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SPECIAL ABBREVIATIONS

Unit of Measure

Prefix	M :	Mega- = 10^6
	K :	Kilo- = 10^3
	C :	centi = 1/100
Force	N :	Newton = 1 kg·m/s^2
Pressure	Pa:	Pascal = 1 N/m^2

Special Conversion Factors

1 kgf/m^2 = 9.80665 Pa

1 kPa = 1/98 kgf/cm^2

1 N = 10^5 dyn

1. INTRODUCTION

The object of a construction material survey for the feasibility study of the Beris dam is; (1) to find adequate sources of fill materials and concrete aggregate, (2) to estimate available quantity, and (3) to evaluate quality of the materials for the Beris dam including the main and saddle dams and their appurtenant structures.

Field investigation was carried out for the period from December 1983 to February 1984 involving site reconnaissance and sampling of materials. The laboratory tests for sampled materials were undertaken by the Government of Malaysia.

During the survey period, three alternative quarry sites, two alternative borrow pits for cohesive soil (impervious core) materials and four possible borrow pits for sand and gravel (filter and concrete aggregate) were investigated.

The requirement of construction materials is set out in Section 2, and proposed material sources are described in Section 3. Section 4 itemizes the laboratory tests executed in this survey. Mechanical properties of the residual soils are assessed on the basis of the laboratory test results in Section 5, while the properties of sand, gravel and rock are evaluated in Section 6. Basic zoning design and applied design values of a rockfill dam are studied in Section 7.

2. CONSTRUCTION MATERIAL REQUIREMENT

As introduced in Main Report, the Beris dam comprises the main dam with height 41 m and volume about 60,000 m^3 as a concrete gravity dam, and also saddle dam with height 28 m and volume of about 120,000 m^3 as a rock-fill dam.

The required volume of construction materials as-built condition is preliminarily estimated on the basis of the dam design, and it is shown in Table 1.

3. CONSTRUCTION MATERIAL SOURCES

3.1 General

The sources of construction materials are classified into the following three setouts:

(1)	Quarry site;	rock for fill dam and masonry, fine and coarse aggregates for concrete dam and other concrete structures, and filter and drain materials for fill dam and other embankments.
(2)	Borrow pit for cohesive soil;	impervious core material for fill dam, earth materials for other embankment and backfill.
(3)	Borrow pit for sand and gravel;	filter and drain materials for fill dam, fine and coarse aggregates for concrete dam and other structures.

Plate 1 shows the location of alternative and possible borrow pits for cohesive soils, sand and gravel, and quarry sites. Quality and available quantity of these material sources are preliminarily evaluated and summarized in Tables 2 and 3.

3.2 Cohesive Soils

No predominant deposit of alluvial soil was found around the proposed Beris damsite. The cohesive soils in the project area are mostly composed of residual soils, which are originated from sandstone and/or shale.

Two prospective borrow pits of B1 and B2 are identified as alternative material sources for an impervious core of the saddle dam and other embankments. The B1 borrow pit is located on the right bank along the Beris river, 0.2 to 1.0 km northwest (downstream) of the main damsite. The B2 borrow pit is also on the right bank, and is 0.3 to 1.1 km northwest of the saddle damsite.

The soils of these borrow pits are composed of reddish and lateritic clays. They are classified into the soils of shale origins and sandstone origins. The soils in B1 and B2 borrow pits are mainly originated from shale and sandstone, respectively. Both soils are sufficiently impervious material for core zone of rockfill dam. However, regarding the trafficability and shear strength, borrow pit B2 is judged to be better than borrow pit B1 based on the laboratory test results.

The available quantity of the B1 and B2 sites is estimated around 400,000 m^3 and 300,000 m^3, respectively. The thickness of usable soil layer is assumed to be 3 m. The depth of layer is not constant but varies between 2 m and 5 m from the ground surface. The ground water was not observed within a depth of 5 m.

3.3 Sand and Gravel

No major terrace deposit of sand and gravel is found along the Beris and Muda rivers within a reasonable distance from the proposed damsite. On the other hand, minor deposite of sand and gravel are observed in the river channels of the Beris river upstream of the damsite and in the Muda river upstream of the confluence of the Beris river. These deposits are mostly submerged in the river channel even in the dry season.

Four major deposits of SG1, SG2, SG3 and SG4 are identified as alternative sources for concrete aggregates, and filter and transition materials of fill dam. In the four sites, the SG2 and SG4 sites are estimated to have relatively large quantity.

In the Beris river, medium and coarse sands are deposited in the river channel while fine sands are identified on both banks. The thickness of sand layer is about 1 m. Some sand layers consist of very uniform gravel of less than 10 mm. There lies a gravel layer below the sand layer in places. The thickness of gravel layer could not be measured because of river water.

The deposits in the Muda river are larger in particle size than those of the Beris river. The thickness of the layer is around 2 m. The sand layers are mostly composed of medium and coarse sands.

The available quantity of SG1, SG2, SG3 and SG4 is approximately estimated at 3,000 m^3, 10,000 m^3, 1,000 m^3 and 10,000 m^3, respectively. However, the required quantity of sand and gravel materials is much larger than the available one, therefore most of concrete aggregates, and filter and drain materials accordingly should be produced by a crushing plant from quarried rock.

3.4 Quarry

In Part 1 study, Quarry site Q1 was proposed on the basis of the results of geological surface exploration. However, the subsurface exploration results by using boring machine indicates that the rock material in Q1 site is inadequate because the quality of rocks is deemed worse for construction materials. Consequently, Q2 and Q3 sites were investigated additionally.

According to the geological investigation, it could be judged that the Q2 site is the best among the three sites in terms of quality of rock, available quantity of fresh rock and cost effectiveness. The geological features of these quarry sites are discussed in detail in Annex G "Engineering Geology".

The available quantity of fresh rock is estimated at $300 - 400 \times 10^3$ m^3 for Q2 and 200×10^3 m^3 for Q3 respectively.

4. LABORATORY TEST SCHEDULE AND TESTING METHOD

The principal object of the laboratory tests is to evaluate the physical, chemical and engineering properties of the prospective fill materials and concrete aggregates in and around the Beris damsite in the stage of feasibility study.

The laboratory test items and their sample numbers undertaken in this study are listed in Tables 4 and 5.

The head of the sample number denotes the number of the test pits or bore holes. The location of test pits is shown in Fig. 1.

4.1 Cohesive Soils

All cohesive soils sampled from the test pits, gradation analysis (particle size distribution), specific gravity test, field moisture content test, Atterberg's limits test were done as a series of physical and chemical properties tests. The analyses of clay mineral content and soluble salt content were done for the selected 5 samples.

As for mechanical property test for moisture-density relation using a rammer, the permeability test with falling head, the triaxial compression test (CU; consolidated undrained) with sample diameter of 38 mm, the consolidation test with sample diameter of 60 mm, and the swelling test with sample diameter of 60 mm were done for the selected samples. The Proctor compaction test was done with variable compaction energy of the standard compaction, twice and three times of the standard compaction energy (say 1E, 2E and 3E).

The samples for the permeability, triaxial compression, consolidation and swelling tests were compacted under optimum moisture content (OMC) with variable compaction energy (1E, 2E & 3E) in order to figure out the relation among mechanical properties, compaction energy and compaction method. The triaxial compression tests were executed under consolidated and undrained condition after the samples were saturated, consolidated and the porewater pressure was also measured so as to obtain the effective-stress parameters.

The sieve analysis was done under water washing. A same naturally dried sample was used repeatedly in process of getting the optimum moisture content (OMC) for time saving because the effect of water sensitivity was considered being negligible.

The tests performed in the DID laboratory were according to the British Standard, BS1377-1975.

4.2 Sand, Gravel and Quarried Rock

For sand and gravel, particle size distribution and specific gravity were measured. Organic content was measured for sand only.

For quarried rock, specific gravity test, bulk density test, moisture content test, water absorption test, mechanical durability test and compressive strength test were done.

5. SOIL MECHANICAL PROPERTIES OF RESIDUAL SOILS

5.1 Physical and Chemical Properties

The cohesive soils in the project area are mostly composed of residual soils which are the product of rock weathering accumulated in place. The parent rock of the residual soils are considered being shale, sandstone and alternation of shale and sandstone which are the predominant rocks formations in the project area. The particle size distribution differs significantly among some samples even if taken from the same area. The particle size distribution depends on the degree of weathering and the matrix of the parent rock. It is impossible to clarify the main factors which cause the variation of particle size distribution, but it can be inferred that the sand content may be high in the area having predominant sandstone formation (BR5, BR7 and BR8) while the silt and clay content may be high in the area having the predominant shale formation (BR1, BR3 and BR4).

The results of physical and chemical property tests of the residual soils are summarized in Tables 6 and 7.

(1) Particle size distribution, consistency and the Unified Soil Classification System

The content of silt and clay (smaller than 0.06 mm) is very high, i.e., 65 to 85% for shale originated soil and 34 to 58% for sandstone originated soil. The content of sand and gravel (larger than 0.06 mm) are 15 to 35% for shale originated soil and 42 to 66% for sandstone originated soil respectively. The maximum size of gravel ranges from 2 to 10 mm.

The particle size distributions of the residual soils are shown in Figs. 2 to 4. The resulting high content of fines and comparatively poorly graded shale originated soils imply a low compacted density and indicate proneness to cracking after being compacted.

The liquid limit (WL) ranges 36 to 98%, with an average of 81.8% for shale originated soil and with an average of 53.8% for sandstone originated soil, respectively.

The plasticity index (Ip) ranges 14 to 66%, with an average of 49.1% for shale originated soil and with an average of 25.8% for sandstone originated soils respectively.

The soils of shale origins are reddish and lateritic silts and clays and they are classified to be MH or CH in the Unified Soil Classification System (See Table 8 and Ref. H 2) as shown in Fig. 5. They also indicate the medium to high plastic soils with high resistibility to piping for impervious core materials. Whereas, the soils of sandstone origins are classified to be SM or CL as shown in Table 8 and Fig. 5, i.e., silty sands and sandy clays with low to medium plasticity.

(2) Specific gravity, organic content and pH

The specific gravity is in the range of 2.6 to 2.7. The organic content was not tested for cohesive soils because no organic substance was found by eye observation. The tests in Part 1 Study showed that the content was less than 1% (Ref. H 1).

The value of pH is 4.5 to 4.9 and all the soils are considered to be slightly acid.

(3) Dry density, OMC and field moisture content

Compaction tests on soil samples are carried out in accordance with BS 1377: Test 12 (standard compaction test). Furthermore, the compaction energy is changed in a range from the standard compaction energy (6.075 kg/cm^2 say 1E) to twice and three times of the standard compaction energy (say 2E and 3E). The results of the compaction test are shown in Figs. 7 to 9 and are summarized in Table 21.

Table 21 shows that compacted dry densities of shale originated soils (BR1, BR3 and BR4) are lower than those of sandstone originated soils (BR5, BR7 and BR8).

The maximum dry densities of shale originated soils at 1E are 1.4 to 1.62 Mg/m^3, with an average of 1.50 Mg/m^3, whereas those of sandstone originated soils are 1.64 to 1.83 Mg/m^3 with an average of 1.73 Mg/m^3. This is due to the larger percentages of silts and clays, and the poorly graded materials as well as the high moisture content of shale originated soils.

The optimum moisture content (OMC) decreases (moves to dry side) and the maximum dry density increases in proportion to the increase of compaction energy from 1E to 2E, but there is little change in the range from 2E to 3E. These facts imply that the over-compaction phenomenon occurred at 3E compaction energy.

The field moisture content of shale originated soils is 21 to 29% with an average of 26.0%; comparatively high. That of sandstone originated soils is 14 to 24% with an average of 18.2%.

Since the field moisture content in dry season is slightly wetter (2 to 6%) than the OMC at 2E, which is the recommendable compaction energy during the construction stage, the field moisture content at the beginning and end of dry season is inferred to be on wetter side, the material is required to dry out artificially to around the OMC to achieve the best mechanical properties, of compacted soil, imperviousness and strength as well as trafficability.

(4) Clay mineral content

The test results of analysis of clay mineral content are shown in Table 9. The loss on ignition is 6.9 to 10.6%. Silica (SiO_2) and Alumina (Al_2O_3) are major minerals, and their contents are 77.6 to 83.9% and 6.9

to 11.0% respectively. Calcium Oxide (CaO), Magnesium Oxide (MgO), Potassium Oxide (K_2O) and Sodium Oxide (Na_2O) are contained but to quite a minor extent.

The composition of clay minerals was analyzed by a X-ray scanning machine with a Cu-target X-ray tube and a scintillation counter. The samples are dispersed in distilled water, treated with glycolate and heated at 550°C.

Only Kaolinite and trace amount of Illite are identified from the 5 samples as shown in Table 10. Some fine quartzs suspended with the clay fraction are also detected on the diffractograms. Since Halloysite and Montmorillonite are not identified, residual soils are evaluated to be relatively stable against chemical deterioration.

(5) Soluble salt content

The soluble salt content shown in Table 11 was measured in terms of Ca^{++}, Mg^{++}, K^+ and Na^+ to check dispersive character of the residual soils. The total soluble salt content is only less than 0.2% of the total clay mineral content (See Table 9).

According to the suggestion by J.L Sherard etc. (Ref. H 3), the amount of dissolved sodium relative to other salts in the porewater is the main factor determining whether a clay is dispersive or not. From the study shown in Fig. 6, the relation of porewater salts and dispersion of compacted samples indicates that the residual soils in the proposed borrow site are inferred to be non-dispersive.

5.2 Assessment of Mechanical Properties Required for Rolled Earth Dams

5.2.1 Mechanical properties of compacted soils

The permeability test, the triaxial compression test ($\overline{CU}$), the consolidation test and the swelling test were done for the samples compacted with the standard compaction energy (1E) under OMC at first. On the basis of these test results, the following conclusions are reached:

(1) Trafficability

The trafficability of the residual soils, especially of shale originated soils will be inadequate, if the placement moisture content is in wet-side from OMC (1E).

According to the experience of the Feasibility Study of Reman Project, (Nov. 1983), the penetration resistance of residual soils in a cone penetration test of compacted samples ranged from 24 to 68 kg/cm^2 at OMC, indicating that the movement of heavy construction equipment, i.e., dump-tracks, on the embankment will not be hampered, however, it decreases to 8 to 19 kg/cm^2 at about 4% wet-side placement moisture from OMC; only the dozer-type equipment movable.

Judging from the comparatively high field moisture content, of shale originated soils in rainy season, some control of the placement moisture or the mixing method with the other coarse material, weathered sandstone or weathered congromerate, will be required, otherwise the embankment work will be restricted only during the dry season.

(2) Shear strength

The triaxial test ($\overline{CU}$) was done for the specimen compacted with standard compaction energy (1E) under OMC, 2E and 3E. The test results are shown in Tables 12 - 14 and Figs. 13 - 22. In the effective stress condition of standard compaction energy, the cohesion (C') is 0.37 - 1.4 kg/cm^2 and the angle of internal friction (ϕ') is 17 - 26.5°. In the total stress condition the cohesion (Ccu) is 0.58 - 1.65 kg/cm^2 and the angle of internal friction (ϕcu) is 5 - 14°.

The cohesion is fairly high but the internal friction angle is low; accordingly, this material is evaluated to be inadequate for high homogeneous embankments which require high shear strength, but it can be used for the impervious core of the central-core type fill dams of several ten m in height.

(3) Permeability

The coefficient of permeability is in a range of 3.7×10^{-5} - 4.3×10^{-7} cm/sec if samples are compacted with the standard compaction energy under OMC (See Tables 6 & 7). It is considered that these residual soil are suitable for forming an impervious core.

(4) Compressibility and swelling

The consolidation test results are shown in Tables 15 - 19. The compressibility is estimated using the void ratio - consolidation pressure relationship shown in Figs. 10 - 12, and it is listed in Table 20.

The compressibility $(e_o - e_i)/(1 + e_o)$ under standard compaction energy is high of 5.5 - 6.9% under a loading pressure of 2 kg/cm^2, 8.2 - 9.1% under a loading pressure of 4 kg/cm^2 and 9.7 - 11.8% under a loading pressure of 6 kg/cm^2.

The measures to prevent large settlement are the sufficient compaction by heavy compactor (compaction energy 2E) and the mixing of coarse material as well as controlling of placement moisture by drying to the optimum moisture content.

The change in height due to swelling is 0.25 - 0.5% and the swelling pressure is 0.05 - 0.1 kg/cm^2. These are considered being rather low though the content of clay and silt is extremely high. The swelling process and its testing procedure are shown in Fig. 23.

5.2.2 Dry density - permeability - shear strength - compressibility relationship

The compaction energy was changed in the range from the standard compaction energy (say 1E) to three times of the standard compaction energy (say 3E) and the variation of the maximum dry density, the permeability, the shear strength parameters, the compressibility and the swelling were measured.

Figures 23 and 24, Tables 20, 21 and 22 shows the behaviour set out below:

i) The optimum moisture content (OMC) decreases (moves to dry side) and accordingly the maximum dry density increases in proportion to the increase in compaction energy from 1E to 2E, but they do not change in the range from 2E to 3E (See also Figs. 7 - 9 and Table 21).

ii) The permeability decreases remarkably with increase in compaction energy from 1E to 2E, but its change is insignificant if energy is increased from 2E to 3E. (See also Table 22).

iii) The compressibility is improved by 0-3.9 to 0.7-5.0% in proportion to the increase of compaction energy from 1E to 2E and 3E (see Table 20).

iv) The shear strength increases a little with the increase of compaction energy. (See Fig. 24)

v) No major effect due to variation of compaction energy is observed in swelling. The increase in sample height due to swelling is 0.25 to 0.5% if an energy of 1E or 2E is applied, while it is 0.1 to 0.2% under 3E. (See Fig. 23)
Further, the swelling pressure is very low of 0.05 to 0.1 kg/cm^2, soils may be regarded as non-swelling.

5.3 Conclusions and Recommendations

i) Based on the field investigation and soil test results the proposed impervious soils are classified as shale originated soil and sandstone originated soil.

ii) The sandstone originated soils (Borrow Pit B-2) are suitable for use as the impervious core material of the rockfill dams. However, the shale originated soils (Borrow Pit B-1) are unsuitable for the core material, because;

a) The sandstone originated soils are classified to be SM-SC or CL, which are silty sands, clayey sands or sandy clays with low to medium plasticity. These soils have the engineering properties such as sufficient trafficability, imperviousness, shear strength, piping resistance, etc., and they can be used for the core material without mixing course material. Moisture content can be controlled easily at around OMC without special processing.

b) The shale originated soils are classified to be CH or MH, which are inorganic clay of high plasticity or inorganic silt. These soils have the engineering properties such as insufficient trafficability in rainy season, low shear strength and poor workability (ease of moisture density control). Since the content of fine particle (0.06 mm under particle) is more than 65 to 85%, much shrinkage crack will occur.

According to the above conclusions on the basis of technical assessment of soil mechanical properties, only sandstone originated soil is recommended as an impervious core material of rockfill dam. Because, shale originated soil is difficult to use as a fill material without mixing with coarse material, mixing process is costly, and available quantity of sandstone originated soils is sufficient to meet the requirement. Consequently, Borrow Pit B-2 is recommended to develop for the core material source.

Prior to the development of Borrow Pit B-2, test trenching should be done to investigate the fluctuation of moisture content and particle size distribution of the sandstone originated soils. Excavation by using bulldozer with ripper can be made effectively for these soils.

6. PROPERTIES OF SAND, GRAVEL AND ROCK

6.1 Sand and Gravel

The physical and chemical test results are summarized in Tables 23 and 24. The particle size distributions are shown in Figs. 25 and 26.

The samples are all submerged in river water and thus almost no clay and silt portion is contained. The particle size distribution is rather well graded. The maximum grain size is around 10 mm and sand particles (0.06 - 2 mm) accounts predominant portion (48 - 96%). These sand and gravel deposits are classified in the Unified Soil Classification System as:

SG1 : SW
SG2 : GP, SW, SP (can be mixed easily)
SG3 : GP-SP
SG4 : SW

The specific gravity is 2.62 - 2.81 and the organic content is as low as 0.2 - 0.5%. The property of these materials is evaluated being good and resembles to that of the proposed quarry rock (see Section 6.2).

6.2 Rock

The specific gravity, the bulk density, the moisture content, the water absorption, the chemical durability and the compressive strength were measured for the rock core samples from the bore holes in the alternative quarry sites. These test results are shown in Table 25.

The apparent specific gravity is 2.68 - 2.73 ($>$ 2.6). The oven-dried bulk density is 2.51 - 2.59. The moisture content is 0.2 - 0.5%. The water absorption is 0.4 - 0.8%. The weighted percentage loss by sodium sulphate is 1.5 - 4.2 ($<$ 10%). The compressive strength is 124,700 - 187,450 kPa (1,272 - 1,813 kgf/cm^2). These test results show that the rock quality of the tested specimens is adequate for concrete aggregates and rock embankment.

7. ZONING DESIGN OF ROCKFILL DAM

7.1 Design of Filter and Transition Zones

7.1.1 Filter design

A requirement of grain size distribution for the filter materials, which is specified in the Design Criteria for Dams (Japanese National Committee on Large Dams; Ref. H 4), is shown below:

i) (D_{15} Filter)/(D_{15} Core) $>$ 5

ii) (D_{15} Filter)/(D_{85} Core) $<$ 5

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

iv) If materials to be protected by filter contain coarse materials, (i) and (ii) shall be applied to the materials under 25 mm size.

v) Filter materials shall not be cohesive and not contain more than 5 percent fine passing the No. 200 (0.074 mm) sieve. If the materials to be protected are cohesive, these rules may be somewhat mitigated.

where,

D_{15} Filter : 15% grain size of filter materials

D_{15} Core : 15% grain size of materials protected by filter

D_{85} Core : 85% grain size of materials protected by filter

If these rules are applied to the sandstone originated soils of a grain size distribution of Borrow Pit B2 shown in Fig. 4, the 15% grain size of filter material is specified as follows:

i) (D_{15} Filter)/(D_{15} Core = 0.0003 mm) $>$ 5

$\therefore$ (D_{15} Filter) $>$ 0.0015 mm and;

ii) (D_{15} Filter)/(D_{85} Core = 4 mm) $<$ 5

$\therefore$ (D_{15} Filter) $<$ 20 mm

According to the particle size distribution of sand in the prospective borrow area as shown in Figs. 25 and 26, all sands can be utilized as filter materials.

Fine concrete aggregate produced by a crushing plant from quarried rocks is also suitable for filter material, because the standard grain distribution of the fine aggregate satisfies the above-mentioned criteria.

To secure the safety of dam, the filter design will be prescribed with the above criteria strictly.

7.1.2 Transition zone between filter and rock zones

The two principal requirements for a transition zone are that it must be more pervious than the protected filter, and that it must be fine enough to prevent particles of the protected filter from washing away through its voids.

The requirement of grain size distribution for transition materials is also applied the Design Criteria for Dams described in Subsection 7.1.1.

7.2 Design Values

The construction materials of the saddle dam embankment are classified into 4 zones, namely an impervious core as zone 1, a filter as zone 2, a transition as zone 3 and a rock as zone 4 for zoning design and stability analysis of dam body. The design values for each zone are determined as shown in Fig. 27 and Table 26.

The values for the zones 2, 3 and 4 are not supported by any test results but are assumed on conservative side based on experiences under similar condition.

To confirm the assumed design values, additional investigations should be done in the detailed design stage. Future investigation is described in Section 8.

8. FUTURE INVESTIGATION

Additional construction material survey should be done in the detailed design stage to confirm the assumed design values and estimated quantities of the investigated materials in the feasibility study. Items and quantities for the future investigation are proposed as follows:

(1) Test pitting

Borrow pit B-2	:	3 test pits, 2.0 m x 2.0 m x 5 m deep. Sampling, 2 points per each pit.

(2) Test trenching

Borrow pit B-2	:	1 trench, 50 m long, depth up to the top of weathered bedrock or 10 m deep. Sampling, 3-5 points.

(3) Reconnaissance for additional sand and gravel borrow pit	:	Along the Beris river and the Muda river other than the investigated areas in the feasibility study stage. Sampling, 3-5 points.

