COUNTERMEASURES FOR SHORTEN THE CONSTRUCTION PERIOD OF YAMBA DAM

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Abstract: Yamba concrete gravity dam with a height of 116 m and a volume of about 1,000,000 m³, is under construction on the Agatsuma River which is a branch of the Tone River that flows through the upstream region of the Tokyo area. The purpose of the dam is flood control, water supply, and hydro power, which is expected to be completed at an early period. The concreate placement period is being greatly reduced by measures as follows; using the Roller Compacted Dam-concrete (RCD) method for rationalizing the construction; shortening the construction period by extending the concrete placing facility to improve the placement speed; shortening the installation period by the method of preassemble and transfer of the flood discharge conduits facilities; adoption of precast members for outlet facilities and gate chamber, diversion which was installed in the dam body, inspection gallery and elevator shaft, overhang zone and changing point of slope gradient; and increasing the number of days of construction during winter by taking special countermeasures, etc..

Keywords: RCD, rationalization of construction, precasting, construction during winter

1 INTRODUCTION

Yamba Dam is a multi-purpose dam which is currently under construction at Gunma Prefecture, in the middle reaches of the Agatsuma River, which is a main branch of the Tone River(see Figure1). It is a concrete gravity dam with a height of 116 m, crown length of 291 m, volume of about 1,000,000 m³, and water storage volume of 107,500,000 m³. The owner is the Kanto Regional Development Bureau of the Ministry of Land, Infrastructure, Transport and Tourism (MLIT).

The construction joint venture of Shimizu, Tekken, and IHI Infrasystems specializing a different construction types commenced work on excavation of foundations for the construction of the main dam in January 2015, and as of the end of June 2018 concrete placing in the dam has proceeded to a height of 93 m and a volume of 830,000 m³. Major reduction in the construction time was achieved by the implementation of various technical initiatives proposed by the contractor [1].

Figure 1: Location of Yamba Dam

2 SIGNIFICANCE OF CONSTRUCTION OF THE YAMBA DAM

Agatsuma River is one of the main branches of the Tone River and accounts for about 1/4 of the catchment area in the upstream part of the Tone River. To date there has been no flood control facility installed on the Agatsuma River. As a result of installation of the Yamba Dam, a flood control function will be provided during times of heavy rain, to enable flood damage to be reduced not only in the Agatsuma River catchment and the Tone River catchment downstream, but also over wide areas in the downstream section of the Tone River.

Also, in the downstream Tone River basin that includes the capital area there is a tight supply of water, and in the past 10 years restrictions on water intake have been imposed three times: in 2012, 2013, and 2016. As a result of completion of the dam, it will be possible to supply mains water to Tokyo and the prefectures downstream, and it is expected to stabilize the water use in the Tone River water system. In addition, an 11,700 kW output power station will be installed, thereby promoting the use of natural energy.

For the above reasons it is desirable for Tokyo and the prefectures downstream on the Tone River that the dam be completed and enter into service as soon as possible. In addition in the year 2020 the Tokyo Olympics will be held, so all those involved in the project are working hard to complete the construction of the dam as soon as possible.

3 INITIATIVES FOR EARLY COMPLETION OF THE DAM

Although it is desirable that the dam be completed as soon as possible, the construction time for a dam body is typically from 5 years to at most 10 years. We believe that improving construction efficiency and completing a dam in a shorter period which will enable the appearance of early benefits. The following is a description of the various initiatives being undertaken in order to shorten the construction time for the Yamba Dam.

3.1 Points to note regarding shortening of construction period

Yamba Dam is a comparatively large scale dam, so efficient placing of the concrete is essential. On the other hand there is a very large number of internal structures within the dam such as outlet facilities, cross galleries, etc., that divide the dam body into the left and right banks, and there has been a total of 8 cases in which the passage of vehicles was obstructed, which is a very high frequency.

Also, in the initial scheme which the owner planed and proposed, stoppage period of concrete placement associated with installation of outlet facilities, galleries, etc., was extremely long, which tended to increase the concrete placing period. In addition, the weather conditions during winter are severe, so a concrete placement stoppage period was set, and the concrete placement schedule was arranged taking this into consideration.

