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Three recent Malaysian dams

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INTRODUCTION

The paper describes and contrasts the design of three dams recently completed, or approaching completion, in Johore, West Malaysia and in Sabah, East Malaysia. Although it is only by chance that these dams were designed and constructed at the same time, it is instructive to compare, in a single paper the various problems encountered at each site and the solutions that were used to deal with them The principal statistics of each dam are given in Table 1.

TIMBANGAN DAM

Purpose of the dam

Timbangan dam, situated on the Sungei Timbangan between Tawau and Semporna in Sabah, East Malaysia (Fig 1) is the most straightforward of the three dams discussed. The purpose of the dam, which is owned by the Public Works Department (JKR), is to impound water for the supply of the town of Semporna.

Hydrology

The Sungei Timbangan, which flows south into the Celebes Sea has a catchment area at the dam of 22 km^2 of steeply sloping jungle. The mean annual rainfall is 2150 mm, and the estimated annual potential evapotranspiration is 1300 mm. In the absence of any relevant streamflow data the mean annual runoff was estimated by a simple water balance approach, to be 18 Mm^3. The reservoir top level was set at a height of 11.5 m above river bed level so that the reservoir storage is equal to three months (the longest recorded period of drought) supply to Semporna at a daily rate of 9000 m3.

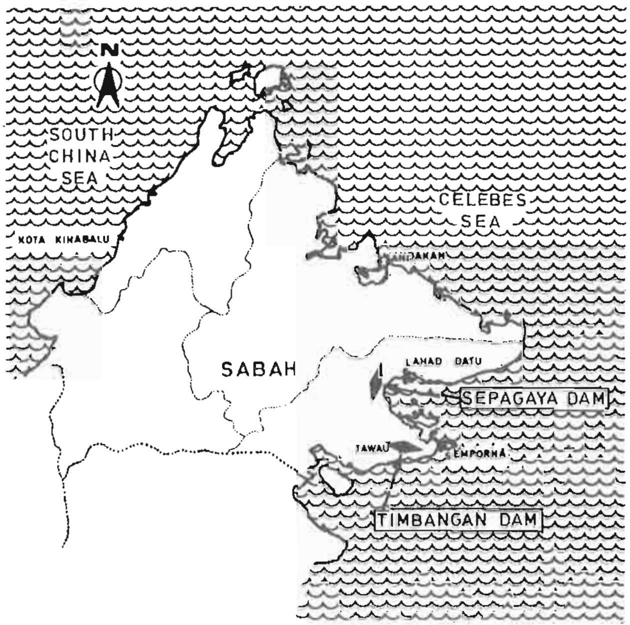

Figure 1 Sabah dams location plan

Description of the dam site

The river, at the dam site, flowed in a V - shaped valley where many exposures of bedrock a massive andesite, were evident in the river bed and on the lower slopes, higher up. Especially on the left bank, the andesite has weathered to depths of up to 5 m.

Choice of dam

The existence of the massive strong andesite at shallow depths over the site make the choice of a gravity dam attractive. Such a dam was selected, in preference to an embankment dam, as the more economical for the site, for the following reasons :

TABLE 1 - PRINCIPAL STATISTICS

	TIMBANGAN	SEPAGAYA	SEMBRONG
Dam Type	Concrete gravity	Rockfill	Earthfill
Dam Height (m)	15	23	11
Dam Length (m)	160	70	900
Dam volume (m^3)	7,500	50 000	650 000
Spillway type	Free overflow	Bellmouth	radial gates
Design flood (m3/s)	165	300	400
Reservoir volume (Mm3)	0.8	2	18
Construction cost (US $ Million)	2.2	5.0	9.4
Contractor	Pemborong Tan / Jurubena Jaya J.V.		Manong

a) the problem of river diversion during construction is minimised with a gravity dam.

b) the cost of the spillway is less with a gravity dam because the spillway is an integral part of the structure and water flows over the downstream face of the dam. This is not possible with an embankment dam where the water is spilled by means of a separate structure.

c) similarly, abstractions from the reservoir are made through the dam itself, in contrast to the need with an embankment dam for a separate draw-off structure.

