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IMPLEMENTATION OF SUSTAINABLE DAM SAFETY MANAGEMENT – A CASE STUDY OF TWENTY PROJECTS IN HIMALAYAN REGION

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1. INTRODUCTION

1.1 Why Dam Safety

Infrastructure projects such as dams are national property – constructed for the development of the national economy and in which large investments and other resources have been deployed. With the increase of population & economic growth, higher demands of water and energy are to be substantiated with the construction of safe dams for sustainable water development and energy system. The safety of the dams is an important aspect for safeguarding the national investment and needs to be examined for continued accrual of benefits as well as to protect the d/s reaches from any potential hazard and ensuring public confidence.

With the passage of time, the number of older dams is increasing and so is the probability of dam failures. Advancement of modern technologies / methods of survey & investigation, geological & geotechnical investigations, design, construction, invention & adoption of new materials, improved operation & maintenance, and rehabilitation, the incidents related to dam failures has reduced significantly. However, new challenges such as climate change and global warming are rising which needs to be addressed in a timely and proper manner to respond positively to these increasing social expectations for higher safety levels and allay any unwarranted fear on dam safety issues.

Himalayan Rivers carry large quantity of sediments during monsoon requiring frequent repairs due to erosion of hydraulic structures like spillway glacis, piers and stilling basins. Erosion of hydraulic structures takes place due to progressive disintegration of solid by cavitation, abrasion and impact. Repair materials and methodologies need to be adopted depending upon identified 'Erosion conditions' of the project components. In NHPC, Performance of materials such as High Performance Concrete, Cementitious mortars (R4), Epoxy compounds and Steel-liners etc. was evaluated during dam safety inspections for various erosion conditions, on numerous dams on Himalayan rivers, to identify the best suited material based on international guidelines/codes, to optimize the cost and frequency of repair and enhance the safety aspects (1).

The safety of dam is to be integrated at various stages of hydropower development viz. conceptualization, planning, design, construction, maintenance and operation in a framework that ensures effective mitigation of the effects of natural and manmade adverse situations or emergency especially to avoid loss of human life.

2. DAM SAFETY INSTITUTIONAL FRAMEWORK IN INDIA

In general, exhaustive BIS standard codes/guidelines provide for design and construction of new dams under various parameters such as survey & investigation, geological & geotechnical investigations, hydrological & hydraulic calculations, stability and structural design of the dam & spillway under various loading conditions including site specific seismic parameter studies. Based on above, Pre-Feasibility reports (PFR)/ Detailed Project Reports (DPR) are prepared covering all aspects related of dam safety viz. dam-design, hydro-mechanical equipment's, hydrology, geotechnical investigations & Instrumentation, etc. These reports are scrutinized by various appraising authorities comprising of CWC, CEA, GSI,

CSMRS, etc. and techno-economic clearance is accorded prior to construction of hydro projects. Further dam break studies are being carried out to ascertain the extent of flood waters in an adverse case of dam failure to minimize the extent of damages and loss of life in the downstream of dams.

The general framework of the Dam Safety Management Program is related with three identified Dam Safety Management Pillars (2), comprising:

- Maintenance and operation - includes maintenance activities at the dam (vegetation control, outlet works, accesses..) and dam operation rules during normal operation and during floods.
- Instrumentation, surveillance and inspections – deals with surveillance and regular safety inspections of the dam, including reading and maintenance of data instrumentation and analysis of the data gathered.
- Emergency Action Planning – deals with implementation of an Emergency Action Plan, including the development and update of emergency response procedures and warning systems.

Recently Union Cabinet has enacted Dam Safety Act, 2021, which will help dam owners to ensure uniform safety procedures to ensure dam safety who own, control, operate, or maintain a specified dam according to the regulations made by the Authority under this Act.

3. HIGHLIGHTS OF DAM SAFETY ACT, 2021

Dam Safety Act provides for surveillance, inspection, operation and maintenance of specified dam for prevention of dam failure related disasters and to provide for institutional mechanism to ensure their safe functioning and for matters connected therewith or incidental thereto (3).

