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Trapezoidal CSG Dam Design and Construction for Kasegawa secondary dam

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ABSTRACT:
This paper reports a trapezoid CSG dam construction method adopted as construction of the Kasegawa secondary dam. The trapezoidal CSG dam can be constructed on relatively soft rock foundation and waste rocks can be used as the main material for the dam body. The Kasegawa secondary dam was carried out to improve the construction and CSG strokes using precast formwork. As a result, cost reduction and rationalization of construction has been achieved.

Keywords: CSG, Trapezoidal CSG dam, Diamond shape theory, Waste rocks, Soft rock foundation

1. INTRODUCTION

The Kasegawa secondary dam is a trapezoidal CSG (Cemented Sand and Gravel) dam with the height of 29 m and the dam volume of 68,000 m^3. It is located about 4 km upstream of the Kasegawa Dam and in the reservoir of the main dam. The Kasegawa Dam is located in Kyushu Island southwest of main island of Japan. Purposes of the secondary dam are to maintain the quality of reservoir water and to create a space for waterside environment at the upstream part of the reservoir. (Fig.1)

A trapezoid CSG dam is a dam of a new type which enabled environmental impact mitigation and cost reduction by attaining simultaneously rationalization of material, rationalization of construction and rationalization of design. The Kasegawa secondary dam was completed in September, 2010 and first impoundment is started on October 19, 2010.

As for the wide-area geology around the Kasegawa secondary dam, the granites of the Cretaceous are distributed widely, and metamorphic rocks are distributed beltlike to the south.
The geology of the Kasegawa secondary dam site is mainly a homogeneous rock mass which does not almost have change in rock face in the biotite granite. Dyke rocks and deterioration veins are identified, weathering advances especially along with faults or a deterioration belt at a riverbed, and the weathered zone was formed in the deep part.

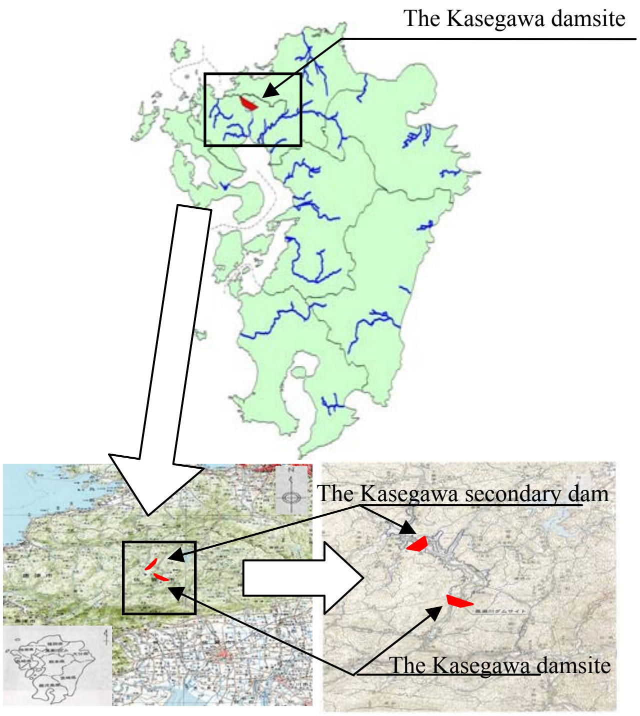


Figure 1. Location of Kasegawa Dam

2. THE DESIGN OF DAM BODY

2.1. Selection of Dam Type.

Although the Kasegawa secondary dam was originally planned as a gravity concrete dam, As a result of considering the application of trapezoid CSG dam, it revealed that construction period could be reduced seven months and cost saving could be up to about 40 percent as compared with concrete gravity dam. The two reasons of advantage of the trapezoidal CSG dam at Kasegawa secondary dam were following. The required cross-section for concrete gravity dam was intrinsically very large because of weak rock foundation. So, the increase of volume of dam body for the trapezoidal CSG dam is not large, up to 20% of a concrete gravity dam. Moreover, since the dam body material is an abandonment rock which cannot be used in the Kasegawa main Dam, the material supply for CSG did not take cost.

2.2. The Basic form of the Dam

The fundamental structure of the Kasegawa secondary dam is shown in Fig.2, It consists of CSG as main material, protection concrete at top, upstream and downstream faces, seepage control concrete at the upside of bottom and curtain grouting. The bottom part was made using rich-cement CSG.

