Consolidation	Mechanical tests:	Physical tests: Specific gravity	Physical tests: Grain size analysis	Physical tests: Moisture content	Physical tests: PL and LL	Physical tests: Specific Gravity, Absorption	Physical tests: Field seive analysis	Remarks
1979	I-TP-1	1.0							●	●	●	●			
	"	2.5	●			●	●		●	●	●	●			
	I-TP-3	1.5							●	●	●	●			
	"	2.5 ~ 3.0	●	●	●	●	●		●	●	●	●			
	I-TP-4	1.5							●	●	●	●			
	"	3.0	●	○	○		●		●	●	●	●			
	I-TP-5	1.0							●	●	●	●			
	"	1.5 ~ 2.5							●	●	●	●			
	"	3.0	●	●	●	●	●		●	●	●	●			
	I-TP-6	1.5							●	●	●	●			
	"	3.0	●			●	●		●	●	●	●			
	I-TP-7	2.5	●			●			●	●	●	●			
	I-TP-8	2.5 ~ 3.0	●			●	●		●	●	●	●			
	I-TP-9	1.5							●	●	●	●			
	"	2.5 ~ 3.0	●			●			●	●	●	●			
	I-TP-10	1.5							●	●	●	●			
	"	2.5 ~ 3.0	●			●	●		●	●	●	●			
	I-TP-11	1.5							●	●	●	●			
	"	2.5 ~ 3.0	●			●			●	●	●	●			
	I-TP-12	2.5 ~ 3.0	●	●	●	●	●		●	●	●	●			
	"	4.5 ~ 5.0							●	●	●	●			
	I-TP-13	3.0	●	●	●	●	●		●	●	●	●			

● Completed

○ Not yet obtained (as of July 1980)

Table. 3-5 Laboratory Investigation Items for Soil Materials

Year	Sample number	Depth of sampling (m)	Mechanical tests						Physical tests						Remarks
			Compaction test	Triaxial compression UU	Triaxial compression CU	Permeability	Consolidation		Specific gravity	Grain size analysis	Moisture content	PL and LL	Specific Gravity, Absorption	Field selve analysis	
1979	I-TP-14	3.0							●	●	●	●			
	〃	6.0	●			●	●		●	●	●	●			
	I-TP-15	3.0	●			●			●	●	●	●			
	I-TP-16	1.0							●	●	●	●			
	〃	2.5～3.0	●			●	●		●	●	●	●			
	〃	5.0～5.5							●	●	●	●			
	I-TP-17	1.5							●	●	●	●			
	〃	2.5～3.0	●			●	●		●	●	●	●			
	F-0	5.0	●			●	●		●	●	●	●			
	F-1	1.5～5.5							●	●		●			
	II-TP-1	3.0	●			●	●		●	●	●	●			
	II-TP-2	1.5							●	●	●	●			
	〃	3.0	●				●		●	●	●	●			
	II-TP-3	1.5							●	●	●	●			
	〃	3.0	●			●			●	●	●	●			
	II-TP-4	1.5							●	●	●	●			
	〃	3.0	●	●	●	●	●		●	●	●	●			
	II-TP-5	1.5				●			●	●	●	●			
	〃	2.5～2.8							●	●	●	●			
	〃	3.0	●				●		●	●	●	●			
	II-TP-6	1.5							●	●	●	●			
	〃	2.5～3.0	●				●		●	●	●	●			

● Completed

○ Not yet obtained (as of July 1980)

Table. 3-6 Laboratory Investigation Items for Soil Materials

Year	Sample number	Depth of sampling (m)	Mechanical tests						Physical tests						Remarks
			Compaction test	Triaxial compression UU	Triaxial compression CU	Permeability	Consolidation		Specific gravity	Grain size analysis	Moisture content	PL and LL	Specific Gravity, Absorption	Field seive analysis	
1979	II-TP-7	1.0							●	●	●	●			
	〃	2.5 ~ 3.0	●						●	●	●	●			
	〃	5.5 ~ 6.0							●	●	●	●			
	D - 6	0.3							●	●		●			
	〃	3.0							●	●		●			
	D - 8	0.3							●	●		●			
	〃	2.5							●	●		●			
	S - 1	2.0 ~ 4.0	●						●	●	●	●			
	S - 2	〃	●						●	●	●	●			
	TP - 1	〃	●						●	●	●	●			
	TP - 2	2.0 ~ 3.0	●						●	●	●	●			
	TP - 3	3.5 ~ 4.0	●						●	●	●	●			
	〃	2.0 ~ 4.0	●						●	●	●	●			

● Completed

○ Not yet obtained (as of July 1980)

Table. 3 - 7 Laboratory Investigation Items for Soil Materials

Year	Sample number	Depth of sampling (m)	Mechanical tests						Physical tests						Remarks
			Compaction test	Triaxial compression UU	Triaxial compression CU	Permeability	Consolidation		Specific gravity	Grain size analysis	Moisture content	PL and LL	Specific Gravity, Absorption	Field seive analysis	
1980	Soil A	3.0	●				○		●	●	●				
	Soil B	3.0	●				○		●	●	●	●			
	WR - 1	5.0	●			●			●	●	●	●	●		
	WR - 2	15.0	●			●	○		●	●	●	●	●		
	F sand		●			●									
	Mix 1	P' = 2/1	●			●	○								Soil A + WR - 1 (Weathered rock)
	〃	〃 1/1	●			●	○								
	〃	〃 1/2	●			●	○								
	Mix 2	〃 2/1	●	○	○	●	○								Soil A + F sand (Sand)
	〃	〃 1/1	●	○	○	●	○								
	〃	〃 1/2	●	○	○	●	○								
	Mix 3	〃 2/1	●												Soil B + WR - 1
	〃	〃 1/1	●												
	〃	〃 1/2	●			●	○								
	Mix 4	〃 2/1	●												Soil B + F sand
	〃	〃 1/1	●												
	〃	〃 1/2	●			●	○								
	M - TP - 1	2.0													
	〃	3.0	○				○		○	○	○	○			
	M - TP - 2	3.0	○				○		○	○	○	○			
	Marcos 3		○			○	○		○	○	○	○			
	Marcos 4		○			○	○		○	○	○	○			
	Marcos 5		○				○		○	○	○	○			

● Completed

○ Not yet obtained (as of July 1980)

Table. 3 - 8 Laboratory Investigation Items for Soil Materials

Year	Sample number	Depth of sampling (m)	Mechanical tests						Physical tests						Remarks
			Compaction test	Triaxial compression UU	Triaxial compression CU	Permeability	Consolidation		Specific gravity	Grain size analysis	Moisture content	PL and LL	Specific Gravity, Absorption	Field selve analysis	
1980	DA－1	3.0							○	○	○	○		●	
	2	1.0	○			○	○		○	○	○	○		●	
	3	1.0	○			○	○		○	○	○	○		●	
	4	2.0								○				●	
	5	2.0	○			○	○		○	○	○	○		●	
	6	6.0								○				●	
	7	2.0	○			○	○		○	○	○	○		●	
	8	3.0								○				●	
	9	1.0	○			○	○		○	○	○	○		●	
	10	2.0							○	○	○	○		●	
	11	3.0							○	○	○	○		●	
	12	2.0							○	○	○	○		●	
	13													●	
	14	1.0	○			○	○		○	○	○	○		●	
	15	1.0								○				●	

● Completed

○ Not yet obtained (as of July 1980)

Table. 3－9 Laboratory Investigation Items for Soil Materials

Year	Sample number	Depth of sampling (m)	Sand: Seive analysis	Sand: Specific gravity, Absorption	Sand: Unit weight	Sand: Chemical durability	Sand: Mortar strength	Sand: Washing test	Gravel: Seive analysis	Gravel: Specific gravity, Absorption	Gravel: Unit weight	Gravel: Los Angels test	Gravel: Chemical durability	Gravel: Washing test	Gravel: Concrete strength test	Gravel: Field seive analysis	Remarks
1979	A − 1	0.3	●	●												●	
	〃	1.0	●	●	●	●	●	●	●	●	●	●	●	●	●	●	
	〃	2.0	●	●		●		●	●	●			●	●		●	
	A − 2	0.3	●	●												●	
	〃	1.0	●	●		●		●								●	
	F − 2	1.0	●	●	●	●	●	●	●	●	●	●	●	●	●	●	
	F − 3	*Surface*	●	●		●		●	●	●			●	●		●	
	F − 4	1.0	●	●												●	
	〃	2.0	●	●	●	●	●	●	●	●	●	●	●	●	●	●	
	〃	3.0	●	●		●		●	●	●			●	●		●	
	F − 5	2.0	●	●												●	
	〃	4.0	●	●		●		●								●	
	〃	6.0	●	●												●	
	D − 1	1.0	●	●												●	
	〃	3.0	●	●		●		●	●	●			●	●		●	
	〃	5.0	●	●												●	
	D − 2	1.0	●	●												●	
	〃	3.0	●	●	●	●	●	●	●	●	●	●	●	●	●	●	
	〃	5.0	●	●		●		●								●	
	D − 3	1.0	●	●												●	
	〃	3.0	●	●	●	●	●	●	●	●	●	●	●	●	●	●	
	〃	5.0	●	●		●		●	●	●			●	●		●	
	D − 4	1.0	●	●												●	

● Completed

○ Not yet obtained (as of July 1980)

Table. 3-10 Laboratory Investigation Items for Sand and Gravel Materials (No. 1)

Year	Sample number	Depth of sampling (m)	Sand						Gravel								Remarks
			Seive analysis	Specific gravity, Absorption	Unit weight	Chemical durability	Mortar strength	Washing test	Seive analysis	Specific gravity, Absorption	Unit weight	Los Angels test	Chemical durability	Washing test	Concrete strength test	Field seive analysis	
1979	D – 4	3.0	●	●		●		●	●	●			●	●		●	
	〃	5.0	●	●												●	
	D – 5	1.0	●	●												●	
	〃	2.0	●	●		●		●	●	●			●	●		●	
	〃	4.0	●	●												●	
	D – 6	1.5	●	●		●		●	●	●			●	●		●	
	D – 7	1.0	●	●		●		●								●	
	D – 8	1.0	●	●		●		●	●	●			●	●		●	
	D – 9	1.0	●	●		●		●									
	F – 4 Crushed sand			●		●	●										F-4, 2 m
	D – 3 Crushed sand			●		●	●										D-3, 3 m
	Sta. Monica A		●	●	●	●		●									Beach sand
	〃 B		●	●	●	●		●									〃
	〃 C		●	●	●	●		●									〃
	〃 D		●	●	●	●		●									〃
	Abiawin		●	●	●	●		●									
	Sand Stone									●		●					
	〃 B									●		●					
	Lime Stone									●		●					
	Basalt									●		●					

● Completed

○ Not yet obtained (as of July 1980)

Table. 3 – 11 Laboratory Investigation Items for Sand and Gravely Materials (No.2)

Year	Sample number	Depth of sampling (m)	Sand: Selve analysis	Sand: Specific gravity, Absorption	Sand: Unit weight	Sand: Chemical durability	Sand: Mortar strength	Sand: Washing test	Gravel: Selve analysis	Gravel: Specific gravity, Absorption	Gravel: Unit weight	Gravel: Los Angels test	Gravel: Chemical durability	Gravel: Washing test	Gravel: Concrete strength test	Gravel: Field seive analysis	Remarks
1980	A sand	0.5		●	●	●	●	●									
	D sand	〃		●	●	●	●	●									
	F sand	〃	●	●	●	●	●	●									FC + FF
	F.F sand	〃	●	●	●	●	●	●									F Area
	F.C sand	〃	●	●	●	●	●	●									F Area
	S.T.M sand	〃	●	●	●	●	●	●									Beach sand
	D gravel	〃							●	●	●	●	●	●	●		For Fine Aggregate (FC+STM)
	Lime Stone	Surface								●		○	●				
	Sand Stone	〃								●		○	●				
	Gray wacke	〃								●		○	●				
	GS 1-1								●	●			●				
	STM-F	0.5	●	○													Beach sand
	STM-C	〃	●	○	○	○	○	○									Beach sand
	B-1	〃	●	○	○	○	○	○								●	River sand (B-1 – B-4)
	B-2	〃	●	○	○	○	○	○								●	
	B-3	〃	○	○	○	○	○	○								●	
	B-4	〃	○	○	○	○	○	○									
	B-5															●	
	B gravel	0.5							●	○	○	○	○	○	○		
	DA-3 gravel								○	○	○	○	○	○	○		

● Completed

○ Not yet obtained (as of July 1980)

Table. 3-12 Laboratory Investigation Items for Sand and Gravely Materials (No. 3)

The frequency of physical property for strongly weathered

Simbol	Location	Nos.	Max.Gs.	Min. Gs.	Ave. Gs.
▨	I - Up	30	2.91	2.66	2.82
▤	II	15	2.99	2.71	2.86
▧	I - Down	6	2.76	2.63	2.69
☐	Total	51	2.99	2.63	2.82

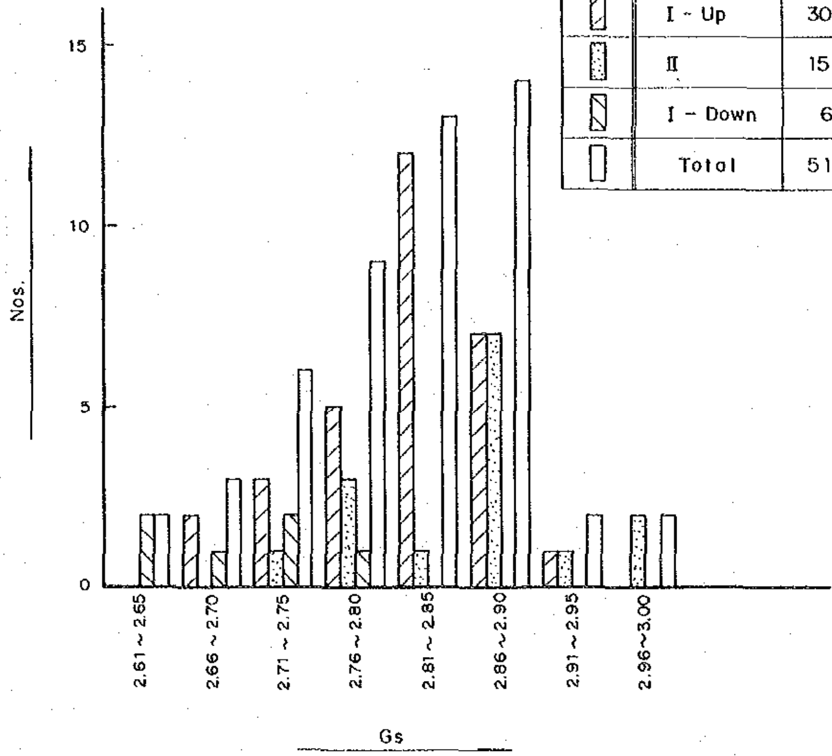


Table 4 - I Specific gravity, Gs

Simbol	Location	Nos.	Max. Wf.	Min. Wf.	Ave. Wf.
▨	I - Up	30	78.5	31.8	62.4
▤	II	16	66.4	15.5	51.2
▧	I - Down	6	64.4	49.1	55.0
☐	Total	52	78.5	15.5	58.1