The cross-section of the dam is shown in Fig 2

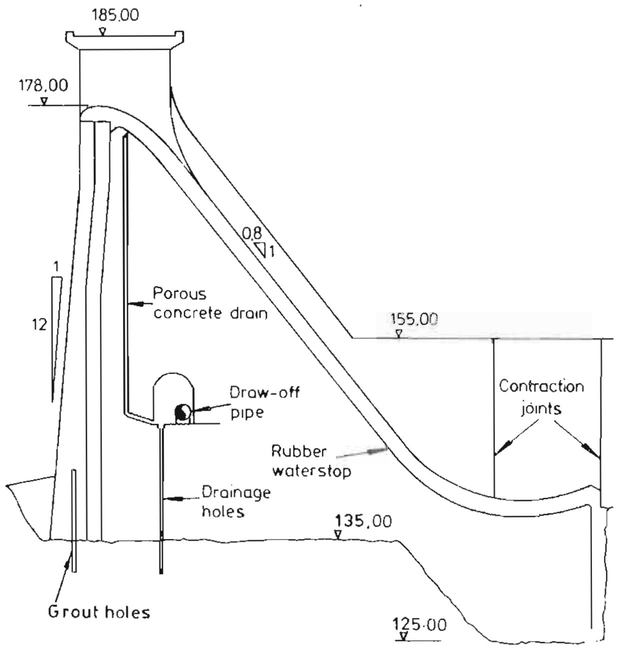

Figure 2 Timbangan dam section

Dam Construction

The dam was completed in 1983 after a construction period of 2 years. One construction problem, solved by a relatively new method, was that of the control of the temperature rise of concrete during construction due to the heat of hydration. To limit undue temperature rise, which can cause cracking, newly cast concrete was thermally cured to maintain high temperatures at the concrete surfaces and to limit temperature differentials. This method was effective and cheap, and was monitored by means of thermocouples cast into the body of the dam and into the surface of the concrete. The traditional method which is more costly, relies on the use of iced water in the concrete mix.

SEPAGAYA DAM

Purpose of the dam

This dam, the highest of the three, is situated some 70 km north of Timbangan, and is currently under construction for the JKR to provide additional storage for the water supply of Lahad Datu. (Fig 1).

Hydrology

The dam is situated on the Sungei Sepagaya a river that flows eastwards to Darvel Bay. The catchment size and characteristics, the rainfall and evaporation are all very similar to those of the Timbangan dam. Sepagaya reservoir is larger, however, as it provides three months supply of 225,000 m^3/day equivalent to a reservoir volume of 2 Mm^3 and a top water level 22 m above river bed level.

Description of the dam site

The Sepagaya river flowed in a deep steep - sided valley in highly fractured serpentenite rock, weathered at its surface so that only in the river channel did the fresh bedrock outcrop. The depth of weathering was not excessive on the left bank, where reasonably strong rock occurred at a depth of less than 5 m. On the right bank, however, weathering has penetrated to great depths and no fresh rock was encountered at any depth in the site investigation.

Choice of dam type

The absence of strong weathered rock at reasonable depths on both sides of the valley precluded the choice of a gravity dam, although such a dam type would have well suited the topography for the same reasons as given above. An embankment dam was therefore chosen, in the design of which the following problems had to be overcome:

a) high rainfall throughout the year creates difficulties for the compacting of clayfill with a controlled moisture content.

b) the diversion of the Sungei Sepagaya in the narrow valley during construction.

c) the high sided valley poses problems for the provision of spilling capacity.

The first problem was resolved by adopting a zoned embankment of rockfill and clay with the clay element, the impermeable core, as thin as possible, to minimise the clay quantity. The maximum hydraulic gradient across the core was 0.5. It was accepted that the moisture content range for the clay would be higher than normal, resulting in a more plastic, but weaker core. Consequently, to maintain stability, the slope of the rockfill shoulders were made flatter than usual, but this was found to be necessary also for reasons of foundation bearing pressures and of stability in times of earthquake. (Sabah is moderately prone to earthquakes: the last, measuring 6 on the Richter scale, occurred in 1976). Furthermore, by inclining the core upstream more working space is provided to the contractor to place rockfill in advance of the clayfill, during

