Current Activities on Construction and Management of Dams in Japan

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ABSTRACT

Dam construction in Japan is still much needed as it provides an effective method of maintaining and harnessing water resources while controlling floods. Since Japan is densely populated, upon dam construction there has been the expenditure of utmost efforts with the participation of local residents and in harmonizing with the natural environment. Furthermore, as regards construction and operational management, not to mention safety and economy, there is a strong demand for technologies that lessen the environmental impact as much as possible. Thus, the following three technological developments are primarily being promoted in Japan.

1. Technological development for maintaining the quality and safety of structures under difficult natural, social and labor conditions
2. Technological development for maintaining economic efficiency and technical reliability despite limited information, land space, materials and human resources
3. Technological development for maintaining environmental integrity that meets the diversified sense of values in the area of the environment

This paper introduces the latest topics in Japan related to construction and operational management technologies for dams.

Key Words: *Dam, Earthquake, Environmental conservation, Maintenance, Redevelopment*

1. Introduction

Japan, a narrow landmass with 75% being mountainous terrain, is situated within the Asian monsoon zone. Japanese rivers are steep in gradient and short in length, and some 120 million people populate the river basin densely. During the rainy season, heavy precipitation results in rainwater gushing towards the sea rapidly. Because of such features, dam construction in Japan is still much needed as it provides an effective method of maintaining and harnessing water resources while controlling floods.

Moreover, since Japan is densely populated, upon dam construction there has been the expenditure of utmost efforts with the participation of local residents and in harmonizing with the natural environment. Particularly in recent years, there has been an increased awareness of local residents concerning the natural environment, which requires dam planners to provide and clarify, in addition to measures for resettlement of affected residents in the dam site areas, the future regional promotion program and natural environmental protection measures in the dam and reservoir areas.

Furthermore, as regards construction and operational management, not to mention safety and economy, there is a strong demand for technologies that lessen the environmental impact as much as possible. Thus, the following three technological developments are primarily being promoted in Japan.

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2. Needs of Dams in Japan and Related Issues

2.1 Issues relating to water in Japan

Some 80% of Japan's municipalities have been victims of flooding over the past decade. This is primarily because flooding occurs as soon as it rains and the flood tends to peak at a high level due to the nature of the water pathways in Japan. The difference between ordinary water amount and that during floods is fairly large, occasionally surpassing the 100 to 1 ratio. Secondly, low-lying land in Japan that comprises some 10% of the entire landmass is densely populated. Perhaps this is because due to geological reasons, about half of Japan's entire population and 75% of her assets has to be concentrated in such locations. In recent years, although such areas have in fact been reduced thanks to the effects of dams and fluvial improvements, the assets contained in such regions have increased due to urbanization and modernization. As a result, the damage potential from flooding has been growing over the years. Thus, a reduction in such damage is a vital issue.

Ironically, water shortage occurs in many areas of Japan. Over the past 16 years, most of the prefectures in Japan have experienced water shortage. This is because, to begin with, although the amount of water stock in Japan (1,714mm/year) is approximately double the global average (973mm/year), per capita amount of water (5,241 m3/year/person) is only one-fifth (26,871 m3/year/person) that of the global average (see Fig.1).

Various industrial activities including production of chemicals, precision machinery and paper among others is dependent upon major industries that use a large amount of water. Recycling of industrial-use water has been promoted to the point of having a 77% recycling rate in 1996, which has also reduced the effluvial amount.

However, even this improved recycling rate has a limit and thus points to the need to establish a stable water supply.

The increase in urbanization has resulted in reductions in underground water. This is because of the increase in areas covered and in the demand for water. Moreover, in rural areas, the increased urbanization and other trends have resulted in the loss of the environmental functions they played. For forests that make up most of the water source areas, furtherance of development and roughshod harvesting of trees by the economically stricken forestry industry has reduced the water retention level. Thus, overall there are ill effects being shown on the water environment that requires action to revive and maintain a healthy water environment.

2.2 Necessity and role of dams

As noted in 1.1, as problems concerning the management of rivers basins in Japan, there are the need to deal with weaknesses against flooding, need to maintain stability of water resources and the need to maintain the water environment that constitutes an important part of the global environment. Important upon solving such problems are the solution of management among the requirements of anti-flooding measures, water usage (water storage for tap water, agricultural and industrial uses as well as for hydropower), environmental preservation, recreation and shipping-use canals, among others. What is now needed is an understanding thereof from the standpoint of the dam as a choice for the overall management of rivers upon dealing with current Japanese riparian problems and future development. This can be accomplished by offering: (1) as many choices, including dams, to deal with the management issue; (2) an evaluation through combination of such choices; and (3) an effective management regimen, through inclusion of processes such as selection of choices that enables participation of the residents.

Upon establishing a policy for preventing flooding, different types of structural and non-structural approaches are fully considered in order to evaluate the best mix of both approaches prior to implementation. Upon this consideration, the dam as a structural approach is offered as a choice. One important reason for selection of the dam as optimal choice in Japan is the fact that the country is situated in the Asian monsoon zone. In Japan, this leads to heavy pinpoint rainfalls and typhoons as well as a geography that lends itself to quick water build-up in the river path. The second reason is that the dam flood control can cover all river areas located downstream to the structure.

Upon planning water use, all types of structural and non-structural approaches are fully considered in order to evaluate the best mix of both approaches prior to implementation. Upon this consideration as well, a comparison of the flood control capability with other choices is of importance.

One of the most important reasons upon the selection of the dam as an optimal choice in Japan is the fact that the country is that it can adjust conditions according to changes supply and demand concerning the water resource depending upon the season and location.

Meanwhile, dams are facilities used to store water, used to store water to control flooding or when demand for water is small, while being used to meet seasonal demand variations during dry spells that cause water shortages or when demand for water is large. Furthermore, by transporting stored water to areas with difficulties in finding water, dams are used to adjust the regional demand for water. Japan, is situated within the Asian monsoon zone which has great seasonal variations as to the rainfall amount and is topographically highly variegated. These limit the amount of aquifer water content. This in turn makes it difficult to distribute water resources. There are also large seasonal temperature differences resulting in huge summertime demand for residential-use water. In addition, social conditions require a large amount of water to be used at certain periods of the year for rice cultivation in the paddy fields.

Based upon a dam's water storage amount, this dam not only offers flood control or water supply capability but also new possibilities for the stored water. By blocking the river path, a dam interrupts the continuity of water flow and thereby alters the water environment prior to dam construction.

Thus, there is a need to aggressively pursue a choice that reduces the impact on the natural environment. On the other hand, the presence of a new reservoir through dam construction can offer a large recreational space in addition to often creating a resting place for migratory birds or promoting diversity in waterborne organisms due to seasonal changes of the water surface. Moreover, hydropower generation provides a clean energy source that does not emit carbon dioxide or sulfuric acid compounds.

Therefore, when considering the environmental impact of dams, it is important to consider not only the temporary impact on the environment in areas near the dam site but the impact over the long term on the overall environment with an eye to the global environment as well.

2.3 Requirement technologies of dams in Japan

The role to be played by dam technology in Japan is, as noted in 1.2, a great one when considering Japan's unique natural and social conditions. On the other hand, such things as the diversification of values as regards dams makes it necessary deal appropriately with the issue. Moreover, dam projects are large scale construction activities which takes a long period of time while exerting a huge impact on the area to be submerged underwater and impact the lives of those living in the areas nearby. Thus, for the construction and management of dams henceforth, the following must be targeted for improved efficiency thereof.

(1) Safety under difficult natural, social and labor conditions

(2) Reliability and economic efficiency regardless of limited information, land, material and human resources

(3) Sound environment that meets various requirements of parties that act on different sets of. In addition, technology development that reduces the impact of dams must also be promoted vigorously.

While dam sites with good geological conditions are starting to run short in Japan, it is necessary to ensure safety of dams against earthquakes from the design stage. Moreover, keeping in mind the high peak level of floodwater due to Japanese climatic conditions and the short period of time it takes for flooding to occur, the concept of controlled flooding and control of dam maintenance facilities especially from the standpoint of ensuring safety is a must. Furthermore, climatic conditions such as the great differences in temperature by season and time of the day requires a detailed eye as to the quality of soil materials upon design as well as the pursuit of reliable implementation of construction work and quality control.