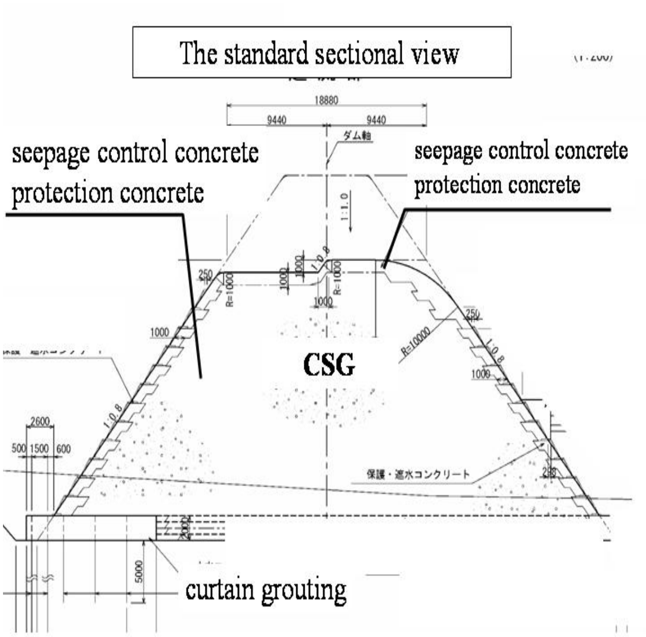


Figure 2. The standard sectional view of the Kasegawa secondary dam (overflow section)

2.3. Examination of Stability

Stress analyses of dam body for usual condition and seismic condition were conducted by two-dimensional elastic analysis using FEM.

2.3.1 Model caces

A number of FEM models to examine the external stability and the inner stability were formed in consideration of the conditions of overflow, non-overflow section configuration and the foundation condition. Moreover, examination was considered including the stability at the time of submersion of dam in consideration of the combination of the water levels at the upstream side and the downstream sides because the secondary dam is built in the reservoir.

2.3.2. Loading condition

The loading conditions for analyses are shown in Table 1 and Fig.3.

Table 1. Loading condition list

Loading items	Load acting		Remarks
	Static Analysis	Dynamic Analysis	
①Dam body weight	○	—	
②Water weight and hydrostatic pressure	○	—	Distributed load to downstream face
③Mud pressure and mud weight	○	—	Distributed load to downstream face
④Seismic force	—	○	Seismic Acceleration wave from Bottm of Dam
⑤Hydrodynamic pressure	—	○	Additional mass on downstream face
⑥Uplift pressure	In elastic analysis does not consider		Considered as static loads when considering external stability

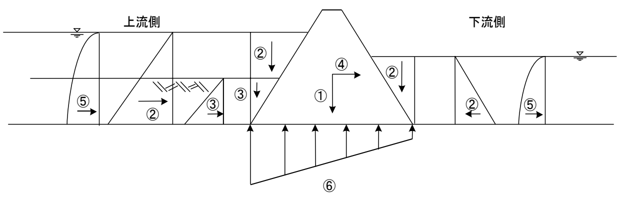


Figure 3. The concept of a load action

2.3.3 Physical properties

Physical properties of each item are shown in Table 2.

Table 2. The physical-properties value list used for analysis

Item		Physical properties	Remarks
Unit weight of dam γc		23.1kN/m^3	
Elastic modulus of dam Ec		2,500MN/m^2	
Poisson's ratio of dam μc		0.25	
Elastic modulus of the ground Er	Case I	500MN/m^2	Grade rocks CL'
	Case II	500MN/m^2	Grade rocks CL'
	Case III	500MN/m^2 800MN/m^2	Grade rocks CL' Grade rocks CL
Poisson's ratio of the ground μr		0.3	

2.4. Calculation Result

2.4.1. Stability for overturing

Perpendicular stress at dam bottom became the compression side in all the cases. So, the stability for overturning is considered to be secured.

2.4.2. Stability for sliding

In all examination cases, the sliding forces were below the resistant ability with required allowance. So, the stability for sliding is considered to be secured.

