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Construction materials for the Sembrong and Bekok Dams, Johor—a case study

AU YONG MUN HENG
Kejuruteraan Maju Sekitar, Kuala Lumpur
and
TAN BOON KONG
Jabatan Geologi, Universiti Kebangsaan Malaysia, Bangi

Abstract: This paper presents a case study on the investigations for construction materials for the Sembrong and Bekok Dams located near Air Hitam/Yong Peng, Johor. The construction materials investigated include earthfill, sands and rock aggregates. Field and laboratory test data are also given to assess the availability and suitability of the materials.

INTRODUCTION

The Sembrong and Bekok Dams form part of a larger scheme, namely the Western Johor Agricultural Development Project. Initially undertaken by the Drainage and Irrigation Department mainly for flood mitigation, the two dams will now also be utilised for water supply purposes by the Waterworks Department. Sembrong Dam is currently under construction, while construction of the Bekok Dam would commence in the near future.

Detailed site investigations have been carried out for the two projects, including geologic and soil investigations for the dam foundations and related areas. Results of these investigations are contained in two separate geotechnical reports listed in the reference.This paper discusses only the investigations for construction materials for the two dams. Other aspects of the investigations at Bekok Dam can be referred to in Tan and Wong (1982), and Tan (1983). The construction materials discussed include soil borrow materials for construction of the dams and embankments, sources of sand filters and possible quarry sites for rock aggregates and rip-rap. Laboratory test results of the various materials are also presented.

These two dams are taken together in this study because of their close proximity to each other, located within similar geological environment and the construction materials required for both the dams are similar and obtainable from common locations. A location map of the two sites is shown in Figure 1.

BASIC CONSTRUCTION MATERIALS

The basic construction materials investigated for the earthfill dams at Sungai Sembrong and Sungei Bekok are as follows:

Materials	Uses
Earthfill	embankment fill
Sand	concreting purposes, filter and drainage blanket
Rock	rock aggregates for concreting, rip-rap and rockfill toe

EARTHFILL

Residual soils derived from weathering of the sedimentary sequence of fine-grained sandstone, siltstone and shales were identified at the immediate proximity to the main dams at both sites. Simple borings, hand augers, test pits and trenches were carried out to delineate the various soil strata present as well as to collect samples for laboratory testing. Based upon the classification tests such as Atterberg limits and particle size analyses carried out on the collected samples, three main types of soils were identified, namely:

—a lateritic yellowish brown-red clayey GRAVEL (GC) with some lateritic sand-sized particles which forms an 'iron capping' generally at the top 1–2 m.

—a greyish yellow-brown, stiff silty CLAY (CL–CH) occasionally with lateritic gravel and some fine sand. This layer may reach up to 10 m thick.

—a variegated yellow-purple-pink-red, stiff to very stiff clayey SILT (ML) with pockets of quartz gravel and intermixed with fragments of shale-siltstone which rests directly on the bedrock.

A typical cross-sectional soil profile of a borrow area at the Sungei Bekok Dam site is given in Figure 2.

The broad trends of soil types as described above are defined by the plasticity charts and grain size distribution curves of the borrow materials at the Sembrong and Bekok Dams, examples of which are shown in Figures 3 and 4. Figure 3 shows the plasticity charts for the fine grained soils in both Sembrong and Bekok borrow areas, the soils are very similar in nature, being predominantly MH–CH. Figure 4 shows the presence of distinctly coarse fractions (gravels) in addition to the predominantly fine-grained soils (silts and clays) in the borrow areas. These gravels, as indicated earlier, are products of laterisation of the fine-grained soils and occur at shallow depths only.

Clay samples were analysed by x-ray diffraction method to detect any presence of expansive clays. Kaolinite predominates with minor occurrence of mica and chlorite and it is concluded that the clays are non-expansive and has a low dispersivity. The low dispersivity of the clays is also substantiated by hydrometer analyses.

By standard Proctor compaction of borrow earthfill, it was determined that the optimum moisture content of the embankment fill material of between 17–37% is in general lower than the natural moisture content by about 5–15%. (Figure 5).

