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CSG CONSTRUCTION METHOD AND QUALITY CONTROL OF KAWAI DAM IN HAIZUKA DAM PROJECT

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INTRODUCTION : Recently, while a demand for economical efficiency and environmental conservation is strongly urged in public work projects, it is now more important than ever to make arrangements for cost reduction and environmental care in the dam projects. In these circumstances, CSG (Cemented Sand and Gravel) method utilizing existing river bed gravel and excavated materials is expected to be applied to dam construction. The Kawai Dam in HAIZUKA DAM project was constructed by the CSG method to reduce financial and environmental impacts. This paper reports quality control and construction method of the Kawai Dam .

OUTLINE OF THE KAWAI DAM : The HAIZUKA DAM is a multipurpose dam whose purpose is flood control and water supply is a concrete gravity dam with a dam height of 50.0m and a crest length of 196.6m. The Kawai Dam, constructed at about 6.5km upstream of the HAIZUKA DAM, is a trapezoid-shaped CSG dam, with a dam height of 13.5m and a crest length of 146.0m. The Kawai Dam creates certain-scale reservoir and induces the sedimentation of suspended solid in it. The purpose of the Kawai Dam is intended to prevent the desolation of upper stream areas above the normal water level of HAIZUKA DAM and to improve the hydrophilic environment in the areas and the river water quality flowing to HAIZUKA DAM reservoir (refer Figure-1 to -3 below).

