Continuous Concrete Placement for Headrace Tunnel in Saguling Hydroelectric Project

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1. Introduction

Saguling Hydroelectric Power Project is located in the mid-stream of the Citarum River in the west Java, Indonesia and consists of a dam 99 m high, two line headrace tunnels and penstocks, and an outdoor type power station. The project was completed in May 1986 and has been one of the main power resources in Java to date. It supplies energy as much as 2,156GWh per annum on the average. NEWJEC conducted whole consulting services since the feasibility study in 1972 till the completion of the project. (See Table 1 and Fig.1)

Table 1 Main Features of the Project

Main Dimension	Max. Discharge Maximum Head Installed Capacity	224 m³/sec 363.6 m 700 MW (175 MW×4 units)
Reservoir	Gross Capacity Effective Capacity Effective Depth Reservoir Area	881×10^6 m³ 609×10^6 m³ 20 m 52 km²
Dam	Type Height Crest Length	Rock Fill Dam 99 m 301.3 m
Headrace Tunnel	**D×L×Lines**	**5.8m×4,620 m×2**
Surge tank	Type D×L×Lines	Differential 12.0m×95m×2
Penstock Tunnel Open	 D×L×Lines Length	 4.3m×574m×2 1,200 m
Power Station	Type W×H×L	Outdoor 32.50m×44m×104.4m

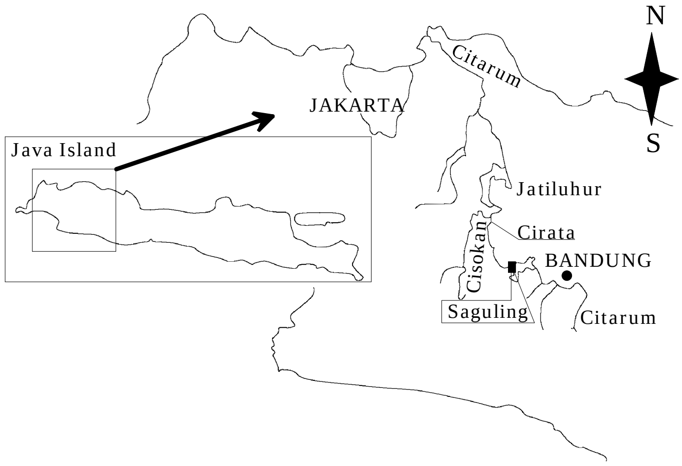

Fig.1 Location Map of Saguling Hydroelectric Project

2. Construction Process of Continuous Concrete Placement for Headrace Tunnel Lining

The headrace tunnels were arranged in parallel with the interval of 35 m between each center. Three construction adits were provided at the Intake area, the mid point of the tunnel alignment and the Surge tank.

Originally concrete lining of the tunnels was scheduled to be in the progress of 250m/month by using 10 m long circle shape steel form unit at 4 locations in each tunnel. Due to delays of the tunnel excavation, however, alternate construction method for concrete lining became necessary to expedite the total tunnel work schedule. As an improved method, continuous concrete placement at a rate of 500 m/month per steel forms was adopted. The major points of the improved construction method (See Figs.2 & 3) consists of the follows; (1) to make a number of connection adits between two tunnels, (2) preparatory works such as leveling concrete placement at invert portion, scaling and installation of reinforcing-bars were executed as backward works and movement of steel form and concrete placement were executed as forward works, i. e. the former works were accessed from the downstream side and the later works were done from the upstream side. For this purpose, fresh concrete was transported using a battery car by a rail method, after placing the invert concrete. (3) the profile of steel form was the same as the original plan, i.e. 10 m span/one unit, but made connected in total 60 m long with 6 units. Concrete was placed continuously in a week and one unit of steel form was moved to the front at every 11 hours. Regarding the tunnel grouting, the main task was concentrated to contact grouting at the crown portion. In the performance, after execution of primary contact grouting hole at each 2.5 m distance, the completeness of contact grouting was checked

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by a non-destructive inspection method, based on the elastic wave resonance principle. In case that the existence of void behind the concrete lining was found, the secondary contact grouting was executed.

Consolidation grouting was only performed in such sections of the tunnels as the rock weak zones were encountered, section of 50 m distant from surge tank , and the intersections with each adit.

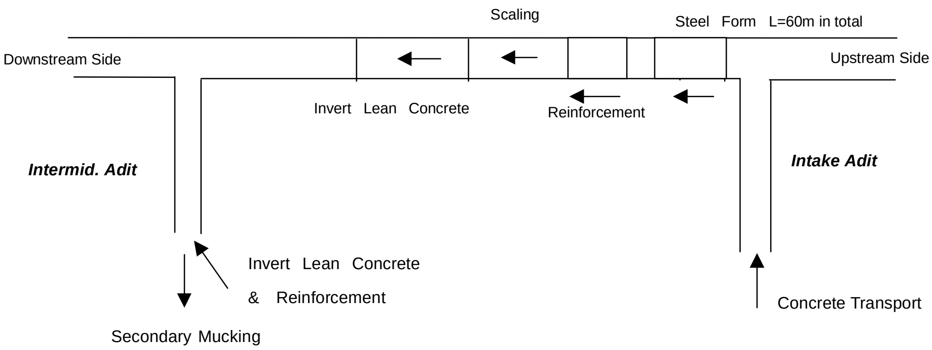

Fig.2 Sequence of Concrete Lining in the Headrace Tunnels

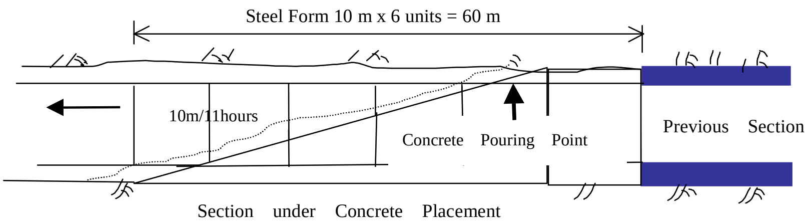

Fig.3 General Layout of Continuous Concrete Placement in the Tunnels

3. Features of Tunnel Design

(1) Consideration of Design Load for Headrace Tunnel

As internal pressures for the pressure tunnel, a maximum high water level at the upstream end and the up-surging water level at the surge tank in the time of load rejection were adopted, respectively. But, for the design of lining concrete, it was considered that internal and external water pressure would act on the lining concrete at the same time. Throughout cracks, which were normally occurred after hardening of lining concrete and filling water in the tunnels, water inside the tunnel and groundwater would flow in and out, and therefore the design pressure for the lining concrete would be almost balanced. For concrete lining, construction joints were not arranged, and by continuous concrete placement it was expected that intentional transverse cracks would be occurred with approximately uniform interval.

(2) Omission of Consolidation Grouting around Lining Concrete

Consolidation grouting works in the surrounding rock zone were omitted except at a part of geological weak zone such as open cracks in the rocks. This was based on the judgment that the surrounding rocks were enough good quality after excavation works not to require another reinforcement by consolidation grouting.

4. Effect to Cost Reduction

By applying the design based on the concept and construction method stated above, it was achieved that;

(1) Quantity of reinforcing-bars was reduced to 50 to 80% of the original design

(2) Quantity of consolidation grouting was reduced to 20% of the original design

(3) Construction period for tunnel lining: 15 months (26 months as original schedule)

(4) Progress rate 442 m/m average and 690m/m at maximum (250m/m as original schedule)