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OVERVIEW OF DAM SAFETY ACTIVITIES IN BBMB PROJECTS FOR SUSTAINABLE WATER MANAGEMENT

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ABSTRACT

Dam Safety is a major and growing global concern. It is priority concern for BBMB also for safeguarding water resources, human life, properties and huge investments in infrastructure. For sustainable water management, dam safety and security is no longer just an issue of safety of ageing infrastructure but also of intensifying water conflicts, food security, and appropriate adaptation of operation and maintenance strategies. Continuous improvement in the reliability and operational safety of the dams requires in-depth study and assessment of their health in terms of operational and technical regulations. Analysis of major dam safety issues across the world indicates that most failures are attributed to factors of either inadequate design, poor quality of construction or due to lack of adequate trained manpower, improper organization of work, violation of safety rules and regulations, as well as poor security control, weak supervision, mismanagement etc. Older dams are approaching an age at which material deterioration and decreasing operational reliability dictate repair and upgrading and suggest more firm approach to safety aspects. Importance of dam safety for sustainable water development is not self-evident and has to be analysed carefully. In exercising dam safety responsibilities, there are certain principles that should be held in common for consistency and correctness. This paper has addressed various practices for safety of dams being followed in BBMB for sustainable water management.

1. INTRODUCTION

The case histories of majority of dam failures have revealed that these were not designed, constructed and maintained in accordance with the recognised standards and norms. It is also admitted that old dams built with technique available at that time of construction may not be safe with current standards. Also dams like any other structure are subjected to decay and deteriorate with passage of time. It is from these cases of failures and experience gained, one becomes wiser and get involved in innovations and research to remedy the situation. No doubt, the dam safety aspect begins right at the conceptual stage of the project and continues till it is translated into reality and thereafter maintenance and operation stage during its lifetime. Matter here is safety aspect of existing dams of BBMB.

2. ABOUT BBMB PROJECTS

Bhakra Beas Management Board is looking after the administration, maintenance and operation of three major hydro-electric projects namely Bhakra Nangal Project, Beas Dam and Beas Sutlej Link Project including Pandoh Dam having total installed capacity of 2918.73 MW.

The Bhakra Dam, located near village Bhakra in District Bilaspur of Himachal Pradesh, is a 225.55 m (740 ft) high straight gravity concrete dam, built across river Satluj in a deep and narrow gorge of the lower Shiwalik hills. The ten generating units of the power plants have total generating capacity of 1379 MW. Nangal Dam, Nangal Hydel Channel and the two Canal.

Power Houses with installed capacity of 153.73 MW form the important components of Bhakra Nangal Project.

The Beas Dam, located at Pong in District Kangra of Himachal Pradesh in the Himalayan foot hills, across Beas River, is an earth core-gravel shell dam, 132.6 m (435 ft) high from the deepest foundation level. The Pong Power Plant has generating capacity of 6 x 66 MW i.e. 396 MW.

The Beas Sutlej Link is the largest hydro-electric tunneling project in the country, consists of an earth-cum-rockfill dam of 76.20 m height at Pandoh across river Beas. A power house comprising 6 units with total generating capacity of 990 MW is located at the tail-end of the system at Slapper.

3. IMPORTANCE OF DAM SAFETY

The safety of dams can be threatened by natural phenomena such as floods, earthquake, landslides, deterioration of construction material etc. The other major threats are due to foundation failure, inadequate spillway capacity, erosion, sedimentation, obsolete instrumentation, poor operation and maintenance, lack of periodic inspections of dam structures etc. Thus safety of these structures are of paramount importance, as any failure of these structures will not only cause loss of life and damage to property but also affect the economy of the region. It is as such imperative that safety of dams is ensured in all aspects by maintaining dams to the highest standard and as per the latest practices.