"specified dam" means a dam constructed before or after the commencement of this Act, which is

– above fifteen metres in height, measured from the lowest portion of the general foundation area to the top of dam; or

– between ten metres to fifteen metres in height and satisfies at least one of the following, namely

  - the length of crest is not less than five hundred metres, or
  - the capacity of the reservoir formed by the dam is not less than one million cubic metres, or
  - the maximum flood discharge dealt with by the dam is not less than two thousand cubic metres per second, or
  - the dam has specially difficult foundation problems, or
  - the dam is of unusual design

The National Committee on Dam Safety (NCDS) has been constituted (i) for evolving dam safety policies, and recommend necessary regulations as may be required, maintaining standards of dam safety and prevention of dam failure related disasters, (ii) Analyzing causes of major dam incidents/failures and suggest changes in dam safety practices to avoid recurrence of such incidents and failures, (iii) evolve comprehensive dam safety management approach as an integration of dam safety evaluation, risk assessment and risk management for the desired level of safety assurance and (iv) make recommendations on the rehabilitation requirements of ageing dams, etc.

The National Dam Safety Authority (NDSA) has been established (i) to implement the policies, guidelines and standards evolved by the National Committee on Dam Safety, (ii) Resolving issues between State Dam Safety Organizations (SDSOs), or between a SDSO and any dam owner in that state, (iii) Specifying regulations for inspection and investigation of dams and (iv) Providing accreditation to agencies working on investigation, design, construction, and alteration of dams.

The Act provides for the constitution of State Committees on Dam Safety (SCDS) by state governments with a function of (i) Reviewing the work of the SDSO, (ii) Ordering dam safety investigations, (iii) Recommending dam safety measures and reviewing the progress on such measures and (iv) Assessing the potential impact on upstream and downstream states. These states will also have their representatives on the State Committee.

State Governments will also establish State Dam Safety Organizations (SDSOs). All specified dams situated in a state will fall under the jurisdiction of that state's SDSO with the function of (i) Keeping perpetual surveillance, inspecting, and monitoring the operation and maintenance of dams, (ii) Keeping a database of all dams, (iii) Recommending safety measures to owners of dams. However, in certain cases the National Dam Safety Authority will act as the SDSO viz. (i) Is owned by one state but situated in another state, (ii) Extends over multiple states and (iii) Is owned by a central public sector undertaking.

Obligations of dam owners:

- Owners of specified dams are required to provide a dam safety unit in each dam.
- This unit will inspect the dams:
  - (i) Before and after the monsoon season, and
  - (ii) During and after every earthquake, flood, or any other calamity or sign of distress.
- Dam owners will be required to prepare an emergency action plan, and carry out risk assessment studies for each dam at specified regular intervals.
- Dam owners will also be required to prepare a comprehensive dam safety evaluation of each dam, at regular intervals, through an independent panel of experts.

The evaluation will be mandatory in certain cases such as major modification of the original structure, or an extreme hydrological or seismic event.

Central Dam Safety Organization (CDSO)

Dam safety is not new in CWC. Central Dam Safety Organization (CDSO) was established by CWC, in 1979 is a secretariat of NCDS. However, prior to the Dam Safety Act, it has an advisory role rather than a regulatory instrument. DSO/Cell is established in 18 States and 4 dam owning organizations (4). NHPC Ltd. (PSU) considered as DSO under the CDSO i.e. CWC for Dam safety related aspects. Dam safety cell of NHPC Ltd has been working under the D&E Division.

4. IMPLEMENTATION OF SAFETY INSPECTION OF DAM AS PER CWC GUIDELINES

The safety of dams has been a prime concern of dam owners. To bring uniformity and standardization in safety inspection of dams across India, Central Water Commission (CWC) published "Guidelines for Safety Inspection of Dams" in June'1987. The objective was to establish the most effective mechanisms to provide the best assurance of dam safety possible within the limitations of the current state of knowledge available to the scientific and engineering communities.

