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Recent RCC Construction Technology in Sg. Kinta Dam Project

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ABSTRACT:
Sg. Kinta Dam is the first RCC (Roller Compacted Concrete) dam constructed in Malaysia. The volume of the RCC used in the dam is approx. 1 million meter cube. Construction of the RCC dam presented a number of unique challenges, particularly construction equipment and method statement. The detail of the production equipment such as the crushing plant or RCC mixing plant is not stated in the specification as well as the RCC method statement. Therefore, the contractor is able to select and plan these production equipment and method statement flexibly. Selection process does implicate economic impact, it is therefore important that the planning is to be properly made by well understanding the idea and philosophy of the designer. This report is described advanced construction technology with regard to the production equipment including the dry type crushing plant and RCC continuous mixing plant as well as the RCC method statement including the GE-RCC and the Slope Layer Method which are adopted in this project.

Keywords: RCC, Dry Type Crushing Plant, RCC Continuous Mixing Plant, GE-RCC, Slope Layer Method

1. INTRODUCTION

In RCC (Roller Compacted Concrete) placing method, very stiff concrete is spread by bulldozer and is compacted by vibratory roller. While the conventional method requires cable crane etc. to transport slump concrete and inner vibrators to compact it, RCC permits rapid construction methodology by using general purpose earth works construction equipment and tools. In this project, the aggregates were produced by dry process and the continuous mixer of nominal production capacity 400 m^3/hr was used for mixing. RCC methodology chosen for construction of the dam was 'High paste' concept.

The SLM (Slope Layer Method) was adopted for RCC placing. As for the edges a predetermined 400 mm width both along upstream and downstream faces, GE-RCC (Grout Enriched RCC) method, a method to compact RCC with cement milk additives by inner vibrator, is adopted in design. This report describes the project profile of the dam that has been constructed by RCC method, explains the production equipment, RCC mix proportion and the construction method, including their results and future challenges.

2. PROJECT PROFILE

2.1. General Information for Sg. Kinta Dam Project

Sg. Kinta Dam Project is part of the Stage 2 development of the Greater Ipoh Water Supply Scheme which consist of 1,000,000 m^3 volume RCC gravity dam, associated 4.5 km raw water pipeline and the water treatment plant at Ulu Kinta. The specification of Sg. Kinta Dam is shown in Table 1. The overall plan and aerial photograph of dam site is shown in Fig. 1.

2.2. Foundation Rock

The base rock of the dam body is generally the coarse-grained granite in Triassic layer. The right

Table 1. Specification of Sg. Kinta Dam

Dam	Type	RCC (Roller Compacted Concrete)
	Height	92 m
	Length	780 m
	Volume	Approx.1.0 million m^3
Spillway	Type	Overflow Type Roller Bucket Type
	Width	100 m
	Flood Flow	2250 m^3/s (PMF: Probable Maximum Flood)
Reser-voir	Catchment Area	143 km^2
	Reservoir Capacity	29,900 Megalitres (FSL: Full Supply Level)