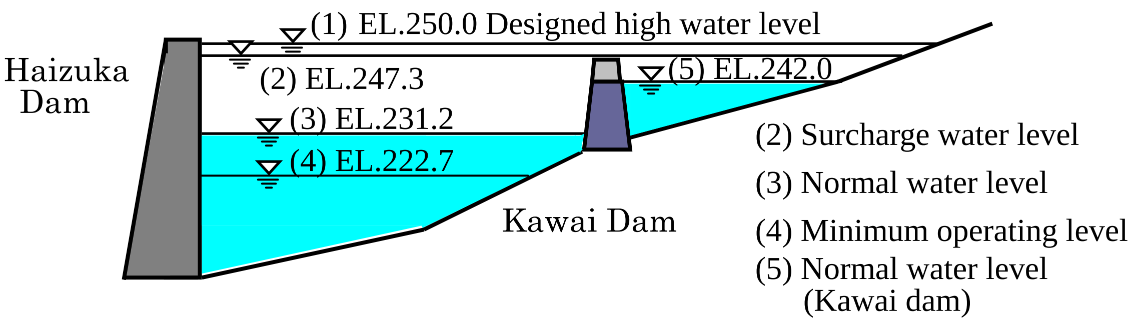


Figure-1 Transversal Section of Reservoir of HAIZUKA and Kawai Dam

Figure-2 View of Completed Kawai Dam

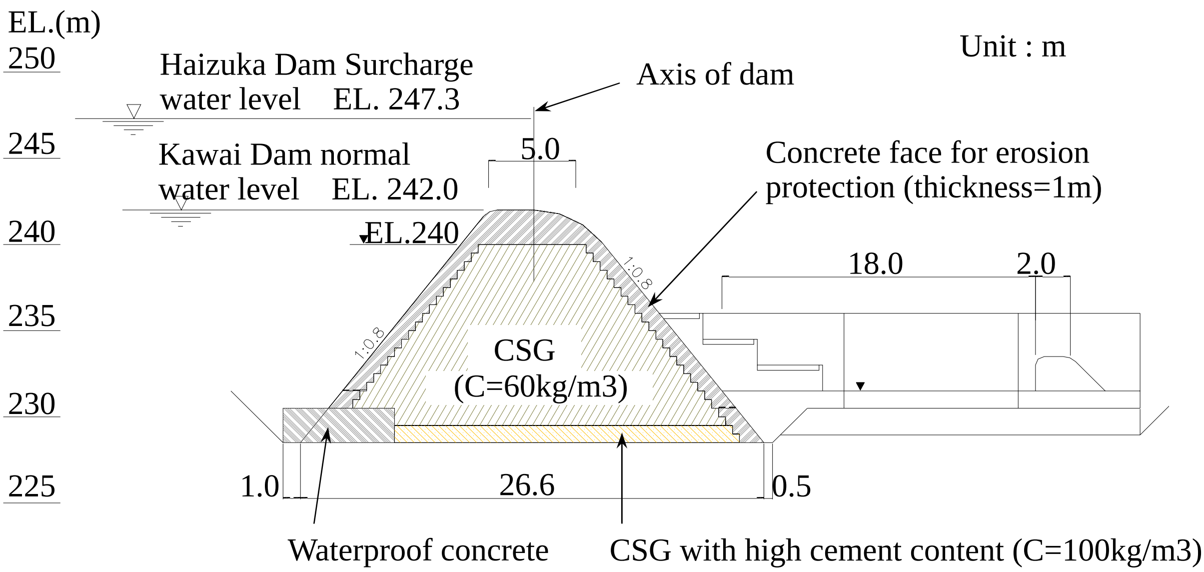


Figure-3 Typical Cross Section of the Kawai Dam

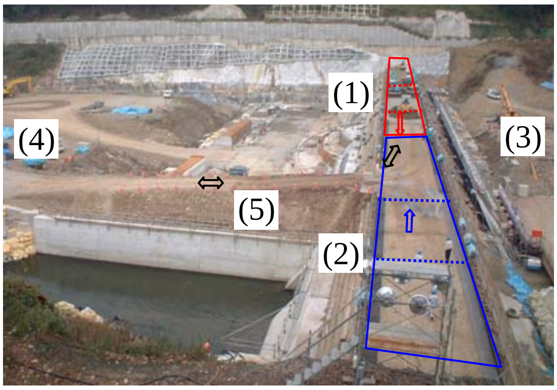
CONSTRUCTION

Outline of Construction Method : Outline of CSG construction work is as follows:

- Place a CSG layer of 50cm in thickness in one lift.
- Construct one lift in two or three days with taking account of the placing capacity of the machinery and working space in construction site.
- Averaged volume of CSG placing was 310m3/day.
- The targeted working hours from the production work to placing the compaction work of CSG were set as four (4) hours based on the results of beforehand trial construction and the margin of safety, and width and length of spreading and compaction lane were determined accordingly.

CSG were transported to the site by 10-ton dump trucks through a temporary access road provided at the dam downstream side. The order of placing CSG layer was from the edge lane to the center for both sides.

The steel meshes shuttering as forms was applied to both of the upper and the lower stream inclined surfaces. Sliding form system was applied to the erosion protection concrete, and concrete was poured by a concrete pump at 1.5 m per lift at three (3) meters below the completed CSG layers. While the placing operation of CSG layers was going on, steel meshes shuttering was set in position at the other side.
Construction joints of CSG layer were made in such a way as to form 1:4 slope, compacted by an 11-ton class vibration roller. On the next day, edge of the joint was removed and CSG was placed thereon to form a new layer as shown below (Figures -4 and -5).



(1) Right side area, (2) Left side area, (3) Upstream, (4) Downstream, (5) Temporary access road

Figure- 4 Sections of Construction

Figure-5 Construction Joint of CSG

<u>Excavation of Raw Materials and Cut Off Oversized Materials</u> : The raw materials of CSG are the river bed gravel piled up in the planned reservoir area of the HAIZUKA DAM. According to a pre-investigation made at 15 locations by trench excavation, it was confirmed that sufficient volume was expected from 2.5 to 3.5 m thickness of gravel layer existing under the topsoil layer of 0.7 to 1.7 m and their quality and grading were good enough as CSG materials.
The raw materials were excavated by a power shovel of 0.7m3 bucket class and transported by 10-ton dump trucks to the stock yard and stockpiled there.
Due to the maximum size of CSG materials specified to be 80mm, the raw materials were selected through a grizzly hopper (inclination of 40 degrees) by which oversized materials were cut off to make them to be within the specified maximum size.