In NHPC, Dam Safety Inspections are being carried out regularly at all power stations and remedial measures suggested. Preparation and Implementation of Emergency Action Plan (EAP), and other statutory documents such as Data book, Reservoir operation manuals, SOP (for sudden downstream releases), Instrumentation manuals, etc. for all the Dams. However, a need was felt that early repair & rehabilitation of civil structures is essential for continued and reliable operation of these valuable assets. Based on the experience gained from the dam safety inspections carried out over thirty years and adopting the latest technological advancements, best practices worldwide, an in house "Guideline for Repair & Rehabilitation of Civil structures of hydroelectric power station, NHPC, Nov-2016" has been prepared & issued covering Technical Specifications & BOQ for use of different type of generic repair materials for ensuring uniformity of repair works and recognition of deviations & deficiencies within the Dams under NHPC (5).

Some of these repair materials mentioned in above NHPC guidelines have also been incorporated in the revised and updated "Guidelines for Safety Inspection of Dams" Jan-2018 by CWC. The revised guidelines address all aspects of dam safety inspection programs. This guideline also consider the preparatory steps to be taken before planning the inspections, selection of inspection team, collection of needed document, and report preparation including suggestive measures (6).

4.1. Objectives Of Dam Safety Inspections

- Ascertain that the dam system is performing as expected,
- Identify deficiencies or areas that need monitoring or immediate repair,
- Assess the soundness of the dam and record any changes that have occurred,
- Collect information to make informed decisions about needed remedial measures, and
- Find out, if the dam is being operated and maintained properly

4.2. TYPES OF SAFETY INSPETIONS

(1) Comprehensive Dam Safety Review/ Comprehensive Evaluation Inspections (DSRP) (every 10 years)

(2) Scheduled Inspections (Pre & post monsoon of every year)

(3) Special (unscheduled) Inspections

(4) Informal/ Regular Inspections

4.2.1 *Comprehensive Dam Safety Review/Comprehensive Evaluation Inspection*

(a) Purpose:

Comprehensive safety reviews are carried out by a group of 'Independent panel of experts' called 'Dam Safety Review Panel' (DSRP) to assess the integrity of a dam based on current acceptable safety criteria (e.g. Engineering standards, dam safety guidelines) or risk management criteria by an independent panel of experts. DSRP team will consist of various domains e.g., Dam Safety Specialist, Design Expert, Construction Supervision Expert, Geologist, Hydrologist, Hydro – Mechanical Expert and Instrumentation Expert.

(b) Procedures:

- Review of all available relevant information/records to determine exact cause of problem.
- Detailed on-site inspection and general assessment of hydrologic and hydraulic conditions, seismic safety of dam and its appurtenant structures
- Review previously identified dam safety issues and the adequacy of their resolution, emergency preparedness, known potential hazards and dam safety threats, etc.

In NHPC, Dams which are due for independent/ comprehensive review (Once in 10 Year since commissioning) by constituting DSRP of competent empanelled experts/officials from CWC & other organizations and review of Dams of Bairasiul, Chamera-I & II, Rangit, Dhauliganga, Dulhasti, Teesta-V and Barrages of Tanakpur & Uri-I power stations has been carried out and recommended remedial measures are implemented.

4.2.2 *Scheduled Inspections*

Scheduled inspections (pre & post-monsoon) are performed to gather information on the current condition of the dam and its appurtenant works, to establish needed repairs and repair schedules, and to assess the safety & operational adequacy of the dam, to evaluate previous repairs.

Scheduled inspections includes (i) Review of past inspection reports, monitoring data, (ii) Visual inspection (iii) Preparation of a report or inspection brief, with relevant documentation and photographs.

In NHPC, the scheduled pre & post monsoon dam safety inspections of Civil & HM equipments of all project components viz. Dam, water conductor system and power house, etc. are being carried out for all 20 power stations by a team of officials of civil, hydrology, hydro-mechanical & geology domains, concerned officials of power stations. The remedial measures, if required are suggested. Two types of safety inspection reports are prepared (i) dam safety inspection as per prescribed format for submission to Dam safety Directorate CWC & State DSO and (ii) comprehensive safety inspection report covering all the project components viz, dam, water conductor system, power house and other important structures for internal use. Some critical issues requiring attention are escalated to the top management. Further, effective monthly monitoring of actionable points raised during Dam safety inspection through online module & regular interaction with the power stations for their successfully implementation.