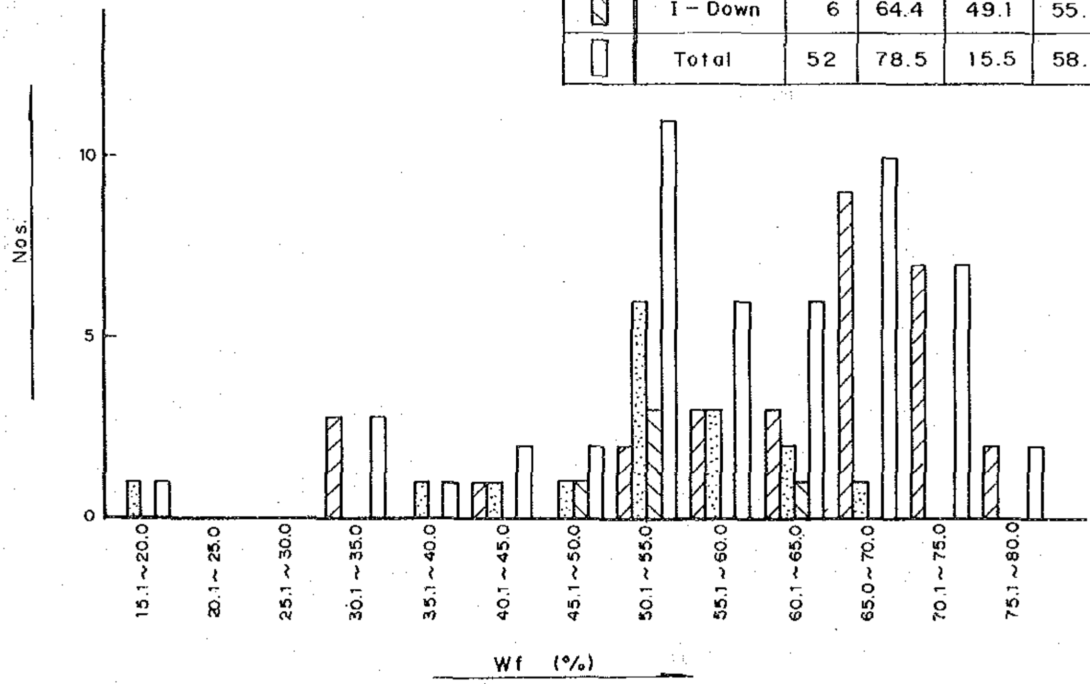


Table 4 - 2 Moisture content, Wf

The frequency of physical property for strongly weathered

Simbol	Location	Nos.	Max. ratio	Min. ratio	Ave. ratio
(hatched)	I - Up	30	67.0	15.0	42.9
(dotted)	II	15	71.0	19.0	45.2
(back-hatched)	I - Down	6	64.0	46.0	56.7
(blank)	Total	51	71.0	15.0	45.2

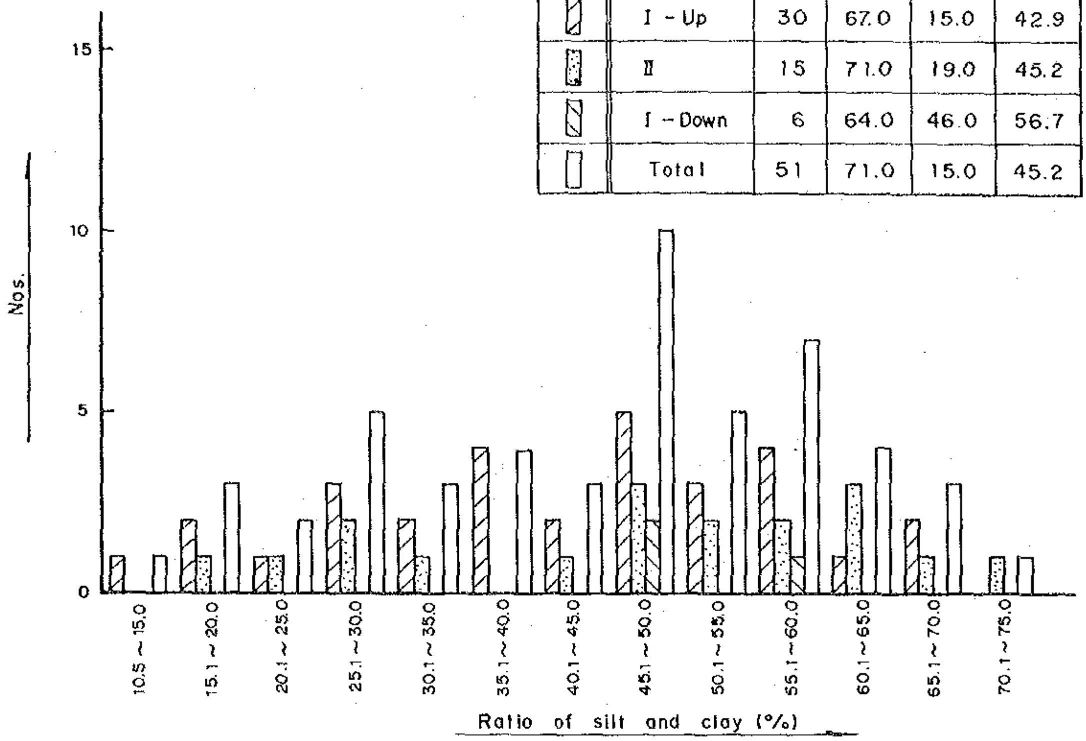


Table. 4-3 Ratio of silt and clay

Simbol	Location	Nos.	Max. Ip	Min. Ip	Ave. Ip
(hatched)	I - Up	30	62.5	19.8	36.7
(dotted)	II	15	38.9	20.7	28.3
(back-hatched)	I - Down	6	25.5	19.7	22.4
(blank)	Total	51	62.5	19.7	32.6

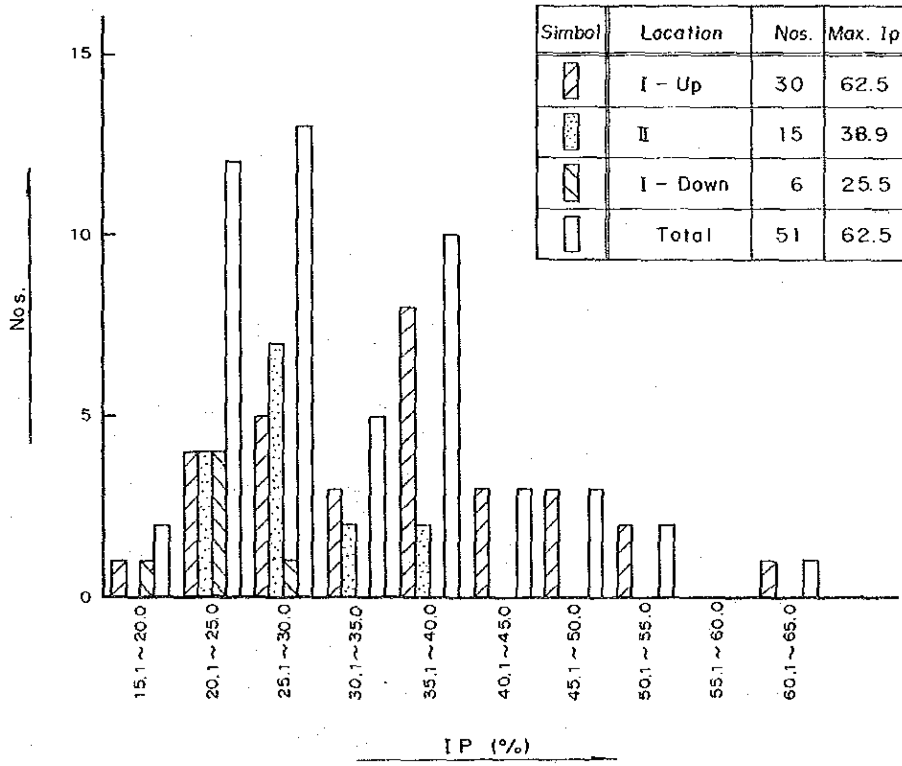


Table. 4-4 Plasticity index, Ip

Sample No.		Initial condition W (%)	Initial condition γ_d (t/m³)	Yielding stress Py (kg/cm²)		
I Up stream borrow area	I-TP-1 (h=2.5[m])	39.3	1.16	5.2		γ_d max Wopt condition
	I-TP-3 (2.5~3.0)	40.3	1.18	6.0		
	I-TP-4 (3.0)	40.8	1.14	5.0		
	I-TP-5 (3.0)	27.7	1.41	> 20	◎	
	I-TP-6 (3.0)	33.0	1.29	10 < Py < 20		
	I-TP-8 (2.5~3.0)	44.8	1.07	4.7		
	I-TP-10 (2.5~3.0)	43.5	1.11	9.0		
	I-TP-12 (2.5~3.0)	27.3	1.43	> 20	◎	
	I-TP-13 (3.0)	43.7	1.17	8.8		
	I-TP-14 (6.0)	35.9	1.30	10 < Py < 20		
	I-TP-16 (2.5~3.0)	38.8	1.18	7.0		
	I-TP-17 (2.5~3.0)	43.5	1.17	4.5		
II Borrow area	II-TP-1		1.12	4.5		γ_d max x 95% Wet side condition
	II-TP-2		1.15	7.0		
	II-TP-4	>40	1.15	6.0		
	II-TP-5		1.27	3.5		
	II-TP-6		1.08	3.0		

Table 4-5 Consolidation Tests
(Heavily weathered materials)

Summary of fine aggregates

Aggregate	Sieve (mm)	Sample name and percentage passing sieve (%)																				Standard value
		Zone A		Zone B		Zone D		Zone F				River sand				Beach sand						
Coarse aggregate	40																					95 ~ 100 (%)
	20																					35 ~ 70
	10																					10 ~ 30
	5																					0 ~ 5
	FM																					6 ~ 8
	Decision																					
Fine aggregate	5.0	99.9	○	100	○	99.5	○	99.9	○			99.7	○			100	○					95 ~ 100 (%)
	2.5	85.3	○	74.4	×	83.8	○	79.5	△			82.6	○			94.0	○					80 ~ 100
	1.5	50.0	○	44.8	×	67.9	○	38.8	×			57.1	○			82.7	○					50 ~ 85
	0.6	18.3	×	19.0	×	51.3	○	12.9	×			35.5	○			60.8	△					25 ~ 60
	0.3	3.2	×	10.1	○	23.1	○	3.6	×			14.8	○			23.6	○					10 ~ 30
	0.15	0.6	×	3.7	○	7.2	○	1.2	×			4.6	○			3.0	○					2 ~ 10
	0.075	0.3		1.3		2.3		0.5				1.5				0.2						
	FM	3.4		3.5		2.7		3.6				3.1				2.4						2.3 ~ 3.1
	Decision	×		×		○		×				○				○						

Table. 5-1 The results of grain size analysis for concrete aggregates

Zone A

	Sieve (mm)	Sample name and percentage passing sieve (%)																				Standard value
		※A−1 0.3m		A−1 1.0m		A−1 2.0m		A−2 0.3m		※A−2 1.0m												
Coarse aggregate	40	100	○	100	○	100	○	100	○	100	○											95 ~ 100 (%)
	20	93.9	×	49.6	○	43.3	○	100	×	96.5	×											35 ~ 70
	10	75.7	×	15.4	○	25.0	○	96.7	×	87.6	×											10 ~ 30
	5	0	○	0	○	0	○	0	○	0	○											0 ~ 5
	FM	6.3		7.4		7.3		6.0		6.2												6 ~ 8
	Decision	×		○		○		×		×												
Fine aggregate	5.0	100	○	99.6	○	100	○	100	○	100	○											95 ~ 100 (%)
	2.5	81.3	○	76.7	△	85.5	○	92.5	○	90.3	○											80 ~ 100
	1.5	45.3	△	25.3	×	52.1	○	64.1	○	63.1	○											50 ~ 85
	0.6	13.4	×	7.8	×	17.5	×	24.5	△	28.2	○											25 ~ 60
	0.3	2.0	×	1.2	×	3.0	×	4.3	×	5.7	×											10 ~ 30
	0.15	0.4	×	0.3	×	0.6	×	0.8	×	0.7	×											2 ~ 10
	0.075	0.1		0.2		0.3		0.4		0.3												
	FM	3.6		3.9		3.4		3.1		3.1												2.3 ~ 3.1
	Decision	×		×		×		×		×												

Table. 5-2 The results of grain size analysis for concrete aggregates

Zone F

Sieve (mm)		Sample name and percentage passing sieve (%)																				Standard value
		F-2 1.0 m		F-3 surface		F-4 1.0 m		F-4 2.0 m		F-4 3.0 m		※F-5 2.0 m		※F-5 4.0 m		F-5 6.0 m						
Coarse aggregate	40	100	O	100	O			100	O	100	O	100	O	100	O							95 ~ 100 (%)
	20	61.6	O	72.0	△			65.7	O	95.0	X	92.8	X	95.2	X							35 ~ 70
	10	31.6	△	27.9	O			36.6	△	62.6	X	81.7	X	80.8	X							10 ~ 30
	5	0	O	0	O			0	O	0	O	0	O	0	O							0 ~ 5
	FM	7.1		7.0				7.0		6.4		6.3		6.2								6 ~ 8
	Decision	O		O				O		X		X		X								
Fine aggregate	5.0	99.9	O	100	O	100	O	99.9	O	99.5	O	99.8	O	100	O	100	O					95 ~ 100 (%)
	2.5	79.7	X	84.9	O	79.8	△	76.8	△	78.6	△	79.4	△	80.6	O	76.3	△					80 ~ 100
	1.5	45.0	X	57.9	O	32.7	X	36.8	X	41.8	X	33.3	X	33.7	X	28.8	X					50 ~ 85
	0.6	16.0	X	33.1	O	7.0	X	11.7	X	11.4	X	8.5	X	8.7	X	6.7	X					25 ~ 60
	0.3	4.8	X	15.0	O	1.3	X	3.2	X	1.9	X	1.8	X	2.1	X	1.7	X					10 ~ 30
	0.15	1.6	X	3.6	O	0.5	X	1.3	X	0.7	X	0.5	X	0.7	X	0.5	X					2 ~ 10
	0.075	0.7		0.7		0.3		0.7		0.4		0.3		0.4		0.3						
	FM	3.5		3.1		3.8		3.7		3.7		3.8		3.7		3.9						2.3 ~ 3.1
	Decision	X		O		X		X		X		X		X		X						