(4) Sampling and laboratory test

Laboratory tests for disturbed soil samples, and sand and gravel samples shall be done to clarify the physical and mechanical properties such as grain size distribution, field moisture content, maximum dry density, shear strength, permeability tests, etc.

(5) Test embankment

Test embankment for impervious core material should be done to find out a suitable embankment method and obtain a useful data to establish technical specifications for construction materials.

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TABLES

Table 1 REQUIRED VOLUME OF CONSTRUCTION MATERIALS

Item	Volume (m^3)
Concrete aggregate	60,000
Rock	80,000
Filter and transition	20,000
Core	25,000

Remark; The volume listed above is assumed on the basis of the proposed design and shown as-built condition.

Table 2 PRELIMINARY EVALUATION OF CONSTRUCTION MATERIALS (1/2)

Source	Location	Quality	Quantity
1. Quarry			
Q1	Within 500 m on the left bank (south) of the main damsite, north ridge of Bt. Damar.	Grit, conglomerate and sandstone, highly weathered or fractured to the depth of 40 m, the quality is not reliable for concrete aggregate, yield rate is less than 50%.	2,000,000 m^3
Q2	Within 500 m on the right bank (northeast) of the main damsite.	Grit, conglomerate and sandstone, quality seems to be much better than Q_1, yield rate of 60 - 80%.	300,000 - 400,000 m^3
Q3	On the left bank, 200 m downstream of the main damsite.	Conglomerate and sandstone, minor fractured to the depth of 20 m and moderately/highly weathered below 20 m.	200,000 m^3
2. Borrow-Pit for Cohesive Soil			
B1	The right bank along the Beris river, 0.3 - 1.5 km west (downstream) from the main damsite.	Yellowish-reddish residual soil with white clay or coarse sand (MH, CH)	400,000 m^3
B2	The right bank, 300 - 600 m apart from the Beris river, 1 - 1.5 km northwest from the saddle damsite.	Reddish residual soil (SM, CL)	300,000 m^3

Table 3 PRELIMINARY EVALUATION OF CONSTRUCTION MATERIALS (2/2)

Source	Location	Quality	Quantity
3. Borrow-Pit for Sand and Gravel			
SG1	0.5 - 1.0 km upstream (east) from the main damsite in the river channel.	Medium to coarse sand including minor gravel of less than 20 mm.	Less than 3,000 m^3, mostly submerged.
SG2	2.0 - 3.0 km upstream (southeast) from the main damsite, around Pantai Molek in the river channel.	Mixture of fine, medium and coarse sand including uniform gravel of less than 10 mm; gravel deposit below the sand layer of about 1 m.	10,000 m^3, mostly submerged.
SG3	At confluence of the Muda river and the Beris river, 2.8 km downstream (northwest) of the main damsite.	Mixture of medium and coarse sand.	1,000 m^3, mostly submerged.
SG4	4 - 4.5 km northwest from the main dam in the river channel of the Muda river around Kg. Tapang, 6.5 km by road distance.	Mixture of medium and coarse sand including minor gravel of less than 20 mm.	10,000 m^3 along the Muda river, mostly submerged.

Table 4 LABORATORY TEST ITEMS FOR COHESIVE SOIL, SAND, GRAVEL AND ROCK MATERIALS FOR BERIS DAM (1/2)

Test Item	Sample No.
COHESIVE SOIL	5 test pits X (1-2 Nos.)
A. Physical and Chemical Property Tests	
1) Grain Size Distribution	9
2) Specific Gravity	9
3) In situ Moisture Content	9
4) Atterberg's Limit	9
5) pH	5
6) Analysis of Clay Mineral Content (Kaolinite, Halloysite, $2H_2O$, Vermiculite, Illite, Monomorillonite, Fe_2O_3, Al_2O_3, SiO_2)	5
7) Soluble Salt Content (Ca, Mg, Na, K, H; milliequivalent/liter)	5
B. Mechanical Property Tests	
1) Compaction Test for Moisture Density Relation Using Rammer, Mold Diameter of 15 cm, Compaction Energy of 1E, 2E, 3E	1E = 8 2E = 8 3E = 8 (Total 24)
2) Grain Size Distribution after Compaction	3E = 8
3) *Permeability with Falling Head	1E = 3 2E = 3 3E = 3 (Total 9)
4) *Triaxial Compression ($\overline{CU}$) (after saturation and porepressure measurement, Ø 38 mm)	1E = 3 2E = 3 3E = 3 (Total 9)
5) *Consolidation (Ø 60 mm) (maximum consolidation pressure 600 kPa)	1E = 3 2E = 3 3E = 3 (Total 9)
6) *Swelling (Ø 60 mm) (each sample be saturated, swelled and consolidated until the volume be returned to the initial condition)	1E = 3 2E = 3 3E = 3 (Total 9)

Remark; *; Samples be compacted with OMC with energy of E (standard compaction energy), 2E & 3E

Table 5 LABORATORY TEST ITEMS FOR COHESIVE SOIL, SAND, GRAVEL AND ROCK MATERIALS FOR BERIS DAM (2/2)

Test Item	Sample No.
SAND AND GRAVEL	4 sites
Physical and Chemical Property Tests	
1) Grain Size Distribution	4 x 2 = 8
2) Specific Gravity	4 x 2 = 8
3) Organic Content (for sand samples only)	4 x 2 = 8
ROCK	2 - 3 sites
Physical and Chemical Property Tests	
1) Specific Gravity	4
2) Bulk Density (dried, natural and satulated conditions)	4
3) Moisture Contents & Water Absorption	4
4) Chemical Durability (Sodium Sulphate Method)	4
5) Compressive Strength	4

Table 6 SUMMARY OF LABORATORY TEST RESULTS FOR COHESIVE SOILS (1/2)

	Sample No.				
	BR1-1	BR1-2	BR3-1	BR3-2	BR3-3
Sample Depth (m)	5.0	1.9	1.5	3.0	5.0
Particle Size Distribution					
Maximum Size (mm)	10	10	10	10	10
Gravel (2 - 50 mm) (%)	5	9	8	21	6
Sand (0.06 - 2 mm) (%)	13	24	27	11	9
Silt (0.002 - 0.06 mm) (%)	32	31	24	30	36
Clay (< 0.002 mm) (%)	50	36	41	38	49
Consistency					
Liquid Limit (WL %)	81.0	69.6	79.3	97.5	93.9
Plasticity Index (Ip %)	48.9	40.8	36.2	53.2	66.4
Unified Soil Classification System	CH	CH	MH	MH	CH
Specific Gravity	2.65	2.74	2.57	2.55	2.59
Field Moisture Content (%)	28.24	20.86	24.76	29.14	29.15
pH Value	4.53	4.84	4.88	4.85	-
Proctor Compaction Test					
Max. Dry Density (γd Mg/m^3)	1.49	1.62	1.48	1.40	
Optimum Moisture Content (%)	28.0	22.0	25.6	29.4	
*Triaxial Compression ($\overline{CU}$)					
Cohesion C' (kg/cm^2)	1.03	0.37			
Internal Friction Angle Ø' (degree)	17°	26.5°			
Cohesion Ccu (kg/cm^2)	1.65	0.58			
Internal Friction Angle Øcu (degree)	5°	14°			
*Permeability					
Coefficient of Permeability (cm/s)	4.3×10^{-7}	1.8×10^{-6}			
*Consolidation					
Compression Index Cc	0.13	0.14			

Remark; *: Samples be compacted with OMC with energy of 1E.

Table 7 SUMMARY OF LABORATORY TEST RESULTS FOR COHESIVE SOILS (2/2)

	Sample No.			
	BR4-1	BR5-1	BR7-1	BR8-1
Sample Depth (m)	2.0	2.0	3.0	2.0
Particle Size Distribution				
Maximum Size (mm)	5	10	10	5
Gravel (2 - 50 mm) (%)	1	25	26	0
Sand (0.06 - 2 mm) (%)	15	28	40	42
Silt (0.002 - 0.06 mm) (%)	41	24	12	35
Clay (<0.002 mm) (%)	43	23	22	23
Consistency				
Liquid Limit (WL %)	69.4	54.2	71.1	36.2
Plasticity Index (Ip %)	48.9	28.3	35.1	14.0
Unified Soil Classification System	CH	SC	SM	CL
Specific Gravity	2.62	2.63	2.71	2.56
Field Moisture Content (%)	23.83	16.20	14.43	23.96
pH Value	-	-	4.92	-
Proctor Compaction Test				
Max. Dry Density (γd Mg/m^3)	1.53	1.83	1.73	1.64
Optimum Moisture Content (%)	25.4	14.9	17.0	19.6
*Triaxial Compression ($\overline{CU}$)				
Cohesion C' (kg/cm^2)			1.40	
Internal Friction Angle Ø' (degree)			17°	
Cohesion Ccu (kg/cm^2)			1.40	
Internal Friction Angle Øcu (degree)			12°	
*Permeability				
Coefficient of Permeability (cm/s)			3.7×10^{-5}	
*Consolidation				
Compression Index Cc			0.19	

Remark; *: Samples be compacted with OMC with energy of 1E.

Table 8 GROUP SYMBOLS AND DESCRIPTION OF UNIFIED SOIL CLASSIFICATION

Group Symbols	Typical Names
GW	Well graded gravels, gravel-sand mixtures, little or no fines
GP	Poorly graded gravels, gravel-sand mixtures, little or no fines
GM	Silty gravels, poorly graded gravel-sand-silt mixtures
GC	Clayey gravels, poorly graded gravel-sand-clay mixtures
SW	Well graded sands, gravelly sands, little or no fines
SP	Poorly graded sands, gravelly sands, little or no fines
SM	Silty sands, poorly graded sand-silt mixtures
SC	Clayey sands, poorly graded sand-clay mixtures
ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands with slight plasticity
CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
OL	Organic silts and organic silt-clays of low plasticity
MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts
CH	Inorganic clays of high plasticity, fat clays
OH	Organic clays of medium to high plasticity
Pt	Peat and other highly organic soils

Remark: Soils possessing characteristics of two groups are designated by combinations of symbols. For example, GW-GC, well graded gravel-sand mixture with clay binder.

Source: Earth Manual (Ref. H 2)

Table 9 CLAY MINERAL CONTENT

Unit: %

	BR1-1	BR1-2	BR3-1	BR3-2	BR7-1
Loss on Ignition	8.65	6.92	10.09	10.55	8.57
Alumina as Al_2O_3	6.91	8.32	10.13	11.01	7.81
Silica as SiO_2	83.81	83.92	78.94	77.55	82.79
Calcium Oxide as CaO	0.07	0.10	0.07	0.05	0.05
Magnesium Oxide as MgO	0.01	0.01	0.01	0.01	0.01
Iron Oxide as Fe_2O_3	0.48	0.67	0.60	0.65	0.70
Potassium Oxide as K_2O	Less than 0.01	Less than 0.01	Less than 0.01	Less than 0.01	Less than 0.01
Sodium Oxide as Na_2O	0.04	0.04	0.07	0.07	0.04
Sulphate as SO_3^{--}	0.01	0.01	0.03	0.04	0.01
Sulphate as SO_4^{--}	0.02	Less than 0.01	0.04	0.05	0.01
Chloride as Cl^-	Less than 0.01	Less than 0.01	Less than 0.01	Less than 0.01	Less than 0.01

Table 10 COMPOSITION OF MINERALS

Mineral Content	BR1-1	BR1-2	BR3-1	BR3-2	BR7-1
Estimated Percentage of clay	80%	15%	15%	90%	20%
Presence of Kaolinite	Present	Present	Present	Present	Present
Presence of Illite	Present	-	-	Present	Present
Ratio of Kaolinite to Illite	92:8	-	-	96:4	98:2

Table 11 SOLUBLE SALT CONTENT

Unit: meq

Soluble Salt	BR1-1	BR1-2	BR3-1	BR3-2	BR7-1
Calcium as Ca^{++}	34.93	49.9	34.93	24.95	24.95
Magnesium as Mg^{++}	8.23	8.23	8.23	8.23	8.23
Potassium as K^+	Less than 2.5	Less than 2.5	Less than 2.5	Less than 2.5	Less than 2.5
Sodium as Na^+	17.4	17.4	30.5	30.5	17.4

Remark: meq = milliequivalent per litter

Table 12 SUMMARY OF CONSOLIDATED-UNDRAINED TRIAXIAL COMPRESSION TEST WITH POREWATER PRESSURE MEASUREMENT (1/3)

Sample No.: BR1-1-1E, Compaction Energy: Standard compaction

	Specimen No.	1	2	3
Effective Consolidation Pressure	(kg/cm^2)	1.0	3.0	5.0
Peak Deviator Stress	(kg/cm^2)	3.905	4.241	4.690
Excess Porewater Pressure at Peak Deviator Stress	(kg/cm^2)	-0.350	1.136	2.600
A-coefficient at Peak Deviator Stress		-0.090	0.268	0.554
Axial Strain at Peak Deviator Stress	(%)	12.0	11.0	15.0

Angle of Internal Friction and Cohesion Intercept
Total stress : Øcu = 5°, Ccu = 1.65 kg/cm^2
Effective stress: Ø' = 17°, C' = 1.03 kg/cm^2

Sample No.: BR1-1-2E, Compaction Energy: 2 x Standard compaction

	Specimen No.	1	2	3
Effective Consolidation Pressure	(kg/cm^2)	1.0	3.0	5.0
Peak Deviator Stress	(kg/cm^2)	4.115	5.104	6.054
Excess Porewater Pressure at Peak Deviator Stress	(kg/cm^2)	-0.214	0.700	1.762
A-coefficient at Peak Deviator Stress		-0.052	0.137	0.291
Axial Strain at Peak Deviator Stress	(%)	15.0	17.0	14.0

Angle of Internal Friction and Cohesion Intercept
Total stress : Øcu = 11°, Ccu = 1.48 kg/cm^2
Effective stress: Ø' = 19°, C' = 1.02 kg/cm^2

Sample No.: BR1-1-3E, Compaction Energy: 3 x Standard compaction

	Specimen No.	1	2	3
Effective Consolidation Pressure	(kg/cm^2)	1.0	3.0	5.0
Peak Deviator Stress	(kg/cm^2)	4.994	5.821	6.871
Excess Porewater Pressure at Peak Deviator Stress	(kg/cm^2)	-0.612	0.540	1.682
A-coefficient at Peak Deviator Stress		-0.123	0.093	0.245
Axial Strain at Peak Deviator Stress	(%)	18.5	15.0	16.0

Angle of Internal Friction and Cohesion Intercept
Total stress : Øcu = 10°, Ccu = 1.92 kg/cm^2
Effective stress: Ø' = 19°, C' = 1.25 kg/cm^2

Table 13 SUMMARY OF CONSOLIDATED-UNDRAINED TRIAXIAL COMPRESSION TEST WITH POREWATER PRESSURE MEASUREMENT (2/3)

Sample No.: BR1-2-1E, Compaction Energy: Standard compaction

	Specimen No.	1	2	3
Effective Consolidation Pressure	(kg/cm^2)	1.0	3.0	5.0
Peak Deviator Stress	(kg/cm^2)	2.203	3.600	5.193
Excess Porewater Pressure at Peak Deviator Stress	(kg/cm^2)	0.348	1.530	2.706
A-coefficient at Peak Deviator Stress		0.158	0.425	0.521
Axial Strain at Peak Deviator Stress	(%)	19.0	18.0	10.0

Angle of Internal Friction and Cohesion Intercept

Total stress : Øcu = 14°, Ccu = 0.58 kg/cm^2

Effective stress: Ø' = 26.5°, C' = 0.37 kg/cm^2

Sample No. BR1-2-2E, Compaction Energy: 2 x Standard compaction

	Specimen No.	1	2	3
Effective Consolidation Pressure	(kg/cm^2)	1.0	3.0	5.0
Peak Deviator Stress	(kg/cm^2)	2.443	3.957	5.747
Excess Porewater Pressure at Peak Deviator Stress	(kg/cm^2)	0.196	1.468	2.544
A-coefficient at Peak Deviator Stress		0.080	0.371	0.443
Axial Strain at Peak Deviator Stress	(%)	16.0	16.0	14.8

Angle of Internal Friction and Cohesion Intercept

Total stress : Øcu = 16°, Ccu = 0.64 kg/cm^2

Effective stress: Ø' = 30°, C' = 0.25 kg/cm^2

Sample No. BR1-2-3E, Compaction Energy: 3 x Standard compaction

	Specimen No.	1	2	3
Effective Consolidation Pressure	(kg/cm^2)	1.0	3.0	5.0
Peak Deviator Stress	(kg/cm^2)	3.011	4.891	6.915
Excess Porewater Pressure at Peak Deviator Stress	(kg/cm^2)	-0.131	1.152	2.476
A-coefficient at Peak Deviator Stress		-0.044	0.236	0.358
Axial Strain at Peak Deviator Stress	(%)	14.5	15.5	11.5

Angle of Internal Friction and Cohesion Intercept

Total stress : Øcu = 19°, Ccu = 0.74 kg/cm^2

Effective stress: Ø' = 34°, C' = 0.03 kg/cm^2

Table 14 SUMMARY OF CONSOLIDATED-UNDRAINED TRIAXIAL COMPRESSION TEST WITH POREWATER PRESSURE MEASUREMENT (3/3)

Sample No.: BR7-1-1E, Compaction Energy: Standard compaction

	Specimen No.	1	2	3
Effective Consolidation Pressure	(kg/cm^2)	1.0	3.0	5.0
Peak Deviator Stress	(kg/cm^2)	4.079	5.102	6.367
Excess Porewater Pressure at Peak Deviator Stress	(kg/cm^2)	0.570	1.278	2.300
$\bar{A}$-coefficient at Peak Deviator Stress		0.140	0.250	0.361
Axial Strain at Peak Deviator Stress	(%)	12.5	15.5	13.0

Angle of Internal Friction and Cohesion Intercept

Total stress : ϕcu = 12°, Ccu = 1.4 kg/cm^2
Effective stress: ϕ' = 17°, C' = 1.4 kg/cm^2

Sample No.: BR7-1-2E, Compaction Energy: 2 x Standard compaction

	Specimen No.	1	2	3
Effective Consolidation Pressure	(kg/cm^2)	1.0	3.0	5.0
Peak Deviator Stress	(kg/cm^2	4.832	5.782	6.799
Excess Porewater Pressure at Peak Deviator Stress	(kg/cm^2)	0.440	1.488	2.330
$\bar{A}$-coefficient at Peak Deviator Stress		0.091	0.257	0.343
Axial Strain at Peak Deviator Stress	(%)	14.0	14.5	15.0

Angle of Internal Friction and Cohesion Intercept

Total stress : ϕcu = 11°, Ccu = 1.8 kg/cm^2
Effective stress: ϕ' = 19°, C' = 1.5 kg/cm^2

Sample No.: BR7-1-3E, Compaction Energy: 3 x Standard compaction

	Specimen No.	1	2	3
Effective Consolidation Pressure	(kg/cm^2)	1.0	3.0	5.0
Peak Deviator Stress	(kg/cm^2)	5.620	6.582	7.314
Excess Porewater Pressure at Peak Deviator Stress	(kg/cm^2)	0.024	1.156	2.238
$\bar{A}$-coefficient at Peak Deviator Stress		0.004	0.176	0.306
Axial Strain at Peak Deviator Stress	(%)	14.0	15.0	14.5

Angle of Internal Friction and Cohesion Intercept

Total stress : ϕcu = 11°, Ccu = 2.1 kg/cm^2
Effective stress: ϕ' = 20°, C' = 1.6 kg/cm^2

Table 15 CONSOLIDATION TEST RESULTS (1/5)

BR1-1-1E

INITIAL HEIGHT OF SPECIMEN = 2.000 CM DIAMETER OF SPECIMEN = 6.000 CM
SPECIFIC GRAVITY = 2.629 DRY WEIGHT OF SPECIMEN = 87.149 GRAMS SOLID HEIGHT OF SPECIMEN = 1.172 CM

PRESSURE KG/CM2	PRESS. INCREMENT KG/CM2	CHG. IN HEIGHT *E-3 CM	HEIGHT CM	AVERAGE HEIGHT CM	STRAIN %	MV CM2/KG	VOLUME RATIO	V D RATIO
0.000	.050	2.5	2.000	1.999	.13	.250E-01	1.706	.706
.050	.050	4.7	1.997	1.995	.24	.471E-01	1.704	.704
.100	.100	13.0	1.993	1.986	.65	.654E-01	1.700	.700
.200	.200	24.7	1.980	1.967	1.26	.628E-01	1.689	.689
.400	.400	34.7	1.955	1.938	1.79	.448E-01	1.668	.668
.800	.800	41.1	1.920	1.900	2.16	.270E-01	1.638	.638
1.600	1.600	45.4	1.879	1.857	2.45	.153E-01	1.603	.603
3.200	3.200	47.0	1.834	1.810	2.60	.811E-02	1.564	.564
6.400	6.400	39.9	1.787	1.767	2.26	.353E-02	1.524	.524
12.800			1.747				1.490	.490

PRESSURE KG/CM2	AVERAGE PRESSURE KG/CM2	T90 MIN	CV CM2/MIN	CV CM2/DAY	CV M2/YEAR	PRIMARY COMPRESS. *E-3 CM	PR.COMP. RATIO	COEF. OF PERMEABILITY CM/MIN
0.000	.025	—	—	—	—	—	—	—
.050	.075	—	—	—	—	—	—	—
.100	.150	.7	.119E+01	.172E+04	.628E+02	5.1	.393	.782E-04
.200	.300	.6	.137E+01	.197E+04	.719E+02	11.1	.450	.859E-04
.400	.600	.5	.159E+01	.229E+04	.837E+02	14.0	.403	.713E-04
.800	1.200	.6	.128E+01	.184E+04	.670E+02	15.0	.365	.345E-04
1.600	2.400	.6	.122E+01	.175E+04	.640E+02	16.2	.357	.186E-04
3.200	4.800	2.7	.257E+00	.371E+03	.135E+02	19.6	.416	.209E-05
6.400	9.600	5.6	.118E+00	.170E+03	.621E+01	25.4	.638	.417E-06
12.800								

REBOUND

P	6.400	3.200	1.600	.800	.400	.200	.100	.050
H	1.752	1.767	1.785	1.801	1.816	1.828	1.840	1.849
E	.494	.507	.523	.536	.549	.559	.570	.577

BR1-1-2E

INITIAL HEIGHT OF SPECIMEN = 2.000 CM DIAMETER OF SPECIMEN = 6.000 CM
SPECIFIC GRAVITY = 2.629 DRY WEIGHT OF SPECIMEN = 91.781 GRAMS SOLID HEIGHT OF SPECIMEN = 1.235 CM

PRESSURE KG/CM2	PRESS. INCREMENT KG/CM2	CHG. IN HEIGHT *E-3 CM	HEIGHT CM	AVERAGE HEIGHT CM	STRAIN %	MV CM2/KG	VOLUME RATIO	VOID RATIO
0.000	.050	9.2	2.000	1.995	.46	.922E-01	1.620	.620
.050	.050	6.9	1.991	1.987	.35	.694E-01	1.612	.612
.100	.100	10.7	1.984	1.979	.54	.541E-01	1.607	.607
.200	.200	14.2	1.973	1.966	.72	.361E-01	1.598	.598
.400	.400	22.0	1.959	1.948	1.13	.282E-01	1.587	.587
.800	.800	24.2	1.937	1.925	1.26	.157E-01	1.569	.569
1.600	1.600	38.6	1.913	1.894	2.04	.127E-01	1.549	.549
3.200	3.200	42.4	1.874	1.853	2.29	.715E-02	1.518	.518
6.400	6.400	52.7	1.832	1.805	2.92	.456E-02	1.484	.484
12.800			1.779				1.441	.441

