Dam Safety Rehabilitation - Indian Experience and Lessons Learnt

Pramod Narayan, Hadush Seged, Yogesh N Bhise
DRIP Project, New Delhi, India

ABSTRACT
Economic sustainability of a country heavily depends on the dams in the country and with over 5700 dams, India ranks 3rd in the world in total number of large dams next to the two world's largest economies China and USA. Dams are not only a source of water for drinking, for industry and for agriculture but also save people from flooding and provide cheap source of producing electricity. A substantial proportion of Indian dams have become old. About 4180 large dams are more than 25 years old, out of which 1200 are more than 50 years old. Aging and absence of maintenance play a critical role in the safety and sustainability of the dams. Several of these ageing dams have various deficiencies as per the present structural and hydrological design standards requiring critical rehabilitation. In line with this, the Dam Rehabilitation, and Improvement Project (DRIP) is among the major initiatives taken up by the government of India to effectively rehabilitate 223 existing dams in 7 States. Rehabilitation measures implemented under DRIP program have helped to improve conditions of these dams. The dams have been strengthened, ability to cater increase in design flood improved, initially observed structural defects rectified, leakages minimized, hydro-mechanical equipment renovated, access roads constructed or upgraded, surveillance systems installed, EAPs and O&M manuals prepared as per guidelines published by DRIP. As a result, the health of dams is enhanced, and risks reduced. Technology transfer and capacity building of the dam owners' engineers are also in place. This paper discusses Indian experience in dam safety rehabilitation and lessons learnt. The first phase of DRIP that successfully rehabilitated 223 dams in 7 states is planned to be closed by June 2021 and is to be followed by a new 10-year DRIP Phases II and III in 19 States with more than 700 dams.

1 INTRODUCTION

1.1 Background

Since rainfall occurs in India only for three months in a few spells, storage by dams is imperative to utilize available water resources. India has thus built and is still building several large dams for agriculture, power generation, domestic and industrial water supply as well as flood protection. As per the Indian National Registry of Large Dams (NLRD, 2020), there are 5745 large dams in India out of which 4180 dams are more than 25 years old with 1200 dams more than 50 years old (Figure 1 (b)).

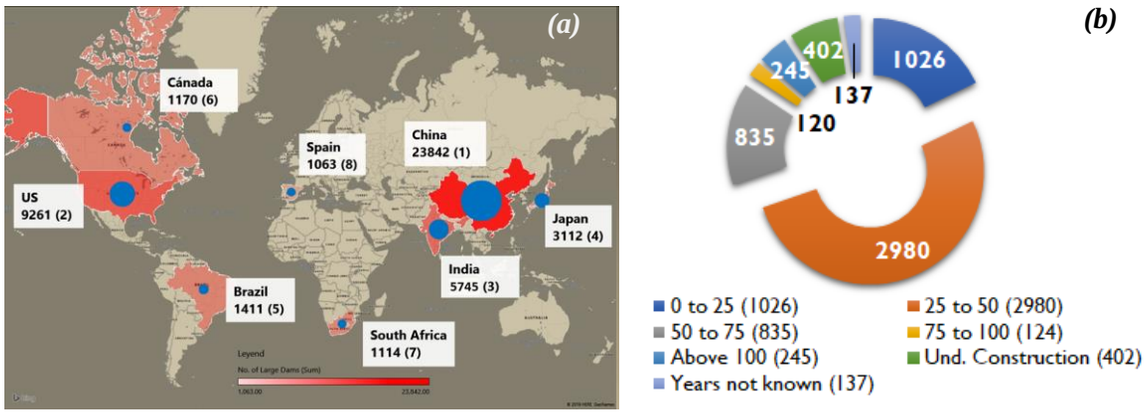

Figure 1. **(a)** Worldwide distribution of large dams and **(b)** Year wise age of Indian dams.