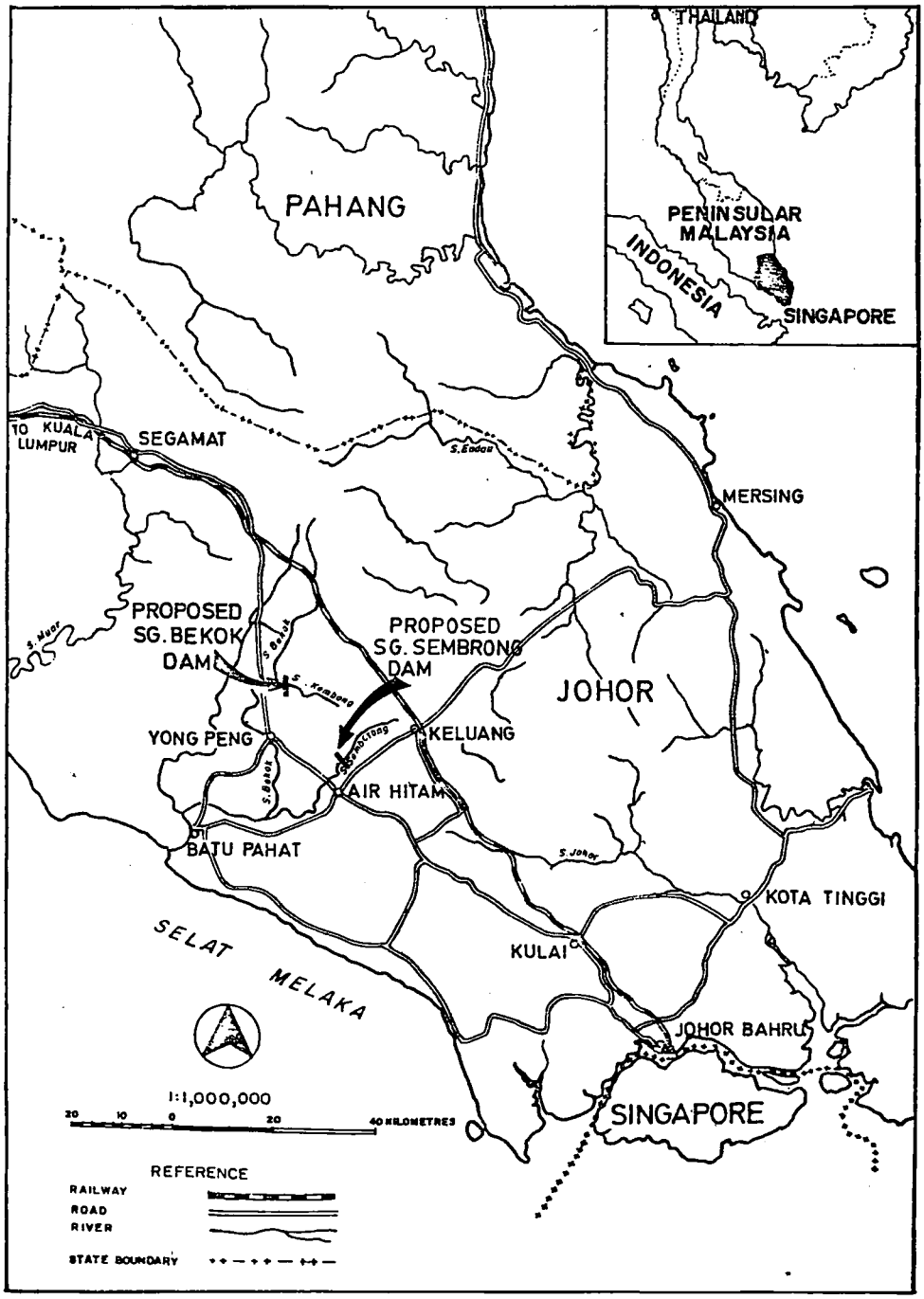

Fig. 1. Location map of Sambrong and Bekok Dams.