PRESSURE KG/CM2	AVERAGE PRESSURE KG/CM2	T90 MIN	CV CM2/MIN	CV CM2/DAY	CV M2/YEAR	PRIMARY COMPRESS. *E-3 CM	PR.COMP. RATIO	COEF. OF PERMEABILITY CM/MIN
0.000	.025	1.2	.703E+00	.101E+04	.370E+02	2.9	.314	.649E-04
.050	.075	.9	.930E+00	.134E+04	.489E+02	3.3	.483	.646E-04
.100	.150	.9	.922E+00	.133E+04	.485E+02	3.2	.301	.499E-04
.200	.300	.6	.137E+01	.197E+04	.718E+02	5.0	.352	.493E-04
.400	.600	.5	.161E+01	.232E+04	.846E+02	7.0	.318	.454E-04
.800	1.200	.6	.131E+01	.189E+04	.688E+02	8.8	.363	.206E-04
1.600	2.400	.4	.190E+01	.274E+04	.999E+02	10.2	.265	.242E-04
3.200	4.800	1.0	.728E+00	.105E+04	.383E+02	11.8	.278	.521E-05
6.400	9.600	1.2	.576E+00	.829E+03	.303E+02	16.8	.318	.263E-05
12.800								

REBOUND

P	6.400	3.200	1.600	.800	.400	.200	.100	.050
H	1.785	1.797	1.813	1.829	1.843	1.857	1.868	1.876
E	.445	.455	.469	.481	.493	.504	.513	.519

Table 16 CONSOLIDATION TEST RESULTS (2/5)

BR1-1-3E

INITIAL HEIGHT OF SPECIMEN = 2.000 CM DIAMETER OF SPECIMEN = 6.000 CM
SPECIFIC GRAVITY = 2.629 DRY WEIGHT OF SPECIMEN = 96.110 GRAMS SOLID HEIGHT OF SPECIMEN = 1.293 CM

PRESSURE KG/CM2	PRESS. INCREMENT KG/CM2	CHG. IN HEIGHT *E-3 CM	HEIGHT CM	AVERAGE HEIGHT CM	STRAIN %	MV CM2/KG	VOLUME RATIO	VOID RATIO
0.000			2.000				1.547	.547
	.050	4.9		1.998	.25	.491E-01		
.050			1.995				1.543	.543
	.050	3.9		1.993	.20	.391E-01		
.100			1.991				1.540	.540
	.100	6.4		1.988	.32	.322E-01		
.200			1.985				1.535	.535
	.200	19.4		1.975	.98	.491E-01		
.400			1.965				1.520	.520
	.400	31.1		1.950	1.59	.399E-01		
.800			1.934				1.496	.496
	.800	37.5		1.916	1.96	.245E-01		
1.600			1.897				1.467	.467
	1.600	37.5		1.878	2.00	.125E-01		
3.200			1.859				1.438	.438
	3.200	53.0		1.833	2.89	.904E-02		
6.400			1.806				1.397	.397
	6.400	48.3		1.782	2.71	.423E-02		
12.800			1.758				1.360	.360

PRESSURE KG/CM2	AVERAGE PRESSURE KG/CM2	T90 MIN	CV CM2/MIN	CV CM2/DAY	CV M2/YEAR	PRIMARY COMPRESS. *E-3 CM	PR.COMP. RATIO	COEF. OF PERMEABILITY CM/MIN
0.000								
	.025	.5	.169E+01	.244E+04	.889E+02	1.6	.317	.830E-04
.050								
	.075	2.0	.421E+00	.606E+03	.221E+02	1.2	.313	.165E-04
.100								
	.150	2.0	.419E+00	.603E+03	.220E+02	2.3	.365	.135E-04
.200								
	.300	2.5	.331E+00	.476E+03	.174E+02	6.9	.355	.162E-04
.400								
	.600	1.6	.504E+00	.725E+03	.265E+02	9.1	.293	.201E-04
.800								
	1.200	2.0	.389E+00	.560E+03	.204E+02	12.3	.329	.952E-05
1.600								
	2.400	2.2	.340E+00	.489E+03	.179E+02	14.4	.385	.424E-05
3.200								
	4.800	1.4	.509E+00	.732E+03	.267E+02	13.9	.262	.460E-05
6.400								
	9.600	1.8	.374E+00	.539E+03	.197E+02	18.4	.382	.158E-05
12.800								

REBOUND

P	6.400	3.200	1.600	.800	.400	.200	.100	.050
H	1.765	1.771	1.778	1.784	1.792	1.797	1.806	1.813
E	.365	.370	.375	.380	.386	.390	.397	.402

BR1-2-1E

INITIAL HEIGHT OF SPECIMEN = 2.000 CM DIAMETER OF SPECIMEN = 6.000 CM
SPECIFIC GRAVITY = 2.639 DRY WEIGHT OF SPECIMEN = 91.620 GRAMS SOLID HEIGHT OF SPECIMEN = 1.228 CM

PRESSURE KG/CM2	PRESS. INCREMENT KG/CM2	CHG. IN HEIGHT *E-3 CM	HEIGHT CM	AVERAGE HEIGHT CM	STRAIN %	MV CM2/KG	VOLUME RATIO	VOID RATIO
0.000			2.000				1.629	.629
	.050	.8		2.000	.04	.800E-02		
.050			1.999				1.628	.628
	.050	2.9		1.998	.15	.290E-01		
.100			1.996				1.626	.626
	.100	9.5		1.992	.48	.477E-01		
.200			1.987				1.618	.618
	.200	15.3		1.979	.77	.387E-01		
.400			1.972				1.606	.606
	.400	28.0		1.958	1.43	.358E-01		
.800			1.944				1.583	.583
	.800	37.4		1.925	1.94	.243E-01		
1.600			1.906				1.552	.552
	1.600	51.4		1.880	2.73	.171E-01		
3.200			1.855				1.510	.510
	3.200	56.5		1.826	3.09	.867E-02		
6.400			1.798				1.464	.464
	6.400	43.3		1.777	2.44	.381E-02		
12.800			1.755				1.429	.429

PRESSURE KG/CM2	AVERAGE PRESSURE KG/CM2	T90 MIN	CV CM2/MIN	CV CM2/DAY	CV M2/YEAR	PRIMARY COMPRESS. *E-3 CM	PR.COMP. RATIO	COEF. OF PERMEABILITY CM/MIN
0.000								
	.025	—	—	—	—	—	—	—
.050								
	.075	—	—	—	—	—	—	—
.100								
	.150	.5	.168E+01	.242E+04	.884E+02	3.0	.316	.802E-04
.200								
	.300	.5	.166E+01	.239E+04	.873E+02	3.9	.254	.642E-04
.400								
	.600	.6	.135E+01	.195E+04	.712E+02	7.1	.254	.484E-04
.800								
	1.200	.6	.131E+01	.189E+04	.688E+02	9.6	.255	.318E-04
1.600								
	2.400	.6	.125E+01	.180E+04	.657E+02	12.1	.236	.213E-04
3.200								
	4.800	.9	.786E+00	.113E+04	.413E+02	12.2	.216	.760E-05
6.400								
	9.600	1.0	.669E+00	.964E+03	.352E+02	9.7	.223	.255E-05
12.800								

REBOUND

P	6.400	3.200	1.600	.800	.400	.200	.100	.050
H	1.758	1.764	1.772	1.779	1.788	1.793	1.798	1.801
E	.431	.437	.443	.449	.456	.460	.464	.466

Table 17 CONSOLIDATION TEST RESULTS (3/5)

BR1-2-2E

INITIAL HEIGHT OF SPECIMEN = 2.000 CM DIAMETER OF SPECIMEN = 6.000 CM
SPECIFIC GRAVITY = 2.639 DRY WEIGHT OF SPECIMEN = 92.549 GRAMS SOLID HEIGHT OF SPECIMEN = 1.240 CM

PRESSURE KG/CM2	PRESS. INCREMENT KG/CM2	CHG. IN HEIGHT *E-3 CM	HEIGHT CM	AVERAGE HEIGHT CM	STRAIN %	MV CM2/KG	VOLUME RATIO	VOID RATIO
0.000	.050	9.2	2.000	1.995	.46	.922E-01	1.612	.612
.050	.050	6.0	1.991	1.988	.30	.604E-01	1.605	.605
.100	.100	10.0	1.985	1.980	.51	.505E-01	1.600	.600
.200	.200	13.6	1.975	1.968	.69	.346E-01	1.592	.592
.400	.400	25.0	1.961	1.949	1.28	.321E-01	1.581	.581
.800	.800	32.0	1.936	1.920	1.67	.208E-01	1.561	.561
1.600	1.600	47.0	1.904	1.881	2.50	.156E-01	1.535	.535
3.200	3.200	56.4	1.857	1.829	3.08	.964E-02	1.497	.497
6.400	6.400	54.7	1.801	1.773	3.08	.482E-02	1.452	.452
12.800			1.746				1.408	.408

PRESSURE KG/CM2	AVERAGE PRESSURE KG/CM2	T90 MIN	CV CM2/MIN	CV CM2/DAY	CV M2/YEAR	PRIMARY COMPRESS. *E-3 CM	PR.COMP. RATIO	COEF. OF PERMEABILITY CM/MIN
0.000	.025	.5	.169E+01	.243E+04	.887E+02	2.0	.217	.156E-03
.050	.075	.5	.168E+01	.241E+04	.881E+02	1.6	.259	.101E-03
.100	.150	.5	.166E+01	.239E+04	.874E+02	3.2	.322	.839E-04
.200	.300	.5	.164E+01	.236E+04	.863E+02	3.4	.253	.567E-04
.400	.600	.5	.161E+01	.232E+04	.846E+02	6.8	.271	.516E-04
.800	1.200	.5	.156E+01	.225E+04	.822E+02	9.1	.285	.326E-04
1.600	2.400	.6	.125E+01	.180E+04	.657E+02	10.3	.220	.195E-04
3.200	4.800	.7	.101E+01	.146E+04	.533E+02	13.3	.236	.976E-05
6.400	9.600	.8	.833E+00	.120E+04	.438E+02	16.4	.301	.402E-05
12.800								

REBOUND

P	6.400	3.200	1.600	.800	.400	.200	.100	.050
H	1.749	1.756	1.763	1.770	1.775	1.780	1.784	1.787
E	.410	.416	.421	.427	.431	.435	.438	.441

BR1-2-3E

INITIAL HEIGHT OF SPECIMEN = 2.000 CM DIAMETER OF SPECIMEN = 6.000 CM
SPECIFIC GRAVITY = 2.639 DRY WEIGHT OF SPECIMEN = 93.590 GRAMS SOLID HEIGHT OF SPECIMEN = 1.254 CM

PRESSURE KG/CM2	PRESS. INCREMENT KG/CM2	CHG. IN HEIGHT *E-3 CM	HEIGHT CM	AVERAGE HEIGHT CM	STRAIN %	MV CM2/KG	VOLUME RATIO	VOID RATIO
0.000	.050	2.0	2.000	1.999	.10	.200E-01	1.595	.595
.050	.050	2.1	1.998	1.997	.11	.210E-01	1.593	.593
.100	.100	4.7	1.996	1.994	.24	.236E-01	1.591	.591
.200	.200	10.7	1.991	1.986	.54	.269E-01	1.588	.588
.400	.400	18.7	1.980	1.971	.95	.237E-01	1.579	.579
.800	.800	30.6	1.962	1.947	1.57	.197E-01	1.564	.564
1.600	1.600	37.2	1.931	1.913	1.94	.122E-01	1.540	.540
3.200	3.200	45.0	1.894	1.872	2.40	.751E-02	1.510	.510
6.400	6.400	64.0	1.849	1.817	3.52	.550E-02	1.474	.474
12.800			1.785				1.423	.423

PRESSURE KG/CM2	AVERAGE PRESSURE KG/CM2	T90 MIN	CV CM2/MIN	CV CM2/MIN	CV M2/YEAR	PRIMARY COMPRESS. *E-3 CM	PR.COMP. RATIO	COEF. OF PERMEABILITY CM/MIN
0.000	.025	—	—	—	—	—	—	—
.050	.075	—	—	—	—	—	—	—
.100	.150	2.0	.421E+00	.607E+03	.221E+02	.9	.189	.993E-05
.200	.300	2.0	.418E+00	.602E+03	.220E+02	2.3	.218	.113E-04
.400	.600	1.8	.458E+00	.659E+03	.241E+02	3.7	.196	.109E-04
.800	1.200	2.7	.297E+00	.428E+03	.156E+02	5.1	.167	.585E-05
1.600	2.400	2.0	.388E+00	.558E+03	.204E+02	6.2	.167	.471E-05
3.200	4.800	2.0	.371E+00	.535E+03	.195E+02	7.8	.173	.279E-05
6.400	9.600	2.0	.350E+00	.504E+03	.184E+02	10.8	.168	.193E-05
12.800								

REBOUND

P	6.400	3.200	1.600	.800	.400	.200	.100	.050
H	1.787	1.794	1.802	1.810	1.819	1.824	1.827	1.831
E	.425	.431	.437	.443	.450	.454	.457	.459

Table 18 CONSOLIDATION TEST RESULTS (4/5)

BR7-1-1E

INITIAL HEIGHT OF SPECIMEN = 2.000 CM DIAMETER OF SPECIMEN = 6.000 CM
SPECIFIC GRAVITY = 2.644 DRY WEIGHT OF SPECIMEN = 83.730 GRAMS SOLID HEIGHT OF SPECIMEN = 1.120 CM

PRESSURE KG/CM2	PRESS. INCREMENT KG/CM2	CHG. IN HEIGHT *E-3 CM	HEIGHT CM	AVERAGE HEIGHT CM	STRAIN %	MV CM2/KG	VOLUME RATIO	VOID RATIO
0.000	.050	5.2	2.000	1.997	.26	.521E-01	1.786	.786
.050	.050	2.6	1.995	1.993	.13	.261E-01	1.781	.781
.100	.100	11.0	1.992	1.987	.55	.554E-01	1.779	.779
.200	.200	20.2	1.981	1.971	1.02	.512E-01	1.769	.769
.400	.400	34.5	1.961	1.944	1.77	.444E-01	1.751	.751
.800	.800	36.3	1.926	1.908	1.90	.238E-01	1.720	.720
1.600	1.600	50.7	1.890	1.865	2.72	.170E-01	1.688	.688
3.200	3.200	66.5	1.839	1.806	3.68	.115E-01	1.642	.642
6.400	6.400	65.0	1.773	1.740	3.73	.584E-02	1.583	.583
12.800			1.708				1.525	.525

PRESSURE KG/CM2	AVERAGE PRESSURE KG/CM2	T90 MIN	CV CM2/MIN	CV CM2/DAY	CV M2/YEAR	PRIMARY COMPRESS. *E-3 CM	PR.COMP. RATIO	COEF. OF PERMEABILITY CM/MIN
0.000	.025	—	—	—	—	—	—	—
.050	.075	—	—	—	—	—	—	—
.100	.150	—	—	—	—	—	—	—
.200	.300	.3	.275E+01	.395E+04	.144E+03	11.0	.545	.141E-03
.400	.600	.3	.267E+01	.384E+04	.140E+03	14.2	.412	.118E-03
.800	1.200	.3	.257E+01	.371E+04	.135E+03	11.7	.321	.612E-04
1.600	2.400	.3	.246E+01	.354E+04	.129E+03	16.0	.316	.418E-04
3.200	4.800	.3	.231E+01	.332E+04	.121E+03	19.0	.286	.265E-04
6.400	9.600	.3	.214E+01	.308E+04	.113E+03	20.0	.308	.125E-04
12.800								

REBOUND

P	6.400	3.200	1.600	.800	.400	.200	.100	.050
H	1.711	1.718	1.725	1.732	1.741	1.745	1.751	1.755
E	.528	.534	.541	.546	.554	.558	.564	.567

BR7-1-2E

INITIAL HEIGHT OF SPECIMEN = 2.000 CM DIAMETER OF SPECIMEN = 6.000 CM
SPECIFIC GRAVITY = 2.644 DRY WEIGHT OF SPECIMEN = 94.185 GRAMS SOLID HEIGHT OF SPECIMEN = 1.260 CM

PRESSURE KG/CM2	PRESS. INCREMENT KG/CM2	CHG. IN HEIGHT *E-3 CM	HEIGHT CM	AVERAGE HEIGHT CM	STRAIN %	MV CM2/KG	VOLUME RATIO	VOID RATIO
0.000	.050	1.5	2.000	1.999	.08	.150E-01	1.587	.587
.050	.050	1.6	1.998	1.998	.08	.160E-01	1.586	.586
.100	.100	7.4	1.997	1.993	.37	.371E-01	1.585	.585
.200	.200	9.6	1.990	1.985	.48	.242E-01	1.579	.579
.400	.400	20.6	1.980	1.970	1.05	.261E-01	1.572	.572
.800	.800	30.8	1.959	1.944	1.58	.198E-01	1.555	.555
1.600	1.600	47.1	1.929	1.905	2.47	.155E-01	1.531	.531
3.200	3.200	46.0	1.881	1.858	2.48	.774E-02	1.493	.493
6.400	6.400	39.2	1.835	1.816	2.16	.337E-02	1.457	.457
12.800			1.796				1.426	.426

PRESSURE KG/CM2	AVERAGE PRESSURE KG/CM2	T90 MIN	CV CM2/MIN	CV CM2/DAY	CV M2/YEAR	PRIMARY COMPRESS. *E-3 CM	PR.COMP. RATIO	COEF. OF PERMEABILITY CM/MIN
0.000	.025	—	—	—	—	—	—	—
.050	.075	—	—	—	—	—	—	—
.100	.150	.7	.120E+01	.173E+04	.632E+02	1.6	.210	.447E-04
.200	.300	.5	.167E+01	.241E+04	.878E+02	2.3	.243	.404E-04
.400	.600	.6	.137E+01	.197E+04	.720E+02	4.2	.205	.358E-04
.800	1.200	.5	.160E+01	.231E+04	.842E+02	7.0	.227	.317E-04
1.600	2.400	.6	.128E+01	.185E+04	.674E+02	10.2	.217	.198E-04
3.200	4.800	.7	.105E+01	.151E+04	.550E+02	10.3	.225	.809E-05
6.400	9.600	.6	.116E+01	.168E+04	.612E+02	8.2	.210	.393E-05
12.800								

REBOUND

P	6.400	3.200	1.600	.800	.400	.200	.100	.050
H	1.799	1.806	1.815	1.822	1.829	1.834	1.847	1.854
E	.428	.433	.440	.446	.452	.456	.466	.471

Table 19 CONSOLIDATION TEST RESULTS (5/5)

BR7-1-3E

INITIAL HEIGHT OF SPECIMEN = 2.000 CM DIAMETER OF SPECIMEN = 6.000 CM
SPECIFIC GRAVITY = 2.644 DRY WEIGHT OF SPECIMEN = 100.960 GRAMS SOLID HEIGHT OF SPECIMEN = 1.351 CM

PRESSURE KG/CM2	PRESS. INCREMENT KG/CM2	CHG. IN HEIGHT *E-3 CM	HEIGHT CM	AVERAGE HEIGHT CM	STRAIN %	MV CM2/KG	VOLUME RATIO	VOID RATIO
0.000			2.000				1.481	.481
	.050	3.0		1.998	.15	.300E-01		
.050			1.997				1.479	.479
	.050	4.0		1.995	.20	.401E-01		
.100			1.993				1.476	.476
	.100	7.2		1.989	.36	.362E-01		
.200			1.986				1.470	.470
	.200	11.2		1.980	.57	.283E-01		
.400			1.975				1.462	.462
	.400	19.8		1.965	1.01	.252E-01		
.800			1.955				1.447	.447
	.800	21.8		1.944	1.12	.140E-01		
1.600			1.933				1.431	.431
	1.600	31.1		1.917	1.62	.101E-01		
3.200			1.902				1.408	.408
	3.200	39.9		1.882	2.12	.663E-02		
6.400			1.862				1.379	.379
	6.400	45.0		1.840	2.45	.382E-02		
12.800			1.817				1.345	.345

PRESSURE KG/CM2	AVERAGE PRESSURE KG/CM2	T90 MIN	CV CM2/MIN	CV CM2/DAY	CV M2/YEAR	PRIMARY COMPRESS. *E-3 CM	PR.COMP. RATIO	COEF. OF PERMEABILITY CM/MIN
0.000								
	.025	—	—	—	—	—	—	—
.050								
	.075	—	—	—	—	—	—	—
.100								
	.150	2.1	.400E+00	.575E+03	.210E+02	1.6	.216	.145E-04
.200								
	.300	2.1	.396E+00	.570E+03	.208E+02	2.2	.198	.112E-04
.400								
	.600	2.1	.390E+00	.561E+03	.205E+02	3.6	.180	.982E-05
.800								
	1.200	1.8	.445E+00	.641E+03	.234E+02	4.4	.204	.624E-05
1.600								
	2.400	2.2	.354E+00	.510E+03	.186E+02	5.4	.175	.359E-05
3.200								
	4.800	1.6	.469E+00	.676E+03	.247E+02	6.1	.153	.311E-05
6.400								
	9.600	1.0	.717E+00	.103E+04	.377E+02	8.9	.198	.274E-05
12.800								

REBOUND

P	6.400	3.200	1.600	.800	.400	.200	.100	.050
H	1.821	1.824	1.837	1.845	1.854	1.860	1.862	1.865
E	.348	.350	.360	.366	.373	.377	.379	.381

Table 20 VOID RATIO AND COMPRESSIBILITY OF COHESIVE SOILS

Borrow Pit	Sample No.	Compaction Energy	Void Ratio				Compressibility (%)		
			Initial	2 kg/cm2	4 kg/cm2	6 kg/cm2	2 kg/cm2	4 kg/cm2	6 kg/cm2
B1	BR1-1-1E	1E	0.706	0.588	0.552	0.530	6.9	9.0	10.3
	BR1-1-2E	2E	0.620	0.540	0.507	0.486	4.9	7.0	8.3
	BR1-1-3E	3E	0.547	0.457	0.422	0.398	5.8	8.1	9.6
	BR1-2-1E	1E	0.629	0.540	0.495	0.471	5.5	8.2	9.7
	BR1-2-2E	2E	0.612	0.523	0.483	0.457	5.5	8.0	9.6
	BR1-2-3E	3E	0.595	0.531	0.498	0.477	4.0	6.1	7.4
B2	BR7-1-1E	1E	0.786	0.676	0.623	0.576	6.3	9.1	11.8
	BR7-1-2E	2E	0.587	0.518	0.483	0.461	4.3	6.6	7.9
	BR7-1-3E	3E	0.481	0.422	0.398	0.381	4.0	5.6	6.8

Table 21 COMPACTION ENERGY - MAX DRY DENSITY - OMC RELATIONSHIP

Borrow Pit	Sample	1E MDD (Mg/m^3)	1E OMC (%)	2E MDD (Mg/m^3)	2E OMC (%)	3E MDD (Mg/m^3)	3E OMC (%)
B1	BR1-1	1.49	28.0	1.60	22.0	1.61	21.6
	BR1-2	1.62	22.0	1.72	20.2	1.75	17.9
	BR3-1	1.48	25.6	1.47	25.0	1.51	26.0
	BR3-2	1.40	29.4	1.52	24.5	1.49	28.8
	BR4-1	1.53	25.4	1.56	21.8	1.58	24.0
B2	BR5-1	1.83	14.9	1.87	11.8	1.91	11.6
	BR7-1	1.73	17.0	1.87	12.7	1.83	14.4
Other Pit	BR8-1	1.64	19.6	1.74	15.3	1.75	15.8

Remarks: (1) MDD = Maximum Dry Density
OMC = Optimum Moisture Content

(2) 1E = Standard compaction energy
2E = Twice of the standard compaction energy
3E = Three times of the standard compaction energy

Table 22 COMPACTION ENERGY
- PERMEABILITY RELATIONSHIP

Unit: cm/s

Samples	1E	2E	3E
BR1-1	4.26×10^{-7}	5.88×10^{-8}	3.15×10^{-8}
BR1-2	1.75×10^{-6}	2.82×10^{-8}	3.80×10^{-8}
BR7-1	3.65×10^{-5}	7.58×10^{-7}	1.67×10^{-6}

Remarks: 1E = Standard compaction energy
2E = Twice of the standard compaction energy
3E = Three times of the standard compaction energy

Table 23 SUMMARY OF PROPERTY TEST RESULTS FOR SAND AND GRAVEL (1/2)

Description	Sample No. SG1-1	SG2-1	SG2-2	SG2-3
Sample Depth (m)	-	-	-	-
Particle Size Distribution				
Maximum Size (mm)	-	-	-	-
Gravel (2 - 50 mm) (%)	3	52	13	1
Sand (0.06 - 2 mm) (%)	96	48	87	96
Silt (0.002 - 0.06 mm) (%)	1	-	-	3
Clay (<0.002 mm) (%)	0	0	0	0
Unified Soil Classification System	SW	GP	SW	SP
Specific Gravity	2.62	2.69	2.81	2.64
Field Moisture Content (%)	-	-	-	-
Organic Content (%)	0.29	0.26	0.21	0.39

Table 24 SUMMARY OF PROPERTY TEST RESULTS FOR SAND AND GRAVEL (2/2)

Description	Sample No. SG3-1	SG4-1	SG1-2	SG1-3
Sample Depth (m)	-	-	-	-
Particle Size Distribution				
Maximum Size (mm)	-	-	-	-
Gravel (2 - 50 mm) (%)	49	25	24	7
Sand (0.06 - 2 mm) (%)	48	75	76	93
Silt (0.002 - 0.06 mm) (%)	3	0	0	0
Clay (<0.002 mm) (%)	0	0	0	0
Unified Soil Classification System	GP-SP	SW	SW	SW
Specific Gravity	2.72	2.69	2.79	2.77
Field Moisture Content (%)	-	-	-	-
Organic Content (%)	0.41	0.54	0.23	0.24

Table 25 SUMMARY OF ROCK PROPERTY TEST RESULTS

Quarry Site	Quarry 1	Quarry 3	Quarry 2	Quarry 2
Bore Hole No. 1/	BQ 3	BQ 4	BQ 5	BQ 6
Sample Depth (m)	9.4-9.7	11.9-12.0	19.0-19.3	27.7-28.0
1) Specific Gravity	2.70	2.68	2.72	2.73
2) Bulk Density (Mg/m^3)				
a) Oven-dried	2.59	2.51	2.55	2.57
b) Natural	2.60	2.52	2.56	2.58
c) Saturated	2.61	2.54	2.58	2.59
3) Moisture Content (% by dry mass)	0.2	0.5	0.4	0.3
4) Water Absorption (% by dry weight)	0.4	0.8	0.6	0.4
5) Soundness by Sodium Sulphate (5 cycles) ASTM C88				
Sample Depth (m)	9.7-10.0	11.8-11.9	18.8-18.9	28.1-28.2
Weighted Percentage Loss (%)	1.5	4.2	3.8	2.5
6) Unconfined Compression				
Sample Depth (m)	9.4-9.6	12.4-12.2	18.3-18.8	27.3-27.7
Specimen Length (mm)	96.9	98.8	101.0	82.5
Specimen Diameter (mm)	49.3	49.7	52.5	52.1
Rate of Loading (kN/min)	16.6	12.7	16.9	19.0
Density (kg/m^3)	2,600	2,520	2,560	2,580
Measured Compressive Strength (kPa)	156,050	124,700	187,450	169,750
Computed Compressive Strength (kPa)*	155,700	124,600	186,550	164,550
E = Young's Modulus ($x\ 10^6$ kPa)	(67.6)	101.1***	120.0***	111.1**

Remarks:
*: Computed strength of an equivalent L/D = 2 specimens
**: Tangent modulus at some percent of ultimate strength
***: Average slope of linear portion
1/: See Fig. 1.