The scheduled dam safety inspections have helped to timely identify the major issues related to the health of dam and other components of the power stations which have been effectively restored by suggesting corrective measures along with repair methodology in view of limited working period along with quality assurance and monitoring system.

4.2.3 *Special (Unscheduled) Inspections*

The unscheduled inspections are being carried out as per requirement in addition to scheduled dam safety inspections by the dam safety team subject to unusual events or conditions and report submitted accordingly.

4.2.4 *Informal (Regular) Inspections*

The surveillance and informal (regular) inspections are being carried out by the officials of the concerned power station and issues, if any are addressed accordingly.

5. INSTRUMENTATION

Instrumentation plays a pivotal role providing an understanding of the foundation and structural behavior both during construction and operation of dam. In NHPC, instrumentation is planned and installed with various instruments such as survey targets, piezometers, inclinometers, extensometers, etc. for all project components. Regular collection of data, data processing and continuous monitoring program is being adopted to understand the performance. Remedial measures, if required are suggested and carried out.

During dam safety inspections, check status of installed instruments, registers/readouts of observations and damages, if any are observed. Some of the instruments such as Strong Motion Acceleographs installed at all the dams in NHPC power stations are continuously monitored at the control room in the dam area and a centralized control room at corporate office. In order, to achieve the objective of dam safety, initiation of the process of implementation of Real Time monitoring of dam safety, hydro-mechanical equipments and automatic weather station, EWS for flood forecasting, etc. installed at project components of all power stations is in progress.

6. IMPLEMENTATION OF VARIOUS SAFETY PLANS IN NHPC

The following dam safety plans and procedures are being implemented in NHPC:

- Emergency Action Plan
- Inundation Maps (i/c Dam Break Studies)
- SOP for sudden d/s release of water from dam
- Mock Tests & Drills
- Installation of Alert & Warning Systems and proper communication systems

7. REPOSITORY OF DOCUMENTS / DATA BASE PREPARED FOR SAFETY EVALUATIONS

List of documents/data base prepared/ developed in NHPC power stations which are being frequently referred during dam safety inspections are as follows:

- Design Reports, Design memos
- As Built Drawings
- Construction History, TAC reports
- Completion Report
- Data Books
- Reservoir Operation Manual
- HM Operation Manual
- Past Incidents/failures
- Repair & Rehabilitation Drawings/Sketches

8. DAM SAFETY ORGANISATION (DSO) OF NHPC LTD

- Pre & post monsoon dam safety inspections are regularly being carried out for all 20 power stations. For effective monitoring of actionable points raised during Dam safety inspection, development of online module for monthly progress has been successfully implemented.
- Submission of consolidated Pre & Post monsoon (Twice in a year) dam safety inspection report as per prescribed format published by CWC (CDSO) in “Guidelines for safety inspection of Dams” as Appendix-B to Dam safety Directorate CWC & State DSO.
- Submission of consolidated Annual Instrumentation report as per prescribed format by NCDS to Instrumentation Directorate, CWC, & State DSO.
- Submission of compliance report (ATR) of minutes issued during NCDS meeting to DSO, CWC & State DSO, as per requirement.
- Comprehensive review (Once in 10 Year since commissioning) by Dam Safety Review Panel (DSRP) for NHPC Dams which are due for independent panel of experts.
- Prepare various generic statuary documents i.e. Emergency Action Plan (EAP) & SOP (for sudden d/s release) as per guidelines issued by relevant authorities like CWC, NDMA etc.
- Implementation of Emergency Action Plan in consultation with DDMA (District Disaster Management Authority).
- Preparation of Data book, Instrumentation manuals & other statuary documents such as SOP (for sudden d/s release) as per guidelines published by CWC.

- As a general practice, two types of safety inspection reports are prepared during the scheduled inspections (i) dam safety inspection as per prescribed format for submission to Dam safety Directorate CWC & State DSO and (ii) comprehensive safety inspection report covering all the project components viz, dam, water conductor system, power house and other important structures for internal use. These scheduled dam safety inspections have helped to timely identify the major issues related to the health of dam and other components of the power stations.