The economic efficiency and reliability for the dam project must be ensured, which requires measures that must ensure quality under differing conditions. That is, in recent years, the aging of he skilled workforce needed for the project makes it difficult to bring together the human resources, thereby adding to the labor, material and equipment cost greatly. Therefore, it is important to consider the wide range of impact rather than the limited impact a new technology would have upon technology development. Moreover, during construction, not only a reduction in the cost or time required due to technology development can be brought about but also the realization of early operational results would improve the entire project's effectiveness. Furthermore, enhanced flood control capability and development of new water resources will effect not only new dam construction, but also such items to be considered for effective use of the dam facilities such as the removal of dam water silt and reduction of incoming soil and silt flow as well as structural additions.

Dam projects require that a full look at the impact on the environment surrounding the construction, which is large in scale and extended in terms of the time required.

Moreover, when environmental impact cannot be avoided, implementation of a mitigation scheme to reduce such impact takes place. For example, comprehensive regimen for ameliorating the situation, such as dealing appropriately with turgid water and refuse materials that emanate from the project, as well as promoting the greening of areas directly effected by the construction work, must be adopted. In addition, a reduction in activities involved and implementation of seedling plantings as well as establishment of biotopes taking place.

Furthermore, such improved water

environment can be used for recreational purposes, thus having a positive effect not only on the direct beneficiaries of the dam project but for everyone, for a proper recognition of the value of the project.

3. Topics in the State-of-the-Art Technologies for Dam Construction

3.1 Development of Concrete Preparation Technologies

Conventional concrete preparation equipment uses a batch mixer to knead materials. The equipment repeats a batch cycle where measured materials are put into and kneaded by the mixer, and the uniform mass is taken out. The process is intermitted every time a batch is finished. It is inefficient in working time.

To reduce waste time, a new technology was developed to continuously knead materials. The new system continuously kneads materials, and yields a finished mixture with good qualities (see Fig.2). In addition, the new system can shorten the process time if its kneading units are set one on the top of another, because a continuous kneading of material is performed by gravity with no extra energy supply.

3.2 Application of Self-compacted Concrete to Dams

In recent years, fewer and fewer skilled workers were available in the Japanese construction industry. Specifically for concrete dam construction, skilled workers have been required to build, among other parts, reinforced concrete structures around outlet conduits and other steel members, galleries and gate doorstops in the dam body. During this task, workers needed to be adept in putting together or setting up steel members, iron rods and frameworks while being obliged to place concrete in confined space surrounded by the steel and iron structure. The concrete placement method must be streamlined to save labor while maintaining safety. A possible solution is to make partial use of self-compacted concrete in dam construction, and such cases are growing in number.

"Self-compacted concrete" is concrete that has been prepared with highly enhanced fluidity and resistance to material separation compared with conventional types of concrete. With good self-filling property, the new concrete requires no internal vibrator to fill up a framework and thus leaving no vacancy (see Fig.3).

The new concrete is advantageous for dam construction use in that it can fully fill up a framework without the need for the piping of the concrete placement in narrow rooms and internal vibrator compaction. This feature leads to the construction endowed with greater reliability, and to the lower need for labor skill and activities on site.

Self-compacted concrete was used to support precast galleries, parts around outlet conduits and concrete placed secondarily in intake gate block out.

Spillways and other large outlet works are often seated on an installing platform as seen in Fig.4. Besides, iron rods and dowels are crowded around outlet works. Concrete to be placed there thus should be self-compacted. Fig.4 shows self-compacted concrete placed under outlet works of Hinachi Dam (PG, Height=70.5 m, Volume=426,000 m^3).

Those cases were just concerned with a small part of the dam body. However underway is research of self-compacted concrete with so large maximal aggregate size (Gmax80mm) that it will make up the whole dam body.

3.3 CSG Method

Economical dam construction involves effectively using materials as well as streamlining design and building works. As a promising solution, the CSG (Cemented

Sand and Gravel) method was developed, and, in 1991, was employed in building an upstream cofferdam (Height=14.9m, Volume=22,900m^3) for Nagashima Dam (PG, Height=109 m, Volume=842,000 m^3). In the CSG method, cement is added to such locally yielded materials as bed sand and gravel dug at or around the dam site and muck produced by the dam excavation and the roadwork. They are mixed, and the mixture is carried, applied and compacted as is the material of rock-fill dams. The method is effective not only in using materials, but also in enhancing economical construction and shortening the period of works.

In the CSG method, locally yielded materials to be mixed with cement are cleared of rocks larger than 150 mm across. It is different from the rockfill-dam material in containing cement, and from concrete in evading the size control of aggregate. The CSG material is thus poorer than the concrete in strength, uniformity of quality, and imperviousness, but much more advantageous over the rockfill-dam material in strength and overflow resistance.

Here are steps of the method:

1. Rocks 150 mm across or larger are removed by a grizzly from raw material produced at the site.
2. Cement is added to the material by a backhoe or other conventional means.
3. The mixture is carried by a dump truck or other measures to a banking yard.
4. The dumped mixture is laid out by a bulldozer and compacted by a vibratory roller.

Steps 3 and 4 are similar to what is done by the RCD(Roller Comacted Dam Concrete) method. In the early implementation of the CSG method, Step 3 relied on a backhoe, though a simple mixing plant is increasingly employed today to get greater blending power and homogeneity of the product.

Among advantages of the CSG method are cost reduction and shortened term with no large investment of equipment, saved resource because of effectively procuring materials at the site, and accelerating the construction. Unfortunately, researchers of the new method still have to solve some technical challenges: 1. The product quality differs according to properties of the materials gained at the site; 2. Its strength and imperviousness vary in a low and rather wide range; and 3. There is as of yet no control system for ascertaining construction and quality.

With those features and merits, the CSG method was applied to rather small temporary constructions such as cofferdams (Nagashima Dam, Surikamigawa dam, Chubetsu Dam, Kubusugawa Dam, Tokuyama Dam, Takizawa Dam, etc), temporary revetments (Tomisato Dam and Tokuyama Dam) and checkdams (Mizunashi River No.1 Dam at Mt. Unzen Fugen in Nagasaki Pref.).

For example, Surikamigawa Dam (ER, Height=111 m, Volume=8,900,000 m^3) employed a material made of tunnel muck (Fig.5). Tokuyama Dam (ER, Height=161 m, Volume13,900,000 m^3) is placed to be built with sediment material of the existing Yokoyama Dam (PG, Height=80.8 m, Volume=320,000 m^3, completed in 1964) lying downstream. At the same time, the removal of sediment material restored the validity of Yokoyama Dam.

At the sediment trap dam (PG, Height=34 m) placed near the most upstream point of the reservoir of the above-mentioned Nagashima Dam, an inner part was built with the CSG concrete so that the construction work was accelerated at a lower cost (Fig.6).

3.4 Using Precast Concrete Products

To streamline the construction of concrete dams, the RCD and ELCM methods have been implemented to place concrete effectively. But form work and steel bar placing require lots of time and skills in structural blocks such as galleries, elevator shafts and gate control room. Such difficulties seriously affect the lift schedule of concrete. Besides, there are dangerous manual works on a hanging scaffold such as installing a hanging form.

In those cases, precast concrete products (factory-made) are used to streamline the installation of forms and steel bars, and to secure the safety.

A precast concrete product should be reinforced, in case it should be strengthened to incorporate with the dam body.

Merits of Using Precast Concrete Products

1. Shortening work period

The period of construction is shortened because only placing ready-made products is necessary without form work and steel bar placing.

2. Securing safety

Construction works are made safer because such dangerous works as assembling forms or timbering at heights are less required.

3. Securing quality

Factory-made precast concrete products secure reliable quality.

4. Simplifying concrete works

Less form work and steel bar placing simplify concrete work so that non-skilled workers can make it.

For example, Unazuki Dam(PG, Height=97 m, Volume=510,000 m^3) and Tsunakigawa Dam(ER, Height=74 m, Volume=2,160,000 m^3) used precast concrete products for their gallaries(see Fig.7, 8 and 9).