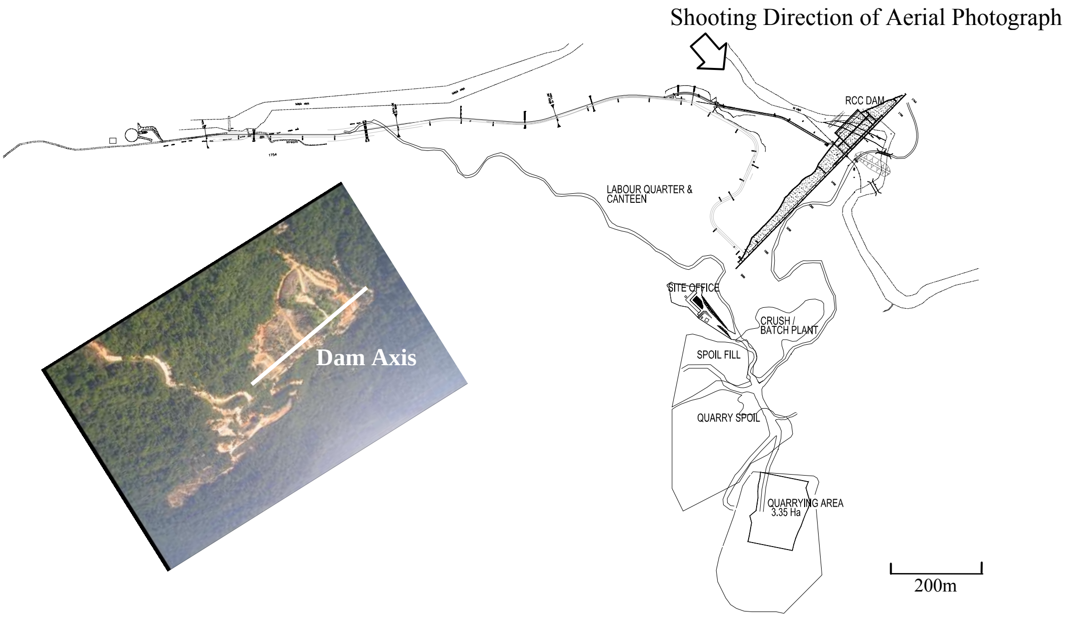

Figure 1. Overall plan and aerial photograph of dam site

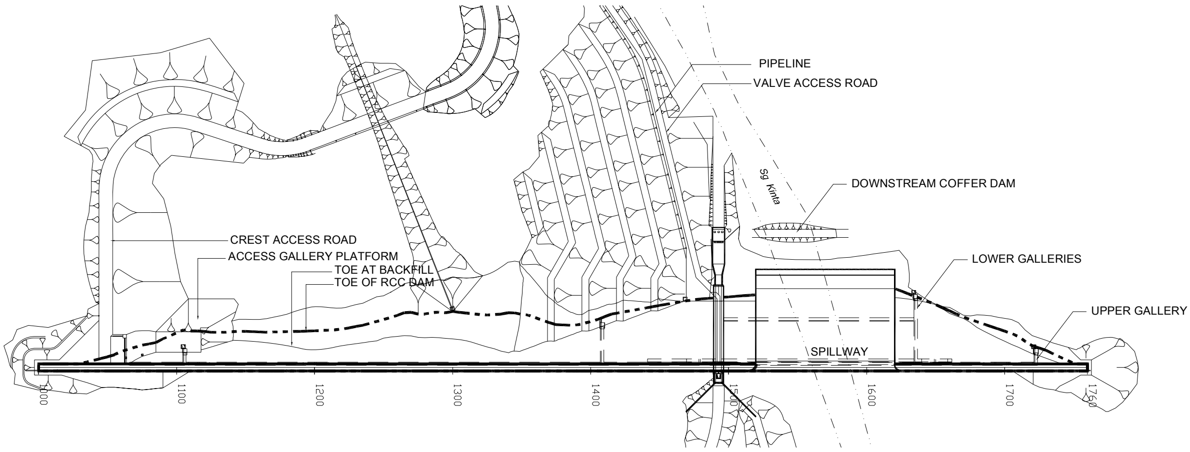

Figure 2. Dam plan

abutment side has relatively precipitous gradient, while the left abutment side has gentle gradient. The mixture of rocks deformed by shearing stress is observed, and the existence of several faults is confirmed. As the riverbed width is wide enough, open diversion method is adopted. As the faults were found in the central part and on the left abutment side, excavation was conducted to make 5 m depth depression and CVC (Conventional Concrete) was placed therein. Single row curtain grout was injected as the foundation treatment. Specified drilling is up to the tertiary hole (3 m spacing).

