PEOPLE'S REPUBLIC OF BANGLADESH

JAMUNA RIVER BRIDGE CONSTRUCTION PROJECT

FEASIBILITY STUDY REPORT

VOLUME [illegible]

GEOLOGY AND SEISMIC [illegible]

AUGUST 1976

JAPAN INTERNATIONAL COOPERATION AGENCY

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VOLUME VI

GEOLOGY AND STONE MATERIAL

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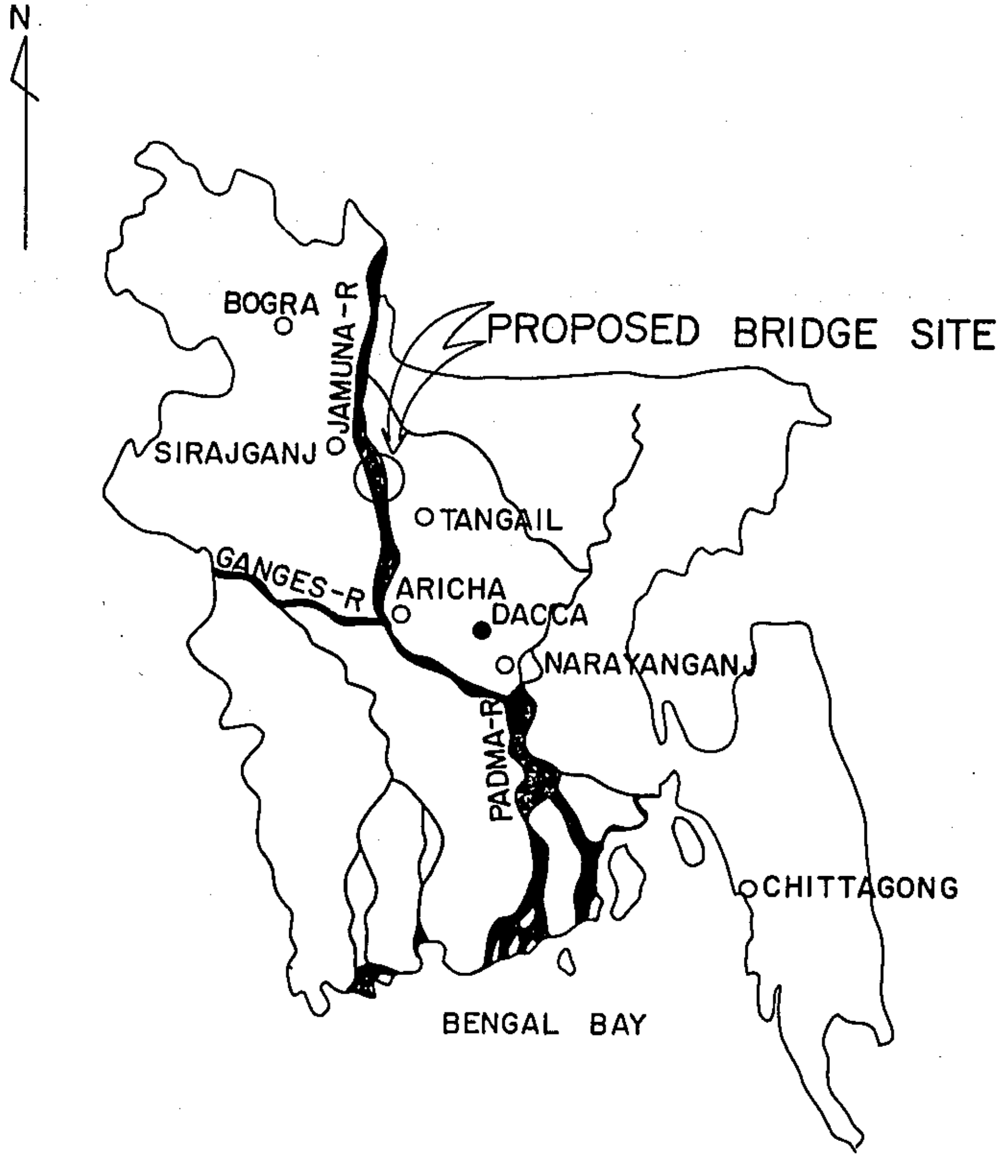
GUIDE MAP OF BRIDGE SITE



ABBREVIATION AND UNIT

Bangladesh	The People's Republic of Bangladesh.
Prefeasibility Report	Prefeasibility Report on Jamuna River Bridge Construction Project prepared by the Japanese Government Study Team for the OTCA in March 1973.
OTCA (JICA)	Overseas Technical Cooperation Agency, renamed to Japan International Cooperation Agency, Government of Japan.
Interim Report	Interim Study Report on Jamuna River Bridge Construction Project, prepared JICA, March 1975.
BWDB	Bangladesh Water Development Board.
D_{10}	effective grain size at 10 % passing.
D_{60}	grain size at 60 % passing.
U_c	Uniformity coefficient of grain size.
N	N-value, given the blow numbers of standard penetration test.
E	deformation modulas of soil.
C	Cohesion.
ϕ	Internal friction angle (degree).
γ_t	wet density, (unit weight).
k	coefficient of permeability.
m	meter.
mm	millimeter.
km	kilometer.
cm	centimeter.
g or gr.	gram.
kg	kilogram.
sec.	second.

cm^3	cubic centimeter.
cm^2	square centimeter.
W or w	moisture content.
%	percent.
Wn	natural moisture content.
D	degree of compaction on AASHO.
AASHO	American Association of State Highway Officials.
C.B.R.	California Bearing Ratio.
γs, or Gs	specific gravity of soil grains.
γd	dry density.
GL	ground level.
WL	water level.
GWL	ground water level.
EL	elevation level, (BWDB standard).
N	N-value, given the blow number of Standard Penetration Test.
L.L.T.	Lateral loading test (or tester).
JIS	Japan Industrial Standard.
ASTM	American Society for Technical Materials.
Cc	compression index for consolidation.
e (or eo)	natural or initial void ratio.
E	deformation modulas.
Em	measured elastic modulas.
H	measured water level of tank of LLT.
K	coefficient of soil reaction, meaning unified K-value.
Km	Measured K-value.
ko	specific K-value.

Ko	Model K-value.
Po	soil pressure at rest.
Py	yield pressure on LLT preconsolidation pressure on consolidation.
P	gage pressure of cell water on LLT.
P'	gage pressure of supplied gas on LLT.
P_G	reaction of rubber, given H-P_G curve for LLT.
Ps	static water head on LLT.
Pe	effective pressure on LLT.
C	coarse)
F	fine) in case of grain size.
M	medium)
C	clay)
M	silt) in case of soil classification.
S	sand)
U	undisturbed sample.
D	disturbed.
qu	unconfined compression strength.
ε	strain at failure, given unconfined compression test.
ν	poisson's ratio.
y	displacement of foundation.
rm	hole radius for calculation on LLT.
ro	initial hole rudius on LLT.

PART I

GEOLOGY

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CONTENTS OF DATA BOOK

The original data of investigations are compiled on separate volume, (DATA BOOK OF SUBSOIL INVESTIGATION), The contents of a Data Book are as follows.

PART II

STONE MATERIAL

— Field exploration of concrete aggregates and riprap materials for construction of Jamuna Bridge Project —

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PART I

GEOLOGY

SUMMARY

In the Jamuna River Bridge Construction Project, 4 proposed bridge sites were selected in 1973. (Prefeasibility Report, 1973.) And Sirajganj Site, Site No.3 shown in Fig. S-1, was selected as the best of these sites, based upon the results of the first-stage investigation works which were carried out from 1973 to 1974 to compare the 4 selected sites with each other. (Interim Report, 1974.)

In our second-stage investigation works, the feasibility of the Sirajganj Site was an object of researches. The investigation works were carried out by the Subsoil Investigation, Quarry Survey, Topographical Survey and River Training teams etc., and the present report was prepared by the Subsoil Investigation team to compile the results of investigations.

The works by the Subsoil Investigation team were classified in the investigations on the foundation of the bridge piers and the rough investigations on the foundation of the access roads to connect the bridge to the existing all-weather roads as well as on their bank materials.

As it is described in the geological report of the first-stage investigation works (Interim Report, 1974), the ground in the Jamuna basin consists of basal rocks which are sedimentary rocks of the Tertiary placed in the extremely deep position by the subsidance due to influenced by the Himalayan orogenesis and the erosion due to the lowering of sea level in the Glacial Epoch, deposits of the Pleistocene covering the basal rocks and placed in the depth of scores meters in a larger part also by the subsidance and erosion, and a large alluvium of the Holocene covering the deposits unconformably.

Fig. S-1 shows an estimated geological profile of the Jamuna River drawn up, based upon the results of the first-stage investigation works. The first-stage investigation works came to a conclusion that the Site No.3 is the best bridge site, if the stratum Al_1 which forms a gravel layer in Fig. S-1 has a stable continuity. Our investigation works were carried out mainly to confirm that the stratum Al_1 has a continuity in the direction of the bridge axis. As a result, the continuity of the gravel layer which constitutes the bearable bed for the bridge foundation was confirmed and therefore, the advantageousness of Sirajganj Site was heightened.

To carry out the Geological Investigations on the Foundation of Bridge Piers, 5 borings were performed in the depths, 92 m to 123 m. Fig. S-2 shows a summarized drawing illustrating the results of investigations by the 5 borings in addition to those in the bore S-0 used in the first-stage investigation works (1973). (Geological Profile and Explanation Table on Bridge Axis).

In this figure, it is found that the bridge foundation has a stable stratification almost similar to that estimated in the first-stage investigation works and that the layers in bores are well correlated, though the 5 borings are performed with the space of over

1 km.

In Fig. S-2, the stratum Du_3 and lower strata are Pleistocene deposits (diluvium), that is, so-called Dupi-Tila formation. The stratum Al_1 is a basal gravel bed of alluvium, and the stratum Al_2 and upper strata forms an alluvium.

The sea level was about 100 m lower in the Gracial Epoch (about 20 thousand years ago) in the latter half of the Pleistocene than in the present time. If the river in that epoch is called the Proto-Jamuna, the River Proto-Jamuna had a steep gradient so that a great amount of ultracoarse grains were carried away from the river by floods, deposits of the stratum Al_1.

Afterwards, the gradient of the Proto-Jamuna was gentler as the sea level rose (that is, with marine transgression in the postglacial epoch), and the alluvial deposits in the Proto-Jamuna basin were finer grains in the higher level. These deposits form the strata Au_2 to Al_2.

Foundation of the Bridge;

It is well known that the turbulent flows which are produced around the bridge piers during their construction score the strata of the river basin very deeply, and the scoring depth depends on the form of structure, flow speed, flow rate, soil grains forming the strata of the river basin and their density and solidity, etc.. Fig. S-3 shows a typical grain size distribution of every stratum.

Fig. S - 1

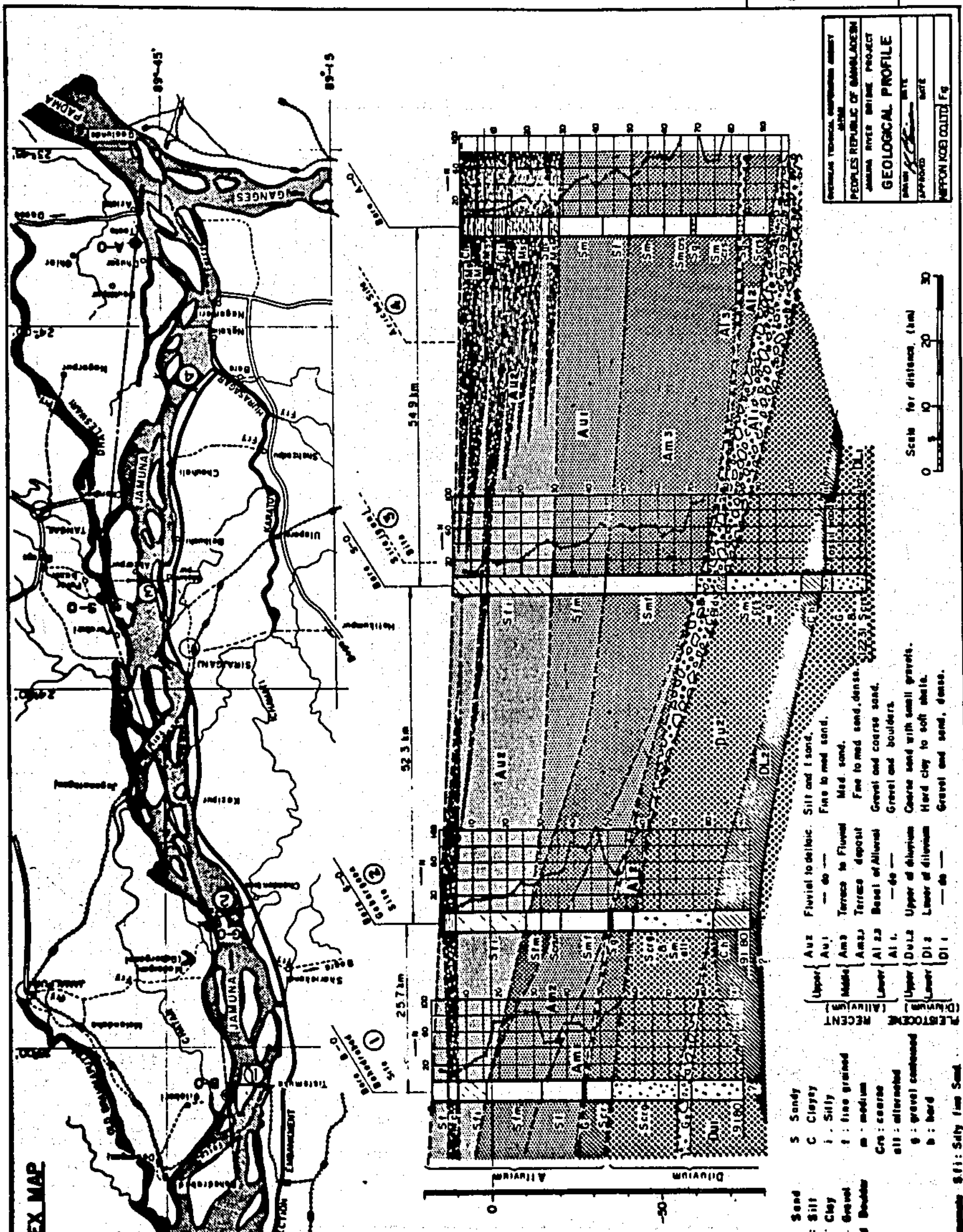

INDEX MAP
GEOLOGICAL PROFILE
JAMUNA
GANGES
PADMA
ELEVATION IN METER

Fig. S-2

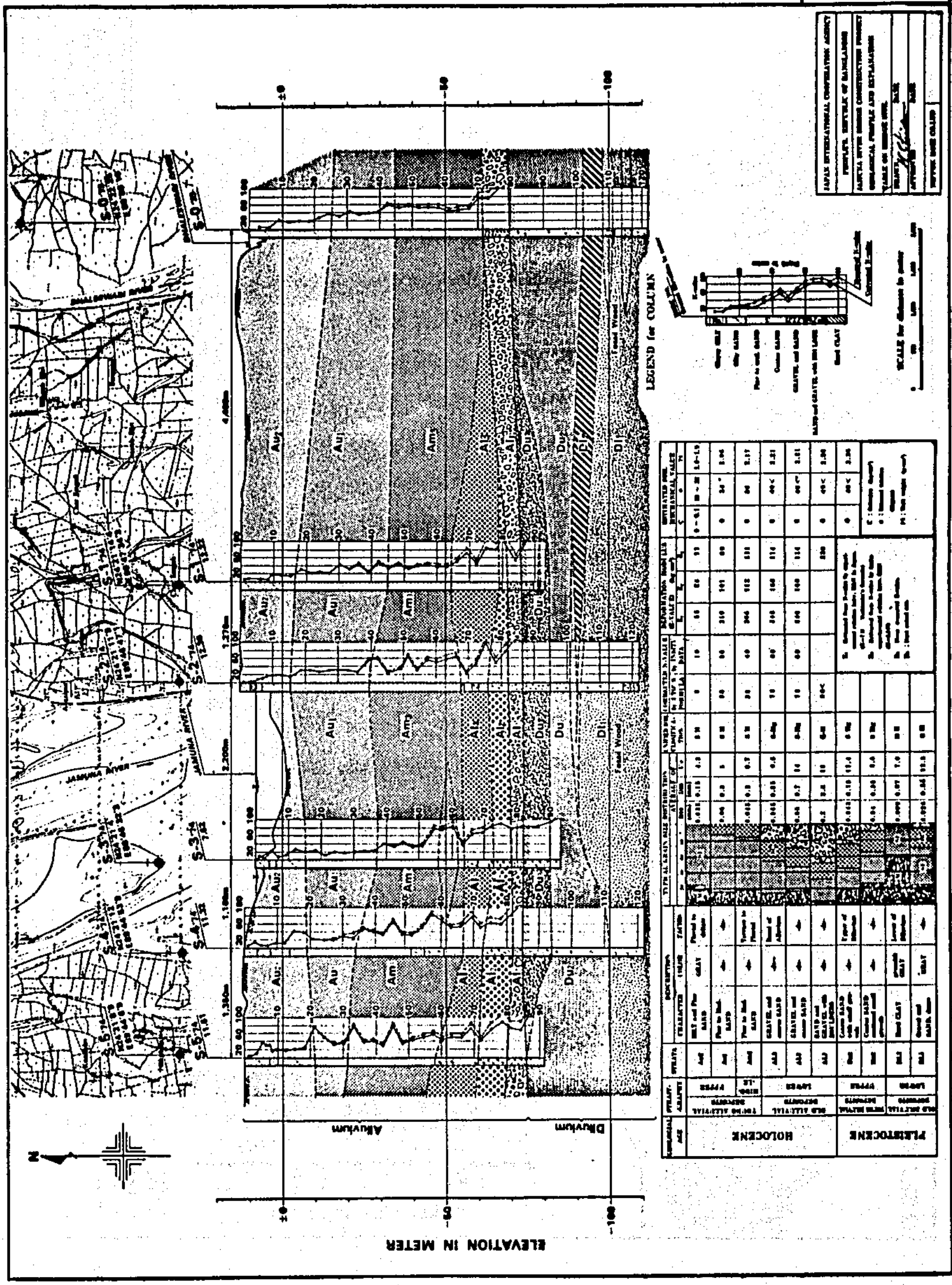
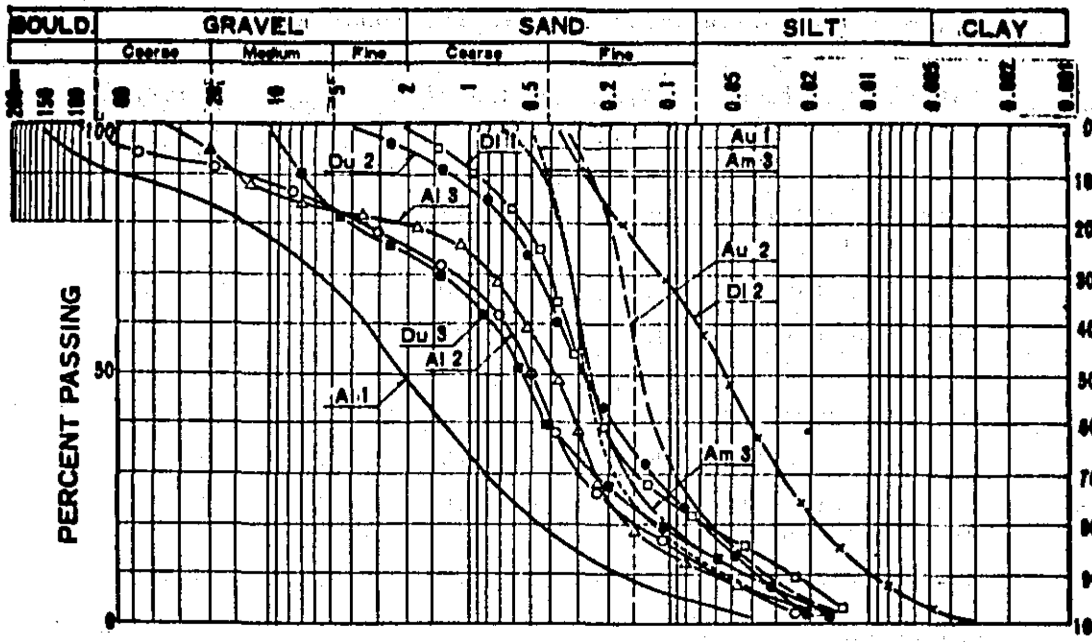

ELEVATION IN METER
Alluvium
Diluvium
JAMUNA RIVER
LEGEND for COLUMN
HOLOCENE
PLEISTOCENE

Fig. S-3 Typical Grain Size Distribution of every Stratum



In reference to Figs. S-2 and S-3, the stratum Am_3 and upper strata consist of poor-graded fine sand, and the middle to upper alluvium of these strata has an extremely small scoring resistance. It is known that the stratum Au_2 in Fig. S-3 is made of the finest sand and has a low density and that this stratum is easily scored in the riverbank of the present Jamuna. Therefore, this stratum has a scoring resistance almost equal to zero. The stratum Au_1 is also made of typically poor-graded fine sand and seems to have little scoring resistance. The stratum Am_3 is estimated to be subject to no scoring, because it has a little higher density than the stratum Au_1 and is placed in the depth where the scoring energy is mall, though it has the same grain size distribution as the stratum Au_1. The strata Al_2 and Al_3 which contain gravel fractions trailed or inserted in them have higher density, but they are not solidified so that they have not a high resistance against scoring, but a little possibility of being scored.

The stratum Al_1, which is a well-graded gravelly bed with as big gravels as human head, have perhaps no possibility of being scored, because it is placed in the depth of EL-70 m and because it is made of coarse grains, even if the upper stratum is scored.

Considering the lateral soil reaction and the scoring depth, the bearing strength of pier foundation point can be enough stable, if the pier foundation is of caisson structure in the depth of the stratum Al_1 (EL-70.0 m) or lower stratum. Though the stratum Al_1 is relatively thin, 3 to 5 m in depth, the lower stratum Du_3 is a solidified gravelly bed which can be called conglomerate and has a depth of 7 to 8 m. Therefore, the gravelly bed having a total depth of 10 to 13 m can be the bearable bed for the pier foundation. Besides, the strata Du_2 and Dl_1 are mainly made of sand, but they are very stable because they have N-values of over 100 and are in semisolid state.

Table S-1 indicates selected design soil factors for substructures, based upon the analyses of our investigation data.

Table S-1 Design Soil Factors for Substructures

Stratum	Material(unified symbol)	D_{10} (mm)	Grain size D_{60} (mm)	Uc	Corrected N-value (blow)
Au_2	Silt & Fine sand (SM)	0.035	0.15	4.3	8
Au_1	Fine sand (SM)	0.06	0.30	5.0	30
Am_3	Fine sand (SM)	0.45	0.30	6.7	38
Al_3	Gravel & coarse sand(S-Mg)	0.065	0.55	8.5	78
Al_2	" (S-Mg)	0.05	0.70	14.0	78
Al_1	Sand & gravel(GM) with boulders	0.20	3.60	18.0	> 80
Du_3	Coarse sand(SMg) with small gravels, solidified	0.043	0.75	17.4	> 100
Du_2	Coarse sand(SMg) with small gravels scattered	0.04	0.35	8.8	> 100

Stratum	Deformation modulas(E) (kg/cm^2)	C (kg/cm^2)	ϕ (degree)	γ_t (g/cm^3)	k (cm/sec) $\times 10^{-4}$
Au_2	77	0-0.1	13-32	1.8-1.9	30-50
Au_1	89	0	34	2.06	36
Am_3	111	0	36	2.17	20
Al_3	114	0	40	2.21	50-90
Al_2	114	0	> 40	2.21	50-90
Al_1	230	0	> 40	2.26	$\overline{90}$
Du_3	> 200	0	> 40	2.26	$\overline{1}$
Du_2	> 200	0	> 40	2.26	$\overline{0.7}$

The values in Table S-1 were selected as follows:

Grain size .... From the grain size accumulation curves of the same stratum, a typical curve is drawn up in the most frequent zone, and the value is read out on the typical curve;

Corrected N-value .. The measured N-values are corrected according to the depth range by Uto's formula, and the corrected N-values of the same stratum are represented in a histogram, on which the peak value is selected as typical corrected N-value;

Deformation modulas (E)
.... An average of the measured E-values by L.L.T. in the same stratum;

Cohesion(C) .... The C-value of the uppermost stratum is empirically selected, based upon the results of laboratory tests, and the other C-values are estimated at zero (0) as usual because of the sandy soil;

Internal friction (ϕ)
.... The ϕ-value of the uppermost stratum is empirically selected, based upon the N-values and laboratory test data, and the other ϕ-values are calculated by the general N - ϕ relation formula from the typical N-values of respective stratums;

Unit weight(γ_t) .... The γ_t-value of the uppermost stratum is empirically selected, based upon the laboratory test data, and the other γ_t-values are selected by representing the measured specific gravity and natural moisture of the same stratum at the saturation of 100 % in a histogram and calculating the γ_t-value by the rule of physical characteristics from the peak value on the histograma; and

Permeability(k) ..... The k-values are mainly calculated by the Harzen formula of D_{10} - k relation from D_{10}-values, though a part of these values are empirically determined from the values of grain size, density, etc. and discriminated from the other k-values which were estimated experientially, by a mark (——) above each value of k in this table.

Foundation of the Access Route;

The investigations on the features of the foundation of access road route and the banking materials were carried out in a route of the eastside and westside roads of the River Jamuna having a total length of about 30 km and running from Sirajganj to Elenga across the river.

These investigations were carried out simply by the Swedish penetration tests at 37 spots, the auger boring tests at 20 spots and the laboratory CBR tests (with sampling by hand digging) at 10 spots. These investigation works were performed with the purpose of basic designing so that the number of investigated spots was very small, compared with the total length of the route, but the works were successful to the purpose of grasping the general soilmechanical tendency of the route.

Fig. S-4 shows a soil profile of the route foundation and spots investigated. In this figure, the results of investigations were classified in those of three strata, of which the respective soil factors were examined. Besides, the strata ① and ② were subject to examinations as banking materials.

On starting the zoning, it was considered unreasonable that such a long route was classified only in three strata. However, it was found by analysis of the test data of augered samples that the stratum ① contains 20 % to 30 % of sandy soil part, but the larger silty soil part, which was determined as typical soil of the stratum ①. More particularly, all the grain size distribution curves of the stratum ① were superposed one on the other and the curves in the most frequent zone were objects of examinations for the soil factors of the stratum ①. The strata ② and ③ are made of considerably poor-graded fine sand, and the grain size curves in the most frequent zone were adopted similarly for these strata. The part of strata ② and ③ was divided into two strata because the stratum ② is different in density from the stratum ③, though they are similar in grain size distribution. The N-value curves in Fig. S-4 were drawn up by the N-values calculated by the in-situ empirical relation of N - Nsw, in which the values Nsw were determined by the Swedish penetration tests.

Table S-4 indicates the design soil factors of bank materials obtained by the analysis of the investigation data, which have been above-described.

Table S-4 Design Soil Factors of Access Road Foundation and Bank Materials

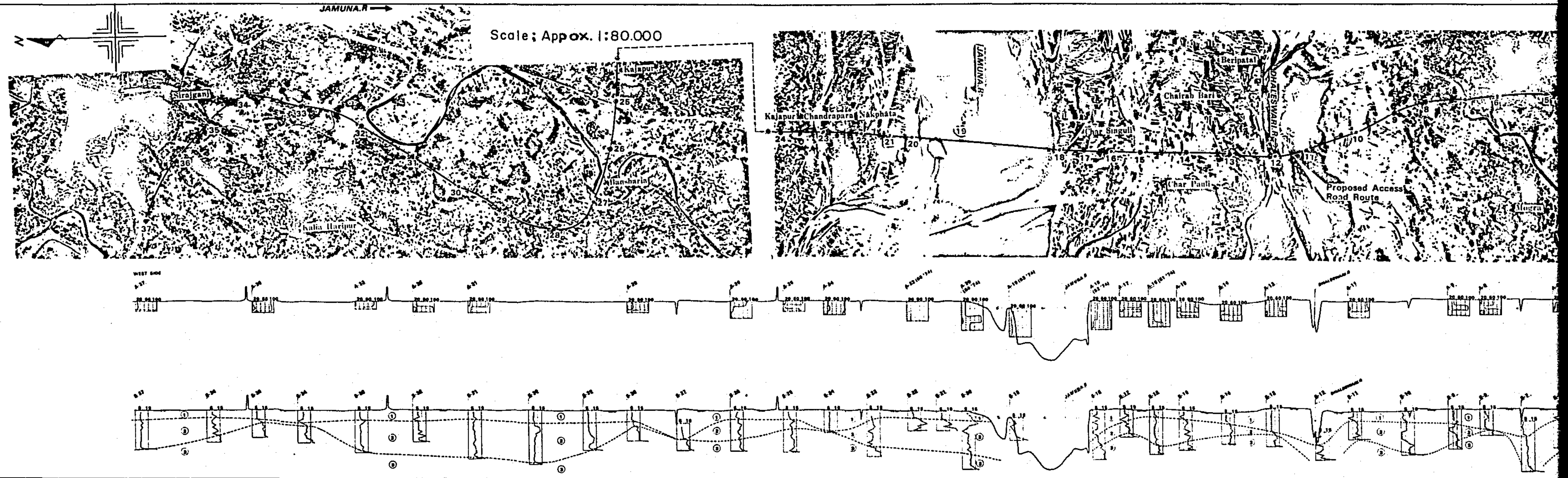
Foundation:

Stratum	Material	Typical N (blows)	γt (g/cm^3)	Wn (%)	γd (g/cm^3)	C (kg/cm^2)	ϕ (deg.)
①	Silty soil with sand	< 6	1.8	32	1.36	0.1	13
②	Silty sand to sand	6 - 10	1.9	20	1.58	0	28
③	Sand	10 - 20	1.9	20	1.58	0	32

Bank materials:

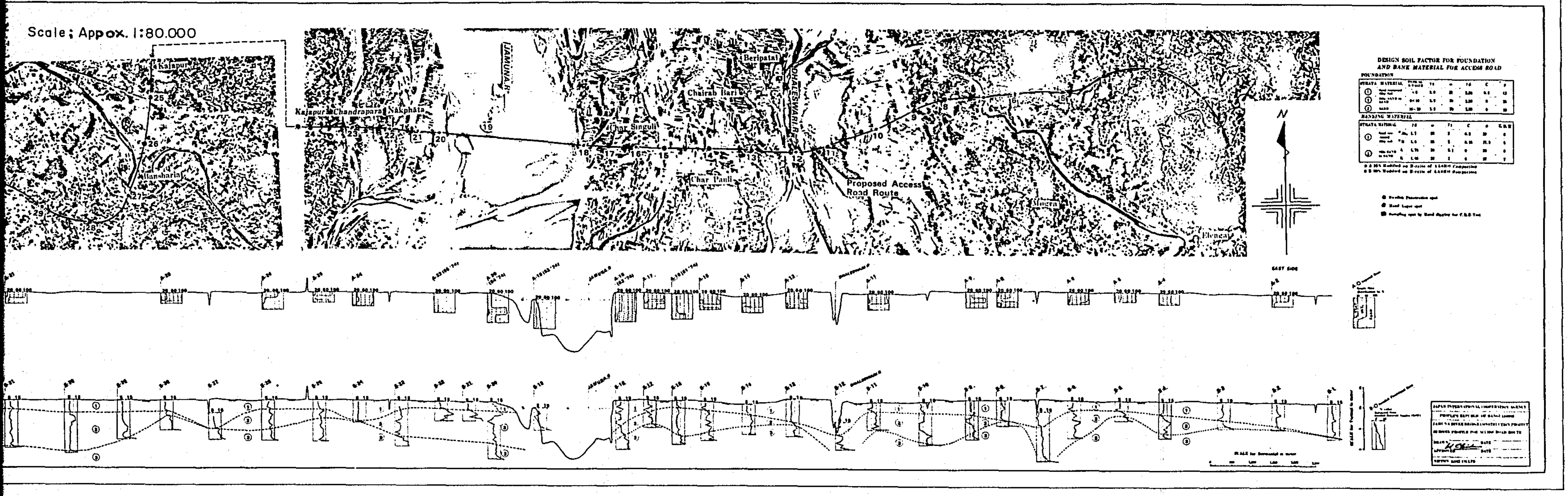
Stratum	Material	D	γd (g/cm)	W (%)	γt (g/cm)	C (kg/cm)	ϕ (deg.)	CBR (%)
①	Silty soil	A	1.7	22	2	0.2	20	6
	with sand	B	1.6	26	2	0.15	17.5	5
②	Silty sand	A	1.75	20	2.1	0	30	8
	to sand	B	1.65	22	2	0	27	7

A: 95 % of AASHO compaction
B: 90 % of AASHO compaction



JAMUNA.R
Scale; Appox. 1:80.000
Sirajganj
Kajapur
Kalia Haripur
Kajapur
Chandrapara
Nakphata
JAMUNA.R
Char Singuli
Chairab Bari
Beripatal
DHALESWARI.R
Char Pauli
Proposed Access Road Route

Fig. S-4


Scale; Appox. 1:80.000
Kajapur
Chandrapara
Nakphata
JAMUNA R.
Char Singuli
Chairab Bari
Beripatal
DHALESWARI R.
Char Pauli
Proposed Access Road Route
Mogra
Elenga
N
DESIGN SOIL FACTOR FOR FOUNDATION
AND BANK MATERIAL FOR ACCESS ROAD

The values indicated in Table S-4 were selected as follows:

Design factors of foundation:

Typical N .... The N-values were calculated by the in-situ empirical formula of N - Nsw relation which was deduced from the tests by boring at bridge axis, and the typical N-value of each stratum is an average of these N-values;

Unit weight (γt)......... The Wn - γt relation of the soil in the investigated area was obtained, based upon the test data of the undisturbed samples picked up by boring at bridge axis, then the measured Wn-values (moisture) of the auger boring samples in the whole route were represented in a histogram, and the value γt was estimated from the peak Wn-value by means of the Wn - γt curve;

Natural moisture (Wn) ... The most frequent value of measured Wn-values for augered samples;

Dry density (γd) .... This value was calculated by the rule of γt - Wn - γd relation from the most frequent value (2.70) of the measured values of specific gravity for augered samples;

Cohesion (C) .... This value was determined empirically, based upon the laboratory soil-mechanical test data of bored samples at bridge axis and in reference to the data similar to those of the stratum ①, while the values of the strata ② and ③, which is apparently made of sandy soil, were estimated at zero (0) as usual; and

Internal friction (ϕ) ... The relation of sand fraction and ϕ-values was determined and graphed, based upon the results of soil-mechanical tests in laboratory on the samples picked up by boring at bridge axis, and the ϕ-value was estimated from the sand fractions for augered samples of each stratum. The accuracy of this estimation could be confirmed by the other methods of estimations.

Banking materials:

10 samples for compaction tests include samples of sandy to silty soils. All the samples were picked up in the upper part of the stratum ①, but the samples of sandy soil have approximate grain sizes to the typical grain size of the stratum ②, while the samples of silty soil have approximate grain sizes to the typical grain size of the stratum ①. Therefore, the respective typical curves of sandy

soil and silty soil were drawn up, based upon the drawing in which the γd - W curves and the γd - CBR curves obtained from the results of compaction and inundation CBR tests were superposed one on the other, and then the values corresponding to the compaction degrees were selected as design factors. Besides, the typical values of silty soil were considered as the typical values of the stratum ①, while the typical values of sandy soil were considered as the typical values of the stratum ②.

As for the consolidation settlement of the bank, it is estimated by empirical examinations that the settlement will be at extremely small values, if any, that the settlement will be finished at the same time as the banking be completed, since the stratum ① which has a tendency to settlement is in sandwich form of sand layer between upper and lower silt layers in the upper part and is made of sand in the lower part, and that there will be thus no trouble due to settlement after the banking is completed.

If the earth volume for the in-situ foundation of silty soil (stratum 1) is 1, the variable (swelling or shrinking) earth volume can be estimated probably at 0.85 to 0.95 after compacted (C-ratio) and at 1.25 to 1.35 after loosened by excavation (L-ratio).

CHAPTER I

GENERALITY

1. Purpose and History of Investigations.

Japan International Cooperation Agency carries out the investigations for the Jamuna River Bridge Construction Project, which the Japanese government has entrusted to JICA in answer to the request of the government of Bangladesh. This project makes a part of the plan for connecting the Capital, Dacca, to the northwest area in Bangladesh.

Since 1967, the delegation made up of Mr. Hashimoto, Mr. Kawasaki and others had conducted the preliminary investigations and selected 4 sites proposed for construction of the bridge. And in 1973, an investigation team which was made up of River Training, Bridge, Transportation and other parties was formed to conduct field works for selection of the best among the 4 proposed sites. The result was the "Interim Report, 1974". It was Nippon Koei Co., Ltd. that was in charge of the subsoil investigations on the first stage and offered the report to JICA in November, 1974.

Based upon those reports and the deliberations by the governments of Japan and Bangladesh and the other authorities interested, the Site No.3, that is, Sirajganj site to connect Sirajganj to Tangail was selected as the best.

In 1974, the investigations on the second stage, that was for basic designing of Sirajganj site, was carried out by several teams, particularly Survey team and Subsoil Investigation team.

The present report is a result of the subsoil investigations, in which the design factors of soil for designing of foundations are determined.

2. Experts Concerned and Work Period.

Experts concerned:
Masanobu Sakaita, geologist and part chief and general,
Masao Chida, geologist and general of subsoil study;
Fumio Watanabe, junior geologist of subsoil study;
Yoshiaka Kobayashi, boring instructor;
Osamu Kanzaki, mechanic and managing stuff; and
Soiltech Ltd. (Dacca), company of drilling works and laboratory tests.

The investigations on the first stage were carried out only by the Japanese managing stuffs under the directions of Nippon Koei Co., Ltd., while the field works were done by the sub-contractors in Bangladesh who had considerable difficulties in the works because of their techniques and capacity of material procurement.

In the investigations on the second stage, we took a deliberate and sensible attitude not to neglect the detailed instructions and management to the sub-contractors in the field, based upon the experiences in the investigations on the first stage. Particularly, all the materials except those for laboratory tests were brought in from Japan, Sakaita and Chida were in turn in charge of study and direction, Kanzaki was of material management and general work in the investigation base, Watanabe was of investigations in access routes as well as instruction of investigation techniques and practical works, and Kobayashi was of boring instruction and practical works. With these dispositions and the cooperation of the authorities interested, our investigations were successfully carried out with fruitfully.

Work periods of experts:
Masanobu Sakaita; for 36 days from 24, Jan. to 28, Feb. in 1975,
Masao Chida ; for 45 days from 14, Nov. to 28, Dec. in 1974,
Fumio Watanabe ; for 75 days from 9, Nov. to 21, Dec. in 1974,
Yoshiaki Kobayashi; for 75 days from 9, Nov. to 21, Dec. in 1974, and
Osamu Kanzaki ; for 120 days from 14, Nov. to 14, Mar. in 1974.

3. Study and Work.

The investigations on the second stage can be largely divided in the study works of subground conditions for bridge foundation for one thing and the feasibility study of bank foundation and bank materials for the access roads (which will be constructed on the east and west sides in the total length of about 30 km) between the existing all-weather roads and the bridge site for the other thing.

As for the former, a plan was taken that the soil conditions for bridge construction will be determined by 6 borings in total; one each on the east and west banks of the main stream of the Jamuna River, one each on the east and west lands about 1 Km distant from the main stream and one in the central part of the main stream plus one executed in the first-stage investigations, considering that the geological stratigraphy has been already foreseen, based upon the results of the first-stage investigations and that the scale of bridge construction has been considerably limited. And the boring depth at each point was limited to the extent that the continuity of the gravel layer confirmed near to EL-70 m in the first-stage investigations could be confirmed. In the bored holes, the standard penetration tests and the in-situ lateral loading tests for measurement of soil reaction values were mainly performed. In addition to these tests, the laboratory tests by undisturbed samplings in the shallow layers as well as the soil physical tests by distrubed samplings every 3 m were made in the bored holes. That is, the principal objects of these tests were to confirm the bearable layers for bridge foundation, to determine the characteristic strength of every layer and its lateral soil reaction value to substructures (caisson) and to examine the continuity of each layer.

Considering that the access routes will be constructed through the very flat flood plains of the River Jamuna, which would be estimated in relatively simple ground conditions, and that the sampling would aim at the feasibility design, the examinations on the ground conditions of the site for road-bank foundation were made by simple tests; a Swedish penetration test that was made every about 1 Km over the total distance of about 30 Km and a CBR test that was made in laboratory through disturbed sampling by hand auger boring and hand digging. Then, the design factors of soil were indirectly estimated from the data of these tests plus the data of the laboratory tests for the bridge site. The design factors of banking materials were determined similarly from these data, on the premise that the in-situ soil will be used for the banking materials. The detailed positions of investigations and the summarized results are illustrated in Fig. 1-1 showing the geological profile and explanation table on bridge axis and in Fig. 3-1 showing the subsoil profile for access road route.

Table 1-1 indicates the working quantities tested.

Table 1-1 Working Quantities

Bridge Axis

Bore No.	S-1	S-2	S-3	S-4	S-5	Total
Depth drilled (m)	93.11	122.06	93.2	121.73	93.2	523.3
Standard penetration test	33	45	33	43	35	189
Lateral loading test	6	6	6	6	6	30
(Physical test)						
Natural moisture	36	48	37	48	37	206
Specific gravity	36	48	37	48	37	206
Wet density	3	3	4	4	2	16
Dry density	3	3	4	4	2	16
Grain size analysis	36	48	37	48	37	206
Liquid limit	1	4		1		6
Plastic limit	1	4		1		6
(Mechanical test)						
Unconfined compression test	1	1		2		4
Triaxial compression test	3	3	4	4	2	16

Access Route

Swedish Penetration Test: 37 spots 307.7 m

Auger Boring : 20 spot 64.1

Hand Sampling for CBR Test: 10 spots

(Laboratory Test)

Physical test	Total		Total
Natural moisture	79	Compaction test	10
Specific gravity	79	CBR test	10
Grain size analysis	79		
Liquid limit	8		
Plastic limit	8		

4. General Geology.

The general geology of the Jamuna River basin is detailed in the "Study Report on Subsoil Investigation Works, First Stage, 1974", which will be summarized hereinafter.

In the geology of Bangladesh, the base rock is composed of sedimentary rocks in the Tertiary period and rocks in the pre-Tertiary period, which are subsided in the depth influenced by Himalayan orogenesis throughout this country except in its eastern part where the Tertiary rocks croped out.

This base rock is covered with the Pleistocene deposit, which settles in the depth of scores or more meters in a larger part, though the smallest part of it croped out under river erosion in the lowering time of sea level from the Pleistocene to the lower Holocene.

The alluvial deposits are distributed almost all over the land of this country, filling in the valleys of the glacial epoch.