Worldwide, it has been generally recognized that a successful dam safety assurance program requires a dedicated institutional structure with access to top management attention. In India, dams owned, constructed and maintained by State Governments, State PSUs and Central PSUs. Now, some of the dams are coming under private ownership. Practices of dam safety vary from State to State and from organization to organization. The government of India is working towards evolving unified practices of dam safety and BBMB, after realising the importance of dam safety very early has adopted this programme and have undertaken dam safety activities at organization level.

4. ACTIONS OF GOVERNMENT FOR SAFETY OF DAMS

Realising the importance of dam safety, many countries in the world have initiated action to review the safety of dams in their countries. The Government of India in its first conference of State Ministers of Irrigation held in New Delhi on July 17-18, 1975 adopted Resolution VI regarding Dam Safety Service. Resolution VI recommended that in view of the increasing large dams in India, the Govt. of India to constitute advisory dam safety services to be operated by Central Water Commission.

The Government of India constituted a National Committee on Dam Safety (NCDS). The NCDS acts as a forum for exchange of views on various issues pertaining to dam safety. It oversees dam safety activities in various States and organizations and suggests improvement to bring dam safety practices in line with latest state-of-the-art technology. National Committee has also set up three subcommittees to monitor the safety aspects of select inter-state dams. Till now, thirty nine meetings held so far with last meeting in February 2019 at Bhubaneswar, Odisha.

The Government of India constituted a Central Dam Safety Organisation (CDSO) in CWC in June, 1979 with an objective to assist the State Governments to locate causes of potential distress affecting dams and allied structures and to perform coordinative and advisory role in providing suitable remedial measure to safeguard the situation. It also created awareness amongst the states about dam safety. The Government of India constituted a standing committee to review the existing practices and to evolve unified procedures/criterion to be adopted for the safety of all dams in India during August, 1982. Accordingly guidelines for safety inspection of dams were issued in June, 1987. Thereafter in January, 2018, revised guidelines were issued by the Ministry of Water Resources, CWC which are being followed in BBMB.

5. DAM SAFETY BILL

Dam Safety Bill was introduced in the Lok Sabha on 30th August 2010 “to provide for proper surveillance, inspection, operation and maintenance of all dams of certain parameters in India to ensure their safe functioning and for matters connected therewith or incidental thereto”

Bill was referred to Parliamentary Standing Committee and the recommendations were made to be applicable in States, dam owners (Government and Private) with following institutional and implementation framework:

1. The NCDS will guide proper surveillance, inspection, operation and maintenance of dams for achieving uniform and satisfactory level of confidence in respect of safety assurance of all specified dams in the country.
2. Regulations will be made by NCDS on recommendations of Central Dam Safety Organisation (CDSO).
3. The CDSO will:
 - (a) notify and enforce these regulations.
 - (b) monitor functioning of State DSOs and provide technical & managerial assistance.
 - (c) maintain national level data-base of specified dams, and records of dam failures.
 - (d) examine causes of major dam failures and cause of major public safety concern.
 - (e) formulate guidelines, give directions for uniform actions, and give accreditations to organizations entrusted with dam works.
 - (f) provide general education and awareness, and secretarial assistance to National Committee.
 - (g) resolve issues of dispute.

4. State Committee on Dam Safety (SCDS) will ensure overall surveillance, inspection, operation & maintenance of dams. It will review works of State Dam Safety Organisation (SDSO) and will recommend appropriate measures. It will also establish prioritization for investigation and rehabilitation measures and will assess and coordinate interstate/ cascading implications including provision of funds.

Dam owner will create Dam Safety Unit for each dam under O&M setup. The Duties and functions in relation to dam safety like surveillance & inspection, maintenance of log books, instructions on safety, funds for maintenance, technical documentation, reporting, qualifications/ experience/ training of individuals, jurisdiction of State DSOs, charging of investigation costs, construction, operation or alteration aspects, Initial filling, Responsibility of dam owners etc.

5. Provisions in respect of inspection and data collection are periodical inspection, instrumentations of dam, hydro-meteorological stations and seismological stations.
6. Provisions in respect of EAP and DM are inflow forecast/ emergency warning/ information dissemination and RA studies/EAP & implementation/stakeholder interaction.
7. Offenses and penalties and miscellaneous activities such as annual reports, powers for rules/regulations etc.