<u>Stockpile of CSG Materials</u> : 14,000m3 of CSG materials, which is approximately 80% of the required total volume of 18,000m3, was stocked at the stock yard provided for that purpose in advance of the commencement of the works. During the rainy season, the

stockpile was sheet-covered to prevent the surface water content from being changed and/or increased by rainfall. When the water content increased by rainwater due to typhoons, aeration was executed by the use of power shovel to reduce the water content.

CSG Mixing Plant : As the maximum daily output (CSG placement) required for the construction of the Kawai Dam was approx. 600m3/day, the plant capacity was set up at 80m3/hour. The mixing plant mounting the DKP mixer (continues mixing type) utilizing gravity feeding system was mobilized and installed. The nominal capacity of the DKP mixer was 100m3/hr. The actual CSG production was proceeded successfully with a stable rate of production.

Construction Method:

Excavation and Clean up of Bed Rock :

*Treatment of Bed Rock Surface : Bed rocks of the Kawai Dam consist of andesite-tuff breccia and intrusive rocks of porphrite, and they are mainly classified as soft rocks. The primary excavation was executed by a power shovel of 0.8m3 class. Due to CSG placed in a short time after the excavation finished, covering by mortar for preventing of the surface deterioration was not needed. However, as there was a worry that the rocks would fall down by peeling off of soft rocks on the right bank abutment part, mortar of 5cm in thickness was sprayed on some parts.

*Finishing of Excavation and Clean Up of Surface of Bed Rock at Waterproof Concrete :
Since the contact face between the waterproof concrete and the bed rocks is a significantly important part of the dam structure to secure water cutoff performance, finishing excavation of 50cm was conducted manually in the same way as seen in an ordinary concrete dam construction. The surfaces of the bed rocks were cleaned up by water jet and vacuum operation.

*Cleaning Up of Bed Rock at CSG Part : It was planned to clean up the bed rocks of CSG part by means of compressed air cleaning which was simpler than the ordinary method (water jet and vacuum method). However, some places made it necessary to be cleaned by the ordinary method where the muddy surfaces, occasioned by sump water and rainfall, could not be removed by compressed air.
It is suggested that the cleaning up method of bed rocks for CSG part shall be considered and selected adequately depending on the actual situations/conditions of the site.

Spreading and Compaction of CSG in General Areas/Parts : For general areas/parts, CSG was placed in two (2) layers of 25cm each, totally 50cm, by a 7-ton class bulldozer in transversal direction of the river. The vibration roller (11-ton class: SD451) compacted two layers (50cm) of CSG simultaneously and its passage times were decided to be two (2) times without vibration and six (6) times with vibration, totally 8 times, and a speed of the compactor was controlled at the pace of 1 km/hour, decided in accordance with the results of a trial compaction. Overlapping of the passages was kept more than twenty (20) cm with the adjoining lane.

Figure-6 Spreading of CSG and Compaction in General Area

The trial spreading and compaction of CSG was conducted at the Kawai Dam to investigate and determine the commencement time of compaction. It was confirmed that a 7-hour elapse after mixing till commencement of compaction did not cause any adverse effect to the density in situ. Based on such prior investigation, for the Kawai Dam construction, working hours from mixing till completion of compaction was targeted to be within four (4) hours including some margin time. During the spreading and compaction operation, when the surfaces dried up, adequate volume of water was sprinkled to keep moistened.

<u>Construction of CSG Slope using Steel Meshes Shuttering</u> : Both of the upper and the lower stream inclined surfaces (inclination 1:0.8) were formed in a staircase pattern of CSG layers instead of inclined flat plane, by using embedded steel meshes shuttering made from expanded metal.

Figure-7 Moving H-shaped Steel Shuttering and Installation of Steel Meshes Shuttering.

After many trials and improvements made to enhance workability of steel meshes shuttering works, the simpler installation method was developed, namely, the edge of the steel meshes shuttering was bent up (height 50cm) and was leaned to H-shaped steel (350x350x12x19) to prevent the vertically placed face from being deformed and to keep the horizontal parts of the CSG layer without fixing any anchors into the CSG layer. A power shovel equipped with a crane was used to move H-shaped steel for setting them.