Table. 5-3 The results of grain size analysis for concrete aggregates

Zone D

Sieve (mm)		Sample name and percentage passing sieve (%)																				Standard value
		※D-1 1.0m		D-1 3.0m		※D-1 5.0m		※D-2 1.0m		D-2 3.0m		※D-2 5.0m		※D-3 1.0m		D-3 3.0m		D-3 5.0m		※D-4 1.0m		
Coarse aggregate	40	100	○	100	○	100	○	100	○	100	○	100	○	100	○	100	○	100	○	100	○	95 ~ 100(%)
	20	60.3	○	67.5	○	70.4	△	29.4	X	46.0	○	45.5	○	59.4	○	58.3	○	41.0	○	79.5	X	35 ~ 70
	10	30.3	△	37.6	△	37.2	△	16.1	○	12.1	○	19.9	○	31.6	△	19.8	○	10.6	○	49.8	X	10 ~ 30
	5	0	○	0	○	0	○	0	○	0	○	0	○	0	○	0	○	0	○	0	○	0 ~ 5
	FM	7.1		6.9		6.9		7.5		7.4		7.3		7.1		7.2		7.5		6.7		6 ~ 8
	Decision	○		○		X		X		○		○		○		○		○		X		
Fine aggregate	5.0	99.8	○	99.5	○	100	○	100	○	99.9	○	99.5	○	99.4	○	99.9	○	100	○	99.9	○	95 ~ 100(%)
	2.5	79.7	△	87.9	○	87.6	○	95.3	○	88.6	○	96.9	○	79.1	△	90.1	○	89.1	○	67.9	X	80 ~ 100
	1.5	52.5	○	69.5	○	71.9	○	90.8	X	82.4	○	92.3	X	58.6	○	84.7	○	76.0	○	43.8	X	50 ~ 85
	0.6	31.5	○	43.0	○	55.9	○	75.1	X	66.9	X	74.0	X	40.5	○	68.1	X	53.5	○	31.1	○	25 ~ 60
	0.3	12.9	○	12.5	○	31.3	△	32.4	△	28.8	○	38.1	X	17.3	○	28.7	○	21.0	○	12.4	○	10 ~ 30
	0.15	5.6	○	2.4	○	7.3	○	9.7	○	8.2	○	11.7	△	5.2	○	7.9	○	6.4	○	2.8	○	2 ~ 10
	0.075	2.4		0.9		1.5		3.3		2.6		3.3		1.6		2.3		1.9		0.8		
	FM	3.2		2.9		2.5		2.0		2.3		1.9		3.0		2.2		2.5		3.4		2.3 ~ 3.1
	Decision	X		○		○		X		X		X		○		X		○		X		

Table. 5-4 The results of grain size analysis for concrete aggregates

Zone D

Sieve (mm)		Sample name and percentage passing sieve (%)																				Standard value
		D-4 3.0m		※D-4 5.0m		※D-5 1.0m		D-5 2.0m		※D-5 4.0m		D-6 1.5m		※D-7 1.0m		D-8 1.0m		D-9 1.0m				
Coarse aggregate	40	100	○	100	○	100	○	100	○	100	○	100	○	100	○	100	○					95 ~ 100 (%)
	20	55.8	○	66.1	○	78.3	X	79.9	X	71.0	△	62.2	○	75.6	△	96.3	X					35 ~ 70
	10	11.7	○	32.6	△	47.9	X	35.1	X	34.9	△	30.9	△	45.3	X	63.9	X					10 ~ 30
	5	0	○	0	○	0	○	0	○	0	○	0	○	0	○	0	○					0 ~ 5
	FM	7.3		7.0		6.7		6.9		6.9		7.1		6.8		6.4						6 ~ 8
	Decision	○		○		X		X		○		○		X		X						
Fine aggregate	5.0	99.9	○	100	○	96.2	○	99.4	○	99.3	○	99.0	○	99.8	○	99.4	[illegible]	100	○			95 ~ 100 (%)
	2.5	76.8	△	86.2	○	78.6	△	75.5	△	80.3	○	80.1	○	77.3	△	74.4	△	99.9	○			80 ~ 100
	1.5	59.1	○	73.8	○	53.7	○	55.5	○	68.7	○	52.3	○	60.5	○	45.1	△	99.1	X			50 ~ 85
	0.6	44.0	○	60.7	△	35.2	○	41.9	○	59.5	○	33.1	○	45.4	○	26.9	○	88.4	X			25 ~ 60
	0.3	13.9	○	26.6	○	14.3	○	18.2	○	39.4	X	16.3	○	14.2	○	13.8	○	46.1	X			10 ~ 30
	0.15	3.2	○	6.1	○	3.9	○	7.4	○	18.9	X	7.8	○	3.3	○	6.8	○	13.1	X			2 ~ 10
	0.075	1.2		1.3		1.3		2.5		5.3		3.7	○	1.0		2.6		3.0				
	FM	3.0		2.5		3.2		3.0		2.3		3.1		3.0		3.1		1.5				2.3 ~ 3.1
	Decision	○		○		X		○		○		○		○		X		X				

Table. 5-5 The results of grain size analysis for concrete aggregates

Sieve (mm)		Sample name and percentage passing sieve (%)																				Standard value
		A sand		D sand		F.F sand		F.C sand		B-1		B-2		B-3		B-5						
Coarse aggregate	40									100	O	100	O	100	O	100	O					95 ~ 100 (%)
	20									74.8	X	75.0	X	71.2	Δ	47.3	O					35 ~ 70
	10									42.6	X	41.1	X	37.8	X	18.3	O					10 ~ 30
	5									0	O	0	O	0	O	0	O					0 ~ 5
	FM									6.8		6.8		6.9		7.3						6 ~ 8
	Decision									X		X		X		O						
Fine aggregate	5.0	100	O	100	O	100	O	100	O	100	O	100	O									95 ~ 100 (%)
	2.5	88.4	O	70.5	X	99.2	O	72.3	X	66.1	X	82.7	O									80 ~ 100
	1.5	57.4	O	30.2	X	98.1	X	37.6	X	29.7	X	59.9	O									50 ~ 85
	0.6	17.8	X	8.9	X	89.4	X	19.5	X	11.6	X	26.4	O									25 ~ 60
	0.3	2.1	X	3.3	X	32.4	Δ	6.6	X	5.2	X	15.0	O									10 ~ 30
	0.15	0.4	X	0.5	X	3.3	O	2.0	O	1.6	X	5.7	O									2 ~ 10
	0.075	0.1		0.1		0.4		1.0		0.7		1.9										
	FM	3.3		3.9		1.8		3.6		3.9		3.1										2.3 ~ 3.1
	Decision	X		X		X		X		X		O										

Table. 5-6 The results of grain size analysis for concrete aggregates

Beach sand

Sieve (mm)		Sta. monica A		B		C		D		Ablowin		STM sand		STMF sand		STMC sand						Standard value
		Sample name and percentage passing sieve (%)																				
Coarse aggregate	40																					95 ~ 100 (%)
	20																					35 ~ 70
	10																					10 ~ 30
	5																					0 ~ 5
	FM																					6 ~ 8
	Decision																					
Fine aggregate	5.0	100	○	100	○			100	○	100	○			100	○	100	○					95 ~ 100 (%)
	2.5	93.2	○	99.7	○	100	○	79.7	△	91.9	○	100	○	100	○	87.5	○					80 ~ 100
	1.5	74.3	○	97.5	X	96.1	X	59.5	○	77.8	○	99.9	X	99.9	X	56.8	○					50 ~ 85
	0.6	45.3	○	74.2	X	62.9	△	38.9	○	56.4	○	92.0	X	89.7	X	26.7	○					25 ~ 60
	0.3	20.1	○	36.4	X	17.4	○	15.2	○	20.7	○	41.0	X	30.7	△	7.2	X					10 ~ 30
	0.15	3.1	○	5.4	○	1.9	△	1.6	△	2.3	○	5.3	X	3.8	○	0.9	X					2 ~ 10
	0.075	0.2		0.3		0.1		0.1		0.1		0.4		0.3		0.3						
	FM	2.6		1.9		2.2		3.1		2.5		1.6		1.8		3.2						2.3 ~ 3.1
	Decision	○		X		X		○		○		X		X		X						