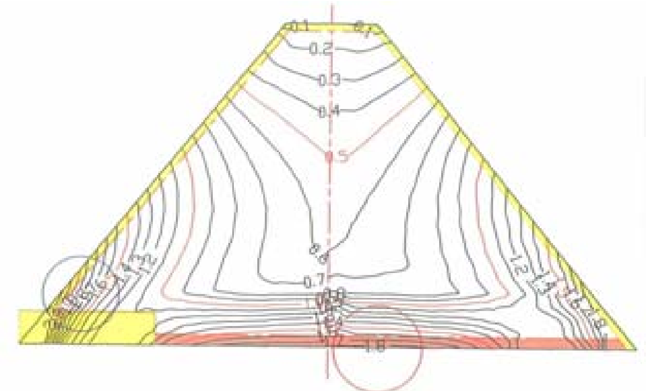
2.4.3. Stability over required intensity

The required compressive-side strength of CSG was evaluated based on the FEM analysis results Fig.4 is a example of distribution of require strength in the dam body.

Here, it asked for required intensity in Table 3.

Table 3. Formula for calculating the necessary strength of the CSG

Required compressive strength determined from compressive stress = Compressive stress×1.5 (Safety factor)
Required compressive strength determined from tensile stress = Tensile stress×7 (The ratio of compressive strength to tensile strength)×1.5 (Safety factor)
Required compressive strength = Is larger or any of the above



Legend

○Required compressive strength determined from compressive stress

○Required compressive strength determined from tensile stress

Figure 4.CSG required strength contour

The part which shows the maximum of require strength for each analysis cases is an end of the up-and-down edge at protection concrete, or dam body bottom in which rich-cement CSG is placed, and the required strength for normal CSG is less than 1.5 MN/m^2. Since the strength of CSG with a large-sized specimen made of actual material exceeded 1.5 MN/m^2, it satisfied the internal stability condition.

3. QUALITY CONTROL

The material of dam body did the check test added from the result of a prior indoor examination and the test construction before construction order.

3.1. Grain Size Distribution

The investigations of materials for CSG were conducted in feasibility study and trial execution just. From the result of investigations, the range of grain size distributions were evaluated shown in Fig.5.

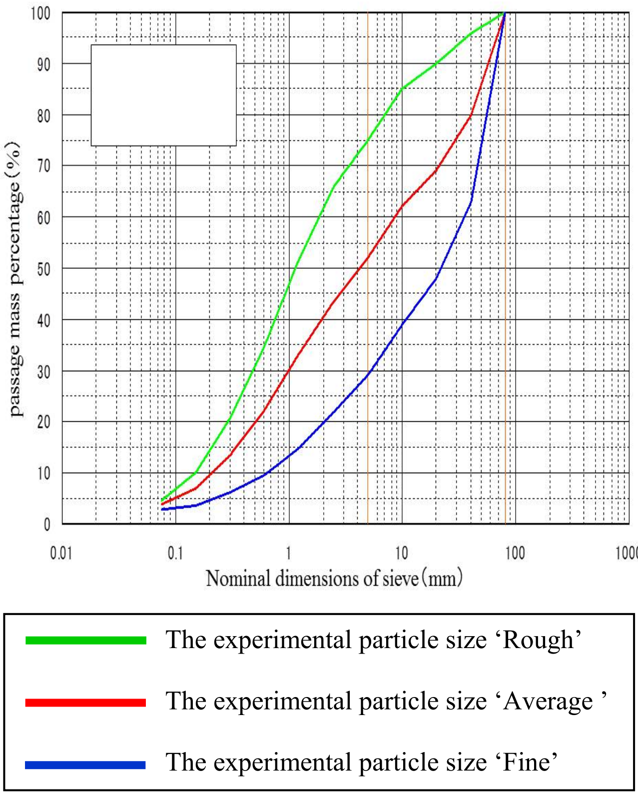
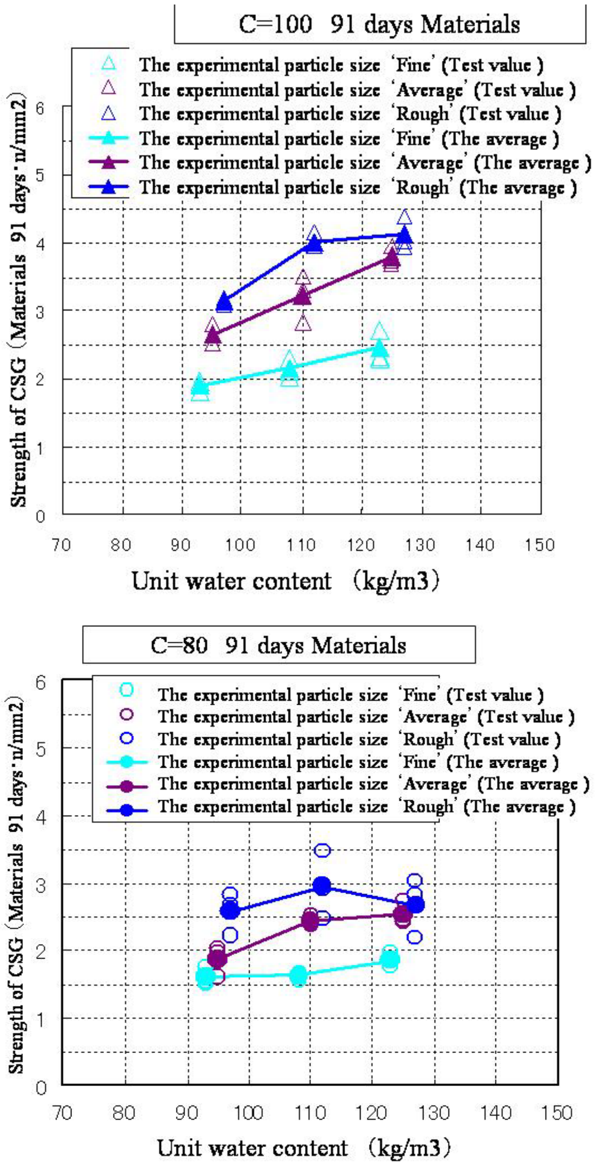