Treatment of Joints between Layers :

*Cleaning Up before Placing : The surfaces of CSG layers were rectified and cleaned by a light mechanical sweeper to remove loose stones and debris and to eliminate ruts made due to vehicle traffic. Where muddy surfaces were found, they were cleaned up by water jet and vacuum operation.

*Mortar Layer on Joints : Cement mortar (cement 1 : sand 3) was placed with the thickness of 15mm on the previously laid surface after sprinkling water and moistened fully. Cement mortar was transported by an agitating truck from the Batching Plant approx. 9 km far from the site and was placed directly on the previous CSG layer and was spread by a pay loader mounted with a rubber plate and manually as well.

Curing : All the surfaces of CSG layer were covered by plastic sheets to protect them against rainwater and also to prevent them from drying up of the surfaces after completion of spreading and compaction operations.

QUALITY CONTROL OF CSG

Quality Control for the Kawai Dam : The essence of quality control of CSG is to ensure that “the gradations of gravel materials and unit water contents are within a certain range which were verified at the pre-investigation to obtain the required CSG strengths”. The strength of CSG is controlled by measuring the compaction energy, namely “control compaction passage times”, and to supplement this measurement, density test in situ shall be conducted. In addition to the above, the qualities of the materials placed shall further be confirmed by the strengths of the test pieces and their fluctuation patterns.

Grading Range of CSG Materials : The gradation of CSG materials for the Kawai Dam was set and specified as shown in Figure-8. The passage percentage of the grains under 5mm in diameter was between 18.5% and 42.5%.

Relationship of Unit Water Content and Compressive Strength of CSG :

Relationship of unit water content and CSG compressive strength is as follows:

In the preparatory stage of the project, the laboratory trial mixes had been conducted and their details were as shown below:

- Three kinds of grading as shown in Figure-8: coarse, average and fine
- Unit cement content: 60kg/m3
- Three different times of compaction: 20, 40 and 60 seconds

Large cylindrical test pieces (dia. 300mm and height 600mm) were prepared using a mechanical pot type mixer and cured. Figure-9 shows the strengths of test pieces in case of the compaction time of 40 seconds by an electric-powered tamping hammer and three kinds of unit water content and grading. From the result of testing as mentioned above, it was confirmed that the strength of CSG had satisfied the requirement of design strength of 0.55N/mm2 of CSG structure as long as the mixture was consistent with the gradation within a range between the coarsest and the finest ones and the unit water content between 90kg/m3 and 120kg/m3.

While the trial construction of CSG after the commencement of the actual works had been executed with the water content of 120kg/m3, it was recognized that waving of the surfaces of CSG occurred during compaction with vibration and it might cause difficulties in finishing.

Therefore the control range of water content was reduced to 90-110kg/m3.