In Fig. S-1, the layers above the Al_1 layer are alluvial deposits, while the deeper layers are diluvial deposits. The larger part of the alluvial deposits is mainly made up of fine sand and medium grain sand, the deposits have a greater density as they are deeper, and the basal plains of alluvium are gravel layers. In the site for construction of the bridge, these gravel layers are about 60 m to 70 m below the present sea level and have a good continuity. The delivium under the alluvium is made up of sandy soil having a higher density, interbedded with gravelly soil, stiff to hard clay and others.

In Fig. S-1, the layers under Du2 are upper diluvial deposits, and it can be considered that they correspond to the typical Dupi Tila formation in the diluvial epoch. It was determined by the radiocarbon dating (C^{14}) of a fossil wood sampled in the stratum that it is a stratum formed 28,320 years ago. And it was thus confirmed that this stratum is in the Wurm Ice age. Similarly, the layers above the Al_1 layer are alluvial deposits, and the Al_1 layer is basal gravel for that laver. This alluvial deposits are made of fine to medium sand in general and have medium to high densities.

This classification in strata is an original method conceived by our project team, considering stratigraphy in addition to grain size, density and other characteristics of stratum.

The results of our geological investigation works are that the site proposed for construction of bridge is a very flat alluvial plain through which the River Jamuna meanders in the dissected depth of a little more than 10 m from north to south, that the anabranches are in similar form and that the water level rises to the alluvial plain, which is flooded in the vicinity of the river, in the rainy season (or flood season). Fig. 1-2 showing a geological map of Jamuna River area (an original drawing of Bangladesh geological survey) illustrates the general geology in the Jamuna River area. In this figure, the determined bridge site is in Site No.3.

CHAPTER II

FOUNDATION OF BRIDGE SITE

1. Classification and Circumstances of Stratum.

Fig. 1-1 showing a geological profile and explanation table on Bridge Site was drawn up, based upon the results of investigation works. The chronological and stratigraphical classifications used in this figure are originally conceived by our project team for convenience, but not authorized.

These classifications take consideration of grain size, density and stratigraphy. The boundary between Holocene and Pleistocene is determined in such a way that the gravelly soil layers distributed uniformly in the area near to EL-70 m are considered as basal gravel of alluvium, under which the layers are considered as diluvium.

Besides, the area near to EL-100 m (Bore S-0 and Bore S-2) was verified as diluvium by the radio-carbon dating (C^{14}) of a fossil wood sampled there.

Explaining the Explanation Table in Fig. 1-1 additionally, the grain size distribution was made up by superposing a number of results of grain size analyses by stratum, drawing a typical curve according to a series of the most densely superposed points and indicating the read-out figure as typical grain size, as it is shown in Fig. 2-1. The result can be relatively well shown in Fig. 2-1 except the Au2 layer where there is considerable irregularity.

The unified soil classification is in conformance to the Japanese Standard. The corrected N-value and the soil reaction value (E-value) essential for designing of caisson structure, as well as C, ϕ, γt, etc. are described in detail in the paragraph 3.

As it is shown in Fig. 1-1, the soil near around the bridge axis is made of silty fine sand in the uppermost layer, of gradually coarser grain sand with higher density in the deeper levels, and of gravelly sand including as big boulders as human heads and having a good continuity in the undermost layer of the alluvium, which uppermost face is almost horizontal to EL-70 m.

Going into the diluvium, it is made of gravel, gravelly sand, stiff to hard clay and other layers and has such a greatly high density that it looks like a soft rock in some parts.

2. Explanation of Strata.

(1) Stratum Au2

The stratum Au2 is made of drifted sand deposits by floods of the River Jamuna and the following shifting of the river and anabranches. So in this stratum alternate the micro-fine sand, sandy silt and clayey silt layers having a small depth according to the variation of the flow velocity of the deposits. The whole stratum is, hoever, mainly made of fine sand with a considerable amount of cohesive soil in the depth of less than several meters.

This shallower layer is object of bank foundation, of which the high shearing stress can not be expected.

As for the coefficient of permeability (k) that will be essential value for excavation, it can be estimated at $k = 2 \times 10^{-5}$ to $k = 1 \times 10^{-4}$ cm/sec in the layer having a larger silt fraction, based upon the grain size distribution and the laboratory tests made in the first-stage investigation works. The silty layer is, however, relatively thin in this stratum and it is placed between upper and lower sand layers without exception, so that the permeability of the sand layers must be in fact considered as a factor of great importance. A larger must be in fact considered as a factor of great importance. A larger part, 75 to 80 %, of the sand layer is made of fine sand, as it is shown by the grain size curve in Fig. 2-1, and the samples corresponding to this sand layer, used by the laboratory tests in the 1st-stage investigation works, represented practical data; $k = 2.8 \times 10^{-3}$ to $k = 5.1 \times 10^{-3}$ cm/sec. Therefore, sufficient attention should be paid to the possible quick-sand action during excavation works.

(2) Stratum Au1

Compared with the stratum Au2, the stratum Au1 consists mainly of more concentrated and poorer graded medium sand fraction of which 70 % is 0.2 mm to 0.55 mm in grain size and of smaller silt fraction of about 13 % (thin silt layer). It presents a characteristic that the grain size distribution is the lest irregular among all the strata (Fig. 2-1). The grains of this stratum are mainly of sub -angular quartz with a great amount of fine biotite fragments.

The stratum Au1 has a considerably high density, that is, 30-blows of typical N-value, while the stratum Au2 has a relatively low density (8-blows of typical N-value).

It has, however, a higher permeability, since it is mainly made of poor-graded sand.

For example, the permeability of this stratum can be calculated according to the Harzen formula as follows:

$$k = C \cdot D_{10}^2 \quad \text{......} \quad (2.1)$$

wherein k is coefficient of permeability (cm/sec), C is constant (50 to 100) and D_{10} is effective grain size (cm).

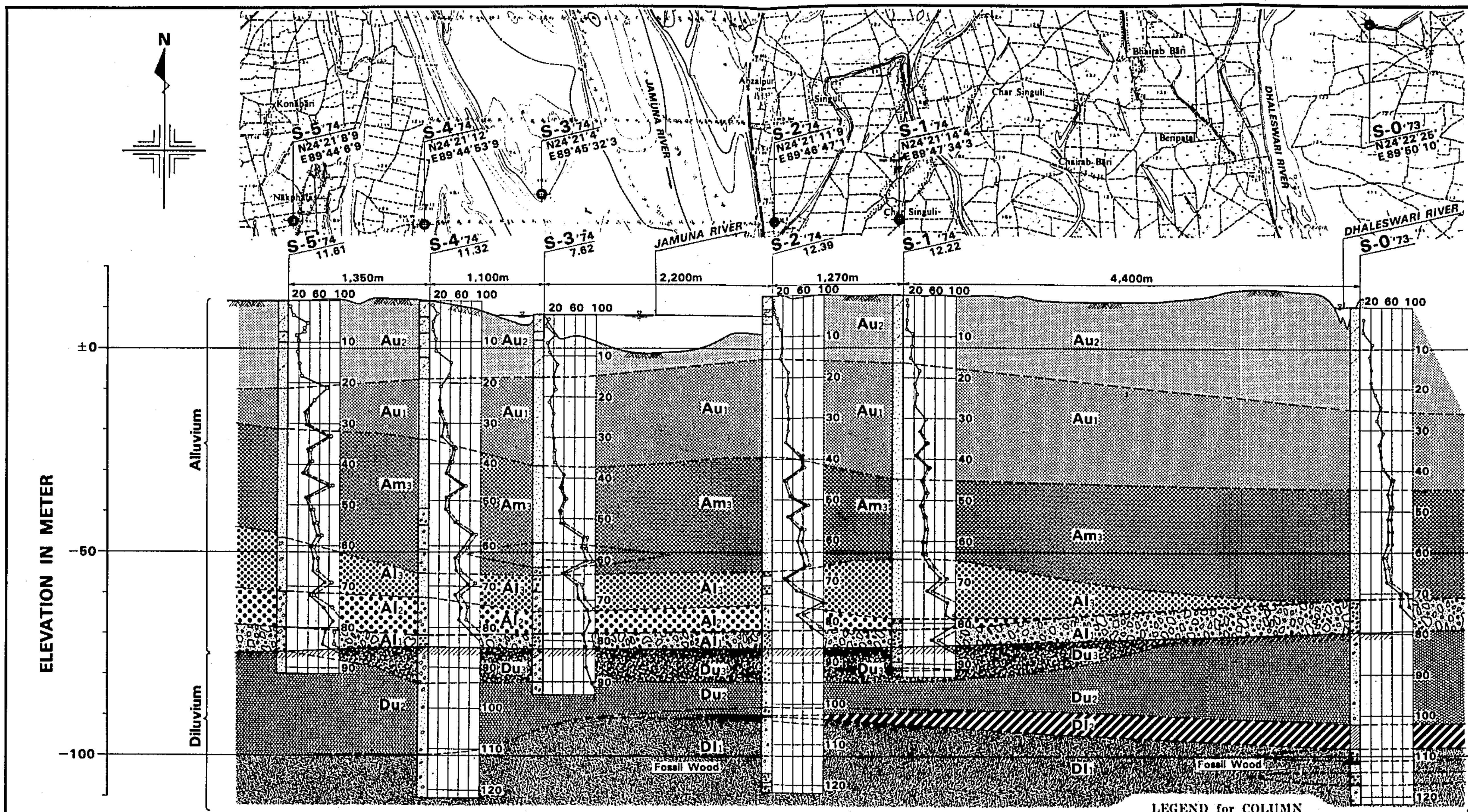
If D_{10} is 0.004 to 0.009 and 0.006 cm in average, the following values will be obtained by the formula (2.1);

$$k_{max} = 8.1 \times 10^{-3}, \ k_{min} = 1.6 \times 10^{-3}$$

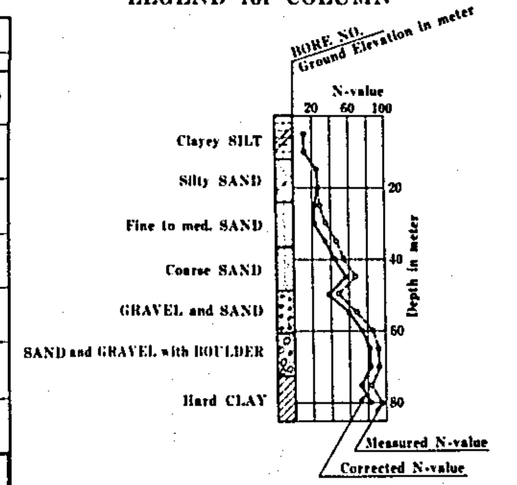
and $k_{average} = 3.6 \times 10^{-3}$

If can be confirmed also by these values that the stratum Au1

Fig. 1-1



LEGEND for COLUMN



GEOLOGIAL AGE	STRAIT--GRAPHY		STRATA	DESCRIPTION			TYPICAL GRAIN SIZE DISTRIBUTION	AVERAGE OF			UNIFIED SOIL CLSSIFICATION	CORRECTED N-VALUE		DEFORMATION MODULUS (E-VALUE) (kg/cm²)			ESTIMATED SOIL MECHANICAL VALUE		
				CHARACTER	COLOR	FACIES	20 40 60 80 %	D10 (mm)	D60 (mm)	Uc		by UTO'S FORMULA	by INSITU DATA	E_1	E_2	E_3	C	φ	γt
HOLOCENE	YOUNG ALLUVIAL DEPOSITS	UPPER	Au2	SILT and Fine SAND	GRAY	Fluvial to deltaic		0.035	0.15	4.3	S M	8	10	56	28	77	0 ~ 0.1	13 ~ 32	1.8~1.9
			Au1	Fine to Med. SAND	-do-	-do-		0.06	0.3	5	S M	30	36	210	101	89	0	34	2.06
		MIDD-LE	Am3	Fine to Med. SAND	-do-	Terrace to Fluvial		0.045	0.3	6.7	S M	38	40	266	112	111	0	36	2.17
	OLD ALLUVIAL DEPOSITS	LOWER	AL3	GRAVEL and coarse SAND	-do-	Basal of Alluvium		0.065	0.55	8.5	S-Mg	78	60	546	168	114	0	40<	2.21
			AL2	GRAVEL and coarse SAND	-do-	-do-		0.05	0.7	14	S-Mg	78	60	546	168	114	0	40<	2.21
			AL1	SAND and GRAVEL with BOULDERS	-do-	-do-		0.2	3.6	18	G-M	80<				230	0	40<	2.26
PLEISTOCENE	YOUNG DILUVIAL DEPOSITS	UPPER	Du3	Coarse SAND with small gravels	-do-	Upper of Diluvium		0.043	0.75	17.4	S Mg						0	40<	2.26
			Du2	Coarse SAND scattered small gravels	-do-	-do-		0.04	0.35	8.8	S Mg								
	OLD DILUVIAL DEPOSITS	LOWER	DL2	Hard CLAY	greenish GRAY	Lower of Diluvium		0.009	0.07	7.8	M H								
			DL1	Gravel and SAND, dense	GRAY	-do-		0.028	0.35	12.5	S M								

E_1 Estimated from N-value by experimental relation betw. E&N in Japan. (E=7N Yoshinaka's formula)
E_2 Estimated from N-value by insitu experimental relation betw. E&N (E=2.8N)
E_3 Mean measured E-value.
E_3 : Most actual one.

C : Cohesion (kg/cm²)
φ : Internal friction (degree)
γt : Unit weight (g/cm³)

SCALE for distance in meter

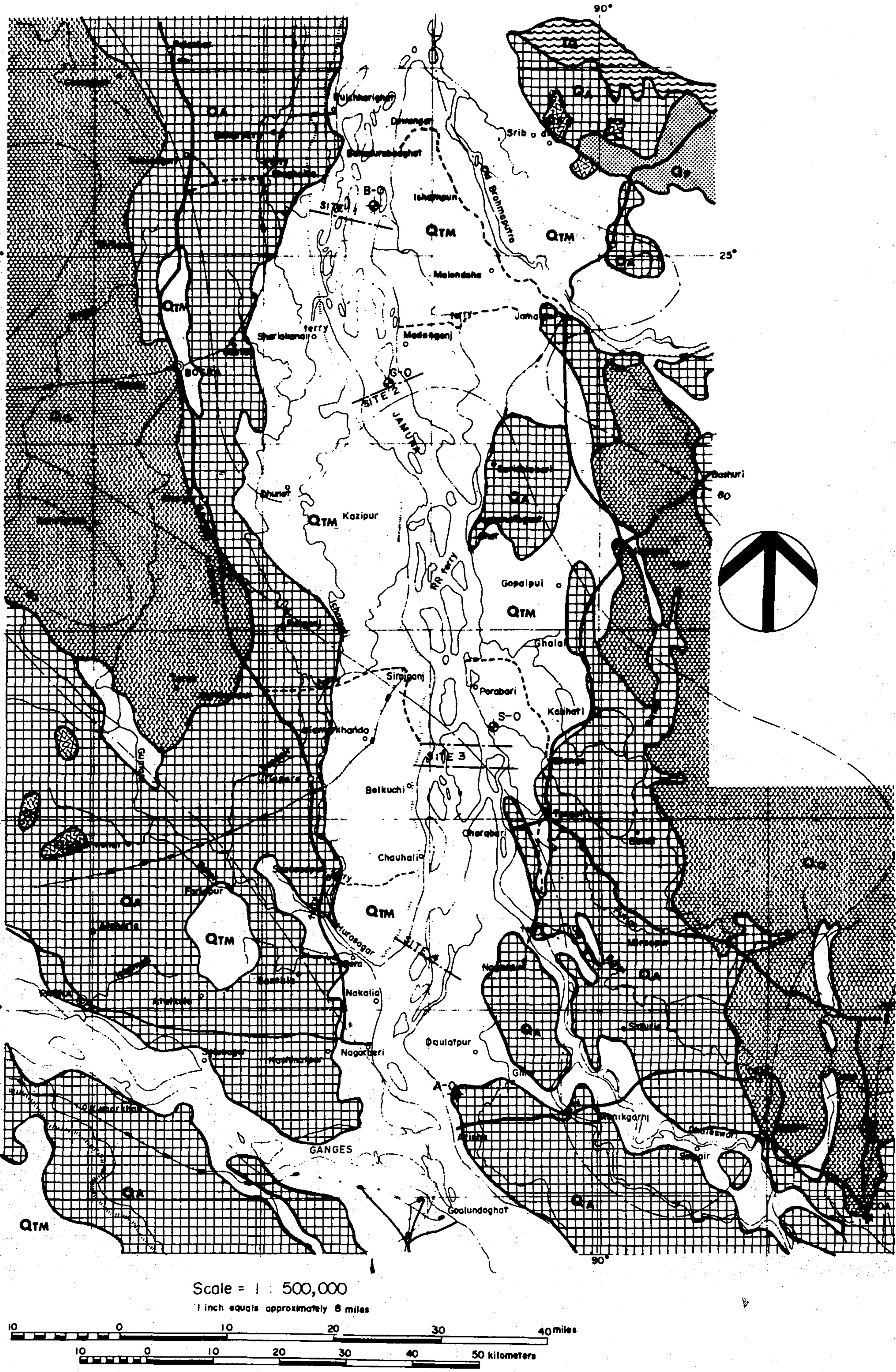
JAPAN INTERNATIONAL COOPERATION AGENCY

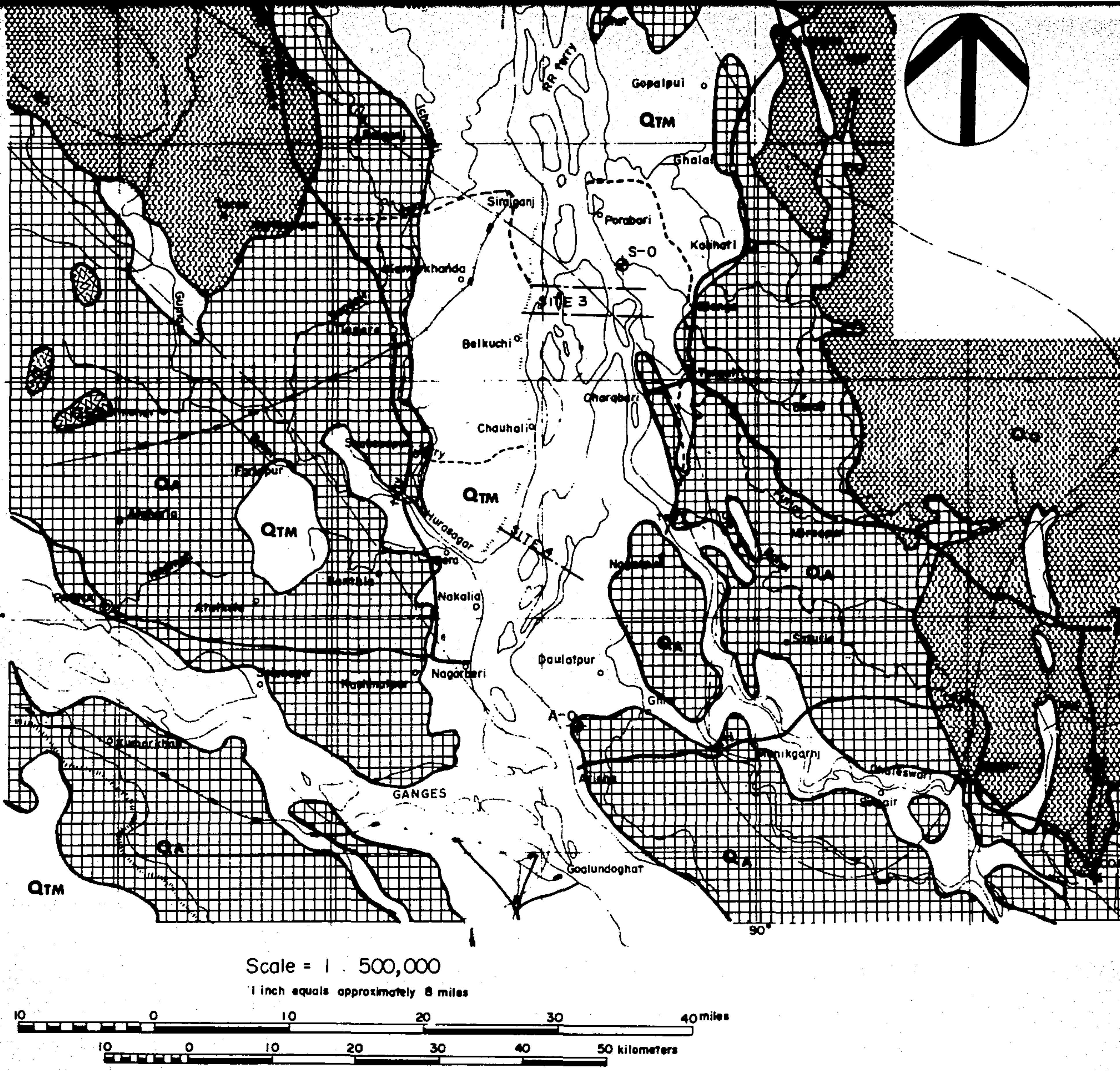
PEOPLE'S. REPUBLIC OF BANGLADESH

JAMUNA RIVER BRIDGE CONSTRUCTION PROJECT

GEOLOGICAL PROFILE AND EXPLANATION TABLE ON BRIDGE SITE.

DRAWN [signature]	DATE 14. Nov. 1975
APPROVED	DATE
NIPPON KOEI CO.LTD	


90°
25°
24°
QTM
QA
Srib
Old Brahmaputra
Dewanganj
B-0
SITE 1
Melandaha
Madarganj
BOGRA
G-0
SITE 2
JAMUNA
Kazipur
Bashuri
80
Gopalpur
RR ferry
Ghatail
Sirajganj
Porabari
S-0
SITE 3
Belkuchi
Charabari
Chauhali
Faridpur
Nakalia
Nagarbari
Daulatpur
A-0
GANGES
Goalundoghat
Scale = 1 : 500,000
1 inch equals approximately 8 miles
10 0 10 20 30 40 miles
10 0 10 20 30 40 50 kilometers



GEOLOGICAL EXPLANATION

QS	QD	QDS	QTM

QS, Swamp deposits
QD, Deltaic deposits
QDS, Swamp and deltaic deposits, undifferentiated
QTM, Terrace and meander deposits, including swamp deposits in some areas

QP

Piedmont Deposits

Detrital material derived from the highlands of India and Burma and deposited on gentle slopes to the south and west.

QA

Interstream Deposit

Silt, sand, and gravel deposits at a slightly higher altitude than adjacent flood plain and low level terrace deposits

Older Alluvial Deposits

Madhupur Clay; mostly red and orange clay deposits at a slightly higher altitude than interstream deposits (Qia) and having an incised dendritic drainage pattern; generally not subject to seasonal flooding. Possibly equivalent to the Dupi Tila formation.

TQ

Pleistocene And Pliocene Sedimentary Rocks

REGEND

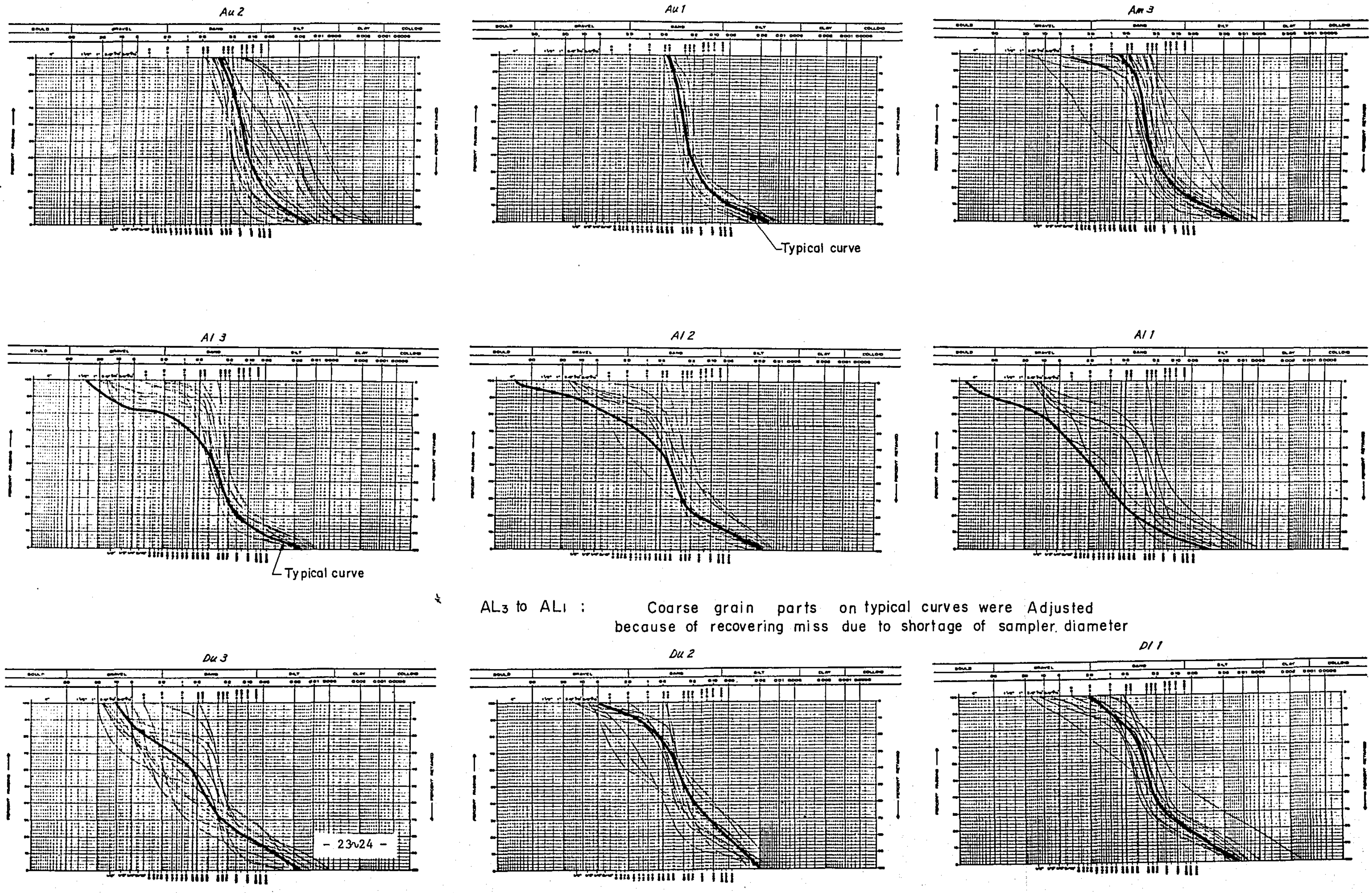
- ★ Provincial Headquarters
- ◉ Divisional Headquarters
- ◎ District Headquarters
- o Subdivision or Thana Headquarters smaller towns and villages
- Railroads
- Embankment
- All Weather Road
- —80— Annual Rainfall (in inches)
- - - - - Existing Road
- SITE 1 — Proposed Site of Jamuna Bridge
- Proposed Aligament
- S-0 Soil investigation hole for Bridge Site (Bored by O.T.C.A Japan)

Cited from Bangladesh Geological Survey data

OVERSEAS TECHNICAL COOPERATION AGENCY JAPAN	
PEOPLES REPUBLIC OF BANGLADESH	
JAMUNA RIVER BRIDGE PROJECT GEOLOGICAL MAP OF JAMUNA RIVER AREA	
DRAWN	DATE
APPROVED	DATE
NIPPON KOEI CO.,LTD	Fig

Fig. 1-2

Fig 2 - 1 Grain Size Distribution for strata



has a higher density and is mainly poor-graded sand with high coefficient of permeability. These mean that the quick-sand actions will be easily caused during excavation works in this stratum as in the stratum Au2.

(3) Stratum Am3

The stratum Am3 has a grain size distribution of a little coarser grains than the above-described stratums, but it is made of concentrated and poor-graded sand as the statum Au1. It has a higher density, 40-blows of typical N-value, than the Au1 having a density of 30-blows. The grains are mainly of sub-angular quartz with fine fragments of biotite.

The permeability is relatively high, since it is made of poor-graded sand, and can be calculated according to the formula (2.1) as follows:

If D_{10} max is 0.009 cm, $K_{max} = 8.1 \times 10^{-3}$ cm/sec

If D_{10} min is 0.002 cm, $K_{min} = 4.0 \times 10^{-3}$ cm/sec

If D_{10} average is 0.0045, $K_{average} = 2.0 \times 10^{-3}$ cm/sec

Therefore, it can be considered that there is no great difference in coefficient of permeability between the strata Am3 and Au1, since the strata have an almost same grain size.

(4) Stratum Al_3

The stratum Al_3 consists of alternations between a sand layer similar to the stratum Am3 with small gravels scattered and a gravel seam. The gravel seam in the alternation contains 20 % to 40 % of round gravels having the largest diameter of about 30 mm. The 50 % of sand fraction is as same as that in Am3.

The sand grains are mainly sub-angular quartz grains with fine fragments of biotite. The gravel fraction is made of hard and water-rounded stones such as gneiss and siliceous sandstones. The permeability of this stratum is $k = 5 \times 10^{-3}$ cm/sec in the sand layer and k = Approx. 9×10^{-3} cm/sec in the gravel seam. The typical N-value is in a large range of 30-blows to 100-blows, but concentrated at 70 to 80-blows in a larger part of this stratum.

(5) Stratum Al_2

The stratum Al_2 is similar to the stratum Al_3 except that the former has a larger fraction of gravels. The gravels are scattered in the sand layer, and form seams in some parts. The sand and gravels are both hard and well water-rounded siliceous stones. In the sand layer are found laminations of biotite and green minerals inserted in the sand. The density and permeability of Al_2 can be considered as almost same as those of Al_3.

(6) Stratum Al_1

The Stratum Al_1 is so-called basal gravel layer in the lowermost part of the alluvium. This stratum is characterized by the fact that it consists mainly of big boulders having the estimated maximum diameter of about 30 cm. As it was found in the Fig. S-1 geological profile along the River Jamuna during the first-stage investigation works, it extends almost continuously all over the projected area surely. In the projected site for construction of a bridge, the surface of this stratum extends flatly in the level almost horizontal to EL-70 m. The gravels and boulders in this stratum are hard rocks such as granite-gneiss, siliceous sandstones, slates, quartzites, limestones, and in addition to them, soft shale of Pleistocene rarely. They are all well water-rounded. The core-samples picked up by boring are all limited in size by the bit diameter (ϕ 86 mm), but the feeling performed during boring works verified that the boulders having diameters of more than ϕ 60 mm would represent 10 to 20 % of the whole of fraction.

It can be considered that there may be underflows in this stratum, because some amount of drill-mud was lost during boring works and sometimes diluted, and that this stratum may have a considerably high coefficient of permeability.

It can be also considered that it has a high density, because it is well graded in grain size and because it is placed in the extreme depth.

Therefore, it is considered as sufficiently tough and strong for the bearable layer to support caissons for piers.

(7) Stratum Du_3

The stratum Du_3 and the lower strata constitute the diluvium, which is pale green in a larger part and pale brown in the other part, and much denser with layers containing a number of fine sand fractions and being in stiff to solid state, so that it has a low natural moisture and an impermeability.

This stratum Du_3 consists of gravel fraction having the maximum diameter of ϕ 20 mm in a considerable large part of over 20 % to 40 %, and silt and sand fractions equally distributed in the rest. It is mainly characterized by the fact that it has such a high density that it can be in semi-solid state and called soft conglomerate. For instance, N-value could be 100 blows for only approx. 10 cm penetrations in the standard penetration tests. This stratum is dark green in a larger part and brown in the other part. Soft siltstones (stiff silt) and dense fractions of fine sand are rarely inserted in this stratum.

(8) Stratum Du_2

The stratum Du_2 is a well-graded sand layer in which coarse sand layer in which coarse sand to silt are equally distributed. Small gravels are also scattered in the whole stratum, and small gravel seams and siltstone seams (or stiff silt) are inserted in it as well. This stratum is as very dense as the upper stratum but rarely in stiff state. It has a low natural moisture and a impermeability, since it is highly dense. The N-value is 100 blows for 15 to 20 cm penetration.

(9) Stratum Dl_2

The stratums Dl_1 to Du_2 fall in the same group, but there is a muddy stratum in the middle part between Dl_1 and Du_2, which was represented as Dl_2.

This stratum is made of mudstones or siltstones so that it can be represented as stiff and cohesive clay layer. The part containing a larger sand fraction has a low solidity, while the part containing a larger silt and clay fractions is completely solidified. The solidified fractions are often recovered as solidified core samples during boring works.

This stratum was 5.8 m thick in the bore S-0 (The first-stage investigation works in 1973), but it was 0.5 m thick in the bore S-1 for the second-stage investigation works and sometimes recognized as seams.

(10) Stratum Dl_1

This was the lowermost stratum in this investigation work. The features of this stratum are similar to those of Du_1, except that it is green in a larger part and that mudstone seams are inserted in it in form of lamina. In the other terms, it is a dense sand layer in which small gravels are scattered in some parts and mudstone seams are inserted in the other parts, and it can be a very stable foundation. The N-value is 100 blows for 10 to 15 cm penetration in general.

3. Design Soil Factors for Bridge Foundations.

The following examinations were made to select the design soil factors necessary for bridge foundation.

a) The subsoil within the depth range investigated was classified in 10 strata from the stratigraphical point of view (Fig. 1-1).

b) The physical characteristics (grain size distribution, specific gravity, natural moisture) of each stratum were represented in histograms, and their typical values and their distributions were examined. (Figs. 2-1, 2-2 and 2-3)

c) As the standard penetration tests were made in the extreme depths, examinations and required corrections of the test results according to the depth were made. (Paragraph 3.1.)

d) The N-values of each stratum were represented in histograms, and examinations were made on their distribution and their typical value. (Fig. 2-4)

e) Examinations were made on the lateral soil reaction values that is related with designing of the caisson foundation. Besides, the methods of deducing the values directly from measured values and indirectly from N-values were also examined. (Paragraph 3.4.)

f) The coefficient of permeability for each stratum was indirectly estimated from the grain size distribution (Paragraph 2.)

From the above-described examinations were obtained the soil basical values of N, C, ϕ, γt, γs, E, and k, which are essential as design soil factors for bridge foundation. The process of deduction for every value will be described in detail hereinafter.

Fig. 2-2 Histograms of specific gravity for strata

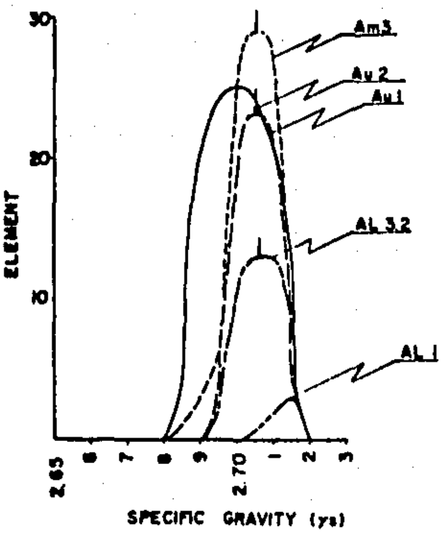


Fig. 2-3 Histograms of natural moisture for strata

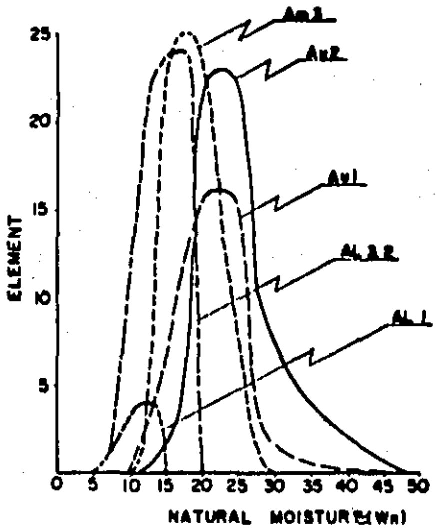
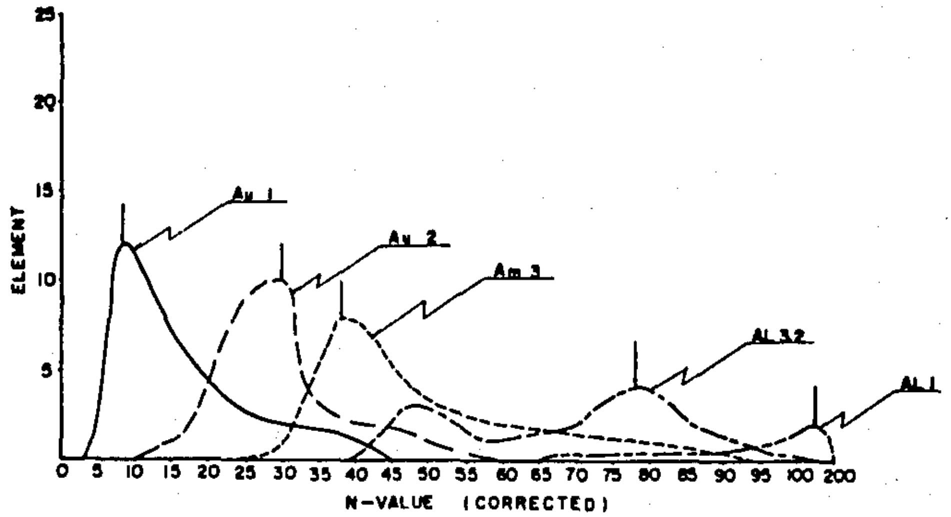


Fig. 2-4 Histograms of N-value for strata



3.1. Examinations on N-values.

The measurement of N-values by the Standard Penetration Test which was one of the important insitu tests made in our investigation works. Nevertheless Measured value were encountered a problem because of blow energy would have kinds of losses on the way to the bed in the very deep position where the measurements were obtained imperfectly.

A number of study results have been provided by Terzaghi-Peck (1948), Ikeda (1959), Thornburn (1963), Uto (1974) and others on the correction of such measured values.

Here, considering that the highest is the loss of blow energy caused on the way of its transmission to the bottom of a bore, the loss-error of the measured value was corrected by the formula of Uto (1974), and the corrected value was then applied to the N-value which would be introduced in the design value.

Formula for N-value correction (Uto, 1974)[8]

$$N = N' \qquad (L < 20\ m)$$
$$N = (1.06 - 0.003\ L)N' \qquad (L \leq 20\ m) \qquad (2.2)$$

L: Length of drill rods.

wherein N is corrected N-value and N' is measured N-value.

Besides, the results of the in-situ LLT tests were corrected in relation to N-values and compared with the corrected N-values by Uto formula to confirm the accuracy of the formula. The results of comparison were that there was no great difference between the results of LLT tests and the corrected N-values and that the Uto formula would be available for the correction.

3.2. Examinations on C and ϕ.

The soil in th is projected site consists of sandy soil and gravelly soil in a larger part. Therefore, the value ϕ could be deduced indirectly from the N-value with examinations, though the mechanical tests could not be made directly on the soil because of their difficulty.

A number of study works had been provided on the relation of N-value to ϕ-value by Peck-Hanson-Thornburn (1953), Dunham (1954), Terzagi-Peck (1948), Meyerhof (1956), Ohsaki (1959) and others.

Here, the ϕ-value was obtained from the Dunham formula which was considered as the most adequate.

Dunham Formula: (2.3)

Round and poor-graded sand .... $\phi = \sqrt{12N} + 15$

Angular and well-graded sand .... $\phi = \sqrt{12N} + 25$

Round and well-graded sand .... $\phi = \sqrt{12N} + 20$

Angular and poor-graded sand .... $\phi = \sqrt{12N} + 20$

The sandy soil in the projected site is generally made of round and poor-graded grains, though angular grains are also in the soil. From this point of view, the formula (2.3) was adopted here.

This formula by Dunham is formed on the assumption that the soil is sandy. It can be considered that every stratum of the projected site consists of sandy to gravelly soil, as it is shown by the typical grain accumulation curve of the stratum in Fig. 2-1..

Especially, the strata Au_2, Au_1, Am_3, Du_2 and Dl_1 are made of typical sand, and the strata Al_2, Al_1, Al_3 and Du_3 are of gravelly sand. Fig. 2-1 shows a grain size distribution of every stratum obtained by the grain size analysis.

Fig. 2-4 shows histograms of N-value distributions.

The peak values were adopted for the N-values of the strata Au_1, Am_3 and Al_2. The measured value of the stratum Al_1 containing a large fraction of gravels was possibly overestimated with measurement errors. So the minimum value corrected from the measured value by the formula (2.2) was adopted for the N-value of the stratum. In the stratum Du_2 and the rests, it is $N > 100$. It can be estimated that the N-values of over 100 are unreliable, from the view point of N-value measurement mechanism, so that the upper limit is determined at 100.

The cohesion C of the sandy soil is generally as extremely small as negligible, and so it was neglected in the strata except the shallower layer of the stratum Au_2 in which the cohesion C was deduced from the laboratory test values.

The table 2-1 indicates the values N, C and ϕ of strata obtained by the above-described processes.

Table 2-1 Values N, C and ϕ of Strata

Strata	N	C	ϕ
Au_2 Silty	8	0.1	13
Sand	10	0	32
Au_1	30	0	34
Am_3	38	0	36
Al_3, Al_2	78	0	> 40**
Al_1	> 80*	0	> 40**
Du_3	> 80*	0	> 40**

* The measured values were recorded as over 100, but they were considered as overestimated and so the lower limit of 80 was adopted.

** These values could be over 40°, deduced from the N-values. In the literature (5), it is provided that the deduced values from N-values shall be estimated at under 45°, and so the range of 40° to 45° is available.

3.3. Examinations of γt.

The determination of moisture(Wn), specific gravity of soil grain and grain size was performed by laboratory tests on the disturbed samples picked up in bores every about 3 m of depth by means of a split spoon sampler.

The frequency distributions of moisture and specific gravity for the soil of every stratum were examined by means of the histograms, and the peak values were selected as respective typical values for each stratum. (Fig. 2-2 and Fig. 2-3)

The value γt can be determined by the following equation.

$$\gamma t = \frac{1 + Wn/100}{1/\gamma s + Wn/(\gamma w \cdot Sr)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2.4)$$

wherein γt is wet density (unit weight) g/cm^3, γs is specific gravity of soil (g/cm^3), Wn is natural moisture content (%), γw is specific gravity of water (1 g/cm^3) and Sr is saturation degree.

If Sr is 100 % and γw is 1 g/cm^3 in the strata more deeply placed than Au_1, because the underground water level is in the level GL-4.5m or less, γs is uniformly 2.70 g/cm^3 for every stratum, though there is found such an irregularity of it as shown in Fig. 2-2, and Wn is read out in Fig. 2-3, the values γt are calculated as indicated in Table 2-2 and they are sufficiently reliable. Besides, the value γt of stratum Au_2 is deduced from the results of laboratory tests.