1.2 DRIP Initial and Revised Projects/ Costs

In April 2012, the Ministry of Water Resources, River Development and Ganga Rejuvenation with assistance from the World Bank, embarked upon a six-year Dam Rehabilitation and Improvement Project (DRIP) at a preliminarily estimated initial cost of Rs.2100 Crore targeting rehabilitation and improvement of about 250 dams initially in four, later in seven states - namely: Karnataka, Kerala, Madhya Pradesh, Odisha, Tamil Nadu, Jharkhand, and Uttarakhand. In June 2018, the project was extended by two years, until June 2020 with a revised project cost of Rs.3466 Crores including a 370-crore construction of additional spillway project in Odisha, whose Contract commenced in October

2018 but was terminated in January 2020 due to poor progress of works. DRIP was later again extended twice until December 2020 and June 2021. The current revised cost for DRIP is Rs.2642 Crores, out of which Rs. 2285 Crore (87%) is allocated for Component 1 (Rehabilitation and Improvement of Dams and Associated Appurtenances), Rs. 133 Crore (5%) is allocated for Component 2 (Dam Safety Institutional Strengthening) and Rs. 224 Crore (8%) is allocated for Component 3 (Project Management). The total number of dams under DRIP stands at 223 under 198 dam projects. Figure 2 shows the original and revised dam projects and costs agency wise.

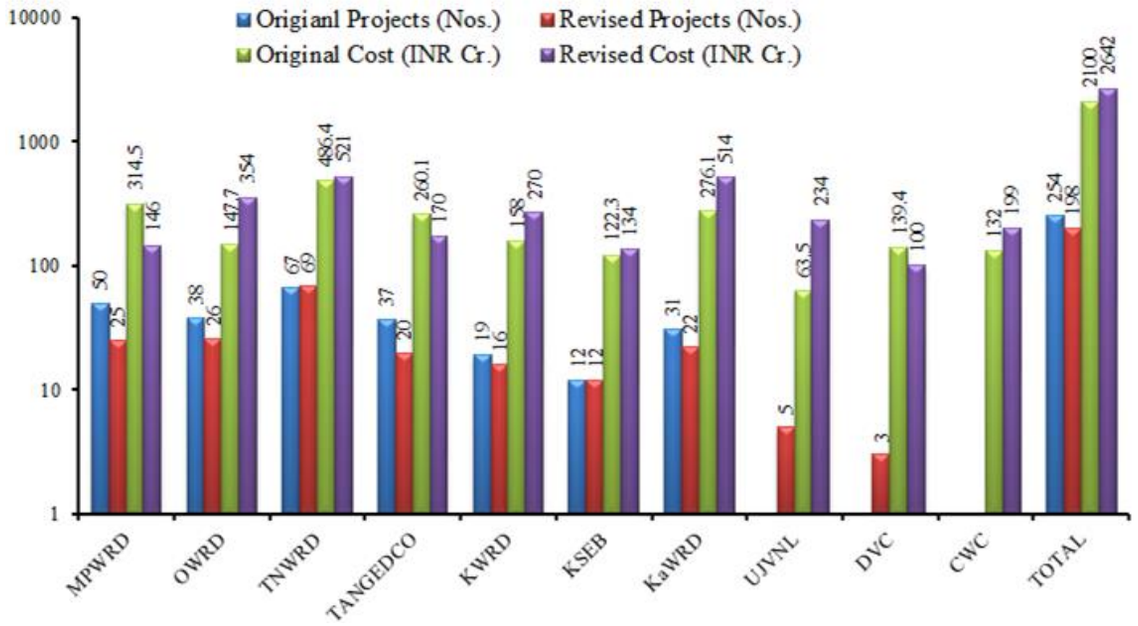

Figure 2. Agency-wise original and current dam projects/costs under DRIP

As can be seen from the above data, there has been major variations in the original projects and costs and revised project and costs. As shown in Figure 3, revised costs increased significantly in some IAs (UJVNL, OWRD, KSEB, KaWRD, KWRD), reduced other IAs (MPWRD, TANGEDCO, DVC).