9. CASE STUDIES OF SOME CRITICAL REPAIR WORKS BASED ON SAFETY INSPECTION

Implementation of various dam safety inspections and procedures has resulted in

- Enhanced safety of dams,
- Maintaining live capacity of reservoirs for designated use,
- Increased generation as forced shut down periods due to non-availability of waters are not required
- Reduction in the cost & frequency of repairs or major issues of dam safety are reduced
- Standardization of the technical specifications for repair materials & innovative methodologies for proper execution of work. Use of appropriate materials with standardized performance characteristics has optimized the cost and frequency of repair and enhanced the safety aspects of dam and appurtenant structures.
- Preparation and issue of "Guideline for Repair & Rehabilitation of Civil structures of hydroelectric power station" covering Technical Specifications & BOQ for different type of generic repair materials for uniformity of repair works within the Dams under NHPC. These standardized repair materials & methodologies proved handy for implementation of repair & rehabilitation works of all power stations. Futher these were extensively used for 'Renovation & Modernization, Uprating and Life Extension (RMU&LE) of hydro plants' of Bairasiul & Loktak power stations as per CERC norms after 35 years for extending the useful life by 25 years.

Further, based on dam safety inspections, case studies of some important repair works taken up for dams and other components of the power stations are as follows:

9.1. Dhauliganga Power Station

Dhauliganga Power station (280MW) witnessed unprecedented flood of 1377 cumec on 16th & 17th June, 2013 which led to sever damages to many components of the power station.

Orifice spillways, gate sills, bucket, piers, d/s guide walls and apron got severely damaged. The Spillway glacis, concrete apron and invert of Spillway tunnel were repaired with base concrete (M25A40) and HPC (M60A20) along with 25 mm φ anchors and epoxy bonding. Latter spillway crest & upper part of glacis was provided with steel liner. Sill beam were restored. The repair of pier & guide wall was done with high bond strength cementitious mortar conforming to the requirement as per EN: 1504-3(R4). The abrasion/ depressions , cracks & exposure of reinforcement observed in some of panels of Concrete Faced Rockfill Dam (CFRD) and cracks developed in HRT were treated with high bond strength cementitious mortar conforming to EN: 1504-3(R4). Further Contact grouting was done behind lining at the crack position. Re-grading was done in bed of Elagaad nallah which rose by about 10m and choked the TRT outlet. A retaining wall with boulder trap was constructed on upstream of TRT outlet to deflect nallah water and boulders.

The innovative idea of fixing steel liner with the countersunk bolts near the existing spillway crest & upper part of glacis and use of structural grade High performance cementitious mortar conforming to EN 1504-3(R4) with high bond strength was done for the first time in India. The above restoration works have performed satisfactorily and now being used in many other projects of NHPC Ltd.

9.2. Tanakpur Power Station

Tanakpur Power Station was commissioned in 1992 and has attained 26 years of operation. In June-2013, the barrage experienced an unprecedented flood of 5.35 Lakh cusec. This caused large deposition of RBM in central portion of the reservoir and substantial increase in flow concentration of the river channel along the both afflux bunds, thereby scouring and damaging them. Innovative solutions of activation of central channel was adopted for diverting a part of river flow through it and PP rope gabion, mechanically woven hexagonal wire mesh gabion and small nose spurs of tetrapods used to protect afflux bunds on both banks. The frequency of damages has significantly reduced even at high velocities and this has helped to standardize the procedure of repair now.

In spillway glacis, a wearing layer of 500mm is provided over the structural base concrete with Epoxy grouted L-shaped steel anchors along with epoxy bonding. The performance of the stilling basin provided with HPC has been found satisfactory

over last 8 years. The repair of the warp wall d/s of barrage gate no.1 could be done by converting counterfort retaining wall into gravity wall in place of dismantling damaged counterfort retaining wall and also due to meticulous planning and execution.

Further the reservoir operation guideline was also updated to improvise sediment flushing and to minimize damages. In 2021, about 5 lakh cusec flood was managed without any major damage.