3.2 Measures to shorten the construction period

The following is a description of the measures taken to shorten the concrete placement period as a result of technical proposals from the contractors based on the above points.

3.2.1 Enlargement of the concrete placing equipment capacity

It was decided to use the RCD construction method for rationalizing the dam body concrete of the Yamba Dam. The concrete placement plant was selected to have the capacity to suit the high-speed construction of the RCD method, and to maximize the concrete placement efficiency based on the surrounding environment, economics, and other conditions.

The characteristics of the concrete placement equipment at this dam were as follows.

1) The concrete placement plant consisted of 2 Nos. of 18 t fixed cable cranes, and a Spiral Pipe Transportation Method (SP-TOM, 700 1 No.). Also, a 4.9 t class cable crane was

installed on the downstream side for transport of miscellaneous items, in order to enable the cable cranes to be used for a long period of time as transport and placement equipment

2) The concrete production plant consisted of 2 Nos. of 3.0 m3 2 batching plant in order to maintain the high placement capacity

3) Lightweight buckets capable of transporting 6.0 m³ concrete per cycle were introduced. These are described in detail below (see Figure 2).

(1) Concrete transport equipment

There are many internal structures and construction on the left and right banks is frequently separated, so 2 Nos. of cable cranes were installed for placement on the separated right bank side, and a SP-TOM was installed to enable simultaneous placement of concrete on the right bank side and on the left bank side. Also, the capacity of the plant was increased, in order to ensure a minimum level of placement capacity even when construction was separated. Figure 3 shows the arrangement of equipment at the dam site. The equipment in the initial plan is indicated in blue characters, and the equipment modified by the technical proposal of the contractors is indicated in red characters. In addition to increasing the capacity of the two cable cranes, the SP-TOM was installed to ensure transport via 3 systems. The SP-TOM is a plant for transporting concrete by rotating a transport pipe with a drive motor, and the speed of movement of the concrete is controlled by vanes that are fitted within the pipe, in order to reduce separation of the materials. It is a large transport capacity item of plant that can ensure the quality of the concrete.

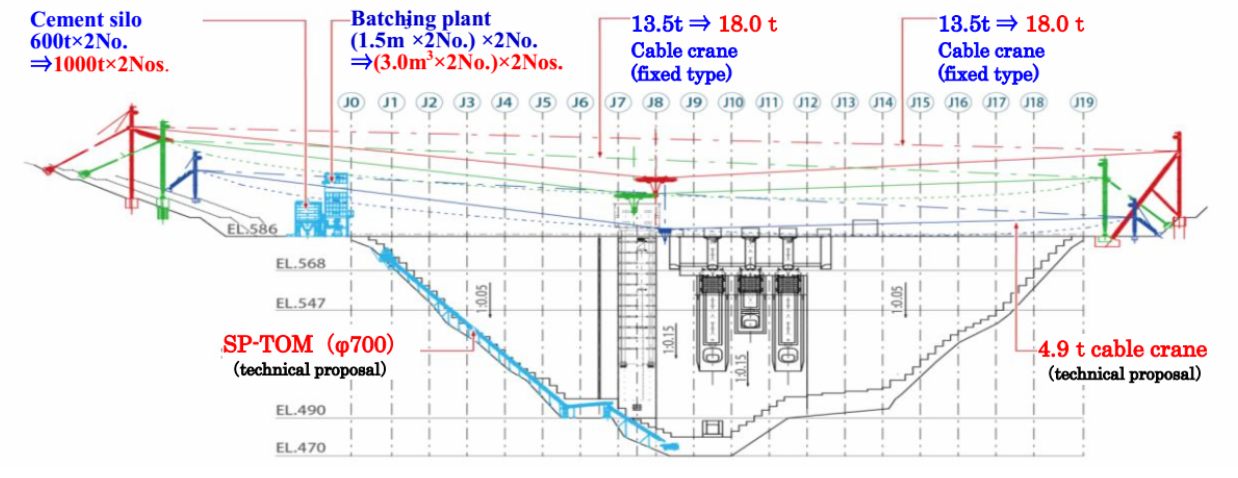

Figure 2: Vertical cross-sectional arrangement at dam site

(blue characters: initial scheme, red characters: technical proposal)