3.5 Remote sensing for reservoir management

There is a wide spectrum of investigations concerned with dam construction: hydrologic, meteorological and environmental to be done beforehand as well as those performed during construction works, and those for the dam maintenance and administration.

Those investigation technologies have been remarkably advanced with the dam construction. The advancement these days is, however, particularly great because of the dam information technology newly exploited and provision of information equipment in implementing such technology.

It is important to obtain actual information accurately on the water quality of reservoirs and lakes in order to retain their water quality.

It is desirable to have actual three-dimensional information date to keep track of the water quality of reservoirs and lakes at aiming to forecast the trend in water quality.

As measurement activities involved upon doing this, site observation at the reservoirs extended to vertical and horizontal directions should be surveyed in order to make a better water quality movement model.

In conducting the survey, it is possible to monitor the water quality alterations in reservoirs by getting information on distribution date extending to the water surface.

Thus, it is most efficient to utilize the satellite remote sensing system to widely survey the extension of surface water quality.

With technological progress, the observation by remote sensing enables judgment of objects (such as water surface, plants, soil and so on) and the surveying of the surface distribution water quality, through analyses of detailed data on reflection or radiation of electromagnetic waves from objects.

The measurement of water quality by remote sensing system is more effective upon measuring water temperature, suspended solids and generation of algae (chlorophyll “ a ”), in accordance with experimental results.

Fig.10 shows outline of the system and Fig.11 shows results of the observation on water quality at the Lake Biwa.

4. Dam Reservoir Redevelopment

4.1 Background to dam redevelopment in Japan

As social constraints concerning dam construction increases while on the other hand locations available for dam sites dwindle, there is still a strong demand as regards dam constructions.

Such a background has led to the attempt at redevelopment of dams in existence, with the concomitant effects being larger than new dam constructions, thereby resulting in recent attempts to be put in place on several occasions.

4.2 Dam redevelopment ways

There are three ways for redevelopment of existing dams, as follows.

(1) Increasing storage capacity of reservoir

By raising the existing dam instead of constructing a new one, use of more water, with the water volume becoming relatively large in comparison with the level of the heightening, is made possible. This method offers the merit of enabling the forecast of various changes, thanks to the fact that topological surveys have been carried out when the existing dam was constructed which has led to such attempts becoming more often implemented in Japan.

Two examples of the heightening, Shin-Maruyama Dam and San-noukai Dam, are introduced.

Maruyama Dam (PG, 98m high, dam volume, 500,000m^3) was completed as a multipurpose dam in 1956. Redevelopment is in progress for the enhancement of flood control function and protected flow of the river. The dam is to be raising some 24m, with the current active storage capacity of 38,390,000m^3 to be raised to some 6,700,000m^3.

Upon construction work, because the dam is used for flood control more than 40 times a year and two hydroelectric power stations with a total capacity of 188,000kW are installed, there are restrictions. Namely, the current dam water provision (maximum 4,800m^3/s) is to be carried out even during the work; the water level is to be maintained as under the existing design. This is in order to prevent the stop or reducing of the two power stations and to maintain the dam stability.

Under such restrictions, a new dam axis some 47.5 m downstream of the existing dam axis is to be construct with nine food control outlet works gates (conduit gate W 5.0m x H 6.5m) for letting out 5,700m^3/s of the designed 10,000m^3/s amount to be added and to be construct 10 uncontrolled spillways for letting 15,000 m^3/s combined with food control outlet works (Fig.12).

Sannohkai Dam (ER, 37.4m height, 150m crest length, total reservoir storage capacity 9,600,000m^3) is an earthfill dam. This dam for irrigation purpose was completed in 1952. In the four decades that passed since the dam was constructed, the expansion of agricultural land including farmland by redevelopment has created a shortage of irrigation water. To cope with this situation and to assure stable supply of water, it was decided to heighten the existing dam. A new dam under construction, (trial water discharge date set during fiscal 2000) is a rockfill structure with center impervious zone, 61.5 m high, 242 m long along the crest and gross storage volume of about 38.4 million m^3, which is almost four times the storage volume of the existing dam (Fig.13).

As a method of raising the existing dam level, the possibility of using the old waterfill? zone was considered, but at Sannohkai Dam (i) using the old zone would mean that construction that makes use of the old structure would be difficult and (ii) the actual zone is not clearly identifiable, so it was decided that a new dam axis would be built downstream to the old axis.

(2) Changing operation system of the dam reservoir

This changing operating system of the dam reservoir reconstruction the intake work and outlet work without changing the scale of existing dam, or adding new outlet work that can correspond to top priority objectives; this is the most common redevelopment way in Japan today.

Moreover, there is also a case where the effective use of water by networking several reservoirs with a new channel, thereby altering the operation system for these.

The Dams Networking Project of Upper Kinugawa river entails water being shared through connection via waterways of dams with differing capacities, Ikari Dam (PG, 112.0m height, crest length 261.8m, dam volume 468,000m^3, active storage capacity 46,000,000m^3 and drainage area 271.2km^2) and Kawaji Dam (VA, 140.0m height, crest length 320,0m,dam volume 650,000m^3, active storage capacity 76,000,000m^3 and drainage area 144.2km^2), to enable combined operation of the reservoirs and improve the flow in the Oga River and the Kinugawa River proper.

The overflow from Ikari Dam being added to the Kawaji Dam's available capacity would mean a maximum of 20m^3/s being added; on the other hand, should the flow from Ikari Dam fall short, it can be supplemented with water from Kawaji Dam.

(3) Improving the supplying water quality of dam and reservoir

As required, the water quality is improved as per 2) where the intake and outlet work are altered or new one added, often seen in the case of old dams. 5-3 provides an example.

5. Management for Dams and Reservoirs

5.1 Countermeasures against sedimentation in dams and reservoirs

Countermeasures against sedimentation in the reservoir can roughly be divided into two methods. One is the excavation and dredging method and the other is the sediment flushing facilities by the tractive force of flowing water. The countermeasures by the excavation and dredging are difficult to be adopted as the reservoir managing plan on the grounds that the disposal area for the machinery of dredging and transportation, and for a large amount of dredged sediment in case of a large quantity of sediment inflow. On the other hand, if the conditions are settled, the sediment flushing facilities is possible to be adopted as the permanent reservoir managing plan. In this section, the sediment flushing facilities are described.

(1) Sediment flushing gate

A dam, which enables the water level to lower below the sediment level in the reservoir operation, makes sediment flushing possible by sediment flushing gates. There are some examples so far.

Here, an example of the sediment flushing gate of Unatsuki Dam is introduced.

A specific sedimentation rate is adopted 3,300 m^3/km^2/year which is obtained by the stochastic method from the relationship between results of sediment volume in Kurobe dam located upstream side Unatsuki dam and the annual floods. As estimated inflow sediment volume of 140,000,000 m^3 is extremely large and spoils the function of the dam, therefore, the installation of sediment flushing facilities was decided.

A reservoir operation is examined to secure the necessary sediment volume on the basis of the discharge in the last 25 year. An annual mean discharge of the bedload and suspended load records are estimated as the annual sediment of 800,000 m^3 with three times operations of the sediment flushing a year. Sediment flushing is done during the flood taking the influence of the downstream area into consideration and after finishing the function of flood control, the water level is lowered and discharge of sediment is carried out.

Fig.15 shows standard cross section of sediment flushing facility in Unazuki Dam. basic structure of sediment flushing facilities meets the structural criteria for outlets and its members are repairable and exchangeable, as the need arises, taking the environment of the maintenance works into consideration to keep necessary functions.

For channels and open channel-type tunnels in the dam body, the lining materials are fixed on the surface with exchangeable members to avoid a bad influence by a large-scale repair was adopted. Stainless materials are for the reason of the maintenance and the economical point. A life of lining materials of 30 mm thick is presumed of to be 30 year.

(2) Sediment bypass

In a dam, which can not lower the water level below the sediment level, even if a sediment flushing gate is open in the high water level in the reservoir, the are of flushing would be limited only near gates and there is no restoration effect for the active storage capacity of the reservoir.

In case of the above situation, there is a countermeasure against the sedimentation to construct a bypass tunnel detouring the reservoir. Concretely, a check dam is constructed in the upstream end of the reservoir and the bedload of large grain size is settled there. From an intake located in the upstream check dam, the suspended sediment and the wash load are flushed out downstream through a channel that detours the reservoir.