The draft of the Bill was shared by Ministry of Water Resources with all the states during August, 2016 and detailed comments were received from states in last meeting of NCDS during January, 2018. The Union Cabinet during June, 2018 has approved the proposal for introduction of Dam Safety Bill, 2018 in the Parliament, but could not be passed in Rajya Sabha. The Ministry of Jal Shakti, New Delhi has introduced Dam Safety Bill, 2019 in Lok Sabha on 29.07.2019 and Lok Sabha passed this bill on 02.08.2019. This bill is with Rajya Sabha.

6. DAM SAFETY ACTIVITIES OF BBMB

Realizing the importance of Dam Safety, BBMB also initiated action to review of safety of its three projects. As per guidelines of CWC of the year 1987, the inspection/ examination of each large dam has to be carried out after 10 years interval by Dam Safety Review Panel. Accordingly, BBMB constituted its first Dam Safety Committee (DSC) headed by Chief Engineer during 1987. The committee was assigned to inspect and recommend any further safety measures, any special maintenance, operation, modification etc. for all the three projects and other appurtenant works under BBMB. Subsequently, BBMB established a dedicated Dam Safety Directorate headed by the officer in the rank of Director in September, 1989 to look after the safety aspects concerning BBMB projects. Thereafter, 2nd and 3rd Dam Safety Committees were constituted during the years 2000 & 2010 respectively. BBMB in its 215th Board's Meeting held on 30.08.2013 decided that the projects be inspected after the frequency of 3 years instead of 10 years as the dams are becoming older and needs frequent inspections and expert advice. Accordingly, 4th and 5th Dam Safety Committees of eminent experts were constituted during the year 2014 and 2017. The above committees carried out the Dam Safety review of all three projects and proposed some studies and remedies in their reports since been published. BBMB has gained excellent experience during construction, post construction and maintenance activities to attain dam safety standards which have served as bench mark for other large dams in India and abroad.

BBMB is also participating in DRIP-II & III initiated by the Ministry of Jal Shakti, Government of India with the help of World Bank having an objective to improve dam safety and operational performance of selected existing dams, along with institutional strengthening with system wide management approach.

A. DAM SAFETY ACTIVITIES AT BHAKRA DAM

I. Repair of Spillway Apron by Caisson Method

During the initial years of operation of the Bhakra spillway and river outlets, the spillway apron suffered extensive damage, as a result of high velocity flows, churning of the debris/steel scrap (which had collected on the apron, during the hoist chamber failure, in 1959), and rolling back of boulders from the remnants of the downstream coffer dam. The apron floor was cleared off debris/foreign material with the help of divers who reported damage to the floor. The underwater repair of stilling basin carried out with the help of divers was found not much of success. Thereafter, the stilling basin repair work was started in the year 1982 by deploying a caisson method which is being carried out during non-monsoon period every year. The fifth DSC desired to monitor the actual location of such damage over the years to study the performance of the repair works. The repair carried out is intact and no damage is re-occurring on the same chainage/station. The quantum of repaired area is now less than 1% of the area repaired in the year 1983-84. The performance of the stilling basin with regard to energy dissipation is satisfactory.

II. Under Water Inspection of Upstream face of Dam by Remote Operated Vehicle (ROV)

The scanning of submerged upstream portion of Bhakra Dam (dam block joints, trash racks for river outlets and trash racks for Penstocks) along with its video recording is being conducted by Central Soil Material Research Station (CSMRS) with help of ROV at interval of 5 years. These under water inspections have been carried during the years 1991, 1998, 2002, 2005 and lastly in 2014. The reports indicate that there is no physical damage to trash racks and no

clogging was observed between the adjoining bars of trash racks. The general condition of dam block joints and concrete is reported to be good.