Table 2-2 Unit Weights of Strata

Strata	Moisture	Specific Gravity	Unit Weight
Au_2 Silty	32 %	2.70 g/cm^3	1.8 g/cm^3
Sand	20	2.70	1.9
Au_1	22	2.70	2.06
Am_3	20	2.70	2.17
Al_1	15	2.70	2.21
Al_2	15	2.70	2.21
Al_3	13	2.70	2.26
Du_3	13	2.70	2.26

3.4. Examinations on soil reaction value.

1) Methods of examinations.

The bridge foundation is very likely to be built up in the great depth with caisson wells. In this case, great lateral forces due to earthquake, hydrodynamic pressure, wind pressure, etc. will work on the foundation. And the foundation will bear these forces with its own rigidity and the lateral reaction of the surrounding soil. Therefore, it was one of the important objects in our investigation works that the lateral reaction of soil would be determined.

To determine the lateral reaction of soil, there are several methods; (a) empirical calculation from N-value, (b) measurement by plate loadtest, (c) measurement with test pile and (d) measurement by loading on bore wall with rubber tube. Among these methods, it is (a) and (d) that are generally used in investigation works. We also adopted (a) and (d) for examinations on reaction value of soil.

For the rubber tube method (d), the DOKEN (Public Works Research Institute under the government of Japan) system, the LLT system and the pressio-meter system are generally used in our country. And we adopted the LLT system here. The mechanism and analysis method of LLT system will be detailed in Data Book 1.5.1.

To determine the soil reaction value, the base values are loading area (foundation scale) and deformation modulus (E-value) proper to the soil. To determine the E-value, examinations were made on the measured values by LLT system, the empirical N - E relations obtained in Japan and the measured N - E relations in the field. Besides, the method for depth-correction of measured N-value with measured E-value was examined.

2) N - E relation.

Several empirical formulas of N - E relation in Japan have been provided. Among them, the Yoshinaka formula, $E = 6.78\ N^{0.99}$ (Literature 6) ($E \fallingdotseq 7\ N$), is typical. On the other hand, we obtained such formula in the field, $E = 2.8\ N$, (Fig. 2-5)

This formula, $E = 2.8\ N$, was deduced from the drawing plotted up without considering the depth. Fig. 2-6 shows diagrams of N - E relations by measured depth range, and Fig. 2-7 is a diagram showing the N - E relations together in a sheet. Fig. 2-8 shows diagrams to deduce E-value from N-value according to the depth easily. Therefore, the measured N-E relations in the field are also in relation with the depth so that they can not be surely represented by a simple formula.

In this case, the corrected N-value by Uto formula (Formula 2-2) is applied to the N-value. This corrected N-value can be corrected again by using Fig. 2-8 so as to meet conditions in the field.

3) Calculation of E-value.

a) E_1, estimation from N-value by Yoshinaka formula:

This value can be calculated from the typical N-value for each stratum (Fig. 2-4) by the following formula.

Yoshinaka formula;

$$E = 7\ N \quad \cdots\cdots \quad (2\text{-}5)$$

b) E_2, estimation from the N - E relation in the field:

Field formula (Fig. 2-5)

$$E = 2.8\ N \quad \cdots\cdots \quad (2\text{-}6)$$

c) E_3, estimation from the measured value in the field:

This value is an average measured value for each stratum, as it is indicated in Table 2-3.

Table 2-4 indicates the above-described three kinds of E-values.

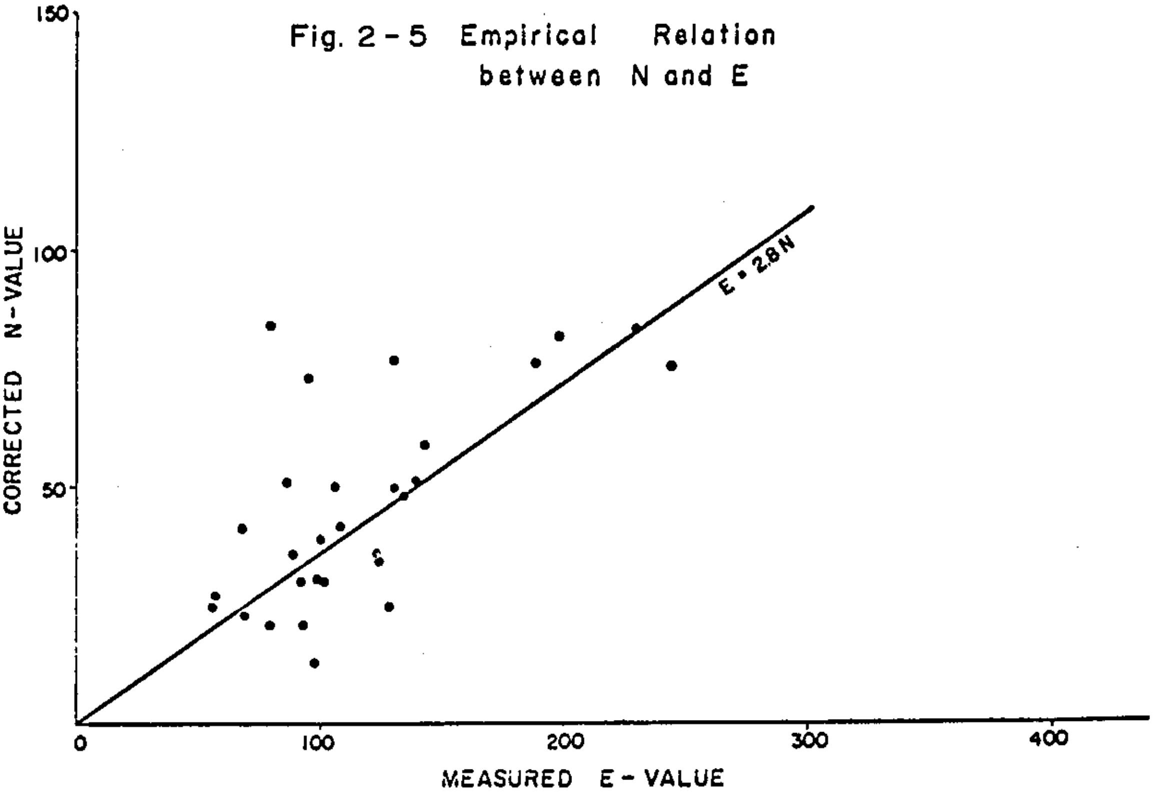


Fig. 2-5 Empirical Relation between N and E

Fig. 2-6 N-E Relation on Each Depth

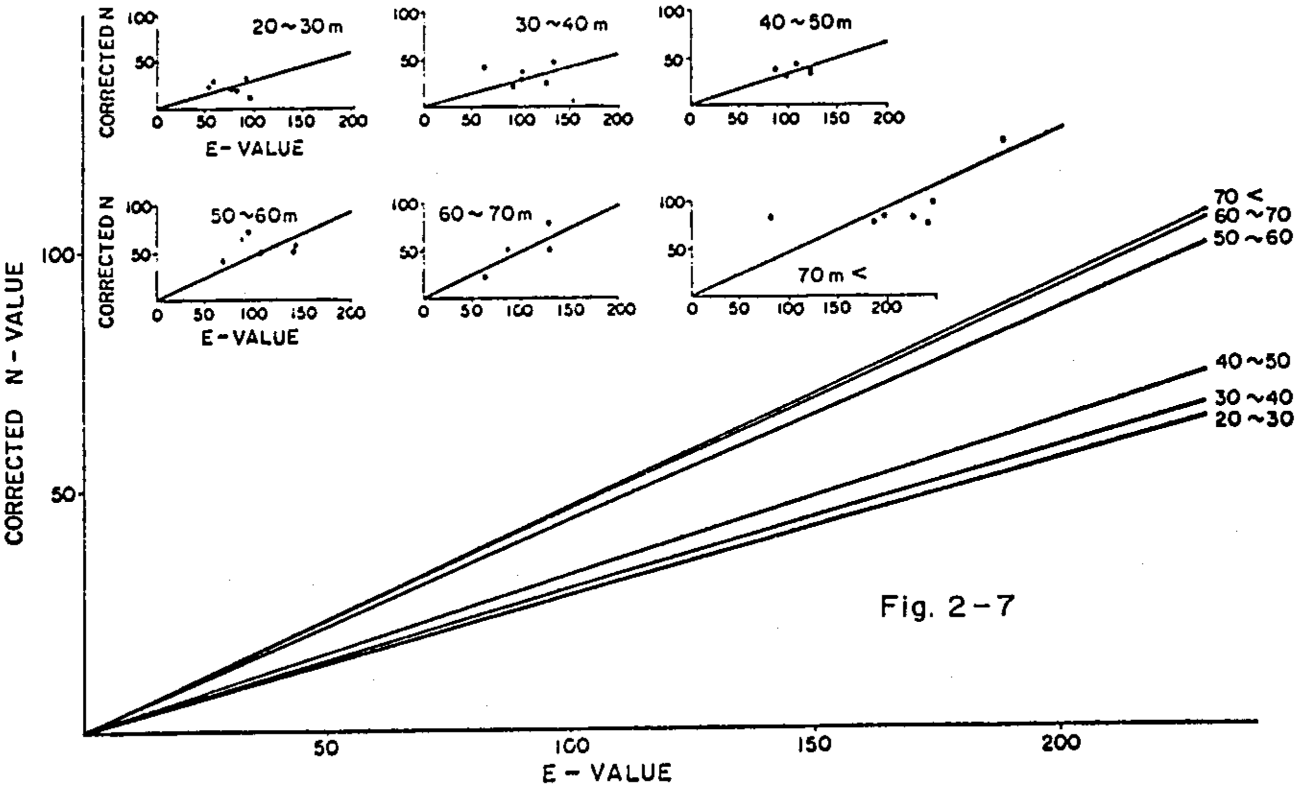


Fig. 2-7

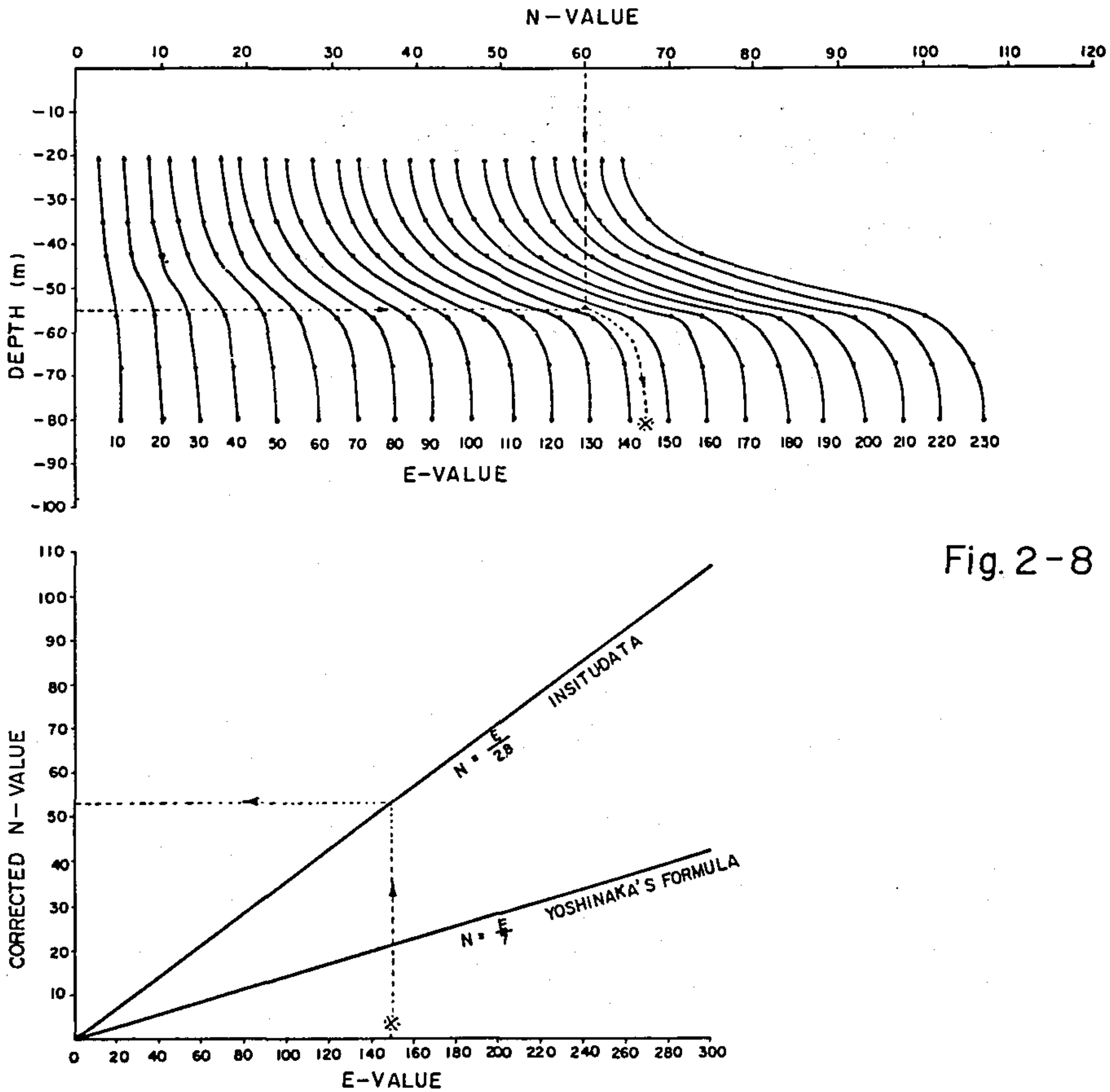


Fig. 2-8 EXPERIMENTAL RELATION between Measured N-value, E-value and Corrected N-value

Table 2-3 Measured Results of Lateral Loading Test

Strata	Bore No.& Depth (m)	Materials	Measured N-value	Mearsured K-value km(kg/cm³)	Initial radius r_o(cm)	Calculated radius r_m(cm)	Measured soil Reaction E(kg/cm²)
Au-2	S-0 16.40	Fine SAND	20	13.6	4.43	4.58	81.0
	S-0 22.56	Med. sand	28	15.8	4.48	4.60	94.5
	S-5 20.50	Fine to Med. SAND	25	8.1	5.00	5.29	55.73
							* 77.07
Au-1	S-0 30.96	Fine to Med. SAND	44	8.7	5.23	5.52	62.4
	S-1 23.20	-do-	27	9.8	4.30	4.49	57.2
	S-1 32.40	-do-	31	16.3	4.56	4.76	100.88
	S-2 20.40	-do-	30	16.5	4.12	4.29	92.0
	S-2 35.50	-do-	26	20.7	4.58	4.77	128.5
	S-3 20.60	-do-	13	16.2	4.44	4.65	97.9
	S-3 35.40	-do-	22	13.4	4.87	5.37	92.5
	S-4 20.40	-do-	21	12.4	4.59	4.83	79.1
							* 88.8
Am-3	S-1 47.20	Fine to Med. SAND	45	16.0	4.80	5.23	108.8
	S-1 56.30	-do-	46	9.8	5.01	5.36	68.6
	S-2 48.50	-do-	37	20.6	4.42	4.63	123.99
	S-2 59.40	-do-	57	18.1	4.30	4.51	106.08
	S-3 47.50	-do-	33	14.3	5.09	5.36	99.7
	S-3 56.30	-do-	82	15.7	4.10	4.47	94.2
	S-4 35.50	-do-	51	21.3	4.47	4.53	135.4
	S-4 47.50	-do-	39	19.7	4.50	4.79	122.7
	S-4 53.20	-do-	57	22.8	4.40	4.51	140.4
	S-5 36.10	-do-	41	16.2	4.61	4.81	100.3
	S-5 47.50	-do-	39	13.6	4.53	5.02	88.7
	S-5 56.40	-do-	66	20.6	5.05	5.35	143.3
							*111.01
AL-3,2	S-1 65.55	Grovel and SAND	58	23.8	4.10	4.23	130.8
	S-2 68.50	-do-	27	11.1	4.07	4.79	69.03
	S-2 79.80	-do-	93	31.0	4.45	4.78	189.34
	S-3 71.20	-do-	99	12.6	4.25	4.92	80.6
	S-4 66.90	-do-	90	21.5	4.33	4.66	130.3
	S-5 65.50	-do-	59	14.0	4.43	4.74	86.3
							*114.3
AL-1	S-1 84.90	Grovel and Boulder	100	33.8	4.45	4.57	197.86
	S-4 83.20	-do-	100/25	43.3	4.24	4.43	248.4
	S-5 80.40	-do-	91	39.9	4.49	4.71	244.3
							230.1
Du-3	S-3 83.50	Coarse sand with gravel	102	31.8	5.28	5.5	229.4

* Average of measured soil reaction value.

Table 2-4 Comparison between E-values obtained by three calculations

Strata	Typical-N	E_1	E_2	E_3
Au_2	8	56	28	77 (kg/cm^2)
Au_1	30	210	101	89
Am_3	38	266	112	111
Al_3, Al_2	78	546	168	114
Al_1	> 80	> 560	> 224	> 230

In Fig. 2-4, many of the corrected N-values for Al_1 which consists of gravelly soil are over 100, and the lower limit is about 80. So this value was adopted for the typical N-value.

Compared the values E_1, E_2 and E_3 with each other, the value E_1 is higher by 0.7 to 4.7 times than the value E_3. This great difference between the value E_1 which was deduced from the empirical N - E relations in Japan and the value E_3 which is an average measured value in the field seems to mean that the soil in the field is made of poorer-graded grains than the general sandy soil in Japan, but it is not sure.

The value E_2, which was deduced from the empirical N - E relations in the field, must not be so largely different from the value E_3. So it can be estimated that the difference is due to an irregularity in the N - E relations.

The value E_3, which was measured in the field, is more reliable and recommendable for design value.

However, if the number of measurement spots is not sufficient, and if the E-value in a local place where the N-value has been already measured in required, the value E can be advantageously obtained from N-values and their corresponding depth ranges in Fig. 2-8. The approximation of E-value can be obtained according to the formula 2.6 without any high error.

Table 2-5 indicates the typical E-value of every stratum for basic design. These E-values are recommendable for calculations in basic design.

Table 2-5 Deformation Moduli (E-values) of Strata for Basic Design

Strata	Au_2	Au_1	Am_3	Al_3	Al_2	Al_1
E(kg/cm^2)	77	89	111	114	114	230

CHAPTER III

SOIL CONDITIONS OF ACCESS ROAD ROUTE

1. Guidelines of Investigation and Study Works.

The projected bridge site is situated downstream 10 km distant from the town of Sirajganj, and there is no all-weather road in the vicinities of the both riversides, but several narrow roads such as bull-cart roads. The nearest all-weather roads are a road going from Asian Highway to Sirajganj branched Hatikumpul in the westside area and a national road from Tangail through Elenga to Mymensingh in the eastside area. The access roads to the projected site for construction of a bridge across the River Jamuna are intended to be about 30 km in total length from Sirajganj to Elenga in order to connect the east and west all-weather roads one to the other, as it is shown in Fig. 3-1.

It is planned that the access roads will be constructed by banking and that the approach parts to the bridge structure will be especially high banks. (Hereinafter, the access road will include these approach parts.)

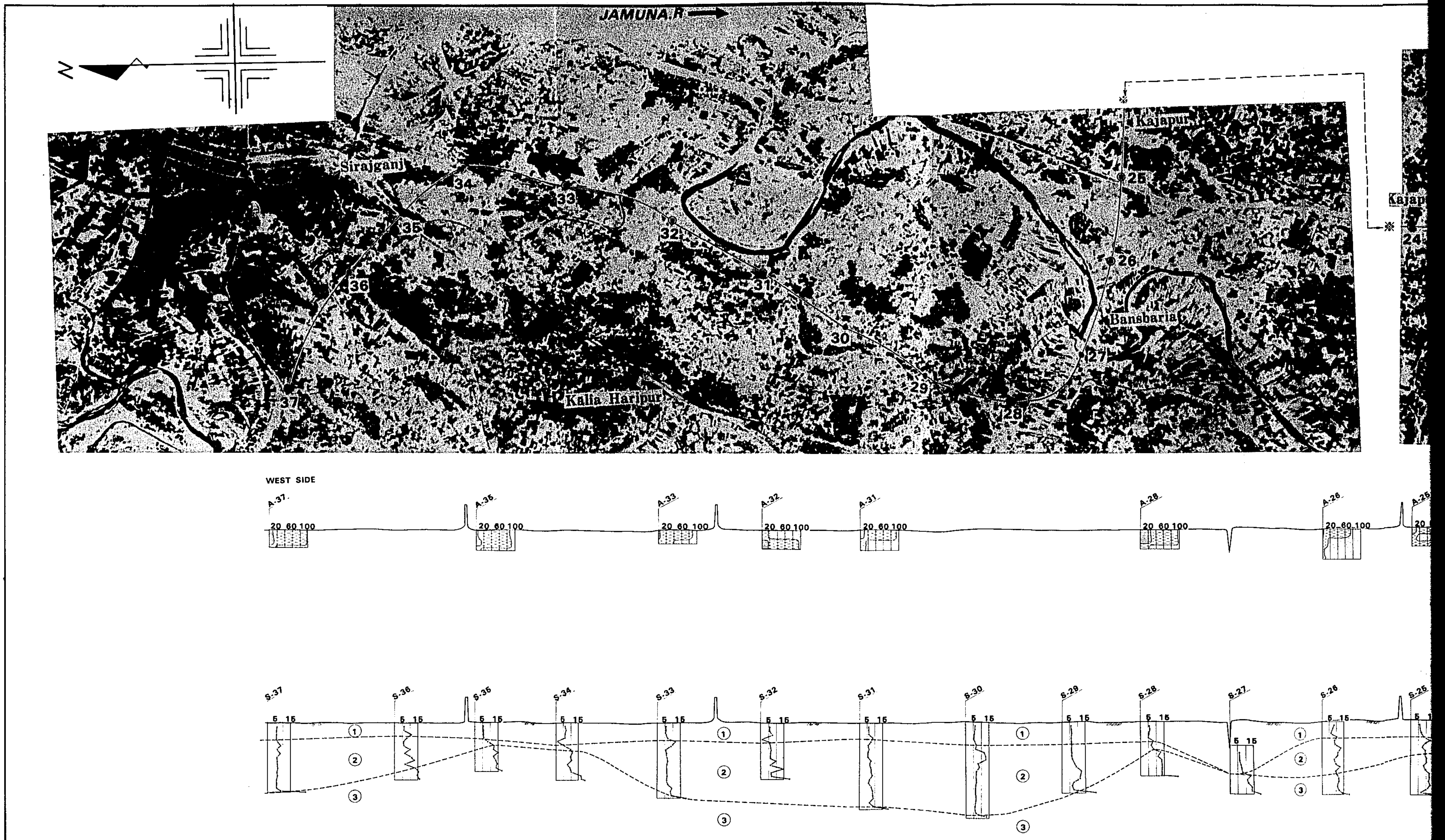
The original object of this project is the bridge construction, but the basic planning of the access roads intended to be additionally executed.

Therefore, the ground investigation works for the access route are only to determine the outline of its conditions. In detail designing, however, the survey and ground investigation works will have to be done regularly and in detail, of course.

The contents of the investigation work on the access route are shown in Fig. 3-1 and Table 1-1. Particularly, the Swedish penetration tests were made every about 1 km along the route planned (INTERIM REPORT, 1974) by the road study team, and then the N-value was estimated indirectly from the Nsw-value. And the disturbed samplings were done with hand augers at the same and principal spots, and the laboratory tests were made on each sample to determine its grain distribution, moisture content, specific gravity, etc.. Besides, the disturbed samplings were effected by hand digging at 10 principal spots selected freely, and the compaction and CBR tests in laboratory were performed on the samples. Considering the data of these tests and the results of field investigations from the overall point of view, estimations were made on the design soil factors of bank foundation and bank materials.

2. Outline of Ground Conditions.

According to Mr. Oya (Literature No.1, 1974), the ground along the River Jamuna near the proposed site can be geomorphologically classified in an alluvial sector region, a natural levee region and a background swamp region. The proposed access route belongs to the natural levee region, which forms a vast alluvial plain. This



JAMUNA.R
Sirajganj
Kajapur
Bansbaria
Kalia Haripur
Kajap
WEST SIDE
A-37
A-36
A-33
A-32
A-31
A-28
A-26
A-25
20 60 100
S-37
S-36
S-35
S-34
S-33
S-32
S-31
S-30
S-29
S-28
S-27
S-26
S-25
5 15
①
②
③

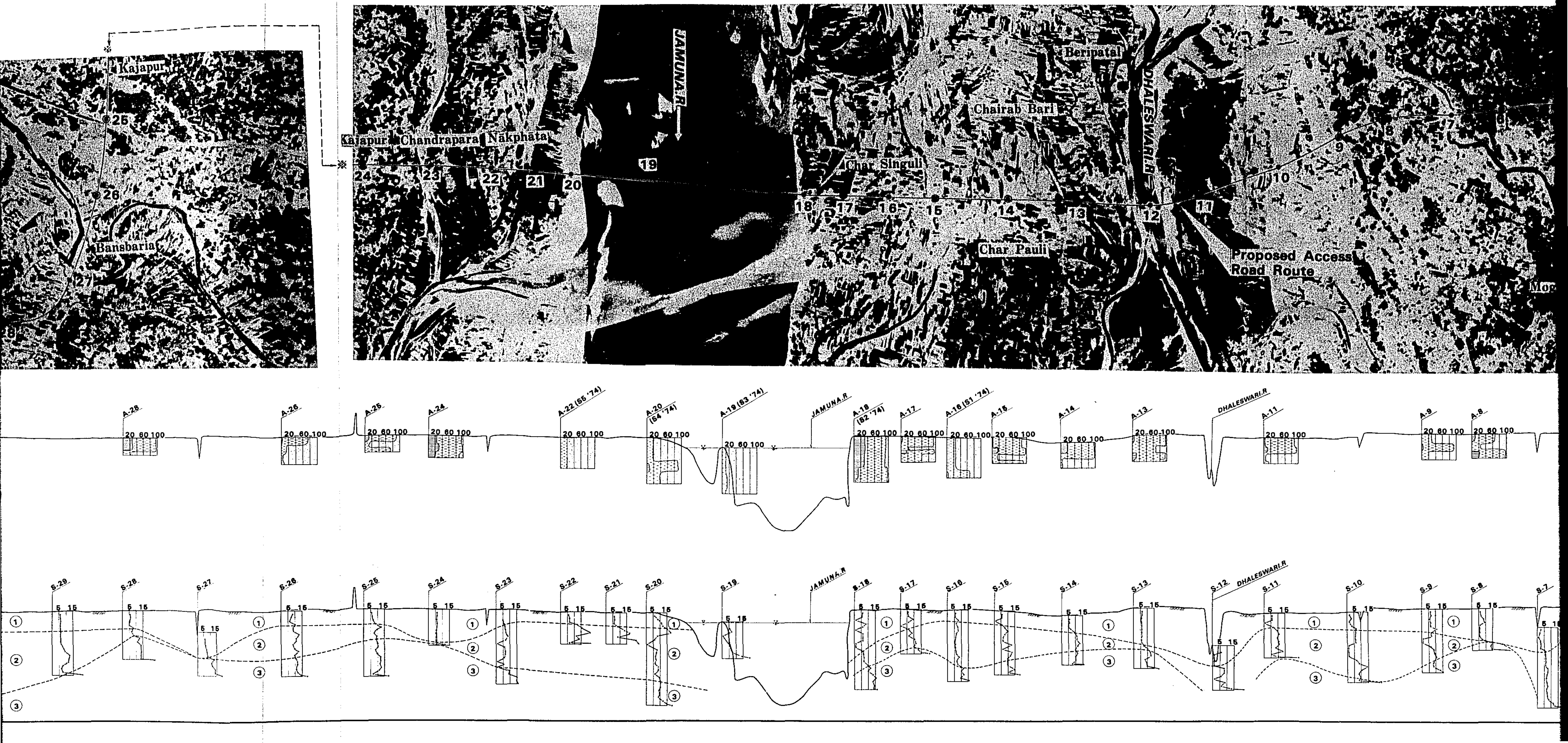
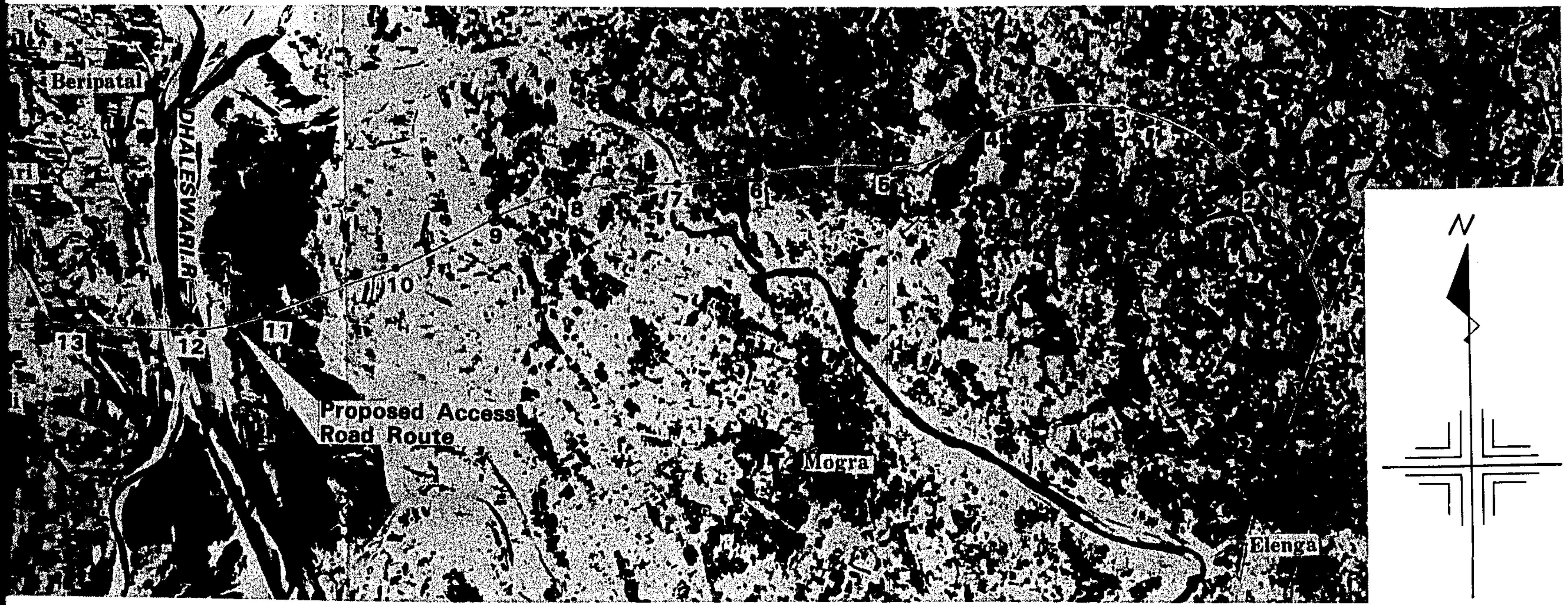

Kajapur
Bansbaria
Kajapur
Chandrapara
Nakphata
JAMUNA R
Char Singuli
Char Pauli
Chairab Bari
Beripatal
DHALESWARI R
Proposed Access Road Route
A-28
A-26
A-25
A-24
A-22 (55 '74)
A-20 (54 '74)
A-19 (83 '74)
JAMUNA.R
A-18 (82 '74)
A-17
A-16 (51 '74)
A-15
A-14
A-13
DHALESWARI.R
A-11
A-9
A-8
S-29
S-28
S-27
S-26
S-25
S-24
S-23
S-22
S-21
S-20
S-19
JAMUNA.R
S-18
S-17
S-16
S-15
S-14
S-13
S-12
DHALESWARI.R
S-11
S-10
S-9
S-8
S-7

Fig. 3-1



DESIGN SOIL FACTOR FOR FOUNDATION AND BANK MATERIAL FOR ACCESS ROAD

FOUNDATION

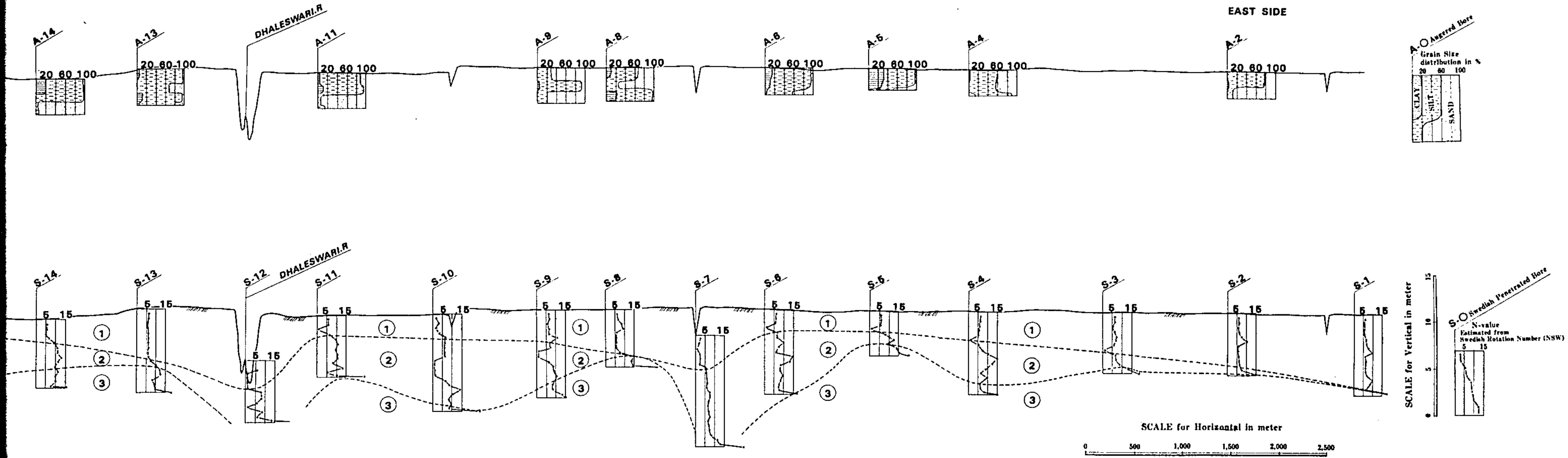
STRATA	MATERIAL	TYPICAL N-VALUE	γt	ω	γd	C	φ
①	Sand contained Silty Soil	<6	1.8	22	1.36	0.1	13
②	Silty SAND to SAND	6<10	1.9	20	1.58	0	28
③	SAND	10<20	1.9	20	1.58	0	32

BANKING MATERIAL

STRATA	MATERIAL		γd	ω	γt	C	φ	C.B.R
①	Sand con-tained Silty soil	* A	1.7	22	2	0.2	20	6
		* B	1.6	26	2	0.15	17.5	5
②	Silty SAND to SAND	A	1.75	20	2.1	0	30	8
		B	1.65	22	2	0	27	7

* A 95% Modified on D-ratio of AASHO Compaction
* B 90% Modified on D-ratio of AASHO Compaction

- ● Swedish Penetration spot
- Hand Auger spot
- Sampling spot by Hand digging for C.B.R-Test



JAPAN INTERNATIONAL COOPERATION AGENCY
PEOPLE'S REPUBLIC OF BANGLADESH
JAMUNA RIVER BRIDGE CONSTRUCTION PROJECT SUBSOIL PROFILE FOR ACCESS ROAD ROUTE
DRAWN [signature] DATE
APPROVED DATE
NIPPON KOEI CO.LTD

alluvial plain can be divided in an old alluvial plain (or low alluvial terrace) and a present alluvial plain roughly. Furthermore, these alluvial plains can be subdivided in normal fluvial plain, natural levee, meander scroll, dry river bed, abandoned river channel, etc..

A greater part of the access route passes through the normal fluvial plain, and the rest passes through special spots partly. For instance, the spots No. 36, 9, 8, 4 and 2 shown in Fig. 3.1 are obviously on the natural levees. The spots No.28 and 15 are on the meander scrolls. The spots No. 20, 19 and 12 are on the dry river beds and No. 27 and 7 are in the abandoned river channels.

These geomorphological classifications have, however, no great significance from the view points of earthworks and engineering. In the other terms, the results of investigations can have no relation with these geomorphological classifications, and the ground of the proposed site has only a trifle variation in the horizontal direction. It was found that the variation in the depth direction is much more significant.

So we came to a conclusion that the foundation of bank is made up of silty soil in a larger part and has not a very high soil mechanical strength, though there will be no trouble due to consolidation settlement because of the silty soil layer being relatively thin and the lower layer being made of sandy soil.

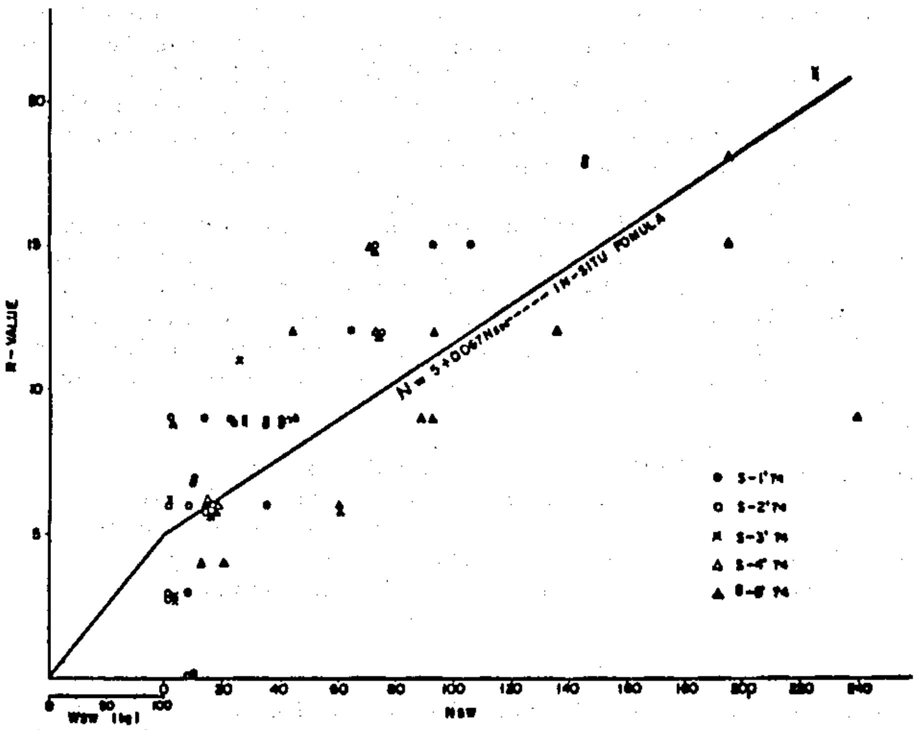
3. Classification in Strata.

As it is listed in Table 3-2, the classification in strata was obtained by determining the N-values by the in-situ empirical formula from the Nsw-values obtained by the Swedish penetration tests, in reference to the data obtained by the laboratory physical tests of samples picked up by the hand auger boring (to the extent of the underground water level) and by boring at the bridge axis. This classification is also shown in profile in Fig. 3-1.

Table 3-1 Classification of Access Route in Strata

Stratum	Typical N-value	Principal soil
1	$N < 6$	Silty soil and sand -contained silt
2	$6 \leq N \leq 10$	Silty sand and sand
3	$N > 10$	Sand and fine sand

Fig. 3-2 Experimental Relation
between
N-value and Nsw & Wsw-values

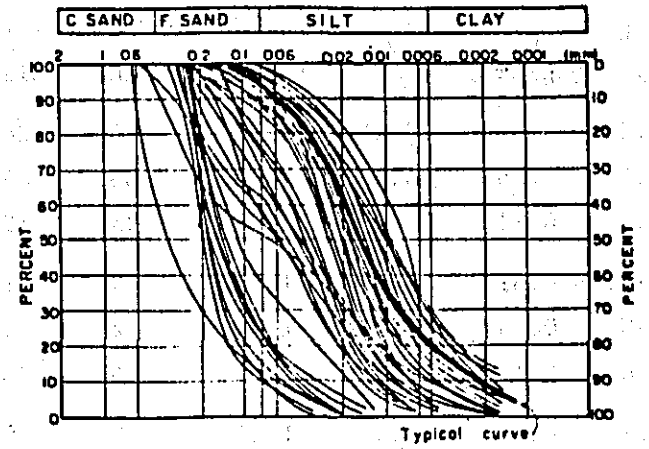


4. Soil Design Factors of Bank Foundation.

4.1. Stratum ①.

This stratum was subject to sampling by auger boring and to tests of grain size analisis, moisture and specific gravity. Fig. 3-3 shows the grain size distributions. As it is shown in this figure, this stratum consists of silty soil in a larger part and sandy soil in a considerably large part. The silty and sandy soils are distributed in alternation in this stratum, but the characteristics of the silty soil act a prominent role in examinations on the stability of this stratum as bank foundation. Therefore, the part of sandy soil was neglected in our examinations, and the typical curve of the silty soil shown in Fig. 3-3 was examined as typical grain size distribution of the stratum ①.

Fig. 3-3 Grain Size Distribution of Stratum ①



1) Examinations on Internal Friction (ϕ).

According to the typical distribution curve in Fig. 3-3, this stratum contains 9 % of sand fraction, 70 % of silt fraction and 21 % of clay fraction. In examinations on the soil characteristics of this stratum, the following means could be devised to select a typical ϕ-value of the long access route, based upon the investigation and test data.

a) Estimation of the typical ϕ-value, based upon the results of mechanical tests on the samples having approximate grain sizes to the typical grain size;

b) Estimation of the typical ϕ-value by using the typical N − ϕ formula in which the N-value is deduced from the results of Swedish penetration tests; and

c) Estimation of the typical ϕ-value corresponding to all the sand fraction contents obtained by grain size tests made along the whole route. The relations between the sand fraction contents (Sn) and the ϕ-values, determined from the results of mechanical tests on bridge axis boring samples.

In case of a), the test data which are the most approximate to the typical grain size are those of S-2 group in Table 3-2. The ϕ-values of this group are 13° to 19°.

Table 3-2 Results of Mechanical Test, Undisturbed Sample of Bridge Axis Bores

Bore No.	Stratum	Depth (m)	C (kg/cm2)	ϕ	γ_t (g/cm3)	Grain distribution (%) sand	silt	clay
S-1	1	2-2.57	0.27	30.25	1.72	74	26	
	2	5-5.75	0.28	26.5	1.84	33	64	3
	3	7-7.9	0.21	30	1.95	85	15	
S-2	1	2.4-3.18	0.31	13	1.8	9	61	30
	1	4.7-5.45	0.25	17	1.9	2	86	12
	1	6.1-6.7	0.14	19.25	1.81	6	90	4
S-3	1	2-2.7	0.16	31.5	1.81	90	10	
	2	4-4.7	0.14	39	1.89	86	14	
	2	6-6.7	0.35	36.5	1.9	91	9	
	2	8-8.65	0.2	37	1.94	84	16	
S-4	1	2-2.7	0.14	33	1.73	83	17	
	2	4-4.73	0.36	12	1.77	9	83	8
	2	6-6.7	0.28	34	1.84	62	38	
	2	8-8.7	0.12	36	1.85	98	2	
S-5	2	2-2.4	0 28	30	1.77	80	20	
	2	4-4.5	0.14	36	1.94	82	18	

In case of b), the average N-value N = 6 was obtained from the N-values * indicated in Fig. 3-1 (* The N-values could be obtained from Nsw by Fig. 3-2) The formulas of N - ϕ relation which are generally reliable are as following formulas.