2.3. Dam Body

As the dam body is entirely composed of RCC, there are no other different class of concretes such as internal concrete or surface concrete. Structures to be constructed by using CVC are the crest of spillway, the training wall, the roller bucket and the intake tower. The dam plan and the typical cross sections are shown in Fig. 2 and Fig. 3

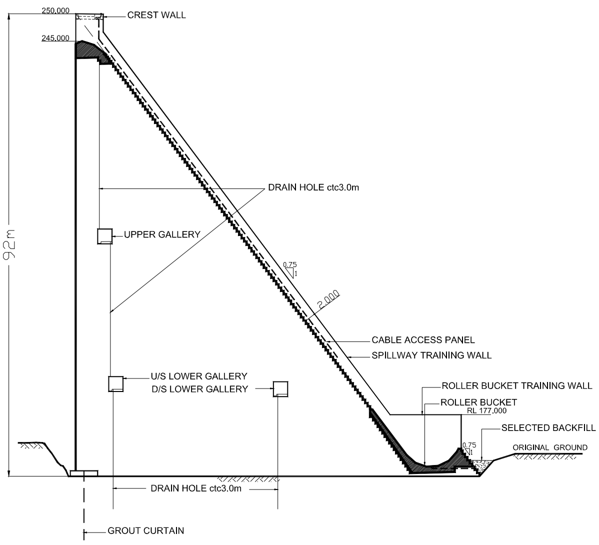

Figure 3. Dam typical cross section

respectively. As for the edge of the forms of both upstream and downstream face, the periphery of structures, GE-RCC is adopted. In the area adjacent to rock abutments where area does not permit articulation of earth moving equipment, the placing was started with Levelling Concrete first in order to achieve a decent working place and then shifted to RCC method.

3. CONSTRUCTION EQUIPMENT

3.1. Outline of Construction Equipment

Primarily manufacturing of RCC and CVC at Sg.Kinta were 400m^3/hr RCC continuous plant and a 90m^3/hr CVC twin shaft batching plant. Aggregates were fed to the plants from the compartmentalized covered storage by manner of integrated belt system and cement / flyash components using normal gravity feed silos. Water treatment plant on site was both for manufacturing RCC / CVC as well as for curing and green cutting purpose on the dam. Power source to the entire project site were from the main national grid.

3.2. Aggregate Plant

The quarry face was located approximately 800 m from the dam site whereas the quarry plant was located between them. The plant features the dry production and introduction of the vertical shaft impact crusher (Barmac 9000) to produce crushed aggregates abundant with fine particles of sieve size less than 75 µm. The aggregate plant facility is single system, and primary crushing plant, primary surge stock pile, secondary, tertiary & quaternary crushing plants, and products stockpiles were placed in this order. Production capacity of the primary crushing plant is 550 t/h (Fig. 4) and that of the secondary, tertiary & quaternary crushing plant is 350 t/h (Fig. 5), which permits an RCC placing rate of 4,000 m^3/day at peak. The products stockpile was covered with roof and the screen was placed above it to overcome the narrowness of the site. These products would be fed to the RCC plant on tunnel conveyors.

Figure 4. Aggregate plant (Primary crushing plant)

Figure 5. Secondary, tertiary & quaternary crushing plant and products stockpile

3.3. Continuous Mixing Plant

A modular concept RCC continuous mixing plant, Modumix-II (Aran, Australia) was installed (Fig. 6). The plant is compact and easy to install and dismantle. It comprises 2 silos (60 t each), 5 aggregate bins (14 m^3 each), water supply pump, admixture supply pump and continuous mixer, and its production capacity is 400 m^3/h. Aggregates go through the fixed opening over the feeder, and volume of aggregates per unit time is regulated and measured by speed of the belt. Cement and fly ash go through the feeder with fin belt at bottom of the silo, and their unit volume is regulated and measured by speed of the feeder. The plant is compact and easy to install and dismantle. Twin shaft forcible mixer continuously mixes RCC agitating its materials by arms with 72 blades attached to 2 shafts. After cleaning of the plant, sand and water are put in the mixer before starting the next RCC production. This will build a sand wall inside the mixer, and sand liner will form a coat between concrete and inner wall of the mixer reducing wear. This method does not require the steel liner, and results in cost reduction of consumables.