Table. 5 - 7 The results of grain size analysis for concrete aggregates

F I G U R E S

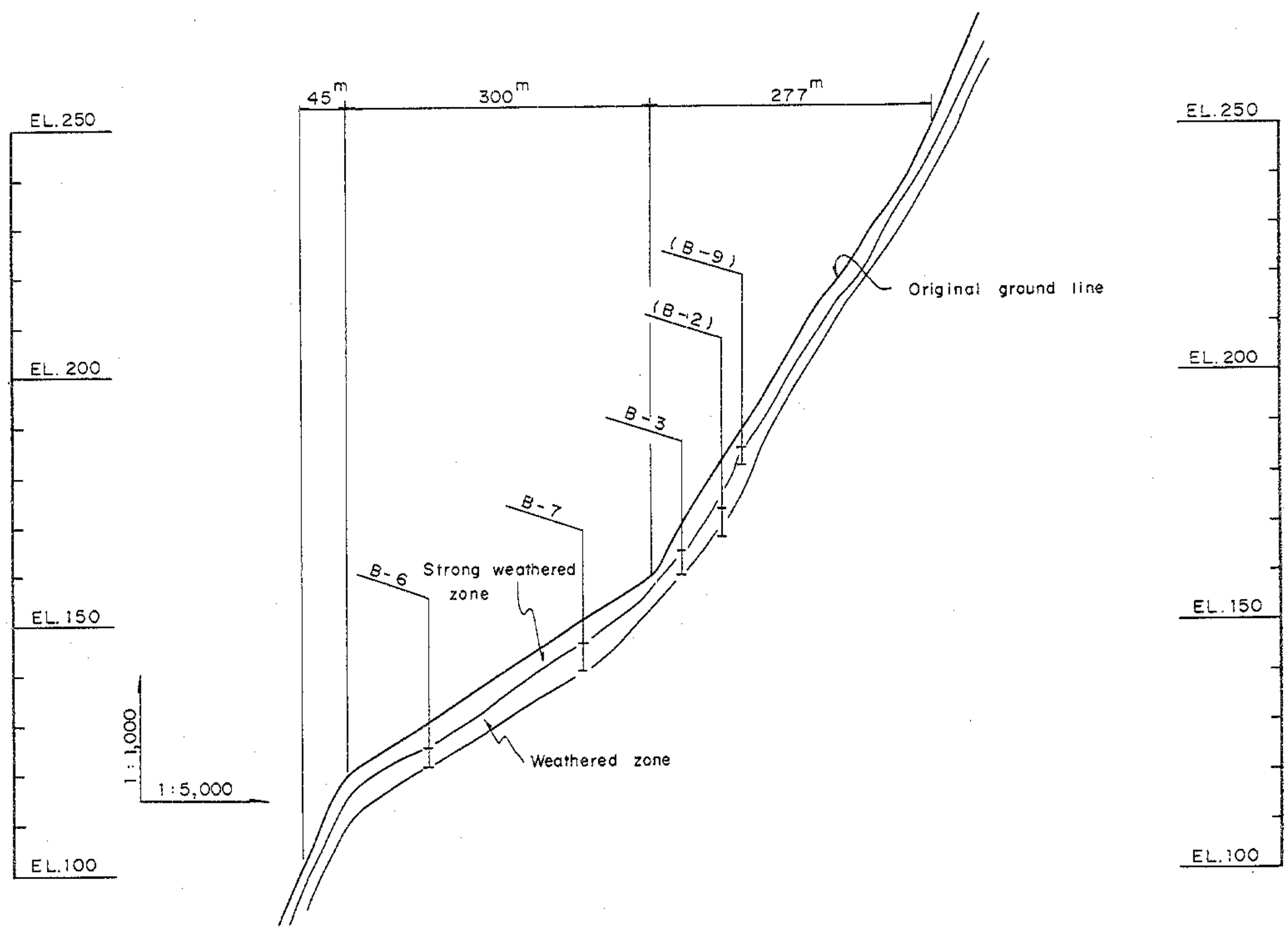


Fig. 2 -1 Distribution of Superficial Weathered Layers

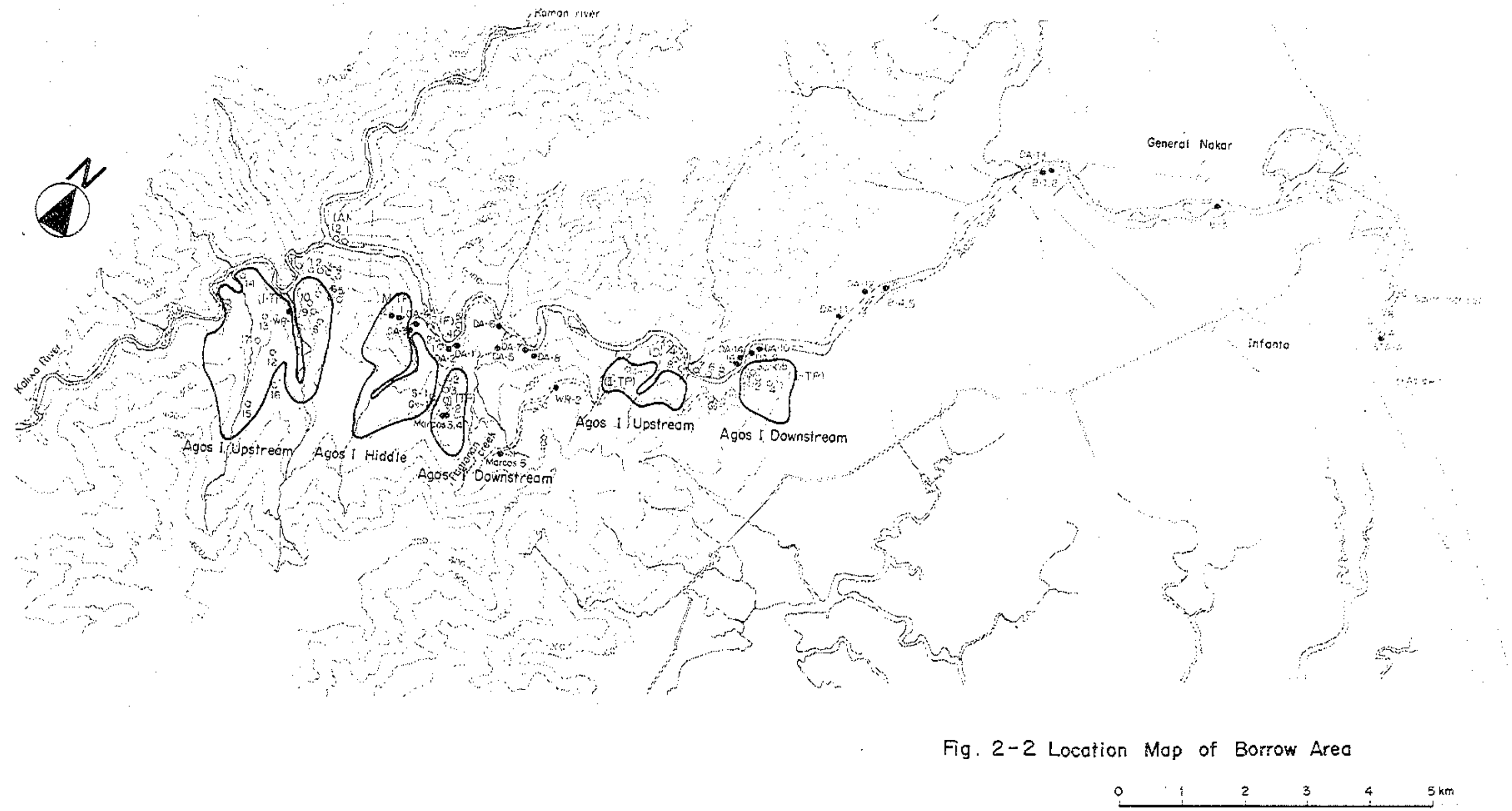


Fig. 2-2 Location Map of Borrow Area

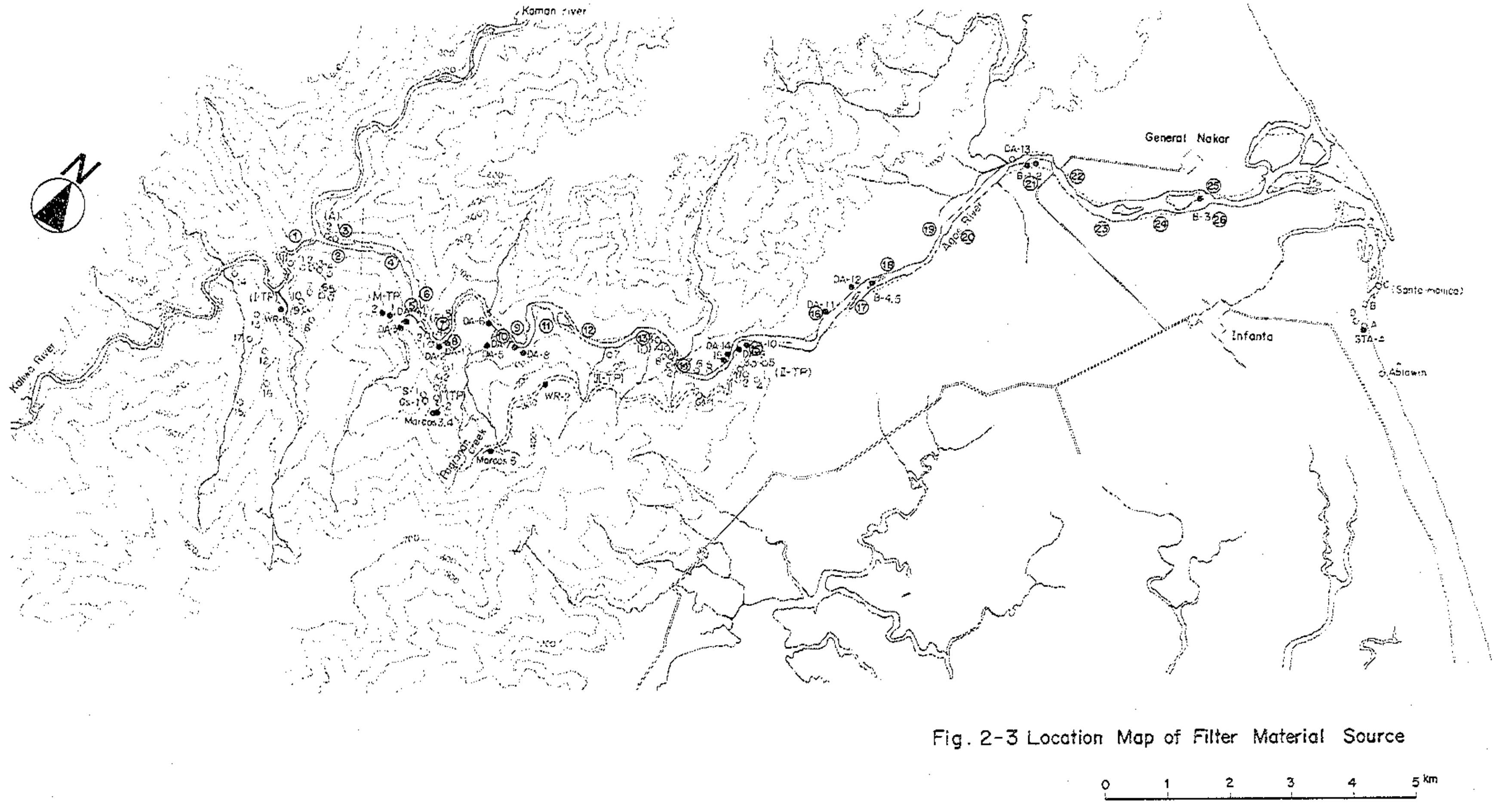


Fig. 2-3 Location Map of Filter Material Source

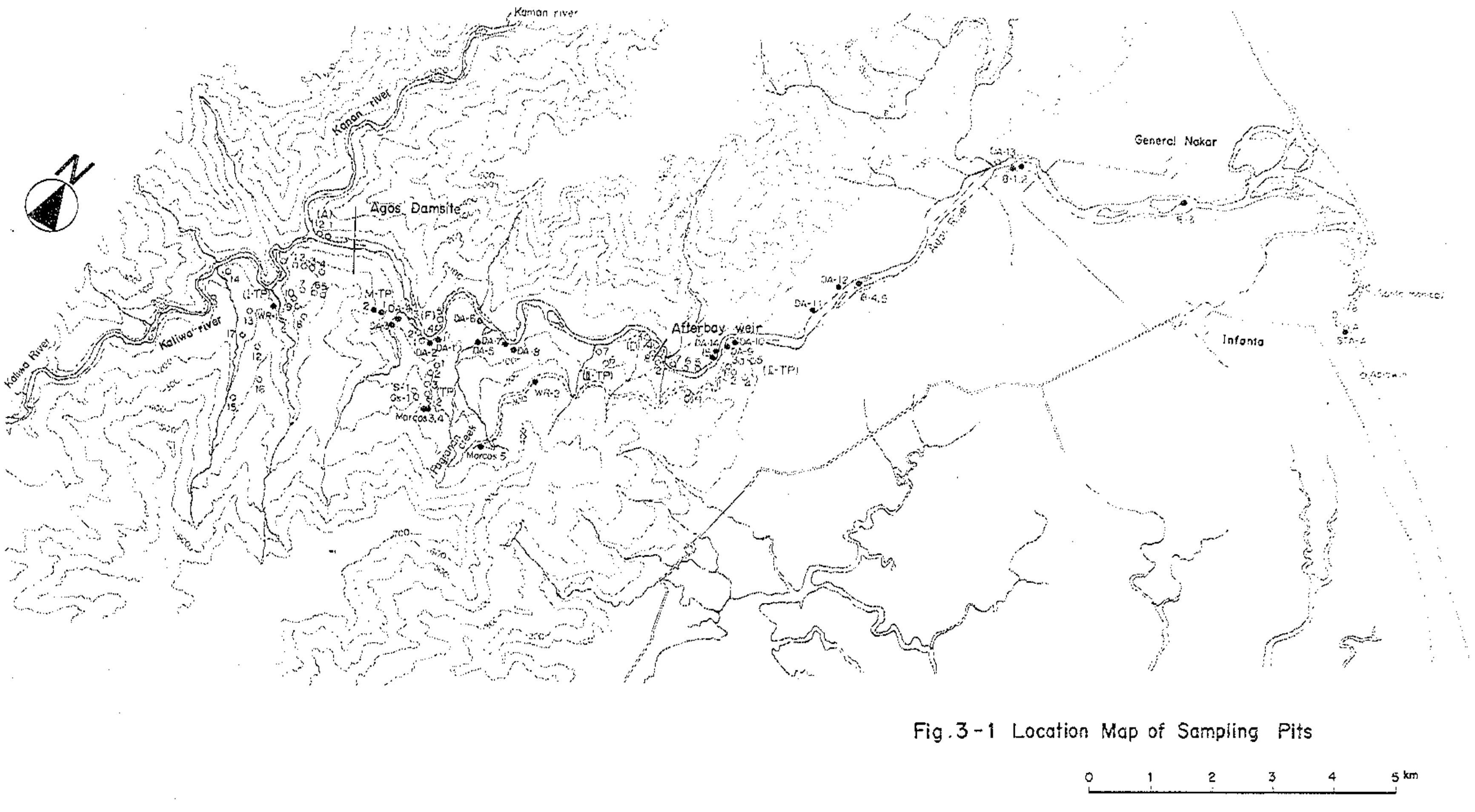
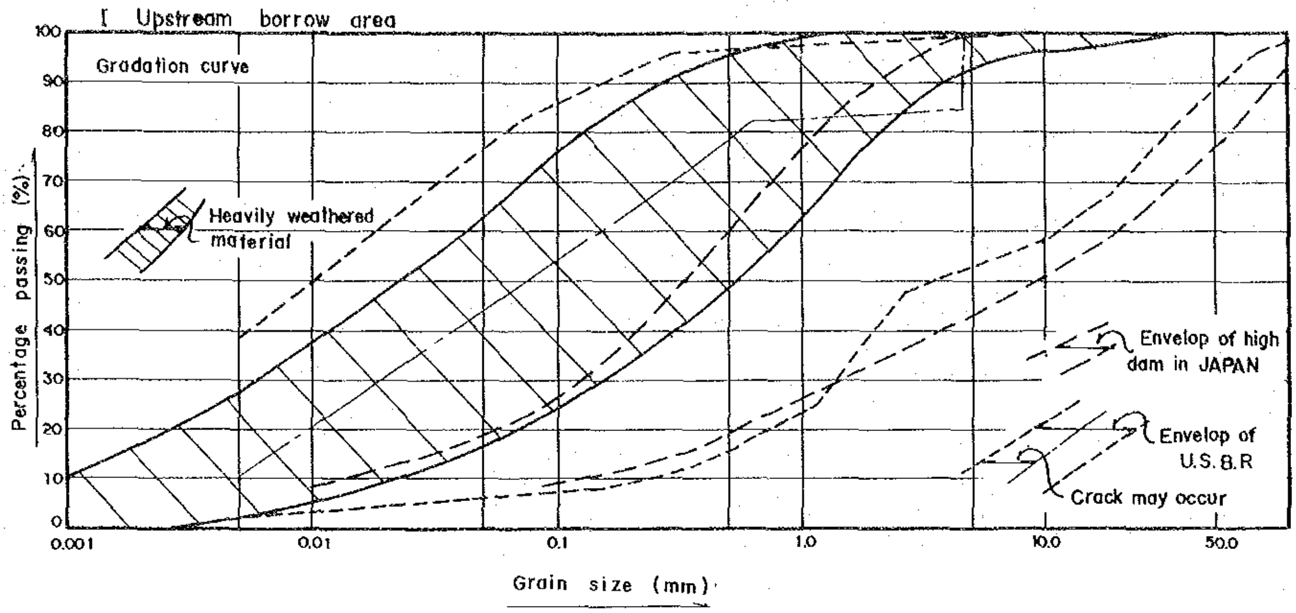


Fig. 3-1 Location Map of Sampling Pits



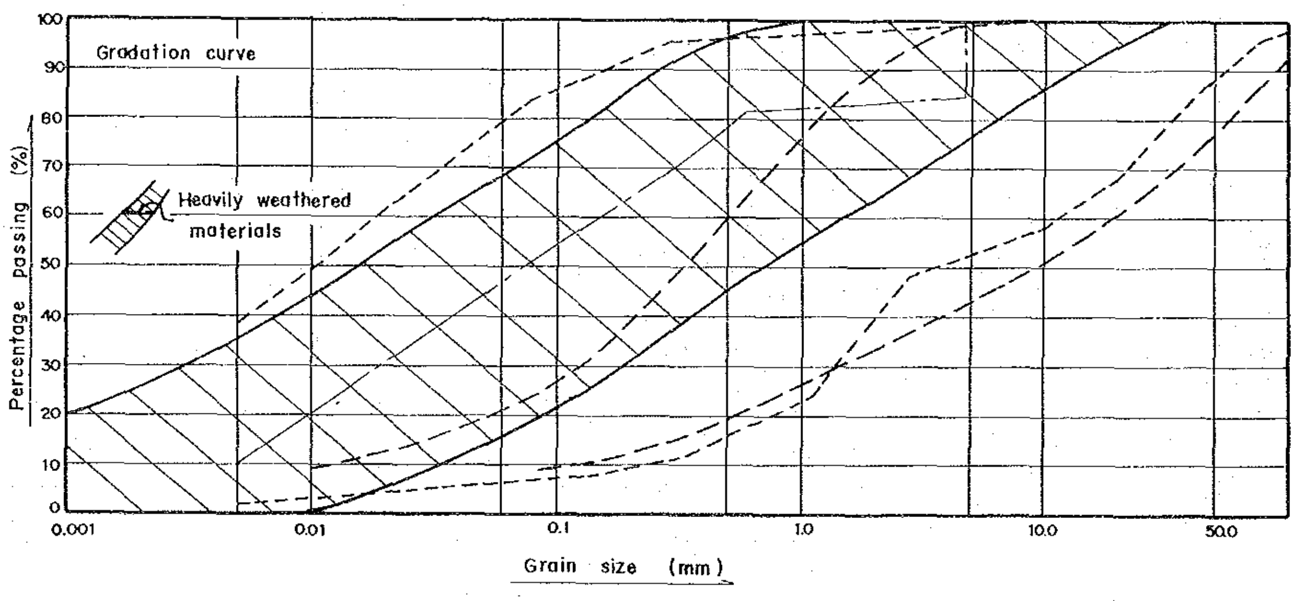
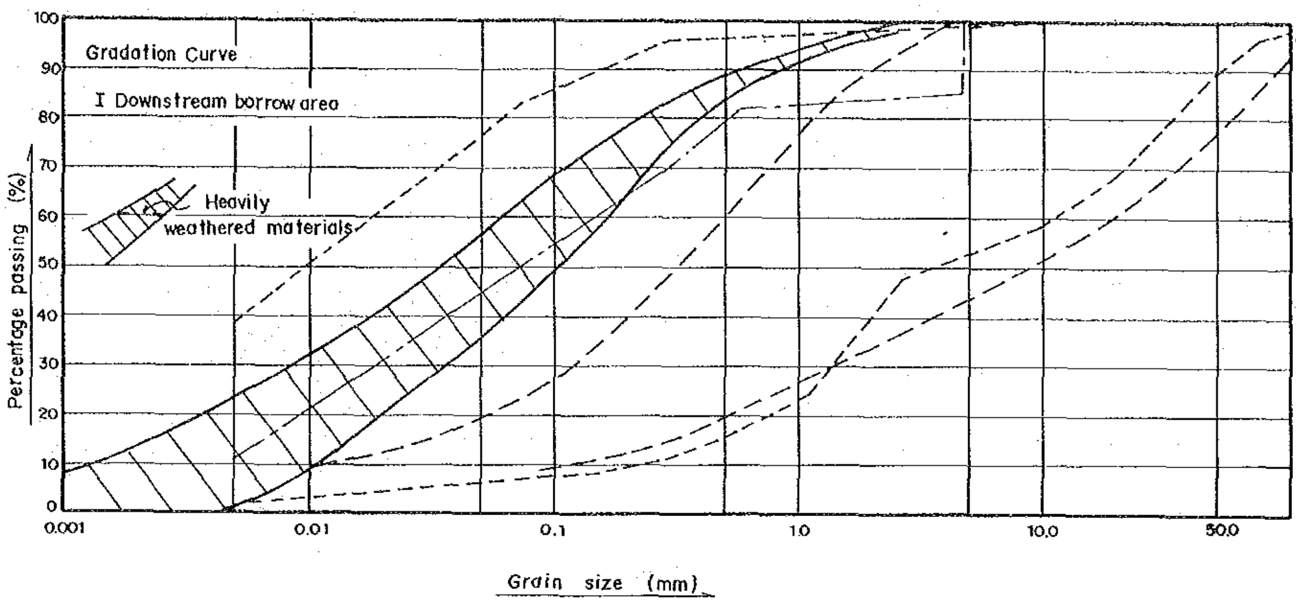