III. Non Destructive Testing of Upstream and Downstream Faces of Dam

The non-destructive testing of concrete of Bhakra Dam using Portable Ultrasonic Non Destructive Digital Indicating Tester (PUNDIT) is being carried out periodically to monitor the general condition of the concrete on upstream and downstream faces of Bhakra Dam. This Non Destructive Testing (PUNDIT) has been carried out seven times and lastly during June, 2014. The result of the latest report indicates that overall quality of concrete is good as per the pulse velocity acceptance criteria adopted and no significant change in the concrete has been recorded over a period of last ten years.

IV. Treatment of Right Abutment of Dam

The cracks were observed on the upstream side of the Right Abutment of the dam. The third DSC during inspection in the year 2011 observed wide open cracks at approximate level of El. 512 m (El. 1680 ft). The gunniting of the area (about 2240 sq ft) was carried out where ever the cracks were visible from El 511.8 m (El 1679 ft) to El 472.4 m (El 1550 ft). In addition, as suggested by the Committee, the necessary treatment by rock anchoring with 32 mm diameter nineteen number MS Pins (20 to 30 ft long) has been carried out. The treatment provided is intact and new telltales provided in the area are also intact. The continued monitoring is being done to watch any movement in the area. The analysis of data of survey points (upstream rocks rib points) indicates stable conditions in the area. The fifth DSC during inspection of Bhakra Dam in the year 2017 has recommended that Multipoint Bore Hole Extensometers (MPBX) may be installed at two to three locations in effective zone for monitoring the treatment.

V. Treatment of Left Abutment of Dam

The gunniting work of about 6628 sq ft is carried out on the left bank rock mass upstream of the Dam Axis during the year 2018 and 2019. The appropriate drainage holes have also been provided to avoid development of pore water pressure behind this gunniting work.

VI. Real Time Decision Support System (RTDSS)

The second DSC recommended that comprehensive Telemetry system be provided. BBMB has establish a Real Time Decision Support system (RTDSS) with the help of World Bank under Hydrology Project Phase-II for inflow forecasting (short, medium and seasonal) for integrated operational management of its reservoirs for sustainable Water management for which the consultancy services were given to DHI, Denmark. The BBMB has installed real time Data Acquisition System with installation of about 100 satellite based telemetry station in the Satluj and Beas Catchment areas.

VII. Dynamic Analysis of Dam

Analysis of the stability and structural adequacy of the dam in accordance with assumed foundation excavation profiles, elastic properties of the foundation rock and concrete and construction programme were carried out by United State Bureau of Reclamation (USBR), Colorado, USA for various conditions in the year 1952 and Trial Load Analysis was again done by USBR in the year 1964. Subsequently, reassessment of the theoretical stresses and the structural behavior (plumb line deflections) was made, in the year 1981, by the Finite Element Method for the 2-D (un-grouted transverse joints) and 3-D (grouted transvers joint) conditions, by IIT, Roorkee. In all these studies, the analysis for the seismic conditions was made by the Pseudostatic method. The first DSC recommended that the dynamic analysis of dam, besides a review of the structural stability of the dam for the normal static loading conditions, may have to be carried out, as result of review of the inflow design flood and review of the seismic activity of the dam area, as well as taking into consideration the insitu properties of materials (such as, rock and concrete moduli, etc.) and efficacy of the grouted joints of dam.

Accordingly, Seismic Stability Analyses (2-D) of the Bhakra Dam was carried out by IIT, Roorkee. The study report (2016) indicate that the dam is found to be safe under the static load condition whereas under Design Basic Earthquake (DBE) condition, the stresses at heel, slope change at upstream face and dam neck may develop tension which may lead to tensile cracks without jeopardizing the stability of the dam. The non-linear static pushover analysis and the non-linear dynamic analysis indicate that the dam may undergo slight damage at the heel. This damage may not jeopardise the stability of the dam. Regarding remedial measure to be taken by BBMB, it was suggested by fifth DSC that in the event of earthquake, vulnerable points of the dam are to be inspected.