Figure 6. RCC Plant

4. RCC PRODUCTION

4.1. Materials

RCC materials are shown in Table 2. Fly-ash used is of the thermal power plant newly built in the district of Manjung, Perak State, which is one of two major thermal power plants in Malaysia. As there were no standards for them to comply classifying the fuel vas ash, fly-ash granulation varied widely and therefore didn't always comply with ASTM C618 requirements. For fine aggregates, alluvial but inert washed sand "mining sand" available near the site was purchased in addition to the crushed sand produced from the dry aggregate production process.

Mining sand was got from open cast mining schemes adopted in the past by prospective tin miners and there are a number of old tin mine remnants around the city. Initial source of the mining sand was from an old tin mine located at 20 km from the site, but later in the project, it came from a mine 50 km away.

4.2. Specified Mix

Prescription of RCC design and specified and specified RCC mix proportion are shown in Table 3 and Table 4 respectively. Fine aggregate ratio in RCC was 36 % in trial mix. Dam placing was started with 41 % after the trial embankment, but it was subtly adjusted within the range of 39 %-44 % in order to alleviate segregation contributed by the coarse materials and to optimize water-cement ratio.

Sieve size distribution of aggregates is shown in Fig. 7. Typically this is a high paste RCC, meaning the mix is rich in paste/mortar, with higher fine aggregate ratio. Therefore, fresh RCC is more flexible before it is roller compacted with segregation of coarse aggregate at its minimum.

4.3. Fresh RCC

4.3.1. VB test

For control purposes during production & placing RCC, VB consistency exercise is undertaken to keep the RCC that are produced at a high rate by the continuous plant consistent. VB test was conducted hourly and achieving a target paste/mortar travel time below the entire perspex diameter within 12 – 17 sec. The VB density of the RCC mixed proportion was also conducted.

4.3.2. Field density test

RCC was spread and compacted to measure density and water content of fresh RCC by nuclear densimeter. Measurement was conducted per 250 m^3 at depth of 250 mm, 200 mm and 100 mm. Where compacted density is no more than 97 %, it was compacted again, or disposed off in case more than 45 minutes elapsed.

Table 2. Specification of Sg. Kinta Dam

Materials	Notat-ion	Application
Cement	C	Ordinary Portland Cement Density: 3.15 g/cm^3 Specific surface: 3,500 cm^2/g
Fly-Ash	F	Generated from TNBJ Thermal Power Station Density: 2.09 g/cm^3 Fineness: 10～30% (45μm residual)
Crushed stone	G1	Raw rock: Granite
	G2	Density of surface-dry aggregate: 2.62 g/cm^3, Absorption capacity of aggregate: 0.5%
	G3	G1: 63–40mm, G2: 40–20 mm, G3: 20–5 mm
Crushed sand	Qs	Density of surface-dry aggregate: 2.62 g/cm^3, Absorption capacity of aggregate: 0.5% FM:2.5 ~ 3.0 Less than 75 μm:10 ~ 15 %
Mining sand	Ms	Density of surface-dry aggregate: 2.62 g/cm^3, Absorption capacity of aggregate: 0.5% FM:2.9~3.1 Less than 75 μm:2.0 ~ 3.0 %
Admixtures	Ad	Retard type water reducing agent (P100Ri)

Table 3. Specification of Sg. Kinta Dam

Target VB Value	12 – 17 seconds
Specified Concrete Strength	15Mpa (compressive strength at 90 days age) 1.0Mpa (Tensile strength by direct test at 90 days age)
Adiabatic Temperature Rise	less than 15℃
Density	wet density is no less than 98% of total air free density

Table 4. Specified mix proportion of RCC

Gmax	W/C	Air	s/a	Unit content (kg/m^3)								
(mm)	(%)	(%)	(%)	W	C	F	Ms	Qs	G1	G2	G3	Ad (liter)
63	75	0	41	150	100	100	329	493	221	441	529	0.8