Fig. 4-1 Comparison of Gradation for Core Material



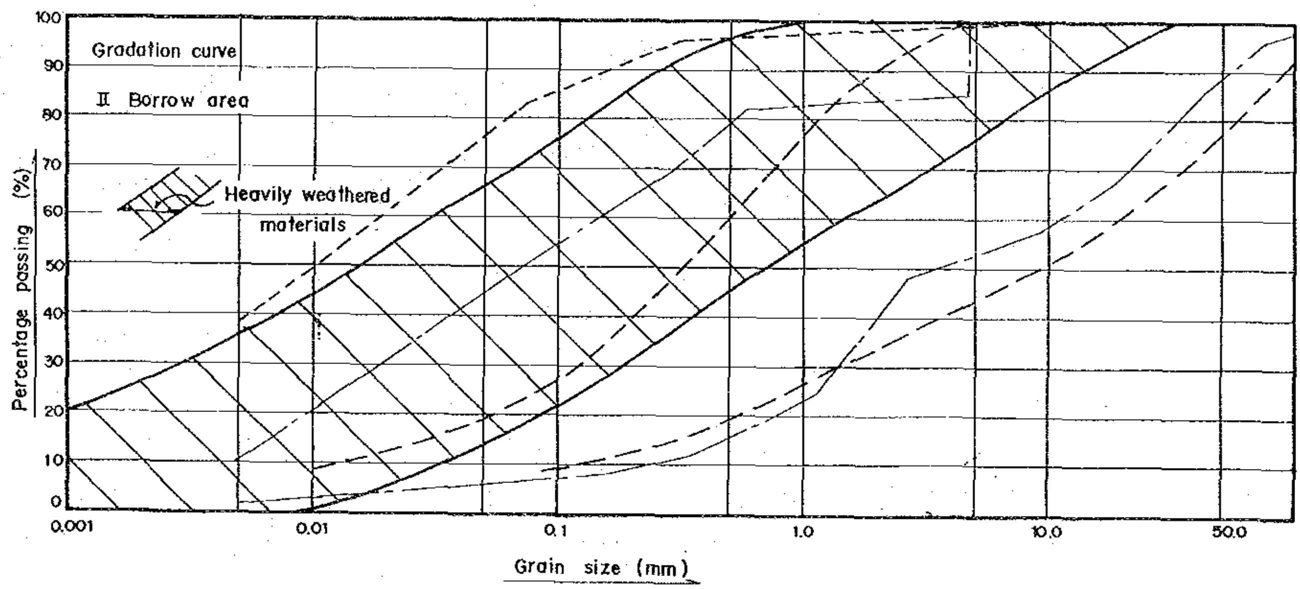
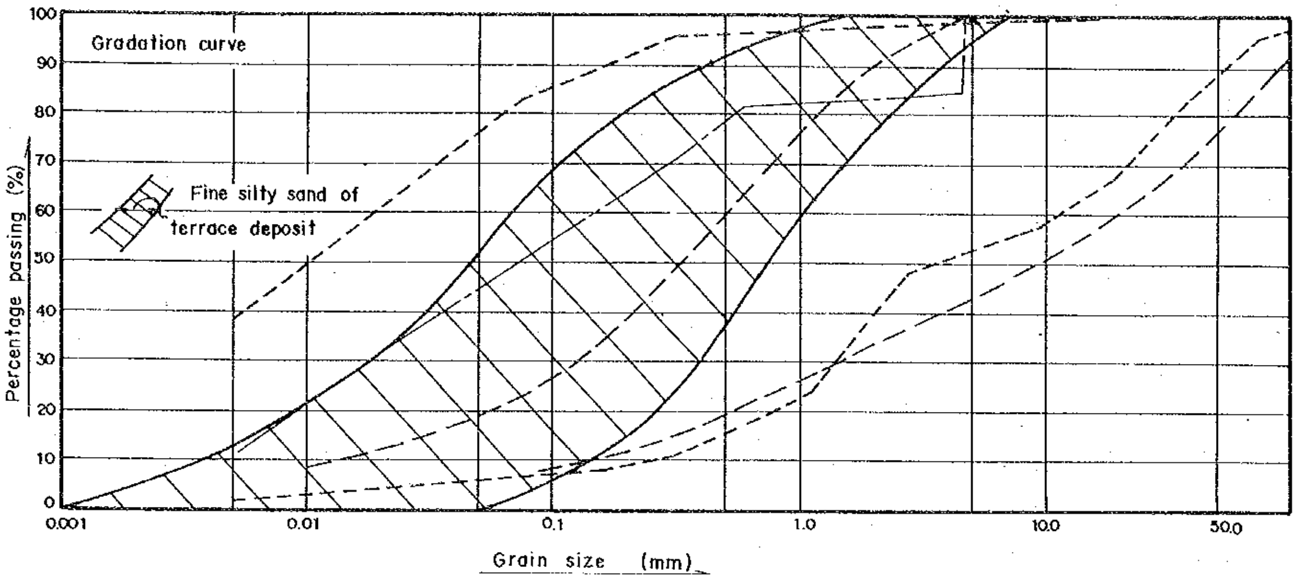


Fig. 4 - 2 Comparison of Gradation for Core Material



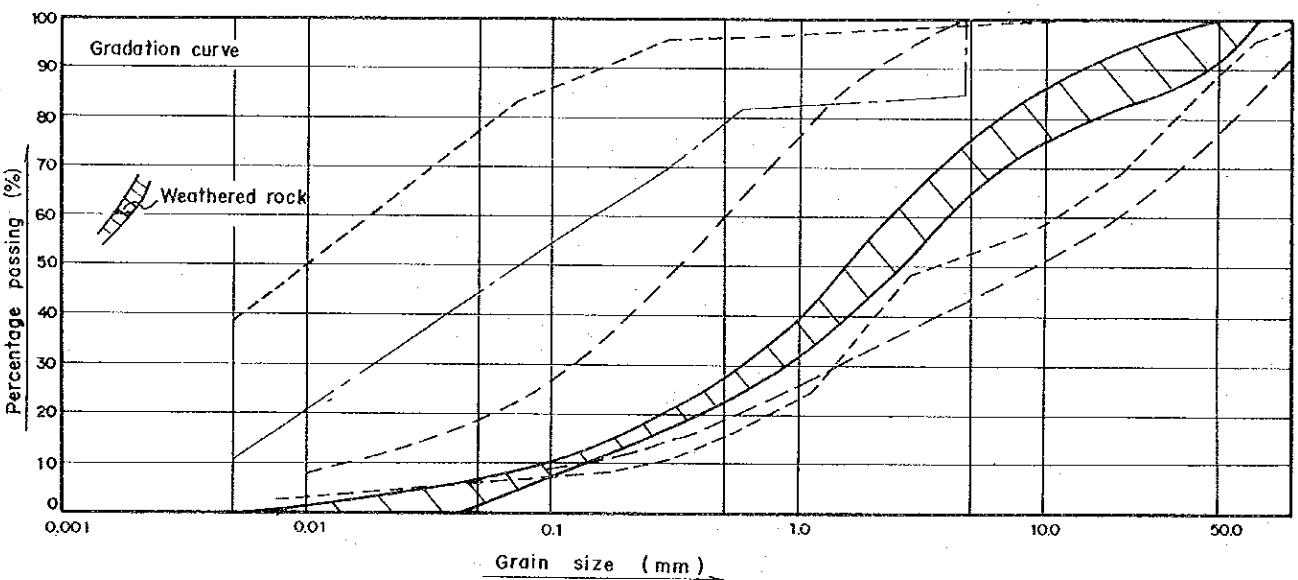


Fig. 4 - 3 Comparison of Gradation for Core Material

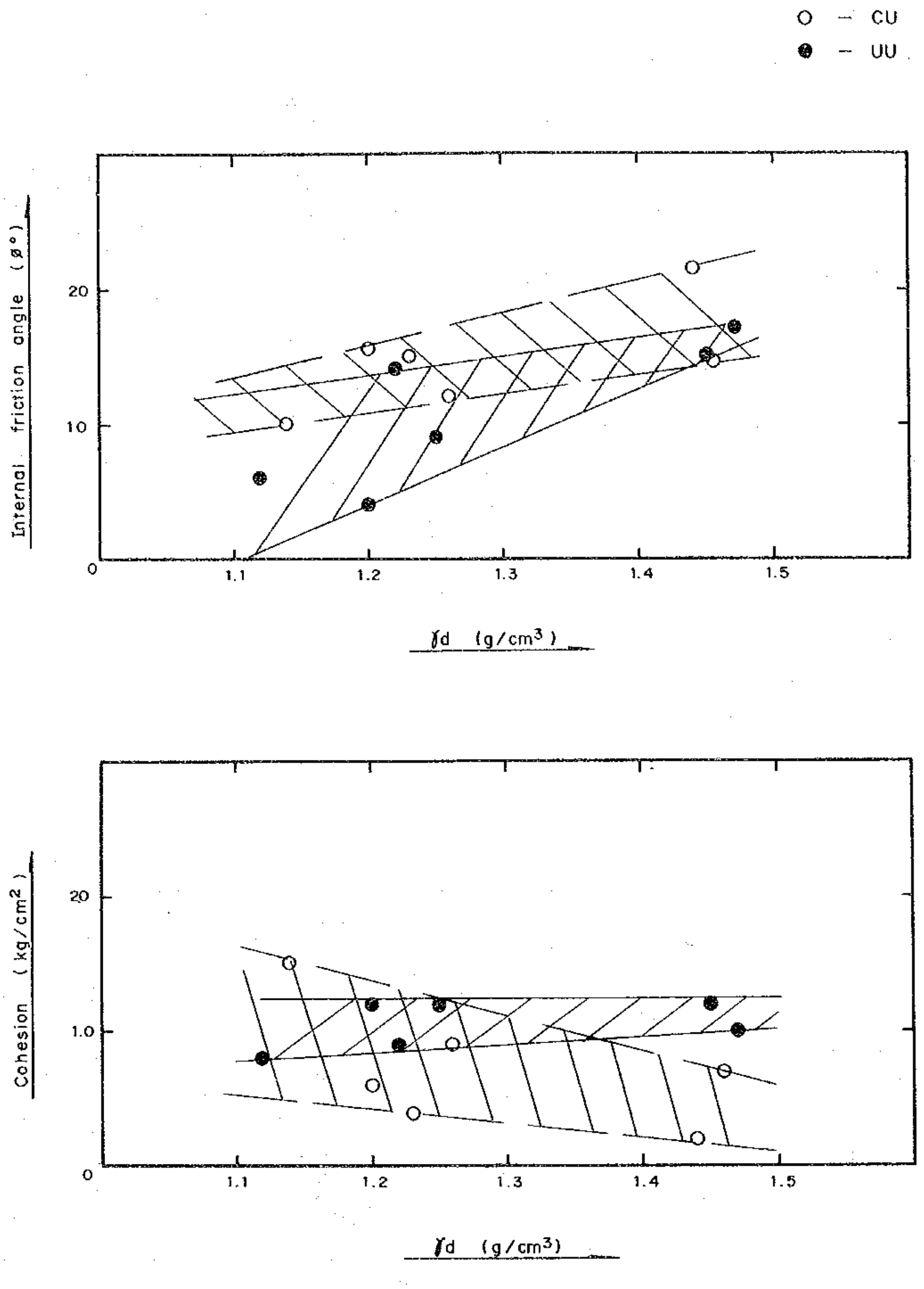
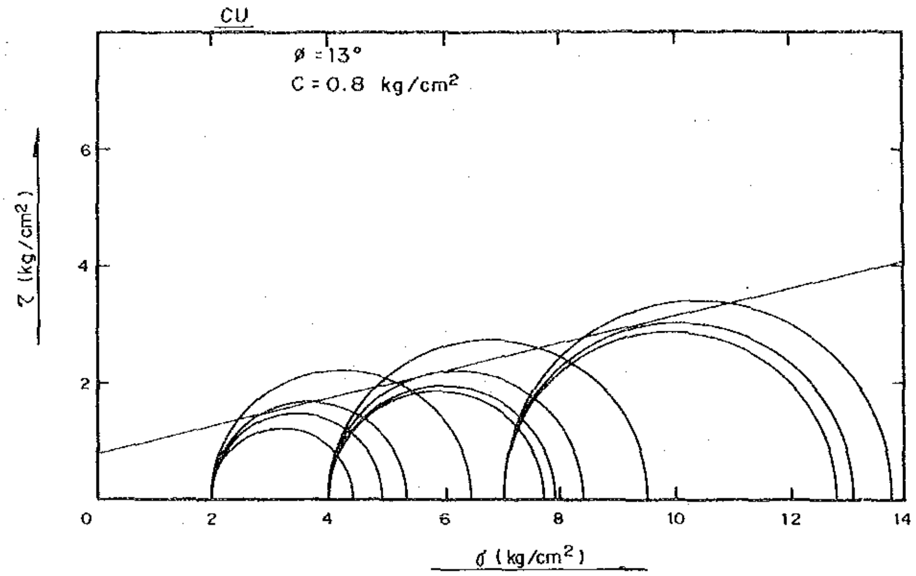