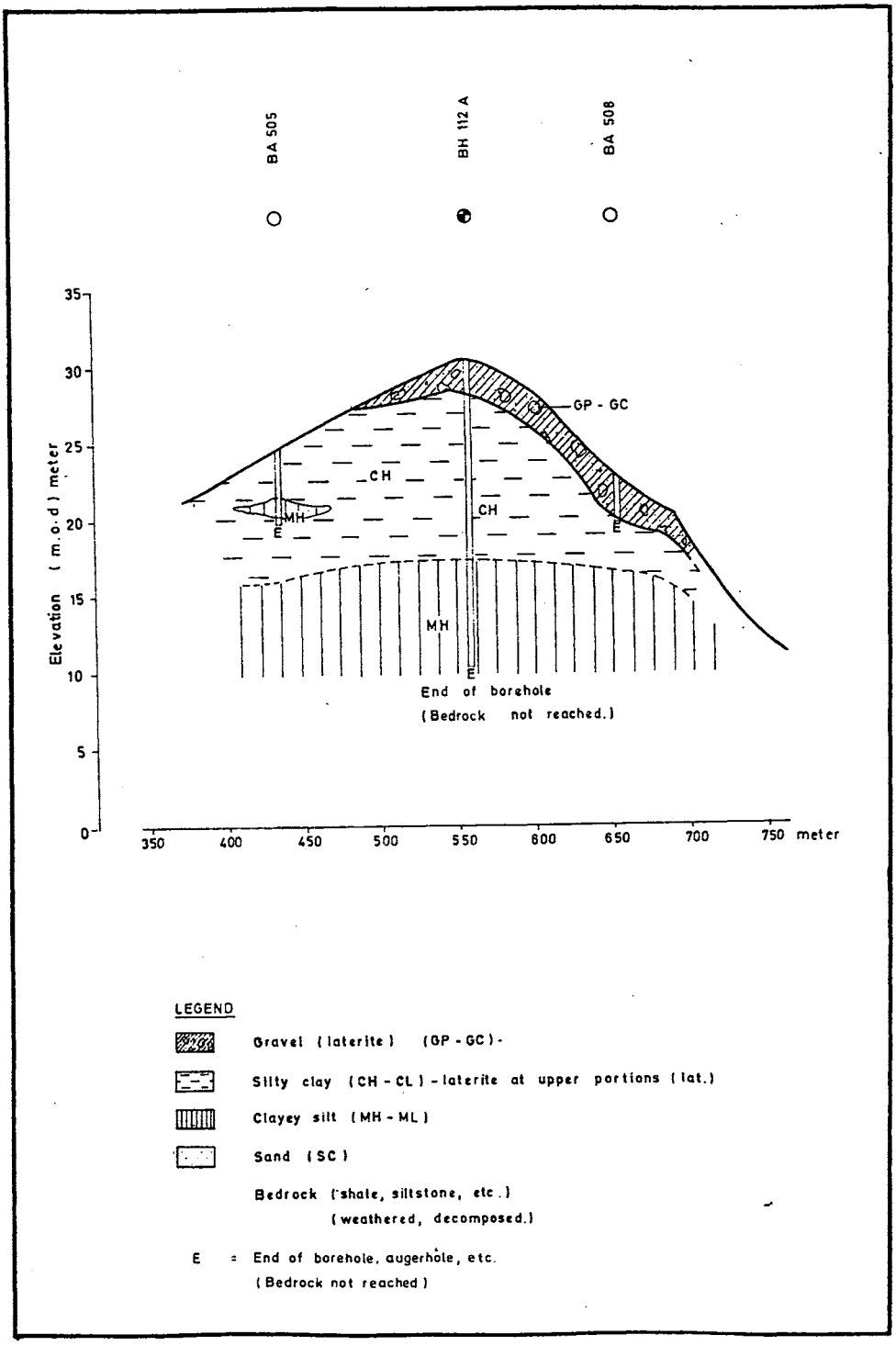

Fig. 2. Typical cross-sectional profile of borrow area at Sungai Bekok Dam site.