Table 26 DESIGN VALUES

Design Value	Zone 1 Impervious Core	Zone 2 Filter	Zone 3 Transition	Zone 4 Rock
1) Dry Density (t/m^3)	1.5	1.8	1.9	1.9
2) Wet Density (t/m^3)	1.9	1.9	2.0	2.0
3) Saturated Density (t/m^3)	1.94	2.0	2.1	2.2
4) Cohesion, C' (t/m^2)	5.0	-	-	-
5) Internal Friction Angle Ø' (degree)	22	36	36	40
6) Coefficient of Permeability (cm/sec)	1×10^{-6}	-	-	-

Remark: Ø' and C' are the values in effective stress.

FIGURES

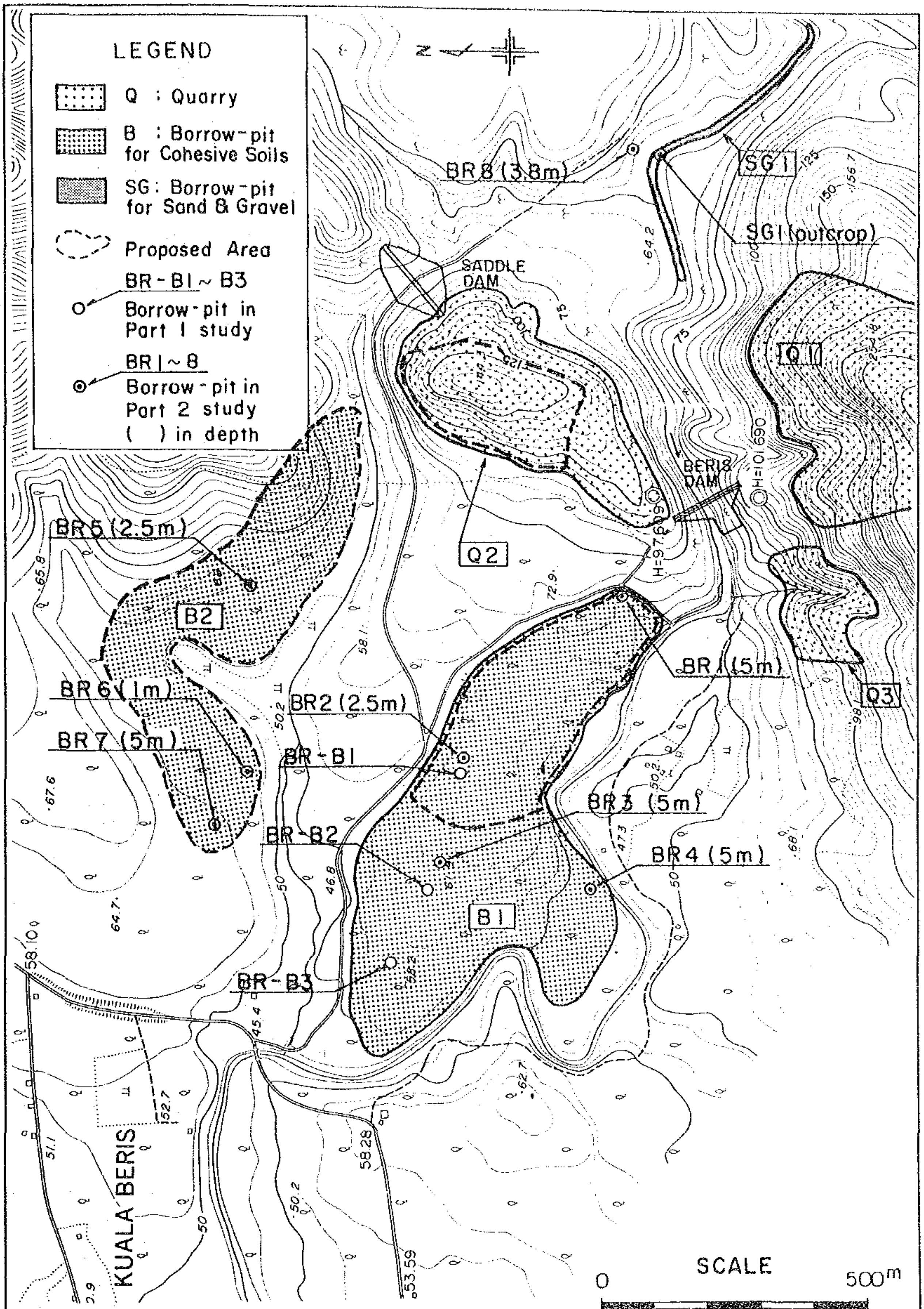

Fig. 1 Alternative Construction Material Sources and Test Pits

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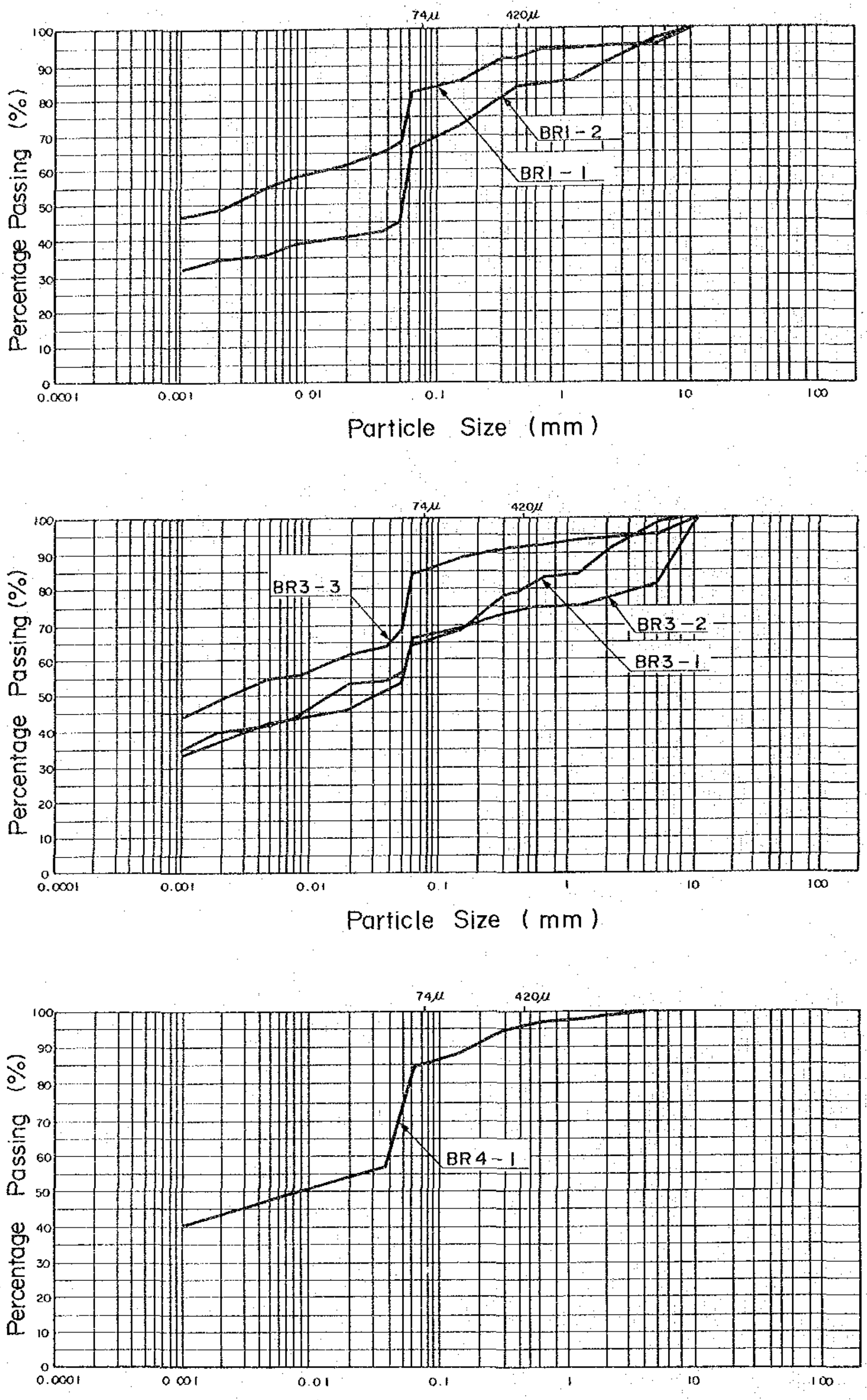

Fig. 2 Particle Size Distribution of Residual Soils in Prospective Borrow Area (1/3)

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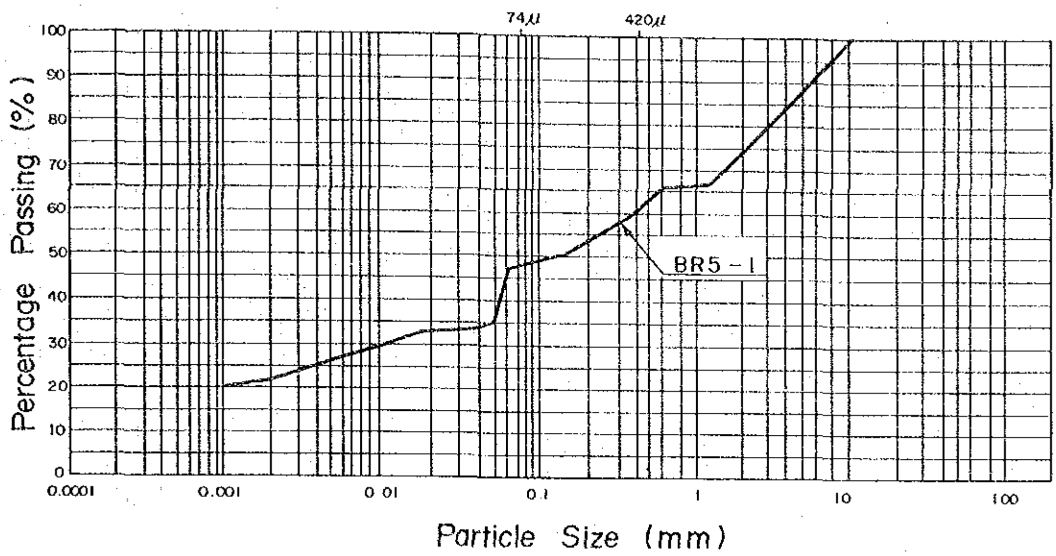

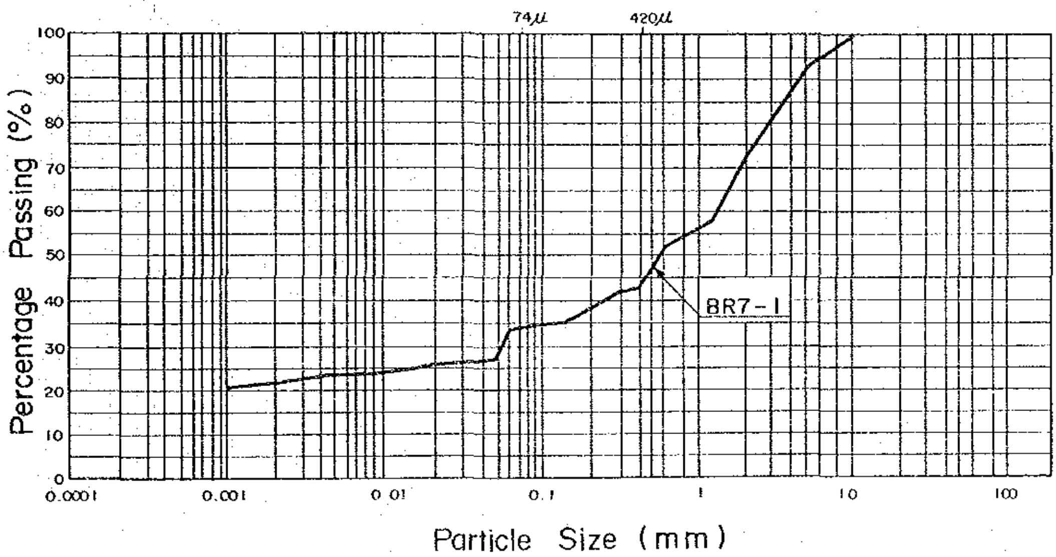

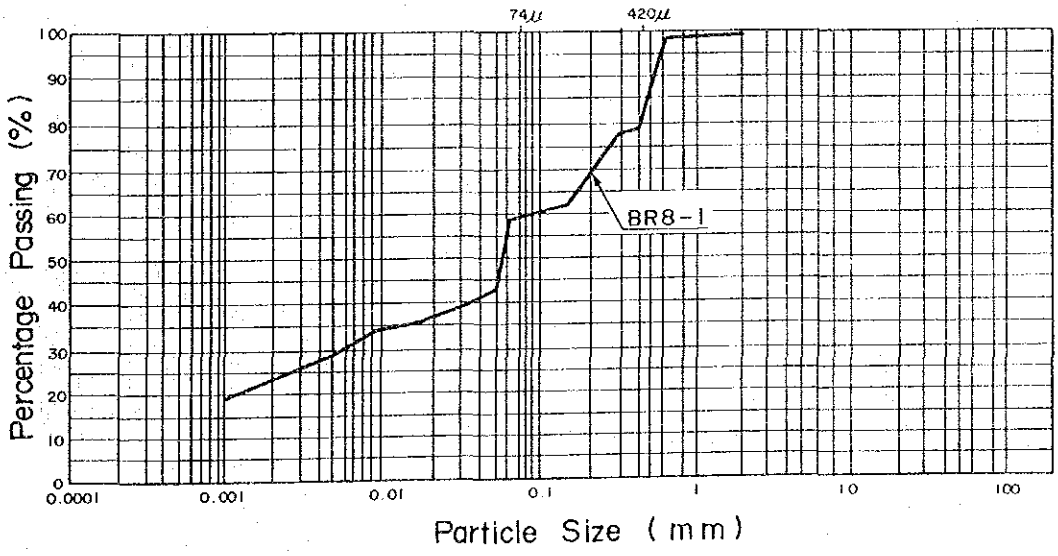

Fig. 3 Particle Size Distribution of Residual Soils in Prospective Borrow Area (2/3)

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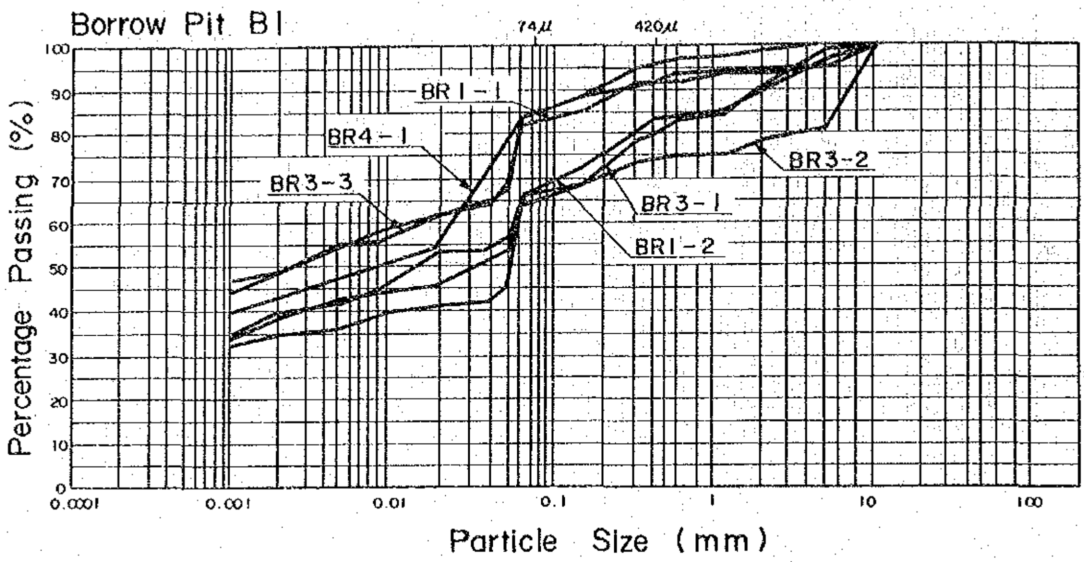

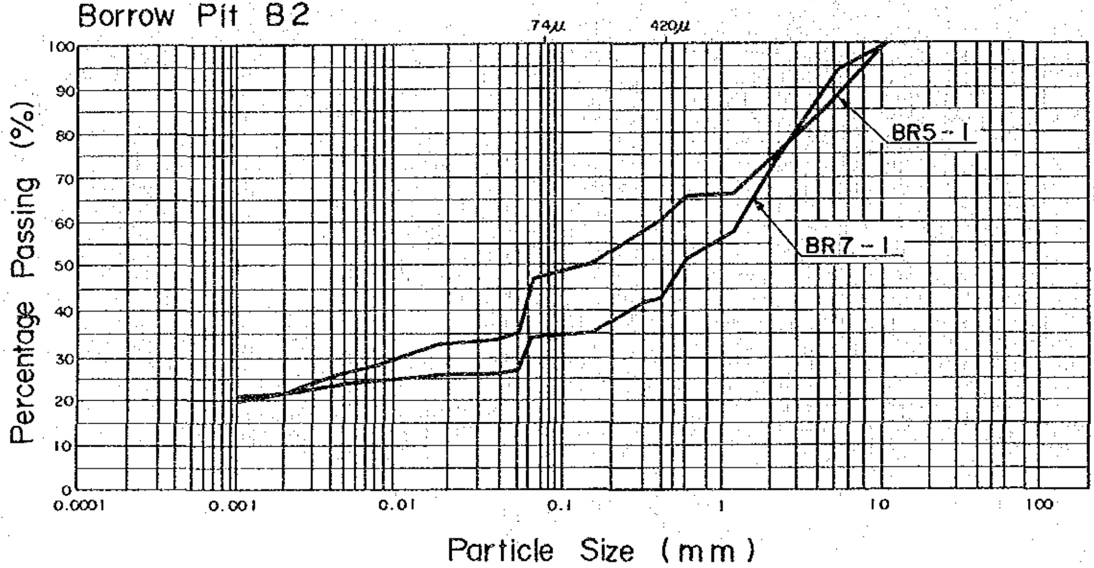

Fig. 4 Particle Size Distribution of Residual Soils in Prospective Borrow Area (3/3)

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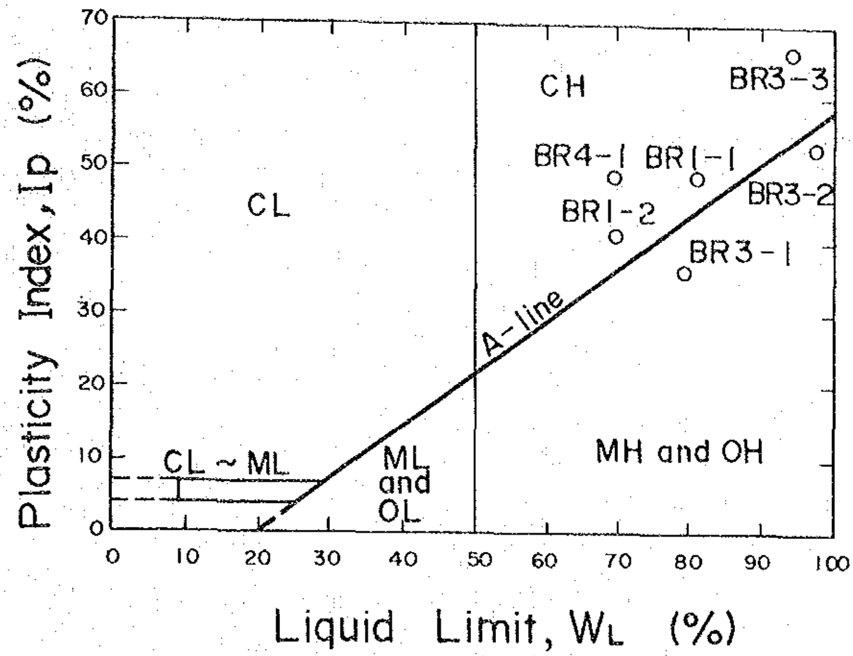
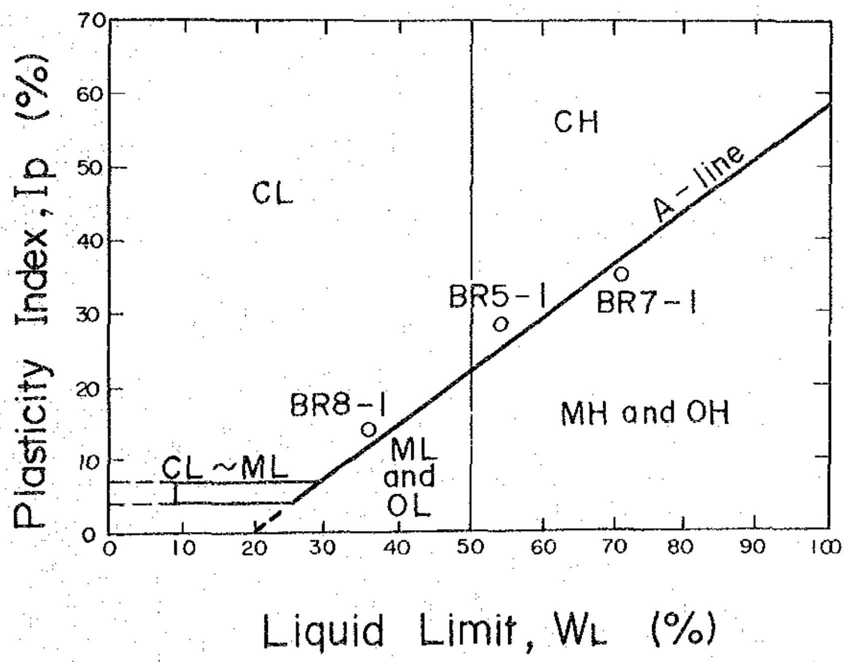
B - 1