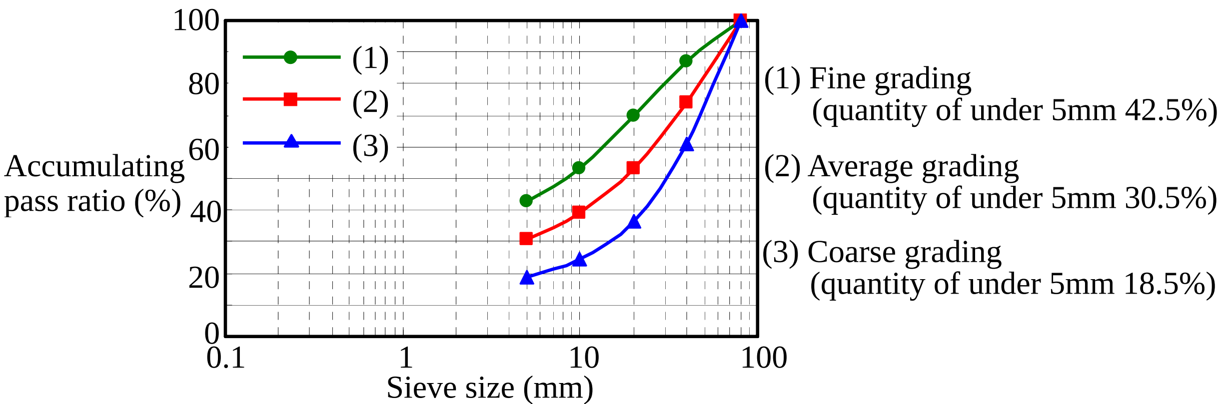


Figure-8 Grading of Gravel Material while Trial Mix

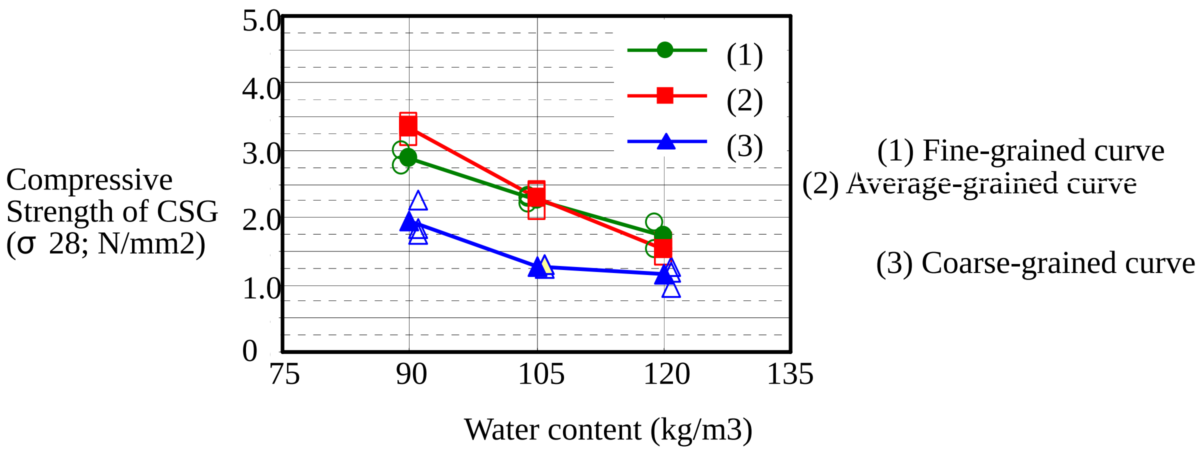


Figure-9 Relationship between Unit Water Content and Compressive Strength of CSG

The site trial mixes of CSG were done using an actual Mixing Plant installed at the site in the same manner as the laboratory trial mixes except the plant.
It was confirmed that the relationship between unit water content and strength and the strength of mixture using averaged grading material showed the same tendency and results as seen in the laboratory trial mixes.

Relationship between Density in Situ and Density of Large Test Piece :
After the commencement of the actual works, the density in situ was tested by a sand replacement method and the density by large size cylindrical test pieces (dia.300mm and height 600mm) were also tested for comparison, and with a certain compaction time (compaction energy), it was evaluated that the density in situ might be equivalent to the large size test piece density obtained with the 40-second compaction. The density in situ was tested for the layer compacted by a vibration roller (11-ton class); two (2) time passages without vibration and six (6) time passages with vibration.

Quality Control Testing of the Kawai Dam : The quality control testing items of CSG in the Kawai Dam are categorized in the following five (5) items:

Prior Confirmation of the Quality of Raw Materials by Trench Excavation : As aforementioned for the Kawai Dam for which the raw materials were to be taken from the river bed, it was confirmed, prior to commencement of the works, whether the grading (as shown in Fig.-8 above) and quality of the raw materials to be obtained from trench excavation at the actual site near the Kawai Dam had satisfied the requirements determined previously by the tests conducted in advance of the commencement of the works.

Control of CSG Materials : The specific gravity of saturated surface-dry condition, percentage of water absorption, grading and surface water of samples taken from the relevant stock yard were checked on every working day and on its previous day to control and confirm the conditions of CSG materials before supplying to the project site.

*Conditions of CSG Materials : The following tests for specific gravity of saturated surface-dry condition and percentage of water absorption were conducted once a day to grasp the conditions of materials:

- To check if no significant changes have been made in quality such as specific gravity and water absorption; and
- To figure out surface water volume for adjustment of the mixing proportion.