VIII. Geo-Environmental Impact Analysis

As recommended by the DSC, the study on Geo-environmental impact analysis of Gobind Sagar has been carried out by Geological Survey of India (Report December-2002). According to report, the area is covered with dense open mixed jungle comprising mostly bamboo trees or occasionally the pine trees. The area around Gobind Sagar reservoir is by and large quite stable. The re-examination of latest status of slides with the use of satellite imageries as per the recommendation of the DSC has been taken with GSI by the BBMB. The report of GSI, Lucknow for Geological

Monitoring of Landslides around Gobind Sagar Reservoir of Bhakra Dam, Himachal Pradesh using High Resolution Satellite Imageries with Limited Field Checks (2019) has been received. It has interpreted the resolution merge satellite images prepared by IRS Resourcesat 2 LISS IV imagery and PSLV-C40 CARTOSAT-2 combined images of 2006 & 2008, as well as 2014 & 2015 and identified incidences of 50 landslides. Out of 50 landslides, three landslides are present within the 200 to the 500-meter radius of the dam site, require annual monitoring. Geotechnical interpretations of the 12 soil samples collected from the landslide area indicate that they are mainly poorly graded sandy loam, silty loam and loamy sand of non-plastic nature. The cohesion of the soil is low (0.05 kg/cm²-0.28 kg/cm²) and the angle of internal friction is high (32°-43°). On the whole, the area in and around Gobind Sagar reservoir is not prone to large landslides however it is recommended that, the landslide zonation map, may be prepared and taken as a general guiding reference, while undertaking major slope excavation for development activities like road construction, urban planning etc. in the area.

IX. Sedimentation of Govind Sagar

To study and compare actual silt deposits vis-a-vis the project assumptions, capacity surveys were carried out annually from the year 1963 to 1977 and thereafter these surveys are being carried out on alternate year.

As per latest Sedimentation Report for the period 2016-18, the percentage loss of live and dead storage capacity up to the year 2018 has been worked out as 16.51 % and 42.93% respectively. The overall capacity loss of reservoir is 23.02 % ending March 2018.

The 5th DSC during inspection of Bhakra Dam Project during year 2017 recommended that, a study containing the various aspects may be conducted for the multiple options available for management of silt in dams. Accordingly, BBMB has

- (i) entrusted a study to IIT Ropar to identify the hot spots/vulnerable reaches in Satluj catchment area for taking suitable measures.
- (ii) assigned to IIT, Roorkee for productive use of silt for which 64 number of silt samples collected from periphery of Gobind Sagar Reservoir for their testing.

The preventive and corrective actions will be planned after receipt of final reports.

X. SEISMIC INSTRUMENTS AT DAM

Four number of Strong Motion Accelerographs (A 800-A) were installed at Bhakra Dam during December, 1993 as replacement to the old instruments.

A Committee with experts from IIT, Roorkee, IMD as well as BBMB officers was constituted by BBMB in April, 2015 to look into the requirements of seismic instrumentation for Bhakra Dam. The Committee proposed five number strong motion accelerographs with latest state of the art technology having software with all capabilities to analyses the recording of seismic motions and other ambient dynamic activity in order to continuously monitor dam structural safety within the context of a safe operating dam environment. BBMB is in process of procurement of these instruments with real time communication facility.

XI. 3-D FEM analysis of Bhakra Dam

In view of scenario of increasing trend of deflection and revision of PMF value (22592 Cumecs) of Bhakra Dam, BBMB requested CWC to carry out Finite Element Analysis for 3D modeling of Bhakra Dam. National Council for Cement and Building Materials (NCB) carried out the field and laboratory investigations on concrete and rock properties of Bhakra Dam in the year 2017. FEM analysis of Bhakra Dam has been completed by CWC using ABAQUS modelling tool and report has been received in June, 2019. The FEM study concluded that

- (i) there is no immediate danger to the safety of the dam under normal loading conditions.
- (ii) Bhakra dam is one of the best instrumented dams in India nevertheless regular maintenance and advanced instruments be installed.
- (iii) Response spectrum analysis shows that Bhakra dam is critical in both DBE and MCE condition. Linear time history shows milder risk to safety of dam however indicates necessity of non-linear studies as confirmation.
- (iv) two dimensional analyses may be performed first using nonlinear values.