There was redundancy in the concrete placement plant, so even when the left and right banks were separated it was possible to carry out construction with the two cable cranes on the right bank side, and the SP-TOM and one cable crane on the left bank side. Therefore placement could proceed without a major reduction in the placement capacity (see Figure 3). 32 t dump trucks and 21 t bulldozers that could not be lifted and moved by the cable cranes were deployed in the necessary numbers on the left and right banks in order to maximize the concrete transport equipment capacity.

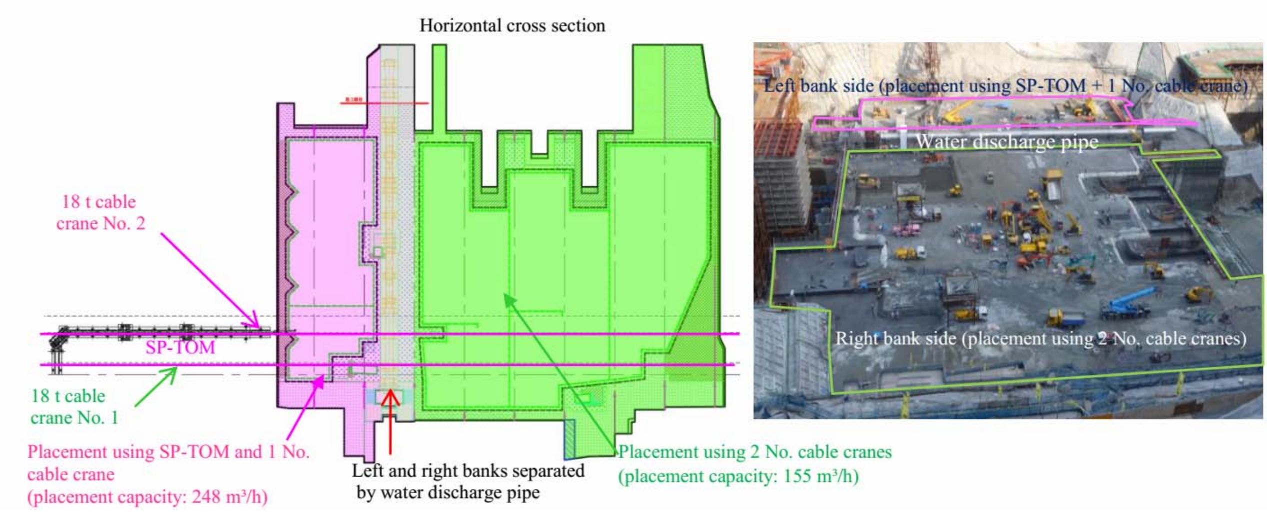

Figure 3: Construction when left and right banks are separated

(2) Selection of concrete production plant

In order to ensure capacity of the concrete production plant corresponding to the concrete placement equipment, 2 Nos. of biaxial forced mixer 3.0 m³ 2 batching plants were adopted. There were 3 systems of transport equipment, and these could be supplied by supplying one of the 18 t fixed type cable cranes from one of the batching plants, and supplying the SP-TOM (700) from the two batching plants. The specification for selected concrete production plants are shown in Table 1.

Table 1: Selected concrete production plant

Concrete production plant		Concrete placement equipment		Remarks
Specification	Production capacity	Equipment name	Equipment capacity	
Biaxial forced mixer 3.0 m³ 2 (unit No. 1)	180 m³/h	18 t fixed type cable crane No. 1	About 110 m³/h	The difference between concrete production plant capacity and cable crane transport capacity is allocated to the SP-TOM
		SP-TOM (700)	153 m³/h	
Biaxial forced mixer 3.0 m³ 2 (unit No. 2)	180 m³/h	18 t fixed type cable crane No. 2	About 110 m³/h	
Total	360 m³/h	Total	373 m³/h	

(3) Adoption of lightweight buckets for concrete

In order to utilize to the maximum extent the lifting capacity of the 18 t cable cranes, the concrete buckets used were made lightweight, thereby increasing the weight that can be transported per bucket, and reducing the number of journeys.