Here, an example of the sediment bypass of Miwa Dam is introduced.

Miwa dam (PG, dam height = 86.1 m, dam volume = 147,300 m^3, catchment area = 39.2 km^2) was constructed on the Mitsumine river in the Tenryu river system. The dam works started in 1953 and completed in 1959. The dam is a multipurpose dam for the flood control, the irrigation and the power generation.

In the drainage basin of the Mitsumine river, there have been repeated and large flood such as that of 1959,1961,1982,1983. Therefore, unexpected sediment flows into the reservoir. An active storage capacity is secured by gravel gathering in the upstream end of the reservoir. However, there is the possibility to deteriorate the functions of the dam if this situation leaves as it is. Accordingly the works of sediment excavation and removal have been executed for the purpose to secure a storage capacity for 100-years sediment volume and a new storage capacity for the flood control and the industrial water. Furthermore, the sediment bypass system which is composed of the weir for diversion and the flood bypass tunnel is planned, as the permanent countermeasures to restrain the sedimentation in the reservoir.

A mean annual inflow sediment in the reservoir of Miwa dam is the bedload and suspended sediment of approximately 160,000 m^3 and the wash load of 525,000 m^3. A rate of wash load portion is 76 percentage. Therefore, the flushing wash load leads to the reduction of the sediment in the reservoir.

As the bypass system is for the wash load only, it is composed of the check dam and the weir dam for diversion which has the functions of diverting the flood and capturing the bedload and the suspended sediment, and the bypass channel (side flow weir), the bypass tunnel and the energy dissipater (Fig.16). It is necessary, however, to excavate and remove in the accumulated sediment in the check dam.

(3) Check dam

A check dam is applied when the actual sediment inflow is considerably larger than the expected quantity in the dam planning stage.

For the purpose to capture the inflow sediment, a check dam is constructed in the upstream end of the reservoir and captures the inflow sediment. As a result it stops the inflow sediment into the reservoir and after flood, the sand deposit is excavated and dredged.

Mainly, its purpose is to capture the sand deposit more than grain size of the bedload. Partials of suspended and fine fraction of the wash load are difficult to be captured. Therefore most of them are discharged into the reservoir.

5-2 Dam management

Although most dams in Japan were constructed in modern times, there have been dams that were constructed by the monk Kobodaishi (774-835, one of the introducers of Buddhism into Japan). Many of these dams have been renewed until today, making them an important water resource for the respective regions.

On the other hand, there are some earlier dams from this century that have become antiquated and have seen their seismic resistance degraded, making it necessary to renew and to ensure the safety of these dams.

Here are some examples of dam refurbishment.

(1) Yamaguchi Chouseichi dam

Yamaguchi Reservoir dam is located on the Tokyo-Saitama boundary, located within three cities and one town; construction work on the dam (TE, 34.6m high, 691m crest length, active storage capacity 19,528,000m^3) was begun in 1927 and completed in 1934, and has since then continued to supply Tokyo with a stable supply of water.

The structure is an integrated earthfill dam and its seismic structure has been recognized; however, with the occurrence of the 1995 Hanshin-Awaji earthquake, surveys conducted showed that should a direct quake (magnitude 7 class) strike, although the structural integrity would be maintained, the top part of dam (bank) could be subsided.

Thus, since water supply would depend on the reservoir in the event of a natural disaster and since urbanization was proceeding downstream, measures to further enhance its seismic structure were commenced (see Fig.17).

(2) Honenike Dam

Honenike Dam (MV, 31m high, 128m crest length) was completed in 1930 for the purpose of supplying irrigation water. The dam has 6 arch-type buttresses built in the center. The span between 5 buttresses is enclosed by full arch structures and both ends are half-arch structures connecting to gravity sections constructed on the abutments. The dam is a masonry structure with the surface finished with stone tile facing. The spillway is a combination of uncontrolled spillway crest section and 5 siphon spillways , adopting a peculiar discharge system. As 60 years have passes since the dam was constructed, deterioration has set in with water leakage from the dam and foundation, and therefore requiring renovation work for fear of degradation of the dam's function.

In the renovation work, preservation of the peculiar shape and aesthetic value of the dam was taken into consideration, since the dam has been designated a prefectural cultural asset (Fig.18 & 19). Concrete facing for repairing the upper surface of the arch section and installing waterstops in joints prevents leakage of water. Footing was constructed in the span between buttresses to reinforce the base of the dam. As the foundation rock of the existing dam had not been treated by grouting, so, consolidation grouting and curtain-grouting were implemented, and drainholes were drilled in the footing to reduce uplift pressure.

In Japan, according to the guidelines established by Ministry of Land, Infrastructure and Transport or Japan Commission on Large Dams, dam administrators perform the comprehensive inspection periodically. At the comprehensive inspection, to confirm the safety of dams, monitoring of leakage, deformation and so on, as well as visual inspection is made. Dams, at an age of 20 or more, should be checked to evaluate the structural safety, felicity of operation and the system in an emergency by the specialist team organized by Japan Dam Engineering Center.

6 Countermeasures to Earthquakes

6.1 Introduction

Japan is located atop an earthquake-prone zone on the Pacific Rim, and even from a global perspective, is in an area where seismic events occur most frequently. Therefore, almost all permanent civil engineering structure design pays attention to earthquakes, furthermore dams are structures with the highest importance, it needs to be designed and constructed so that damages on dams by earthquakes may not happen. The impacts of seismic events on dams are classified roughly by two types, earthquake motion and ground displacement on the fault line. Dams in Japan have been designed after preliminary checking that there are no active faults near dam site. After the 1995 Kobe Earthquake (the 1995 Hyogoken-Nambu earthquake), measures to active faults became major topics of discussions even for construction of ordinary civil engineering structures. Concerning seismic motions, dams are basically designed by the seismic coefficient method, and if necessary the seismic resistance of dams may be checked in detail by the modified seismic coefficient method and/or the dynamic analysis. During the Kobe Earthquake, fortunately there was little damage to large dams, but the safety of several dams that received strong seismic motion during that earthquake were reconfirmed by detailed investigations.

6.2 Countermeasures in Investigation Stage

When carrying out choosing sites for dams, in addition to the conventional study of past seismic activities, the active fault survey is always carried out. Although earthquake resistance design against seismic motion is performed, the problem of ground displacement cannot be addressed by the design process. Therefore, areas near active faults that could threaten dams are avoided when choosing dam site at present.

The objectives of active fault investigations in dam construction are summarized as below.

a) To confirm whether or not lineaments and faults, both of which are considered to be active faults, are indeed active faults.

b) To locate active faults with sufficient precision such that they can be avoided when building structures.

c) To identify the activity history of active faults to predict future earthquake occurrence.

Active fault investigations for dam construction include literature research, geomorphological surveys, and geological surveys. Fig.20 shows the flow chart of investigations. Thorough comprehensive consideration of these survey results, it must be clear whether such faults requiring caution upon dam construction exist or not, and if exist, an evaluation as to the length and continuity of the existing active fault must be made.

Since the Kobe Earthquake, trenching and various investigations have been conducted on active faults, and the location and history of activity of large- scale active faults and active faults near major cities have been obtained. However, the state of active faults in mountainous areas where many dams are planned to be construct has not been clarified sufficiently, nor have effective method been established for investigating and evaluating active faults in such areas where little is known about the base topographies. Existing methods for investigating and analyzing active faults for dam constructions have not been fully established; therefore, improving investigation methods and accumulating knowledge on active faults are needed to establish the satisfactory evaluation concepts of active faults.

6.3 Countermeasures in Design Stage

Earthquake resistance designs of dams in Japan are conducted basically by the seismic coefficient method accordingly the present design criteria. There have been no large damages due to earthquakes on dams designed by the Japanese present design criteria. But, because the assumption of the acceleration distribution of the dam in the seismic coefficient method doesn't completely match to the real dynamic behavior of the dam, the investigation of the effects of earthquakes on dams are taking place in Japan in order to establish more rational earthquake resistance design methods. In this regard, the modified seismic coefficient method, which takes into account the characteristic of vibration characteristic of dams when deciding the seismic force distribution, has been proposed. In the case of filldams, the cross section designed by the seismic coefficient method is re-checked the safety by the modified seismic coefficient method. Of course, research activities about dynamic analysis methods are being carried out at universities and public/private research institutions in Japan, and especially in areas where earthquakes may pose serious problems due to dam construction, the dynamic analysis is conducted for individual dam in order to ascertain safety against earthquakes.