(Shale Originated Soils)

B - 2



(Sandstone Originated Soils)

Fig. 5 Plasticity Chart for Unified Soil Classification of Residual Soils in Prospective Borrow Area

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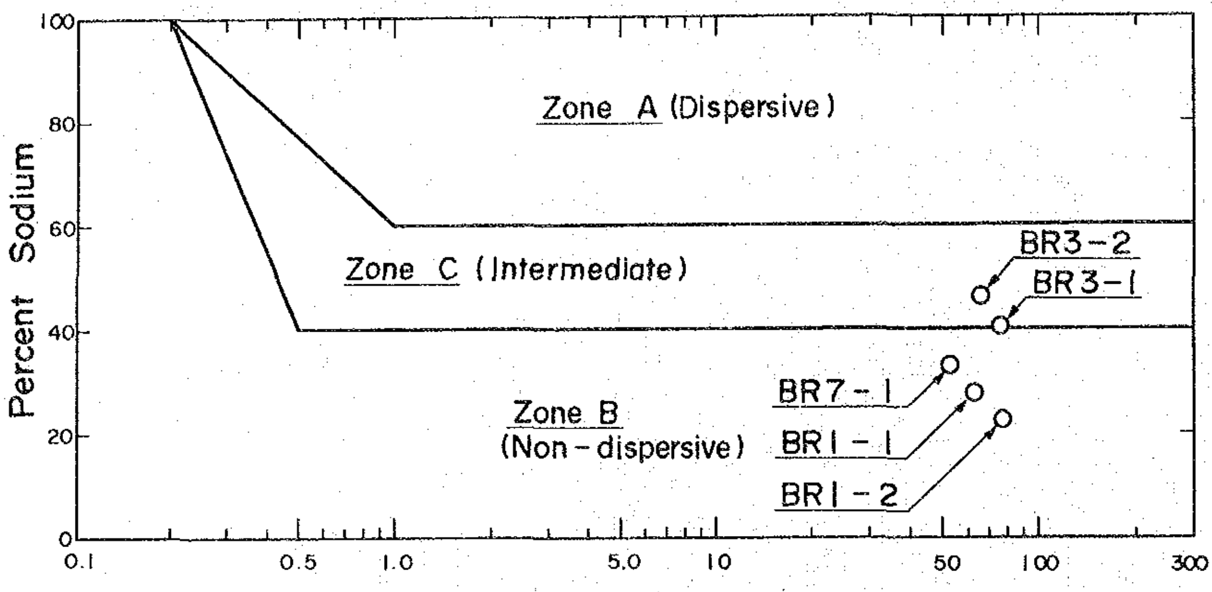
$$\text{Percent Sodium} = \frac{Na\,(100)}{Ca + Mg + Na + K}$$

(all measured in milliequivalents per liter of saturation extract)



Total Dissolved Salts in Saturation Extract in Milliequivalents per Liter

(TDS = Ca + Mg + Na + K)

Zone A. - Much experience shows that damaged and failed dams all over the world have been constructed of these dispersive soils. Almost all soils are dispersive in the pinhole test.

Zone B. - The great majority of these soils are nondispersive. These are the soils generally considered "ordinary erosion resistant clays," but include silts of low plasticity (ML), also nondispersive. A small percentage of exceptional soils in Zone B erode in the pinhole test in exactly the same fashion as soils of Zone A, and some of these can be identified only by the pinhole test.

Zone C. - Soils in this group may range from dispersive to non-dispersive. This group contains a few soils which give intermediate reaction in pinhole tests, with apparently colloidal erosion but at a very slow rate compared with soils of Zone A.

Fig. 6 Relation of Pore - water Salts and Dispersion of Soil

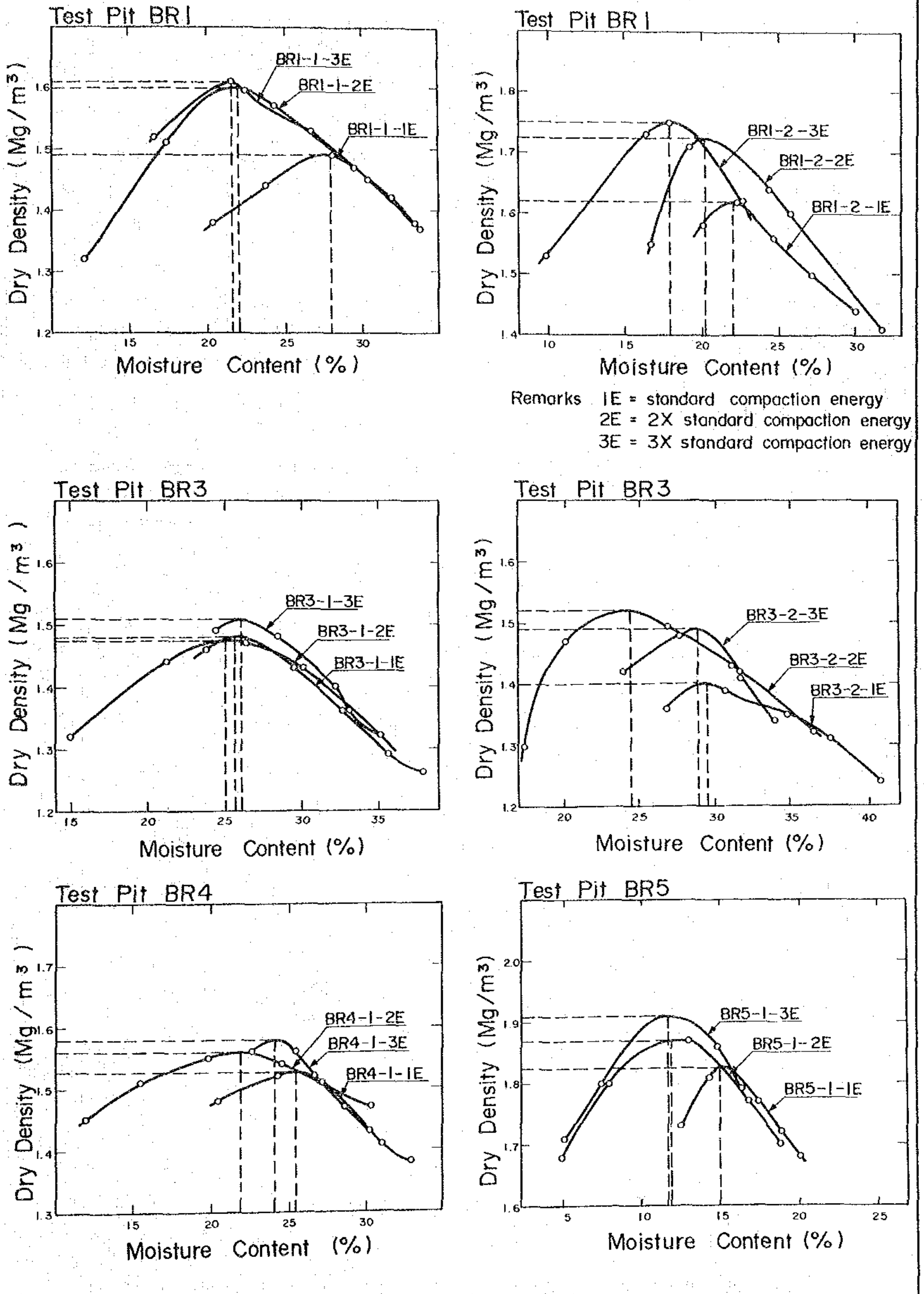


Fig. 7 Moisture - Dry Density Relationship of *Residual Soils in Prospective* Borrow Area (1/3)

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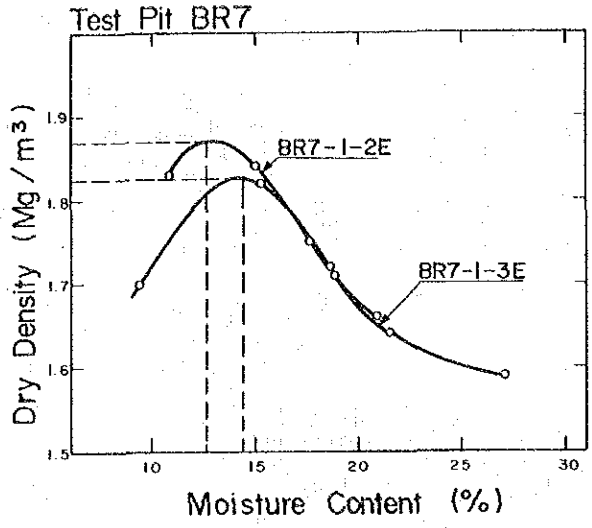
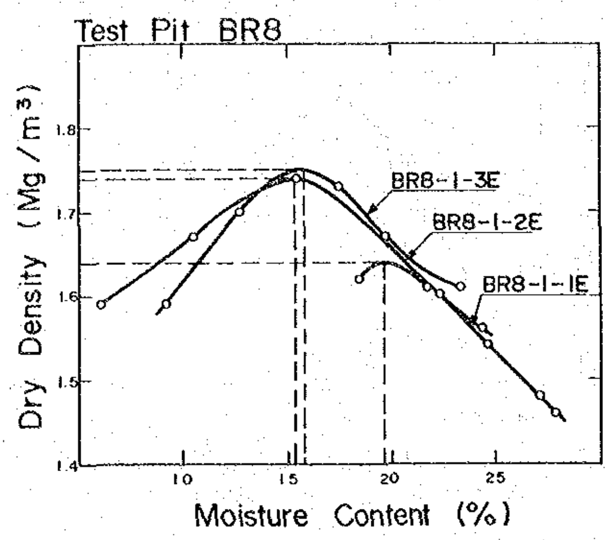
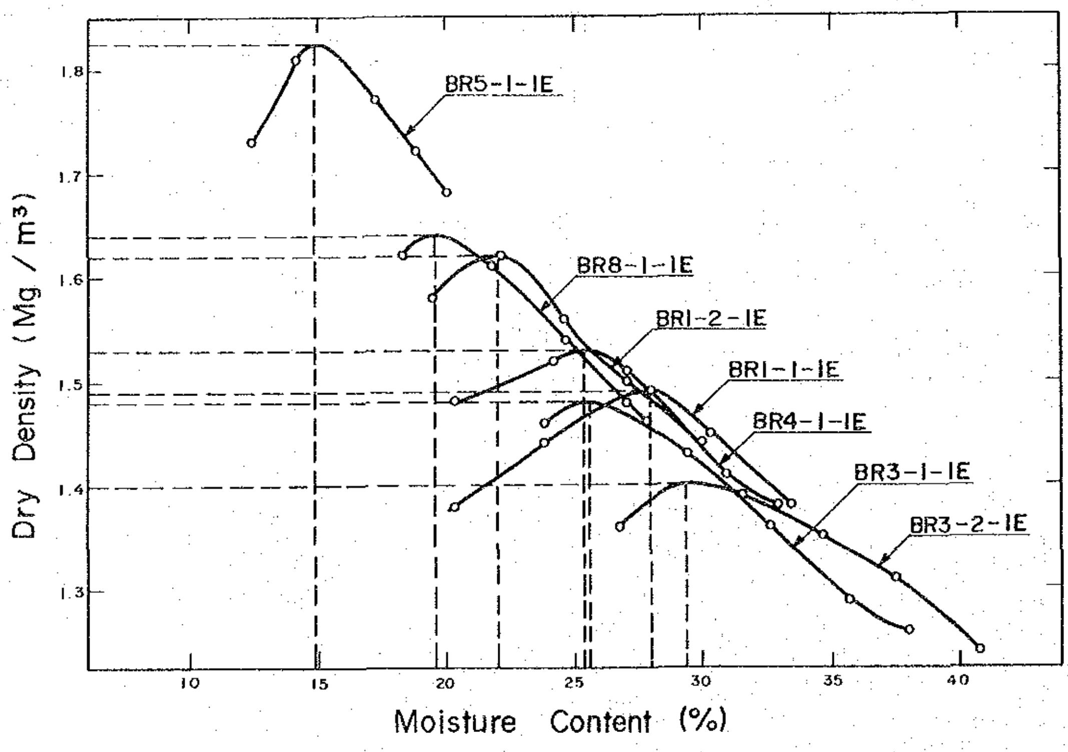




Remarks 1E = standard compaction energy
2E = 2 X standard compaction energy
3E = 3 X standard compaction energy



With Standard Compaction Energy

Fig. 8 Moisture-Dry Density Relationship of Residual Soils in Prospective Borrow Area (2 / 3)

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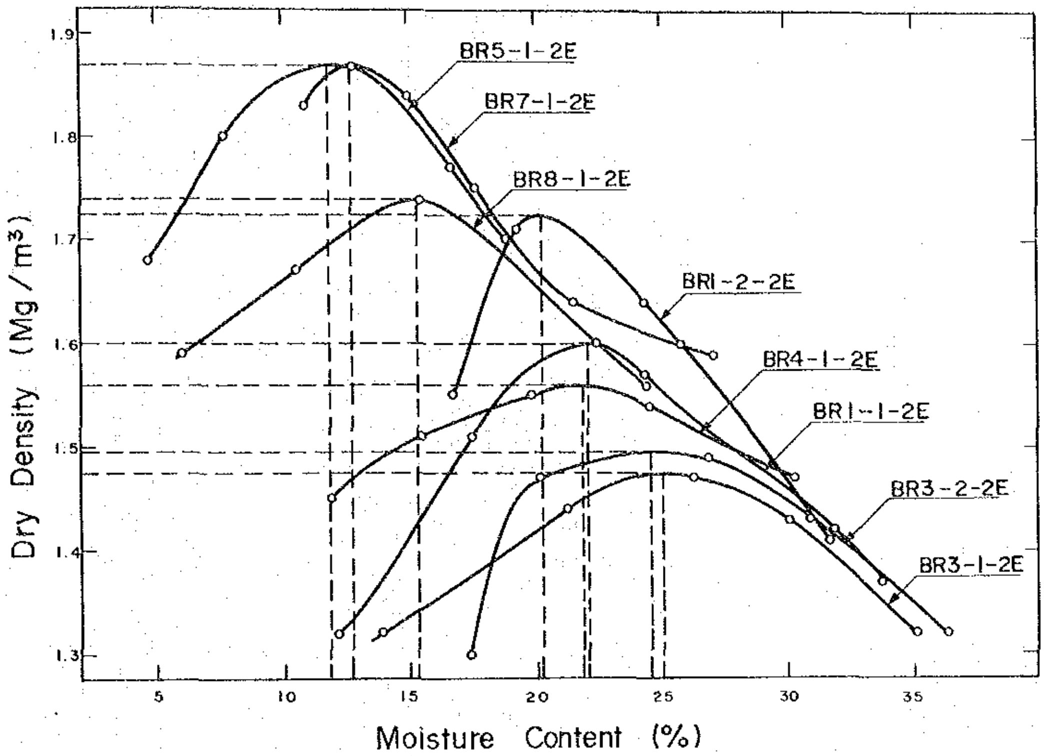
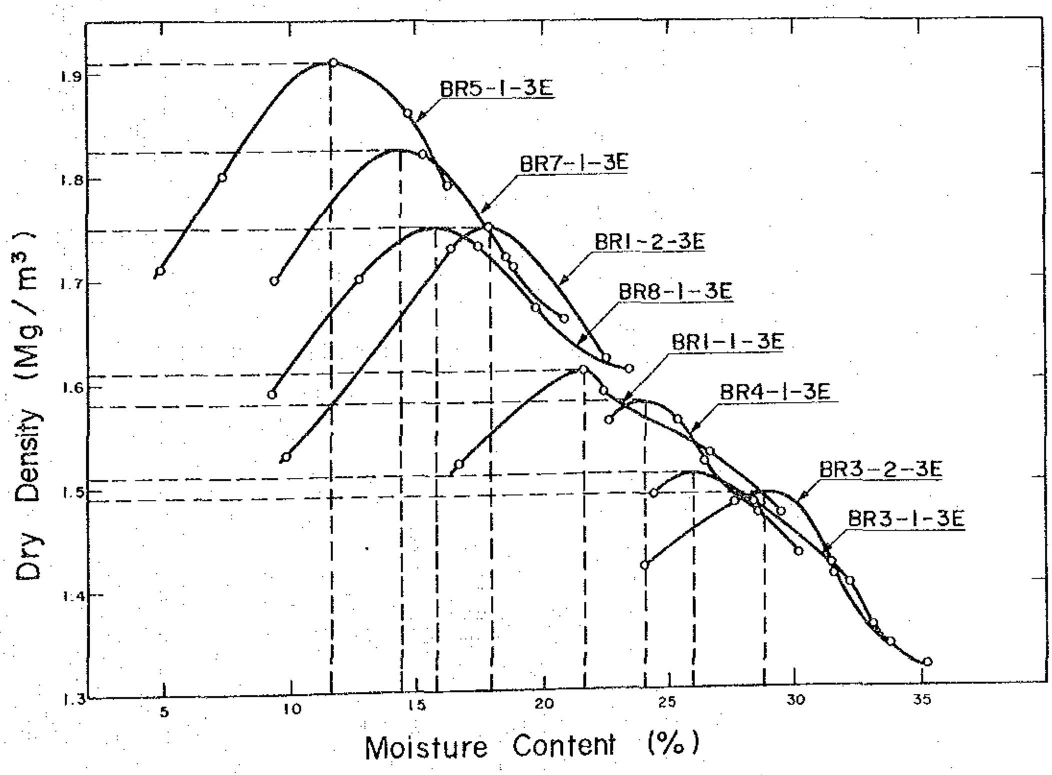


With 2X Standard Compaction Energy



With 3X Standard Compaction Energy

Fig. 9 Moisture-Dry Density Relationship of Residual Soils in Prospective Borrow Area (3/3)

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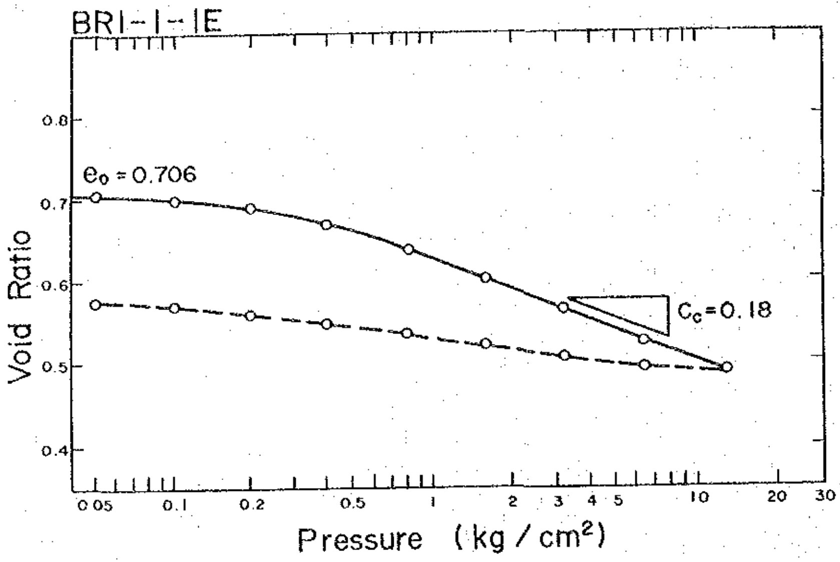

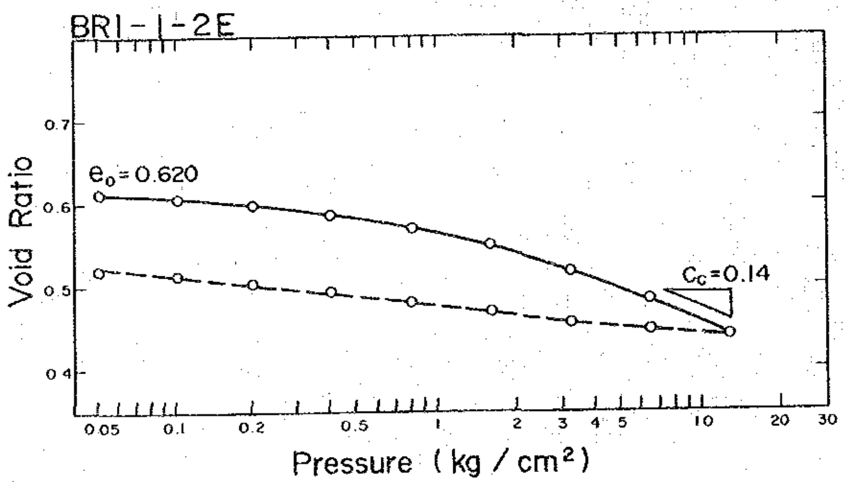

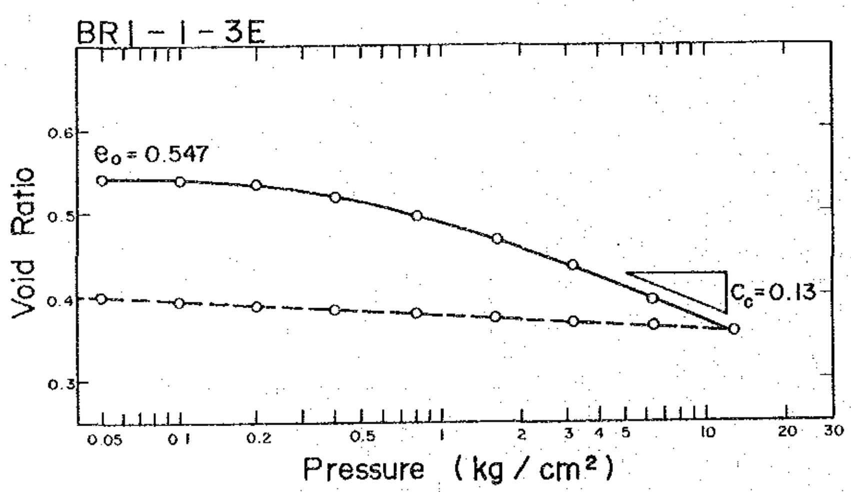

Fig. 10 Void Ratio - Consolidation Pressure Relationship of Cohesive Soils (1 / 3)

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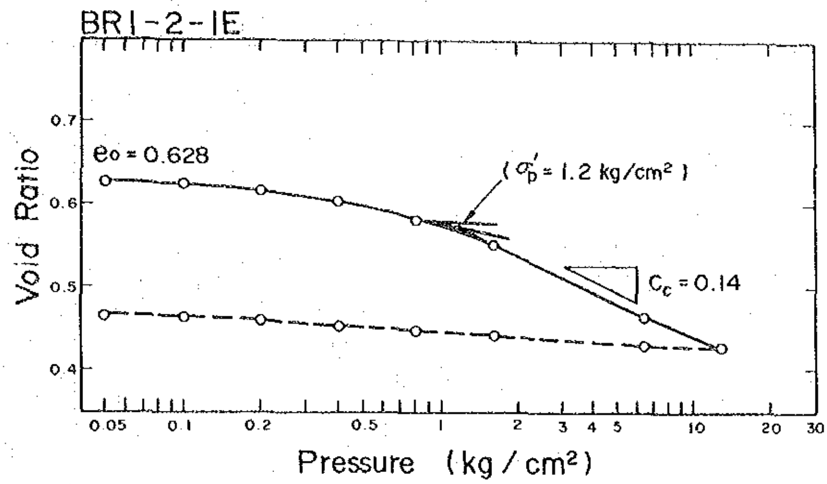