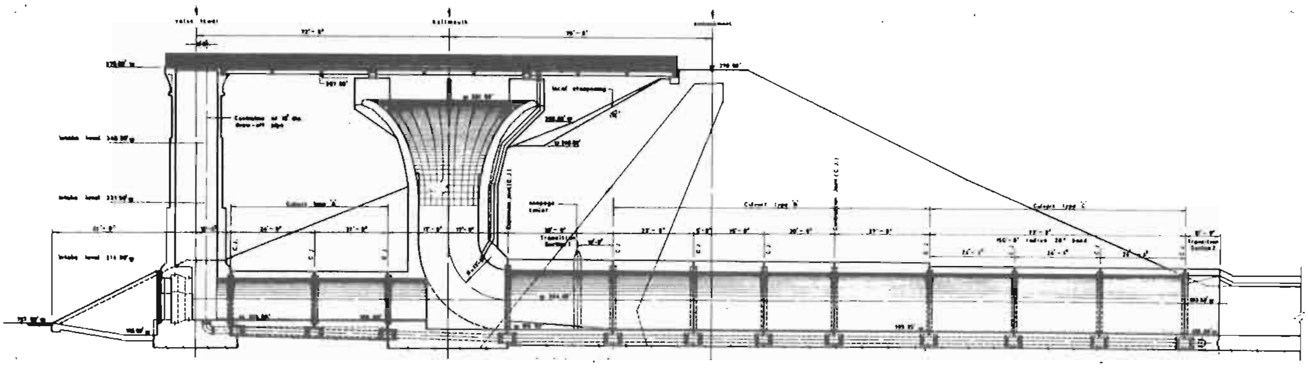

Figure 3 Sepagaya dam section

wet weather, in the downstream shoulder.

The second and third problems were solved together by the adoption of a bellmouth spillway discharging into a concrete culvert as shown in Fig 3. During the construction of a concrete dam it is possible to divert the river over concrete already poured, but the equivalent method is not available to the constructors of an embankment dam. During construction of such a dam the river must be diverted either through a tunnel driven in one of the abutments or in a culvert buried in the fill. Both alternatives were examined in the case of Sepagaya and the culvert alternative chosen on grounds of cost. Two alternatives also presented themselves for the spillway: either a simple overflow spillway in a channel excavated into one of the abutments, or a shaft spillway utilising the culvert that must be provided for diversion. Because of the relatively large flow to be provided for (300 m^3/s) and the very large volume of excavation involved in the first option by reason of the high-sided valley, the bellmouth option was found to be 15% cheaper. A model was therefore made of the bellmouth spillway, shaft, culvert and stilling basin to check its hydraulic performance and especially that of the culvert and stilling basin which are curved in plan to accommodate a bend in the river.

One radically different solution was considered but not adopted, was that of an overflow rockfill embankment. In such a dam no spillway structure is provided and all spillages pass over the crest of the dam and its downstream slope, which are reinforced with a grid of galvanised steel bars.

This idea has been tried in Australia but is still relatively new and imperfectly understood: also a reasonably strong and non-eroding foundation is necessary. For these reasons it was felt that a conventional solution should be adopted at Sepagaya.

SEMBRONG DAM

Purpose of the dam

This dam is the lowest of all three, being only 11 m high, but involves by far the greatest volume of fill and impounds the largest reservoir. Situated on the Sungei Sembrong near Air Hitam in Johore, (Fig 4) the dam, which is owned by the Drainage and Irrigation Department (JPT), is designed to provide flood protection to the very flat Batu Pahat plain, and is one part of the JPT's Western Johore Agricultural Project. The dam can also provide up to 0.5 m^3/s (43,200 m^3/day) for local water supplies.

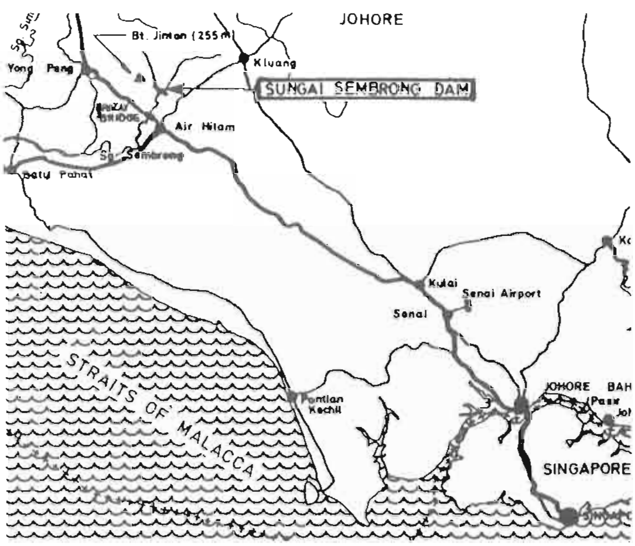

Figure 4 Sembrong dam location plan

Hydrology

The Sungei Sembrong flows south westwards into the Malacca Straits and has at the damsite a catchment area of 130 km^2. The mean annual rainfall is 2250 mm.

Description of the Project

The project comprises an 11 m high main embankment of a total length of 1700 m. Ancillary structures comprise a Flood Regulating Outlet and a free overflow spillway both discharging into a common stilling basin, both of which are founded on the hill composed of residual soil which forms the left abutment of the main embankment.