$\phi = \sqrt{12N} + 15$ .... (3.1) Danham

$\phi = \sqrt{20N} + 15$ .... (3.2) Osaki

$\phi = \sqrt{15N} + 15$ .... (3.3) Literature 5)

If N = 6 is introduced in these equations, the ϕ-values will be obtained respectively as follows;

(3.1) $\phi = 23.5°$ ($\tan\phi = 0.435$),

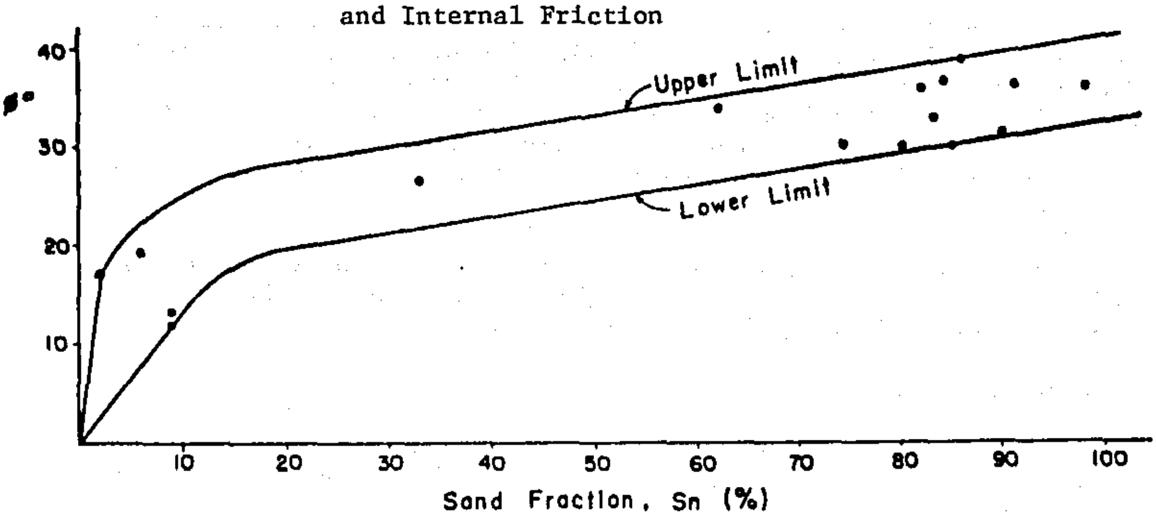
(3.2) $\phi = 26.0$ ($\tan\phi = 0.488$), and

(3.3) $\phi = 24.5$ ($\tan\phi = 0.456$),

provided that these formulas are for clean sand so that they can not be used for the stratum ① which is made of silty soil. Larger is the silt fraction, lower is the value ϕ. This tendency is especially strengthened as the fraction having grain sizes smaller than 2/100 mm is larger. On the assumption that the ϕ-values determined by these formulas are lower by the 40 % of silt fraction having grain sizes smaller than 2/100 mm as shown in Fig. 3-3, the following ϕ-values are obtained respectively.

Formula	tan ϕ	Correcting value	Corrected tan ϕ	Corrected ϕ
(3.1)	0.435	0.4	0.174	9.8
(3.2)	0.488	0.4	0.195	11.2
(3.3)	0.459	0.4	0.182	10.3

Fig. 3-4 Relation between Sand Fraction and Internal Friction



In case of (c), a relation between sand fraction (Sn) and ϕ as shown in Fig. 3-4 was obtained by the results of tri-axial compression tests on samples picked up by bridge axis boring. If this relation is applicable to all the strata of the whole access route, the value ϕ can be determined by (Sn).

The value Sn of the stratum ① is 9 % according to Fig. 3-3. If the value ϕ is determined by the lower limit curve in Fig. 3-4, it is $\phi = 13°$

The values ϕ in these cases a), b) and c) can be summarized as follows:

a) $\phi = 13$ to $19°$

b) $\phi = 10$ to $11°$

c) $\phi = 13°$

Among these values ϕ, the value of c), $\phi = 13°$, is the most adequate. The reasons are as follows:

- In relation between grain size and mechanical characteristics, the soil containing 85 % or more of sand fraction has a tendency to be sandy soil (C = 0), while the soil containing 60 % or less of and fraction has a tendency to be cohesive soil (ϕ = 0). The soil of the stratum ① which contains 9 % of sand fraction falls in the cohesive soil. But it cannot be so simply determined as clay, because its principal fraction is of silt. The grain of silt itself has characteristics close to that of sand. Therefore, the stratum ① of which the grains of 2/100 mm or more in size represents several scores percent can be expected to have a range of internal friction values, ϕ = 10° to ϕ = 19°, as a result of examinations.

- If the most approximate data to that of the stratum ① is grain in Table 3-2, based upon the grain sizes of the samples submitted to triaxial compression tests, it can be those of S-2 (2.4 to 3.18 m in depth). For this stratum, the ϕ-value is 13°.

- Among the three cases, the value ϕ in b) is calculated by four stages of determination/ determination of Nsw-value by the Swedish penetration tests, calculation of N-value from the Nsw-value, deduction of ϕ-value from the N-value and correction of the ϕ-value by the content of fine grains. The value ϕ calculated by these four stage is approximate to the results of estimation a), b) and c), but less reliable.

For these reasons, it can be considered that the values of a) and c) are available and that the value of a) includes that of c) so that the value of c) is the most reliable.

2) Cohesion (C).

It has been above-described that the grain sizes of the stratum S-2 in Table 3-2 is the most approximate to the typical grain size of the stratum ①, based upon the results of laboratory tests on the disturbed samples picked up by boring at the bridge axis.

The data of S-2 is C = 0.14 to 0.31, which average value is about 0.2.

The stratum ① is mainly made of silt, which has mechanical characteristics closer to those of sandy soil than those of cohesive soil, so that it is rather a little dangerous in general to adopt the test value without correction. In addition, the number of samples is not surely sufficient to make this test represent all the values with accuracy. Here, we recommend as design factor of soil the value, C = 0.1 kg/cm^2, which is 50 % of the average test value.

3) Wet Density (γt).

Fig. 3-5 shows relations between natural moisture (Wn) and wet density (γt) of undisturbed samples picked up by boring at the bridge axis, while Fig. 3-5 shows a histogram of natural moisture of samples obtained by auger boring along the whole access route. This figure shows clearly that there is a difference between sandy soil and silty soil. Since the typical grain size curve in Fig. 3-3 represents a very high content of silt fraction in the stratum ①, it can be estimated that the typical moisture of the stratum ① is 32 % in Fig. 3-6. The natural wet density (γt) of this stratum can be determined by applying the typical moisture value, 32 %, to the relation in Fig. 3-5. The relations between Wn and γt have an irregular zone of the shaded portion in Fig. 3-5, and so the typical value of γt is read out at 1.8 for the Wn-value of 32 %, applying the lower limits of the relations. Examining the samples having a sand fraction of Wn > 10 %, these samples are rather approximate in grain size to the stratum ②. Therefore, the typical natural moisture of these samples can represent that of the stratum ②. So the typical γt-value of the stratum ② can be estimated at 1.9.

Fig. 3-5 Wn - γt Relation by Data of Bridge Axis

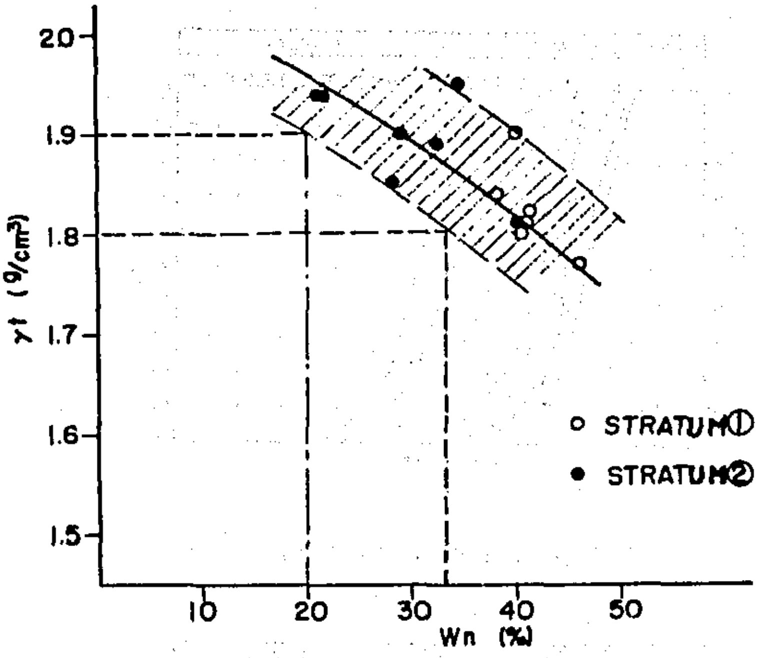
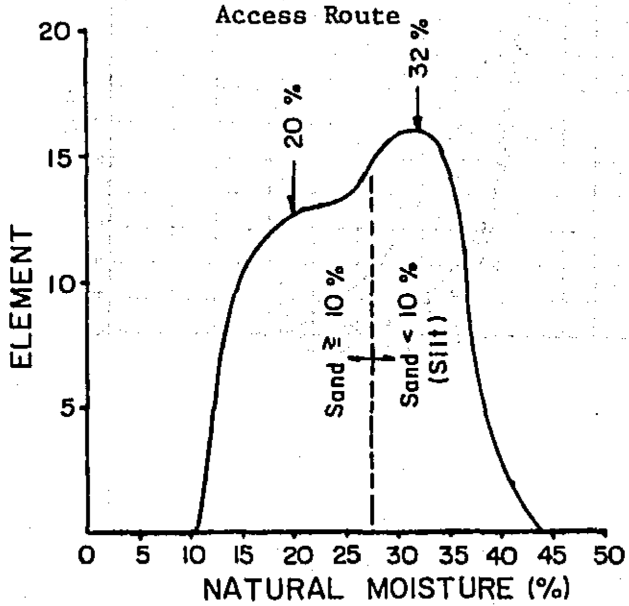


Fig. 3-6 Histogram of Moisture of Access Route



4.2. Strata ② and ③.

The hand auger boring could reach these strata (especially in the depths under the underground water level) with difficulty, so that the number of samples picked up in these strata was insufficient. So adding the data obtained by boring at the bridge axis, the results of grain size analyses were as shown in Figs. 3-7 and 3-8.

Fig. 3-7 Grain Size in Stratum ②

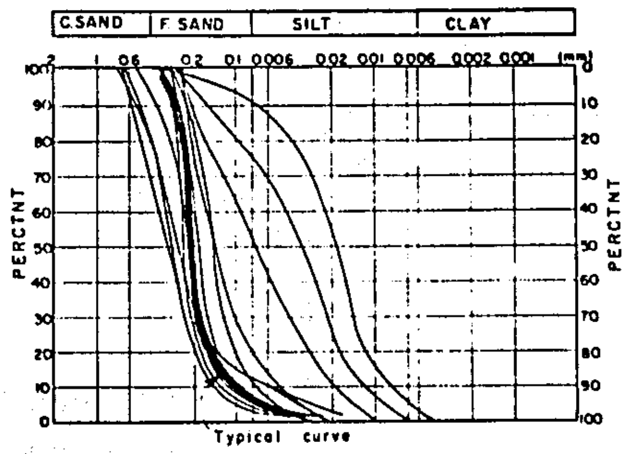
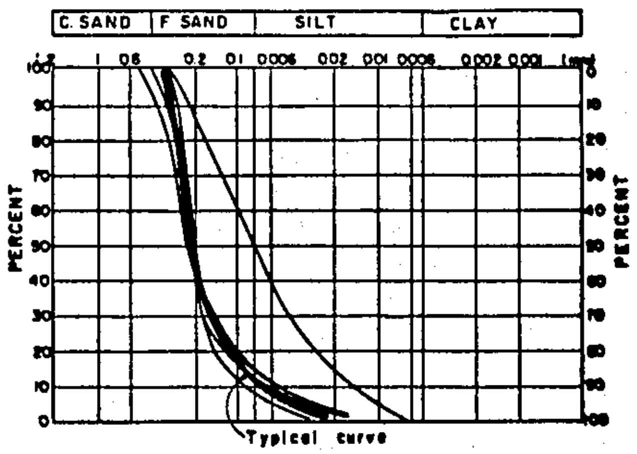


Fig. 3-8 Grain Size in Stratum ③



These figures show that the strata ② and ③ contain a larger fraction of fine sand, though they contain a fraction of silty soil. As these strata have a tendency of sandy soil even according to the N-value distribution in Fig. 3-1, they can be considered as of sandy soil. Figs. 3-7 and 3-8 also show respective typical curves of sandy soil, neglecting the silty soil.

1) Examinations on ϕ.

The following three methods could be provided to select the ϕ-value:

a) Estimation of ϕ from the mechanical test data of samples having approximate grain sizes to the typical grain size;

b) Estimation of ϕ from the Swedish penetration test data; and

c) Estimation of ϕ by applying the sand content to Fig. 3-4.

In case of a), the sand content of the stratum ② can be read out at approx. 90 % on the typical grain size curve in Fig. 3-7. Table 3-3 is a table in which the test data only corresponding to the sand fraction of over 80 % in the stratum ② are picked up,

Table 3-3 Internal Friction of Stratum ②

Sample No.	Depth (m)	Degree ϕ-value	Sand content %
S-3	4.0-4.7	39	86
	6.0-6.7	36.5	91
	8.0-8.65	37	84
S-4	8.0-8.7	36	98
S-5	2.0-2.4	30	80
	4.0-4.5	36	82
Average		35.8	86.8

The estimation of the stratum ③ is difficult because of insufficiency of data, but the ϕ-values of this stratum can be estimated at almost same levels as those of the stratum ②.

In case of b), the average N-value of the stratum ② is N = 8 according to Fig. 3-1. If this value is introduced in the formulas (3.1), (3.2) and (3.3), the ϕ-values can be determined respectively; ϕ = 24.8°, ϕ = 27.6° and ϕ 25.9°.

Similarly, the average N-value of the stratum ③ is 14. Therefore, the ϕ-values are 27.9°, 31.7° and 29.5° respectively.

In case of c), the sand contents of the strata ② and ③ are about 90 % equally on the typical grain size curves in Figs. 3-7 and 3-8. Applying this value, 90 %, to Fig. 3-4, the ϕ-

Value is $\phi = 32°$.

The estimations according to the three cases can be summarized in Table 3-4.

Table 3-4 Comparison of ϕ-values on Strata ② and ③

Method	Strataum 2	Stratum 3
a)	35.8	-
b)	24.8 - 27.6	27.9 - 31.7
c)	32	32

The ϕ-value of $\phi = 38.5$ is too high to select it as design factor, for the reasons that silty seams are interbedded in some parts of the stratum ② and that the Swedish penetration test data are not so high as $\phi = 38.5$, and from the empirical point of view as well. The ϕ-value of $\phi = 32°$ is considerably approximate to the Swedish penetration test data, but considering the relatively high accuracy of the Swedish penetration test, it can be judged that the maximum value of the stratum ②, $\phi = 27.9°$ (that is, Approx. 28°), by b) is the most adequate for design factor. Similarly, the value of the stratum ③, $\phi = 31.7°$ (Approx. 32°), is recommendable.

2) Cohesion (C).

The laboratory tests provided several consierable values of cohesion (C) for the strata ② and ③. However, the typical sand contents of these strata are both as high as 90 % in Figs. 3-7 and 3-8 showing their grain size distributions. And it is general to neglect the cohesion itself in selection of design factor for the sandy soil containing over 85 % of sand fraction. This is true from the theoretical point of view. Therefore, the C-value of C = 0 is recommendable for the strata ② and ③ as usual,.

3) Wet density (γt).

These examinations were made similarly as those of the stratum ①. The test data of the stratum ② proved that it contains a larger fraction of soil having a natural moisture (Wn) of about 20 % Applying this value to Fig. 3-5, the value γt can be read out at Approx. 1.9. As for the stratum ③ the examinations on γt-value are generally difficult because of insufficiency in the obtained data, but the γt-value is $\gamma t = 1.95$ g/cm^3 according to some test data (Table 3-2, S-1, 7.0 to 7.9). The Swedish penetration tests proved also that the stratum ③ has a higher density than the stratum ②. The wet density of the stratum ③ can be empirically estimated only a little higher, that is, in a range of 1.9 to 1.95, than that of the stratum ②. Therefore, the value of 1.90 g/cm^3 is recommendable for rather reliable and secure design factor. The specific gravity for this stratum is estimated at 2.70, based upon test data.

The results of examinations Paragraphs 4.1 and 4.2 are summarized in Table 3-5.

Table 3-5 Design Soil Factors for Bank Foundation

Stratum	Material	N	γt	w	γd	γs	C	φ
①	Silty soil	6	1.8	32	1.36	2.70	0.1	13
②	Silty sand to sand	8	1.9	20	1.58	2.70	0	28
③	Sand	14	1.9	20	1.58	2.70	0	32

5. Bank Materials.

It is assumed that the bank materials will be borrowed directly in the nearest places to the proposed site for banking, as far as the stability of the bank to be constructed is secured, or that the soil for banking will be as same as that for bank foundation.

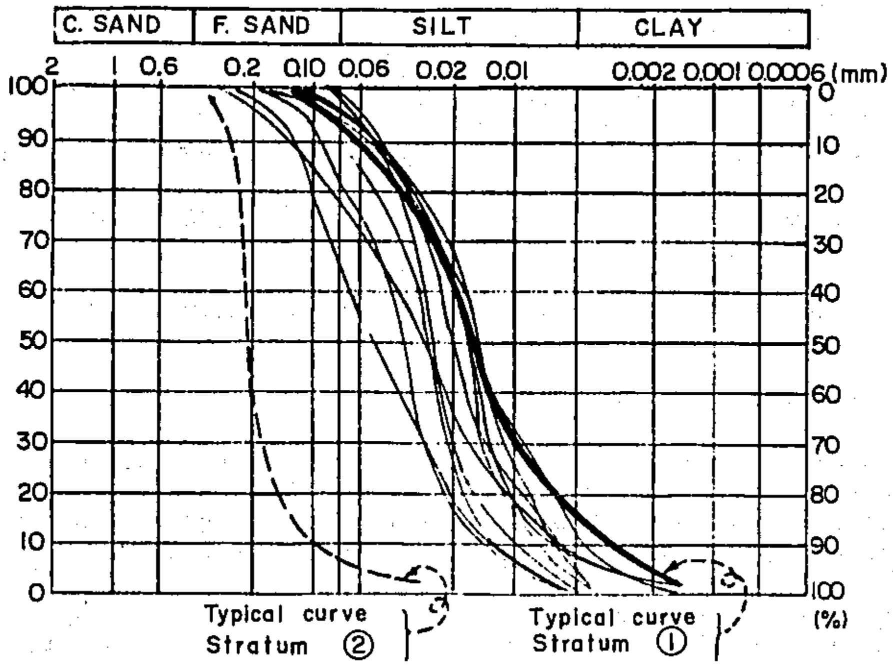
The investigations for bank materials were carried out by disturbed sampling through hand digging to the depth of about 1 m and then by compaction and CBR tests. 10 samples were picked up at 10 sampling spots every about 3 km along the access route. It will be examined hereinafter if these 10 samples can represent the soil of the whole route.

5.1. Check of samples.

As it was above-described, the outlined data of the whole route has been already given by the results of the Swedish penetration tests made every about 1 km along the route as well as the grain size distribution, natural moisture and specific gravity tests on the samples picked up by hand auger boring every 1 to 2 km along the route. It will be verified by comparison of these data with the data of CBR tests if the limited number of CBR test data can represent the data of the whole route.

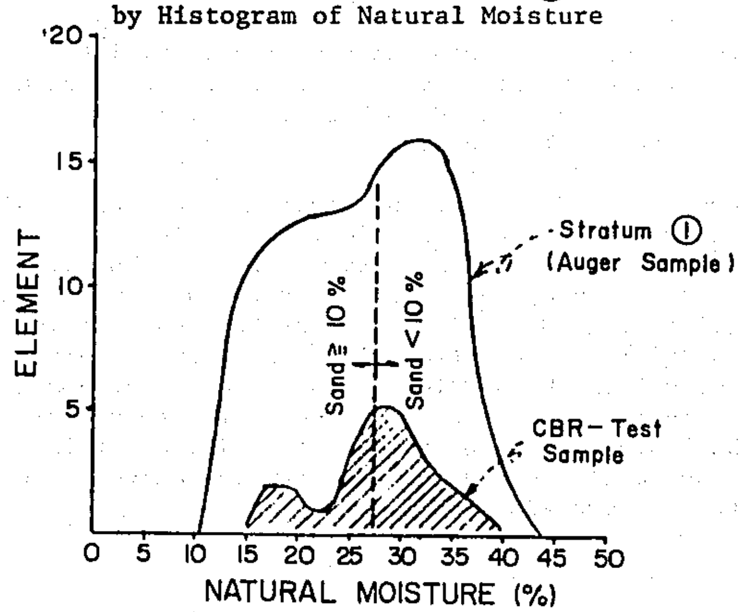
As for grain size distribution, Fig. 3-9 shows grain size distribution curves of CBR test ssmples. The thick line in this figure corresponds to the typical curve of the stratum ① in Fig. 3-3, and the discontinued line corresponds to the typical curve of the stratum ② in Fig. 3-7. Although the CBR test samples which were picked up mainly in the stratum ① are considerably different in characteristic from the samples of the stratum ② and the typical curve of CBR samples has a tendency to be on the coarse side, compared with the typical curve of the stratum ①, as it is shown in Fig. 3-9, it may be considered that the typical curves of CBR samples and the stratum ① are almost similar.

Fig. 3-9 Grain Size Distributions of C.B.R. Test Samples



Besides, Fig. 3-10 shows a comparison between the stratum ① and the CBR sample by histogram of natural moisture. In this figure, the curve for the stratum ① is not in similar form to that of CBR sample because of the limited number of CBR samples, but the two curves are almost similar in width and peak. This can verify that the CBR samples are similar in characteristics to the samples of the stratum ①.

Fig. 3-10 Comparison between Stratum ① and CBR Sample by Histogram of Natural Moisture



Checking in detail the test data shown in Fig. 3-10 in regard to the stratum ① and CBR samples which are both mainly made of silty soil, it is found that the samples having 10 % or more of sand fraction are on the higher side in moisture than 27 % to 30 %, while the samples having under 10 % of sand fraction are on the lower side in moisture. This is true both for the samples of the whole route and the samples of CBR tests.

Finally, the average value of specific gravity (γs) is estimated at 2.692 for the whole route samples and 2.685 for the CBR samples, between which there is no great difference. So the value of 2.7 is available both for the former and latter samples by approximation.

The above-described comparisons in grain size distribution, natural moisture and specific gravity between the whole route samples and the CBR test samples lead to the conclusion that there is no great difference between them so that the CBR test samples are available as representative of the samples of the stratum ①.

5.2. Examinations on the CBR test data and selection of design factors.

Fig. 3-11 shows the results of compaction and CBR tests. Table 3-6 is a list of the principal values picked up in Fig. 3-11. In these table and figure, NO. indicates that of sampling spot and sample. (See Fig. 3-1)

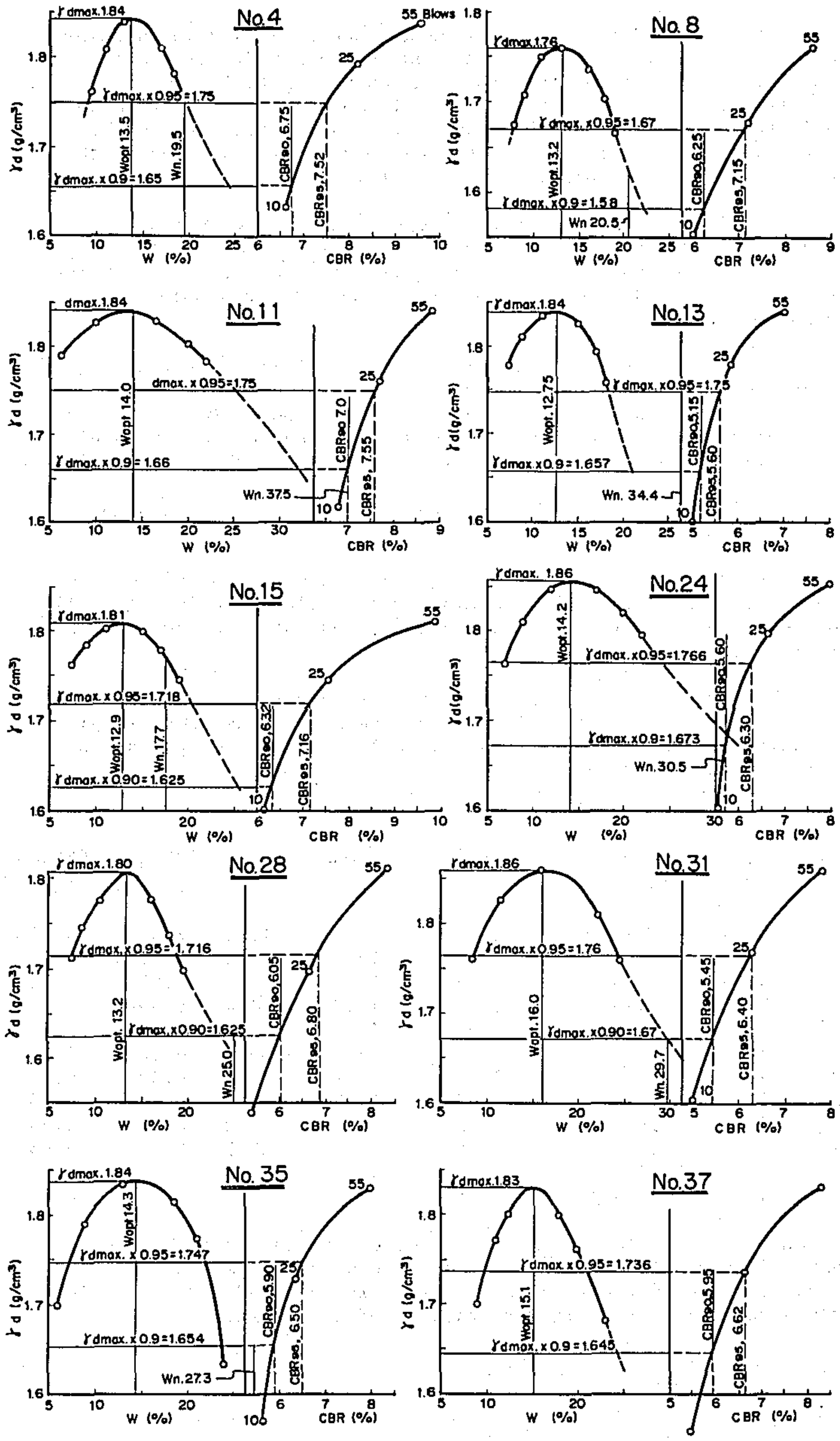
The "Ave" in Table 3-6 means an average obtained by simple arithmetical calculation. Inspite of average values, for example, the value of γd_{max} varies from 1.76 to 1.86 and the CBR_{95} varies from 5.60 to 7.52 without constancy.

Table 3-6 Compaction and CBR Tests' Results

NO.	γd_{max} (g/cm^3)	γd(95%) (g/cm^3)	γd(90%) (g/cm^3)	Optimum W (%)	Wn (%)	CBR_{95} (%)	CBR_{90} (%)
4	1.84	1.75	1.65	13.5	19.5	7.52	6.75
8	1.76	1.67	1.58	13.2	20.5	7.15	6.25
11	1.84	1.75	1.66	14.0	37.5	7.55	7.00
13	1.84	1.75	1.66	12.8	34.4	5.60	5.15
15	1.81	1.72	1.63	12.9	17.7	7.16	6.32
24	1.86	1.77	1.67	14.2	30.5	6.30	5.60
28	1.81	1.72	1.63	13.2	25.0	6.80	6.05
31	1.86	1.76	1.67	16.0	29.7	6.40	5.45
35	1.84	1.75	1.65	14.3	27.3	6.50	5.90
37	1.83	1.74	1.65	15.1	32.7	6.62	5.95
Ave	1.83	1.74	1.65	13.9	27.5	6.76	6.04

Such an irregularity was estimated due to the fact that the samples having higher values of γd and CBR contain a considerably large fraction of coarse silt or a fraction of sand, while the lower values correspond to a larger fraction of fine silt.

Fig. 3-11 Compaction and CBR Test Record



The thin lines in Fig. 3-12, which correspond to the curves in Fig. 3-11 respectively, show the irregularity more clearly. The result of examinations on these curves, their forms and their corresponding grain sizes was that on the Yd - W curve, the higher part than the maximum dry density (γd_{max}) of Approx. 1.82 represents the soil containing a fraction of sand or a large fraction of coarse silt, soil having a tendency to normal sandy soil, while the lower part represents the soil containing a large fraction of fine silt, soil having a tendency to rather cohesive soil. So the peaks of the Yd - W curves in Fig. 3-11 were divided in the higher and lower groups and the average peak of each group was selected as typical peak of each group in the figure. Then, a curve representing a tendency to sandy silt and a curve representing a tendency to cohesive soil were selected among the element curves (that is, Yt - W curves shown by thin lines), and a curve similar t to each selected curve and passing the typical peak of each corresponding group was drawn up as typical Yd - W curve, which is shown in Fig. 3-12 by thick line.

As for the Yd - CBR curves, the typical Yd - CBR curves representing a tendency to sandy silt and a tendency to cohesive soil respectively were drawn up similarly in Fig. 3-12 by thick lines.

From these typical curves were determined the CBR values for sandy silt and cohesive soil, based upon the AASHO method. Table 3-7 is a summary of the results.

Fig. 3-12 Selection of CBR

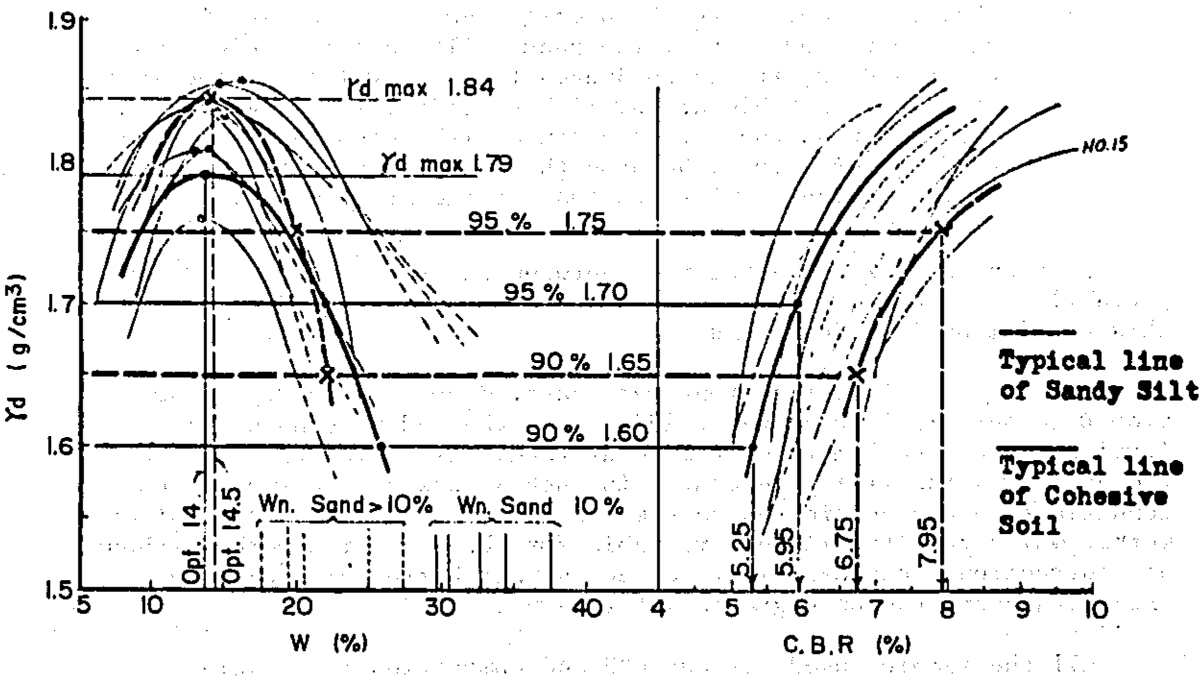


Table 3-7 Typical CBR of Materials

Material	γd_{max}	W.Opt.	95% AASHO Compaction			90% AASHO Compaction		
			γd	W	CBR	γd	W	CBR
Sandy Silt (Stratum ②)	1.84	14.5	1.75	20	7.95 (8)	1.65	22	6.75 (7)
Cohesive Soil (Stratum ①)	1.79	14.0	1.70	22	5.95 (6)	1.60	26	5.25 (5)

Note: The values indicated in Table 3-7 are analyses of a limited number of data and only represent a general tendency of materials. The values in ( ) can be used practically for CBR values in designing. The materials in this table are generally silty soil, which is classified in sandy silt and cohesive soil. The sandy silt is different from the so-called sandy silt and has a mechanical tendency to sandy silt. The cohesive soil in this table is also different from the so-called cohesive soil and has a mechanical tendency to rather cohesive soil. Pay a special attention to these points. The values of cohesive soil in this table can be considered as typical values of the stratum ①, and the values of sandy silt have tendencies to rather sandy soil according to the test data of the samples of Stratum ① and represent the stratum ② rather than the stratum ①. The typical grain size of the stratum ② obviously represents the poor-graded fine sand and is different from that of the sandy silt in this table. Notwithstanding, it can be judged that the values of the sandy silt in this table are available for those of the stratum ② as far as they are concerned with compactability (including CBR value), because the sandy silt presents similar compactability to that of the stratum ②.

In banking works, the relation between natural moisture and compactability has a great influence on the executability. Hereinafter, this problem will be described.

Second-stage investigations were carried out in the dry season from December, 1974 to January, 1975, when the underground water level was about GL-2 m to GL-4 m in average. As it is expected that the banking works will be executed in such a season, the excavation conditions can be considered as similar as those of our investigation works, which results will be available for the execution works without any correction. Besides, it is ecpected that borrow pits will be excavated above the underground water level.

All the samples used for our CBR and Compaction tests were procured about GL-1 m about the underground water level.

As it is indicated in Fig. 3-12, the typical sample of the stratum ①) (sand < 10 %) presents a natural moisture (Wn) of 30 % to 37 %, and the samples picked up about the underground water level where borrow pits will be excavated have a natural moisture of about 30 % in general. Therefore, in order to attain the natural moisture of 22 % that the typical material of the stratum ① has for the compaction degree of 95 %, it is required for the soil in borrow pits to be air-dried by about 8 % of W, while there is no problem to procure the materials having a natural moisture of 26 % corresponding to the compaction degree of 90 %. For these reasons, the lower subgrade soil will encounter no problem, while the higher subgrade soil requiring higher CBR are expected to procure the samples with difficulty. Although the test samples used in our investigation works were limited to the soil at GL-1 m, the soil about GL-0 m to 0.5 m which was not tested in special is supposed to have an empirical natural moisture of about 20 %, so that it may be easily attain by using materials at shallower levels to obtain the required values.

The material of the stratum ② is sandy silt which has a natural moisture of about 20 % in general. Even if the soil under the underground water level is used for the material, the adjustment of natural moisture is easily made for the bank material. On the other hand, the stratum ① contains partly materials presenting similar characteristics to those of the stratum ②, and so the execution in the similar parts is easily carried out. The presence of such materials is limited in the whole route, so that this report on the stage of basic planning does not discuss such a problem.

6. Shrinkage of Earth Volume.

The soil for bank materials is different in volume between in in-situ, loosen and compacted states. According to the Earth Work Manual for Highway Construction (DOKOO-SHISHIN) 4), the shrinkage coe-coefficients of earth volume, which are represented by ratios to the in-situ earth volume of 1, adequate for the soil in the field are indicated in Table 3-8.

In-situ earth volume (volume to be excavated)
.... Value ν

Loosened earth volume (volume to be transported)
.... Value L

Compacted earth volume (finished bank volume)
.... Value C

Table 3-8 Shrinkage of Earth Volume
(Literature No.4)

Material	L	C
Sandy soil	1.10 to 1.30	0.85 to 0.90
Fine-grain soil (Cohesive soil)	1.25 to 1.35	0.85 to 0.95

The soil in the field is made of sandy to silty soil, and has possibly a medium shrinkage between those of sandy soil and fine-grain soil in Table 3-8.

The value C can be determined according to the density as follows:

$$C = \frac{\gamma t\nu}{\gamma tc}$$

wherein $\gamma t\nu$ is an average in-situ density and γtc is an average compacted density.

The value C can be estimated from the typical density, 1.80 g/cm^3, of the stratum 1 (Table 3-5) and the data of CBR tests as follows;

If $\gamma t\nu$ is 1.80 g/cm^3, and if γd is 1.70, γs is 2.70 and W is 22 % corresponding to the compaction degree of 95 %, $\gamma tc(95)$ for the stratum 1 (Table 3-7),

$$\gamma tc_{95} = (1 + \frac{W}{100}) \times \gamma d$$

$$= (1 + \frac{22}{100}) \times 1.70$$

$$= 2.07$$

If γd is 1.60, γs is 2.70 and W is 26 % corresponding to the compaction degree of 90 %, $\gamma tc(90)$, for the stratum as indicated in Table 3-7,

$$\gamma tc_{90} = (1 + \frac{26}{100}) \times 1.60$$

$$= 2.01$$

$$C_{95} = \frac{1.80}{2.07} \qquad C_{90} = \frac{1.80}{2.01}$$

$$= 0.87 \qquad = 0.89$$

Therefore, these calculated values C_{95} and C_{90} , for th e compaction degrees, 95 % and 90 %, fall in the range of 0.85 to 0.95 indicated in Table 3-8, so that they can be considered as adequate approximations of the value C.

The value L can be estimated only by in-situ tests, but it may be estimated about 1.30 as value on the stage of basic planning.

7. Consolidation Settlement by Banking.

It is especially the marine alluvium and the marine back swamp area along the River Padma in the region extending from Aricha to the Seacoast that are estimated to encounter a problem of sonsolidation settlement in the Jamuna basin. It is so expected that the present site for construction of a bridge will not encounter a great trouble of the ground foundation settling.

No fear needs to be entertained that the layers in the depth of over 8 to 10 m will settle, because they are strata of $N > 15$ as shown in Figs. 3-1 and 1-1.

The layer above GL-8 m which consists of silty to loose sandy soil (strata 1 and 2) is an object of fears of somewhat settlement.

Here, we discuss the outline of the settlement with a simple formula.

If the bank height is 4 m and its unit weight is 2.0 g/cm^3 and if the bank stress is fully transmitted through the layer depth of 8 m, that is, object of normal consolidation having a depth of $H \fallingdotseq$ 8 m, the total settling value (S) is determined by the theory of settlement (3.4) and with the consolidation test data of the typical sample of stratum 1 (Bridge axis bore S-1 at GL-3 m) as shown in Fig. 3-13 as follows:

$$S = H\frac{e_0 - e_1}{1 + e_0} \quad \cdots\cdots\cdots\cdots\cdots\cdots \quad (3.4)$$

$$S = 800 \text{ cm} \times \frac{0.913 - 0.872}{1 + 0.913}$$

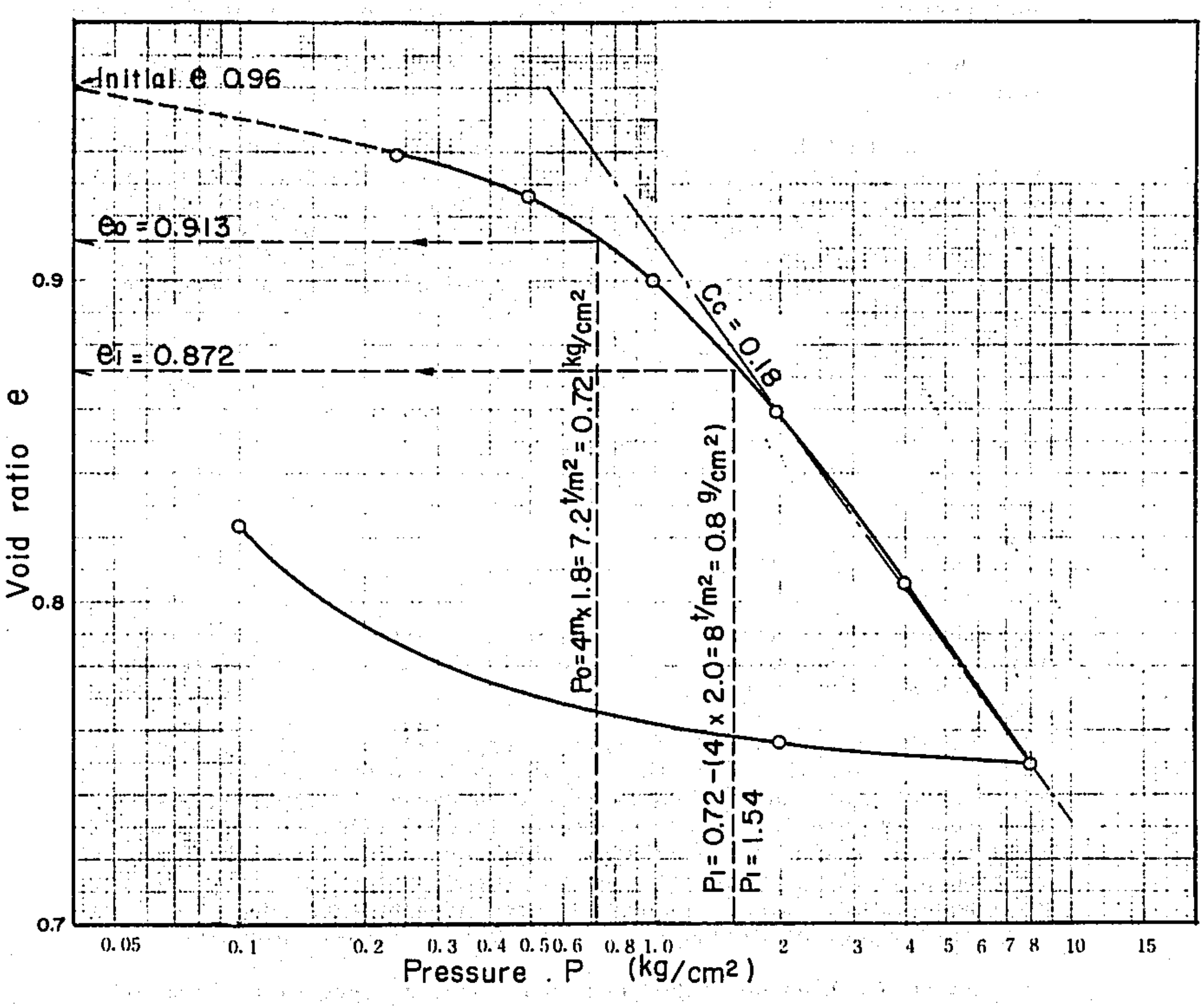
$$S \fallingdotseq 15 \text{ cm}$$

wherein the initial stress is Po, the initial void ratio corresponding to Po is e_0, the final stress is P_1 and the final void ratio corresponding to P_1 is e_1.