6.4 Countermeasures in Operation Stage

Measurements of uplift pressure, water seepage amount, displacement, etc. are mandated for dams in Japan. Although measurement of earthquake motion is not mandated, recently constructed dams oftentimes are equipped with seismometers. In Japan, the special safety inspections should be conducted for dams where the recorded acceleration is more than 25 gal by the seismometer installed in the dam and the nearest station of Japan Meteorological Agency records a seismic event of intensity 4 or greater. The results of such special safety inspections should be informed to the river administrators by the site management offices of each dam, and through them the river administrators can comprehensively consider the impact of an earthquake upon the dams. The special safety inspection is categorized into primary and secondary inspections, the former being based upon visual inspection immediately after an earthquake while the latter based upon a detailed visual inspection as to the external appearance and safety checks of the data recorded by the measurement equipment installed.

Due to the Kobe Earthquake, the networking of seismometers installed upon civil engineering structures and the ground surface has been rapidly promoted for forecasting earthquake damages. As regards dams, such seismometer networking is being pushed forward, with a nationwide seismometer network to be realized in the near future in order to collect various seismic data immediately after seismic events.

6.5 Activities about sesmic design after the 1995 Kobe Earthquake

Japan Society of Civil Engineers has been recommending using two types of seismic motions, Level 1 and Level 2 earthquake motions, for the sesmic design of civil structures after the 1995 Kobe Earthquake. Level 1 earthquake motion is equivalent to OBE(Operation Basis Earthquake), and level 2 earthquake motion to MCE(Maximum Credible Earthquake), respectively.

In order to secure the safety of dams, it is necessary to set the Level 2 motion clearly at a dam site and to clarify the behavior of the dam during a big earthquake. In order to set Level 2 motion, it is necessary to grasp the characteristics of the earthquake motions at dam sites. Then, some researches that develop prediction formula of an acceleration spectrum have progressed using the statistical techniques based on the recorded earthquake data. Some researches have also progressed that an earthquake scenario is set and an earthquake motion derived from an active fault is estimated using semi-empirical techniques etc. Moreover, to predict the seismic behavior of a dam, analytical researches, which consider cracks of a concrete dam body generated by earthquakes, are progressed. For embankment dams, numerical methods which consider the plastic deformation and centrifuge modelling are also progressed.

7 Dam and the Environment

7.1 Outline

in 1972 the environmental impact assessment (EIA) was adopted for public works. Then each organization operating the projects and local public governments also have been adopting their own regulations for environmental protection. The establishment of the Basic Environment Law in 1993 legally promoted EIA. Then the promulgation of the Environmental Impact Assessment Law in 1999 filled up the former method of assessments.

The standard items on EIA of dam projects are natural, atmospheric, water environment and abundant relations between man and nature ("Man in Nature"), and they are more enriched than the former ones.

7.2 Environmental preservation measures

Upon construction of dams, it goes without saying that not only minimizing the construction area but also considering not alter the present situation of river is the most effective measures to reduce the impact on the environment. But the projects are hard to be compatible with environmental preservation, so there are many attempts to restore flora and fauna after the environment has been altered.

(1) Biotope

Biotope is a man-made marshy ground for a habitat of flora and fauna. For dam projects, there are some examples on replacing or restoring environment that have been lost due to dam construction as a part of preservation measures for natural environment. The purposes of such measures are preservation of flora and fauna habitats and their diversity, water purification and recreation.

(2) Artificial floating island

The waterfront shore zone is an important part of the flora and fauna habitat, and has an important role to improve a diversity of flora and fauna. Dam reservoirs with changing water levels do not lead to stable shore zones, so other measures are planned to create the functions similar to the shore zone. One of the measures to provide a habitat environment and to improve the waterside landscape is to make the artificial floating island.

The effects of such an island would be providing a habitat for flora and fauna, specifically for birds that could nest and lay eggs and for fish that could spawn.

(3) Fishway

In order to reduce the impact of dams on the migration of fish and aquatic life both upstream and downstream to the structure, fishways have been built. According to the purposes such as fish migration upstream and downstream, conservation of fishery resources and ecosystem, various fishways have been built in consideration of dam site conditions.

Currently, there are some 40 dams with fishways in existence or under planning. Table 1 shows the technical features of fishways in recent years.

In Japan, raptores protection is also important. Raptors are superior to other kind of species within the food chain of ecosystem. In order to protect the life of such birds for long time, it is necessary to be formed the food chain that provides rich feed animals constantly and to conserve the ecosystem composed of various species.

The most dams are constructed among the mountains, so golden eagles and mountain hawk eagles often become the subjects of discussion because they mainly live in such area. These birds are to be researched carefully to protect ecosystem and rare species.

Upon dam construction, based on such surveys, measures concerning birds of prey are adopted at the dam site, the temporary construction, the roads for construction and substitution, the picking site, and so on.

7.3 Water Quality Preservation Measures

At reservoirs, where river water is detained for a long period of time, the mechanism behind water quality change is different from that of rivers. There sometimes happen characteristic water quality change at dam reservoirs.

On phenomenon of water quality changes at reservoirs, especially concerned problems in Japan are discharging of cold water, prolongation of turbid water, and eutrophication, among others.

The measures for preserving water quality at reservoirs can be classified into 2 categories: Catchment Area Measures, which aims at reducing the influx of substances that worsen water quality of dam reservoirs; Measures in Reservoir, which aims at controlling water quality change.

(1)Catchment Area Measures

Water quality deterioration is led by influx of wastewater, and/or by influx of sediment and turbid water caused by forest denudation. Measures are taken to preserve water quality at catchment area of the Dams.

Catchment Area Measures adopted in Japan are as follows:

●Improvement of public water treatment facilities at upstream of the dams in order to clean wastewater flowing into reservoirs.

●Protection of river banks by works covering with concrete or plants, based upon projects for preserving water quality at reservoirs, in order to lesson the amount of sediment and turbid water flowing into the reservoirs; Establishment of environment preservation belts and tree zones (lakeside woods) in order to preserve quality of influx water.

●Planting trees and other measures are carried out at areas for reducing turbid water and for controlling influx sediment.

(2)Measures in Reservoir

i) Cold Water Discharges

Cold water has negative impact upon crop and fish growth. So, it comes to problem when the temperature of discharged water from the dam is lower than that of the river water. This problem occurs due to the relationship between the vertical distribution of water temperature in reservoirs and the relationship between the height of intakes.

To deal with this problem, the selective intake facility can be introduced. In this facility, the height of intakes is changeable, and it is possible to discharge water that temperature would be same or higher than the influx water to reservoirs.

This selective intake facility is generally accepted among the dams that are recently constructed. It is often the case for old dams, which have not this facility, to introduce the facility newly to them, or to improve the old ones.

ii)Turbid Water

In case of flood, the turbid water flowed into reservoir mixes with existing water at reservoirs, making all the water in the reservoirs turbid.

The phenomenon that the discharging water keeps turbid for long period of time is brought by gradual discharging of turbid water after the flood.

As a measure for prolongation of turbidity, above-mentioned selective intake facility is workable.

iii)Eutrophication

Eutrophication might happen when too much nutrient salts are added to the dam water. And depending upon conditions such as water temperature, daylight, and retention period, enormous growth of phytoplanktons follows. Such an occurrence leads to worsening water quality, problems of malodor and filtration block at water purification plant, and negative impact upon the scenery around the reservoirs, among other things.

The following are major categories of measures for eutrophication at reservoirs.

●Measures for reducing influx load at the upper portion of reservoir

● Flow-controlling in reservoir and Bypassing of influx water, etc.

Some examples of measures against eutrophication are introduced.