Tests of specific gravity and water absorption of samples taken three days in advance from the relevant stock yard as shown in Figure-10 (taking into consideration the number of days needed for these tests) were done every day in the morning to confirm the conditions of CSG materials before supplying to the project site.

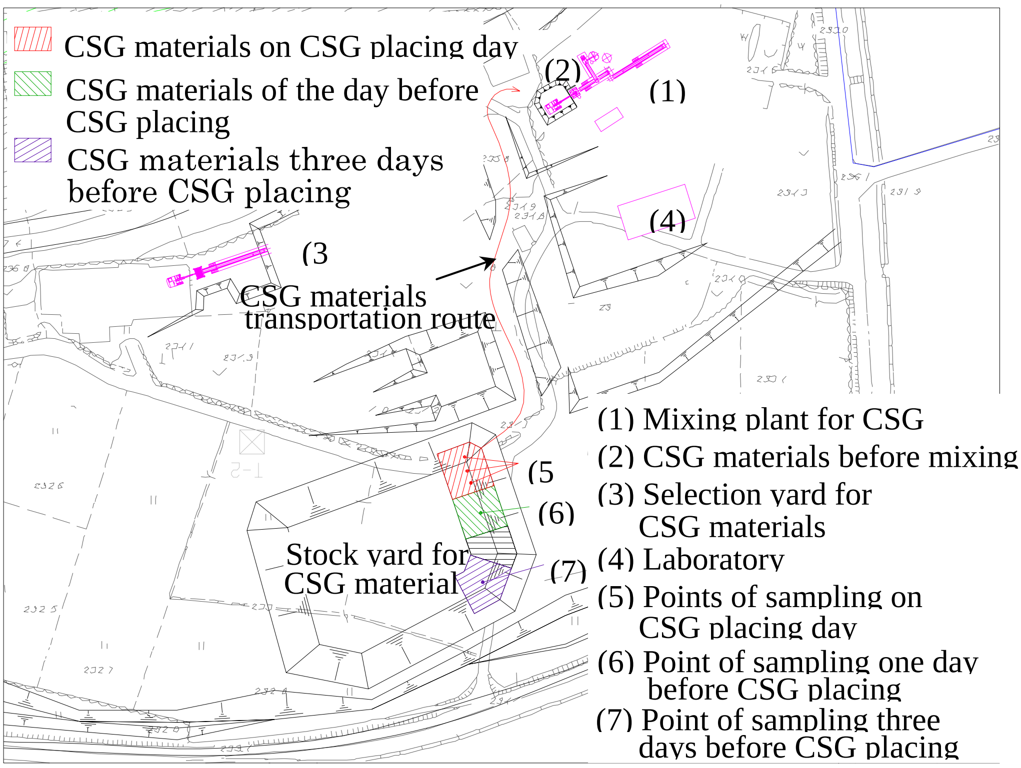
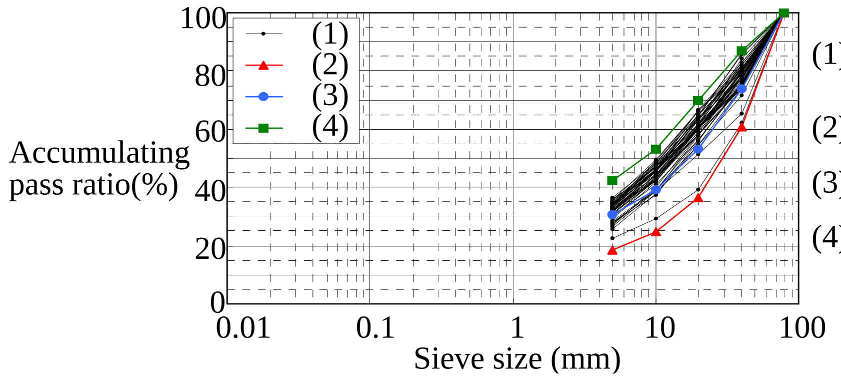


Figure-10 Sampling Places at CSG Materials Stockyard

*Control of Grading and Surface Water of Material One Day before Supply : The grading and water content tests (by means of a drying process method) were conducted on a daily basis to check if the grading and surface water of CSG materials to be used on the next day were within the allowable values introduced as aforesaid, and to check if the control range of water volume was within the designated range. The samples, collected from the CSG material stock yard (shown in Figure-10) early in the evening of the previous day for use on the following day, were put into a dryer or oven to dry up and then, tested in the morning of the day. The power shovel mixed up the CSG materials to reduce fluctuation of grading in some cases.