Simply, the bank of 4 m hight is expected to settle by about 15 cm. Considering that the state of accomplished bank or the state of final settlement can be thus estimated, because the upper stratum of the proposed site is formed in alternations of silty soil layers and sand layers, while the lower stratum is permeable, it can be expected that there will be no trouble due to ground settlement after the bank is accomplished. Besides, such a degree of settlement does not form a special object of discussions on the stage of basic planning.

As it has been described herein before, no special problem of settlement was found from the data of our investigations, but further investigations will be required on this problem of settlement as one of the detailed investigation works that will be carried on in future.

Fig. 3-13 Typical e - logP Curve
for Stratum 1



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APPENDIX

DATA

1) Location map of bore holes.

2) Drill log. S-0'73, S-1'74, S-2'74, S-3'74, S-4'74, S-5'74.

3) Summarized chart of soil character
S-0'73, S-7'74. S-2'74, S-3'74, S-4'74, S-5'74.

4) Summarized chart of augered bores, 20 holes.

JAMUNA RIVER BRIDGE CONSTRUCTIO

SUBSOIL INVESTIGATION WOR

LOCATION OF BORE-HO

Scale, 1 : 40 000

JAMUNA RIVER BRIDGE CONSTRUCTION PROJECT

SUBSOIL INVESTIGATION WORKS

LOCATION OF BORE-HOLES

Scale, 1 : 40 000

DRILL LOG

HOLE NO. S-1 ,74 SHEET NO. OF

PROJECT	JAMUNA RIVER BRIDGE CONSTRUCTION PROJECT 2ND PHASE	CLIENT	JAPAN INTERNATIONAL CO-OPERATION AGENCY
LOCATION	SHINGOLI CHAR (Eastern Bank) — COORDINATE N:24°21'14.4 E:89°47'34.3	DRILL RIG	KR-200 (KANO JAPAN)
ELEVATION	12.22 m — 115 ~ 86 — DATE FROM 29 Dec 1975 to 6 Jan 1976	CHECKED / DRILLED	SOILTECH INT. LTD. DACCA

DEPTH	THICKNESS	COLOR	CONSISTENCY OR REL. DENS.	MATERIAL	FORMATION	DESCRIPTION
1.20	1.20	Brown	Med.	silty		embankment
3.70	2.50	Gray	Loose	Fine SAND	UPPER MOST ALLUVIUM	Very dried sand and very fine sand with scattered mica.
8.60	4.90	Gray	Loose	Fine SAND	UPPER MOST ALLUVIUM	Very fine sand with little silt; high moisture contents
17.00	8.40	Gray	Med.	Fine SAND	UPPER ALLUVIUM	Fine SAND little mud stone. traces mica with scattered little gravels (10.00m - 11.00m)
26.00	9.00	Gray	Med.	Fine SAND	UPPER ALLUVIUM	Very high moisture contents. Fine sand with little mica.
29.60	3.60	Gray	Med.	Fine SAND with GRAVEL	UPPER ALLUVIUM	Sand with gravels (26.00m - 26.50m) and scattered little gravels
36.00	6.40	Gray	Dense	Fine SAND	UPPER ALLUVIUM	Med. moisture scattered little gravels silt 5 to 10 little Med. sand unequality grain
46.00	10.00	Gray	Dense	Fine SAND	UPPER ALLUVIUM	Traces mica little silt 8 to 10 more rich in mica and black mineral sand.
64.00	18.00	Gray	Dense	Fine SAND	MIDDLE ALLUVIUM	Little Med. sand scattered gravels (φ 20mm - 50mm) with a little mica high moisture contents high and poor graded gravel ... generally q Quartz.
74.00	10.00	Gray	Very Dense	Fine SAND	MIDDLE ALLUVIUM	some Med. sand little gravels scattered φ 5 - 8 m/m high moisture contents
79.00	5.00	Gray	Very Dense	Fine SAND	MIDDLE ALLUVIUM	with little mica fine sand equality grain.
80.00	1.00	Gray	Very dense	Gravels	LOWER ALLUVIUM	φ 15 - 25 m/m
81.50	1.50	Gray	Very Dense	Fine SAND	LOWER ALLUVIUM	very fine sand with little silt
86.00	4.50	Grey	Very Dense	Gravels and Boulders	LOWER ALLUVIUM	max φ 200 m/m water leaks, collapse very hard.
89.50	3.50	Light Brown	Very Dense	Gravel with SAND	DELUVIUM	max φ 20 m/m gravels and coarse sand
91.00	1.50	Grey	Very Dense	Fine SAND	DELUVIUM	with little gravels with little mica.
[illegible]	[illegible]	Grey	[illegible]	[illegible]	DELUVIUM	Hard clay.
93.11	1.64	Light Gray	Very Dense	Gravel with sand	DELUVIUM	gravels generally quartz.

Casing up to 88 m deep

SAMPLE NO.	DEPTH	N (blows/cm)	Blows every 10 cm		
D1	1.00	7/30	2	2	3
D2	[illegible]	[illegible]	2	3	3
D3	[illegible]	8/30	2	3	3
D4	[illegible]	6/30	1	2	3
D5	[illegible]	17/30	6	6	5
D6	[illegible]	17/30	5	5	7
D7	15.00	15/30	5	4	6
D8	18.00	30/30	9	9	12
D9	21.50	21/30	7	7	7
D10	24.00	26/30	7	9	10
D11	27.00	21/30	6	7	8
D12	30.00	43/30	11	12	20
D13	33.0	31/30	7	9	15
D14	36.0	46/30	15	15	16
D15	39.0	26/30	10	8	8
D16	42.0	51/30	17	16	18
D17	45.0	36/30	9	13	14
D18	49.0	45/30	9	16	20
D19	51.0	36/30	9	13	14
D20	54.0	44/30	12	15	17
D21	57.00	46/30	11	15	20
D22	60.00	43/30	11	14	18
D23	63.00	43/30	13	13	17
D24	66.00	58/30	15	21	22
D25	69.00	84/30	26	28	30
D26	72.00	53/30	13	19	21
D27	75.00	105/24	31	49	25/4
D28	78.00	97/30	30	32	35
D29	81.00	115/13	75	40/3	
D30	84.00	66/30	13	21	32
D31	87.00	100/12	73	27/2	
D32	90.00	105/12	70	35/2	
D33	93.00	100/11	88	12/1	

Corrected N

HOLE NO. S-1

* CONSISTENCY OR RELATIVE DENSITY
* UNIFIED SOIL CLASSIFICATION

DATE:- 3-3-75 PLAN No. ST-609/D NIPPON KOEI CO., LTD. CONSULTING ENGINEERS. TOKYO.

SOILTECH

INTERNATIONAL LIMITED
DACCA-CHITTAGONG

Client:- NIPPON KOEI, UNDER O.T.C.A.(JAPAN)
Site:- JAMUNA BRIDGE, BENUKURSA-DURGAPUR TANGAIL, SIRAJGANJ SITE (BANGLADESH)

Bore chart of Boring No. S-O

Dia of boring 0.11 m. (4 1/2") CO-ORDINATE (Approx.) LAT. 24°-22'-25" LONG. 89°-50'-10"

REDUCED ELEV. Approx. 10.7 m.

DATE	SHIFT	DEPTH IN METRE	THICKNESS IN METRE	STRATA ENCOUNTERED
17-2-74	2nd shift	3.97	3.97	Greyish loose med. to fine SAND with mica
17-2-74	2nd shift	8.54	4.57	Dark grey loose med. to fine SAND; trace mica
18-2-74	1st shift	10.68	2.14	Dark grey med. dense silty v. f. to f. SAND interbedded with thin layer of mica laminations
18-2-74	1st shift	12.20	1.52	Grey med. dense med. to f. SAND l. silt
18-2-74	1st shift	13.73	1.53	Dark grey med. dense fine to med. SAND little silt; trace mica
18-2-74	1st shift	15.25	1.52	Dark grey med. dense micaceous fine to med. SAND little silt
18-2-74	1st shift	16.78	1.53	Dark grey med. dense fine SAND little silt; trace mica
18-2-74	2nd shift	20.44	2.66	Grey med. dense silty fine to med. SAND; trace mica
18-2-74	2nd shift	22.57	2.13	Light grey med. dense fine to med. SAND little silt; trace mica
18-2-74	2nd shift	24.71	2.14	Grey dense fine to med. SAND little silt; trace mica
19-2-74	1st shift	26.54	1.83	Grey dense med. to fine SAND little silt; trace mica
19-2-74	2nd shift	28.67	2.13	Grey dense silty med. to fine SAND; trace mica
21-2-74	2nd shift	44.53	5.86	Grey dense to very dense silty fine to med. SAND; trace mica
21-2-74	2nd shift	50.33	5.80	Grey very dense silty med. to fine trace coarse SAND; trace mica
22-2-74	1st shift	56.43	6.10	Grey very dense med. to fine trace coarse SAND, little silt; trace mica
22-2-74	1st shift	59.37	2.74	Grey very dense silty med to fine trace coarse SAND; trace mica
22-2-74	2nd shift	62.83	3.66	Grey dense med. to fine trace c. SAND little silt; trace mica
23-2-74	1st shift	68.02	5.19	Grey very dense med. to fine trace coarse SAND with silt; trace mica
23-2-74	1st shift	69.54	1.52	Grey very dense med. SAND with occasional small gravels
23-2-74	1st shift	71.68	2.14	Grey very dense med. to f. & coarse SAND little silt; trace mica
23-2-74	2nd shift	79.91	8.23	Dark grey very dense med. to coarse & fine SAND, GRAVELS & BOULDERS
23-2-74	2nd shift	82.05	2.14	Dark grey very dense silty med. to fine & coarse SAND; trace mica
24-2-74	1st shift	85.10	3.05	Greyish very dense silty med. to coarse & fine SAND interbedded with thin layer of fine silt & clay
24-2-74	2nd shift	89.37	4.27	Dark grey very dense silty med. to coarse & fine SAND with thin layer of silt; trace mica
24-2-74	2nd shift	92.42	3.05	Deep grey very dense silty fine to med. tr. coarse SAND interbedded with thin layer of clay & mica
25-2-74	1st shift	96.38	3.96	Grey very dense silty med. to fine & coarse SAND; trace gravel & mica
25-2-74	1st shift	98.52	2.14	Grey very dense silty fine to med. & coarse SAND; trace mica
25-2-74	2nd shift	102.48	3.96	Light grey very dense silty med. to fine & coarse SAND; trace gravel & mica
26-2-74	1st shift / 2nd shift	108.28	5.80	Dark grey hard fine SILT & CLAY (early stage of shale formation)
26-2-74	2nd shift	111.33	3.05	Grey very dense GRAVELS consolidated with med. to coarse sand
27-2-74	1st shift	111.94	0.61	WOOD (un-decomposed)
27-2-74	1st shift	114.38	2.44	Grey very dense silty med. to fine & coarse SAND; trace gravel
27-2-74	2nd shift	117.43	3.05	Grey very dense coarse SAND & GRAVELS
27-2-74	2nd shift	120.17	2.74	Grey very dense silty fine to med. trace coarse SAND; trace mica with occasional small gravel
28-2-74	1st shift	122.31	2.14	Grey very dense silty fine to med. trace coarse SAND with thin layer of clay & occasional gravels

SOIL SAMPLE	DEPTH (m)	STANDARD PENETRATION TEST N (blows every 10 cm)
1	3.20	6 (2,2,2)
2	6.25	6 (2,2,2)
U-1		
3	9.30	22 (5,8,9)
4	12.35	18 (4,6,8)
U-2		
5	15.40	20 (5,6,9)
6	18.45	20 (5,6,9)
7	21.50	28 (9,9,10)
8	24.55	39 (8,13,18)
U-3		
9	27.60	32 (8,11,13)
U-4		
10	30.65	44 (11,14,19)
11	33.70	36 (10,12,14)
12	36.75	39 (9,14,16)
13	39.80	43 (10,15,18)
14	42.85	64 (18,22,24)
15	45.90	59 (16,21,22)
16	48.95	62 (18,20,24)
17	52.00	59 (16,19,24)
18	55.05	61 (15,21,25)
19	58.10	61 (14,21,26)
20	61.15	49 (14,14,21)
21	64.20	55 (15,18,22)
22	67.25	58 (16,19,23)
23	70.30	89 (23,33,33)
24	73.35	92 (21,33,38)
25	76.40	50 BLOWS FOR 7.5 cm.
26	79.45	55 blows for 7.5 cm.
27	82.50	77 blows for 17.5 cm.
28	85.55	101 blows for 17.5 cm.
29	88.60	81 blows for 7.5 cm.
30	91.65	65 blows for 7.5 cm.
31	94.70	95 blows for 7.5 cm.
32	97.75	158 blows for 25 cm.
33	100.80	162 blows for 10 cm.
34	103.85	126 blows for 10 cm.
35	106.90	62 blows for 5 cm.
36	109.95	50 blows for 2.5 cm.
37	113.00	70 blows for 5 cm.
38	116.05	64 blows for 2.5 cm.
39	119.10	100 blows for 7.5 cm.
40	122.15	105 blows for 2.5 cm.

Measured N

Water level: 2.7 m.

LATERAL LOADING TEST (X Em kg/cm²; ⊙ Km kg/cm³)

Depth	Km	Em
16.16 m.	13.6	81.0
22.26 m.	15.8	94.8
30.78 m.	8.7	83.5
83.27 m.	55.7	320.8

No L.L. Test between 31 m. to 80 m. depth due to supply gas trouble

Em -·-·- DISTURBED SAMPLE ▭ UNDISTURBED SAMPLE ■ Km - - - -

DRN:- [signature] DATE:- 9-3-74 SCALE:- 1: 300 PLAN No. ST-567/D

DRILL LOG

HOLE NO. S-3, 74 SHEET NO. OF

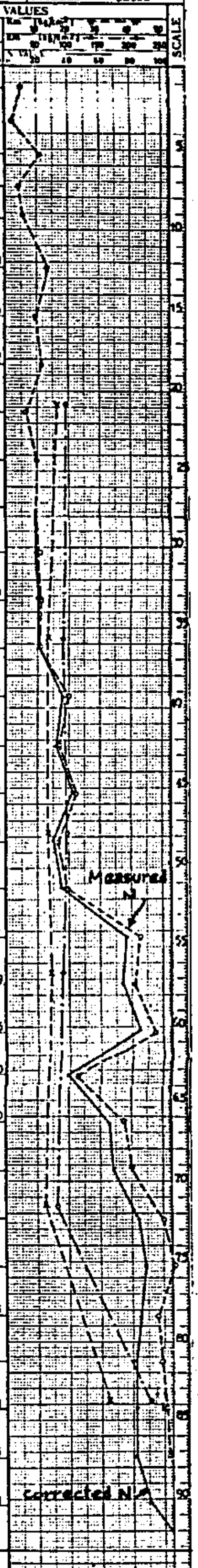
PROJECT	JAMUNA RIVER BRIDGE CONSTRUCTION PROJECT	CLIENT	JAPAN INTERNATIONAL CO-OPERATION AGENCY
LOCATION	BATAR CHAR (Middle of the river) COORDINATE N:24°21'22"4 E:89°45'32"3	DEPTH OF HOLE	93.20 m
ELEVATION	7.62 m, DIAMETER 115 ~ 86 mm	DATE	FROM 3 Feb '75 TO 8 Feb '75

Elevation	Depth	Thickness	Color	Consistency	Material	Formation	Description
3.62	4.00	4.00	Light brown	Medium to loose	Silty SAND	Upper most of alluvium	Very fine sand with silt. Traces of mica and black minerals. Medium moisture contents.
1.62	6.00	2.00	grey	Medium	Fine sand with silt	Upper most of alluvium	Fine sand with little silt, mica and black minerals.
-2.38	10.0	4.00	Light grey	Medium	Fine SAND	Upper most of alluvium	Fine to medium sand with traces of mica and black minerals. High moisture contents.
-9.38	17.0	7.00	grey	Medium	Fine SAND	Upper alluvium	Fine sand with little medium sand. Traces of mica.
-23.38	31.00	14.0	grey	Medium	Fine SAND	Upper alluvium	Fine to medium sand. Traces of laminated mica and black minerals. Unequality of grain sand. 20.0 to 23.0 m high moisture contents. 26 to 28 m with little silt. Fine sand.
-29.38	37.0	6.00	grey	Medium	Fine SAND	Upper alluvium	Fine to medium sand with little gravels. Unequality of grains. Traces of mica and black minerals. Medium to high moisture C.
-36.38	44.0	7.00	Light grey	Dense	Fine SAND	Middle alluvium	Fine to medium sand. Almost medium sand with traces of laminated mica and black minerals. High moisture contents. 40.70 m gravels high sand.
-44.38	52.0	8.00	dark grey	Dense	Fine SAND	Middle alluvium	Fine to medium sand with greenish minerals. Traces of mica. Unequality of grains.
-48.38	56.00	4.00	grey	Very Dense	Fine SAND with gravels	Middle alluvium	Fine to medium sand with some gravels. Traces mica and chloritic minerals. High moisture contents.
[illegible]	[illegible]	[illegible]	dark grey	Very dense	Silty SAND	Middle alluvium	Very fine Silty sand with traces of mica. Medium moisture contents.
-56.38	64.00	2.00	Light grey	Dense	Coarse SAND with gravels	Middle alluvium	Med to coarse sand with gravels & greenish minerals very high moisture contents
-60.38	68.00	4.00	Light grey	very dense	SAND and GRAVELS	Lower alluvium	Medium to coarse sand and gravels. Traces greenish and black minerals. max gravels ø 20 m/m
-65.38	73.00	5.00	grey	Very dense	Fine SAND with gravels	Lower alluvium	Fine to medium sand with gravels. Traces of mica and greenish minerals. Low moisture content.
-80.38	88.00	15.00	grey	Very Dense	SAND and GRAVELS	Lower alluvium	Fine to med. sand & subrounded gravels & boulders, scattered mica & greenish minerals. Gravels & boulders are almost quartzitic. Low to med. moisture contents.
-85.58	93.20	5.20	Greenish	very Dense	SAND with Gravels	Diluvium	Fine to medium sand with Gravels. Scattered greenish minerals, mica. Medium moisture contents.

Casing up to 11.9 m deep

Standard Penetration Test

Sample No.	Depth	Blow/cm	Blows every 10 cm		
D 1	[illegible]	10/30	4	3	3
D 2	[illegible]	4/30	1	1	2
D 3	[illegible]	22/30	7	7	8
D 4	[illegible]	9/30	2	3	4
D 5	[illegible]	12/30	3	4	5
D 6	12.00–12.30	27/30	5	9	13
D 7	15.00–15.30	20/30	4	6	10
D 8	18.00–18.30	23/30	4	7	12
D 9	21.00–21.30	13/30	4	4	5
D10	24.00–24.30	20/30	5	7	8
D11	27.00–27.30	19/30	5	7	7
D 12	30.00–30.30	20/30	5	7	8
D 13	33.00–33.30	22/30	5	7	10
D 14	36.00–36.30	22/30	6	7	9
D 15	39.00–39.30	40/30	11	12	17
D 16	42.00–42.30	34/30	11	12	11
D 17	45.00–45.30	45/30	10	15	20
D 18	48.00–48.30	33/30	9	11	13
D 19	51.00–51.30	30/30	9	14	16
D20	54.00–54.30	85/30	22	31	32
D21	57.00–57.30	83/30	18	25	39
D22	60.00–60.30	95/30	22	28	45
D 23	63.00–63.30	44/30	11	14	20
D 24	66.00–66.30	75/30	21	24	30
D 25	69.00–69.30	80/30	24	25	31
D26	72.00–72.30	99/30	24	33	42
D27	75.00–75.30	107/30	25	35	47
D28	78.00–78.30	96/30	18	35	43
D29	81.00–81.30	99/30	22	36	41
D30	84.00–84.30	102/30	21	38	43
D31	87.00–87.30	103/30	22	36	45
D32	90.00–90.30	117/30	30	38	49
D33	93.00–93.20	107/20	42	65	



* CONSISTENCY OR RELATIVE DENSITY
* UNIFIED SOIL CLASSIFICATION

DATE:–3–3–75 PLAN No. ST-811/D NIPPON KOEI CO., LTD. CONSULTING ENGINEERS TOKYO.

- 69~70 -

DRILL LOG

HOLE NO. S-2, 74 SHEET NO. OF -

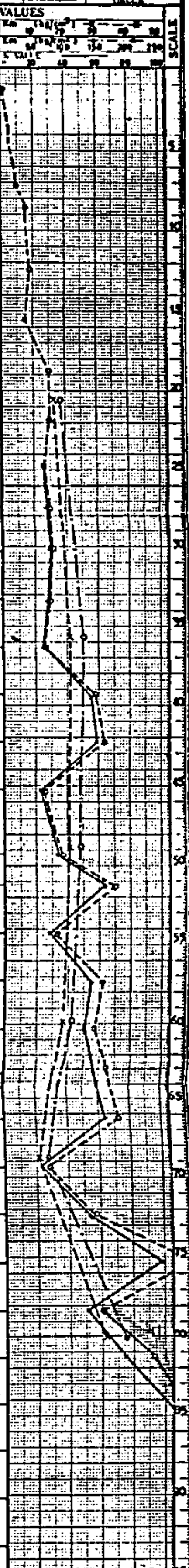
PROJECT	JAMUNA RIVER BRIDGE CONSTRUCTION PROJECT, 2ND PHASE	CLIENT	JAPAN INTERNATIONAL CO-OPERATION AGENCY
LOCATION	BASBORIA CHAR (Eastern Bank) COORDINATE N:24°21'11"9 E:89°46'47"1	DEPTH OF HOLE	122.06 m
ELEVATION	12.39 m, DIAMETER 115 ~ 86 mm	DATE	FROM 13 Dec '74 TO 24 Dec. '74

Depth	Thickness	Color	Consistency	U.S.C.	Material	Formation	Description
3.00	3.00	Orangish	Very loose	(SM)	Silty fine SAND	Upper most of alluvium	Interbeded with thin mica seams.
4.60	1.60	grey	Med.	(ML)	Clayey SILT	Upper most of alluvium	Alternated thin layer of fine sand
6.60	2.00	grey	Med.	(SM)	Silty F.SAND	Upper most of alluvium	Poor graded.
7.90	1.30	dk. grey	Loose	(SP)	F.SAND	Upper most of alluvium	Scattered mica seams, moisture [illegible]
18.00	10.10	gray	Med.	(SP)	Fine SAND	Upper alluvium	Little coarse in fine sand, at upper layer. Consist of quartz sand. Little high moisture at middle portion. Very poor graded med. to fine SAND. Silt contained within 5 to 10%.
32.0	14.0	grey	Med.	(SP)	Fine SAND	Upper alluvium	Little coarse grained than upper layer. (med. sand) Consist of quartz angular sand and micaceous sand. Silt contained up to around of 10%. Generally very poor graded sand.
38.0	6.00	Greenish grey	Med.	(SP)	Fine SAND	Upper alluvium	Well graded fine sand. Very rarely scattered small gravels (5 mm ø). Little silt around of 10 – 15%.
44.00	6.00	Greenish grey	Very dense	(SP)	Fine SAND	Upper alluvium	Ditto, more rich in mica and black minerals sand. Very rarely scattered gravel (5 mm ø). Low moisture.
56.00	12.0	grey	Dense	(S)	Fine SAND	Middle alluvium	Laminated fine sand with little gravels (Scattered). High gravel sound during drilling from 46 m to 64.5 m. Very little silt within 5%. Med. moisture.
67.50	11.50	grey	Very Dense	(S)	Fine SAND	Middle alluvium	Fine and poor graded. Low moisture. Rarely scattered gravels. Lower portion laminated and inter beded mica sand seams (Blackish)
68.50	1.00	grey	Very Dense		SAND & GRAVEL	Middle alluvium	Noted by drill [illegible]
71.0	2.50	grey	Med.	(S)	Fine SAND	Lower alluvium	Contained some gravels (1–2 cm ø)
73.90	2.90	grey	Very Dense	(GW)	SAND & GRAVEL	Lower alluvium	[illegible]
76.00	2.10	Grey	Very Dense	(S)	SAND with Gravel	Lower alluvium	Consist of mostly sand and contained few gravel [illegible]
82.00	6.00	Gray	Very Dense	(GP)	SAND and GRAVEL	Lower alluvium	High to med. moisture. Step – poor graded gravel and sand. (sand is mostly fine).
86.5	4.50	Gray	Very Dense	(GW)	GRAVEL and BOULDER	Lower alluvium	Coarse gravel and boulders (20 cm in max ø probably). Med to high moisture.
95.0	8.50	Greenish mottled tints	Special dense	(GW)	GRAVEL with Sand	Diluvium	Very compact and dense, very low moisture. (So called soft conglomerate). Consist of quartz and siliceous gravel and pebbles, in max dia of 1 cm.
101.0	6.0	Grayish Green	Special Dense	(S)	Fine SAND	Diluvium	Consist of quartz, mica and chloritic fine sand very dense and very low moisture. Rarely contained very small gravels.
103.15	2.15	[illegible]	Special	(G)	GRAVEL with silt	Diluvium	Max. dia. of gravels: 1 cm. Hardly consolidated matrix.
104.5	1.35	[illegible]	Special		[illegible]	Diluvium	Silty hard clay. So called soft [illegible]
[illegible]	[illegible]	Grey	[illegible]		[illegible]	Diluvium	Poor graded gravels with hardly consolidated matrix. Fossil wood 103.5 m
109.5	5.00	Greenish gray		(S)	Med. SAND	Diluvium	Very dense, low moisture, fairly well graded.
117.5	7.80	grey	Special dense	(S)	Fine SAND	Diluvium	Very dense. Very low moisture. Poor graded fine sand. Very rarely gravel.
119.8	2.30	grey	Special	(G)	GRAVEL with SILT	Diluvium	Consist of gravel and small boulders. Hard matrix. (Max. ø 5 cm).
120.6	1.0	grey	[illegible]		[illegible]	Diluvium	Compact.
122.06	[illegible]	grey	Special	(G)	Gravel	Diluvium	Hard consolidated gravel (Max ø 3 cm).

Casing up to 18.3 m deep

Standard Penetration Test

Sample No.	Depth	Blow/cm	Blows every 10 cm		
D 1	[illegible]	1/30	0	0	1
D 2	[illegible]	5/30	1	2	2
D 3	[illegible]	5/30	1	2	2
D 4	[illegible]	8/30	2	3	3
D 5	[illegible]	10/30	3	3	4
D 6	[illegible]	15/30	4	5	6
D 7	[illegible]	15/30	4	5	6
D 8	12.3–12.6	18/30	5	6	7
D 9	15.3–15.6	15/30	4	5	6
D10	18.4–18.7	30/30	7	11	12
D11	21.5–21.8	30/30	10	11	9
D12	24.3–24.6	27/30	8	9	10
D13	27.0–27.3	30/30	8	10	12
D14	30.0–30.3	31/30	9	9	13
D15	33.0–33.3	30/30	8	10	12
D16	36.0–36.3	26/30	7	8	11
D17	39.0–39.3	58/30	15	21	22
D18	42.0–42.3	63/30	18	22	23
D19	45.0–45.3	25/30	4	8	13
D20	49.0–49.30	37/30	11	12	14
D21	51.00–51.30	70/30	22	23	25
D22	54.0–54.3	32/30	9	11	12
D23	57.00–57.3	62/30	19	21	22
D24	60.0–60.3	57/30	11	19	27
D25	63.0–63.3	66/30	17	24	25
D26	66.0–66.3	73/30	16	25	32
D27	69.0–69.3	27/30	6	8	13
D28	72.0–72.3	56/30	13	19	24
D29	75.0–75.3	118/30	23	38	57
D30	78.0–78.3	60/30	19	18	23
D31	81.0–81.3	93/30	24	31	38
D32	84.00–84.19	104/19	50	54/9	–
D33	87.00–87.12	100/12	88	12/2	
D34	90.0–90.12	108/12	86	22/2	
D35	93.0–93.16	100/16	56	44/6	–
D36	96.0–96.25	106/25	28	54	24/5
D37	99.0–99.25	111/25	24	63	24/5
D38	102.0–102.1	125/10	125	–	–
D39	105.0–105.26	100/26	18	32	50/6
D40	108.0–108.17	100/17	32	68/7	–
D41	111.0–111.19	100/19	32	68/9	
D42	114.0–114.16	100/16	46	54/6	
D43	117.0–117.14	100/14	55	45/4	–
D44	120.0–120.16	100/16	10	10/6	
D45	122.0–122.06	100/6			



HOLE NO.

HOLE NO. S-2 ( )

* CONSISTENCY OR RELATIVE DENSITY
* UNIFIED SOIL CLASSIFICATION

DATE:–4–3–75 PLAN No. ST-810/D NIPPON KOEI CO., LTD. CONSULTING ENGINEERS TOKYO.

DRILL LOG

HOLE NO. S-5 .74 SHEET NO. OF

PROJECT	JAMUNA RIVER BRIDGE CONSTRUCTION PROJECT 2ND PHASE	CLIENT	JAPAN INTERNATIONAL CO-OPERATION AGENCY
LOCATION	BANK BAVRA (Western bank of the river) COORDINATE N:24°21'8"9 E:89°44'6"9	DEPTH	93.20
ELEVATION	11.61 m DIAMETER 115 – 86 mm, DATE FROM 1 Jan. '75 TO 17 Jan '75	CHECKED	

Elevation	Depth	Thickness	Color	Consistency	Material	Formation	Description
10.01	1.60	1.60	grey	Loose	Fine SAND	Upper most of alluvium	very dry fine sand with little silt and mica.
7.11	4.50	2.90	Light grey	Medium	Fine SAND	Upper most of alluvium	with a little clay. clay colour is brown traces of mica.
4.11	7.50	3.00	grey	Dense	Fine SAND	Upper most of alluvium	traces of mica with a little silt high moisture contents.
1.61	10.00	2.50	grey	Medium	Silty fine SAND	Upper most of alluvium	traces mica silt 15 – 20 high moisture contents.
-7.39	19.00	9.00	grey	Medium	Fine SAND	Upper alluvium	Fine to medium sand high moisture cont. contents scattered mica.
-16.39	28.00	9.00	Light grey	Dense to very dense	Fine SAND	Upper alluvium	Very fine sand with a little silt with lamination layer traces of mica.
-19.39	31.00	3.00	grey	Dense	Fine SAND	Upper alluvium	Fine to medium SAND traces of mica high moisture contents
-22.39	34.00	3.00	grey	very Dense	Fine SAND	Middle alluvium	Very fine sand with a little silt scattered mica.
-26.39	38.00	4.00	grey	Dense	Fine SAND	Middle alluvium	fine to medium sand traces of mica unequality grading sand.
-28.39	40.00	2.00	grey	Dense	Fine SAND	Middle alluvium	Very fine sand with a little silt traces of mica.
-32.39	44.00	4.00	grey	Dense	Fine SAND	Middle alluvium	fine to medium sand with lamination layer of silt. traces of mica unequality grading sand.
-41.39	53.00	9.00	grey	Dense to very dense	Fine SAND	Middle alluvium	fine sand with lamination layer of mica. from 48.8 m gravels started gravels max ϕ 5 m/m.
-46.39	58.00	5.00	grey	very dense	Fine SAND	Middle alluvium	very fine sand with lamination. with a little gravels scattered traces of mica.
-59.39	71.00	13.00	grey	very dense	Fine SAND with Gravels	Lower alluvium	with some gravels, gravels ϕ max 20 m/m traces of mica. F. to coarse sand with some gravels high moisture contents unequality graying.
-68.39	80.00	9.00	grey	Very Dense	SAND and GRAVELS	Lower alluvium	High to medium moisture content. poor graded Gravels and Sands. Sand is is mostly medium. Gravels (5–10 m/m in ϕ).
-74.39	86.00	6.00	grey	Very dense	GRAVEL and Boulders	Lower alluvium	Med. to high moisture Fine to Coarse gravels & boulders (15–20cm in max ϕ probably) high boulder sound during drilling from 79.00 to 81.00m. Sand is mostly med to coarse.
-81.59	93.20	7.20	Greenish grey	Very Dense	Fine SAND	Delluvium	Very compact, med moisture content. consist of quartz & chlorite fine sand little silt & mica seams. rarely scattered gravels of 5m/m ϕ.

Casing up to 11.9m deep. In-situ tests (LLT): 20.2–20.8, 35.2–35.8, 47.2–47.8, 56.1–56.7, 65.2–65.8, 80.1–80.7.

Sample No.	SPT depth (m)	Blows/30 cm	Blows every 10 cm
D1		4/30	1/0, 1/0, 2/4
D2		10/31	3, 3, 4
D3		39/30	11, 13, 14
D4		34/30	9, 11, 14
D5		34/30	9, 10, 15
D6		18/30	5, 6, 7
D7		20/30	5, 6, 9
D8	12.0–12.3	20/30	6, 6, 8
D9	15.0–15.3	22/30	6, 7, 9
D10	19.0–19.3	25/30	7, 9, 9
D11	21.0–21.3	76/30	28, 24, 24
D12	24.0–24.3	50/30	14, 15, 21
D13	27.0–27.3	36/30	9, 11, 16
D14	30.0–30.3	38/30	10, 12, 16
D15	33.0–33.3	81/30	22, 28, 31
D16	36.0–36.3	41/30	11, 13, 17
D17	39.0–39.3	45/30	12, 15, 18
D18	42.0–42.3	31/30	7, 11, 13
D19	45.0–45.3	85/30	20, 29, 35
D20	48.0–48.3	39/30	8, 14, 17
D21	51.0–51.3	49/30	15, 16, 18
D22	54.0–54.3	56/30	18, 19, 19
D23	57.0–57.3	66/30	17, 22, 27
D24	60.0–60.3	51/30	10, 18, 23
D25	63.0–63.3	59/30	12, 22, 25
D26	66.0–66.3	59/30	11, 18, 30
D27	69.0–69.3	85/30	22, 30, 33
D28	72.0–72.3	50/30	11, 16, 23
D29	75.0–75.3	88/30	22, 33, 33
D30	78.0–78.3	105/30	21, 36, 48
D31	81.0–81.3	91/30	30, 35, 26
D32	84.0–84.3	85/30	22, 33, 30
D33	87.0–87.3	137/30	27, 42, 68
D34	90.0–90.3	125/30	25, 42, 58
D35	93.0–93.2	100/20	37, 63/10

DATE 3-3-75 PLAN No. ST-813/D NIPPON KOEI CO., LTD. CONSULTING ENGINEERS TOKYO

DRILL LOG

HOLE NO. S-4 .74 SHEET NO. OF

PROJECT	JAMUNA RIVER BRIDGE CONSTRUCTION PROJECT 2ND PHASE	CLIENT	JAPAN INTERNATIONAL CO-OPERATION AGENCY
LOCATION	BATRA CHAR (Western bank of the river) COORDINATE N:24°21'12" E:89°44'53"9	DEPTH	121.73 m
ELEVATION	11.32 m DIAMETER 115 – 86 mm, DATE	CHECKED	

Elevation	Depth	Thickness	Color	Consistency	Material	Formation	Description
7.32	4.00	4.00	Greyish	Loose to	Fine SAND	Upper most of alluvium	Little silt arround of 10–15% very low moisture. Scattered mica mainly very fine sand.
3.32	8.00	4.00	Light Brown	Loose	Silty fine SAND	Upper most of alluvium	Med. to high moisture Scattered mica. sand mainly very fine to fine.
-2.68	14.00	6.00	Light Brown	Medium	Very fine to fine SAND	Upper most of alluvium	Poor graded very fine to fine sand silt contained with 10 –15% low medium moisture.
-8.68	20.00	6.00	Greyish	Dense	Fine SAND	Upper alluvium	Very fine sand scattered black minerals with quartz and mica low moisture.
-12.68	24.00	4.00	dark Grey	Medium	Fine SAND	Upper alluvium	Very poor graded med. to fine sand consist of micacious sand & little silt medium moisture content.
-22.68	34.00	10.00	Grey	Medium	Fine SAND	Upper alluvium	Scattered mica & mica seams. Sand is mostly medium with some coarse grain medium to high moisture.
-26.68	38.00	4.00	Grey	Dense	Fine SAND	Middle alluvium	Scattered mica silt contained probably 10–15% medium moisture.
-29.68	41.00	3.00	Grey	Dense	Fine SAND	Middle alluvium	Sand is mostly med. rarely scattered small gravels & mica seams a little silt. high med moisture.
-32.18	43.50	2.50	Dark Grey	Dense	Fine SAND	Middle alluvium	Mica ... medium sand little silt ... black minerals
-35.68	47.00	3.50		Very dense	Fine SAND	Middle alluvium	Silt contain 5–10% scattered mica mostly fine sand
-39.68	51.00	4.00	Dark Grey	Dense	Fine SAND	Middle alluvium	Poor graded med. sand consist of lineated black mineral & micaceous sand little silt medium.
-43.68	55.00	4.00	Grey	Dense	Fine SAND with Gravel	Middle alluvium	Medium sand with little gravels (scattered) high gravel during drilling from 53.5–55.0 metr. little silt.
-49.68	61.00	6.00	Grey	Very Dense	Fine SAND	Lower alluvium	Very fine to fine sand. Scattered mica Silt Contained 10–15% highly compacted low moisture content.
-55.68	67.00	6.00	Grey	Very Dense	SAND with Gravels	Lower alluvium	Medium to Coarse sand with gravels. little silt. high moisture content. fine gravel sand during drilling from 62.00 m 63.00.
-61.68	73.00	6.00	Grey	Very Dense	Fine SAND	Lower alluvium	Fine sand with traces of mica Scattered little gravels Medium moisture contents.
-70.68	82.00	9.00	Grey	Very dense	SAND with Gravels	Lower alluvium	Medium to fine grain sand with gravels. Traces of black minerals and mica. max ϕ 20 m/m Gravels are rounded.
-73.68	85.00	3.00	Light Grey	Very Dense	Gravels and Boulder	Lower alluvium	Gravels mostly quartzite moisture is medium.
-82.68	94.00	9.00	Light grey	Very dense	GRAVELS	Delluvium	Scattered boulders Low moisture C. Gravels are angular to subrounded. little weathering. gravels mostly quartzite.
-89.68	101.00	7.00	grey	very dense	Fine SAND	Delluvium	Fine sand with gravels Traces of mica and black minerals very fine sand. Medium m.c.
-102.68	114.00	13.00	Light grey	very dense	Fine SAND with GRAVELS	Delluvium	Fine to medium sand with gravels. Traces of black minerals. High moisture content unequality grain size with little coarse sand.
	115.00	1.00	Greyish		W. clay		with carbonized wood
	121.73	5.73	Grey	very dense	Fine SAND		Fine sand with gravels. to medium 120.5 to 121.0 greenish sandy siltstone.

Casing up to 11.4m deep. In-situ tests (LLT): 20.1–20.7, 35.2–35.8, 47.2–47.8, 52.9–53.5, 66.6–67.2, 82.9–83.5.