Fig. 4-4 Triaxial Compression Test C,ø – γd
(Heavily Weathered Material)



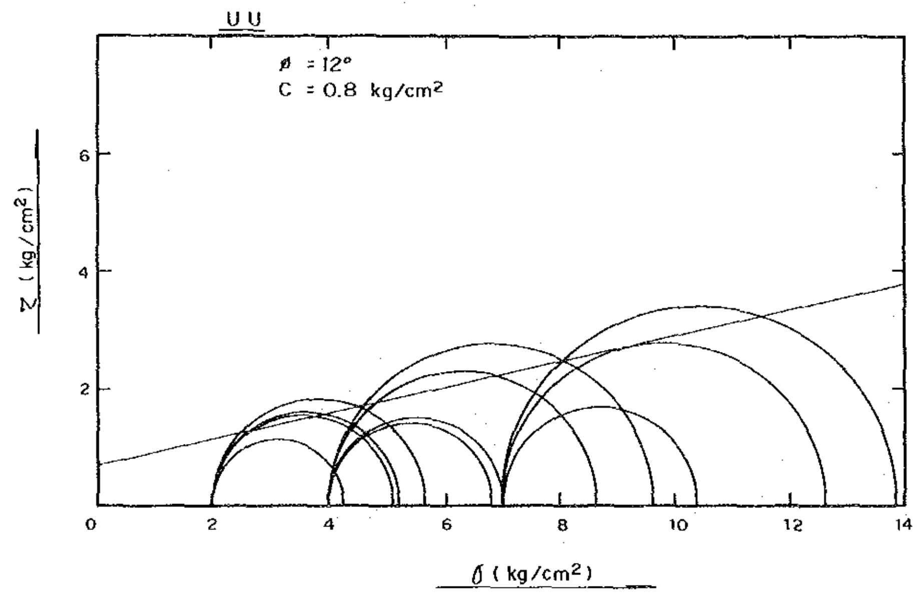


Fig. 4-5 Triaxial Compression Test Results
(Low density group $\gamma d = 1.13 \sim 1.25$ g/cm^2)

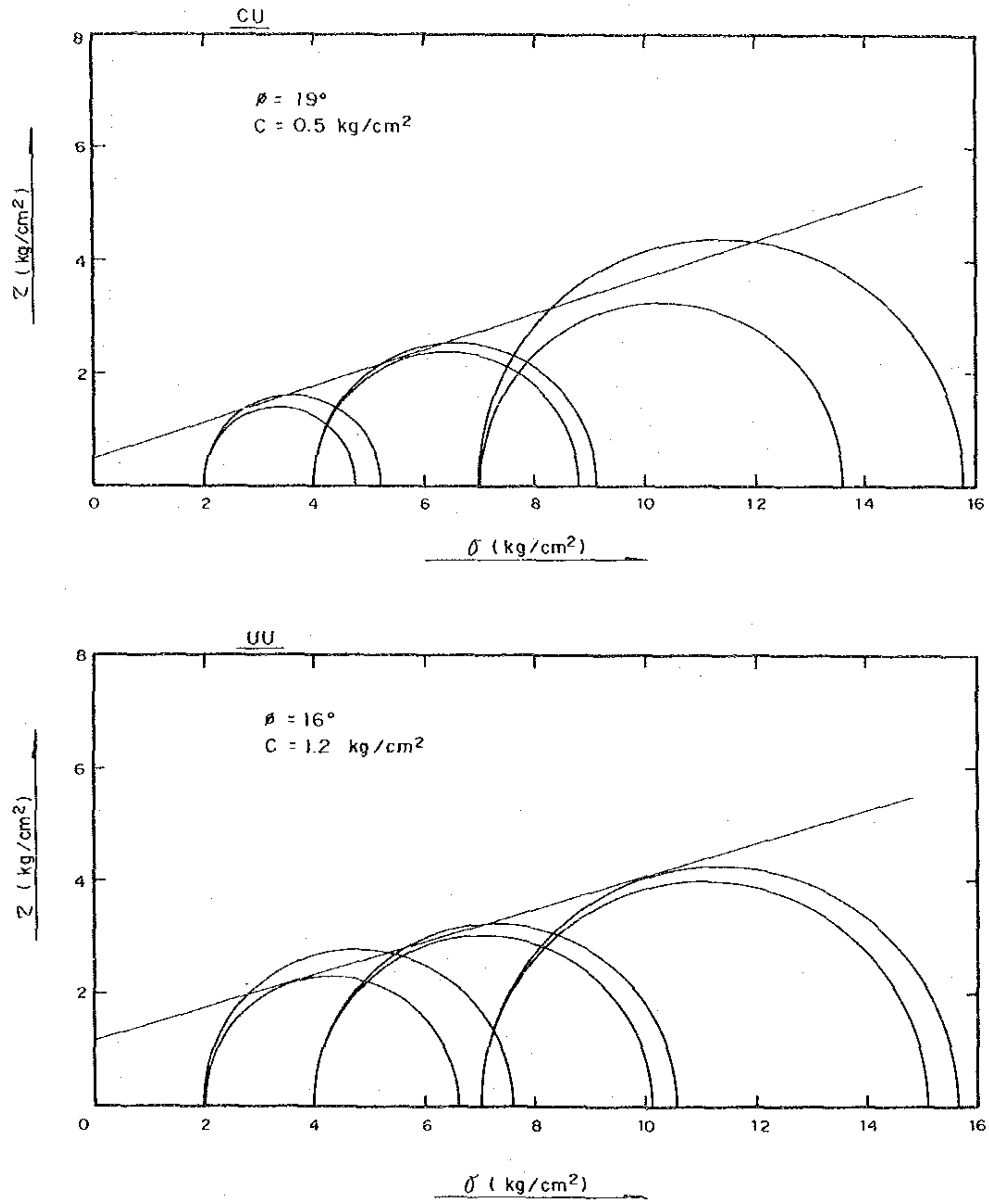
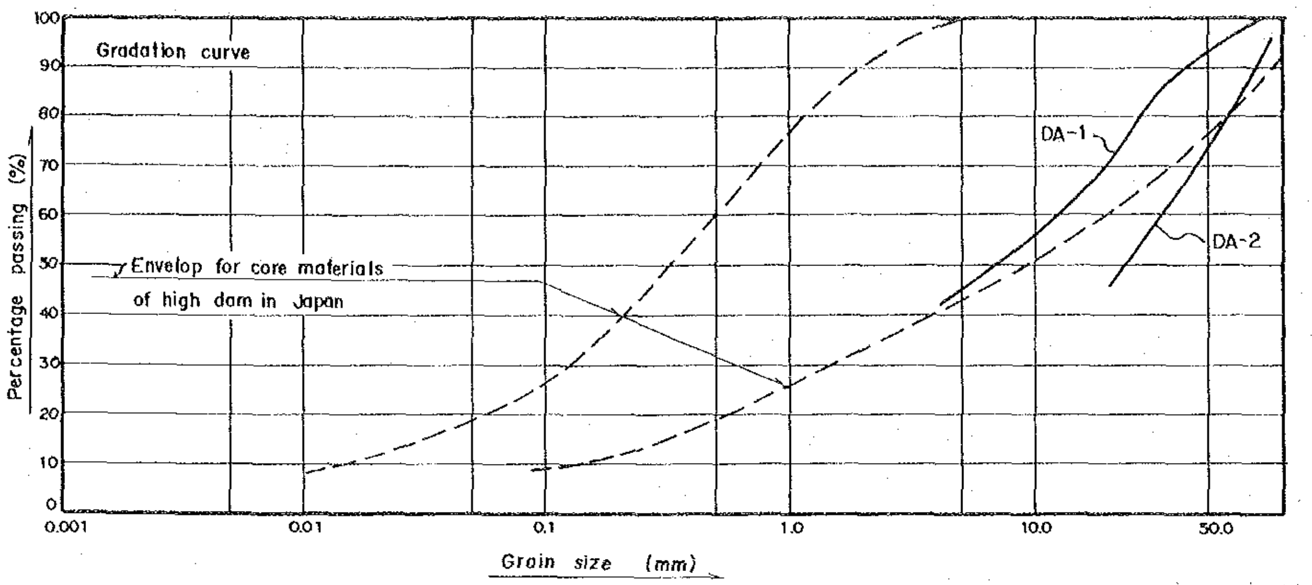
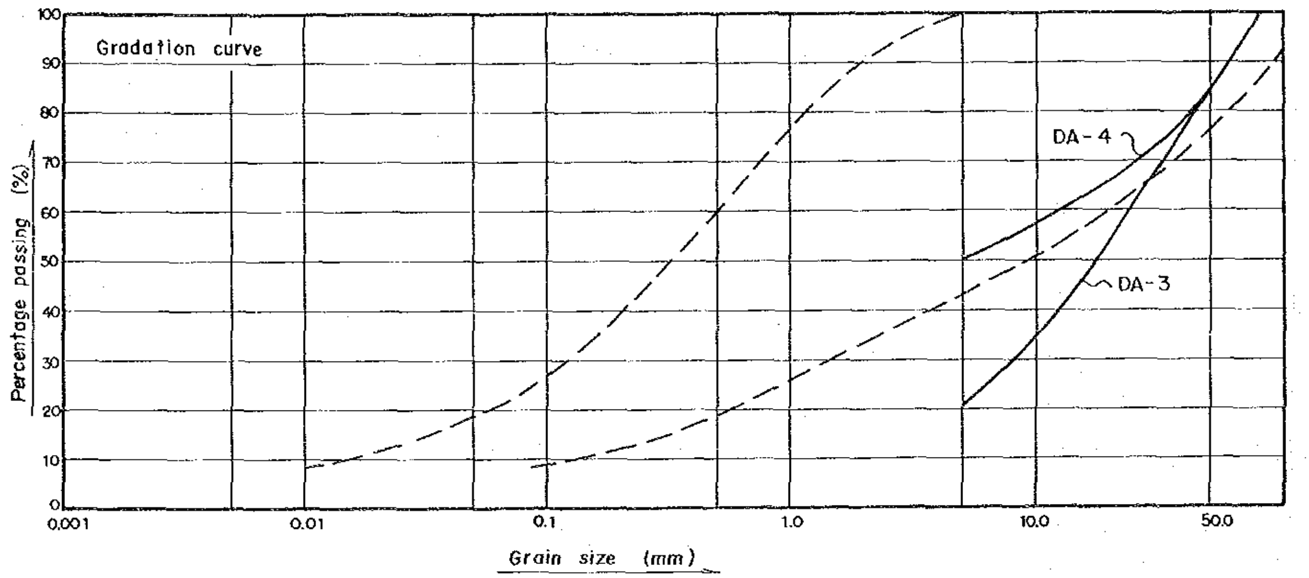


Fig. 4-6 Triaxial Compression Test Results
(High density group $\gamma d = 1.45 \sim 1.47\ g/cm^2$)





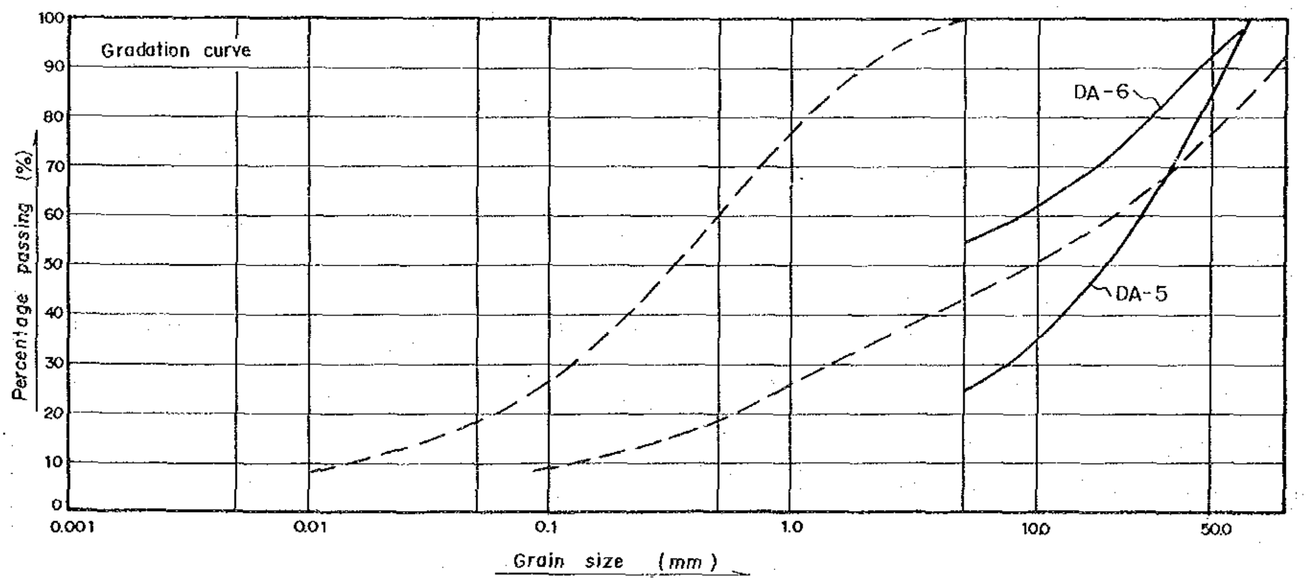
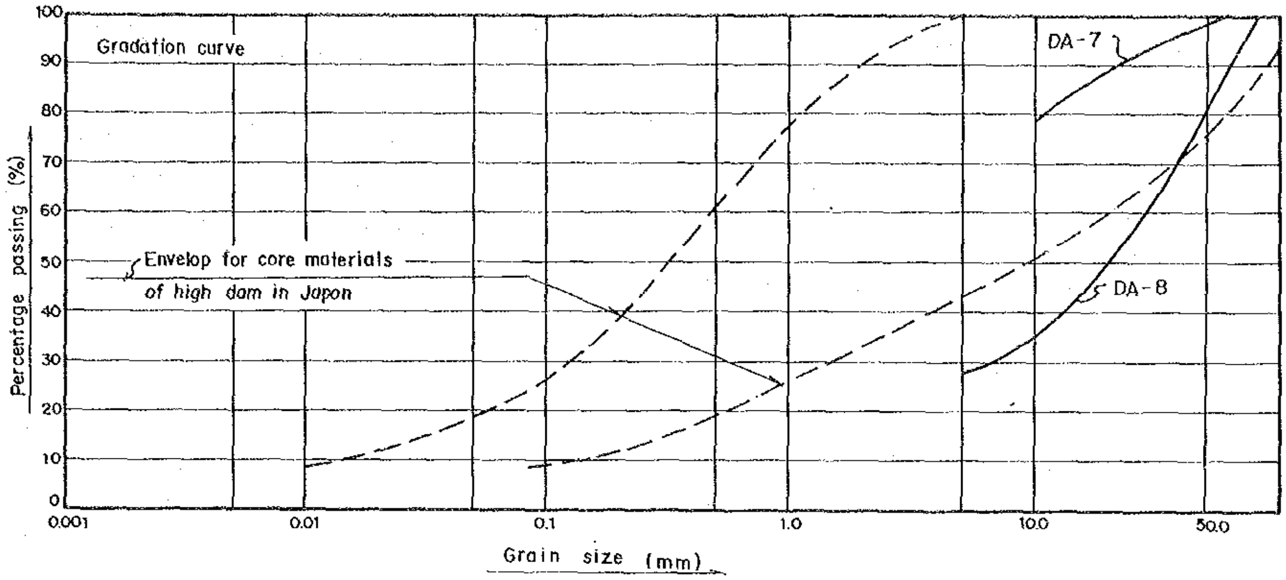
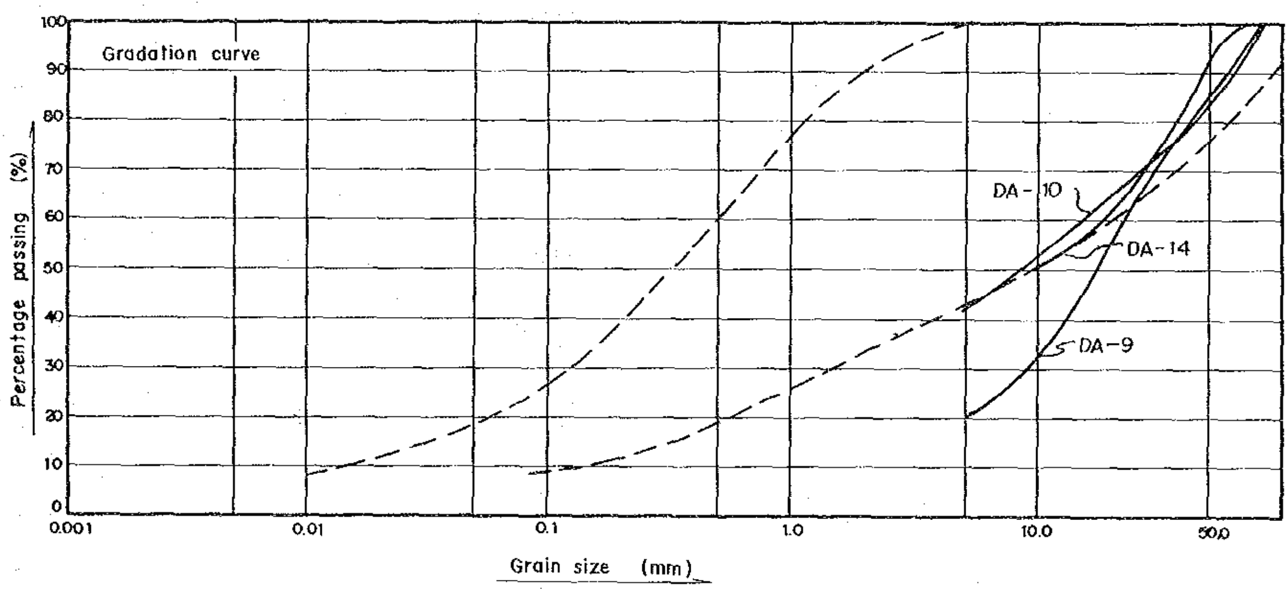