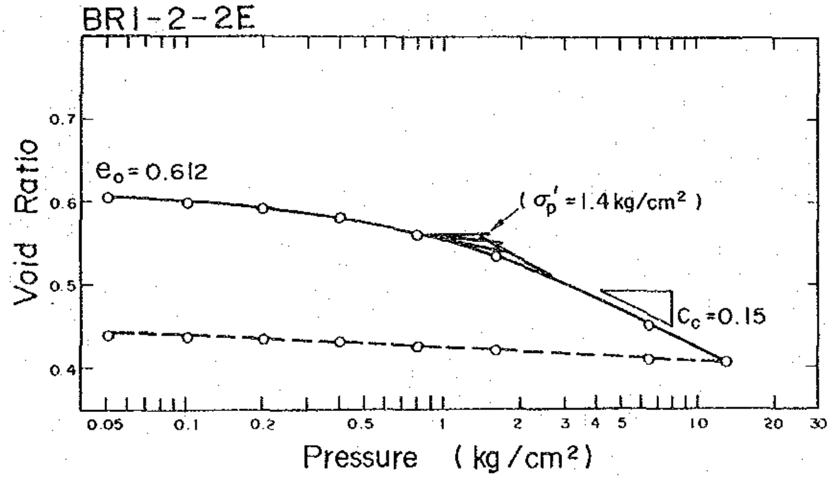

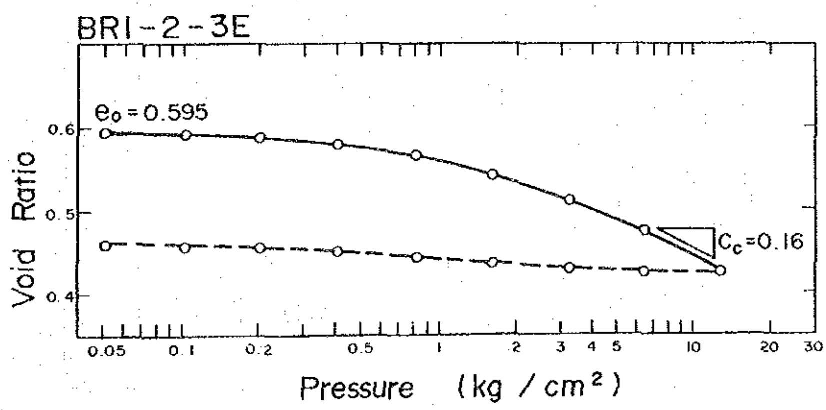

Fig. 11 Void Ratio – Consolidation Pressure Relationship of Cohesive Soils (2/3)

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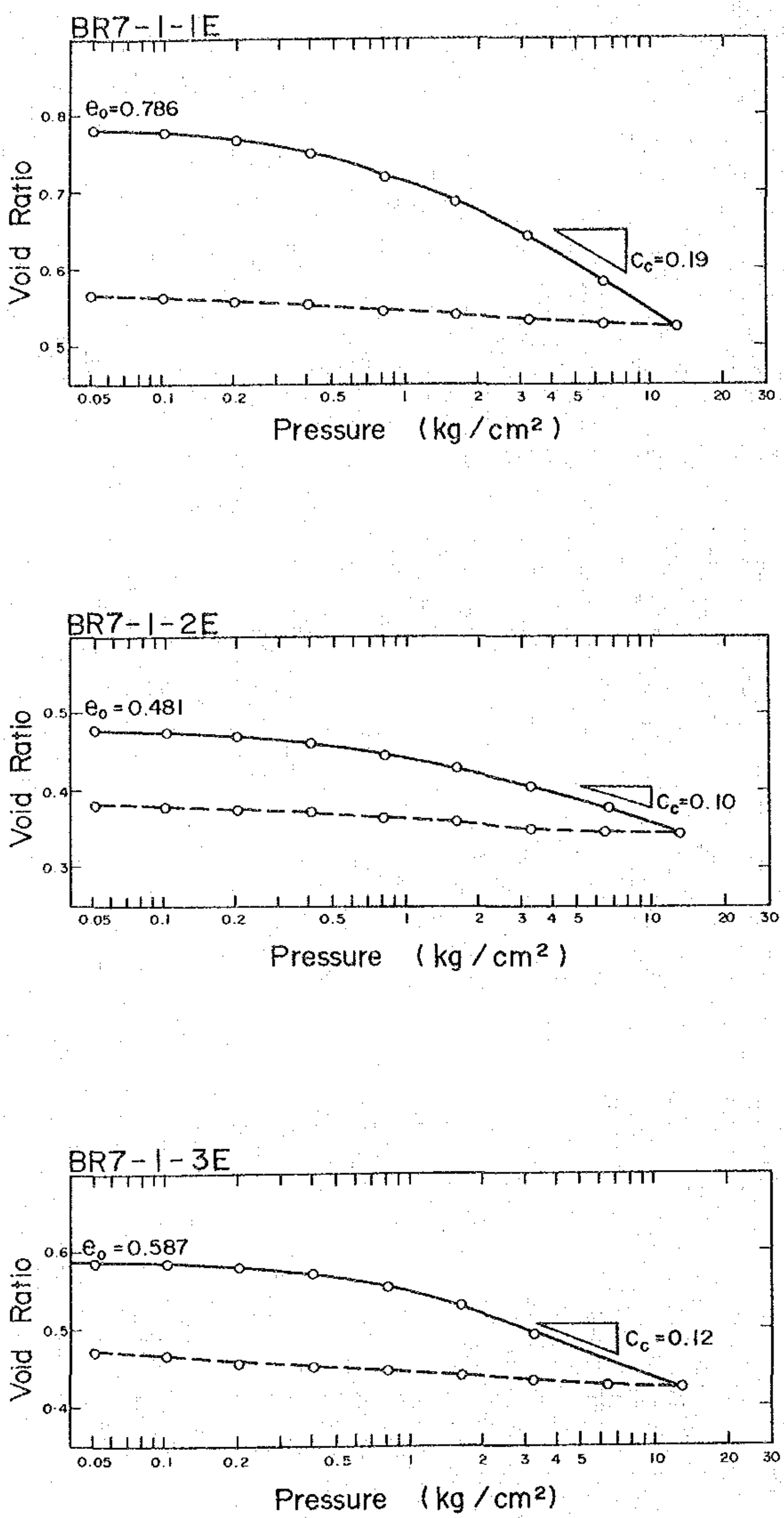

Fig. 12 Void Ratio - Consolidation Pressure Relationship of Cohesive Soils (3/3)

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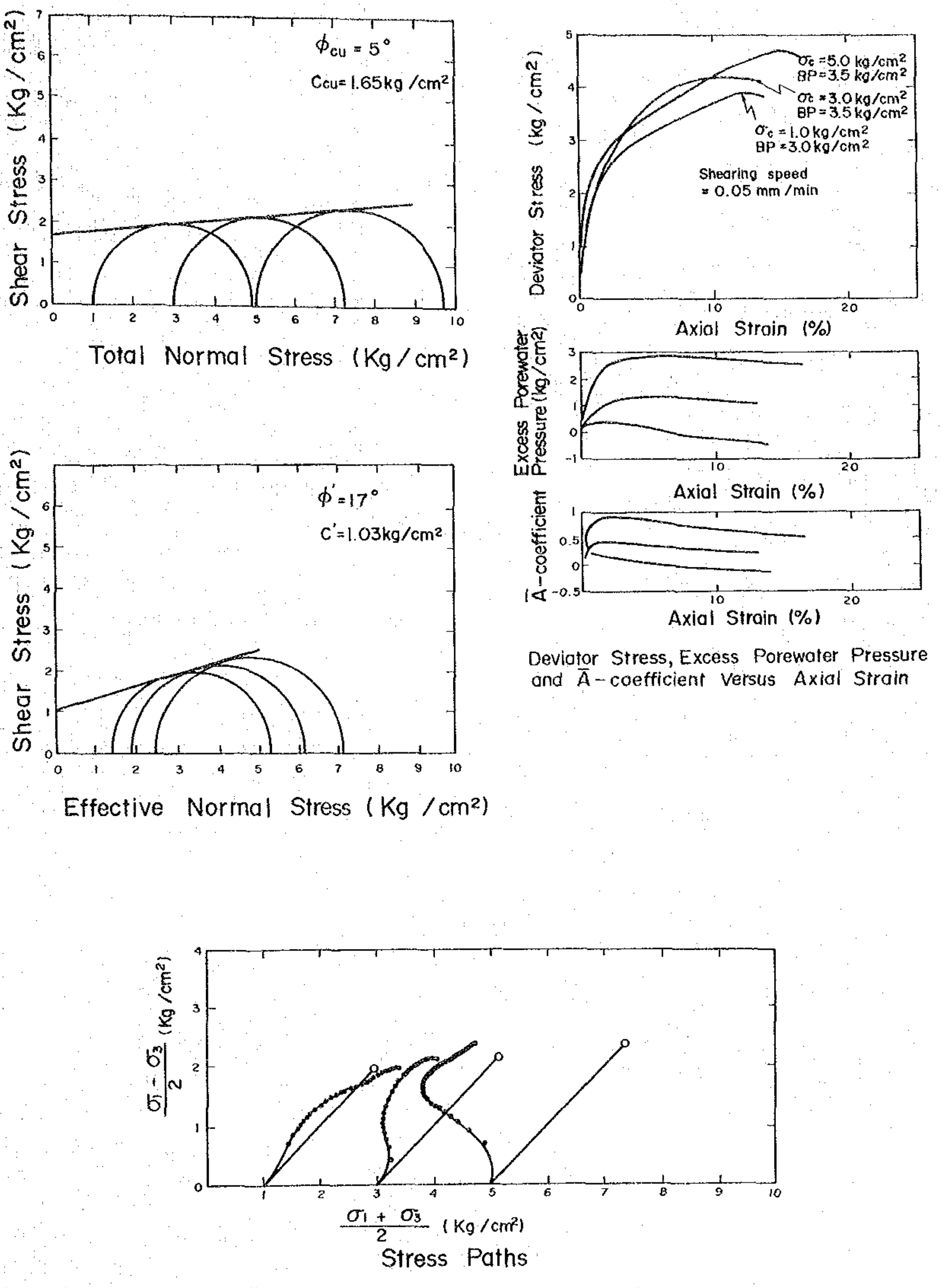

Fig. 13 Triaxial Compression Test Results ($\overline{CU}$), Sample BR1 - 1 - 1E

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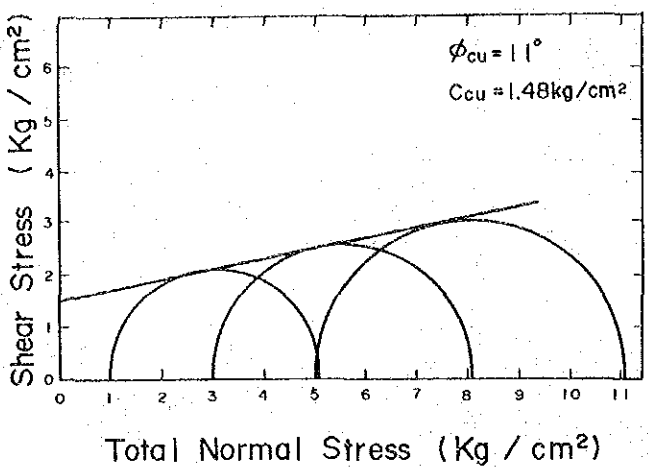
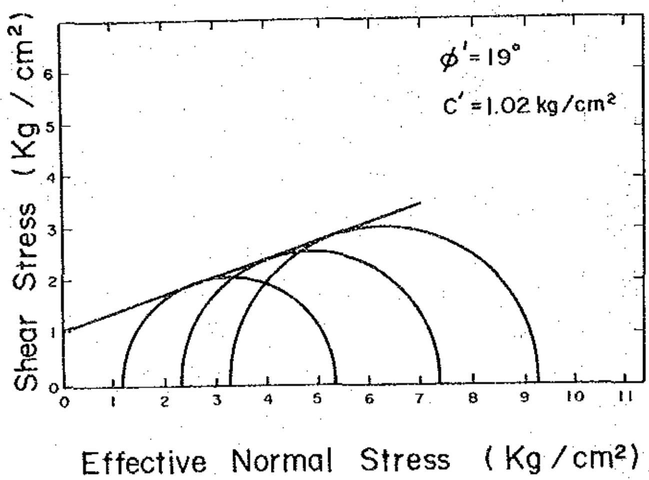
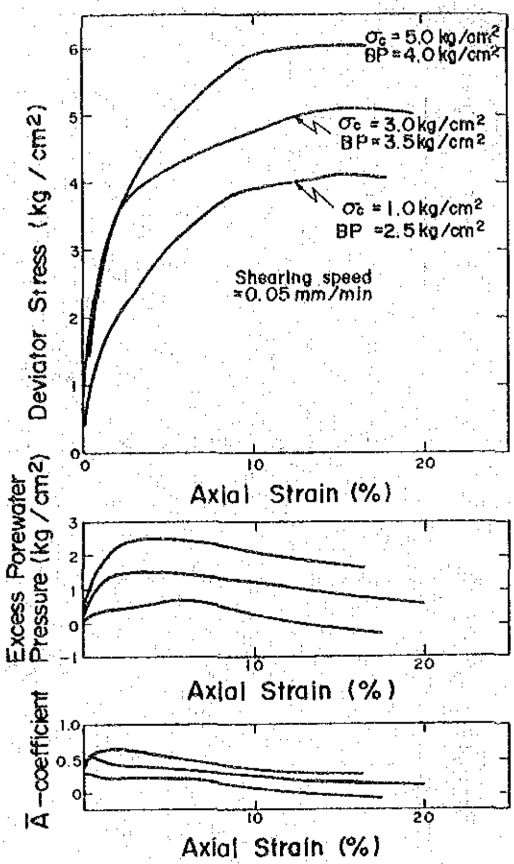
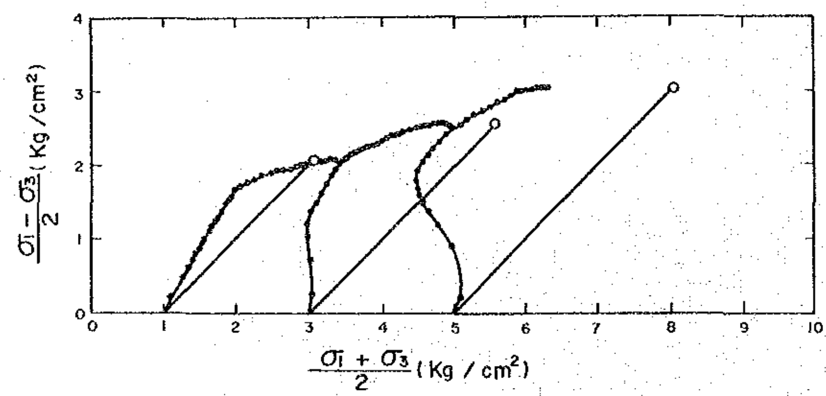






Deviator Stress, Excess Porewater Pressure and Ā-coefficient Versus Axial Strain



Stress Paths

Fig. 14 Triaxial Compression Test Results ($\overline{CU}$), Sample BR1-1-2E

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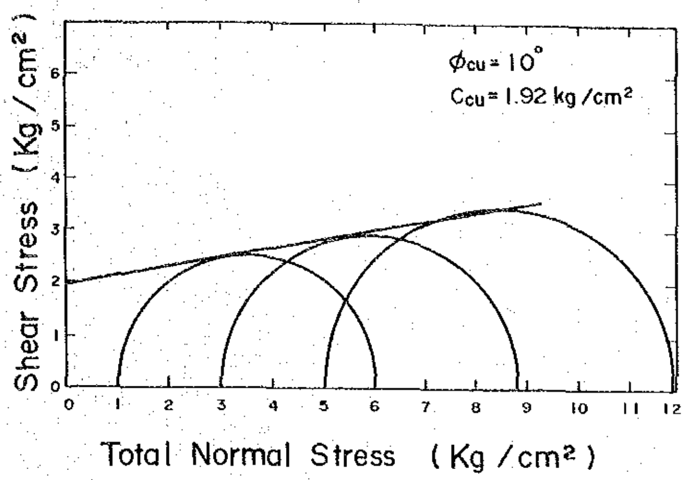
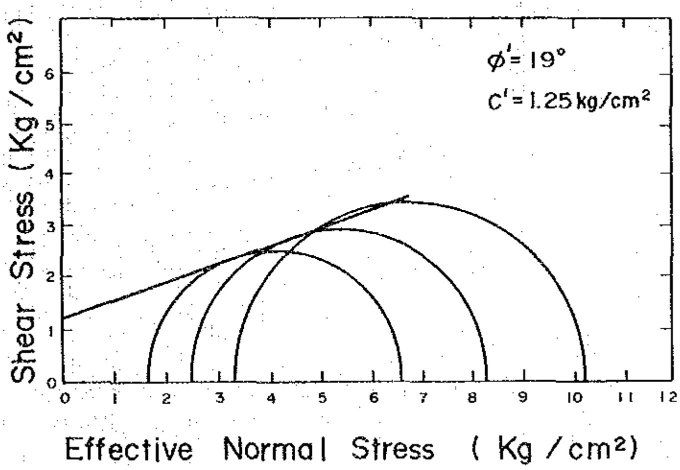
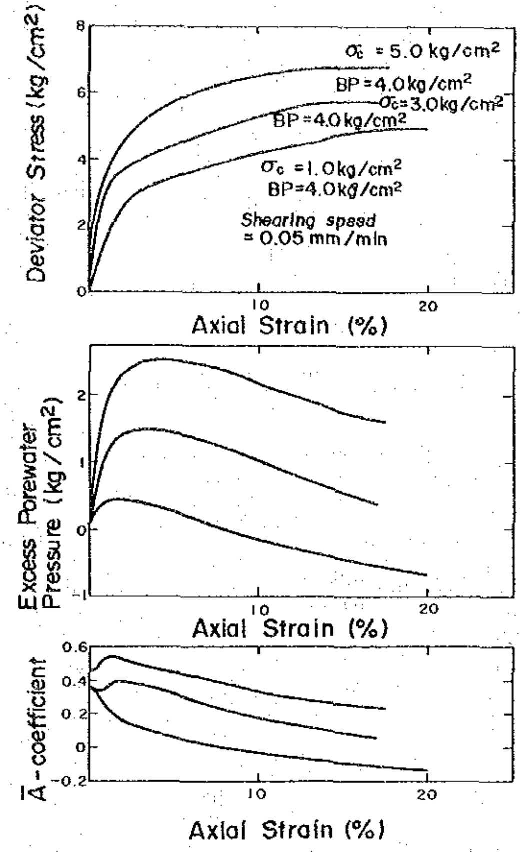
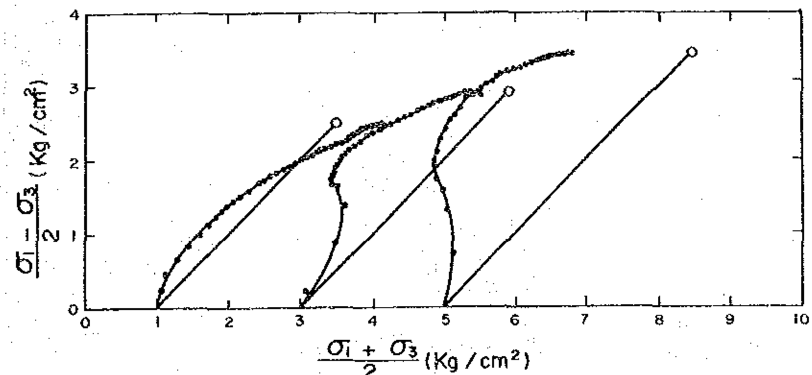






Deviator Stress, Excess Porewater Pressure and $\bar{A}$-coefficient Versus Axial Strain



Stress Paths

Fig. 15 Triaxial Compression Test Results ($\overline{CU}$), Sample BR1-1-3E

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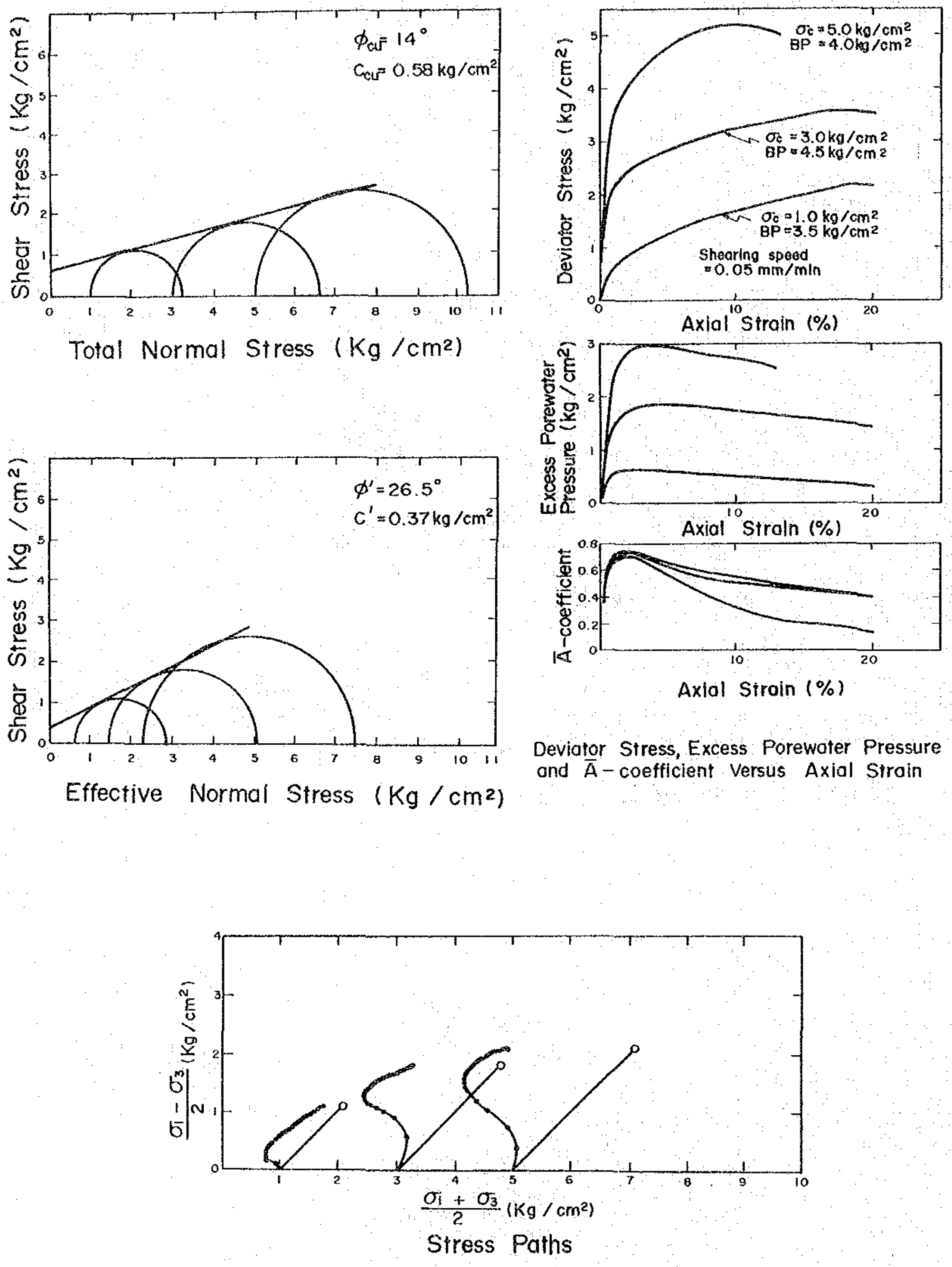