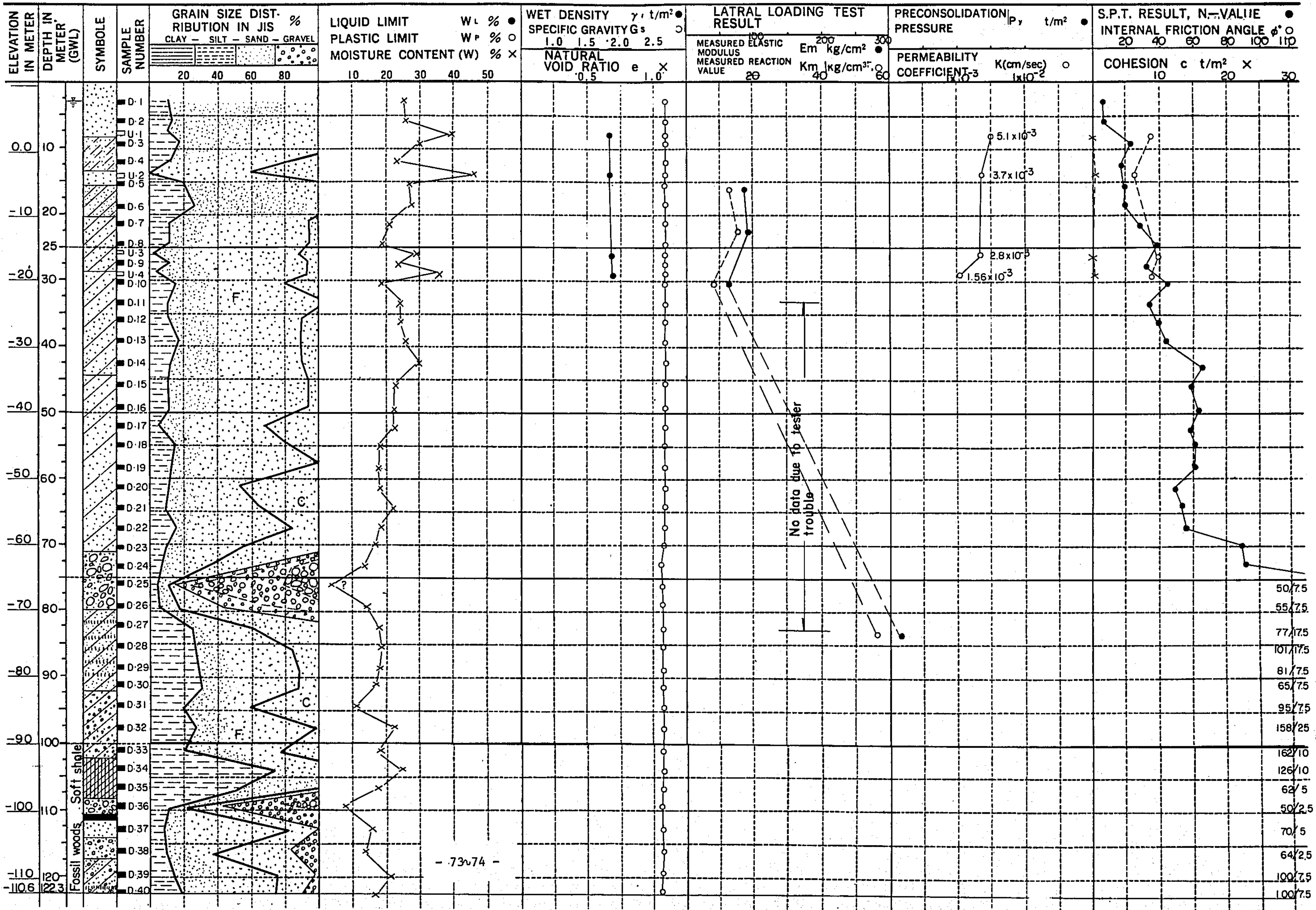
SPT depth (m)	Blows/30 cm	Blows every 10 cm
	7/30	2, 2, 3
	15/30	6, 5, 4
	8/30	3, 2, 3
	6/30	2, 2, 2
	14/30	4, 5, 5
12.0–12.3	14/30	4, 4, 6
15.0–15.3	42/30	11, 15, 16
18.0–18.3	40/30	10, 14, 16
21.0–21.3	21/30	5, 8, 8
24.0–24.3	21/30	6, 7, 8
27.0–27.3	24/30	7, 8, 9
30.0–30.3	35/30	10, 12, 13
33.0–33.3	27/30	8, 8, 11
36.0–36.3	51/30	11, 18, 22
39.0–39.3	45/30	12, 16, 17
42.0–42.3	37/30	11, 11, 15
45.0–45.3	71/30	22, 22, 27
48.0–48.3	39/30	11, 13, 15
51.0–51.3	37/30	11, 12, 14
54.0–54.3	57/30	18, 18, 20
57.0–57.3	93/30	18, 30, 45
60.0–60.3	76/30	22, 26, 28
63.0–63.3	62/30	18, 18, 22
66.0–66.3	61/30	18, 19, 24
69.0–69.3	90/30	28, 31, 31
72.0–72.3	62/30	20, 20, 22
75.0–75.3	76/30	25, 26, 27
78.0–78.3	72/30	18, 24, 30
81.0–81.3	100/	25, 28, 47
84.0–84.25	100/25	20, 40, 40/5
87.0–87.15	115/15	70, 45/5
90.0–90.12	105/12	70, 35/2
93.0–93.11	100/11	88, 18/1
96.0–96.12	105/12	75, 30/2
99.0–99.12	100/12	28, 72/2
102.0–102.3	173/	25, 55, 93
105.0–105.2	101/	33, 68
108.0–108.15	111/15	48, 63/5
111.0–111.1	100/10	100
114.0–114.12	112/12	84, 28/2
117.0–117.11	113/11	30, 83/1
120.0–120.18	100/	35, 65/8
121.6–121.73	100/13	70, 30/3

DATE 3-3-75 PLAN No. ST-812/D NIPPON KOEI CO., LTD. CONSULTING ENGINEERS TOKYO

S-4

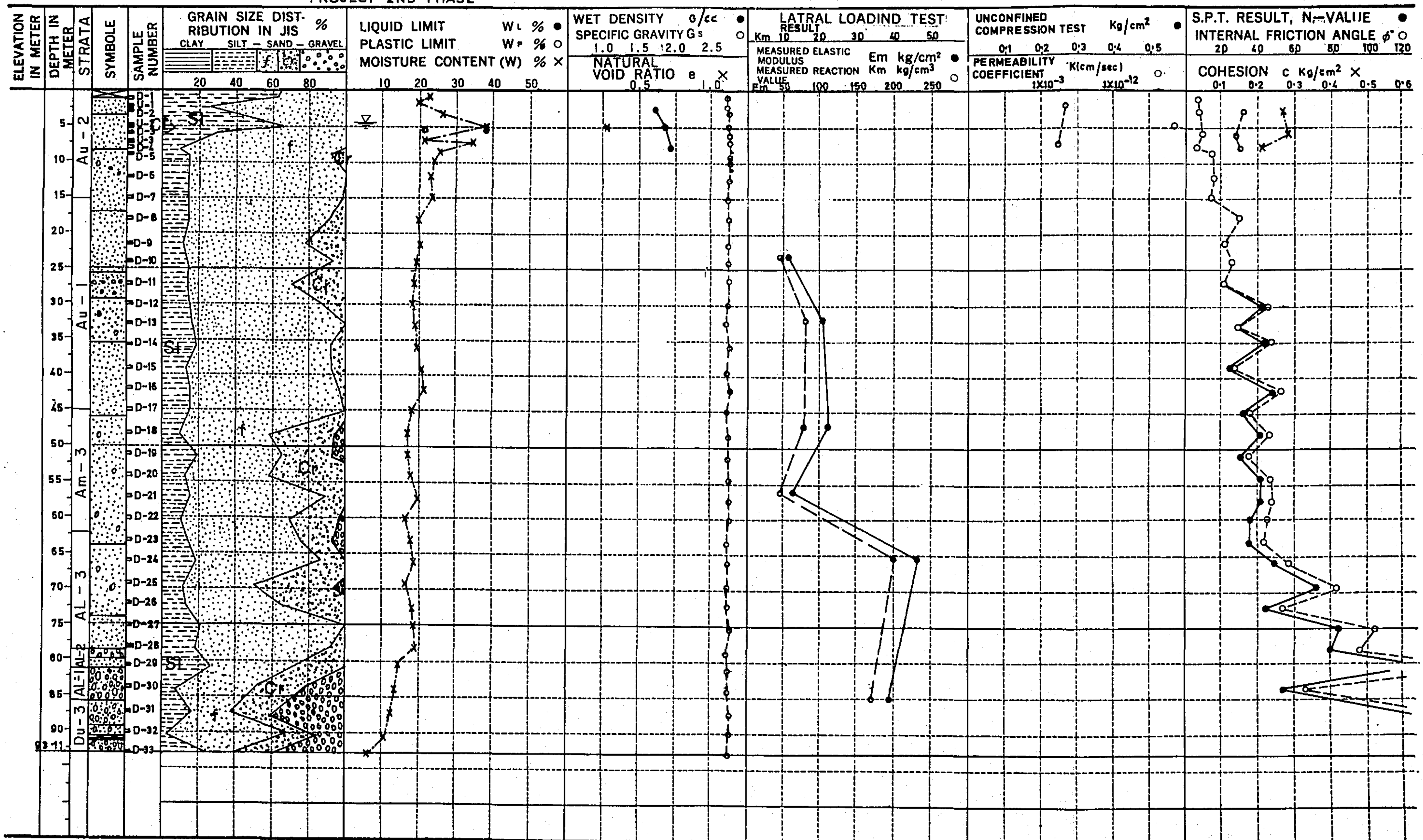
SUMMARIZED CHART OF SOIL CHARACTER

PROJECT JAMUNA BRIDGE (SIRAJGANJ SITE) HOLE NO. S – O EL. APROX. 10.7 m GWL. GL. – 2.70 m COORDINATE: N 24°-22'-25" E 89°-50'-10"



SUMMARIZED CHART OF SOIL CHARACTER

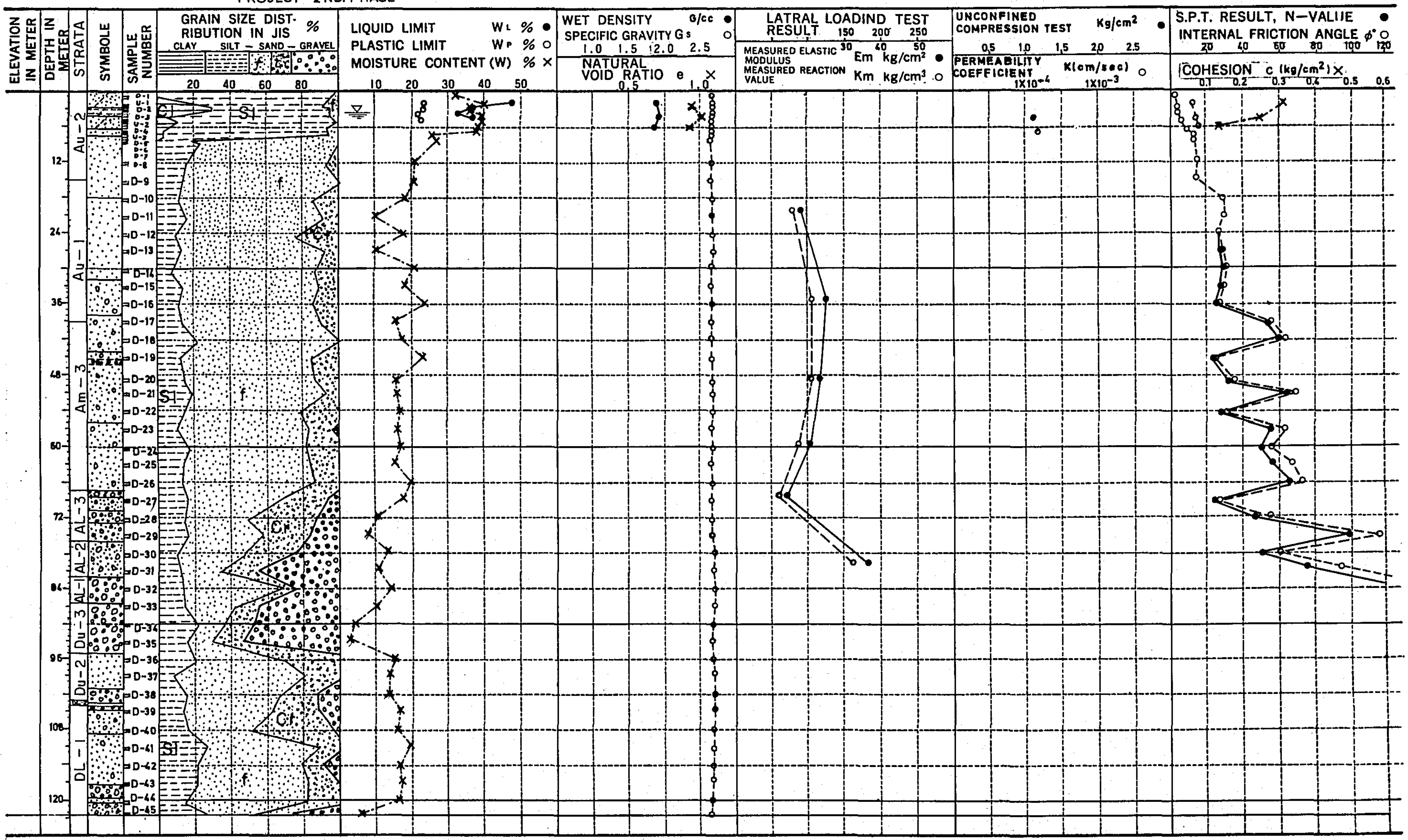
PROJECT JAMUNA RIVER BRIDGE CONST. PROJECT 2ND PHASE HOLE NO S-1'74 EL. 12.22 m GWL. GL.- 4.4 m COORDINATE:N.24°21'14.4" E 89°47'34.3"



 SOILTECH INTERNATIONAL LTD. DATE: 8-3-75 PLAN No. ST-834/D

SUMMARIZED CHART OF SOIL CHARACTER

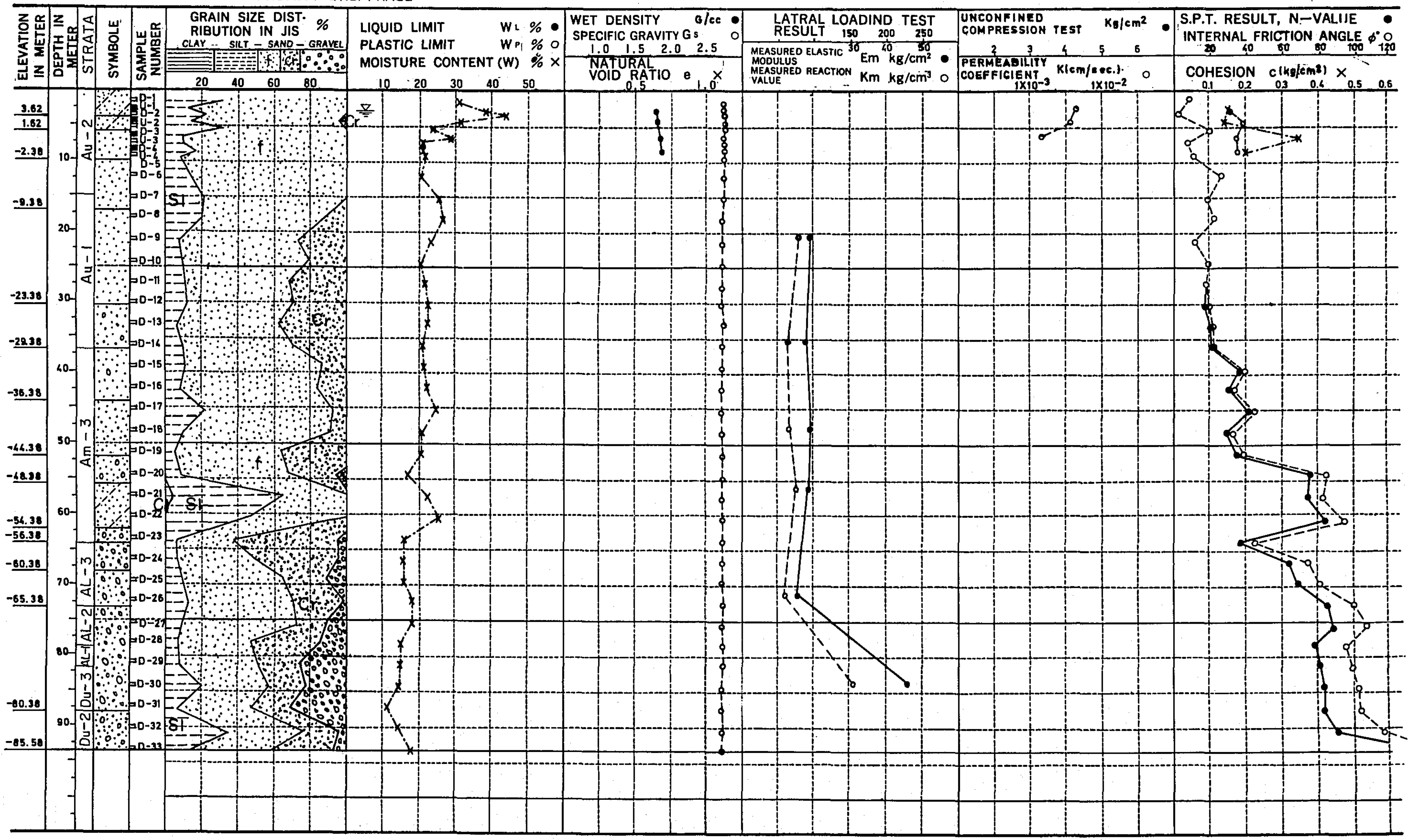
PROJECT JAMUNA RIVER BRIDGE CONST. PROJECT 2ND. PHASE HOLE NO. S-2' 74 EL. 12.39 m GWL. GL.- 4.6 m COORDINATE: N 24°21'11.9" E 89°46'47.1



SOILTECH INTERNATIONAL LTD. DATE:- 6-3-75 PLAN No. ST-835/D

SUMMARIZED CHART OF SOIL CHARACTER

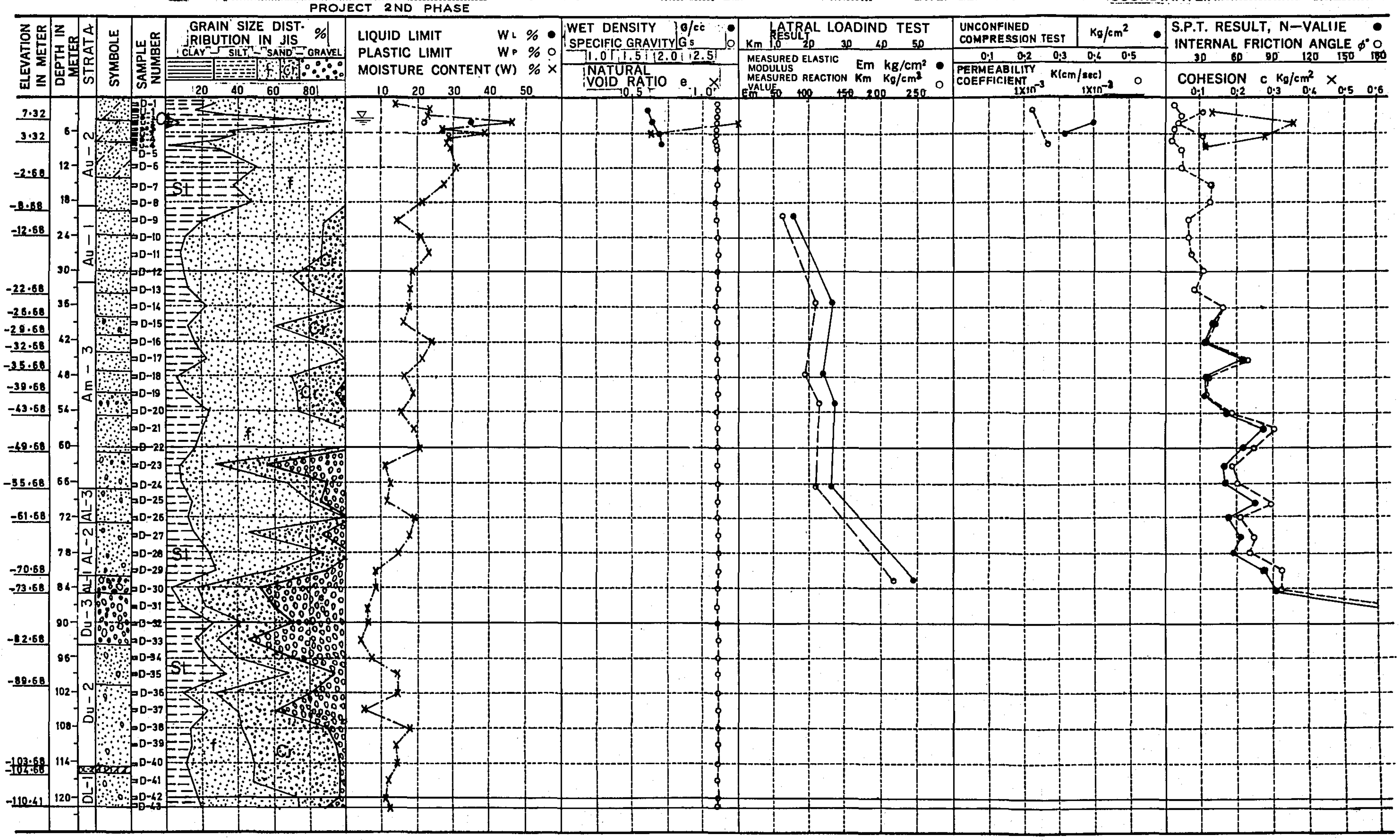
PROJECT JAMUNA RIVER BRIDGE CONST. PROJECT 2ND. PHASE HOLE NO. S-3' 74 EL. 7.62 m GWL. GL. – 1.8 m COORDINATE: N24°21'22."4 E 89°45'32."3



SOILTECH INTERNATIONAL LTD. DATE:- 8-3-75 PLAN No. ST-836/D

SUMMARIZED CHART OF SOIL CHARACTER

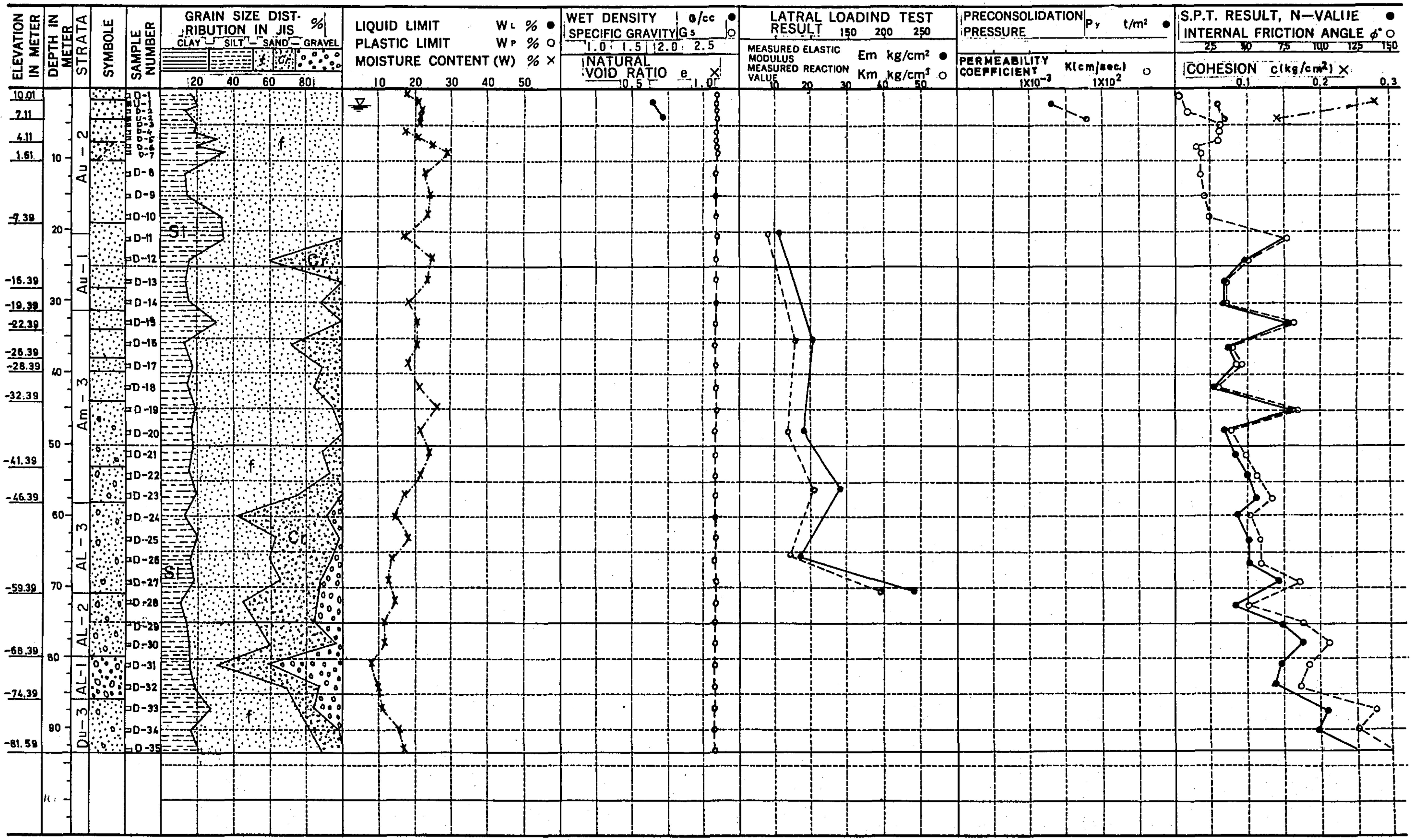
PROJECT: JAMUNA RIVER BRIDGE CONST. PROJECT 2ND PHASE HOLE NO S - 4'74 EL. 11.32 m GWL. GL. - 4.1 m COORDINATE: N 24°21'12" E 89°94'53.9"



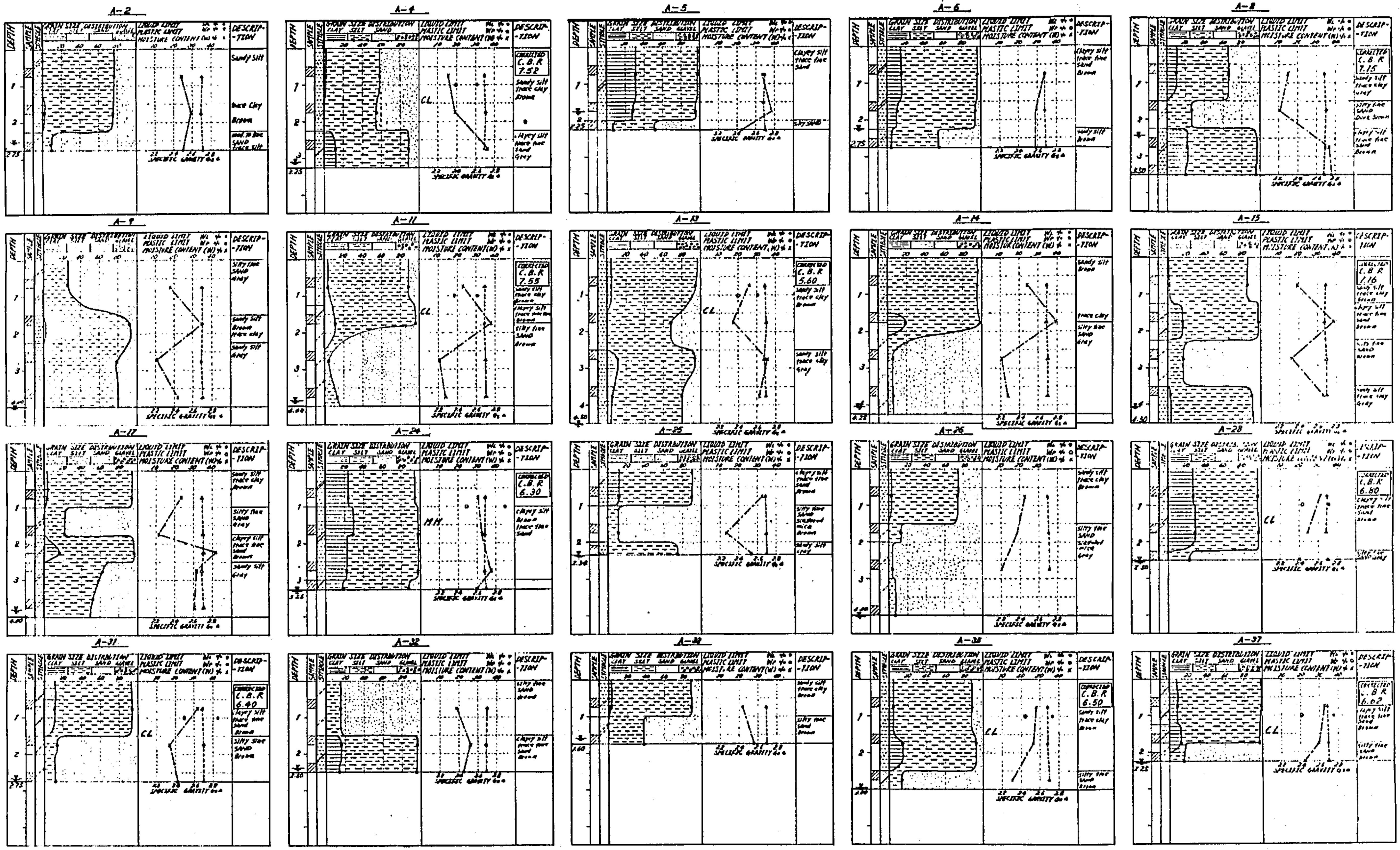
SOILTECH INTERNATIONAL LTD. DATE:- 8-3-75 PLAN No. ST-837/D

SUMMARIZED CHART OF SOIL CHARACTER

PROJECT JAMUNA RIVER BRIDGE CONST. PROJECT 2ND. PHASE HOLE NO. S - 5' 74 EL. 11.61 m GWL. GL. – 2.6 m COORDINATE: N24° 21' 8" 9 E89° 44' 6" 9



SUMMARIZED CHART OF AUGERED BORES



Location of bores is shown Fig. 3.1.1.

JAPAN INT'AL COOPERATION AGENCY
JAMUNA RIVER BRIDGE CONST. PROJ.
SUBSOIL INV., APPROACH ROAD
SUMMERIZED CHART of SOIL CHARACTER, by AUGER BORING
2-3

PART II

STONE MATERIAL

Field exploration of concrete aggregate and riprap materials for Construction of Jamuna Bridge Project

CHAPTER I

GENERAL FEATURE OF EXPLORATION

The Jamuna river is one of the biggest rivers in Asia, having characteristically braided river channels in its lower reaches over the extensive alluvium of the Bengal plain. As a part of the feasibility study of the Jamuna River Bridge Project, a study on the sources of rock materials was made during two dry seasons in 1974 and 1975. Investigations to find out possible sources of stone materials were made all over the territory of Bangladesh, as well as the neighbouring Indian States of Assam, West Bengal and Bihar.

Most part of the territory of Bangladesh is covered with thick Quaternary sediments, except Chittagaong hill tracts, where long parallel ridges of Tertiary formation are extending north-south direction. These Tertiary formation can not provide suitable hard rock. Hard stone materials can be expected only in Pretertiary formations and igneous rocks. That is a reason why the investigations were extended to the areas, where Pretertiary rock formations and trap rocks are well developed.

1. Possible Sources of Stone Materials.

Preliminary survey report prepared in 1972 recommends the following areas as the possible sources of stone materials.

Sylhet District, northeastern Bangladesh
Coal and limestone mining in northeastern Bogra District
Artificial aggregates in Bogra District
Bagmara, southern frontier of Assam State, India
Manikarchar, west of Tura, Assam State, India
Dhubri, right bank of the Brahmaputra river, Assam State, India

Survey team collected many information on stone materials after its arrival at Dacca, January, 1974. As the result, investigation were planned at the following sites.

1) Bangladesh Territory.

River gravel in northern Sylhet District
Pachagarh and Titalia in northern Dinajpur District
Upper Tista River
Limestone project area in Jaipurhat
Ranipukur Hard rock project in Dinajpur District

2) Indian Territory.

Rock quarry sites in Assam State
Pitching stone at the Sirajganj Bank Protection Work which is currently supplied from Assam State.

However, Assam tour was not allowed by Indian government in spite of repeated applications. Questionnaire for the present production of stone materials in Assam state was sent to the Government of India. And some information on the production were received early 1975. In the second year, rock quarries in Rajmahal hill of Bihar State, India were investigated. It is confirmed that Rajmahal hill area is a big producing centre of stone materials and will be the most promising sources for the Jamuna Bridge Project. A hard rock project is now planned by the Bangladesh Government in Ranipukur, Dinajpur District. Though its development plan is not materialized yet, it productivity is also investigated.

2. Study Items.

Investigations are concentrated in rock quality, rock quantity, exploitation and transportation methods and unit cost. Investigation for quantity such as stone mechanical tests and topographical survey to estimate the capacities of sources are not done in this stage of investigation. General appraisal is made for the potential sources of rock materials for the Project.

3. Requirement of Stone Materials.

For concrete aggregates of bridge sub-structures and for riprap materials of the bank protection work, huge amount of stone materials is required. The total requirement is estimated at around 3,000,000 m^3. These stone materials must be supplied during the construction period of three or four years. The daily requirement, will be several thousands tons. Transportation method for these big amount of stone materials, is also important problem to study. Production and transportation costs are also studied carefully.

CHAPTER II

LOCATION OF STONE MATERIAL

Territory of Bangladesh is mostly occupied by inland alluvial plain, except Chittagong hill area where Tertiary mountains extending northsouth direction. Rocks in Teritary formation are generally less hard and liable to be weathered. High quality stone materials required in the Project are hardly expected in Tertiary mountain area. Sources of stone materials are generally expected in the deposits of piedmont alluvial fans and in Pretertiary formations and igneous rock, especially trap rocks. The former is found around the boundary lines between Pretertiary hills and alluvial plain, and the latter is in Pretertiary rocks and trap rocks of volcanic lava.

The fan gravel deposits usually develops where alluvial plain contacts with mountain area. Examples are found in the northern frontier of Bangladesh territory - north of Sylhet District, north of Dinajpur district, Upper Tista river and so called Himalayan Piedment district, south of Darjeeling, West Bengal State of India.

The hard rock in Pretertiary formation is base rock of the Bengal plain basin. They are covered with alluvium formations several hundreds meters deep with in the Bangladesh territory. Geophysical study reveals that the depth of base rocks varies in the range of 600 to 3,000 m in Dinajpur, Rangpur and Bogra districts. These are granodiorite in Ranipukur and limestone in Jaipurhat. Quarternary covering are reported as 150 m thick in Ranipukur and 500 m thick in Jaipurhat. Hard rocks in Pre-Cambrian system expose in Shillong Plateau of Assam State and basaltic trap rocks occurs in Rajmahal hill, Bihar-West Bengal boundary both in India. Hard rocks at southern border of Shillong plateau are washed away southward to the frontier, forming alluvial fan of sand and gravel deposits at the north of Sylhet, as mentioned above. These hard rock formations will be the prolonged and steady sources of stone materials.

Thus, the sources of stone materials, both deposits and quarries are found in or close to mountains and plateau in northern frontier of Bangladesh and in neighboring Indian territory. These sources are all several hundreds kilometers far from the Project and transportation is an important problem.

CHAPTER III

SAND AND GRAVEL DEPOSITS

1. Bholaganj Gravel Deposits, North of Sylhet.

1.1. Occurrence.

A large scale gravel deposits develops in the river bed of the Dahalganj river which rises in Shillong plateau of Assam and flows down across the frontier into Bangladesh. It locates at 25°-8'N, 91°-42'E, 11 miles north of Chhatak town, Sylhet District. The gravel deposits is gainable by means of barge from Chhatak town on the Piyan river, a tributary of the Surma river. Old army road was constructed once directly from Sylhet town, but destroyed.

The gravel pit was opened in the early year of 1,900, and concrete aggregates supplied for Chittagong harbour construction and stone materials for the Kaptai Dam construction. It is reported to have supplied 20 million cu.ft (566,000 m^3) of stone materials for the dam construction.

The Dahalganj river rises at Mt. Mun (6102') in Shillong plateau, carrying down great amount of rock debris of Pre-Cambrian hard rock. Just after it crosses the east-west fault cliff along the frontier line, such debris deposits in the alluvial fan. Present gravel pit has about 2,500 m long north-south direction and 600 - 1,400 m wide in east-west direction with a depth of more than 14 m. It may be the biggest gravel pit, ever developed in Bangladesh territory. Grain size is ranging from 60 cm diameter to sand grain. They comprise granite, gneiss, chart, greywacke sandstone and some basic rock and well-rounded hard grain. It is excellent in use as concrete aggregate and ballast.

According to the Government's study in 1956, stone ballast of 127,000 m^3 is necessary for maintenance and repair of the existing railway 2,600 km long in total and another 85,000 m^3 is required for improvement of road and highway annually. Based on these demands, railway authority started to develop the Bholaganj gravel pit project, having a production capacity of 170,000 m^3/yr. The project was completed in Mar., 1970 at the cost of Rs. 20 million. 8.5 million-cubic meters of deposits were then estimated. The deposits would receive another debris supply of 24,000 m^3 annually during the rainy season.

The project included the following facilities.

1) Bholaganj gravel pit with crushing and screening facilities.

2) Ropeway between Bholaganj and Chhatak 11.25 miles long.

3) Two units of power generator at two ropeway driving stations.

4) Loading facilities at the ropeway terminal.

Test operation of the project taken place in 1970 was disturbed with many troubles and deficits. Actual operation was only 220 hours, producing only 5,100 m^3 of stone materials in the year 1970. During

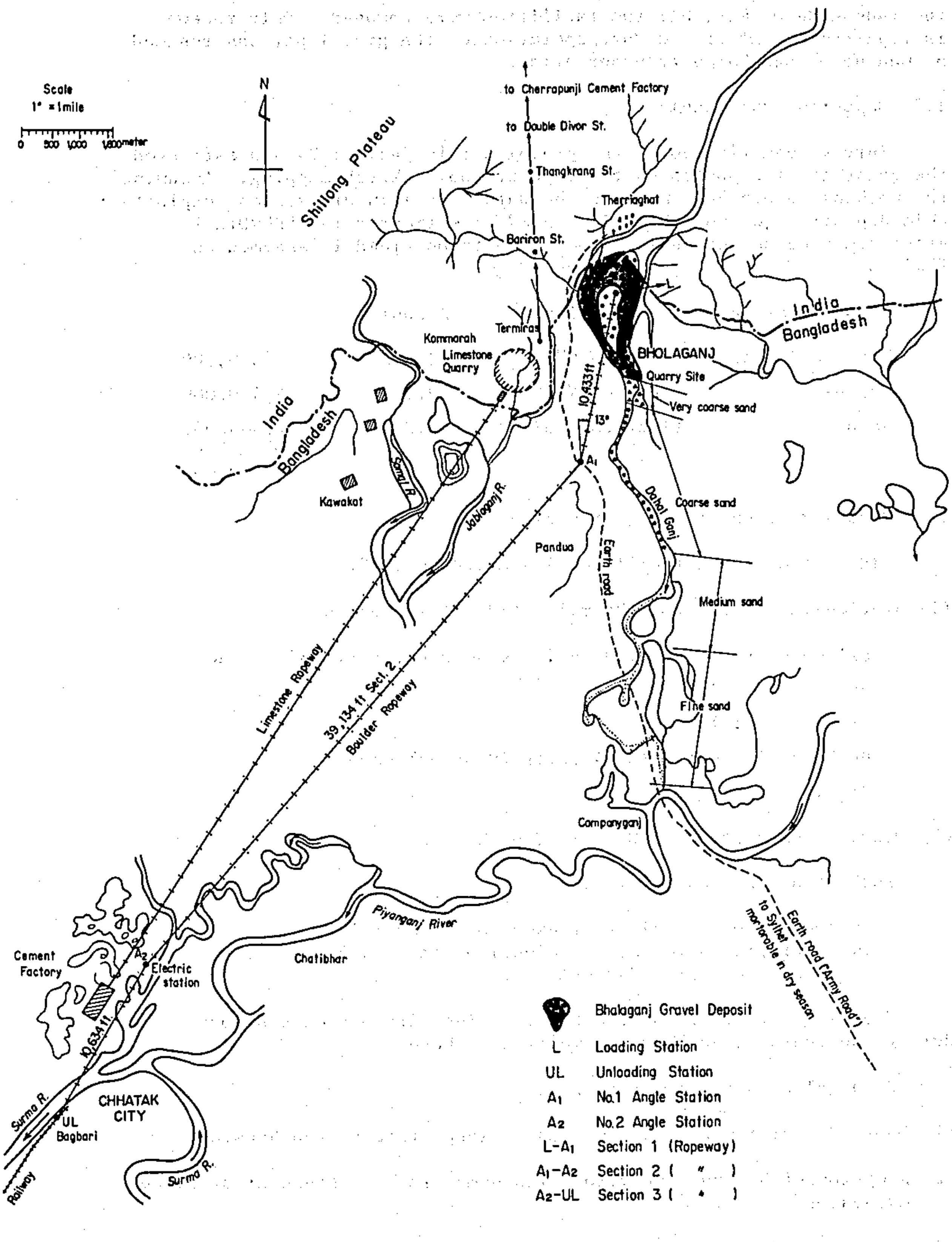


Fig. I Locality Map of Bholaganj Quarry Site, Sylhet District

the Independence War, all the facilities were damaged. Only ropeway is repairable. After the War, operation of the gravel pit was resumed by man power and barge transportation.

1.2. Deposits exploitable.

Survey team visited at the gravel pit in Jan., 1974 and estimated the quantity of deposits on the base of rough sketch mapping. Assuming the workable depth be 6 m below the water level in dry season, exploitable deposits are about 9.1 million m^3 as estimated in APPENDIX I. After crushing and screening, the products obtained is assumed as follows.

Classification	Gradation	Amount	
Pitching stone	above 9"	3.6 %	330,000
Gravel	4" - 3/16"	49.2 %	4,470,000
Sand	finer than 3/16"	47.2 %	4,300,000
			9,100,000

1.3. Reconstruction of the quarry plant.

Old equipment and facilities installed in 1970.

(1) Single-line Ropeway, 11.25 miles (18 km) in length

driven by two sets of diesel engine generator, 237 Hp each

Rope; ϕ 1" - 1/4"

Steel posts; 122 nos.

Buckets; 388 nos., 13.44 cu.ft (0.38 m^3) each

Hourly capacity; 75 ton/hr

(2) Dragline excavators; 100 Hp × 1, 65 Hp × 1

(3) Crushing and Screening Plant

including; one impeller breaker, one classifier, two vibrating screens, two diesel engines (475 Hp × 2) and two generators (242 kVA × 2)

Except ropeway, all of these facilities were broken and lost during the Independence War, as mentioned above.

Proposal of Reconstruction Plan

(1) Damaged facility can not be reused except ropeway and housing.

(2) Adoption of backhoe excavator with dump truck, instead of dragline excavator.

(3) Crushing and screening plants will be installed on flat ground, not on the tower arrangement

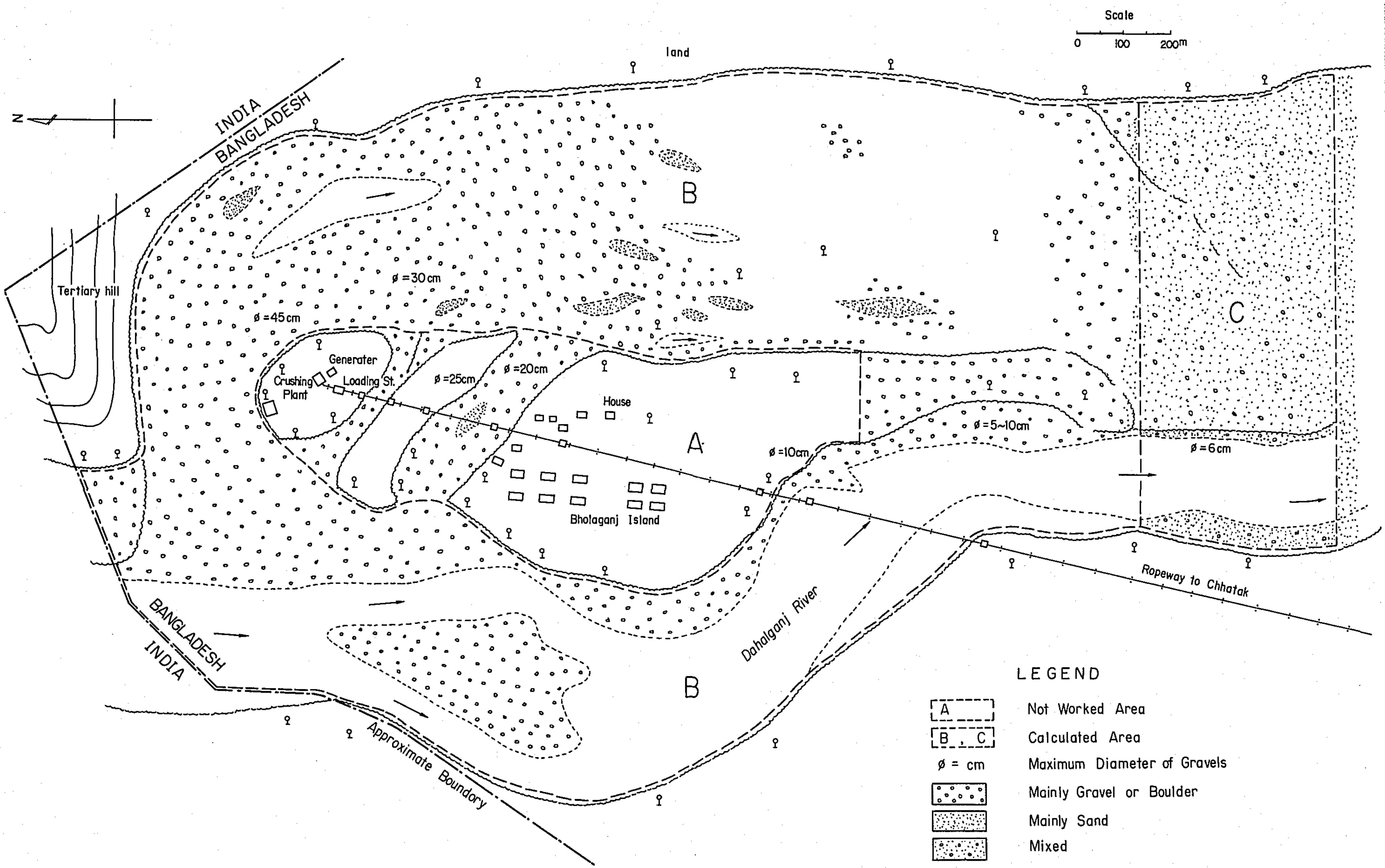


Fig. 2 Geological Map of Bholaganj Quarry Site, Sylhet District, Bangladesh
by Dr. Z.YOSHIDA 17, Jan. 1974.