B. DAM SAFETY ACTIVITIES AT BEAS DAM

I. Left abutment-Intake area – Monitoring of Slopes

In the intake area, abutment slopes in the vicinity of the intake had shown signs of movement of rock along clay shale members C-I and CS-IV, which got exposed in the slope cuts on the reservoir side. The monitoring of the slopes has been continued from August, 1974 onwards by inclinometer. The following remedial measures have been taken by BBMB in the past as per advice of Technical Experts/Design Wing/Centre Water Commission:

- (i) In the year 1990-91, two rows of 305mm (12inch) diameter and 15.24m (50 ft) long sand rock piles on either side of Ch. 12+40 at 1.37m (4.5 ft) center to center have been provided.
- (ii) Horizontal Drainage holes were provided at different benches in order to drain out the surcharge.
- (iii) Loading Berm was provided at El 411.48m (El 1350 ft)

With these measures, the movement which was of the order of 1.8 mm/ month in the year 1974 has reduced substantially to 0.08 mm/month.

The 5th DSC inspected the abutment slopes in the vicinity of the intake area and no sign of distress or cracks were observed at any location. There is no problem in operation of gates. Also, no movement in the access bridge provided for placement of bulk head gates in intake shafts of tunnels has been observed. Even no crack or sign of distress has been observed in the outlet tunnels which are passing below this band. There are no telltale sign of any adverse effect of these movements in the area. The DSC recommended that the observations from slope indicator provided in the intake area be continued. Accordingly necessary monitoring is being carried by BBMB and proper slope draining arrangement as desired by the DSC has been provided.

II. Deformation Normal to Dam Axis

The deformation pattern of Beas Dam was observed after the first filling of the Beas reservoir on 04.07.1974. Normally, deformation of the crest towards the downstream is expected. After construction, the rockfill shell settles and pulls away from the core, reducing the earth pressure at the upper part of the core which may as a result, deflect upstream. In case of other dams where the crest portion moves upstream, it swings back substantially and net deformation is downstream when the reservoir remains full. This has not happened in the case of Beas Dam.

This anomaly of upstream deflection was raised by the second DSC in the year 2001. BBMB referred the problem to United States Bureau of Reclamation (USBR). The USBR while affirming the safety of the dam ascribed the upstream movement due to upstream slope of the foundation rock. The DSC has opined that these movements appear to have stabilized as indicated by the data of past few years. As such, there is no major concern for the stability of the dam. However to make the picture clear, the 5th DSC advised that the 3-D FEM analysis may be carried out using the original properties of the material as first assumption and parametric analysis may be performed to match the observed values by suitably adjusting the material parameters. The FEM analysis has been initiated under DRIP-II.

III. Seismic Instruments At Dam

Two number digital accelerographs, (GSR-18) were provided at Beas Dam in replacement to the three Nos. accelerographs (A-800) during the year 2005. These instruments are working at a triggering level of 0.007g. BBMB referred the matter to CWC for modernization/replacement of instrumentation. As per the advice of CWC, a Committee of experts from IMD, IIT Roorkee as well as BBMB Officers was constituted. One additional digital accelerographs, (GSR-18) has been supplied by IMD and needful action for installation of same at middle level of the dam i.e. EL + 1270 ft. is being taken. In addition, a seismological laboratory having one broadband seismograph along with strong motion accelerograph has been set up by IMD in the vicinity of Beas Dam.

IV. Survey Points of Dam

Review of GTS and temporary bench marks at Beas Dam by Survey of India is being got carried out regularly to bring to light the change if any so as to ensure accuracy in determining settlement or horizontal movement from surface settlement points/parapet settlement palates. The last review of these bench marks was carried out during the year 2014. Accordingly, correction is being applied to all the reference readings of Bench Marks for determining crustal deformation of the dam.