Figure-11 shows the results of grading tests conducted on a daily basis which also show that the CSG materials were within the specified ranges.

*Testing and Control of Grading and Surface Water on the Working Day : As the grading and surface water of CSG materials vary even during one working day, they were tested several times in a day. To make such testing possible to be conducted in a short time, a simple washing and sieving machine was developed to resolve sieving difficulties seen in the wet gravel materials of the CSG for the Kawai Dam (with surface water 60kg/m3 to 100kg/m3) because of the CSG materials of 5mm or less in size being adhered to the CSG materials of 80-5mm. This simple testing method, applied to the grading and surface water test in the Kawai Dam project, took only 50 to 55 minutes and, therefore, was well applicable and workable even with a testing frequency of 1 hour per test.

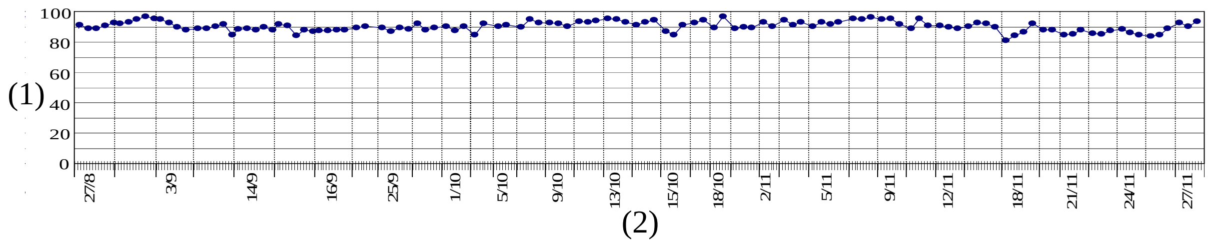


(1) Measurement value by oven-dry method
(2) Coarse-grained curve
(3) Average-grained curve
(4) Fine-grained curve

Figure-11 Grading of CSG Materials by Dry-up Method

For grains of five (5) mm or less which contained much surface water, infrared moisture determination balance (moisture tester) was used to measure the water content. At the initial stage, grading and water were measured once in an hour (one sample per one time testing). However, as the scattering results were observed, measuring frequency and number of samples had been reconsidered and, finally, three (3) samples were collected at one time and were tested in every three hours, and their average values were applied to the assessment of materials.

Figure-12 shows the results of surface water measurements of CSG materials on the working day. They were fluctuated within the range of 60 to 100 kg/m3, but were within the allowable and specified unit water contents for use in the construction.

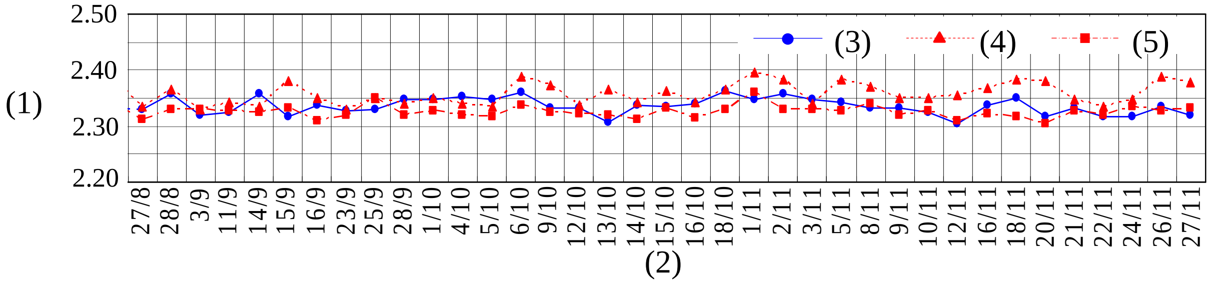


(1) Surface moisture content (kg/m3), (2) The time and day of measurement

Figure-12 Surface Moisture Content of CSG Materials at the Construction Day

Measuring Control : At the CSG Mixing Plant, volumes of the CSG materials, water and cement were measured as a part of the quality control items.