Figure 5. Range of Grain size distribution

3.2. The "Diamond " of the Kasegawa Secondary Dam

The relationship between the strength of the CSG and the unit water content was obtained by the examination of large specimens.(fig.6)

The vibrating time of making specimen by tamper was set to 20 seconds.



※C:Cement content

Figure 6. The relationship between the strength of the CSG and the unit water content

From the result of specimen test and test execution, the "diamond" of the Kasegawa secondary dam was set shown in Fig.7. The "diamond shape" is formed by the upper bound and the lower bound lines of strength of CSG, and lower and upper limit lines of unit water content and it show the range of CGS strength.

The density of specimen with 20-seconds tamper-vibrating was almost equivalent to the density at the trial execution by 8-times roller-compaction. So, the strength of specimen with 20 seconds vibrating is used to determine "diamond shape". The "diamond shape theory" is a concept for the determine of the range of CSG strength.

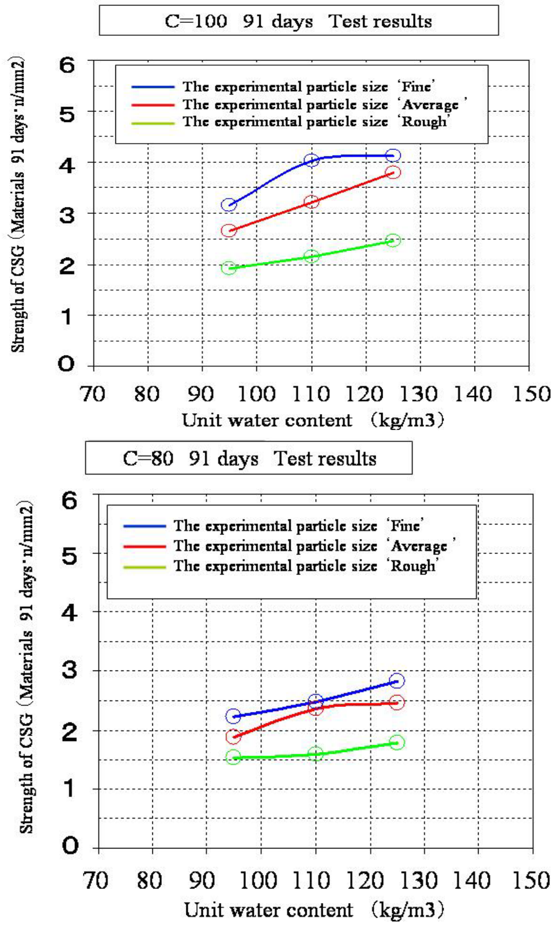


Figure 7. "Diamond" for unit cement content $C=80kg/m^3$ and $C=100kg/m^3$

4. CONSTRUCTION OF THE KASEGAWA SECONDARY DAM

4.1. Preparing and The Stock of CSG Material

The raw material for dam body was made from the waste rock from the Kasegawa main dam, and was crushed by simple equipment and into CSG material. The CSG material was transported and stored in the CSG material stockyard adjacent to a CSG plant yard.