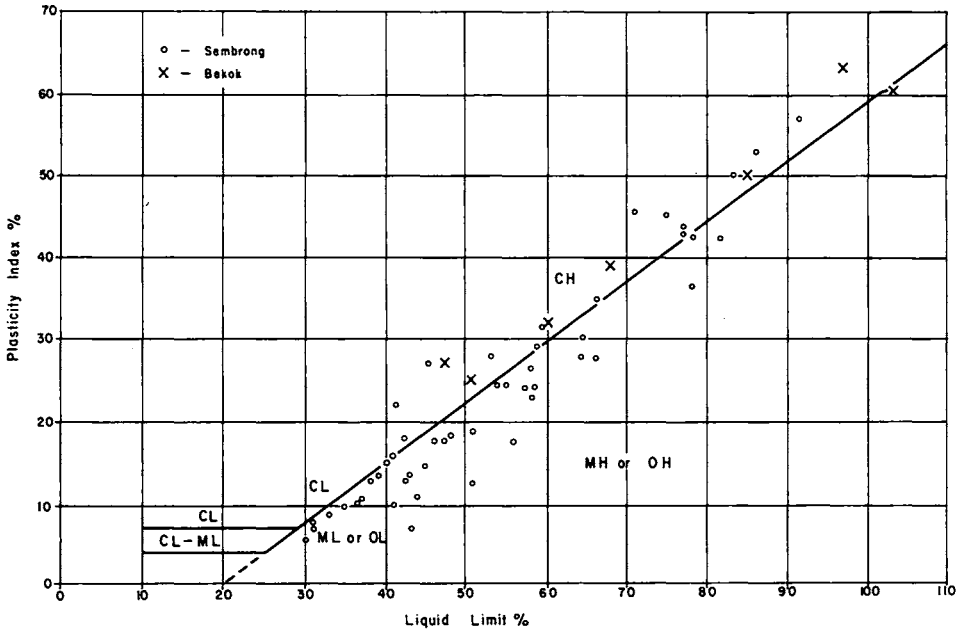

Fig. 3. Borrow materials—plasticity chart.

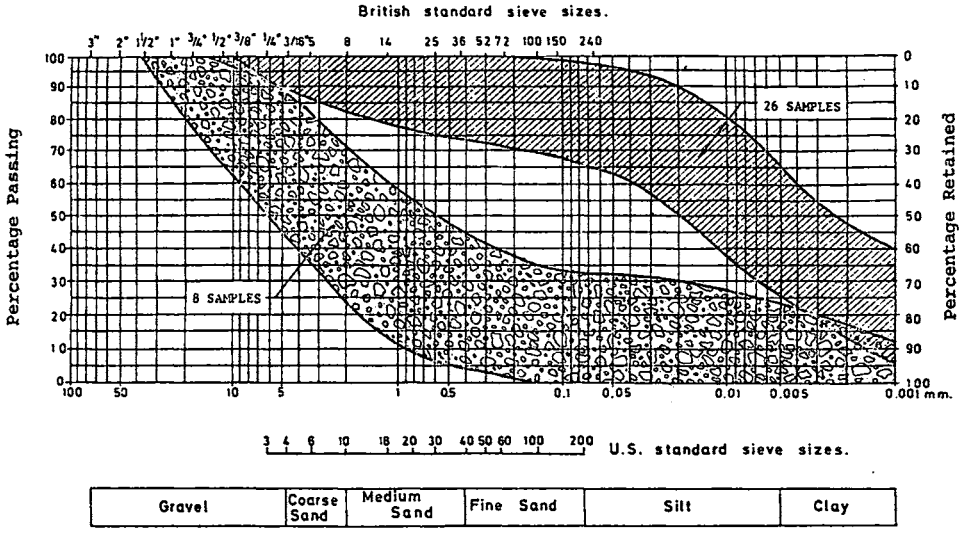

Fig. 4. Grading curves—borrow area no. 1 for Sungai Sembrong Dam.