By using wear resistant steel material and minimizing the associated mechanical equipment, the mass of each bucket was reduced from 3.4 t to 2.2 t, thereby increasing the concrete transport capacity from 5.5 m³ to 6.0 m³ (see Figure 4). In this way the transport capacity was increased by about 10%.

Figure 4: Lightweight bucket

(4) Effect of enlarging the concrete placing equipment capacity

As result of these measures, it was possible to reduce construction period by 2.6 months as of end June 2018.It is considered that the effects of enlarging the concrete placing equipment capacity have been sufficiently realized.

3.2.2 Preassemble and transfer of the flood discharge conduits

There are two flood discharge conduits installed within the dam, and in the initial scheme they were to be assembled and welded on the placement surface, and for this purpose a period of 72 days stoppage of concrete placement was provided in the schedule. This scheme was changed to one in which a platform was installed on the dam, as shown in Figure 5, the assembly and welding operations were carried out on this platform, and when the assembly was completed a preassembled block was transferred onto the dam body, and in this way the time period for stoppage of placement of concrete was minimized. Figure 6 shows a photograph during transfer. In this way the stoppage time could be reduced from 72 days to 11 days, resulting in a shortening of the construction period by 61 days.

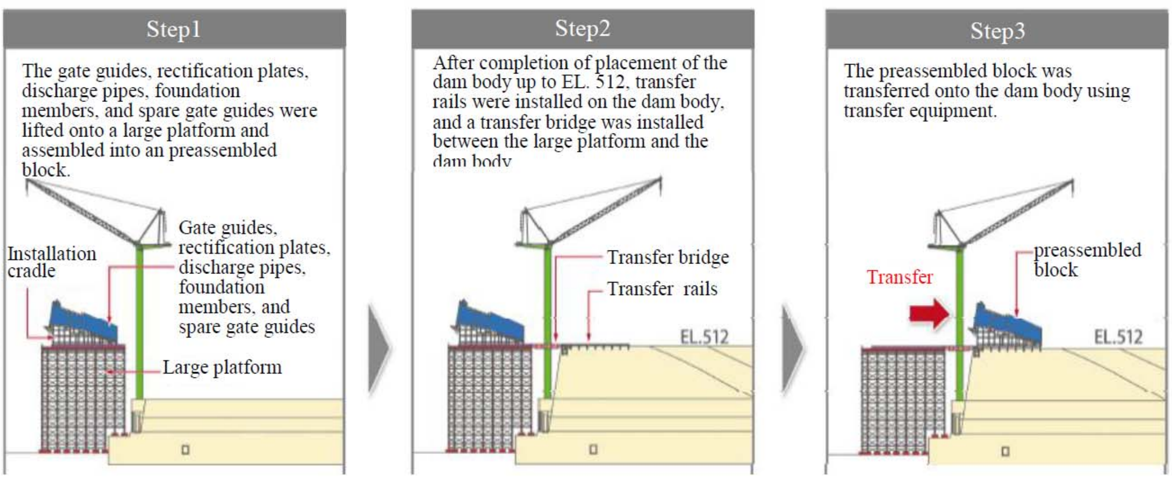

Figure 5: Overview of construction of flood discharge conduits

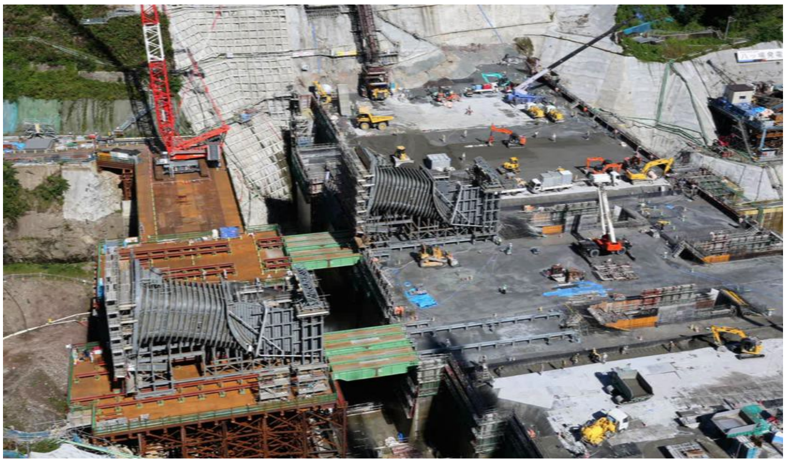

Figure 6: View of transfer of preassembled block of flood discharge conduits

3.2.3 Use of precast concrete

Apart from the outlet facilities, Yamba Dam has many internal structures, such as diversion, inspection gallery and elevator shaft, gate chamber for outlet equipment, etc., and there are many overhang zone and changing point of slope gradient. By using precast concrete members for these parts not only could the construction efficiency be increased, but also it was possible to improve the quality and safety. Precast concrete members were installed at many locations on Yamba Dam for rationalization of the construction, as shown in Figure 7.