V. Low Head Maintenance at Dam

There were five diversion tunnels, out of which two of these were converted to Irrigation outlet tunnels while the remaining three were utilized as power penstock tunnels. As per O & M Manual, these tunnels upstream of gate reaches are required to be inspected and repaired by suitable rotation i.e. at least once in a period of five years to detect any structural damage and to carryout repairs. The maintenance of these tunnels is required to be carried out when low reservoir level around El.395.33m (El.1297 ft) is available for sufficient period (at least three weeks for one tunnel). The opportunity of reservoir level below El.1300 ft was available during April to June, 2016 and May to June, 2017. The Low Level closer, inspection and repair/ maintenance of concrete lined portion as well as steel line portion and other connected hydro mechanical structure like gates; hoist system, top cover etc. of Irrigation tunnel T-2 and three number Power tunnels have been carried out during above period. The low head maintenance of Irrigation tunnel T-2 has been carried after a gap of seven years and Power tunnels after gap of eight years.

The inspection of the upstream rip-rap was carried out during above Low Level period and damage observed was suitably repaired so as to bring it back to the original design provision.

C. DAM SAFETY ACTIVITIES AT BSL PROJECT

I. Flushing of Pandoh Reservoir

During operation of reservoir, river bed material is likely to get deposited in the reservoir in front of intake. Such material is required to be flushed down the spillway by operation of spillway gates. In order to prevent the entry of bed material and to minimize the entry of silt in Pandoh Baggi Tunnel Intake, at least two flushings are being carried out each year depending upon the availability of mandatory inflows suitable for flushing operations. Based on the field experience, the fifth DSC has recommended that the silt clearance operation by partial opening of gates no. 1 & 2 should be carried out when minimum discharge in the river is ranging from 12000 Cusec to 15000 Cusec (since 9000 Cusec is the design discharge of PBT) and the minimum silt level in front of PBT intake structure is ranging from 3 ft to 5 ft.

II. Plunge Pool Area of Dam

To prevent the scouring in and around the plunge pool area, gabion structure from the end of concrete bench below the flip bucket along the line of exposed rock on right side has been constructed as per the recommendations of DSC and Design Wing.

The plunge pool and the adjoining area downstream of the spillway remained covered under a pool of water and after every monsoon period, the scour of plunge pool is evaluated by sounding. During the year 2014-15, the deepest bed level of the scour pit was observed as El 818.08m (El 2684ft) Therefore as a remedial measures, the downstream spillway flow in to river Beas was not only channelized but was considerably broadened simply to minimize the formation of the circumvent aides (in the pit at the tail end of Spillway) leading to uncalled for increase in the depth every year. With these measures, the current plunge pool pit level recorded to 2722 ft which is about 38 ft above the level during 2015 and is quite safe.

III. Cross Drainage Works of Sundernagar Hydel Channel

There was scouring problem inside the water ways of aqueducts of Sundernagar Hydel Channel. As per the recommendations of the DSC, gabion structures (2-3) across the openings, about 1.5 m high, were constructed inside the aqueduct and further at suitable distance downstream of aqueduct so that the flow at the exit of the aqueduct could be contained in the water cushion. These gabion structures reduce the problem of erosion. Such treatment has been carried out at four cross drainage works.

IV. Nagwain Aqueduct at Sundernagar Hydel Channel

Sundernagar Hydel channel is about 11.80 Km long and is a part of about 38 Km long Water Conductor System of BSL Project. Nagawain Aqueduct exists at RD 9724 m (31895 ft) of above channel. Seepage of the order of 30 lpm is being observed through the joints in the concrete works. The Central Ground Water Board Dharamshala, recommended for isotopic analysis to locate the seepage path. Accordingly, the report of isotropic study carried out by IIT Roorkee indicates that the seepage is from Channel itself and the next course of action is being taken on the advice of fifth DSC and global expression of interest (EOI) is under progression.