The amount of stock is determined to be equal to 4 days placement volume (4,760 m^3) in consideration of time for material testing in order to quality control of CSG. And the balance of the amounts of consumption and supply of CSG material was also important viewpoint for stock.

The stockyard was divided into four classified into tree parts and division into four divisions; first part for CSG to be used in a day (1 division), second part for only stock (2 division), and their part for bring-in of CSG material (1 division). CSG material was taken out from one division one by one day by day placing, and was carried to CSG mixture equipment. (Fig.8)

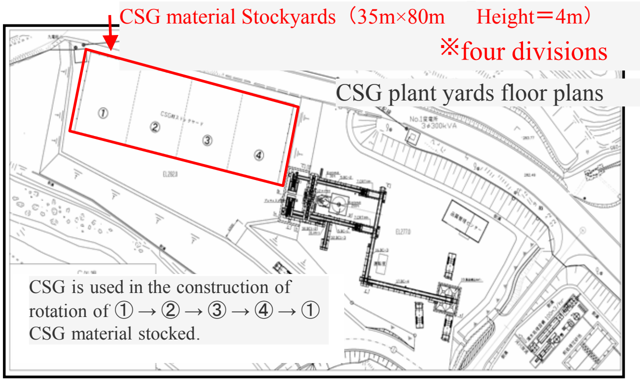


Figure 8. CSG plant yard plan view

4.2. The Construction Method of a CSG Part

The machines used of a CSG construction method are 10t damp trucks for tranporting, 16t swamp bulldozers for spreading and leveling, 11t vibratory rollers for compaction. The number of roller compacting was determined to be 2 times without vibrating and 8 times with vibrating by the results of execution test. Working hours until the end of compaction was set to a maximum of 6 hours from the start of a mixture of CSG. Rotation speed of the pressure of the compaction machine is set to 1km / h, pressure was rolling to overlap more than 20cm. Before the placement of CSG, cement paste was applied to ensure integration of horizontal joint surfaces.

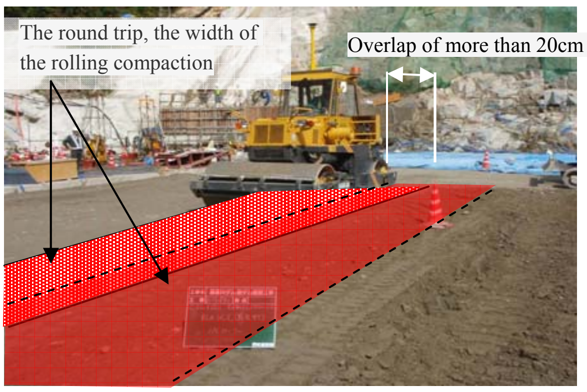


Figure 9. Roller compaction CSG

4.2.1. The examination and the check to the management method of CSG material

The variation per hour of the particle size of CSG material was conducted from October 1, 2009 until January 22, 2010, was to organize the mass percentage passing all the grit size and particle size. The total particle size of CSG material is an average particle size of the range of the particle size defined by the "diamond theory", and the variation in a particle size was seldom seen.

Moreover, it arranged also about the variation per hour of the amount of water of the surface of CSG material. Variation of the surface of the water every two hours, was within ± 10kg in the range of (80-0 mm) whole grain.

Had subsided to within ± 15kg against the values determined by the "diamond".

4.3. Construction of the Junction of the Seepage Control and CSG

4.3.1. The junction of the transverse direction of a dam axis

The junction of the transverse direction of a dam axis so that the junction must not become a way along which water passes. CSG place was stopped 1m away from the seepage concrete block, and concrete with a slump is poured between the seepage water concrete block and CSG in order to assure the joint of two different materials The figure of an outline is shown in Fig. 10.