Fig. 16 Triaxial Compression Test Results ($\overline{CU}$), Sample BR1-2-1E

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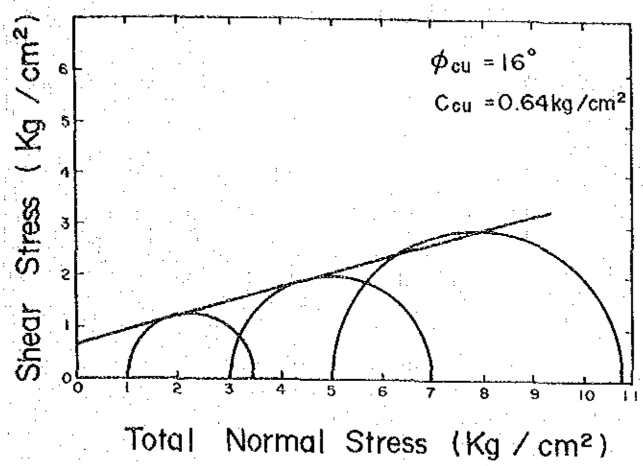
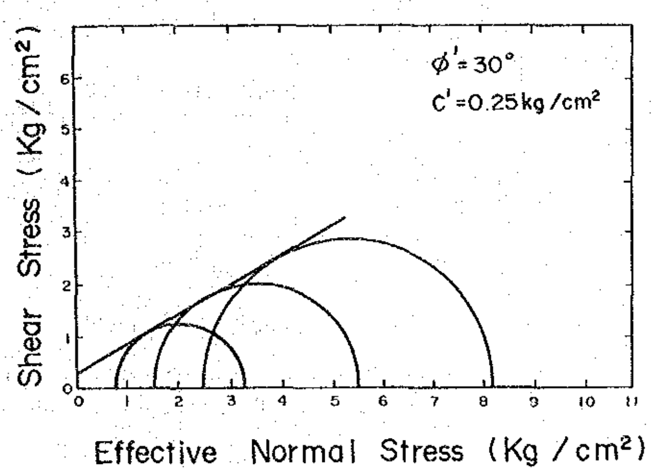
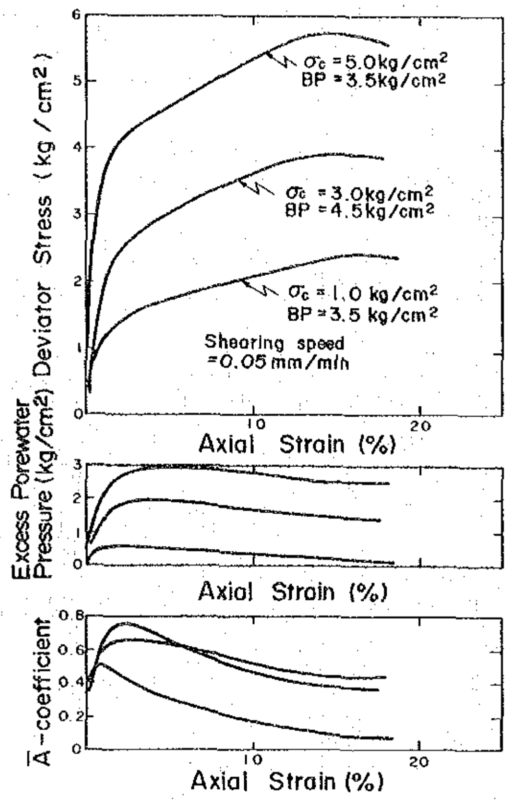
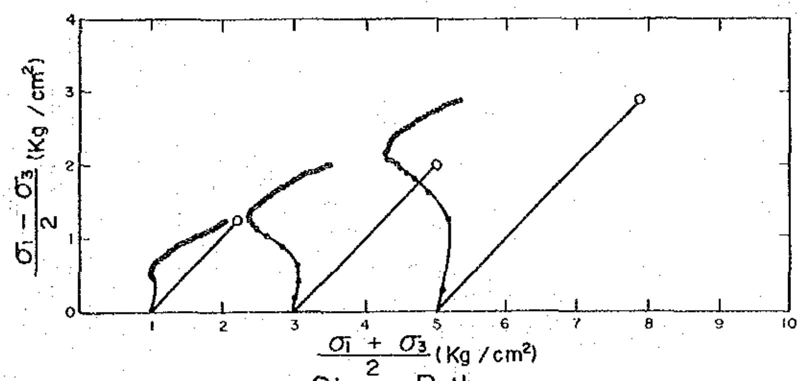




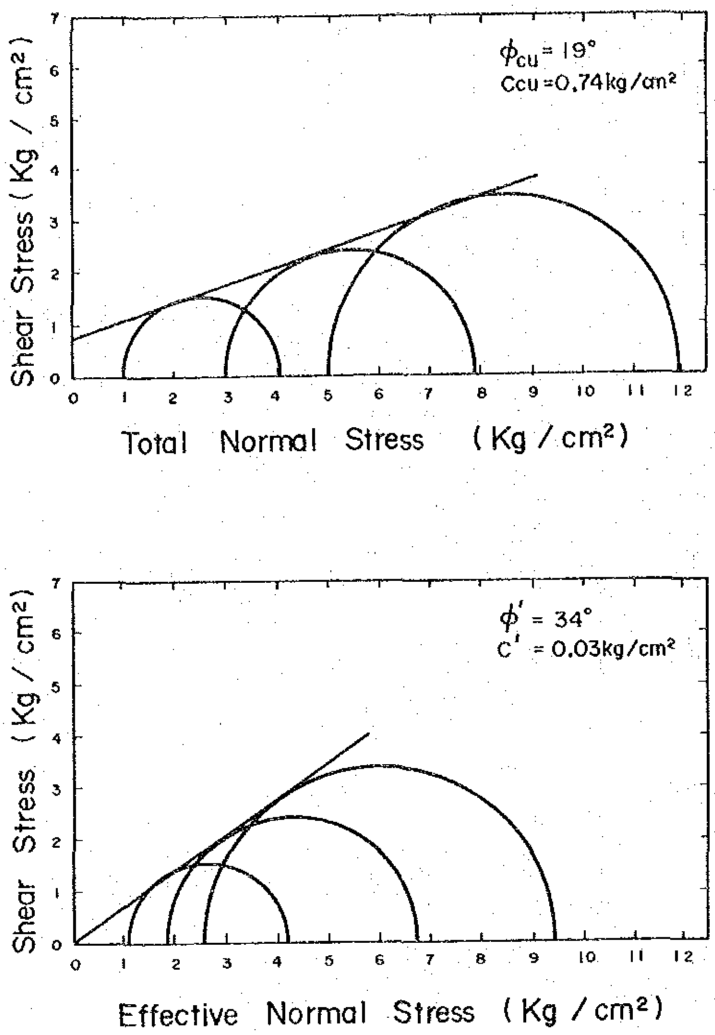


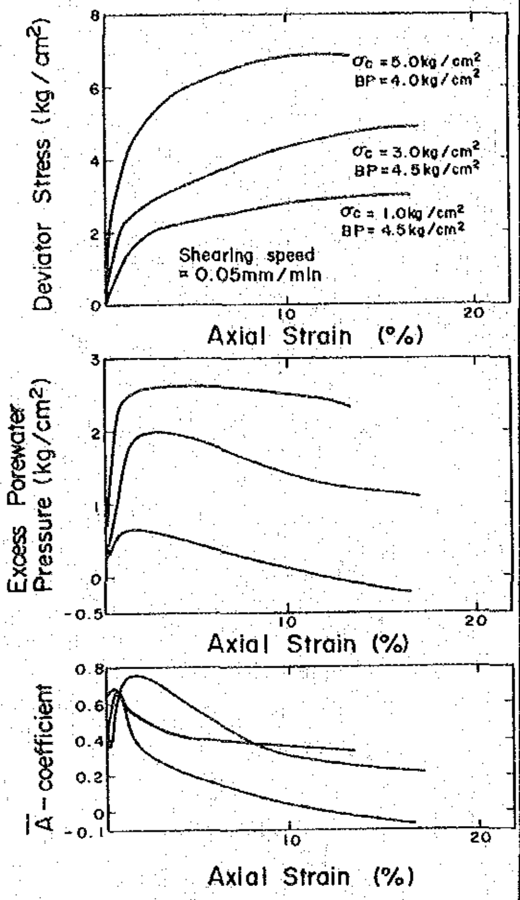
Deviator Stress, Excess Porewater Pressure and $\bar{A}$-coefficient Versus Axial Strain



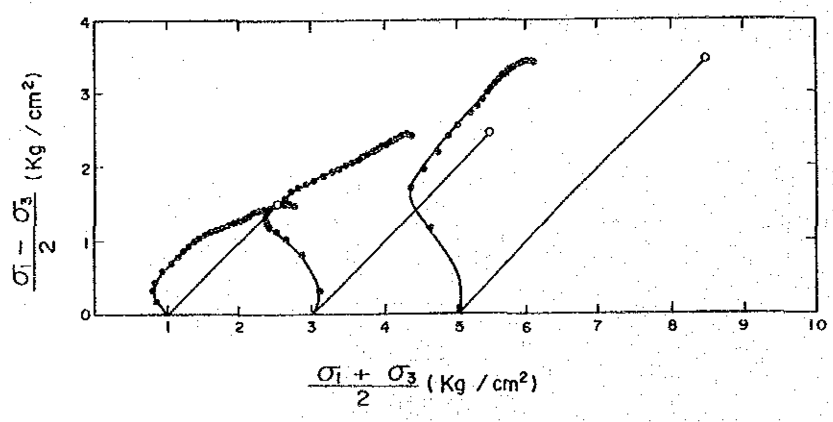
Stress Paths

Fig.17 Triaxial Compression Test Results ($\overline{CU}$), Sample BR1-2-2E





Deviator Stress, Excess Porewater Pressure and $\bar{A}$ – coefficient Versus Axial Strain



Stress Paths

Fig.18 Triaxial Compression Test Results ($\overline{CU}$), Sample BR1 – 2 – 3E

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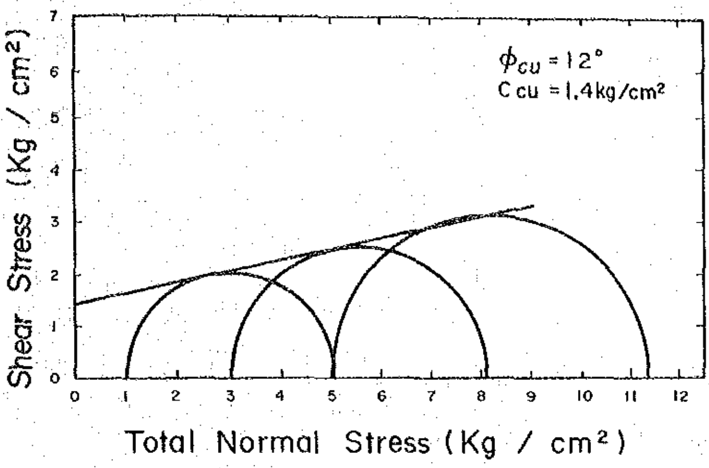
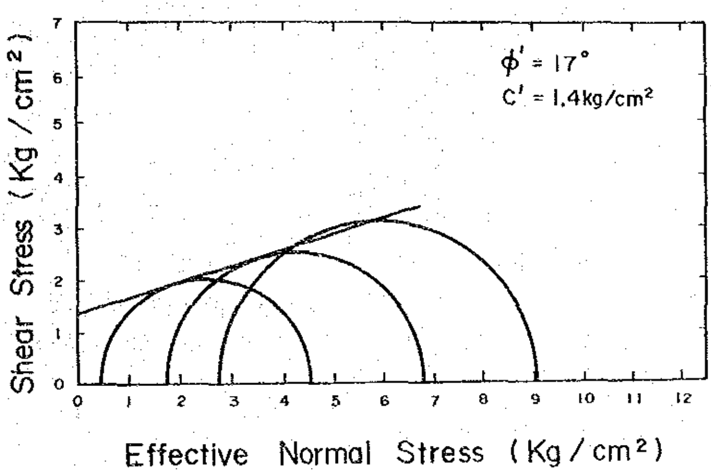
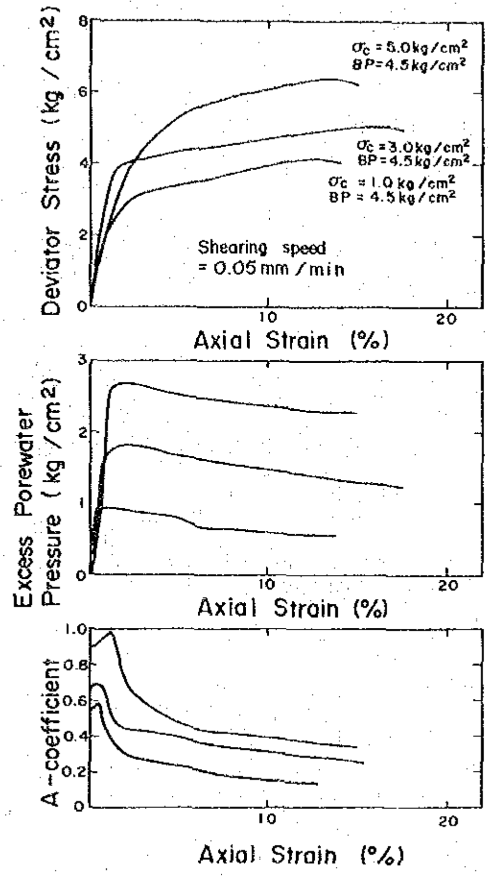
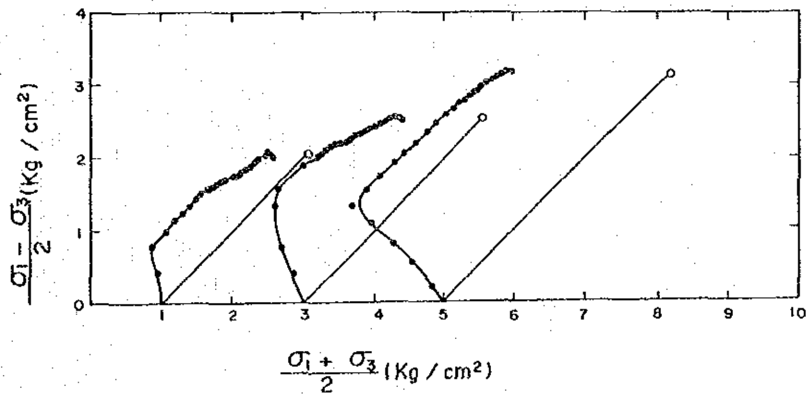






Deviator Stress, Excess Porewater Pressure and $\bar{A}$ – coefficient Versus Axial Strain



Stress Paths

Fig. 19 Triaxial Compression Test Results ($\overline{CU}$), Sample BR7 – 1 – 1E

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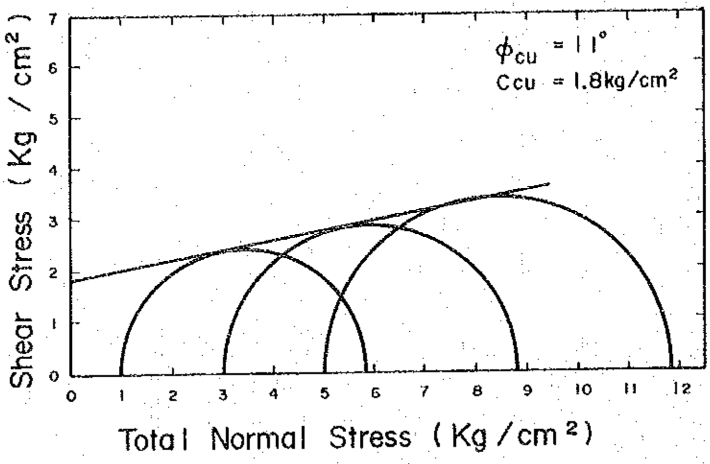
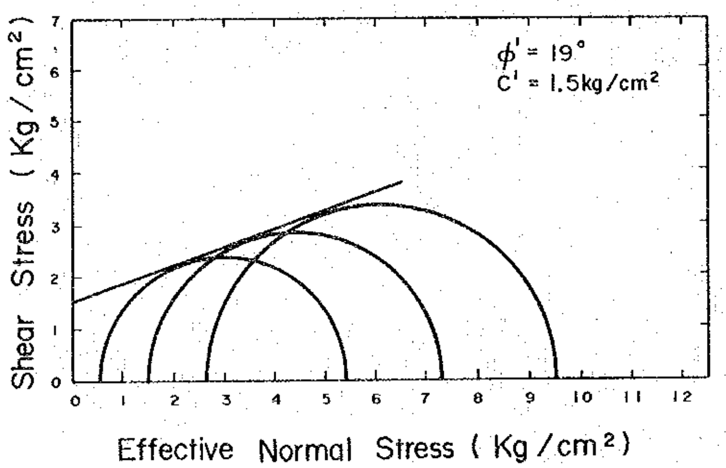
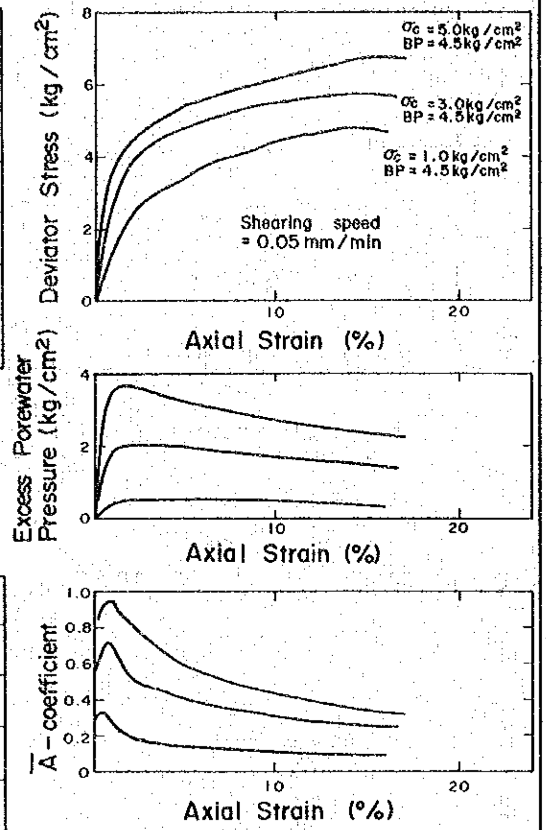
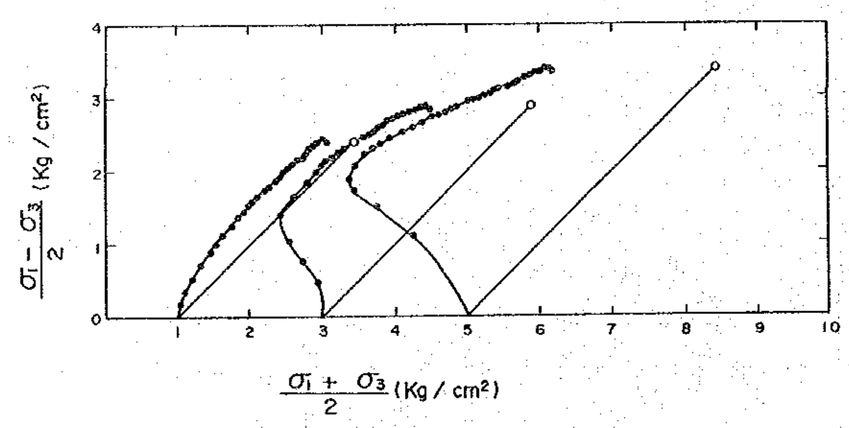






Deviator Stress, Excess Porewater Pressure and Ā – coefficient Versus Axial Strain



Stress Paths

Fig.20 Triaxial Compression Test Results ($\overline{CU}$), Sample BR7 - 1 - 2E

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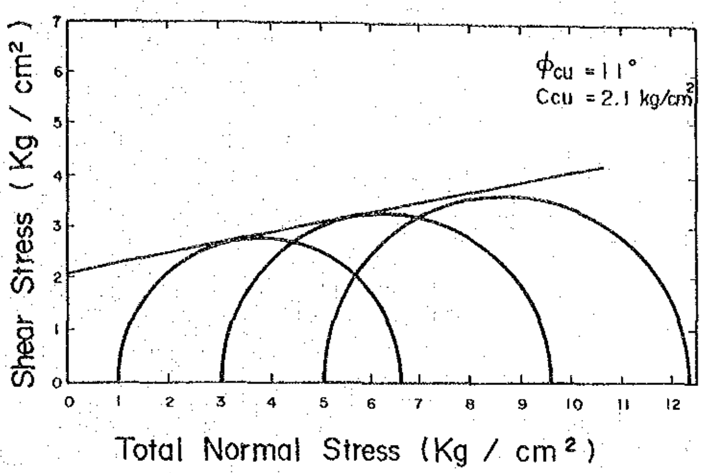
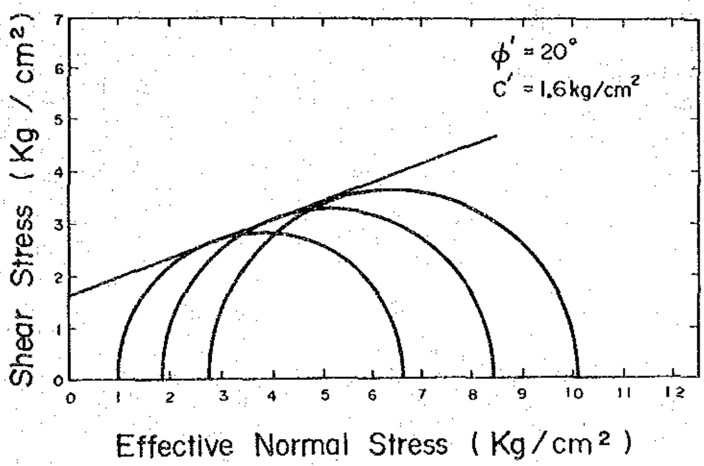
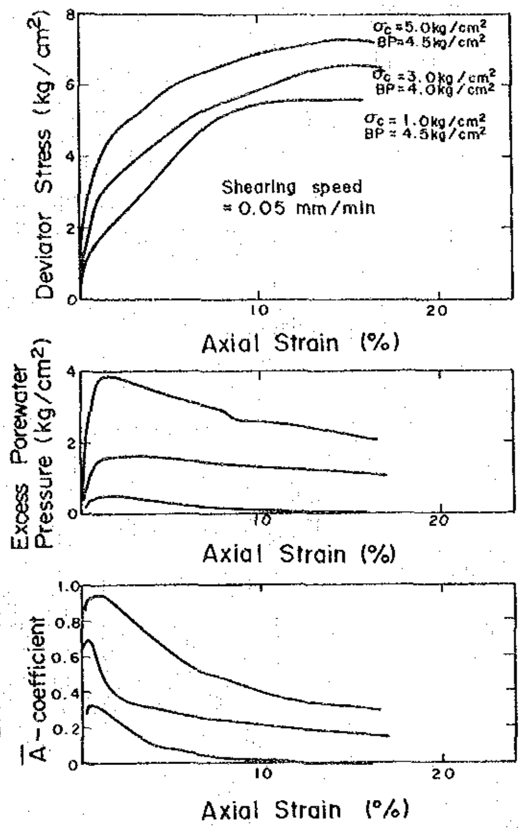
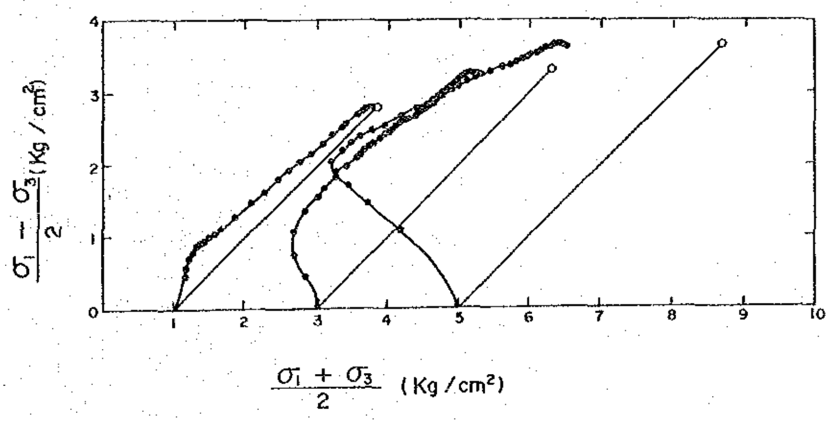






Deviator Stress, Excess Porewater Pressure and Ā – coefficient Versus Axial Strain