Fig. 4-7 Seive Analysis of Terrace Deposit





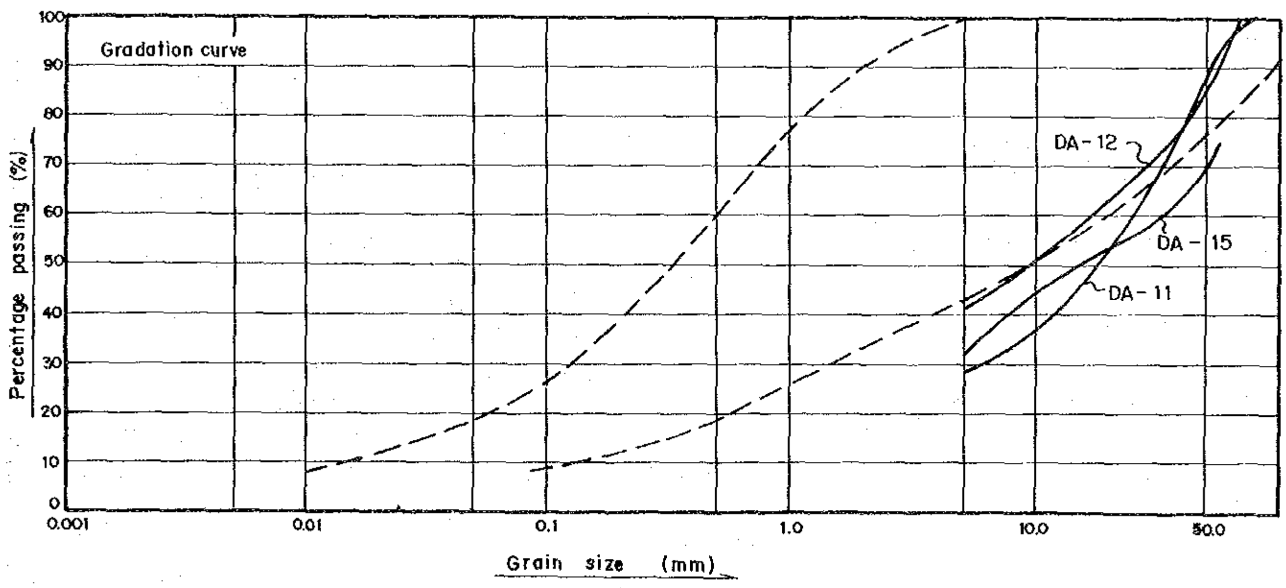


Fig. 4 - 8 Seive Analysis of Terrace Deposit

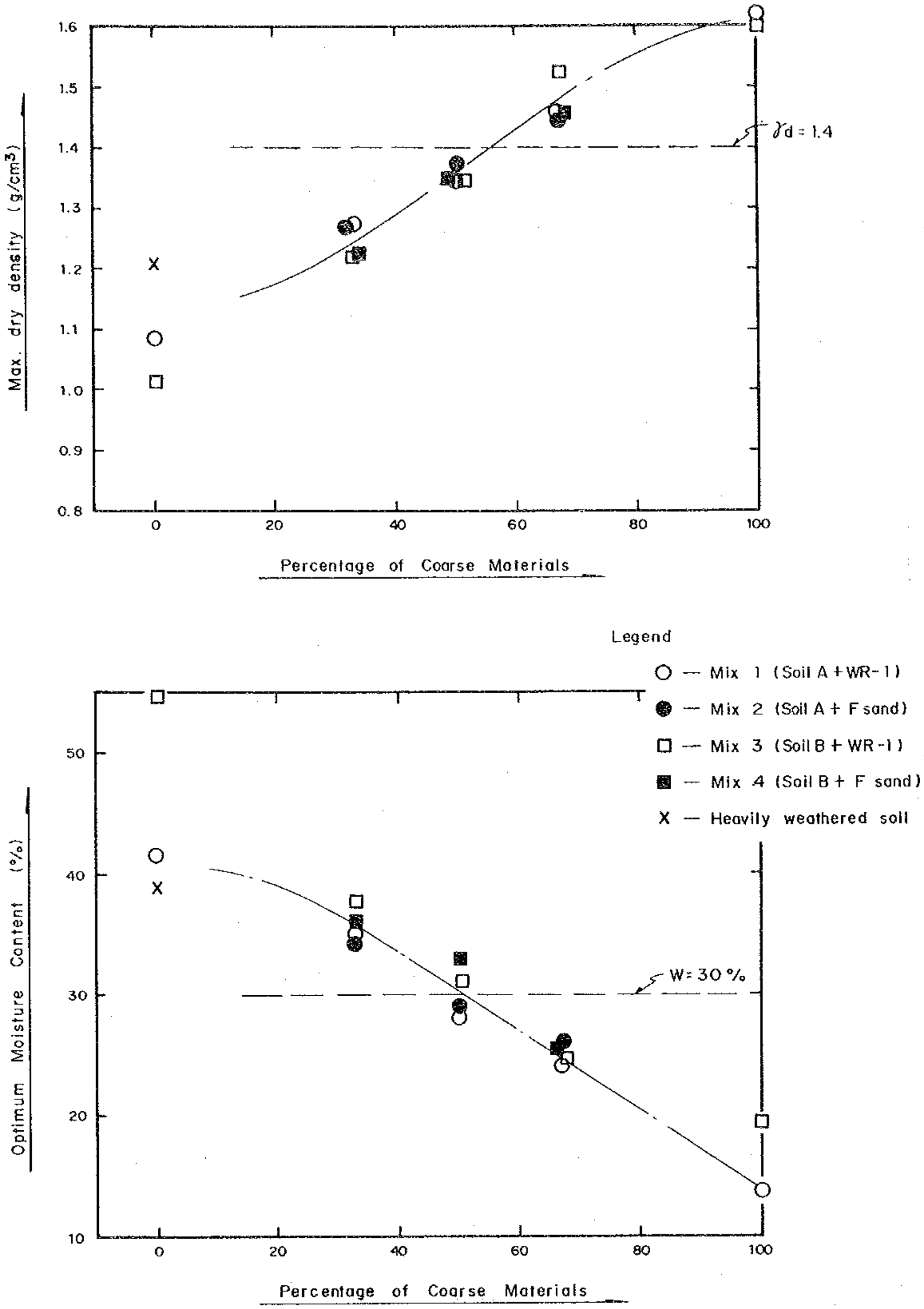


Fig. 4-9 Relation between Percentage of Coarse Materials and γdmax . and Wopt

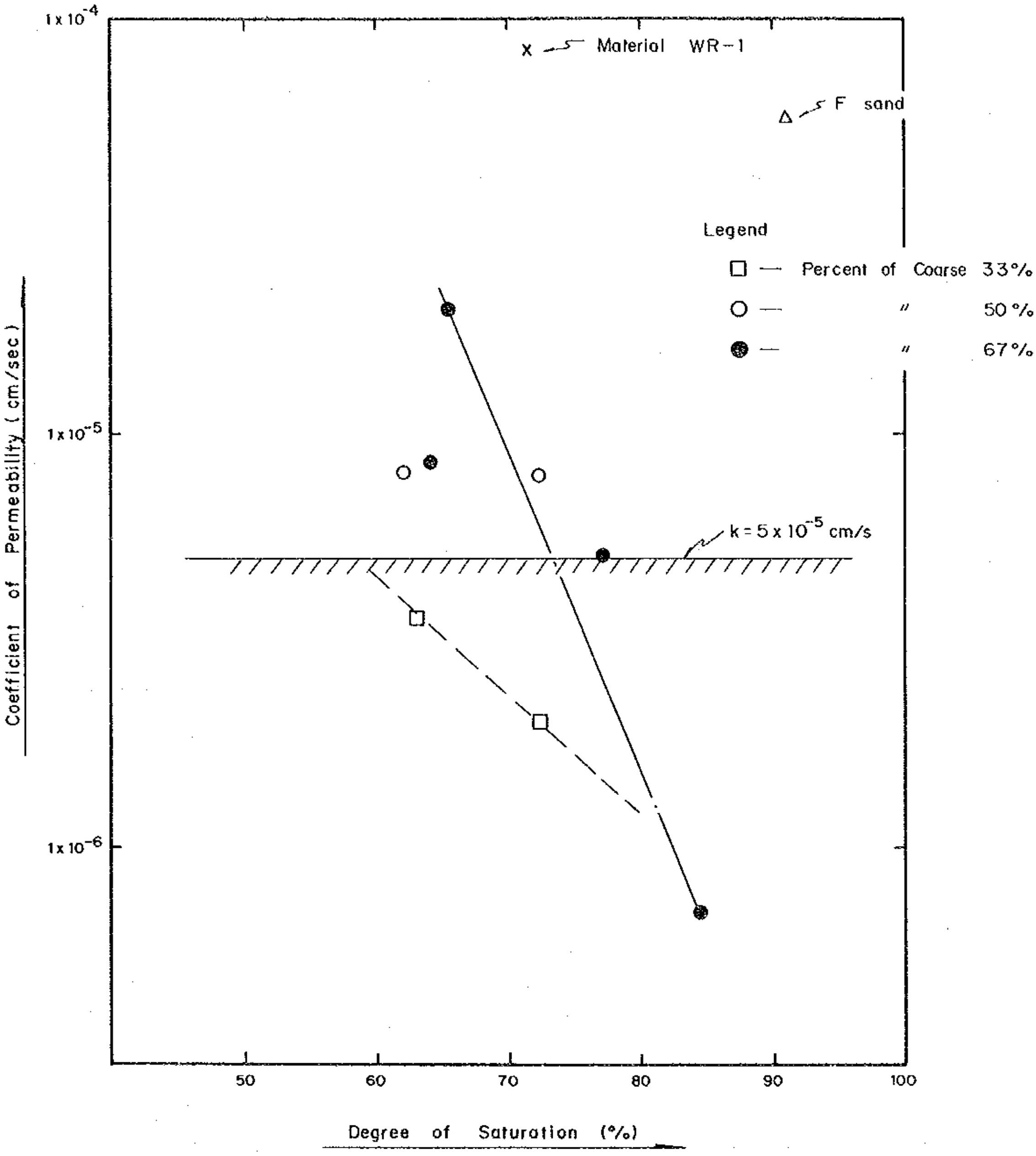


Fig. 4-10 Relation between Permeability and Degree of Saturation

Simbol	Sand	Sample nos.	Max. F.M.	Min. F.M.	Ave. F.M.
■	River sand	36	3.9	1.5	3.0
□	Beach sand	6	3.1	1.6	2.4