Method of Operation

During times of low flow the reservoir will be full to the normal storage level of 8.5 m od. (storage volume of 18 Mm^3) and abstractions may be made for local water supply and for compensation water by means of 700 mm ductile iron pipework. Floods of up to 1 in 100 years return period can be stored (storage 35 Mm^3) and released at a controlled rate of up to 42 m3/s through two radial gates of the Flood Regulating Outlet. Floods of intensity greater than 1 in 100 year recurrence will pass over the uncontrolled spillway. During the probable maximum flood, when the reservoir level will be 14 m, the total volume of water stored is 75 Mm^3 the maximum discharge 400 m^3/s

Embankment design

The design and construction of the 11 m high embankment on the swampy foundations offers a startling contrast to the two dams previously described and is the most remarkable aspect of the overall project.

It was decided to found the embankment on the swampy deposits since their excavation which would have involved dewatering on a large scale and would have been so expensive as to render the entire scheme uneconomic.

However, to design an embankment with such soft foundations it was necessary to understand the mechanical properties of the strata. This is normally done by sampling and laboratory testing, but because the difficulty of recovery of undisturbed samples from the very soft deposits an advanced self boring pressuremeter was used to test the material in situ. The results obtained were used in a finite element stress analysis, a consolidation analysis and stability analyses. Crucial to the stability of the embankment is the pressure of pore water in the foundations, and much of the analysis was devoted to their prediction. In particular the finite element stress analysis predicted the instantaneous foundation pore pressure rise due to the loading caused by the staged construction of the embankment, while the consolidation analysis predicted how this pore pressure distribution would be modified by consolidation over the period of time actually required for construction. As a result of the analysis the embankment was designed with average slopes of 1 vertical to 5 horizontal as shown in Fig 5 and was planned to be built in stages, with the minimum construction period of the last two stages specified as a contractual requirement.

Embankment Construction

The embankment has been constructed in the following phases.

The preliminary phase in which the river was diverted through a channel excavated in the residual soil of the left abutment and roads were formed across the swamp outside the dam area by end tipping laterite gravel.

The construction of bunds in advance of the main embankment to help consolidate the foundations and to improve stability, and also to protect the foundation area of the main embankment from flooding.

The first stage of construction of the main embankment comprised the stripping of about 2 m of decayed organic matter - logs, tree roots etc, to expose the foundation material of soft organic clay. Over-excavation would expose lenses of quicksand. The first 1 m of fill was placed by end-tipping residual clay in 0.5 m thick layers and compacting with the bulldozer. Subsequently fill was placed in conventional layers 20 cm thick and compacted with rollers. Occasional blow-outs through the clay, caused by excessive foundation pore pressure, were experienced and these were dealt with downstream of the core zone, by filling the hole with sand and draining the flow to the downstream toe, to relieve the excess pore pressure. At the end of this stage pneumatic piezometers were installed in the foundations to monitor pore pressures for the control the subsequent rate of filling.

In the 2nd & 3rd stages of the main embankment foundation pore pressures were allowed to dissipate by restricting the construction period of each stage to 150 days. In no instance were the predicted results exceeded and thus it was not felt necessary to further restrict the rate of filling.

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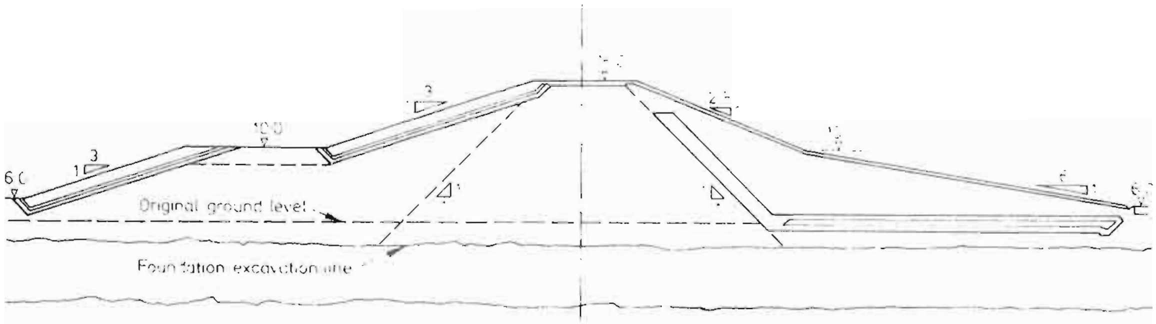

Figure 5 Sembrong dam section