Stress Paths

Fig. 21 Triaxial Compression Test Results ($\overline{CU}$), Sample BR7 – 1 – 3E

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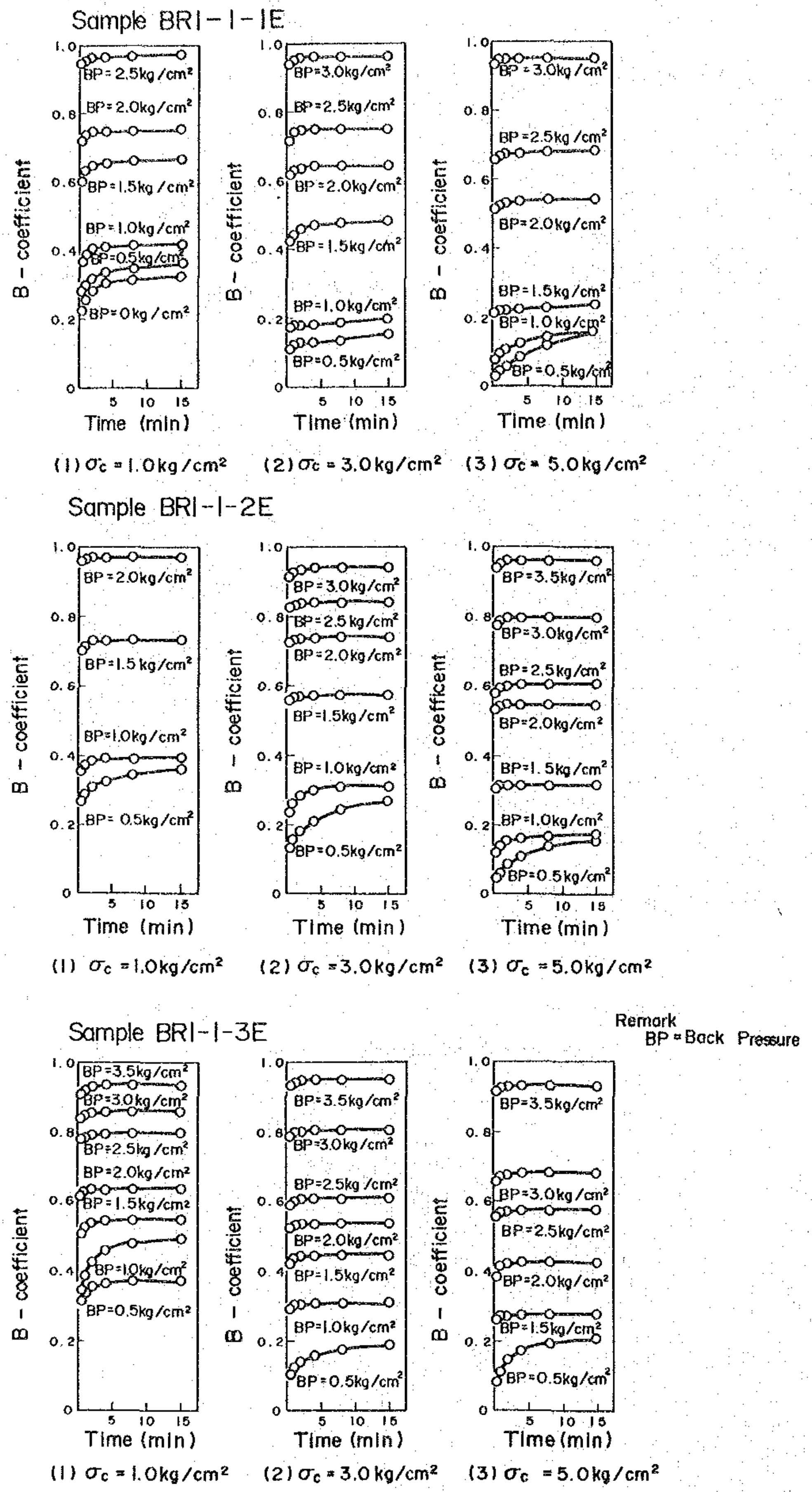

Fig.22 Triaxial Compression Test, B - coefficient Versus Time

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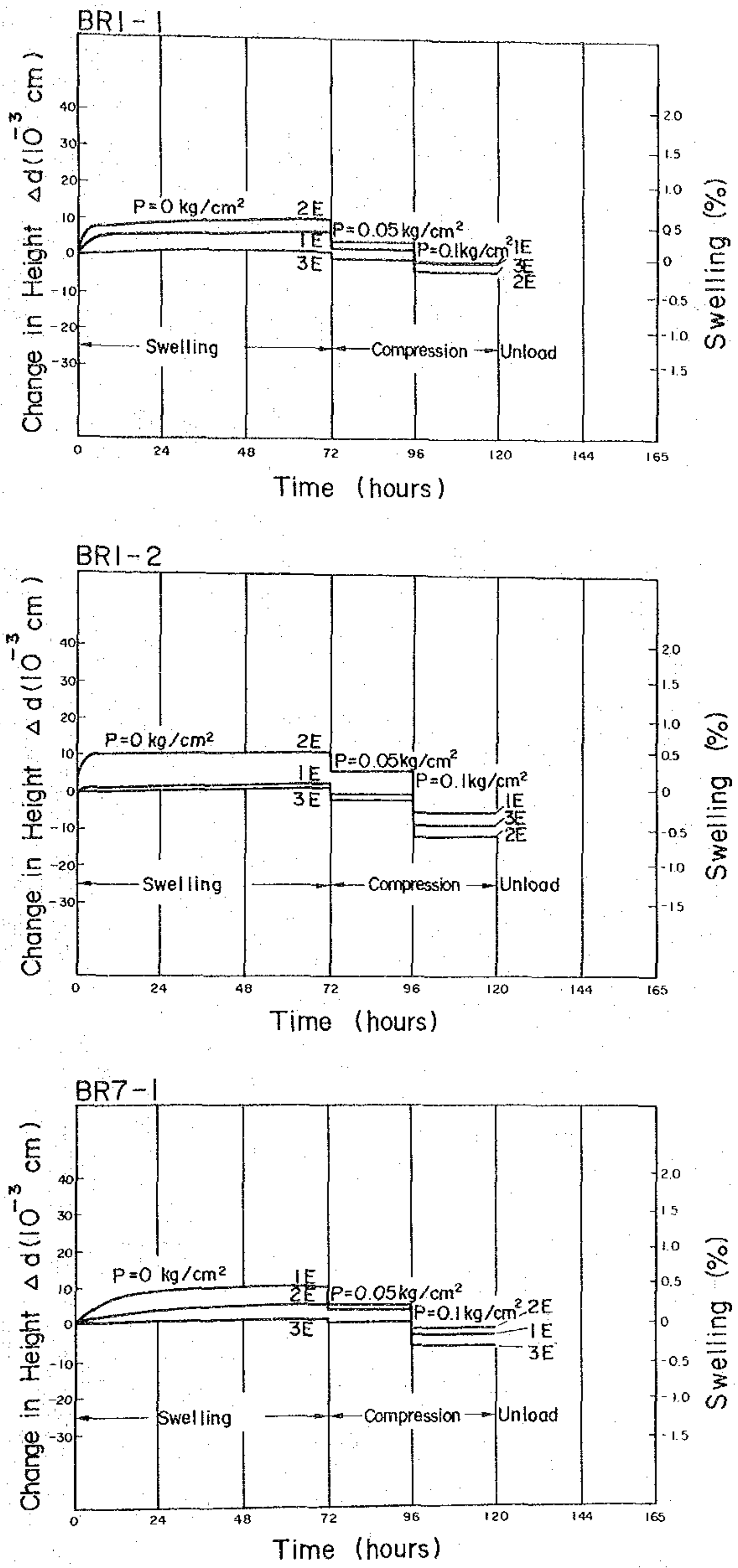

Fig. 23 Pressure - Swelling Relationship

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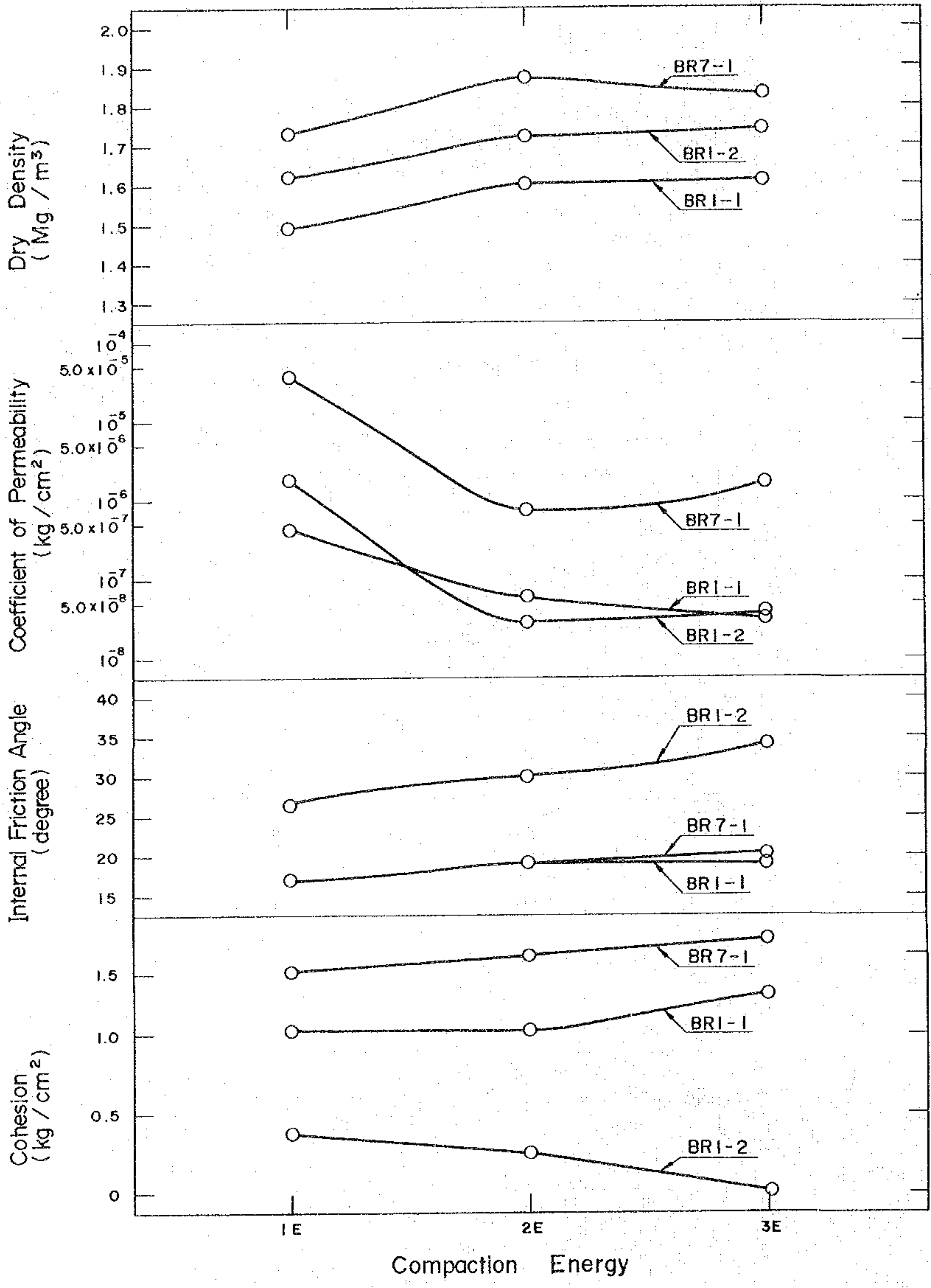

Fig. 24 Dry Density-Permeability-Shear Strength Relationship in Terms of Compaction Energy

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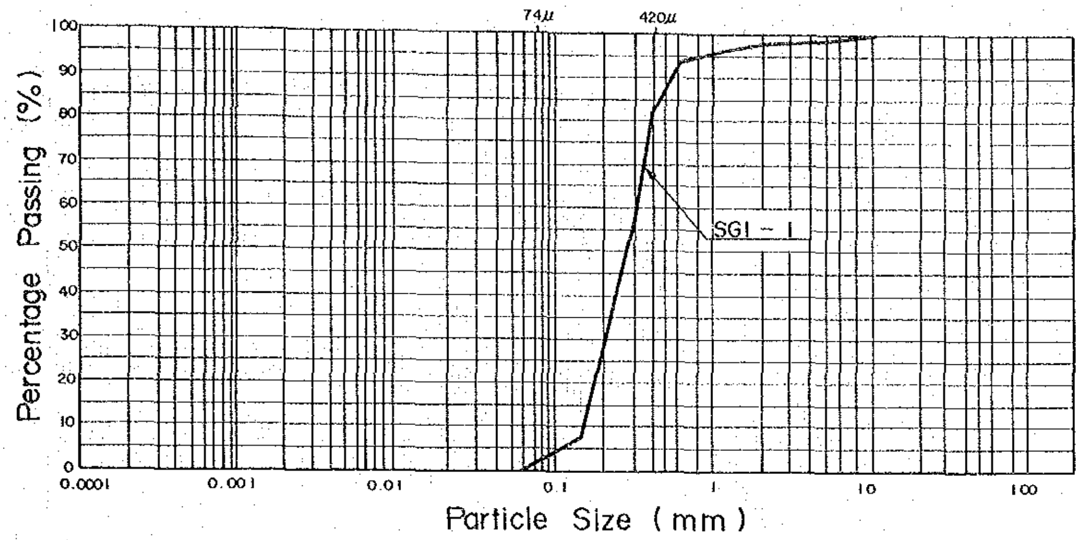

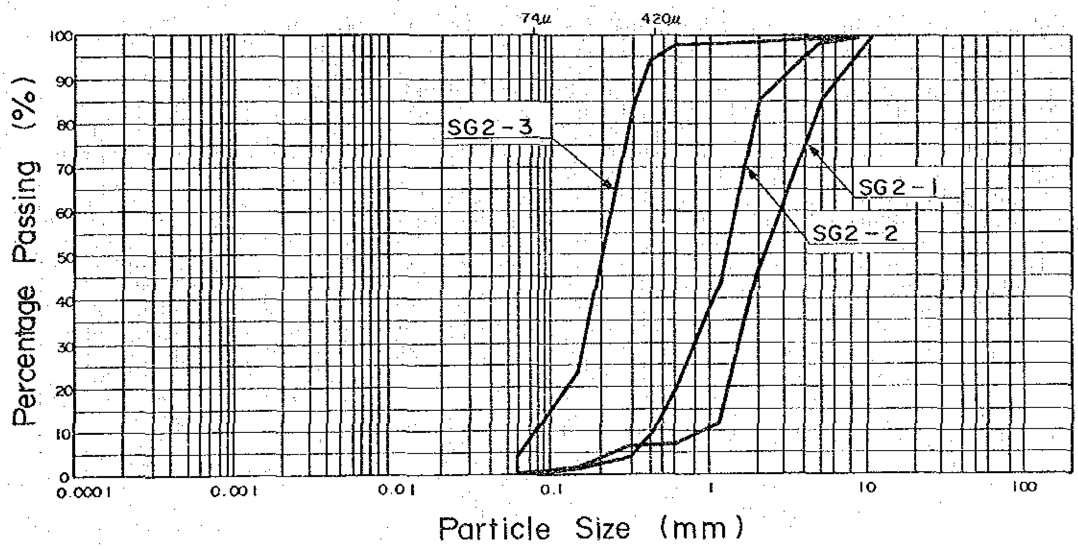

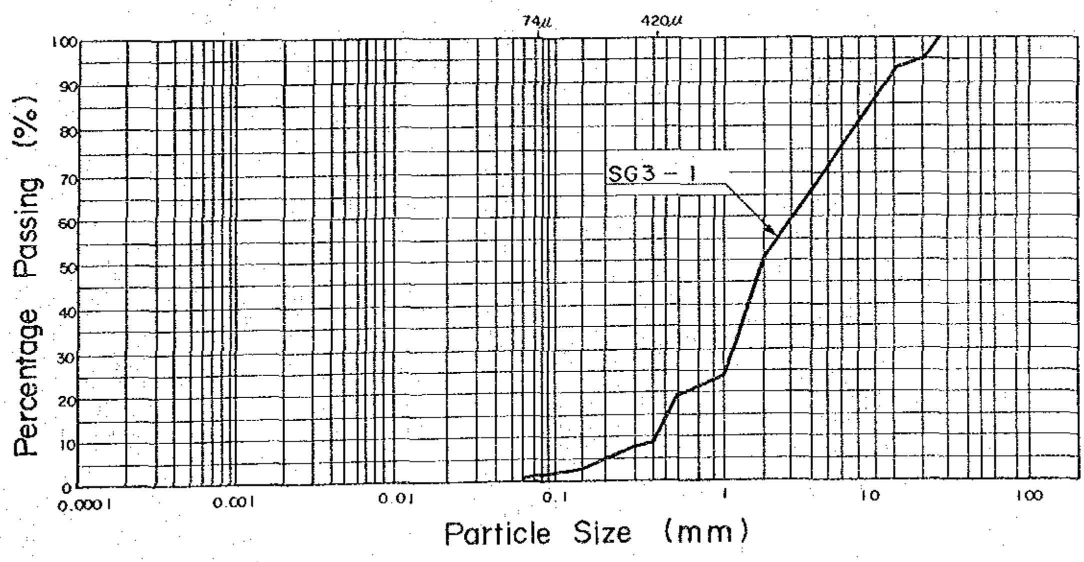

Fig.25 Particle Size Distribution of Sands in Prospective Borrow Area (1/2)

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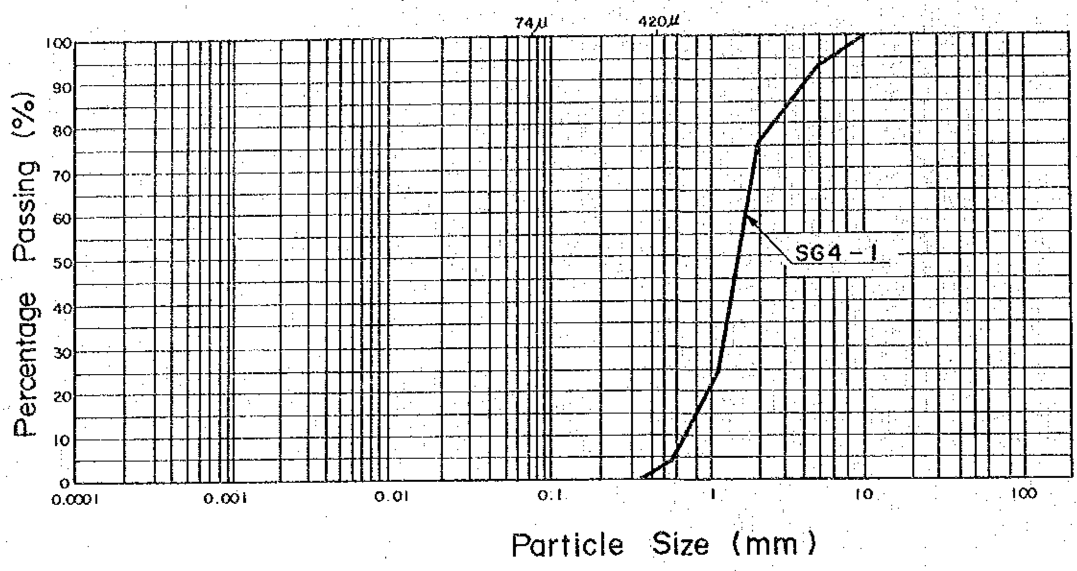

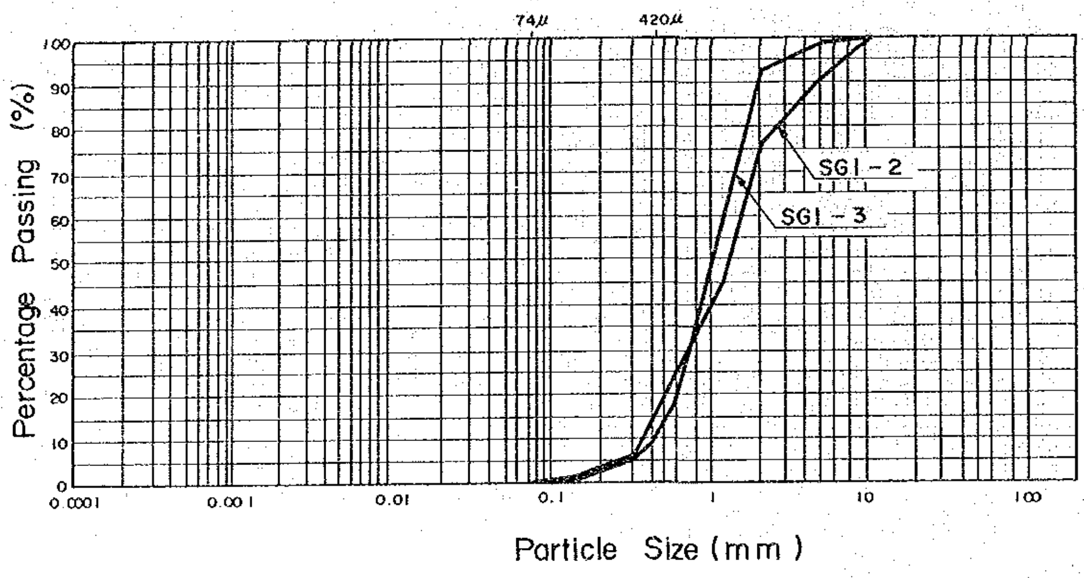

Fig.26 Particle Size Distribution of Sands in Prospective Borrow Area (2/2)

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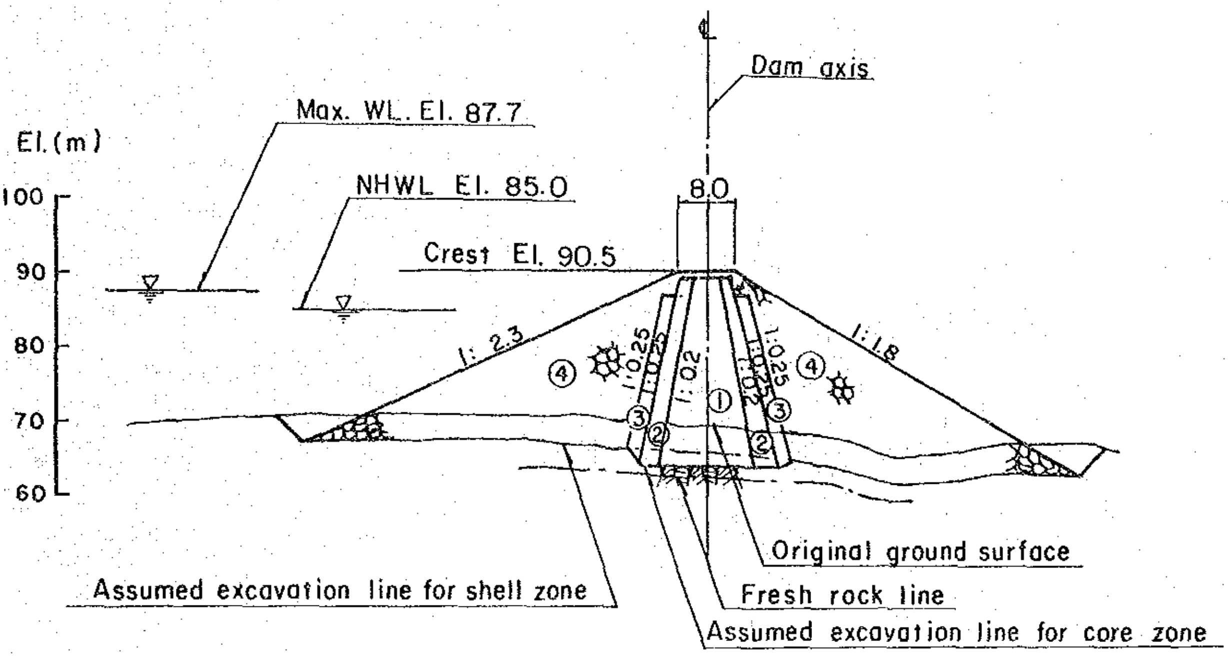

Legend:	
Zone No.	Material
①	Impervious core
②	Filter
③	Transition
④	Rock

Fig. 27 Zoning of Saddle Dam

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