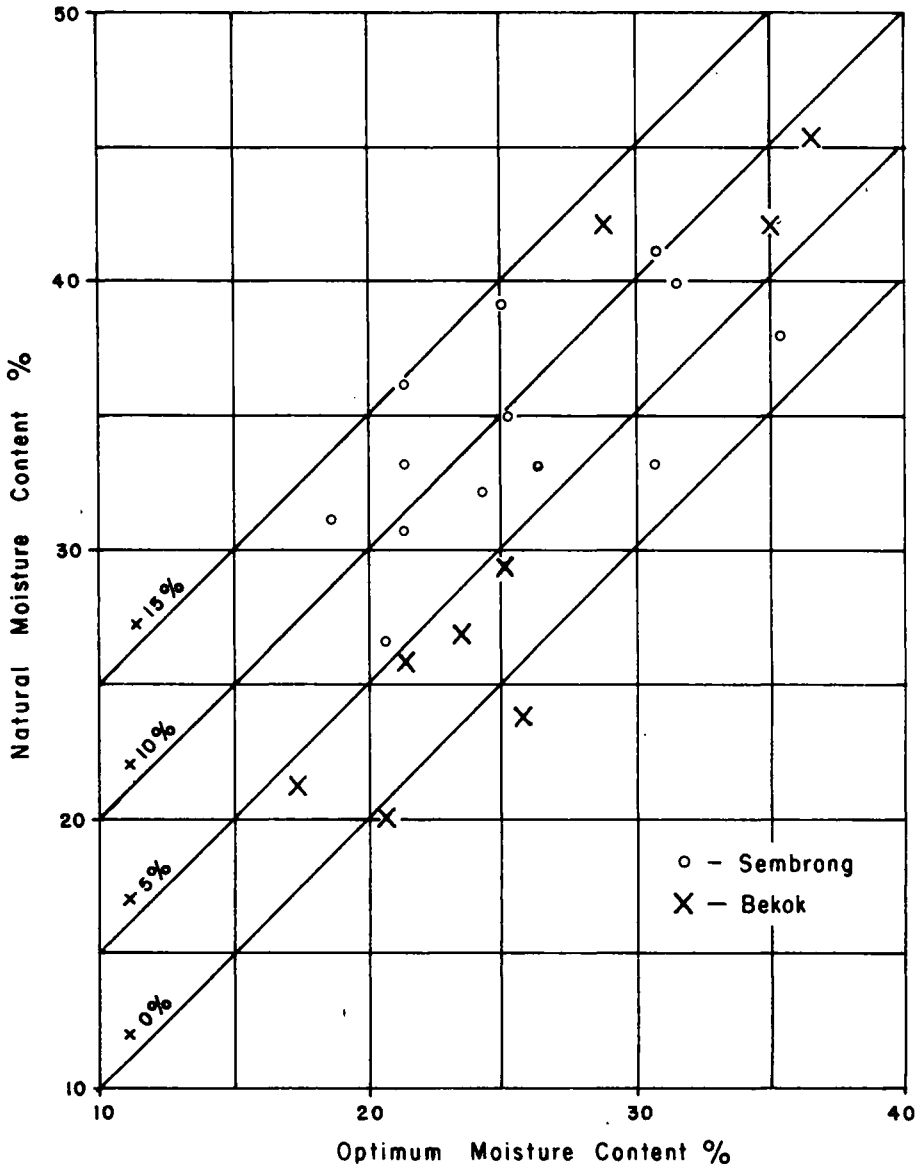

Fig. 5. Natural moisture content versus Proctor optimum moisture content.

Compaction wet of the optimum would therefore facilitate embankment construction since prolonged drying of soils would not be necessary. The more flexible embankment thus obtained would also alleviate problems cuased by differential settlement in the main dams.

The quantity and type of borrow materials that can be obtained in the various subdivided areas 1/1, 1/2 and 1/3 in Bekok, and areas no. 1 and no. 2 in Sembrong are tabulated as shown in Table 1 and 2 below.

TABLE 1

SUNGAI BEKOK DAM VOLUME OF EARTHFILL

Volume of Soil Type (m^3) / Borrow Area	GC-SP (laterite)	CH-CL	MH-ML
No. 1 1	17,000	63,000	86,000
No. 1/2	195,000	643,000	2,516,000
No. 1/3	35,000	535,000	370,000
Sub-Total	247,000	1,241,000	2,972,000
For Design	0.2×10^6	1.0×10^6	2.5×10^6

TABLE 2

SUNGAI SEMBRONG DAM VOLUME OF EARTHFILL

Volume of Soil Type (m^3) / Borrow Area	GC-SP (laterite)	CH-CL	MH ML
No. 1	240,000	560,000	800,000
No. 2	1,600	158,400	
Sub-Total	241,600	1,518,400	
For Design	0.2×10^6	1.2 x 106	

These quantities of materials are adequate for construction of the main dams in the two projects.