(4) Gravel will be carried by ropeway. Sand and one-man-stone will be carried by boat.

(5) Halt of the products will be supplied to the railway and remaining half for the Project.

(6) Operation programme

Ropeway; 75 t/Hr × 24 × 75 % = 1,350 t/day ...	405,000 t/yr.
Other transportation	405,000 t/yr.
	810,000 t/yr.

Quarry and processing

Workable days; 25 days × 9 month = 225 days

Pit requirement; 810,000 t/225 × 90 % = 4,000 t/day

Crushing and Screening plants are operated 300 days a year. 810,000 t/300 × 90 % = 3,000 t/day

Total initial investment will be $6 million (APPENDIX II).

1.4. Unit cost.

	per ton
Exploitation	$0.4
Crush and screen	1.0
Hauling	1.2
Others	0.5
Depreciation	1.9
	$5.0 = Tk.50

where, Depreciation period of exploitation and ropeway facilities is five years and of crushing and screening plants is eight years. Interest rate is taken at 8 % per year.

Resident engineer of railway department in Chhatak suggested the following price of rock materials for the Project.

Price at Chhatak (Tk. 50/ton)	Tk.250/100 cu.ft
Transportation by barge	Tk.500/100 "
Loading and unloading	Tk. 80/100 "
Total :	Tk.830/100 "

2. Other Gravel Deposits along the Frontier with Assam State.

In the range of scores of miles east and west of Bholaganj, there are several rivers coming down from Shillong Plateau to the frontier line. There develop more or less similar alluvial fans.

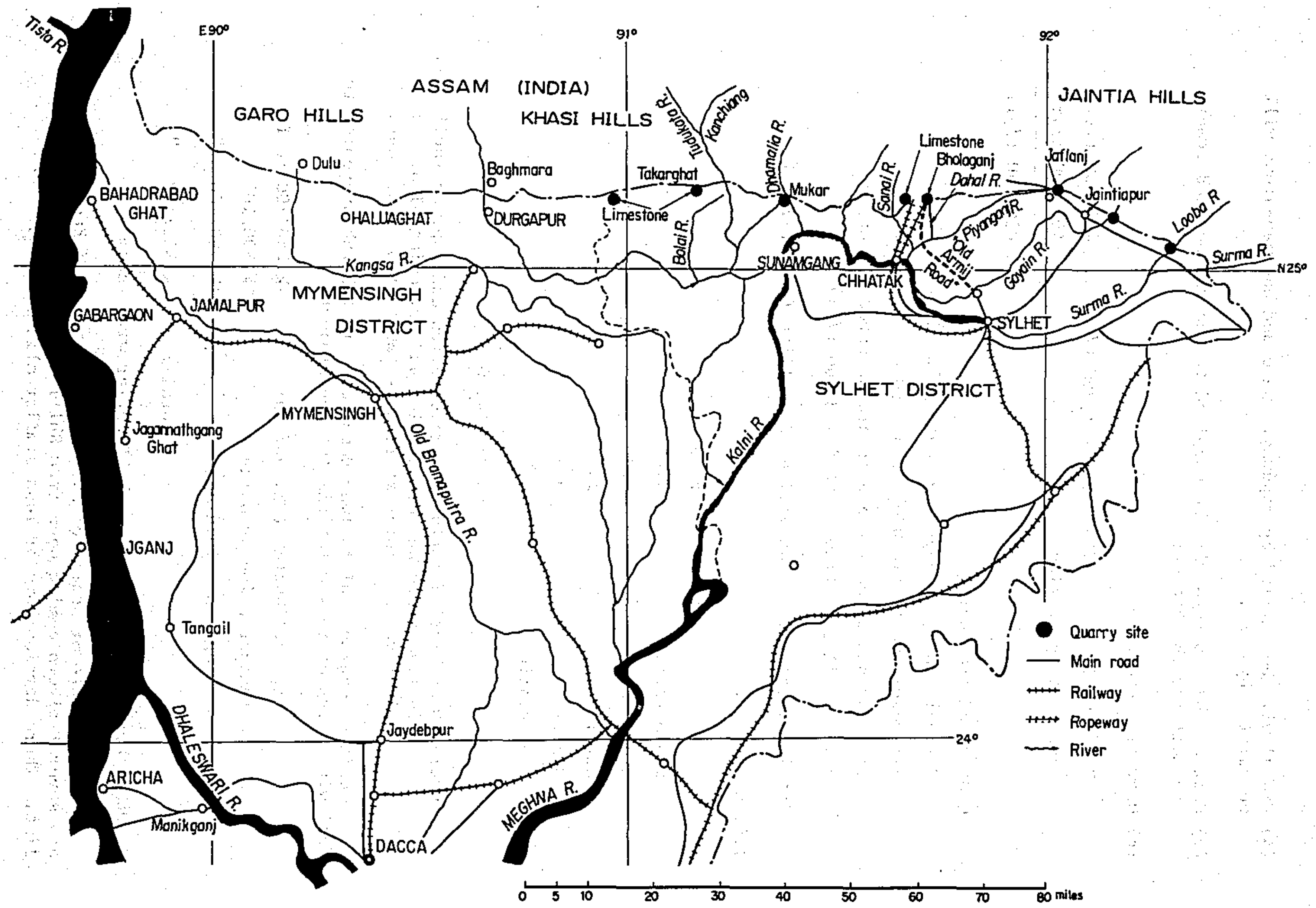


Fig.3 Distribution of Gravel Deposites around Sylhet District

2.1. Loobe (25°-5'N, 92°20'E).

10 million cu.ft (285,000 m^3) of sand and gravel is estimated on the Looba river, 40 miles east of Bholaganj. The gravel can be used for concrete aggregate for the local demands, but not enough for large scale requirement.

2.2. Upper Goyan river.

Riverbed gravels are taken by manual dredging. No further information about its productivity is available.

2.3. Pyanganj gravel.

Fan deposits around the Pyanganj is reported. But no further information is available.

2.4. Sand and gravel in the north of Sunamganj.

300 million cubic ft. (8.5 mliion m^3) of sand and gravel deposit is reported in Indian territory on the Mukai river 7 miles north of Sunamganj. They are reported as fan deposits along the piedmont line of the Shillong Plateau. No further information is available on their accessibility and productivity. Systematic supply of stone materials to the Project cannot be expected from these deposits.

3. Gravel Deposits at the Northwest Corner of Bangladesh Territory.

Sand and gravel are produced at Ramgarh on the upper Karatoya river and at Titalia on the upper Mahananda river. Thin gravel layers interbedded in sandy deposits in the riverbed and on the both banks are exploitable. They are secondary deposits which was transported from the piedmont deposits in the Indian territory. Lenticular gravel layers are formed in every flood season with a thickness of 10 cm to 100 cm. Maximum grain size is 15 cm in diameter. Gravel in each layer are ranging from several cubic meters to a hundred cubic meters. They comprise granite, diorite, gneiss, chert and greywacke sandstone. They are all hard and well-rounded, and most suitable for concrete aggregates and are used for local requirement of concrete aggregates and road ballast. Some of these gravel pits were visited early 1974.

3.1. Ramgarh gravel pit.

A gravel pit is opened in the riverbed of the Karatoya river, 3-1/2 miles west of Pachagarh. National highway is running along the river. The gravel is hauled by truck or by barge. The lenticular gravel layer is also flood deposits, having 20 to 30 cm in thickness. It contains 35 % of sand. Grain size ranges 1" to 3". Villagers are working in manual dradging for local demands. The price is Tk.200/100 cu.ft at the pit.

3.2. Bhojonpur gravel pit.

There are another gravel pits on the right bank of the Karatoya river, 12 miles east of Titalia, 15 miles north of Pachagarh. It locates upstream of Ramgarh and grain size is coarser up to 6".

Deposits is quite the same as that of Ramgarh. Thickness of the lenticular gravel layer is 30 to 100 cm. Production in 1973 was 500,000 cu.ft and sold at Tk.200/100 cu.ft.

3.3. Titalia gravel pit.

Gravel layers intercalated in the flood deposits on the right bank of the Mahananda river is exploitable for gravel pit. The layer is 30-100 cm thick and grain size is under 12 cm. The Mahananda river forms a part of the frontier line between Bangladesh and India. Production is now suspended because hauling cost is expensive.

3.4. Other gravel pit.

According to Hoque's report (1962), many small gravel pits of similar type are developed along the Karatoya, Chami, Telma, Daukhal and Mahananda rivers. Roy* reported their quantities as follows (1964).

Karatoya	10 million cu.ft
Mahananda	5 "
Chami	5 "
Telma	4 "
Barkakhal	160,000 cu.ft
Daukkhal	70.000 "

They are all gravel lavers irregularly intercalated in recent flood deposits. Continuous production can not be expected because of their irregular distribution. They are too small to feed big demands in the Project.

3.5. Patgram, Rangpur District.

In the northwest corner of Rangpur District, there are gravel deposits developing around Rangpur. The products can be hauled by narrow gauge railway to Rangpur. Roy*studies the areas and reported in 1964. According to his report, they are sand and gravel alternation in the piedmont alluvium of the Dharla River basin. Lenticular gravel layers of 15-200 cm thickness are intercalated. Roy summarize these deposits as follows:

	thickness	average thickness
riverbed sand	10 - 120 cm	75 cm
silty clay	20 - 300 cm	180 cm
sand	25 - 150 cm	90 cm
gravel	12 - 120 cm	60 cm

* Amil Baran Roy (1964 "Gravel Deposits of Patgram Thame, Rangpur District", East Pakistan Information No. 18)

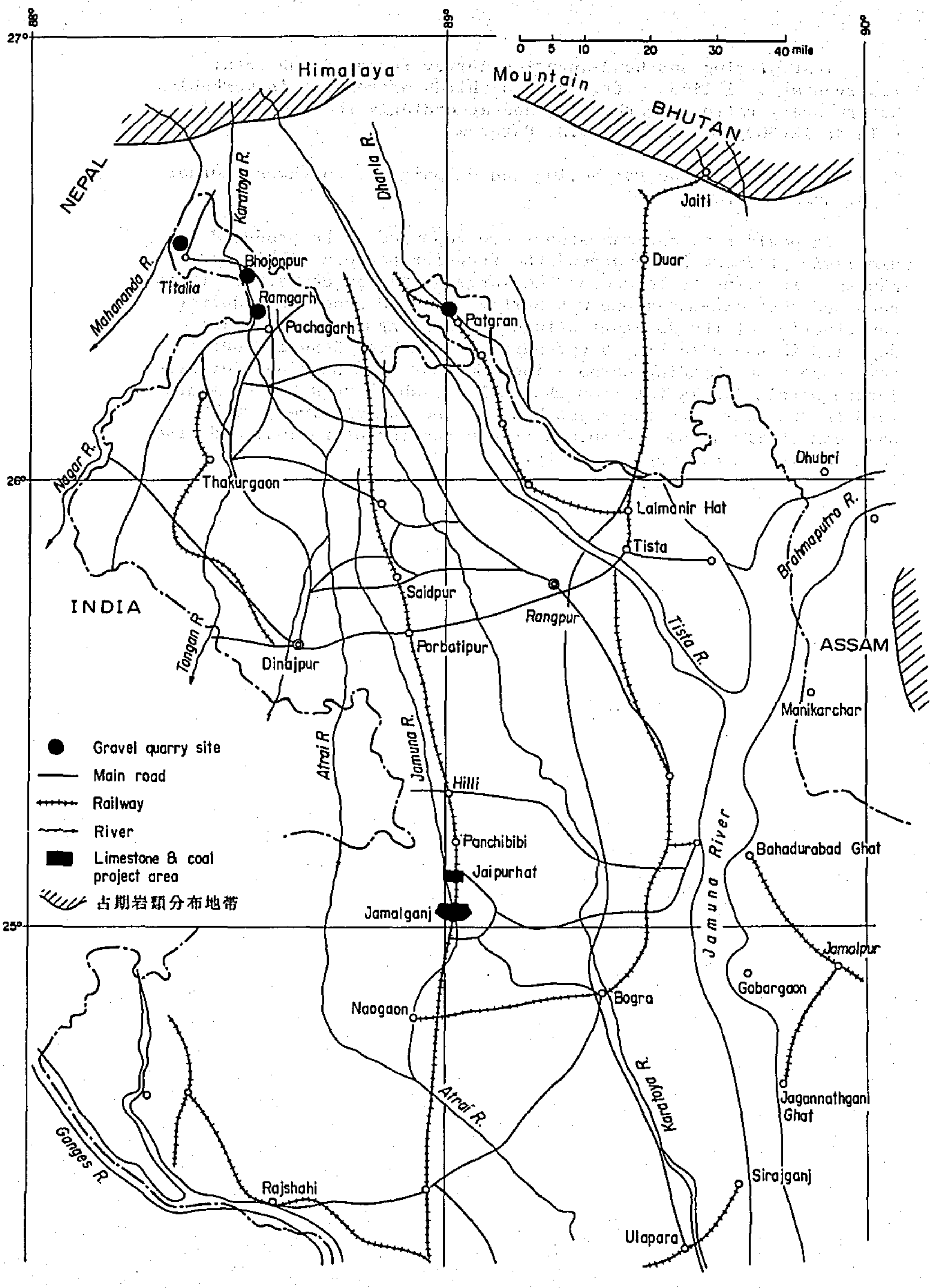


Fig.4 Gravel Deposits in Dinajpur and Rangpur Districts

Test pitting and hand-augering survey revealed the total reserves at 5 million cu.ft. and two-thirds of reserve is workable. But recovery ratio is rather low and accordingly the products is sold at Tk.300/100 cu.ft. F.O.B. Patgram.

4. Boulder pits around Darjeeling and Jalpaiguri, northwest corner of Assam State.

Big boulder or one-man-stones are reported to be produced in Himalayan piedmont plain around the frontier between Sikkim and Bhutan. *It seems to be one of the large-scale fan deposits.* It is recorded that one-man-stone was partly supplied from Jinty during construction of the Hardinge Bridge on the Ganges river. Major deposits is shown in Fig. 5 (prepared by the West Bengal Mineral Development and Trading Corporation, Calcutta). These boulder pits locate within 1-5 km far from the railway, which runs 200 km southward to Phulchari, on the right bank of the Jamuna river, 80 km upstream of Sirajganj. Combined transportation of railway and river is a problem on cost and capacity.

CHAPTER IV

BASE ROCK OF PRE-TERTIARY FORMATION AND TRAP ROCKS

Pre-tertiary base rock in and around the Bangladesh territory have a characteristic occurrence. They expose and form mountains in the Shillong plateau in Assam State. Their west extension are cut at the west end of the Shillong and subside under thick covering of alluvium in the western side of the Jamuna river. They never come to the surface until they reapear in the Darjeeling area, the north-west corner of Assam State. These mountain land of hard base rock can be expected as sources of stone materials, if transportation is favourable.

On the other hand, basaltic trap rock is extensively exposed in the Rajmahal hill in Bihar and West Bengal State. Many quarries were developed for big demands of stone materials in northeastern India since early 1900.

In response to the questionnaires for the production of stone materials in Assam, some information were sent from Indian Government by the end of 1974. Production capability in the quarries along the Brahmaputra river is assumed from these information.

Government of Bangladesh has a plan to develope underground base rock which lies 150 m - 600 m deep under the alluvial plain in northern Rajshahi Division. They are named "Jaipurhat limestone project" and "Ranipukur hard rock project". The former is to combine with cement mill project and already start preparatory work. The latter is for the development of underground rock-quarry, but not started yet. Information of these underground rock development is obtained from the "Mineral Explorations and Development Corporation", Dacca.

Rajmahal hill in West Bengal State was visited in 1974. Mode of occurrence, exploitation, hauling and shipment of quarried materials are studied. Many information on present production capacity and future expansion programme are obtained from the West Bengal Mineral Development and Trading Corporation, who is one of major production enterprise.

1. Pre-Cambrian Rock quarries, Assam State.

Pre-Cambrian rocks extensively expose in Shillong plateau of Assam State, and more than 250 rock quarries are operating in the monadonocks on the plateau. They comprise diorite, gneiss, gabbro, amphibolite and basalt. Goalpara and Dhubri Province are major shipping centers of stone materials. Major quarries, prices at the nearest riverports and production capacity are reported by the Indian Government as follows.

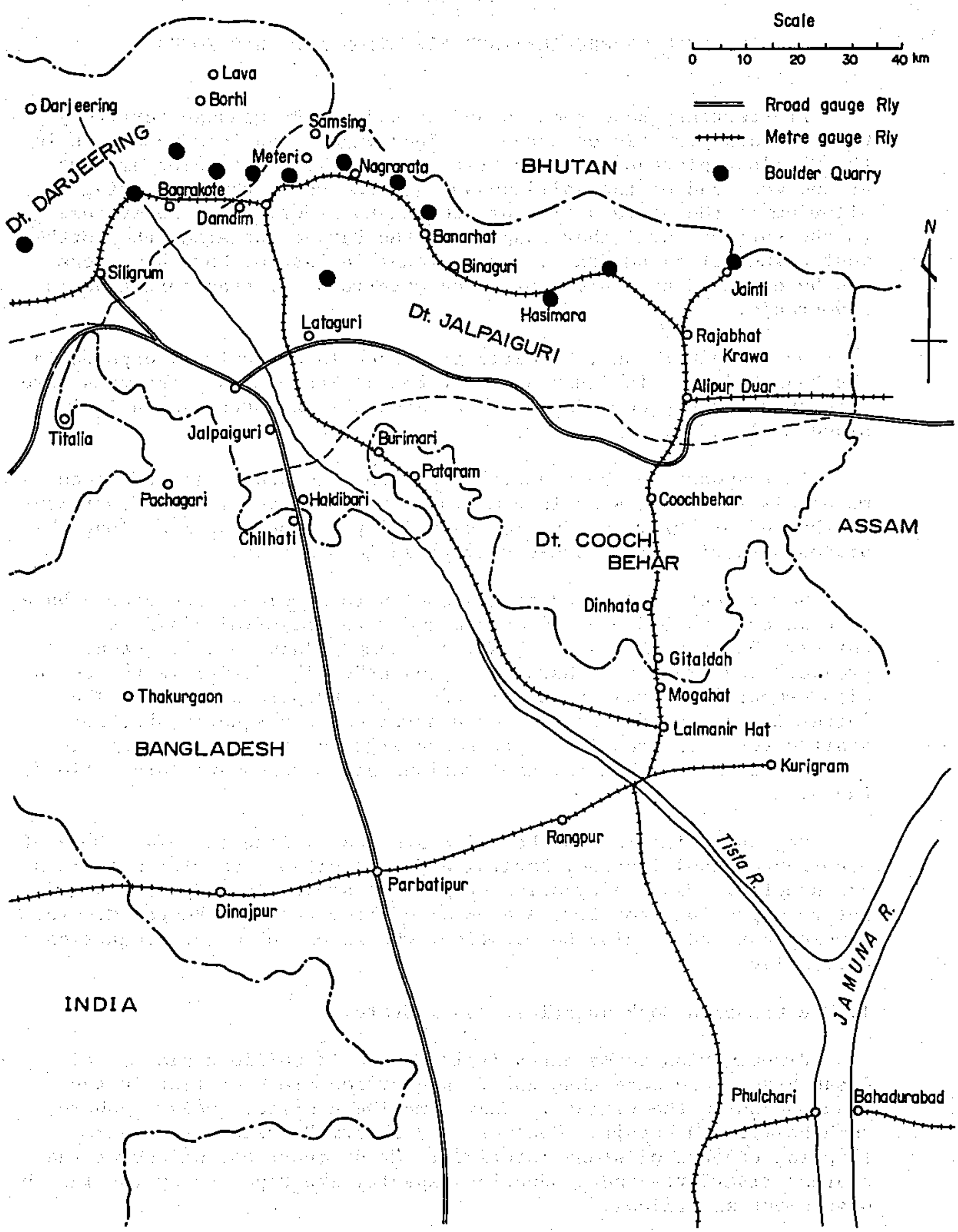


Fig. 5 Locality Map of the River Boulder Quarries at the Himalaya Mountain Foot Area, India

Major quarry areas	Location	Hauling distance to the nearest riverport	Annual Production	Price FOB riverport
Rakhyashini hill	South of Brahmaputra	13 km to Pancharatna	40,000 m^3	Rs 35-45/m^3 (Tk 54.6-70/m^3 Tk 155-198/100 cu.ft.)
Ajagarh hill	"	26 km "	30,000 m^3	
Bhairab hill	North of Brahmaputra	10 km to Jagioghopa	55,000 m^3	
Sonamukk	"	55 - 58 km to Dhubri or Jagioghopa	100,000	Rs 55/m^3 Tk 85.8/m^3 Tk 243/100 cu.ft.
Dudhnath	"			
Tokrabandha	"			
			255,000 m^3 = 405,000 t/yr = 1,215 t/day	

Among these, the last three, Sonamukk, Dudhnath and Tokrabandha, have one million cubic meters of exploitable rock, respectively. Quarries managed and operated by P.W.D. are exploited with open cut method. After crushing and screening, aggregates are hauled to the riverports. Production decrease during the rainy season. If heavy equipments are supplemented, production can easily be doubled.

Jagioghopa and Dhubri are located 280 km and 200 km apart from Sirajganj, respectively.

According to Green and White Ltd., Bangladesh, current cargo charge for stone materials between Dhulian, West Bengal and Sirajganj is Tk. 0.98 per 100 cu.ft. km. Provided that the same rate is applied for the Project:

Jagioghopa - Sirajganj : Tk.0.98 × 280 = Tk.274/100 cu.ft.

Dhubri - Sirajganj : Tk.0.98 × 200 = Tk.196/100 cu.ft.

Therefore, price of aggregates at Sirajganj is estimated as follows.

	from Jagioghopa	from Dhubri
FOB riverport	Rs106 = Tk.165/100 cu.ft.	Rs 156 = Tk.243/100 cu.ft.
Barge freight	Tk.274	Tk.196
Unloading	Tk. 50	Tk. 50
Sub-total	Tk.489	Tk.489
Sale tax	Tk.205	Tk.205
Total	Tk.694/100 cu.ft.	Tk.694/100 cu.ft.

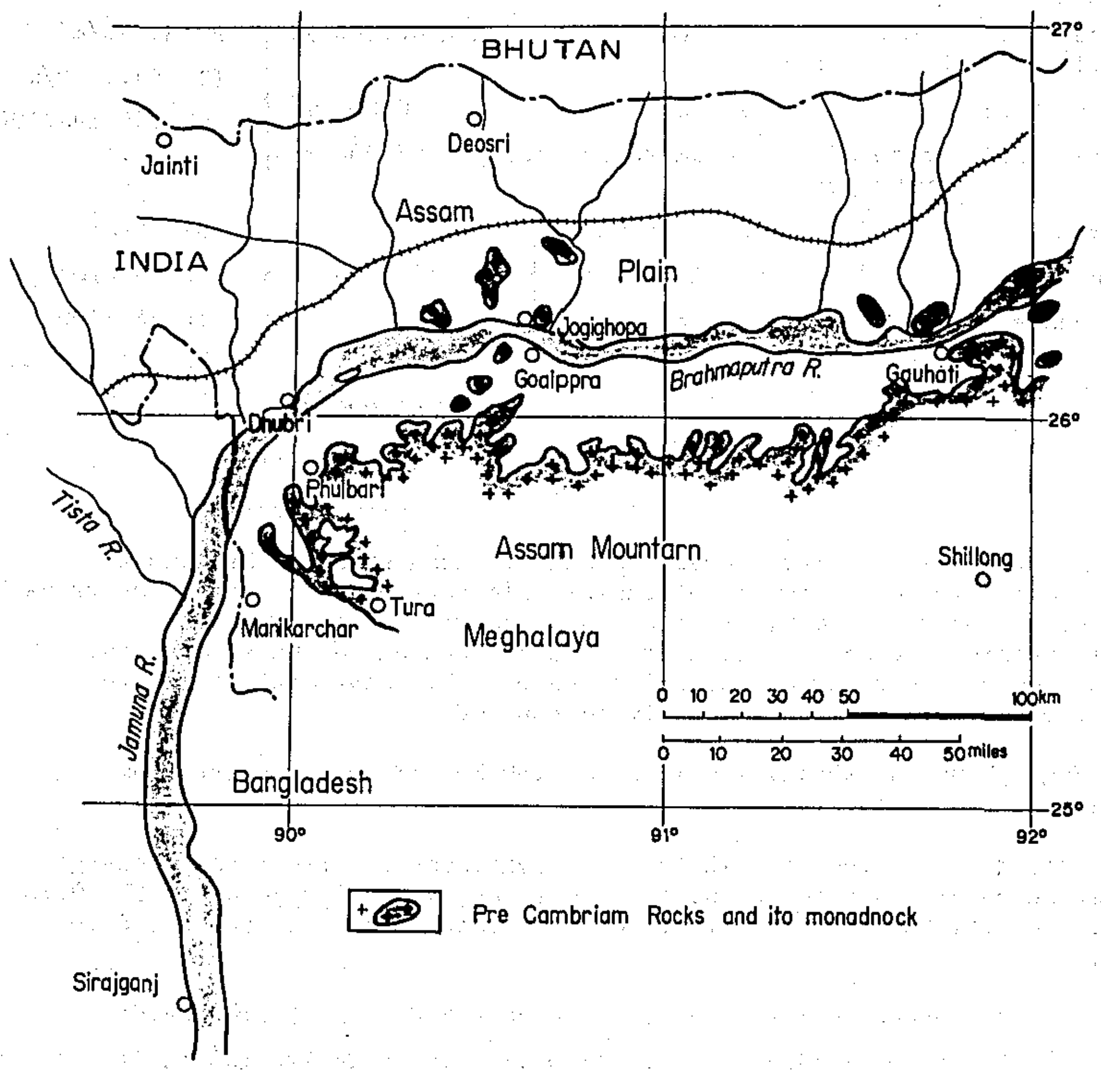


Fig. 6 Distribution of Pre - Cambrian Monadnock near Dhubri and Goalpara Districts, Assam State, India (Geol. Surv. India, 1962)

The ferry site bank in Sirajganj was damaged by the last year flood and the bank protection work is now under way with stone pitching. Materials of stone pitching is supplied from Manikarchar, left bank of the Brahmaputra river, 50 km downstream of Dhubri. Present CIF price at Sirajganj is reported as follows,

Price at Manikarchar	Tk.540/100 cu.ft.
Profit of transporter	Tk. 30
Royality to Indian Government	Tk.100
Tax	Tk. 30
	Tk.700/100 cu.ft.

2. Limestone Hills along South Boundary.

Limestone in paleogene tertiary are distributed in several low hills along the southern boundary of Assam State - Takerghat, Lalghat, Lamakata and Bhangarghat. They are usually covered with overburden 8-20 m in thickness and are unfavourable to be developed by the open cut method. Some of these hill materials are useful for production of cement in the Chhatak cement mill or local lime-kiln. They are too small in production to supply construction materials for the Project.

3. Jaipurhat Limestone Project.

An extensive geophysical exploration had been carried out around Bogra District by the Geological Survey of Bangladesh. The existance of Pretertiary base rock under alluvial deposits and its depth were confirmed by several test borings.

Bangladesh Mineral Exploration and Development Corporation is planning to exploit useful minerals and rock by underground mining. Among these limestone, hard rock projects will be useful for the Project.

In course of test borings in Jamalganj coal project, a limestone seam was found in upper horizon of coal seams. The limestone is the same series as those found at Takerghat in Sylhet District. After tracing the limestone, it was confirmed that big limestone seam is extending in the depth of 600 m at Jaipurhat, 25 miles west of Bogra and 5 miles north of Jamalganj. Feasibility of limestone development was studied by German consultant and reported in 1966. According to the report, sub-horizontal limestone seam was confirmed under the sand and silt alluvium of 80 m in thickness and Tertiary formation of 500 m in thickness. The limestone seam is nearly horizontal, having a thickness of 18 m, of which exploitable limestone as cement material is 10-12 m thick. Exploitable reserve is said to be 100 × 10^6 tons. Production capacity is proposed at 10 millions tons per year.

Low grade limestone and limestone muck produced as by-product during exploitation is expected to be used as stone materials in the Project. But such deep mining project will require long preparation period before full operation. It will take about ten years until its full operation. Limestone or sandy shale in neogene Tertiary seems not to be hard enough. By-product in mining is unstable in quantity. Therefore, it is not suitable for supplying stone materials for the Project.

4. Ranipukur Hard Stone Project, refer Fig. 8.

Wide range geophysical exploration reveals that there is thinner covering of Quaternary formation in the further north of Jaipurhat. Test boring ZDH-7 was drilled in 1967 and base rock of granite was found beneath the quaternary formation of 372 ft in thickness. The results obtained are:

Depth			
0-372'	(113 m)	:	Quaternary
372'-632'	(193 m)	:	Weathered granite
632'-1,100'	(335 m)	:	Fresh granite

Further geophysical investigation was continued in Madhyapara, 8 km southwest of Ranipukur in 1970 and three boring holes GDH-23, GDH-24 and GDH-25, were drilled in 1974. Fresh granodiorite was again confirmed at the depths of 158 m, 130 m and below 190 m, respectively (Fig. 9).

Feasibility study (1966) on the underground mining reported that daily production of 1,000 tons will be possible at unit price of Tk. 1 per cu.ft. with the initial investment of Tk.300 million.

Bangladesh Mineral Exploration and Development Corporation proposed to revise plan for increasing the daily production to 3,000 tons. The estimated unit price is Tk.2 per cu.ft., with the initial investment of Tk.784.89 million (of which 53% is foreign currency).

The plan proposed is reviewed and revised as shown in APPENDIX III assuming the following conditions:

Thickness of Quaternary: 150 m

Thickness of weathered granodiorite: 20 m

Granodiorite, S.G. = 2.7, unit weight after crushing: 1.8 ton/m^3

Hoisting shaft: depth: 410 m } details shown in APPENDIX III
Auxiliary shaft: depth: 360 m }

Cost:

Investment: Tk.506.5 million

Production cost: Tk.82.8 per or Tk.414 per 100 cu.ft.

5. Trap Rock in Rajmahal Hill, West Bengal (refer Fig. 10).

Rajmahal hill is located at the northeastern part of Indian subcontinent. According to the geological map of India (1/2,000,000) published by Geological Survey of India, the Rajmahal Trap rock -

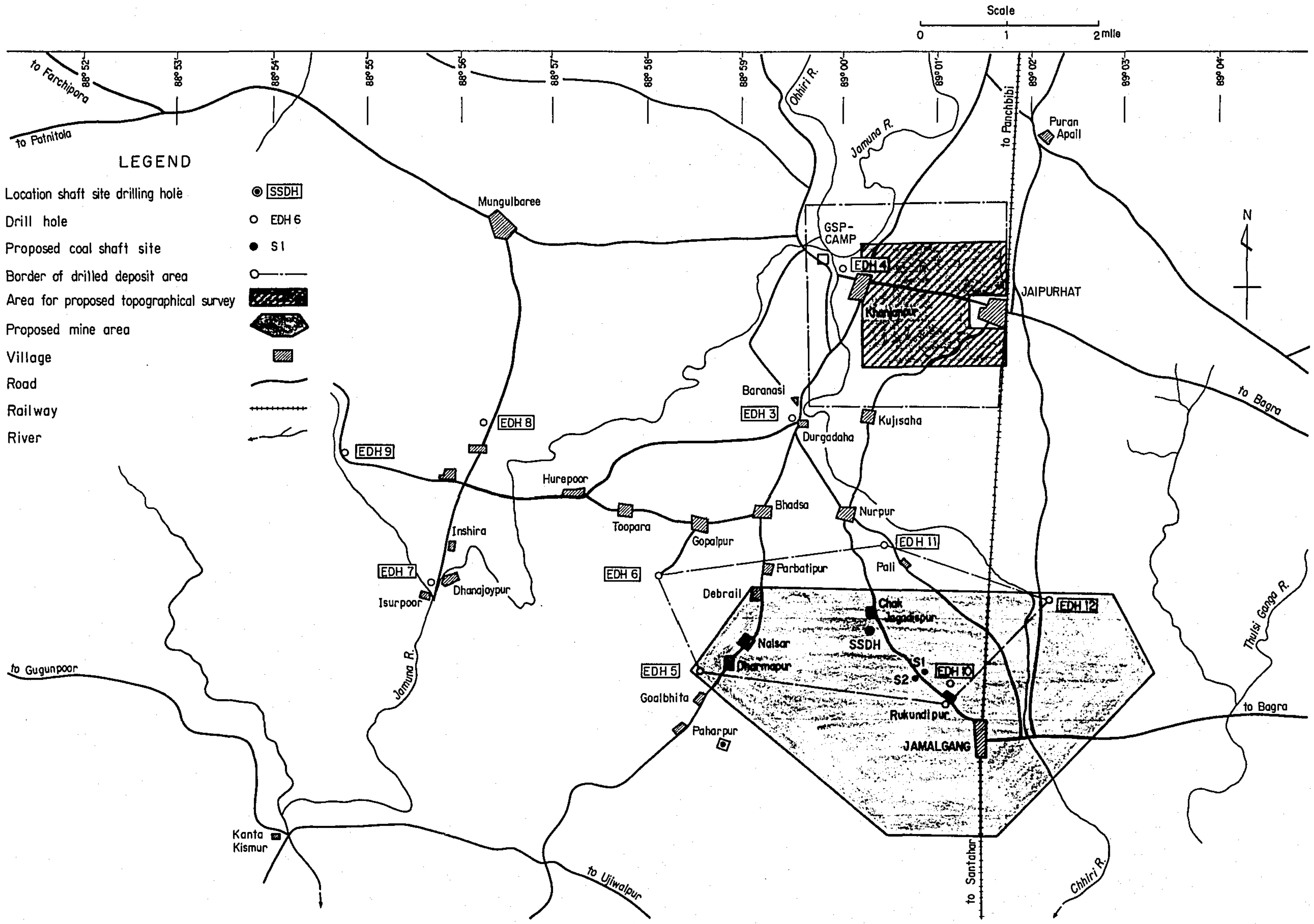


Fig. 7 JAIPURHAT Limestone and JAMALGANJ Coal PROJECT

General Map Showing Mine Area

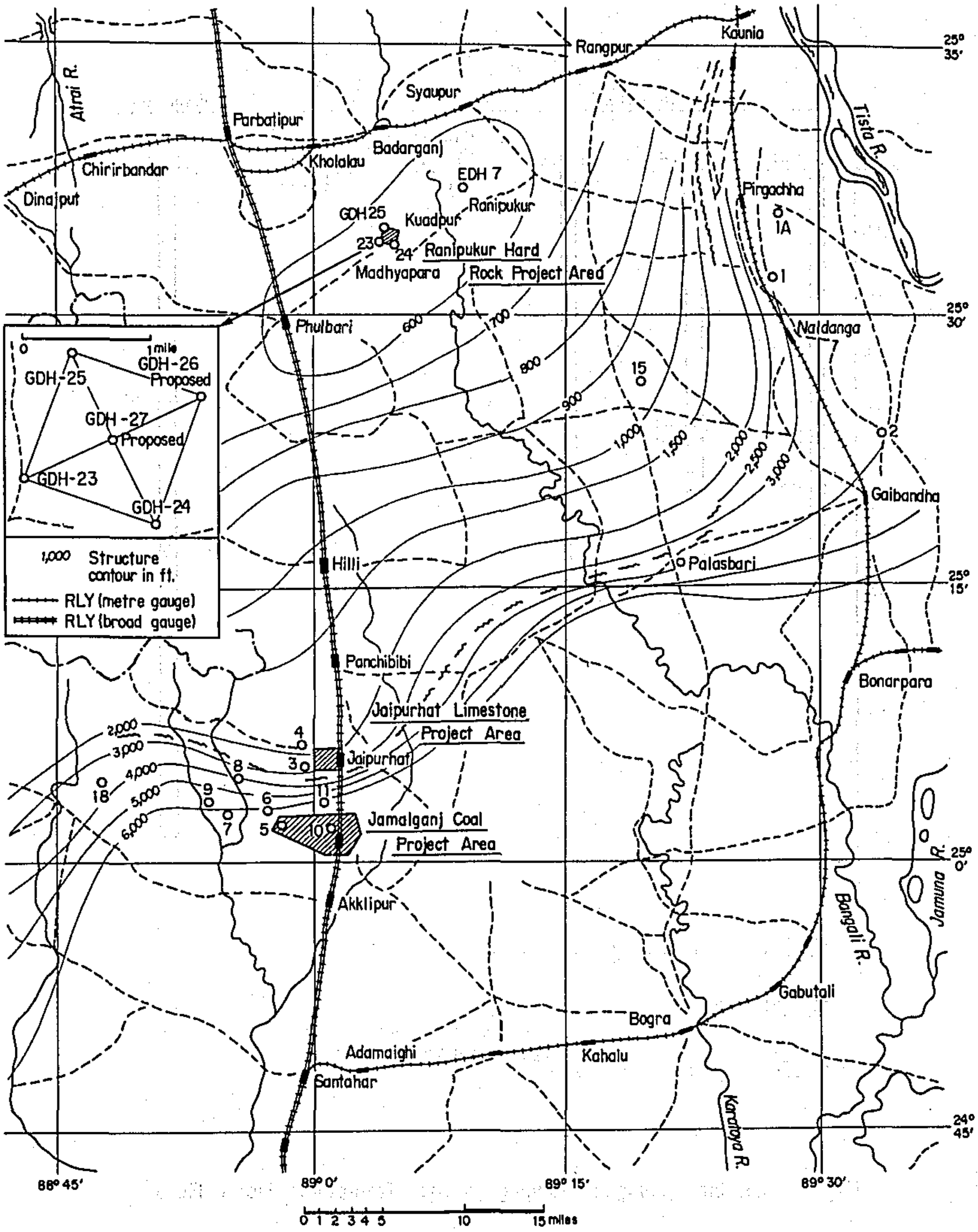


Fig. 8 Structure Contour on the Surface of Archaean Basement Complex in Rangpur, Bogra, Rajshahi Districts, Bangladesh (1969, G.S. of Bangladesh)

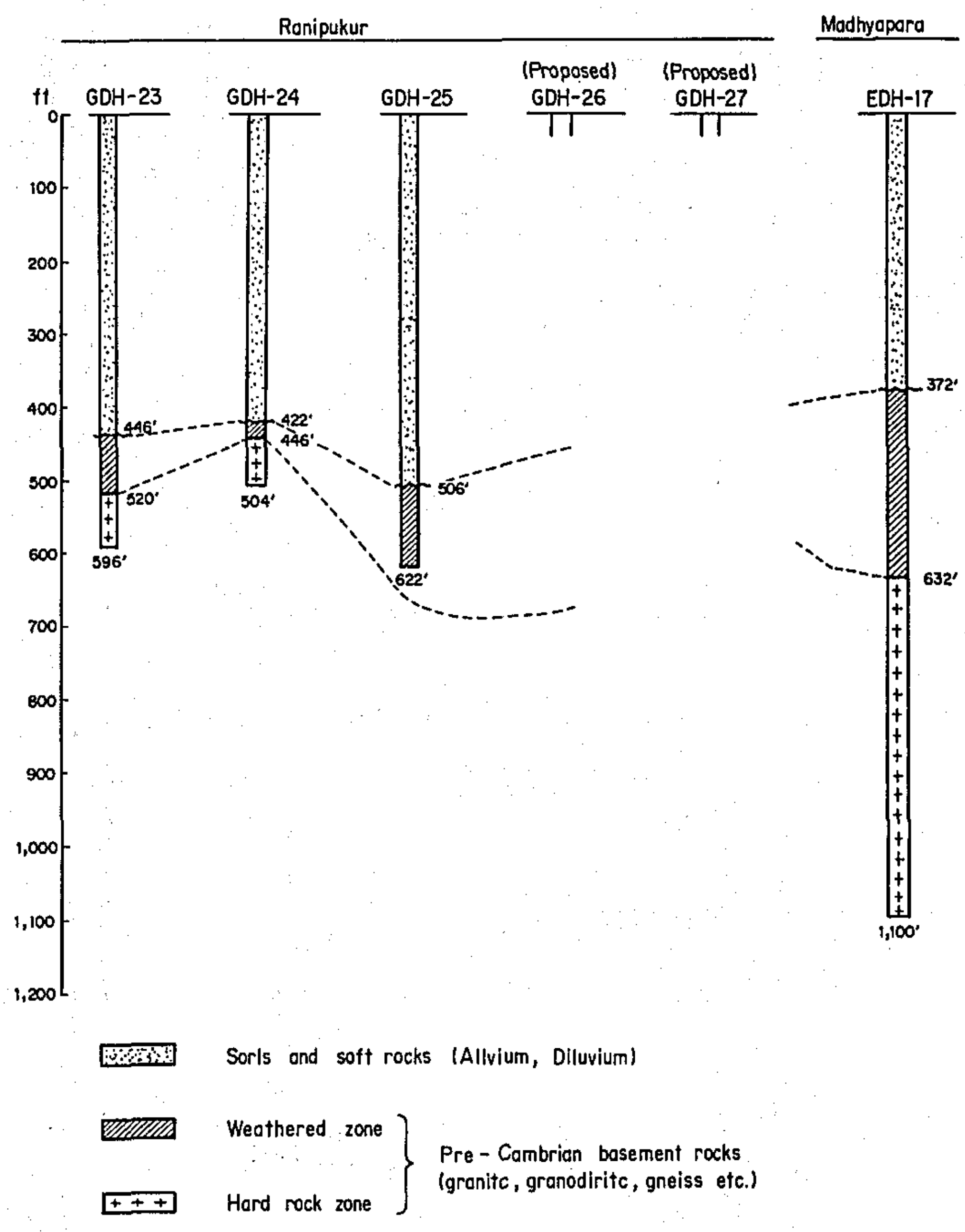


Fig.9 Outline geological logging in the "Ranipukur Hard Rock Project" Area (Compiled by Z. YOSHIDA)

basaltic lava - covers the Pre-Cambrian base rock, extending to an area of 50 km EW and 130 km NS. Its north-south axis is along the boundary line of Bihar State and West Bengal State. Gentle slope is developing eastward from the boundary with undulation of 10-20 m relative height. The sloped ground is rather permeable and covered with grass, having scattered paddy fields in the hollow areas and exposed rocks on the dry slope.