Recommended F.M. = 2.3 ~ 3.1

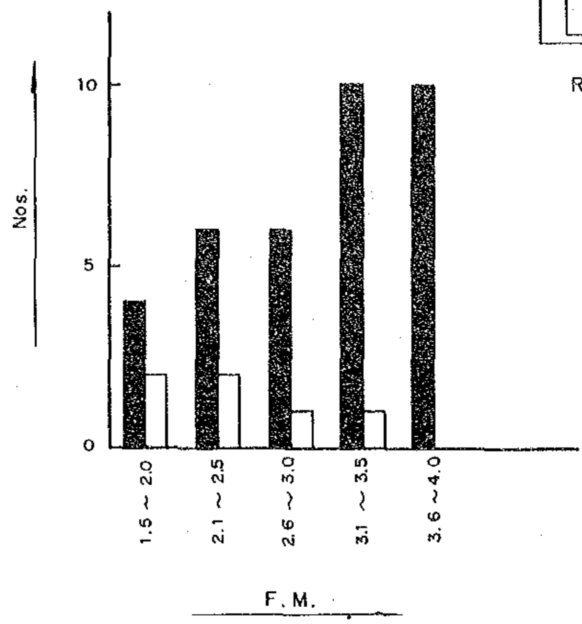


Fig. 5-1 Frequency of Fineness Modulus (F.M) for Fine Aggregates

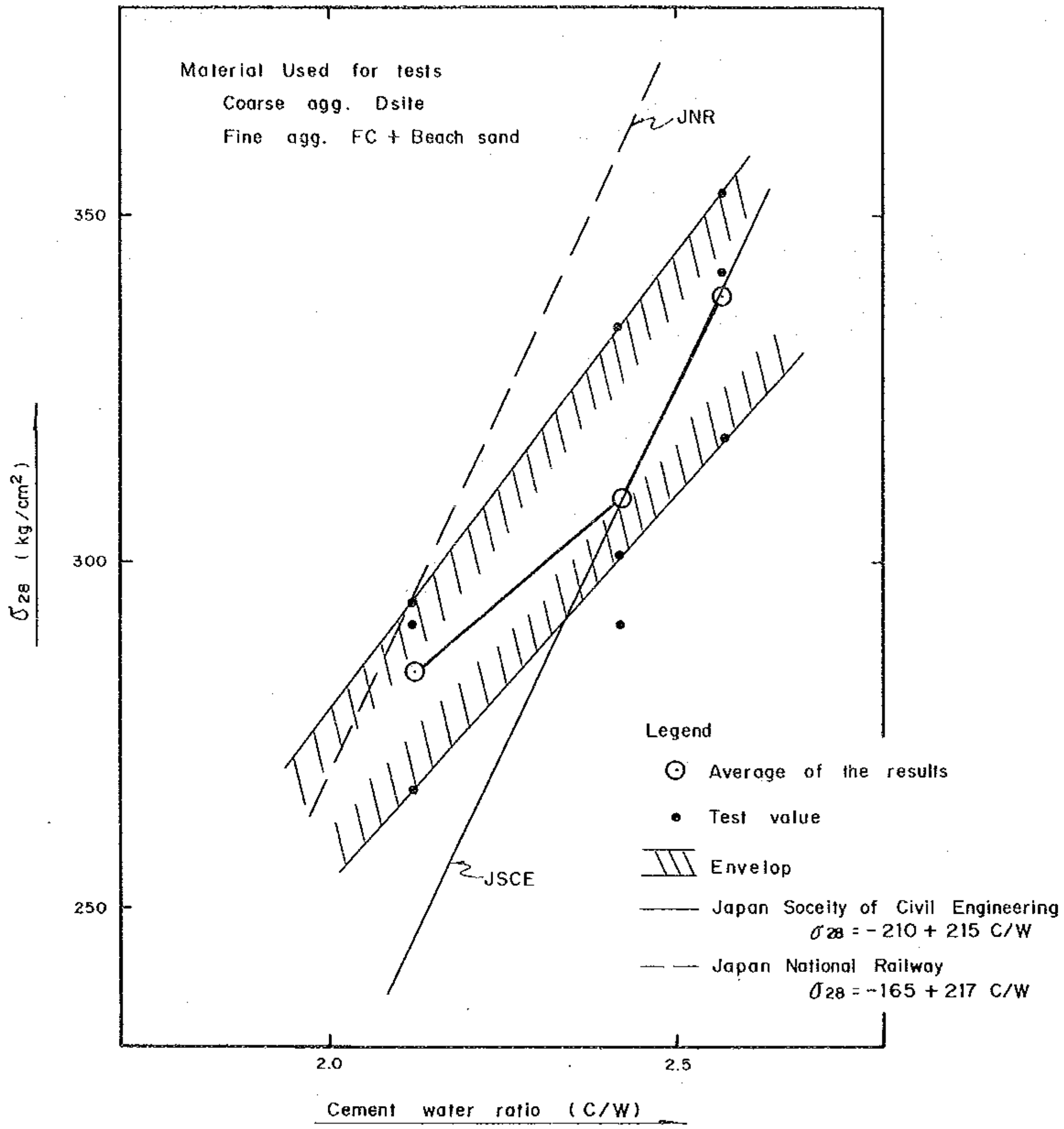


Fig. 5 - 2 Compressive Strength Test of Concrete

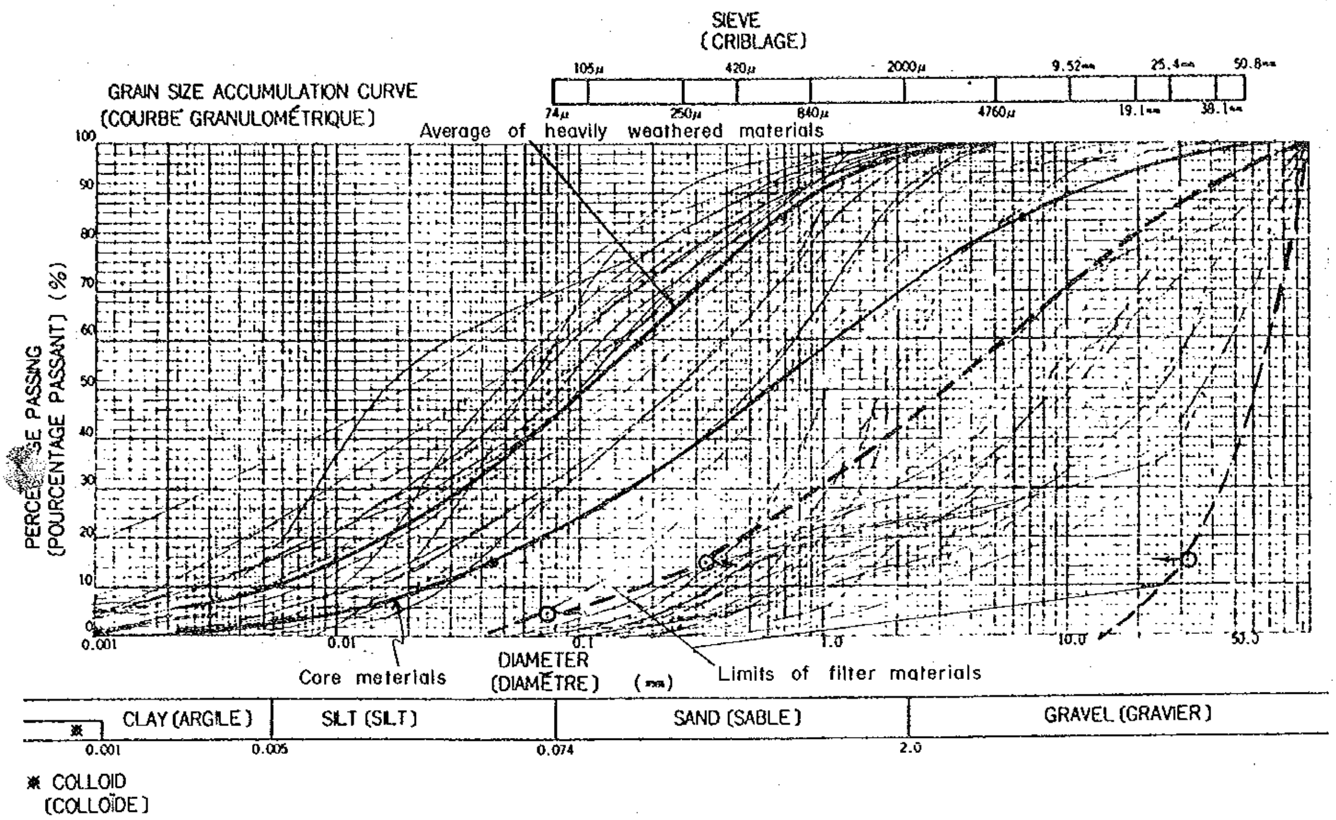
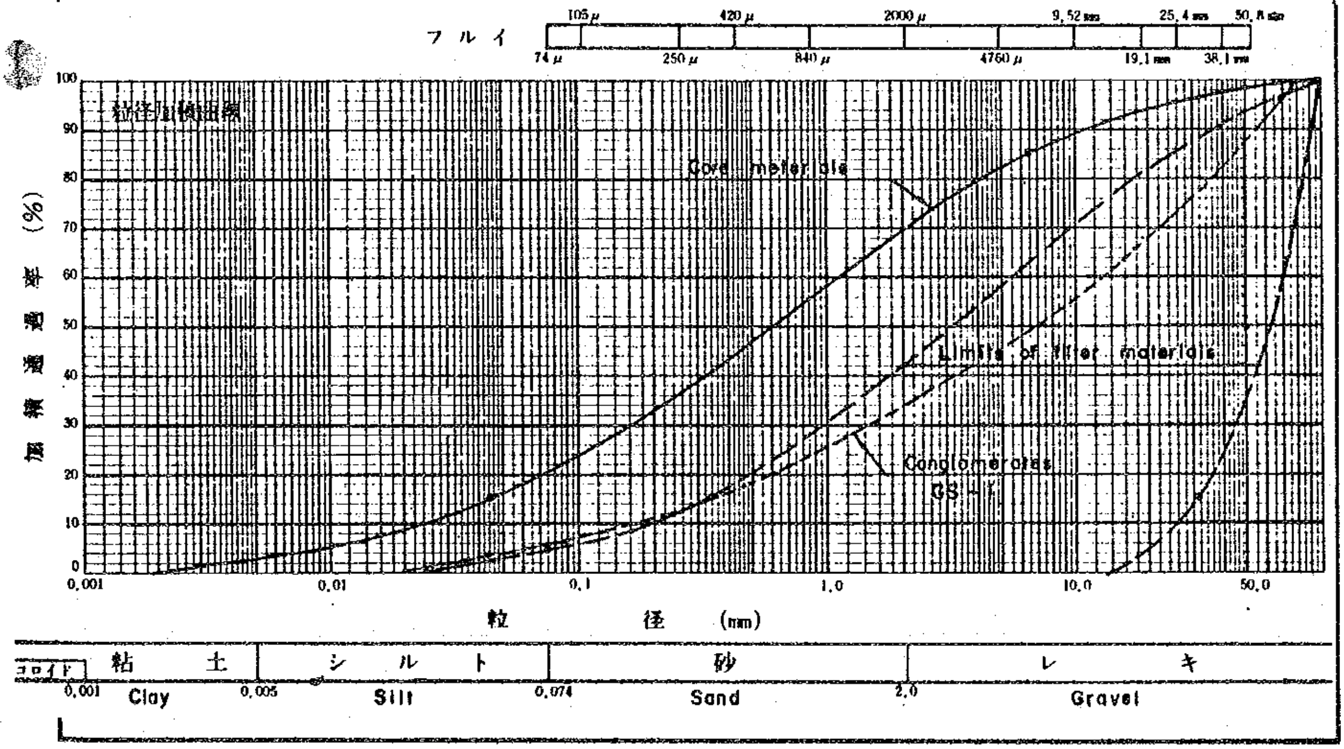


Fig. 5-3 Seive Analysis of Core and Filter Materials



SEKIRED A4 NO. 202 TH Fig. 5-4 Seive Analysis of Conglomerates GS-1

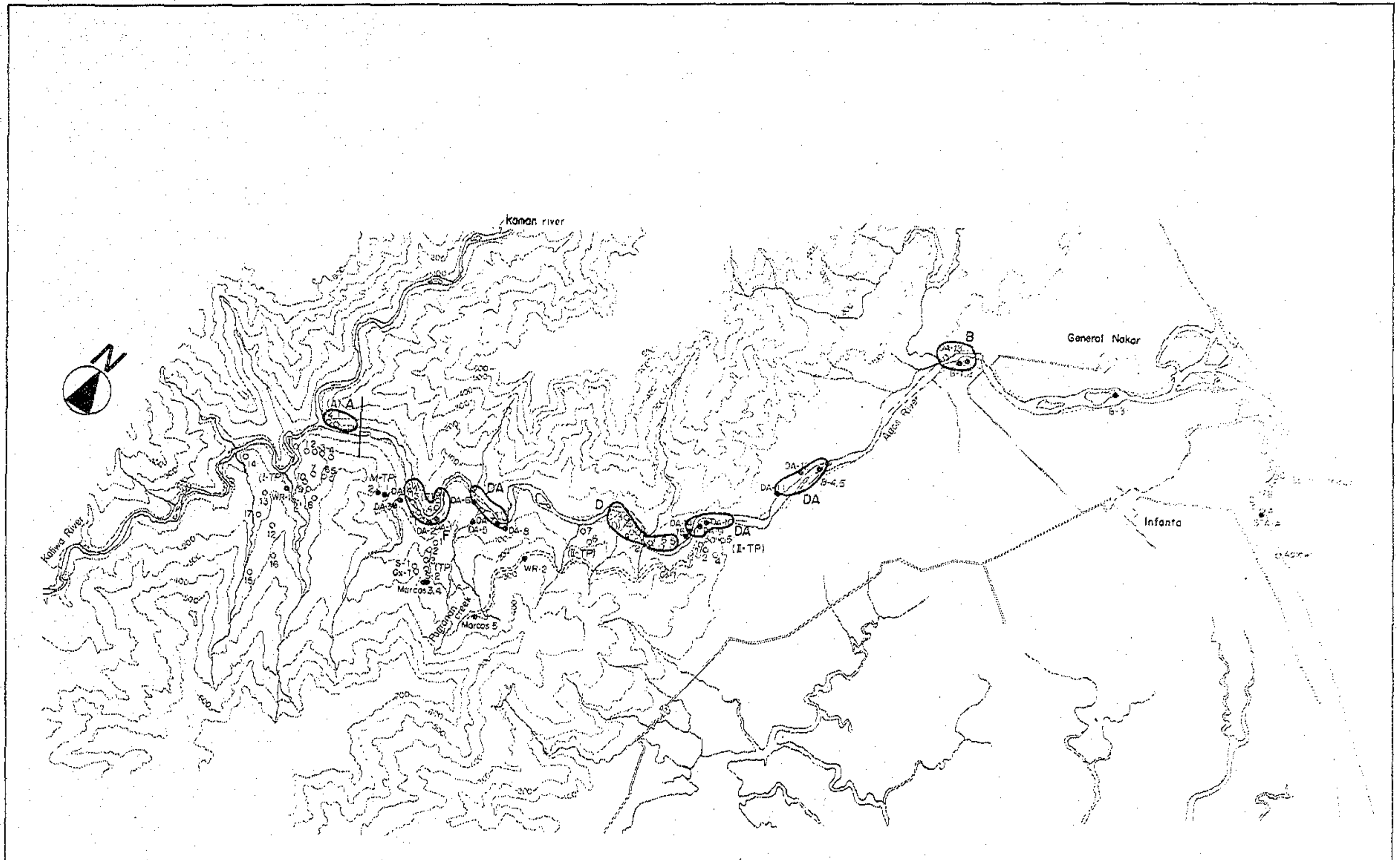


Fig. 5-5 Location Map of Concrete Aggregates Source

JICA