SAND

Sand is used for concreting purposes and as filter material and drainage blanket within the dam. Three sources of sand were identified, namely:

—river sand composed of clear quartz grains derived from weathered granite further upstream,

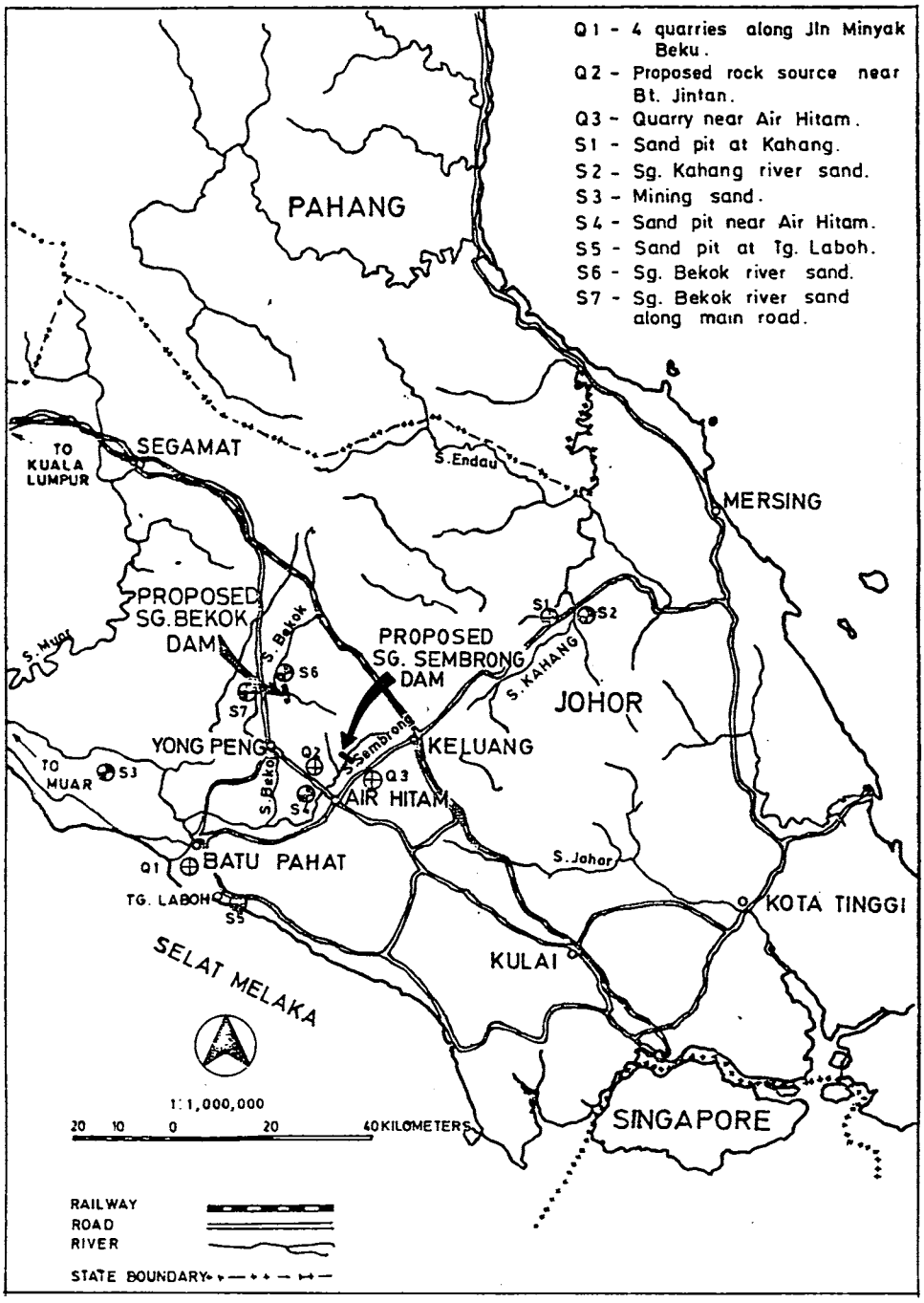

Fig. 6. Locations of rock and sand sources.

—pit sand occurring as terrace alluvium,

—mining sand

Simple test pits and hand augerholes were carried out to determine the extent and quality of the sand deposits. The localities of the sand sources are shown in Figure 6, and the gradings of the various sands are shown in Figure 7.

The sands range in size from fine to coarse grained and contain little or no fines (silts and clays). The quality of the sands is thus generally good and within acceptable limits. However, they might have to be appropriately sieved or washed before use depending on the requirements of each usage being considered. Since only small quantities of sand would be required in the two projects, the sources indicated could easily supply the requirements needed.

ROCK

A proposed rock quarry site was located south-west of Bukit Jintan (Figure 6, Q2), the details of which are shown in Figure 8. The rock quarry has to provide rock aggregates for concreting purposes as well as rip-rap and the rockfill toe of the dams.