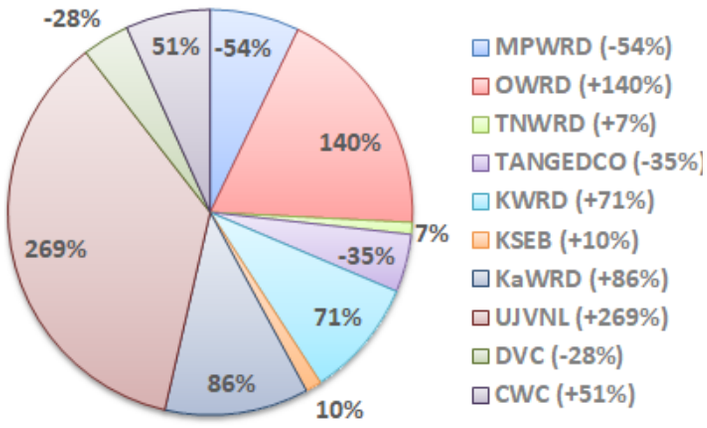

Figure 3. Agency-wise cost variations between original and revised costs.

UJVNL joined DRIP in 2015 and started with a limited budget that was available in the initially planned pool at the time. Later, the agency took up more necessary dam safety works and revised the budget with significant increase. Similarly, in some other implementing agencies costs increased due to additional works as well as variations in works Contracts that were unforeseen in the initial planning and design. To minimize/ avoid such significant cost variations all necessary studies and investigations including underwater investigations shall be carried out thoroughly at the initial stage of the project. In DVC, the DRIP project was closed in June 2020 with some of the initially planned works not fully completed, hence, there was a reduction in the revised project cost as compared to the original cost. DVC is currently completing the remaining works with State own budget. As the DRIP project was extended from the initial planned closure in June 2020 to June 2021, the CWC project management cost also increased by over 50%.

2 PREPARATORY ACTIVITIES

2.1 Dam Safety Inspections

Before taking up any rehabilitation measures under DRIP, dam specific inspections are carried out by a group of experts comprising dam designers, hydrologists, geologists, and dam safety engineers

known as the Dam Safety Review Panel (DSRP). The DSRP examine each dam, identify deficiencies, and provide recommendations for rectifying the observed defects. In line with this, inspections of 260 dam projects were carried out and DSRP reports prepared that were handed over to the corresponding implementing agencies. In parallel, revision of dam specific design flood as per latest design practices were carried out, which were reviewed and approved by CWC. Based on the DSRP and revised design flood reports, the IAs prepared 250 dam specific Project Screening Template (PST) incorporating proposed rehabilitations measures and associated cost estimates. The PST is the main reference document for each dam and were reviewed and approved by CWC and the World Bank.

2.2 Revised Design Floods

In DRIP, out of the 223 dams under 198 projects, 203 dams have independent spillways, and the rest 20 dams are either saddle dams or have a common reservoir and spillway with another dam. Hence, assessment of revised design flood is carried out for the 203 dams.

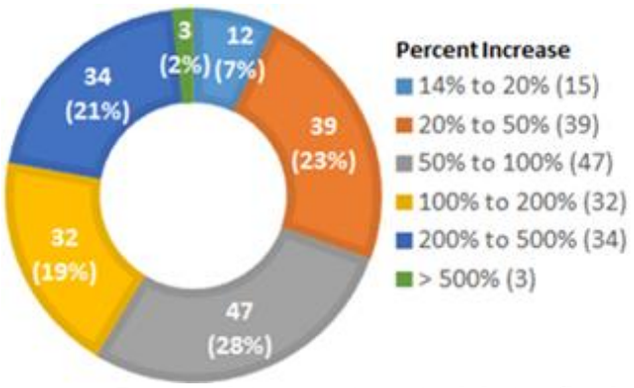

Figure 4. Dams with increase in revised design flood.