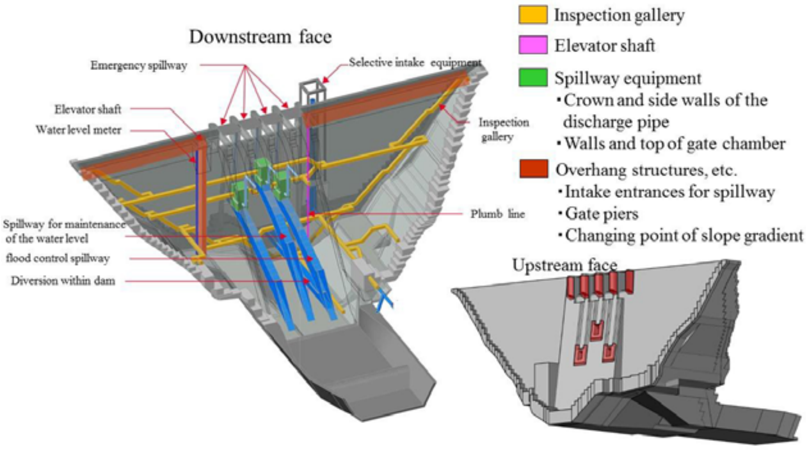

Figure 7: Adoption of precast members

Precast concrete was adopted for all of the many horizontal inspection galleries and diversion. In the initial scheme concrete placement was stopped everywhere during their installation, and installation was carried out together in the same lift. In the technical proposal, because there was margin in the placement capacity precast members were transported and installed using the 18 t cable cranes in parallel with placement, and after placement installation and fixing was carried out using a rafter truck crane. In the case of the horizontal galleries for which the total installation length was long, the construction period was shortened by using two teams with day and night operation, thereby reducing the construction period by 15 days.

In addition in the case of the crown and side walls of the outlet portion, the side walls and slabs of the gate chamber, the changing points of slope gradient, the piers, etc., many days would be required for the operations of assembly of formwork and falsework. In particular in locations where overhanging scaffolding was required the operation of installation and removal of this overhanging scaffolding would be dangerous as it is carried out at elevated locations. Therefore, precast formwork that did not require scaffolding or falsework was adopted, resulting in rationalization and shortening of operations, as well as improvement in safety.

3.2.4 Construction during winter

In the initial scheme concrete placement was stopped from 16th December until 15th March, when the average daytime temperature was less than 4°C. However by implementing measures to enable concreting in cold weather, such as pre-curing joint surfaces with hot water, mixing the concrete using hot water, and providing effective thermal insulation curing after placement, the number of days of concrete placement was increased.