(a)Measures for reducing influx load at upper portion of reservoir (Terauchi Dam)

After the dam was completed, following phenomenon appeared: Outbreak of " water blooms " formed by blue-green algae in summertime, moldy malodor, and filtration problem caused by abnormal appearance of diatomaceae, led by high percentage of nutrient salts in the river which flow into the dam; " freshwater red tides " due to flagellate algae. Thus, in order to reduce the concentration of phosphorus in the inflow rivers, various measures for this problem are to be implemented.

①Waterborne plants

River water is conducted to the shallow ponds where waterborne plants uptake nutrient salts; consequently the phosphorus is reduced. Cresson is being grown as the waterborne plants in this case. (Fig.21)

②Phosphorus absorption materials

River water is conducted to the waterway that is parallel to the river and has phosphorus absorption materials over the bottom; consequently the phosphorus is reduced. (Fig.22)

(b)Flow-controlling at reservoir and Bypassing of influx water (Miharu Dam)

At Miharu Dam, measures for water quality preservation both in inflow-river and in reservoir are implemented. Various new technologies were adopted as measures for water quality preservation.

①Prestorage Pond(small sized reservoir located before the river water enters into the dam)

A prestorage pond was built with some 706,000M3 in capacity (for main stream + affluent). Functions of this reservoir are (a) to precipitate the suspended substances; (b) to let the phytoplanktons, at earlier stage, uptake ortho-phosphate dissolved in river water.

②Influx Water Bypass Duct

A bypass duct constructed is 2.4km long from the prestorage pond to downstream of the dam. The function is to bypassing influx water and load directly to the downstream. Thus, it is possible to reduce the amount of nutrient salts supplied at the first stage of flood, and to repress alga growth. Furthermore, in case water quality is deteriorated within reservoirs, it is also expected to supply upstream water directly to the water purification plant.

③Aerating Circulation Facility and Selective Intake Facility

As a new technology to deal with eutrophication, a flow control system has been designed. The flow control systems utilize Aerating Circulation Facility and Selective Intake Facility comprehensively, and bring circumstances that repress alga growth within the water surface.

Outline of the system is following:

i) Circulate in order to form thick upper layer whose temperature is a little higher than influx water; and conduct influx water (including nutrient salts) into deeper layer where algae can not grow.

ⅱ) Circulate upper layer in order to push down algae (grown at surface layer) into middle layer.

The flow control system (Aerating

Circulation Facility and Selective Intake Facility) adopted at Miharu Dam is shown in Fig.23.

7.4 Landscape Design

Dams and weirs are huge structures; the act of impounding water leads to the creation of a vast new water surface and open space near the water. By blending this sight with nature that surrounds it, a wonderful landscape that can be accepted into the vast surrounding can be created.

Forward-looking adoption of this idea is the landscape design of dam and reservoir. The splendid view created using this idea may produce secondary benefits of tourism and recreation, in addition to improving the accessibility in and around reservoirs. Fig.24 shows an example of landscape design Kanna Dam giving an image of castle wall.

7.5 Creating the Surrounding Environment

Looking to harmonize with the natural blessings in the form of the surrounding environment and reservoirs, the establishment of recreational facilities such as parks and playgrounds that act as greenbelts and open space near the water will create an atmosphere of love for water and greenery around dams (see Fig.25, Kamafusa Dam).

8. Summary

In this paper, the latest topics were simply introduced about dam technologies of construction and maintenance / management. Although many dams have been completed in Japan, flood damage and water shortage damage are still occurring frequently, and dam construction is one of the most effective countermeasures. It is very important both that we tackle for the technical development to secure the safety and to construct economically under the present strict conditions in natural and economical circumstances in Japan, and that we must make efforts to conserve the soundness of natural environment during construction as possible.

Acknowledgement

I would like to express my gratitude to the Japan Commission on Large Dams (JCOLD) that readily gives me the permission to quote from their publication "Current Activities on Dam in Japan (2000)" in this paper.

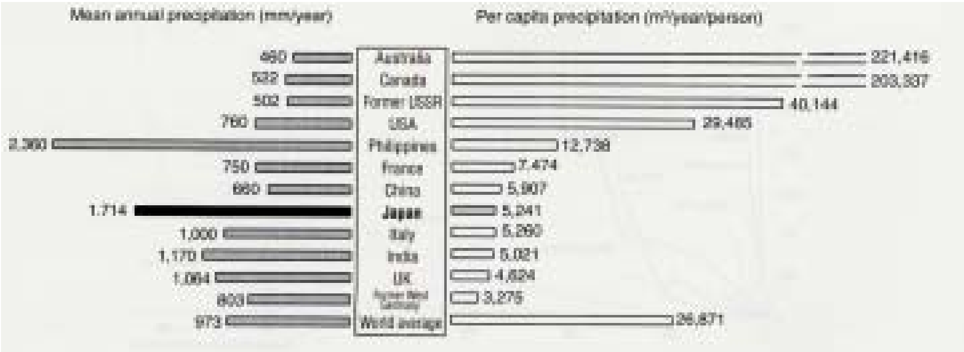

Fig.1 Precipitation around the World

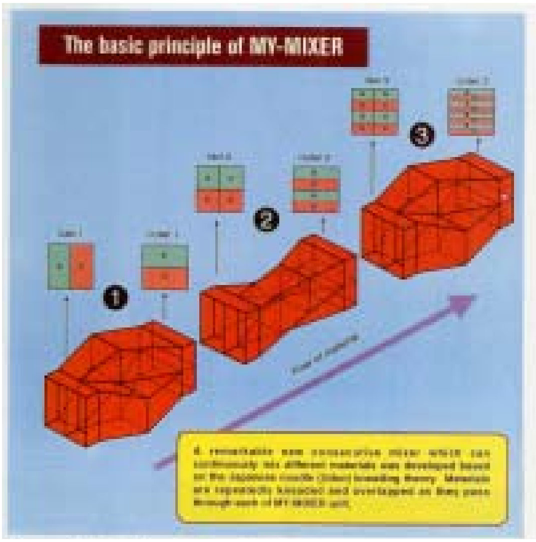

Fig.2 New Technology of Concrete Mixing

Fig.3 Slump Flow Using a Large Cylinder

Fig.4 Placing of Self-compacting Concrete(Hinachi Dam)

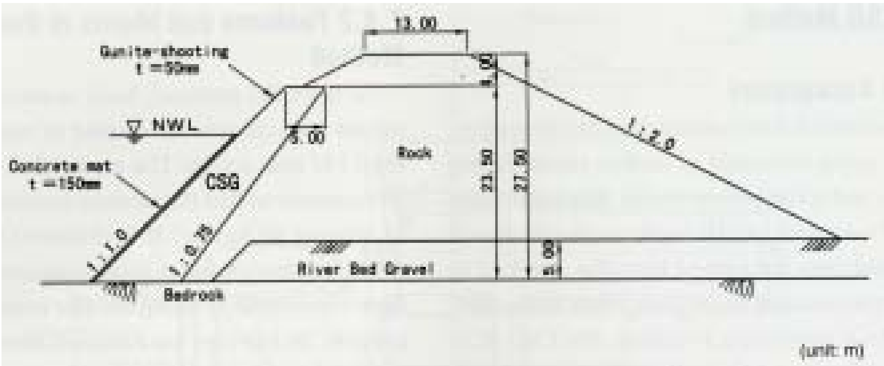

Fig.5 Typical Cross Section of Coffer Dam(Surikamigawa Dam)

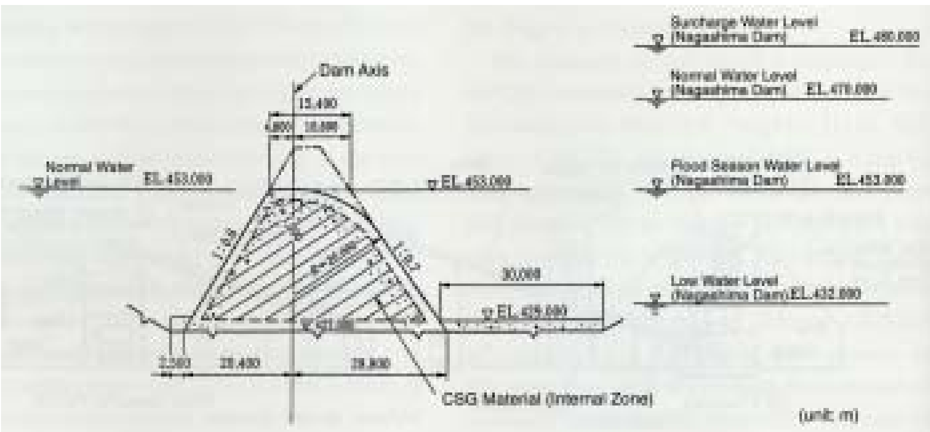

Fig.6 Check Dam Used CSG Material to Inner Part(Nagashima Dam)