Along the eastern fringe of the trap rock, wide-gaged railway runs connecting Calcutta-Burdwan-Rajmahal-Patna. Numbers of stone quarries have been operated to develop trap rock for many years. They are all located within the range of 5-15 km from the railway and their products can be hauled easily to the railway stations nearby. Some of the quarries can be connected to the riverports along the Ganges river. Four quarries were visited and production activities were studied;

Pachami - Hatgacha, Nalhati, Rajgaon and Pakur.

Surface weathering of trap rock is rather thin - usually less than 3 m. Columnat joints are well developed and gives favourable effect on quarrying operation. Moderate annual rainfall does not so much disturb the open cut quarrying. Present quarry works are done by manual system except mechanical crushing and truck hauling. Production capacity will easily be increased by mechanization.

5.1. Pachmai-Hatgacha area.

The area is located at 26 km north of Suri town, 16 km west of Mallarpur station. The station is 194 km far from Howrah (Calcutta) by rail. There are 24 small quarries working in this area, producing 100,000 tons of stone materials per year. In 1975, new 26 quarries will be added and their production will be raised to 200,000 tons per year.

Overburden is usually 0.3 - 2.0 m thick in upland and 1.5 m - 3.0 m thick in sloped ground. Geological survey was done several years ago. It reveals that workable area covers 25 km^2, and basaltic laba of 20 m - 150 m in thickness is confirmed under overburden of 0 - 2.0 m in thickness. Workable reserves were estimated at 70 million m^3 (≒ 175 million tons).

West Bengal Mineral Development and Trading Corporation has a plan to integrate all small quarries, to mechanize and electrify quarry works and to construct hauling railroad of 16 km in length to Mallarpur station. Preparatory works have already started. Production in 1978 is scheduled to be 1.35 million tons per year. Railway freight to Calcutta is Rs 90/100 cu.ft., at the present rate.

5.2. Nalhati quarry.

Trap rock is distributed on the undulated hill, 7 to 8 km west of Nalhati station. Quarry railroad connects between the quarry site and the station. Crushing plant at the Nalhati station has a capacity of 100 t/day at the present stage.

5.3. Rajgaon quarry.

Rajgaon Stone Mining Co. developed the Gopalpur Stone Mine in 1914. Quarry rail of 5 km in length is connecting between the quarry site and the railway station.

Quarry cost: Rs 1.25/cu.ft ..... Rs 24.5/ton

Railway freight to Calcutta (249 km): Rs 105/100 cu.ft = Rs 21/ton

5.4. Pakur quarry.

80 quarry sites are operated in the area, 8 to 13 km west of Pakur station. Total yearly production is 1.2 million tons.

Number of workers: 12,000

Between quarry sites and railway station, quarry rail is available for hauling.

Two Major crush mills:

1) Black Stone Production Co.

Biggest producer in this area.
Hauling distance between Pakur and Dhulian (riverport on the Ganges river): 20 km.
Pakur-Calcutta (259 km by rail) Rs 107/100 cu.ft.
Loading in wagon: Rs 10/100 cu.ft.
Loading on barge: Rs 40-50/100 cu.ft.

2) Pakur Quarries Private Co.

Oldest quarry in the area.
Present capacity of production: 300,000 ton/yr

If all the quarries in Rajmahal hill are mechanized and modernized, total production capacity can be raised up to 250,000 ton per month for ballast and chips, and 25,000 tons per month for one-man-stone. River transportation is available through Dhulian riverport as well as Pakur railway station. Present hauling to Dhulian riverport is restricted due to congestion of traffic. Haul road is passing through town area crossing narrow bridge. Hauling capacity is at most 1,000 t/day. FOB price of Pakur rock is

a) FOB Dhulian (Riverport on the Ganges river)

One-man-stone: Rs 200/100 cu.ft.
Ballast and Chips: Rs 225/100 cu.ft.

b) FOB Benapole (Frontier station on the railway Jessore-Calcutta)

One-man-stone : Rs 275/100 cu.ft.
Ballast and Chips: Rs 300/100 cu.ft.

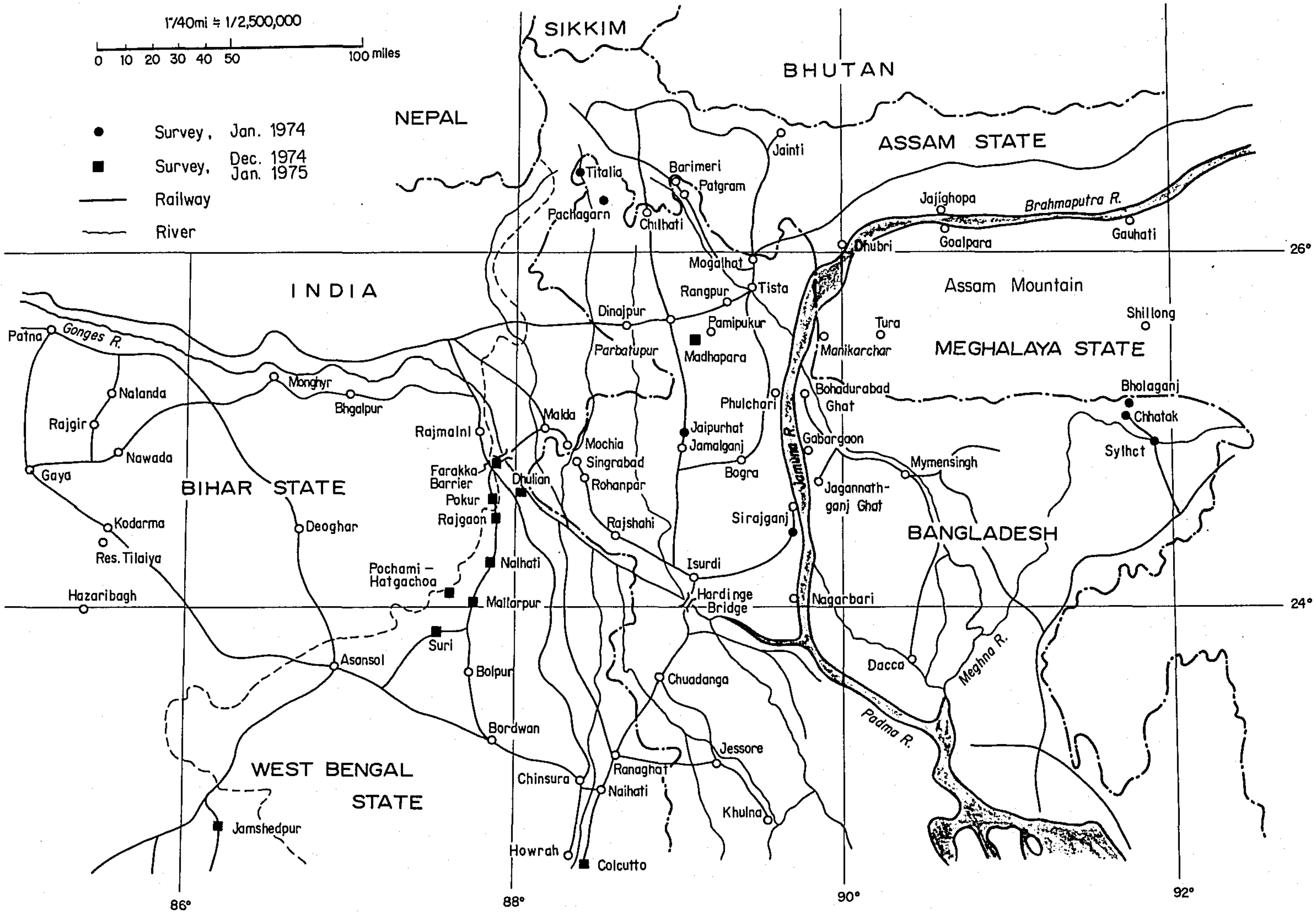


Fig.10 Map of Bangladesh and India

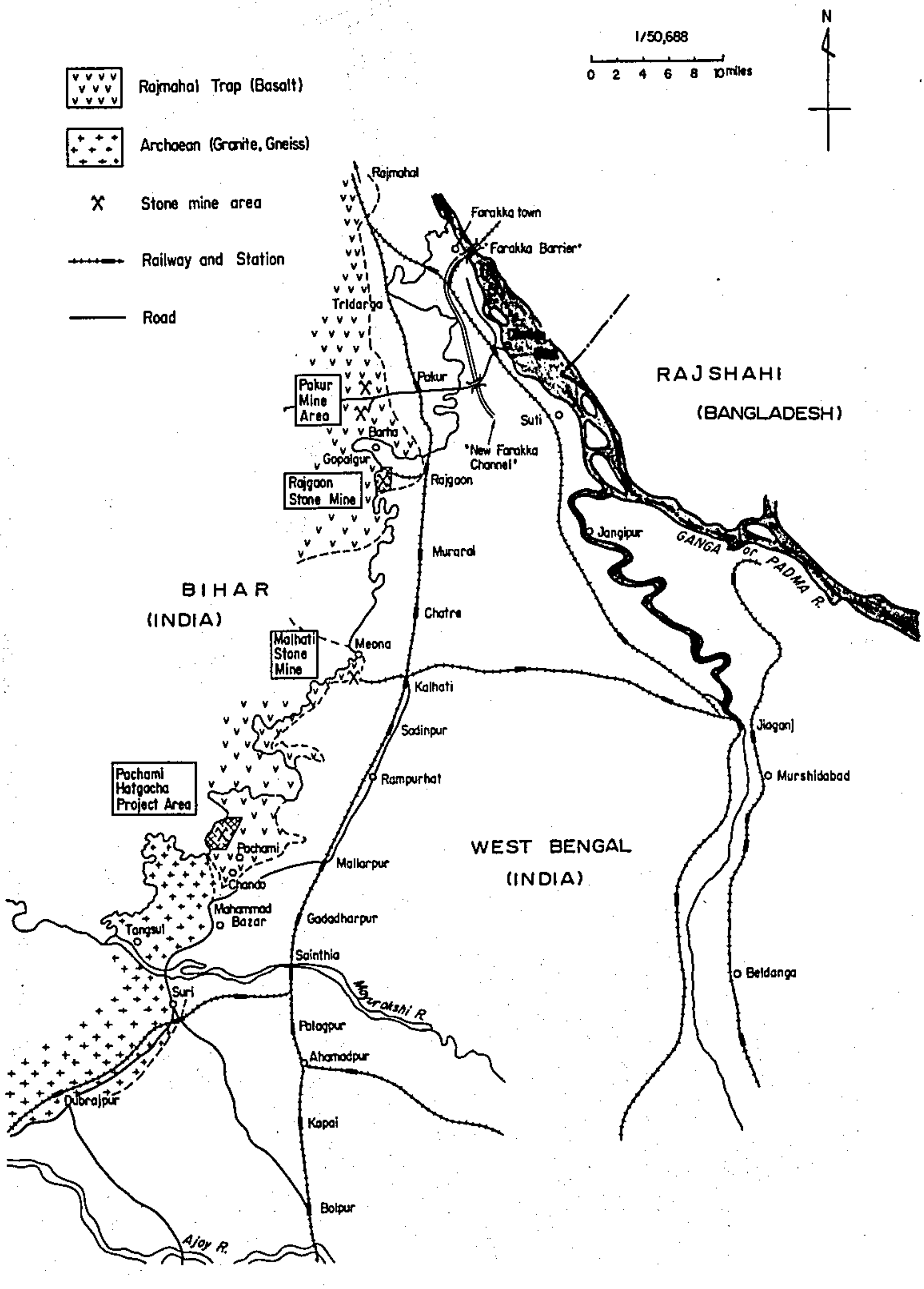


Fig.11 Geological Map of Dt. Birbhum (St. West Bengal) and Dt. Santal Parganas (St. Bihal), India

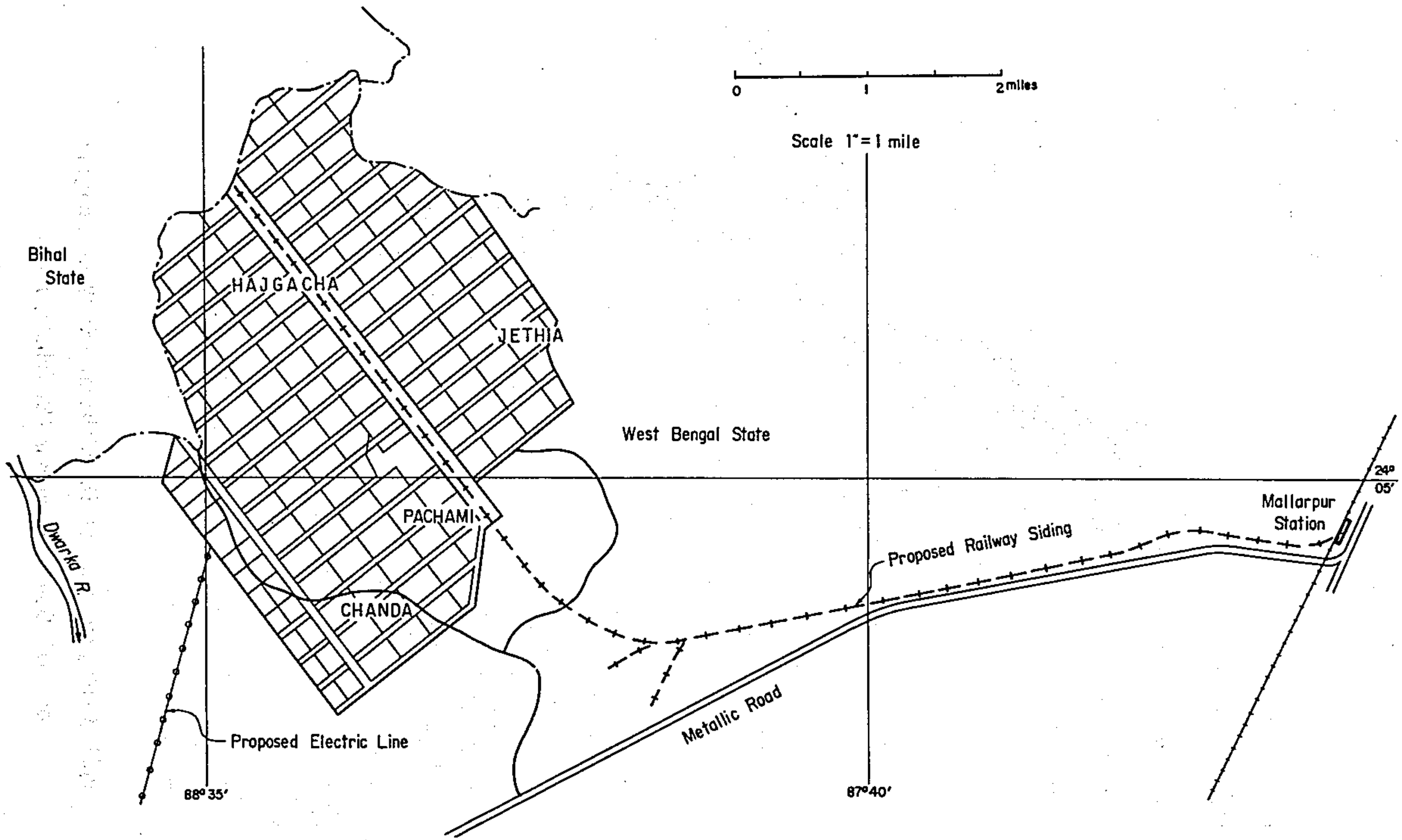


Fig.12 Map Showing Position of Pachami - Hatgacha Project
West Bengal Mineral Development & Trading Corporation Ltd. (1974)

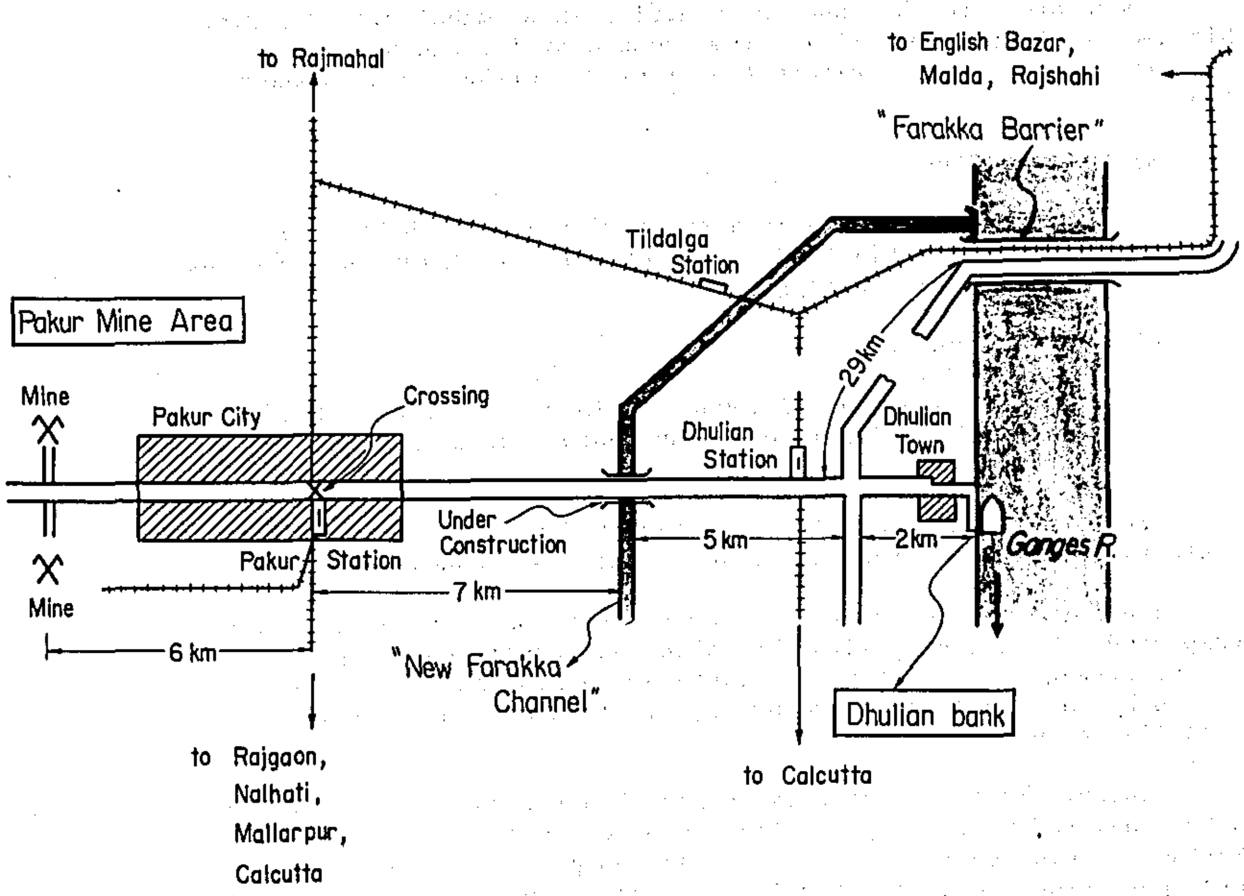


Fig.13 Outline map of road and railway between Pakur Main area and Dhulian Bank (Ganges River Side)

Amount of stone materials exported from Dhulian to Rajshahi (Harding Bridge) was recorded 5,000 tons in 1972.

5.5. Railway transportation of Rajmahal rock.

There are more than hundred quarries in Rajmahal hill district. Big amount of stone materials from these quarries can be sent to the Project through two alternative routes, northern and southern routes.

a) Northern route;

Loading station - Farakka Barrier - English Bazar - Malda - Mochia (India) - frontier - (Bangladesh) Rohanpur - Rajshahi - Sirajganj

b) Southern route;

Loading station - Bordwan - Chinsura - Nalhati (India) - frontier - (Bangladesh) Chuadanga - Harding Bridge - Sirajganj

The latter route has already authorized as international traffic route by Government Agreement between Indian and Bangladesh.

The former route is crossing over the Farakka barrage, recently completed. Wide-gage railway has also been completed. Improvement of narrow-gage into wide-gage between Amura-Rohanpur is nearly completed by the Bangladesh Government. Traffic agreement will be established in a few years.

Southern route is not only longer than the northern route, but also congested with heavy traffic bound to and from Calcutta. Northern route, on the other hand, has enough capacity for cargo transportation and is shorter in distance. Repairs and maintenance of railway bed and bridges will be necessary for continuous heavy traffic.

Railway transportation will be discussed in latter Chapter.

5.6. River transportation of Rajmahal rock.

Quarried rock collected at Dhulian riverport can be carried by river transportation. There are already authorized transportation agencies both in India and in Bangladesh.

a) Central Inland Transportation Corporation Ltd., India.

The corporation is a big transportation organization covering Assam State and Bangladesh territory with many information on the present status of river transportation. Their barge fleet consists of one paddle tug boat of 1000-1200 Hp and two barges of 600 tons each. Tug boat can also be loaded with 200 tons.

Then, transportation capacity: $600\ t \times 2 + 200\ t = 1{,}400$ t/fleet.

The fleet can navigate between Dhulian - Sirajganj twice a month, except three months in the flood season.

Annual transportation capacity: 1,400 t × 9 × 2 = 25,200 t/yr.

The C.I.W.T.C. offers unit freight charge for Dhulian - Sirajganj 224 miles long on water (= 360 km) at Rs. 0.08/ton/km.

Surcharge of 20 % and empty return trip has to be paid.

Then, Rs. 0.08 × 1.2 × 2 = Rs. 0.192/ton/km.

Hence: Dhulian - Sirajganj = Rs. 192 × 361 km - Rs. 69.3/ton.

b) Green and White Ltd., Bangladesh.

They have four fleets at present. One fleet usually comprises one tug boat and four barges. During three months in the flood season, the tug boat draw only two barges. Navigation schedule between Dhulian and Sirajganj is also twice a month.

Transportation capacity: 250 t × 4 × 2 = 2,000 t/month.

Annual transportation capacity: 2,000 t × 9 + 1,000 t × 3 = 21,000 t/yr.

While truck hauling capacity between Pakur and Dhulian port is limited to 1,000 t × 25 = 25,000 t/month.

Present price of Pakur rock at Rajshahi is said to be Tk.519/100 cu.ft.

Future estimate for delivery price at Sirajganj:

FOB Dhulian	Tk.200/100 cu.ft.
Freight (Dhulian-Sirajganj)	Tk.353
Profit	Tk. 50
sub total	Tk.603/100 cu.ft.
Sale tax of import tax (42%)	Tk.253
	Tk.856

The above quoted freight of Tk.353 shows unit charge of $\frac{\text{Tk.353}}{\text{361 km}}$

= Tk.0.98/100 cu.ft.km = Tk.0.196/t.km. This unit rate is very close to Tk.0.192/ton km proposed by CIWTC.

CHAPTER V

SUMMARY OF STONE MATERIAL TRANSPORTATION

1. Conditions and Assumptions for Transportation System.

After reviewing all possible sources of stone materials in Bangladesh and neighbouring Indian territory, major production sources and transportation routes are selected. Unit price of stone materials at the Project site are calculated on the basis of the following conditions.

(1) About 3,000,000 m (5,400,000 t) of stone material will be required for the construction works of the Project. These materials shall be delivered to the Project in the period of three years, that is 1,800,000 t/yr.

(2) Conceivable sources are scattered far from the Project site. Hauling distance to the Project ranges from 140 km to 470 km. Any source alone cannot supply such huge amount of stone materials, judging from its production and transportation capacities.

(3) Total requirement is transported by two systems, railway and waterway. Railway freight will be unloaded on the right bank of the Project, Sirajganj side and waterway freight will be landed on the left bank shore of the river.

(4) Total quantity to be transported will be more than ten times of current freight traffic of this kind. Present facilities of barge fleets and railway trains are not enough for such a big transportation. All the necessary facilities are required to be purchased newly for the purpose. Costs of railway locomotives and wagons are quoted from the information obtained from the State Railway Authority, and their maintenance and repair costs are tentatively estimated at half of those in Japanese National Railway, because of less working hour and lower labour wages. All facilities for marshalling and unloading yards are to be built on the right bank near the Project. The construction cost is estimated at around $0.3 million. The cost is charged on the unit price of stone material as Tk.2/ton.

    In waterway transportation, depreciation cost of newly purchased tug boats and barges with their maintenance cost is estimated. Maintenance and repair costs for tug boat of 1000 Hp is estimated at half of that of the locomotive by the reasons mentioned above.

2. Calculation of Transportation Cost.

2.1. Waterway transportation.

Carrier fleet: one tug boat and two barges.

Transportation capacity: 200 t + 2 × 600 t = 1400 t/fleet.

Tug boat: 1000 HP; Tk 6.8 million
depreciation in 14 years, Tk 486,000/yr

Barge: Tk 2.3 million
depreciation in 12 years, Tk 2.3 million × 2/12
= Tk 383,000/yr

Annual depreciation: Tk 486,000 + Tk 383,000 = Tk 869,000/yr

Repair & maintenance: ¥9,000,000 = Tk 408,000
1/4 = Tk 102,000/yr

Unit cost for depreciation and maintenance

$$= \frac{\text{Tk } 869{,}000 + \text{Tk } 51{,}000}{\text{annual carriage tonnage}}$$

Fuel consumption: 0.2 ℓ/HP. Hr, Tk 1.0/ℓ
Tk 0.2/HP Hr

Consumables, estimated at 30 % of fuel cost
Tk 0.26/HP Hr ; Tk 260/Hr/1000 HP

Wages, Salary of tug crew and sailer wages of barge: Tk 500/day

2.2. Railway transportation.

Freight train: 40 t × 30 wagons .... 1200 t/train

Diesel locomotive: Tk 5 million
depreciation in 12 years .... Tk 417,000/yr

Wagon: Tk 0.23 million
depreciation in 10 years .... Tk 23,000/yr

Annual depreciation per train:
Tk 417,000 + Tk 23,000 × 30 = Tk 1,107,000/yr

Repair and maintenance cost (half of the Japanese Railway's record)

Diesel locomotive: ¥9,000,000 = Tk 408,000,
1/2 Tk 204,000/yr

Wagon: ¥400,000 = Tk 18,200, 1/2 Tk 9,100/yr

Repair and maintenance cost per train:
Tk 204,000 + Tk 9,100 × 30 = Tk 477,000/yr

Fuel and consumables: Tk 0.26/HP. Hr
Tk 260/Hr. 1000 HP

Wages: Salary of engine driver and his assistants: Tk 100/day

3. Cost of Transportation and Cost of Stone Materials.

Costs of transportation from various production sites to the

Project are estimated and summarized in table I. Transportation cost varies in a range of Tk 25/t to Tk 26/t, depending on kinds of carrier, distances and production capacities.

Costs of stone materials at the Project are also estimated and shown in table II. The costs are also ranging between Tk 391 per 100 cu.ft. and Tk 645 per 100 cu.ft. according to their local conditions and transportation distances. The average cost for total requirement is Tk 499/100 cu.ft.

CHAPTER VI

CONCLUSIONS

1. Procurement of stone material in construction of the Jamuna Bridge Project is one of the most important problems.

(1) The Jamuna river is one of the biggest rivers in the Asia, and has characteristically braided river channels. Bridge designed includes very long span and gigantic bank protection work.

Millions of cubic meters of stone materials has to be procured for construction of piers and bank protection during rather short construction period of 3 to 5 years.

(2) The Jamuna river flows across the central part of Bengal Plain where there is no hills or mountains to produce stone materials.

(3) Hard rock material to be used in river revetment works has to be supplied from Pre-tertiary rock formations, trap rock or their derivative gravels. Geological structure of Bangladesh hardly allows to expose these rock formations within its territory. Hardrock formations are distributing in the surrounding countries of India, Sikkim, Bhutan and Nepal.

(4) Long transportation (usually more than 200 km) is necessary for construction. Thus, stone materials required for the Project is much expensive.

2. Possibility of Potential Sources.

After reviewing many possible sources of stone material in all over the Bangladesh territory and neighbouring sources in India, the following major possible sources are selected for the Project:

Rajmahal hill, West Bengal State, India

Upper Jamuna riverside, Assam State, India

Bholaganj gravel, Sylhet District, Bangladesh

Ranipukur hard rock project (under planning), Bangladesh

Many other sand and gravel sources scattered in the northwest corner of Bangladesh are too small in productivity to meet the purpose. Bholaganj gravel is the biggest sources in this country for various demands in domestic construction works. It is especially suitable as materials for concrete aggregates. Ranipukur project is still in planning stage. It is necessary to start preparatory works, such as vertical shafts beforehand, so as to meet the requirement of the Project. Rajmahal is the biggest and the upper Jamuna is the second biggest in their productivity and transportation capacity.

None of these four sources can be a sole source for the Project, because their production and transportation capacity are limited by their respective local conditions.

Multi-sources, and railway and river transportation will meet the requirement.

Under these local conditions, yearly supply in each sources are tentatively allocated as follows.

Bholaganj Gravel	
river transportation	102,000 t/yr
Ranipukur Hardrock Project	
railway transportation	180,000 t/yr
Rajmahal Trap rock	
river transportation from Dhulian	378,000 t/yr
railway transportation from Pakur station	720,000 t/yr
Upper Jamuna river	
river transportation from three riverport	430,000 t/yr
Total	1,810,000 t/yr

Procurement of 5,430,000 tons during 3 years can be thus attained. For these transportation, 10 numbers of freight train of 30 wagons and 27 numbers of freight fleet of one tug boat and two barges, will be necessary. Detailed list and cost are summarized in the Table 1.

3. Cost of Stone Material at the Project.

Transportation schedule and on-site cost are listed in the Table 2. The on-site cost is varying in range of Tk 3.9 to 6.7/cu.ft. Average cost is Tk 5.07/cu.ft.

Table 1 Transportation Cost from Quarry to the Project Site

Railway transportation

	Pakur Station - Sirajganj Station	Ranipukur Station - Sirajganj Station
Distance	300 Km	240 Km
Annual Shipment	1,200 t × 2 trains × 300 days = 720,000 t (2,400 t/day)	1,200 t × 1/2 train × 300 day = 180,000 t (600 t/day)
One traffic cycle	4 days	4 days
Number of train	2 train/day; * 8 train	1/2 train/day * 2 train
Depreciation cost	Tk 1,107,000 × 8/720,000 t = Tk 12.3/ton	Tk 1,107,000 × 2/180,000 = Tk 12.3/t
Maintenance cost	Tk 477,000 × 8/720,000 t = Tk 5.3/ton	Tk 477,000 × 2/180,000 = Tk 5.3/t
Fuel	Tk 260 × 15 Hr × 2/1,200 t = Tk 6.5/t	Tk 260 × 12 Hr × 2/1,200 t = Tk 5.2/t
Wages	Tk 100 × 4/1,200 t = Tk 0.33/t	Tk 100 × 4/1,200 t = Tk 0.33
Charge at marshall yard	Tk 20/t	Tk 2.0/t
Freight Cost	Tk 26.4/t	Tk 25.1/t

Waterway transportation

	Dhulian on the Ganges	Bholaganj in Sylhet District	Manikarchar on the upper Jamuna	Dhubri on the upper Jamuna	Jagioghopa on the upper Jamuna
Distance	300 Km	470 Km	140 Km	200 Km	260 Km
Annual shipment	1,400 t × 2 × 9 m 15 feet= 378,000 t	(1,400 t × 2.7 × 9 × 3)= 102,060 t	(1,400 t × 4.3 × 9 × 3)= 162,540 t	(1,400 × 3.75 × 9 × 3)= 141,750 t	(1,400 × 3.3 × 9 × 3)= 124,740 t
Navigation cycle	15 days, twice a month	11 days 2.7 times a month	7 days 4.3 times a month	8 days 3.75 times a month	9 days 3.3 times a month
Number of fleet	15 fleets	3 fleets	3 fleets	3 fleets	3 fleets
Depreciation	Tk 869,000 × 15/378,000= Tk 34.5/t	Tk869,000×3 / 102,060 t =Tk 25.5/t	Tk869,000×3 / 162,540 =Tk 16.0/t	Tk869,000×3 / 141,750 =Tk 18.4/t	Tk869,000×3 / 124,700 = Tk 20.9/t
Maintenance cost	Tk 102,000 x 15 / 378,000 =Tk 4.0/t	Tk102,000×3 / 102,060 =Tk 3.0/t	Tk102,000×3 / 162,540 =Tk 1.9/t	Tk102,000×3 / 141,750 =Tk 2.2/t	Tk102,000×3 / 124,740 =Tk 2.5/t
Fuel	Tk 260 × 34 Hr × 2/1,400= Tk 12.6/t	Tk60 × 58 Hr × 2/1,400= Tk 21.5/t	Tk260 × 15 Hr × 2/1,400= Tk 5.6/t	Tk260 × 23 Hr × 2/1,400= Tk 8.5/t	Tk260 × 30 Hr × 2/1,400= Tk 11.1/t
Wages	Tk 500 × 15 day/1,400= Tk 5.4/t	Tk 500 × 11/1,400= Tk 3.9/t	Tk 500 × 7/1,400= Tk 2.5/t	Tk 500 × 8 day/1,400= Tk 2.9/t	Tk 500 × 9 day/1,400= Tk 3.2/t
Freight Cost	Tk 56.5/t = Tk 283/100 cu.ft	Tk 54.0/t = Tk 270/100 cu.ft	Tk 26.0/t = Tk 130/100 cu.ft	Tk 32.0/t = Tk 160/100 cu.ft	Tk 37.7/t = Tk 189/100 cu.ft

Table 2 Price of Stone Material delivered at Bridge Site

	Dhulian on the Ganges	Bholaganj Sylhet Dist.	Manikarchar Upper Jamuna	Dhubri Upper Jamuna	Jagioghopa Upper Jamuna	Sub-total	Pakur West Bengal	Total
Annual shipment	378,000 t	102,060 t	162,540 t	141,750 t	124,740 t	909,090 t	720,000 t	1,629,090 t
Price at a station or port (100 cu.ft.)	(Rs.200) Tk312	Tk300	(Old Tk250) Tk390	(Rs.156) Tk243	(Rs.106) Tk165		(Rs.150) Tk234	
" (Tk/ton)	Tk62.4	Tk 60	Tk 78	Tk48.6	Tk 33		Tk46.8	
Freight (Tk/100 cu.ft.)	Tk283.0	Tk270.0	Tk130.0	Tk160.0	Tk189.0		Tk132	
(Tk/ton)	Tk56.5	Tk54.0	Tk26.0	Tk32.0	Tk37.7		Tk26.4	
Loading and Unloading (Tk/100 cu.ft.)	Tk 50	Tk50.0	Tk 50	Tk32.0	Tk37.7		Tk26.4	
(Tk/ton)								
Price of stone (Tk/100 cu.ft.)	Tk64.5	Tk620	Tk570	Tk453	Tk404		Tk391	
(Tk/ton)	Tk129	Tk124	Tk114	Tk90.6	Tk80.8		Tk78.2	
Total amount	Tk 48,762,000	Tk12,655,440	Tk19,000,900	Tk13,367,000	Tk10,078,992	Tk102,868,542	Tk56,304,000	Tk159,192,542

$$\frac{\text{Tk159,172,542}}{\text{909,090 t + 720,000 t}} = \text{Tk97.7/ton}$$

$$= \text{Tk488.5/100 cu.ft.}$$

or Tk175.86/m^3

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APPENDIX I

WORKABLE RESERVES OF EHOLAGANJ GRAVEL DEPOSITS

Conditions:

Estimation is limited in exposed gravel deposits in the present riverbed. Rough sketch survey (Fig. 2) is used for the estimation.

Present treatment yard is kept for the ground of crushing, screening and loading and is excluded in reserve calculation.

Natural grain size distribution is assumed in field observation. Grain size distribution after crushing is quoted from the records in similar crushing plant.

Maximum depth of the deposits is 14 m which is confirmed in the field at the foot of steel post of ropeway. But workable depth was assumed at down to 6 m depth, because maximum depth of backhoe excavation is usually 6 m below dry ground.

Safety factor in survey area: 80 %

Recovering percentage of exploitation: 80 %

Then:

	Area A	Area B	Area C	Total
Surface area	469,000 m^2	1,993,800 m^2	377,400 m^2	2,840,200 m^2

Area A is excluded for treatment yard

Workable reserves: (1,993,800 + 377,400) m^2 × 6 m × 0.8 × 0.8
= 9,105,408 m^3

Grain-size distribution

	Area B		Area C		Total	
Size	Percentage	Volume	Percentage	Volume	Percentage	Volume
9"	4.3	328,205			3.6	328,205
9" 4"	20.6	1,552,218			17.1	1,555,218
4" 3/16"	35.4	2,710,292	20.0	289,843	32.9	3,000,135
Subtotal	60.0	4,593,715			53.6	4,883,558
3/16"	40.0	3,062,477	80.0	1,159,373	46.4	4,221,850
		7,656,192		1,449,216		9,105,408

Boulder bigger than ϕ9" is taken as Pitching stone, coarser grain of ϕ9"-4" is crushed to ballast and sand, then

	Percentage	Crushed Products
4"-3/16"	95 %	1,447,457 m^3
3/16"	5 %	77,761 m^3
Total		1,555,218 m^3

Hence, the above two tables are summarized as:

9" (Pitching Stone)	3.6 %	328,205 m^3
4"-3/16" (Ballast)	49.2 %	4,477,592 m^3
3/16" (Sand)	47.2 %	4,299,611 m^3
Total		9,105,408 m^3

APPENDIX II

COST ESTIMATE FOR DEVELOPMENT OF BHOLAGANJ NEW QUARRY PLANT

Unit : $ 1,000

Items	Number	Weight	Price FOB ($1,000)	Transportation insurance and handling charge	Domestic trans-portation	Instal-lation cost	Total ($1,000)	
Exploitation facilities		190 t	560	96	23		694	
Backhoe 1.2 m^3	3	150 t	420	56	18		494	digging: 7.0 m depth
Bulldozer D-7	2	40 t	140	40	5		185	183 HP, 20 ton
Hauling facilities		127	388	105	15		508	
Wheel loader 23 m^3	2	25	88	25	3		116	12.4 ton
Dump truck 18 ton	6	102	300	80	12		392	230 HP
Dressing facilities		523	1,045	281	62	535	1,923	
Fixed grizzly	1	18	28	8	2		38	5m × 5m × 2, Opening 9"
Hopper	2	120	190	50	14		254	10m × 15m × 3m × 2, 500 ton × 2
Vibrating feeder	1	5	17	5	1		23	1840mm × 2440mm, 11 kW
Vibrating screen	2	18	50	10	2		62	2130 × 6100mm, double deck, 30 kW 2130 × 4880mm, double deck, 15 kW
Cone crusher	1	38	130	38	5		173	1260mm hydrocone, 110 kW
Belt conveyor	400 m	240	460	120	28		608	75mm, 600mm, $100/m × 11.5 %
Chute, with frame		64	100	30	8		138	
Others		20	70	20	2		92	
Installation						120	120	(total tonnage, except hopper) × $300
Foundation						400	400	measurement ton = (total tonnage, without hopper) × 5, $200/$m^3$
Electric facilities			300	85	4	45	434	
Diesel generator 250 kW	3	30	300	85	4		389	
Installation						9	9	total tonnage × $300
Foundation						36	36	measurement ton = total tonnage × 6, $200/$m^3$
Repair shop			60	18	2.4	17	97.4	
Housing & others		20	60	18	2.4		80.4	
Building						17	17	
Road and yard						25	25	
Appurtenant facilities		40	170	50	5	100	325	
Maintenance of ropeway			170	50	5	170	395	
Administration			270				270	
Others			300	100	6	170	576	
Contingency			1,000					
Total			4,263	785	122.4	1,062	6,232.4	

APPENDIX III

DEVELOPMENT OF RANIPUKUR HARD ROCK PROJECT

Production Capacity: 4,000 tons/day, 4,000 t × 300 days = 1,200,000 tons/yr
= 677,000 m^3

1) Vertical shaft sinking.

	Main shaft	Auxiliary shaft
Total length	410 m	360 m
Internal diameter	5 m	5 m
Excavation by J.W.S. method	155 m	155 m
Excavation by S.S. method	255 m	205 m

Note) J.W.S. method: Jet well-sinking method, applied in the upper soft ground.

S.S. method : Short step method, applied in the lower weathered and hard granite rock.

There are many pre-excavation treatments in the soft rock ground, such as chemical grouting and freezing method. But they accompany more or less difficulties in cost and reliability. Jet well-sinking method is to sink a well caisson by its own weight, using water jet excavation under the bottom edge with steel shoe blade. After the well caisson sinks under the natural groundwater level, water pressure is balanced by pouring water inside the caisson. Compressed air jet is then blown out side of the caisson, reducing friction between caisson and ground, and allows its continuous sinking. (Fig. 10). Short step method is to proceed sinking by in situ concrete lining after drilling and blasting in the hard granitic rock.

2) Underground mining.

Between the depth of 220 m and 320 m, the underground mining is done at the bottom of the two blind shaft as shown in Fig. 12. Scraper is used in the quarry face, the diesel locomotive is used in level hauling, and the skip winding is used in the vertical shaft. Ventilation of sufficient capacity through the two shafts.

3) Treatment on the ground

The quarried and winded-up rocks are treated in the series of crushing and screening operations.

4) Cost estimate of Development (in Tk. million).

(1) Vertical shaft sinking	Tk.169.4	
Main shaft, ℓ = 410 m	Tk.94.4;	Excavation: Tk.52.8 Hoisting facilities: Tk.41.6
Auxiliary shaft, ℓ = 360 m	Tk.75.0;	Excavation: Tk.47.2 Hoisting facilities: Tk.22.5 Ventilation facilities: Tk. 5.6
(2) Quarry preparation	Tk. 19.4	
Level tunnelling	Tk. 6.9;	Length of level: 4,260 m Up-stopping: 200 m Other excavation: 2,000 m
Machinery	Tk.12.5;	Drilling, Hauling & Drainage
(3) Process Plant	Tk. 27.8:	Crushing & Screening facilities
(4) Appurtenant facilities	Tk. 83.3:	Repairing shop, Electricity supply, warehouse, magazines, water supply housing and etc.
(5) Administration	Tk. 24.0	Tk.0.3 × 16 persons × 5 yr.
(6) General Expense	Tk. 45	Transportation, Communication, Insurance, Tax business, Handling charge and others
(7) Expense during construction	Tk. 79.3	
Interests	Tk.73.8	8 %, sum of (1) - (6) depreciate 50 % in 5 years
Technical training	Tk. 5.5	
(8) Subtotal	Tk.448.2	
(9) Contingency, 13 % of (8)	Tk. 58.3	
(10) Grand Total	Tk.506.5	

5) Production Cost (per ton)

Exploitation cost	Tk.13.9	
Treatment	Tk. 4.2	
Miscellaneous	Tk. 5.6	
Depreciation	Tk.59.1	Interest 8 % for 10 years
Total	Tk.82.8/ton = Tk.149/m^2 or Tk.414/100 cubic ft.	