9.3. Bairasiul Power Station

Bairasiul power station (3x60MW) has completed its useful life of 35 year in March 2017 and its renovation and modernization works had been scheduled from April 2017 to March 2021. During dam safety visits, the critical issues viz. lower hoisting capacity of desilting/diversion gate which results in reduced live capacity of reservoir, Higher head loss in water conductor system, wastage of precious inflow water of Bhaledh trench weir, repair of intake/DT bridge, requirement of protection wall at u/s of power house, Heavy damage observed at outlet of DT, repair of Siul weir has been observed. The most of the repairs require complete shutdown of power station.

Further in Sep 2017, an unprecedented flood has been observed which have caused major damage at downstream slope of the dam which further endangered the stability of dam. All these issues have earmarked during visits and inspite of their criticality, the project has meticulously operated the spillway gates and only mandatory repair have been undertaken before renovation and above major repairs shifted to shutdown period and unhindered generation was achieved until complete shutdown of power Station under renovation &modernization.

During complete shutdown the hoisting capacity of DT has increased from 65t to 185t, Diversion tunnel, HPC on glacis, construction of additional trench weir, enhancing capacity of feeder tunnel, HRT repair and other major repair has been made and useful life of the power station has extended by 25 years.

9.4. Loktak Power Station

Loktak power station (105MW), Manipur, is a trans-basin project commissioned in 1983 by harnessing the destructive flood water and diverting it for irrigation and hydro power generation. The surface penstocks are supported on 12 anchor blocks (AB) & 68 saddles. Due to poor geology of weak/soil matrix & steepness, movements were observed between AB11-12 during & after construction which were arrested by various remedial measures. In 2014, slope movements caused upheaval of soil, tilting/dislodging of rockers. Catch drains damaged and shearing of restriction piles & inclinometers required unloading of slopes. In 2018, considerable shifting of rockers of rockers at saddle-3 of PS-1 between AB11-12 towards the left edge of foundation requiring extension of saddle concrete, unloading of the adjoining hill slope and earlier execution of restriction bored piles due to safety concerns originally planned as part of Renovation & Modernization works for life extension . Extensive monitoring mechanism has been developed by prism targets. Looking in to the poor geology of weak/soil matrix, steepness, 7No. bored cast-in-situ pile groups having 26 piles of 500mm dia. each has been constructed. These measures have provided great advantage and movements in the hill slope has reduced significantly. Moreover, contour drains, step drains, drainage holes are also proposed in the area. Further, abrasion of barrage spillway glacis, piers & abutments are rehabilitated with high bond strength cementitious mortar conforming to EN: 1504-3(R4).

9.5. Sewa-II Power Station

Sewa-II Power Station (120 MW) witnessed a catastrophic failure of its water conductor system due to massive landslide on 25th Sep' 2020 which washed away about 59m of the Head race tunnel and caused damage to its concrete lining extending to about 165m. A high-level team was constituted immediately for assessing the damage at site and suggesting measures and treatment for restoration of the power station.

Initially, two alternatives were suggested for restoring the water conductor system. One alternative was to keep the same alignment of the tunnel and connecting the open ends of the concrete lined HRT with Steel liners supported over RCC aqueduct. The other option was to detour the tunnel by changing its alignment in such a way that there is sufficient rock cover over it. After, further site visits by engineers and geologists to find out the actual site condition w.r.t. geology of the tunnel and surroundings and estimating the cost of repair and assessing the future vulnerability, the second alternative was chosen for implementation.

In order to strengthen the tunnel, consolidation grouting was done at all the junctions and even in the existing tunnel near the damaged portion. Rock bolts and steel ribs were provided in Class IV and V. Reinforcement was also provided in the concrete lining near the junction of abandoned and new tunnel. Finally, the access points were plugged and curtain grouting was done to ensure that there is no leakage from the tunnel and the Power Station was re-commissioned on 25th Feb 2022.

9.6. Teesta-V Power Station

Teesta-V power station (510MW) is located in Sikkim and was commissioned in year 2008. Teesta-V Dam consists of 5 nos. low level spillway bays for flushing of sediments deposited in reservoir and keeping the intake free of sediments. Due to passing of heavy sediment laden water with rolling boulders, gravels etc. in every monsoon period, spillway damages were repaired with HPC M70/A20.