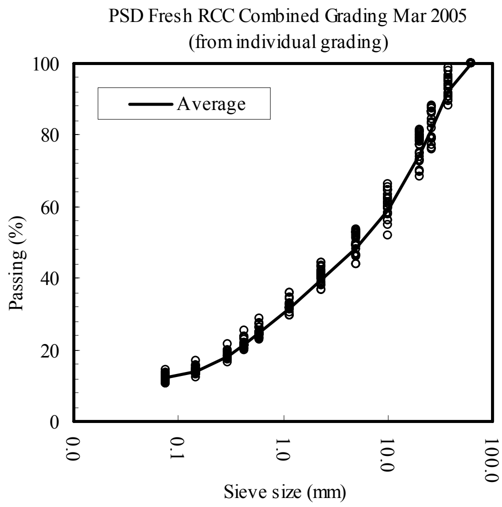

Figure 7. Sieve size distribution

4.4. Compressive Strength

Though it was stated in particular specifications that the mix proportion shall be determined by the Engineer so that more than 80 % shall be greater than 15 MPa at 90 days age, the specified age was changed to 180 days because not every mix proportion would achieve this requirement. The reason for the revision was that the preliminary RCC laboratory trial mix study had not used the original materials from the project quarry face. Furthermore, unit water content was increased according to the property of fresh RCC for adjustment due to the design concept in which fresh RCC viscosity and workability were the crucial determinants.

4.5. Placing Temperature Regulation

The original design criterion was to cool the upstream 4 m to 20 deg C with the rest of RCC behind it to be placed on nominal temperature of 30 deg C. However, it was modified to be no more than 30 deg C by the results from the thermal analysis by three-dimensional FEM (Finite Element Method). Then, in order to ensure safety of the dam body by thermal stress cracking, the transverse joint spacing reduced from 30 m to 20 m.

4.6. GE-RCC

Specified concrete strength of GE-RCC at spillway is 30 MPa (Gr 30), and 20 MPa (Gr 20) for the rest. Strength is determined by water-cement ratio. If water-cement ratio is less than a definite value, the permeability will be lowered and uniform GE-RCC placing will become difficult. According to results from the test, 1 % of F type admixture (ASTM C494-92) was added to cement, and grout milk with 0.7 water-cement ratio was used. 10 % of cement content was replaced with liquid silica fume in grout milk for Gr 30.

5. RCC PLACING

5.1. Outline of RCC Placing

RCC produced by continuous mixing plant is transported to the dam by articulated dump trucks. RCC is spread by bulldozers and compacted by vibrating rollers. While the upstream face is vertical, the downstream face is stepped, so concrete blocks are arranged to make forms. With the exception of predominant distance, RCC was placed by SLM, a method to place RCC continuously making sloping layers. RCC placing by SLM is shown in Fig. 8 and Fig. 9. GE-RCC placing is shown in Fig. 10.

5.2. Placing Method

5.2.1. Treatment of RCC horizontal construction joint

Treatment of horizontal joints would vary depending on RCC condition in its fresh state of previously placed layer. The treatment methods for different stages are

Figure 8. RCC placing by SLM (1)

Figure 9. RCC placing by SLM (2)

Figure 10. GE-RCC placing

Table 5. Joint treatment method

Classification	Treatment
Within Initial Time in Setting Test (- approx. 5 hours)	No treatment
Accumulated Temperature is no more than 1,200 deg C h (approx. 5 hours - approx. 30 hours)	Mortar Layer
Accumulated Temperature is more than 1,200 deg C h (approx. 30 hours -)	Green Cut and Mortar Layer

shown in Table 5. Though the initial setting time test varies depending on the amount of water-reducing and retarding admixture added to concrete, it is set as approx. 5 hours. Accumulated temperature is calculated from (Outdoor air temperature + 10 deg C) x hours. When the accumulated temperature is 1,200 deg C hr, the outdoor air temperature is 30 deg C and the elapsed time is 30 hours. Green cutting treatment would be implemented by high-pressure water and sweeping machine.