A detailed seismic refraction survey coupled with confirmatory borehole drilling was carried out at the proposed site (see Figure 8) to determine the overburden thickness and the character of the rock mass. The overburden thickness varies between 0 to 20m, but is generally between 2 to 8 m, being thickest at the base of the hill as slope wash where it can reach up to 20 m. The bedrock registered a seismic velocity of 5000–6000 m/sec, indicating a very hard rock which requires blasting.

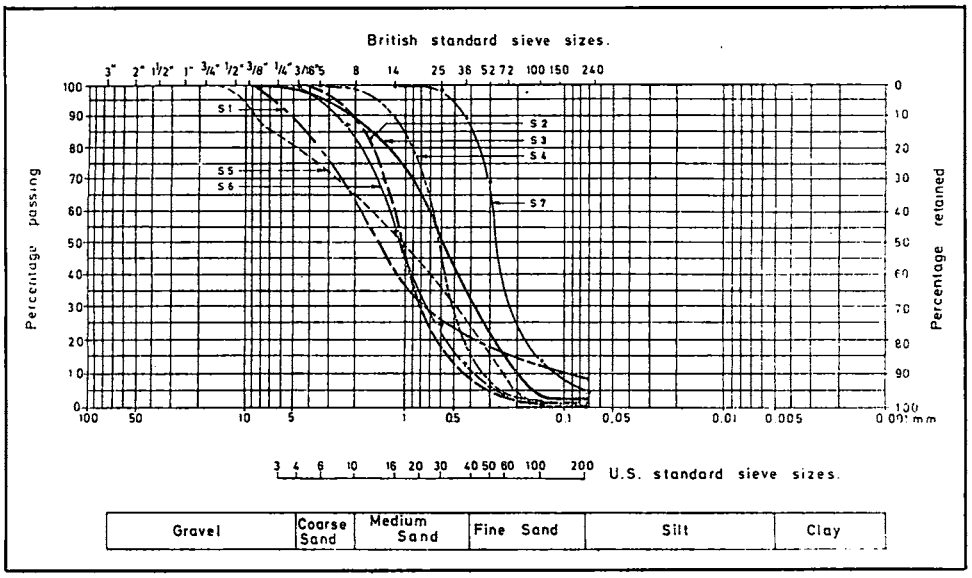

Fig. 7. Grading curves for sands.