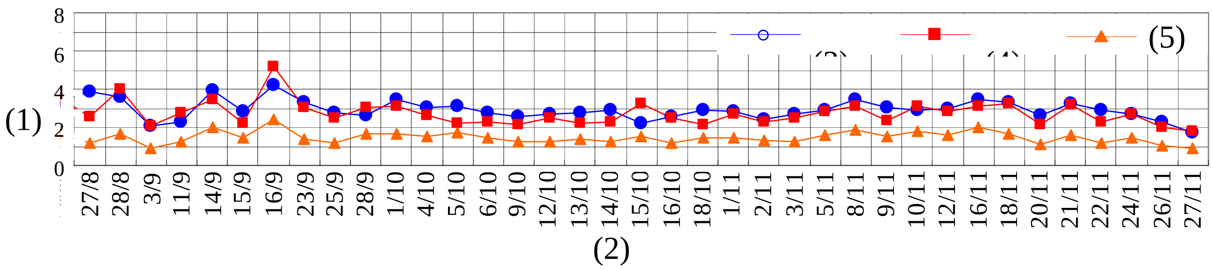
Control of Compaction Energy : Compaction energy control was conducted by controlling passages number of a vibration roller (11-ton class). In addition to that, the density in situ of compacted CSG was tested and checked by a sand replacement method and/or Radio Isotope method. Large size test pieces (cylindrical, dia.300mm, height 600mm) were prepared using the CSG actually placed in situ. Figure-13 shows density in situ (max. and min. values at three locations) and test piece density (40 second-compaction and an average of three test pieces) together in one graph which was measured during the construction period. As shown in Fig-13, the densities in situ corresponded to the density of the large test piece (40second compaction) as expected at the primary stage.



(1) Density (t/m3)
(2) The day of measurement
(3) Average density of CSG of large test piece (40-second compaction)
(4) Maximum density of CSG by sand replacement (in situ)
(5) Minimum density of CSG by sand replacement (in situ)

Figure-13 Relationship of Density In situ and Specimen

<u>Confirmation of Compressive Strength of Standard Size Test Piece by Fluctuation Pattern</u> : In addition to the above-mentioned procedures of quality control, the quality of CSG placed was confirmed by measuring the strength in their fluctuation patterns of 7-day strength of the standard size test pieces (dia.150mm, height 300mm). To complement the result of the strength tests, 28-day strength tests of the standard size test pieces and the large size test pieces (dia. 300mm, height 600mm) were also conducted.



(1) Compressive Strength of CSG(N/mm2)
(2) The day of manufacturing test pieces

Figure-14 Compressive Strength of Test Piece during Construction Period

Figure-14 shows these results (strengths of CSG). It is understandable that the 28-day strength of standard-sized and large-sized test pieces are nearly the same and fluctuation patterns of the 7-day strength of standard-sized test pieces and those as at 28 days are also very similar.

CONCLUSION :

Through the construction of the Kawai Dam designed based on the Trapezoid-Shaped CSG theory utilizing river bed gravel materials, the following aspects concerning the construction method and the quality control procedures were found to be valuable to achieve the required level of quality in such dam construction projects:

* It is verified that the quality control procedures based on the pre-investigations, through which the ranges of grading and unit water contents to achieve the required strength are pre-determined, will lead to the construction of CSG structures of the expected quality (strength). Accordingly, it is also verified that the advantages of the CSG Method are seen in utilization of the existing raw materials with a wider range of grading and water contents and a more efficient construction method than the conventional construction method.
* It is verified that the detailed construction method and quality control procedures described in this paper are effective. And the useful data were obtained which can well be applied to the future Trapezoid-Shaped CSG Dam construction projects.

At the closing of this paper, we would like to express our sincerest respect to the Japan Dam Engineering Center for their great assistance in our design, construction and quality control of the Kawai Dam.

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