V. Dredging in Balancing Reservoir

To restore the capacity of the balancing reservoir, dredging of silt is being carried out with the help of three number dredgers during monsoon period every year. About 800 to 1000 acre-ft of silt is being dredged out every year depending upon the ingress of silt in water conductor system.

D. OTHER DAM SAFETY ACTIVITIES OF BBMB PROJECTS

I. Review of Design Flood

As per recommendation of DSCs and Technical Experts Committee of BBMB, study to work out Probable Maximum Flood (PMF) of Bhakra Dam, Beas Dam and Pandoh Dam on the basis of updated data was entrusted to Central Water Commission. The value of PMF worked out for Bhakra Dam is 22,592 cumec (7,97,800 cusec) against inflow design flood of 11,327 cumec (4,00,000 cusec) adopted for the project.

As per report of CWC, value of PMF for Beas Dam is 23042 cumec (813705 cusec) against the design flood value of 33555 cumec (118500 cusec) and value of PMF for Pandoh dam is 17173 cumec (6,06,465 cusec) against the design flood value of 10194 cumec (360000 cusec). The third DSC has recommended getting it reviewed from Center Water Commission so as:

- (i) To make the PMF values of both Pong and Pandoh Compatible with the high flood value “observed” at Pong in 1977 which was around 19800 cumec (700000 cusec).
- (ii) To make the PMF value for Pong, Pandoh and Largi dam upstream compatible. Accordingly the matter has been referred to CWC for review of above study.

II. For ensuring best quality and timely maintenance, the provision made in the Designer's Criteria for Operation and Maintenance prepared by BBMB is being adopted/ followed and enforced in truest sense of the word.

III. In order to monitor the behavior of dam, a large number of instruments/devices viz uplift pressure pipes, underground water holes, drain holes, settlement bench marks, geodetic survey points, plumb-lines, tilt-meters, traverse markers, embedded instruments, slope indicators, piezometers and seismological instruments have been installed both inside the body of dams and outside it. Periodic observations of these instruments and seepage measurements are made in accordance with the Designers Criteria for O&M observations. The field data is processed and conclusions are drawn regarding the behavior of dam under various loading/ unloading conditions in Annual Observation Reports of BBMB Projects.

IV. Pre-monsoon and Post-monsoon inspections are the important parameters which require immediate attention meticulously. During these inspections, all the mechanical and electrical equipments installed at various locations as well as civil structures of the projects are carried out as per CWC guidelines during the year. The observations/ shortcomings in above inspection are monitored through quarterly status reports and timely implementation is made to observations.

V. Dam Health And Rehabilitation Monitoring Application (DHARMA), a bespoke web-based software package to support the effective collection and management of Dam Safety data in respect of all four large dams of BBMB is being used.

7. CONCLUSIONS AND RECOMMENDATIONS

The dam safety practices shall address all issues concerning regular inspection of dams, comprehensive dam safety review, and adequate repair and maintenance funds for dam safety, instrumentation and safety manuals. They have to be standardised and implemented in synergized manner so as to make these more effective in ensuring the safety of structures. Dam owners will have to play a proactive role in supporting the Dam safety activities and have to undertake capacity building program under various schemes across the country.

It is essential to analyze the existing expertise available in the organization, competencies of the personnel involved and compare it with the expertise and competencies actually required, so that the gaps are identified and the areas of concern are focused for training & skill development activities.

Dam Safety Bill, 2019 approved by Lok Sabha in August, 2019 is one important element to make dam safety a mandatory requirement and aims to provide robust legal and institutional framework under Central & State Governments. The Bill envisages prevention and mitigation of dam failure related disasters through proper surveillance, inspection, operation and maintenance of all dams in the country.

Increased attention to the dam safety aspect is need of the hour, which will ultimately give returns in terms of coherent approach and successful safety management of dams in long run for sustainable water management.

REFERENCES

- The Reports of Dam Safety Committees of BBMB.
- Draft Dam Safety Bill of Government of India
- Operation & Maintenance Manuals of BBMB Projects.