(1) Countermeasures for winter concrete

The following measures were adopted for winter concrete when the average daytime temperature was less than 4°C.

1) Switching from the RCD method to the Extended Layer Construction Method (ELCM) which usimg immersion vibrator and slump concrete with large heat generation due to the high cement content.

2) By carrying out curing with hot water from a boiler on the concrete horizontal construction joints before placement and carrying out curing at constant temperature on the placement surface using foamed polyethylene mats, it was possible to maintain the temperature of the construction joints above 0°C even when the external air temperature was below 0°C.

3) By maintaining the mixing temperature above 10°C by producing the concrete using hot water from a boiler as mixing water, and heating the aggregates within the aggregate silos using a heater, it was possible to maintain the temperature of the concrete above 5°C at the time of placement and at the start of curing.

4) It was possible to maintain the temperature after placement of concrete above 5°C (see Figure 8) and prevent initial freezing damage by heated curing (Eye Lamp) of the formwork surfaces, curing to maintain the temperature at the surfaces of the formwork using foamed styrol, and curing to maintain the temperature at the surface of the placed concrete using foamed polyethylene mats (see Figure 9).

As result of these measures, it was possible to constantly maintain the concrete temperature at higher than 5°C from commencement of mixing of the concrete until after curing, even when the external air temperature was below 0°C.

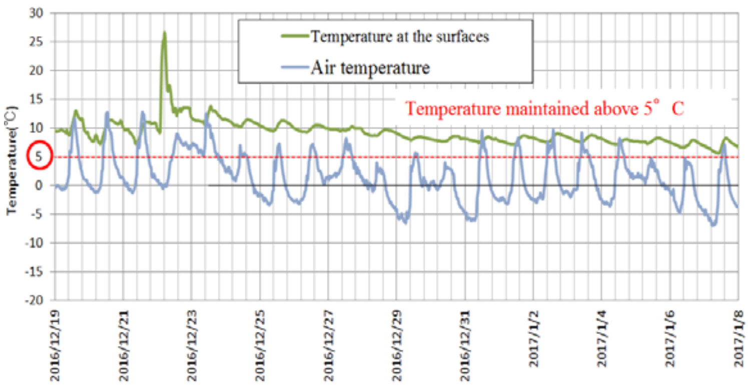

Figure 8: Concrete surface temperature time history after placement

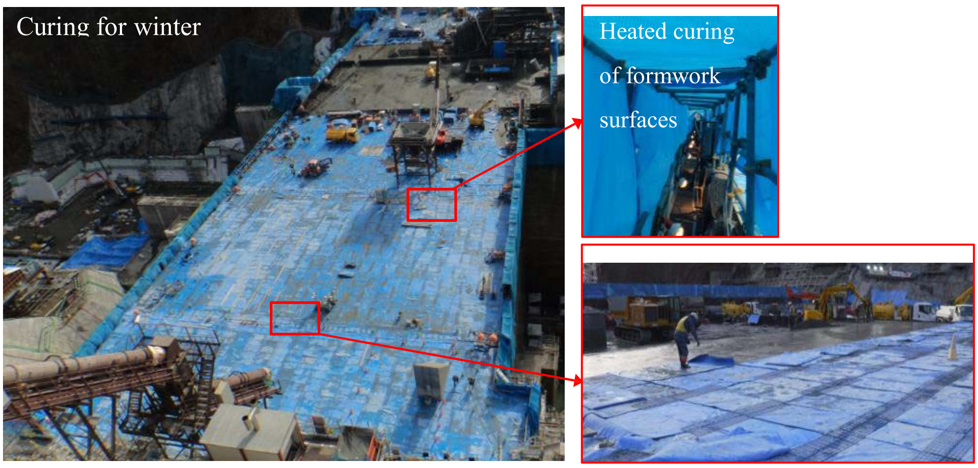

Figure 9: Concrete curing during winter

(2) Effect of construction during winter

As a result of these measures, placement of concrete during winter could be carried out within the time period when the air temperature was 0°C or higher at the commencement of placement, until the air temperature subsequently fell below -5°C (see Figure 10). Note that it is planned that placement should start when it is confirmed that the air temperature is 0°C or higher, and would be completed before it fell to -5°C or lower (by confirmation with weather forecast data in advance using the pinpoint weather forecast system).