Fig.7 Example of Using Precast Gallery(Unazuki Dam)

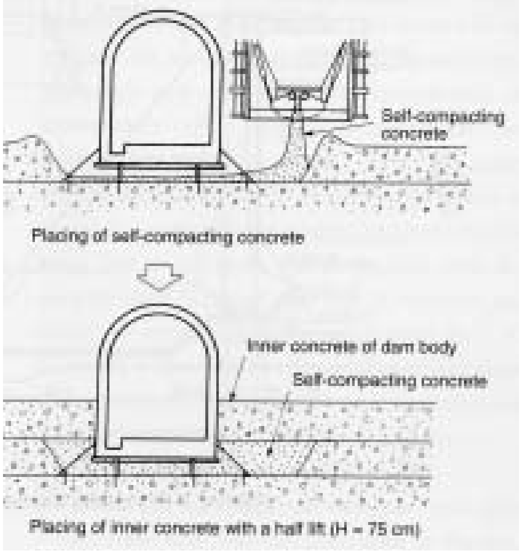

Fig.8 Steps of Placing Concrete Gallery(Unazuki Dam)

Fig.9 Example of Using Precast Gallery(Tokuyama Dam)

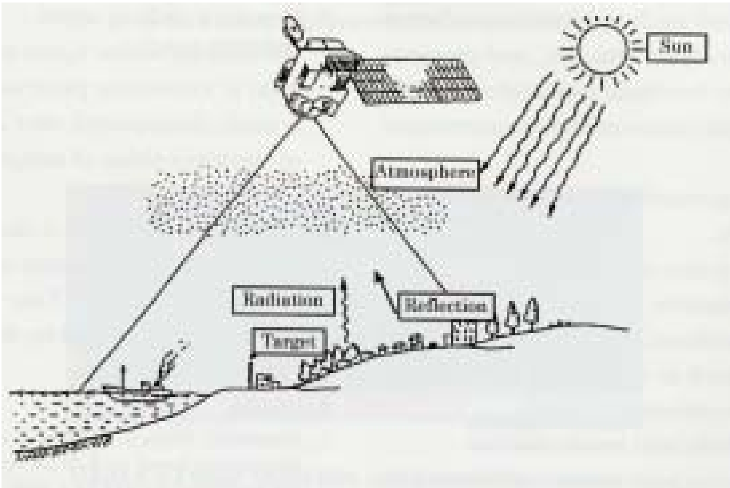

Fig.10 Outline of the System of the Water Management on Reservoirs

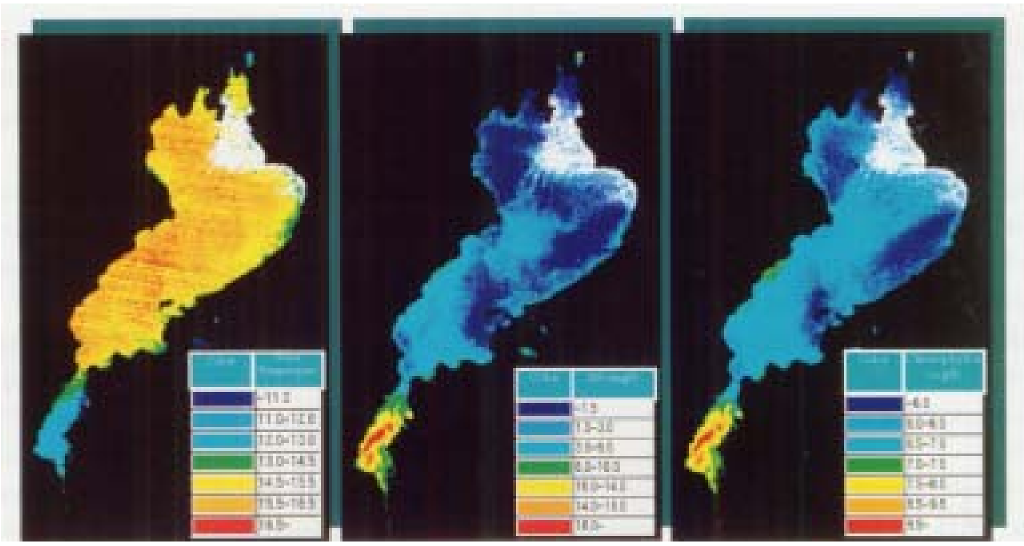

Fig.11 Results of the Observation on Water Quality at Lake Biwa

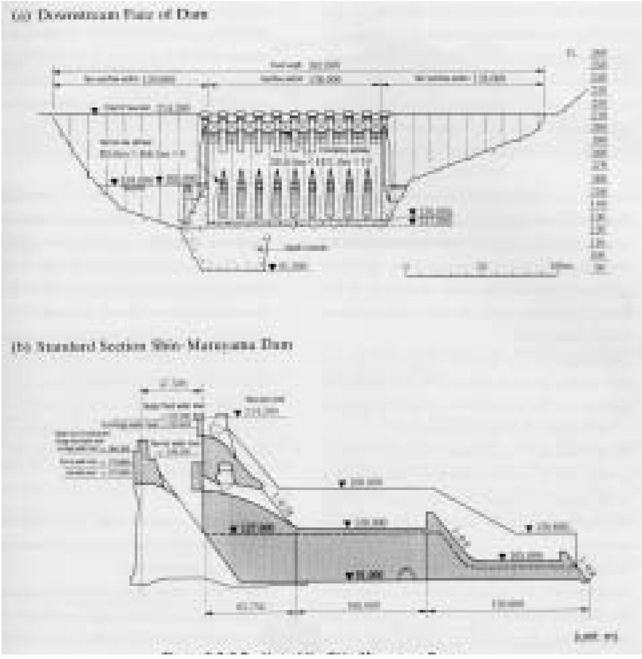

Fig.12 Section of the Shin-Maruyama Dam

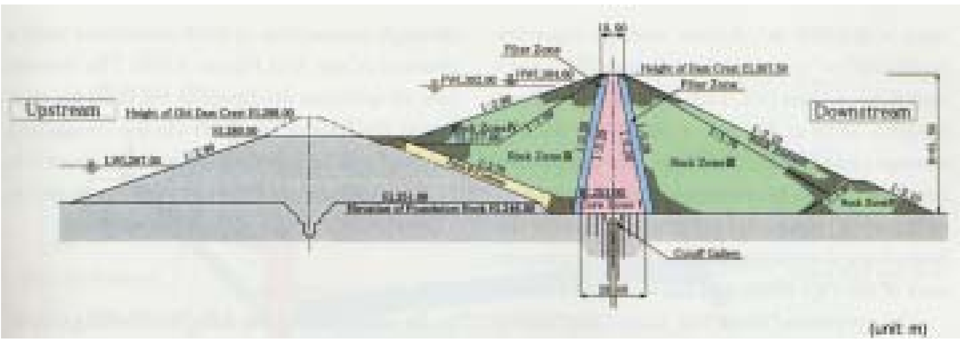

Fig.13 Typical Section of the Sannohkai Dam

Fig.14 Dam Networking System Sequence

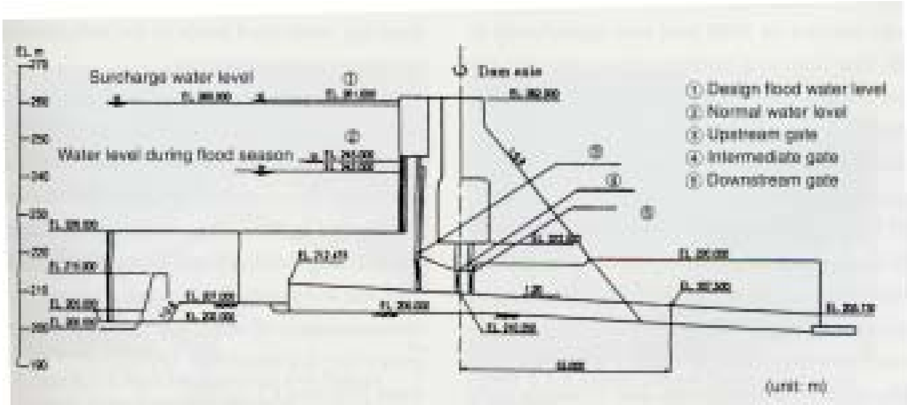

Fig.15 Typical Section of Sediment Flushing Facility at Unazuki Dam

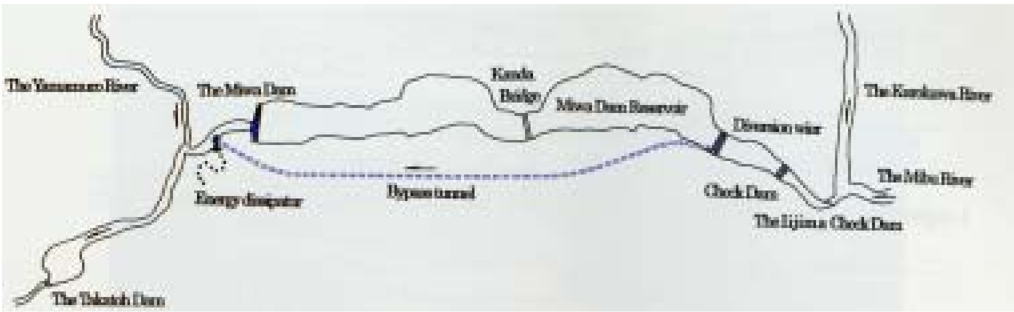

Fig.16 Structural Layout of Bypass System

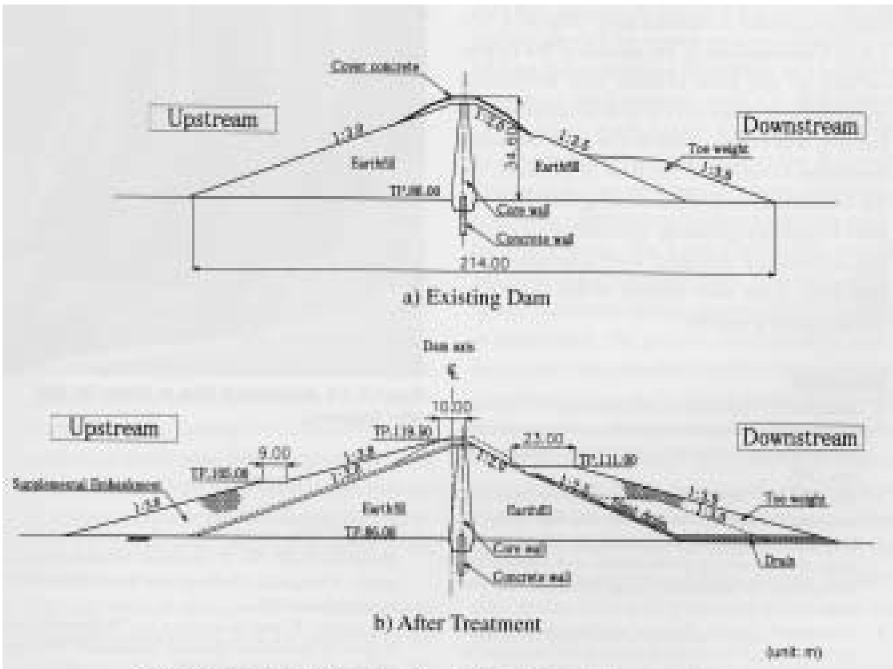

Fig.17 Typical Section of Existing and After Treatment(Yamaguchi Dam)

Fig.18 Upstream View of Honen-ike Dam After Treatment