5.2.2. Transportation, spreading, GE-RCC and compaction

The haul road to the placing work site is 6-8 m wide, downgrade of maximum 15 % gradient. RCC is transported and unloaded by 30 t dump trucks, spread by bulldozers to make 30 cm thick layer, compacted 8 times in total, 2 times without vibration and 6 times with vibration, by roller vibrators. Mist curing was implemented to keep moisture during placing, and compaction was finished within 45 minutes after mix.

The edges on upstream and downstream were placed by GE-RCC method. In GE-RCC method, RCC spreading is implemented first, and then cement milk is added, and compacted by inner vibrator. This is an efficient method because the change of mix proportion during RCC placing is not necessary. Cement milk of amount equivalent to 5 % of RCC volume was poured over the surface of RCC before compaction. After 1-2 minutes infiltration, compaction was started by needle vibrator. To ensure the permeation of cement milk to RCC, holes with diameter approx. 20 mm are punched at approx. 150 mm spacing, and cement milk mixed on site was poured on them. Compaction of the interface between GE-RCC and RCC would be implemented with utmost attention until reaching best compaction. This interface was compacted carefully by 2 t double drum vibrating roller.

5.2.3. Joint cutting, RCC end treatment and block masonry at downstream face

Hydraulic breaker with a T-blade driver retrofitted to an excavator was used as the joint cutting machine to insert galvanized sheet into compacted RCC to form transverse joints with 20 m spacing. At the tip of downward slope, the featheredge was cut back minimum 10 cm vertical thickness. At the downstream face, top surface of GE-RCC was levelled and concrete blocks were laid to construct steps.

5.3. SLM (Slope Layer Method)

Standard method of RCC is HLM (Horizontal Layer Method), in which 30 cm thick one layer is spread horizontally and compacted continuously. While in SLM, which is adopted as rational method, one lift of RCC is set as 3 m. This thickness is determined by the height of forms. 30 cm thick one layer is spread with gradient 1:10-1:20 and compacted by vibrating roller to place RCC continuously from the left abutment side to the right abutment side (or, from the right abutment side to the left abutment side). An image of SLM is shown in Fig. 11.

Dam volume of Sg. Kinta Dam is approx. 980,000 m^3. The concrete volume of one lift (3 m) at mid elevation is approx. 50,000 m^3. On per day RCC rate of 2,500 m^3, placing of one lift (3 m) by SLM is completed within 20 days. Without intermission by either mechanical failure or precipitation during placing, the sloped horizontal surface was treated as hot joint and required neither green cut nor mortar layer. Another advantage with the SLM was that the RCC placement and the formwork installation on the upstream in preparation for the next lift were independent.

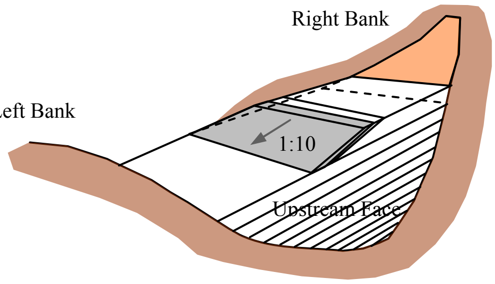

Figure 11. Image of SLM

Figure 12. Completion of Sg.Kinta Dam

6. CONCLUSION

The completion of the RCC works of Sg. Kinta Dam was in April 2006; see Fig. 12. From the experiences of this construction project, the author's assessment is that installation of all the facilities and construction equipment to construct the RCC dam has appeared to be economically justified. The high paste mix proportion abundant with fine particles has, from contractor's point of view, been more workable resulting in less segregation of coarse materials. Furthermore, the use of SLM and GE-RCC was successful and had resulted in speeding up the construction process.

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REFERENCES

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