In the initial scheme the time period from 16th December until 15th March was set as the winter concrete placement stoppage period. As a result of taking proper measures for concreting during winter, the number of days in which concrete was placed was increased. In financial year 2017 the number of days in which concrete could be placed during winter was increased by 71 days.

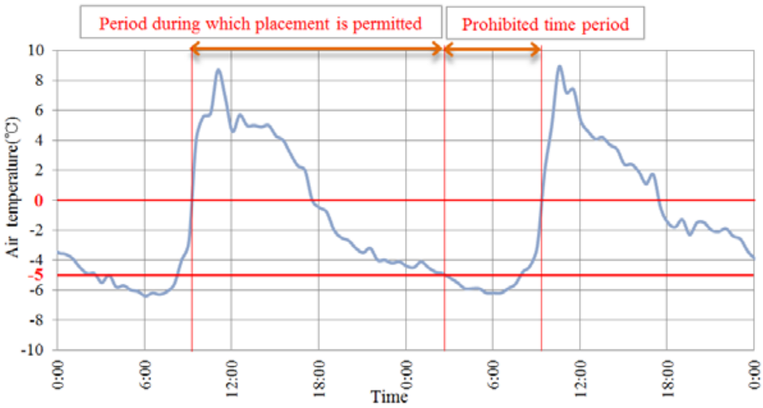

Figure 10: Setting the time period in which placement is permitted

3.3 Effect of shortening the construction period

As a result of the above measures, as of end June 2018, a period of 21 months has passed since the commencement of concrete placement, and a total of 830,000 m^3 has been placed. In the initial scheme it was planned that 28.5 months would be required in order to reach this quantity, so shortening the construction period by 7.5 months has been achieved. It is considered that the effects of the initiatives for shortening the construction period have been sufficiently realized.

4 CONCLUSION

In the construction of the body of Yamba Dam, initiatives to shorten the construction period have been undertaken from various aspects in accordance with technical proposals from the contractors based on the needs at the time of placing the contract.

Characteristics of the dam includes the fact that there is a very large number of internal structures, such as outlet facilities, cross galleries, etc., and frequently the left and right banks are divided on the dam body which obstructs the passage of vehicles. As a result the time in which placement of concrete would be stopped associated with installation of outlet facilities, galleries, etc., was long. Also the weather conditions during winter are severe so a period of three months was set in which concrete placement would be stopped.

In response, by implementing some measures show below, it has been possible to achieve shortening the construction period by about 7.5 months as of the time when more than 80% of the total concrete has been placed.

1) The RCD method was adopted for rational construction of the dam body concrete, the placement facilities were strengthened, even when the left and right banks of the dam body were divided placement could continue without reduction in the construction capacity, so the placement time could be shortened. These measures were the most effective and contributed to 2.6 months of reduction of the construction period.

2) By the method of preassemble and transfer of the flood discharge conduits, the period for placement of internal structures was shortened. The construction period was reduced by

0.5 months.

3) By using of precast members for outlet facilities and gate chamber, diversion which was installed in the dam body, inspection gallery and elevator shaft, overhang zone and changing point of slope gradient, the construction period was reduced by 0.5 months.

4) By taking appropriate measures for winter concrete, it was possible to continue with concrete placement even when the external air temperature was below 0°C. These measures were so effective and contributed to 2.4 months of reduction of the construction period.

On the other hand, regarding the strengthening of the concrete placement plant, if it is possible to further increase the percentage of operating time of the plant by shortening the placement preparation time, etc., it will be possible to further shorten the placement construction period. It is intended to continue with initiatives pursuing shortening of the construction period of the Yamba Dam main body while maintaining quality, in order to complete this dam project even one day earlier.

ACKNOWLEDGEMENT

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