Fig.19 Downstream View of Honen-ike Dam after Treatment

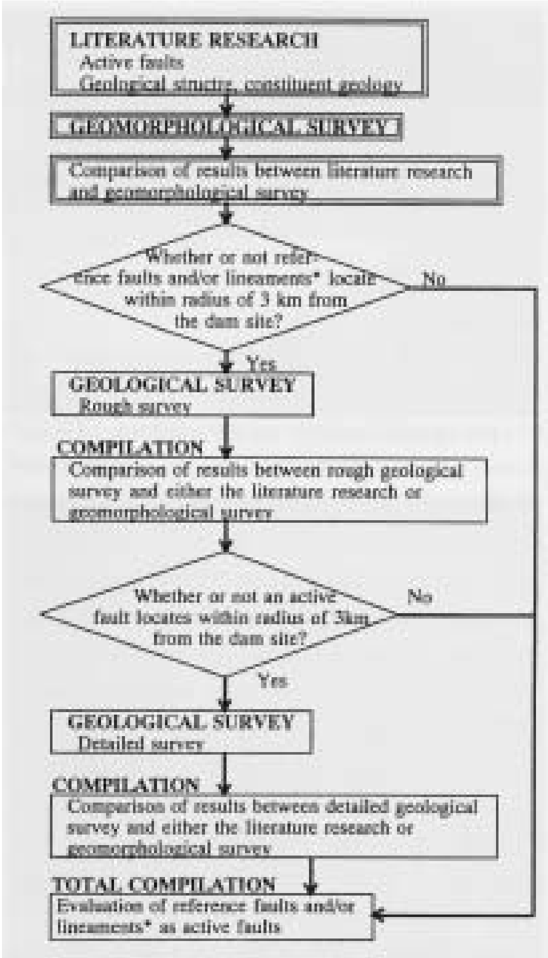

Fig.20 Flowchart of Active Fault Investigation

Table.1 Features of Fishways in Existence

Category	Dam/Name	Features
Pool and Weir type (Spiral fishway)	Nukibetsugawa Dam	Spiral steps allow fishway to be built without taking up space.
Denil type	Imawatari Dam	The peculiar-shaped partitions set up on the rectangular fishway increase the flow resistance and help control the flow speed.
Sector type	Nibutani Dam Meboro Dam	A float is added to part of the fishway (one side) in order to deal with changes in the water level.

Fig.21 Cleansing Using Waterborne Plants(Terauchi Dam)

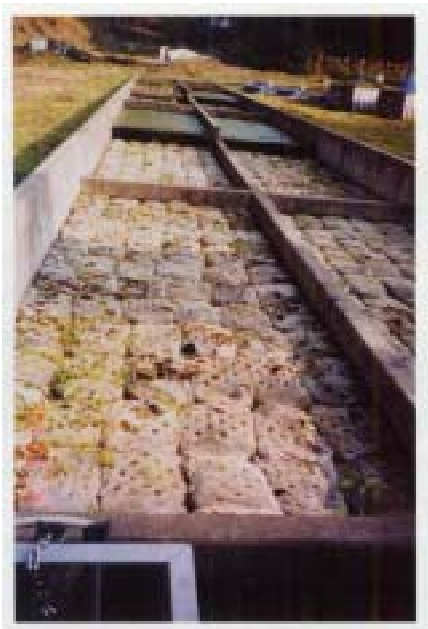

Fig.22 Phosphorus Absorption Materials(Terauchi Dam)

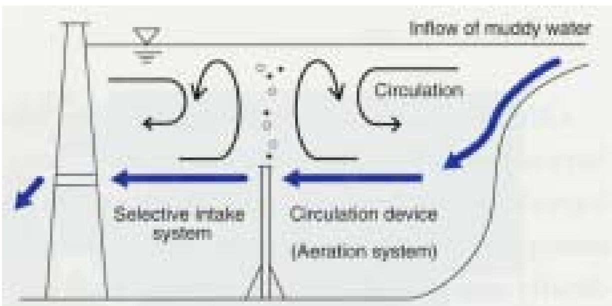

Fig.23 Flow Control System

Fig.24 Landscape Design of Dam Giving an Image of Castle Wall(Kanna Dam)

Fig.25 Colorful Flower Garden(Kamafusa Dam)