With the success of steel liner at Dhauliganga dam, installation of 32mm thick steel liner in the spillway glacis near the regular damaged zone in length of 10 m d/s of radial gate sill beam and approx. 12.2 m u/s of radial gate sill beam was provided. Epoxy mortar conforming to ASTM-C-881 was used to fill the recess between steel liner and pier. Epoxy grout conforming to ASTM-C-881 of bond strength ≥ 10 Mpa at 14 days was used for contact grouting between Steel plate and concrete. The concrete used below the steel liner was non-shrinkable self-compacting concrete of grade min. M35A20. The damages in Pier faces were repaired by applying Cementitious Mortar (R4) complying with EN1504-3.

The performance of steel liner has been found highly satisfactory in eliminating the damages near the sill beam and downstream. After erecting first in one bay, now steel liner has been placed in balance four bays also in 10 m stretch.

9.7. Chamera-I Power Station

Chamera –I. Power Station (540MW) is located in Chamba district of H.P. about 87 km from Pathankot. The project comprises of a 140 m high concrete arch-gravity dam, 6.4 km long 9.5 m diameter horse-shoe shaped power tunnel on the right bank of Ravi and was commissioned in April 1994.

Power Station has experienced problems in the generating units due to loose concrete pieces frequent hitting the under-water parts. The size of concrete pieces hitting the generating unit were of maximum size 1.6m x 1.4m x 0.5m. After taking Shutdown from 01.12.2021, HRT was inspected. Various sizes of concrete blocks lying in the floor were observed. A cavity in the rock mass and other damages mostly in concrete lining at invert, kerb, between kerb and springing line were observed.

After Inspection of HRT, the repair methodology adopted was consists of: Application of Epoxy mortar (based on ASTM C881) for crack opening of 12 mm or less, Application of High Performance cementitious mortar complying EN 1504-3 (R4) for Crack opening/ depth of damage of 12mm to 50 mm and filling with High Performance Concrete (HPC M50 with max aggregate size 10mm) along with mechanical bonding and anchoring with existing concrete for crack opening / damage of 50mm. For cavity treatment, in addition to concrete filling, Consolidation grouting of rock mass, installation of Rock bolt and Reinforcement on rock face was also used. In addition, as per requirement of site conditions, Concrete lining was also stitched with rock mass.

The repair work of HRT was carried out successfully in the shortest possible time in 45days (01.12.2021 to 15.01.2022).

9.8. Chamera-II Power Station

Chamera –II Power Station with an installed capacity of 300MW is located in Chamba district of Himachal Pradesh and was commissioned in year 2004.

A flash flood of the peak of about 3200 cumec was observed due to heavy rainfall during 23rd & 24th Sep-18 which caused extensive damage to the u/s left bank road (Chamba-Bharmour) between RD 165 to RD 400 near dam site along the reservoir rim (u/s of Diversion Tunnel Inlet portal). Dam safety inspection team inspected the damage and suggested the rim treatment in the form of placing PP rope gabions with boulder wire crates where firm rock was not available in the reservoir rim. RCC retaining walls/Concrete cladding was suggested in reservoir rim where firm rock was available. The retaining wall was suggested to be stitched with rock foundation. In addition, it was also suggested to place tetrapods near the sharp bend where formation of eddy currents observed. The Rim treatment as suggested was successfully completed in shortest possible time. The same is being monitored regularly by the dam safety nodal officers and working satisfactorily with some minor distress.

10. CONCLUSION

Effective implementation of dam safety management program of regular maintenance and operation coupled with elaborative monitoring mechanism of instrumentation, surveillance and dam safety inspections has resulted in

- Enhanced safety of dams and other project components,
- Reduction in the cost & frequency of repairs due to use of advanced repair materials, innovative methods & standardization of the same. Regular monitoring to evaluate the performance for the durability of the repair works,

- Maintaining of live capacity of reservoirs through optimized reservoir operation procedures and increased generation and
- Comprehensive safety inspection report covering all the project components including dam, water conductor system, power house have helped to timely identify the major issues related to the health of dam and other components of the power stations and restoration with optimization of shutdown time.

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