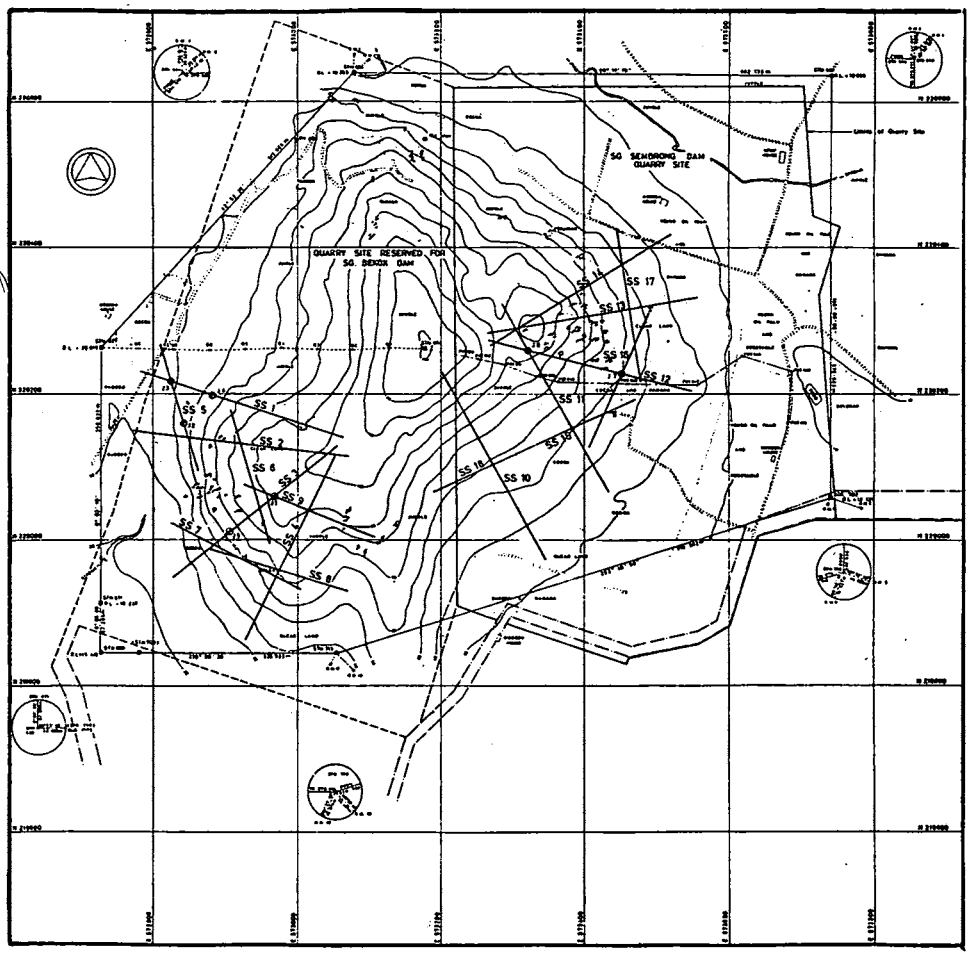

Fig. 8. Site investigations of proposed quarry site at Bukit Jintan.

The rock concerned is a fresh, massive, fine-grained Andesite, slightly metamorphosed with disseminations of pyrite and arsenopyrite. It is veined by quartz occasionally containing pyrite.

The andesite has very sound engineering properties and satisfies all the strength tests. Its extremely high crushing strength and hardness may result in difficulties in drilling and blasting in addition to extra wear and tear of drilling and crushing machinery. Although physically very sound, chemically the andesite contains pyrite which can cause problems particularly in concrete works, since pyrite is a deleterious material and can cause 'pop-outs' and surface staining of concrete. Care must therefore be exercised in the use of this andesite for concrete purposes. Whenever excessive amount of pyrite is present the rock should be pushed aside and be used for other purposes such as rip-rap or rockfill.

TABLE 3

SUMMARY OF LABORATORY TEST RESULTS FOR ROCK AGGREGATES

Location	Specific gravity and absorption of coarse Aggregate (Aashto T85-74)		Los Angeles Abrasion test (Aashto T96-74 (Grading B)		Sodium sulphate soundness test (Aashot T104-74 coarse series, 5 cycles)	Ten percent fines test (BS 812: part 3 1975)	Remarks
	Apparent specific gravity	Water Absorption (% of dry weight)	Ratio of loss	Percentage of wear	Total percentage loss	KN	
Bukit Jintan (Andesite)	2.95	0.20	0.19	8.6	0.25	408	Crushing strength (Uniaxial compression test) 436 MPa (extremely high) Shore scleroscope hardness 89–91 (extremely high)
Air Hitam Quarry (Rhyolite)	2.73	0.50	0.20	13.9	0.04	358	
Acceptable Limits	—	≥ 1.0	—	≥ 40	≥ 10	≤ 100	

An alternative source of rock aggregate for concrete is located at the Air Hitam Eng Seng Quarry at 8th milestone, Air Hitam–Kluang road. The rock here is identified as a rhyolite with a fine grained matrix and abundant phenocrysts of quartz and some plagioclase. The rhyolite also has favourable engineering properties and is thus suitable as concrete aggregates. However, this quarry is private-owned and produces only limited output mainly for road uses.

A summary of the laboratory test results of the rocks at Bukit Jintan and Air Hitam is given in Table 3, which shows that both rocks are acceptable for usage in the projects.

Other possible sources of rock aggregates are the four quarries located in the vicinity of Batu Pahat which are currently operational and producing granite. These quarries, however, are located at much greater distances from the dam sites.

CONCLUSIONS

The investigations at the Sambrong and Bekok Dam sites and vicinities have shown that there is adequate construction materials (earthfill, sands and rock aggregates) of suitable quality for purpose of construction of the two dams. The earthfill and sands are obtainable from the sources delineated during the investigations and would most likely be as indicated. However, the rock aggregates may or may not be obtained from the proposed site at Bukit Jintan, depending on the cost comparison between starting a new quarry at Bukit Jintan and hauling rocks from greater distances from existing quarries, say from Batu Pahat.

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