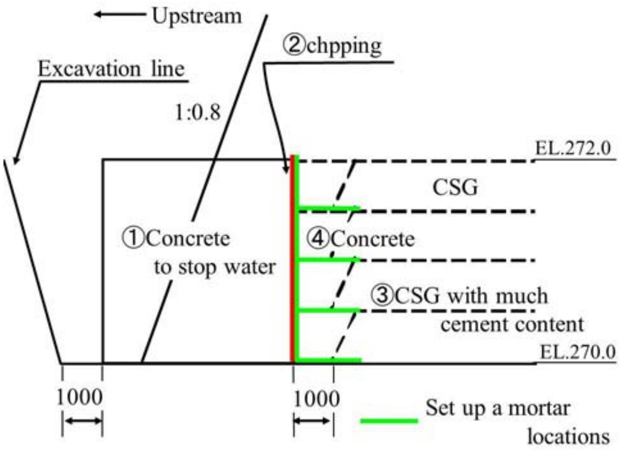


Figure 10. The outline of construction procedure near seepage control concrete: junction of the transverse direction of a dam axis

4.3.2. The parallel junction of a dam axis

For the parallel junction of a dam axis, CSG was placed close to the seepage control concrete, and filled up the junction with cement paste. A mimetic diagram is shown in Fig.10.

First, applying and spreading cement paste to the upstanding face of seepage control concrete, next levelling and compacting 1st and the 2nd layer of CSG with a 60-kg rammer and a 1t vibratory roller, then spreading 3rd layer and filling up a junction with cement paste, finally compacting with same manner

After that, an 11t vibratory roller was used for compacting of a general part which is not close to the junction of the seepage control concrete.

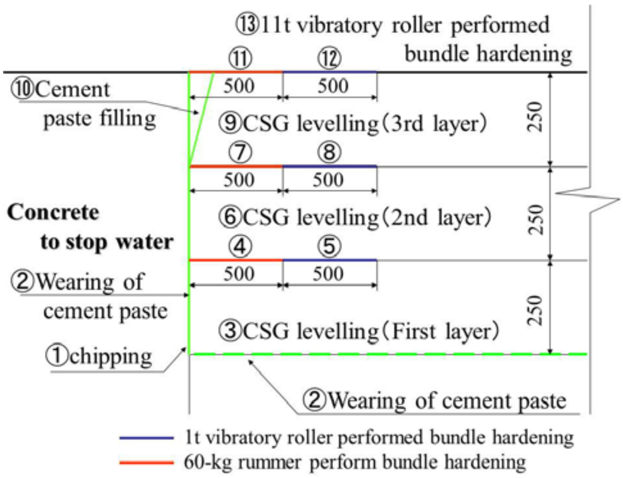


Figure 11. The outline of construction procedure near seepage control concrete: junction of the parallel direction of a dam axis

4.4. Construction Techniques Using Precast Form

The surface of the Kasegawa secondary dam was covered with the protection concrete aiming at strengthen durability and water-tightness. The precast form was used for the mold of the upstream and downstream side of a dam body from a viewpoint of rationalization of construction. A schematic diagram is shown in Fig. 12.

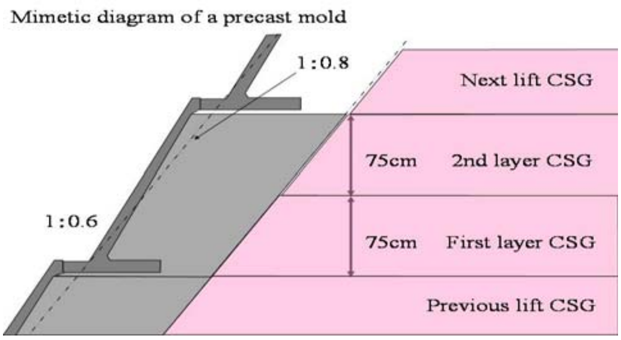


Figure 12. Schematic diagram of a precast form

The configuration of precast form was determined from the viewpoint of economical efficiency, structural stability at transporting and installation and simplicity and certainty of construction work. The mortar can be placed adequately between the bottom of precast form and lift surface of protection concrete, the shape of bottom plate and mixture of mortar were important. Through several tests were conducted used three prototypes of precast form, one type was selected for actual construction use. The arrangement situation of precast forms was shown in Fig.13.

Figure 13. The arrangement situation of precast forms

Figure 14. Installation situation of a precast forms

5.CONCLUSION

The Kasegawa secondary dam was able to do the construction between June 2010 from September 2009 the dam body was designed to ensure quality shots.

The dam body and the surrounding ground has elapsed problem was not observed even after first impoundment has been completed.

Think of this construction is going to be a reference trapezoidal CSG dam construction across the country is planned in the future.

Examine the performance of future assessment and summarized data about the actual situation and construction technology and construction details were obtained

Finally, authors thank the persons who cooperated to design and construction of the Kasegawa secondary dam including Mr. Fujisawa, technical adviser of the Japan Dam Engineering Center for great support and help.