Out of the 203 dams, design floods increased by more than 14% for a total of 167 dams or about 82.3% of the dams (Figure 4). It can also be seen that for 116 dams (57% of the 203 dams), the revised design flood increased by more than 50% and for 69 dams (34% of the 203 dams), it increased by more than 100% of the original design flood. This clearly shows that most of existing/aged dams in India are designed for lesser design floods as per current practices. Hence, assessing and ensuring hydrological safety of existing dams is so paramount in a dam rehabilitation project.

2.3 Flood Routing Study

Once the revised design floods were determined using current standards, for the dams with increased revised design flood, dam specific flood routing study was carried out to assess the capacity of the existing spillway, check the revised MWL (Maximum Water Level), and available freeboard above the MWL. These results were used to determine whether the dam specific existing spillway is sufficient or there is a need to take up a measure to ensure hydrologic safety of the dam. Flood routing study reports reveal that over 51% of the 167 dams with increased design do not have sufficient freeboard as per IS Code 10635 for embankment dams and IS Code 6512 for masonry/concrete dams and hence required structural and non-structural measures to ensure hydrologic safety.

3 REHABILITATION MEASURES

3.1 Hydraulic Safety Measures

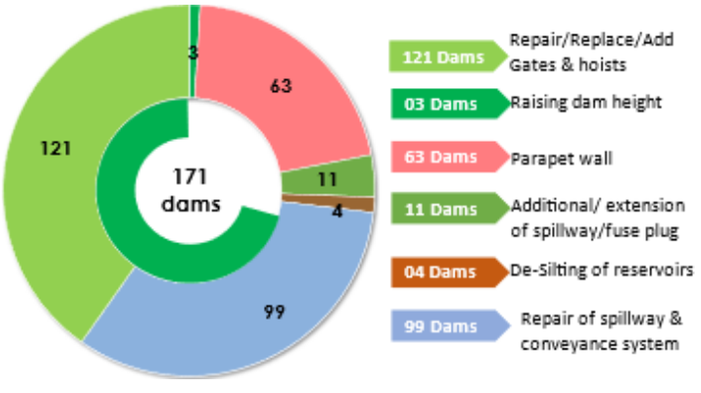

Figure 5. Hydraulic safety measures under DRIP.

Out of the 198 dam projects under DRIP, a total of 171 dams have taken up various rehabilitation measures to improve and ensure the hydraulic safety of the dams. The measures include provision of additional spillway, dam height raising, extension of spillway, repair and provision of parapet wall as part of freeboard, as well as critical repair/ strengthening of deteriorated spillway structures and repair or replacement of gates and hoists (Figure 5).

Among the major hydraulic safety measures taken up in DRIP project, highlights of very few examples

are discussed below.

At Manimukthanadi dam, Tamil Nadu, the original design flood was 926 m^3/s and is revised under DRIP to 3,356 m^3/s which is 3.26 times bigger. To ensure hydrologic safety of dam, additional spillway on left bank (4 no. bays with radial gates of size 10 m x 6.1 m each), 1 m high upstream solid parapet wall, and fuse plug of 250 m long on left abutment are provided (see Figure 6). With these measures, the dam is safe for the revised design flood.

Figure 6. Manimukthanadi dam additional spillway

Figure 7. Sarathi dam raised and weir modified to ogee.

At Sarathi dam, Madhya Pradesh, the design flood is revised from 251 m^3/s to 1651 m^3/s, which is 6.58 times bigger. The hydrological safety of dam is ensured by re-sectioning & raising of earth dam by 1.50 m with top width increased from 2.4 m to 4.5 m. Existing spillway weir is also modified to ogee shape to increase discharge capacity (Figure 7).

At Narayanpur Dam, Karnataka repair of spillway radial gates and provision of new gantry crane & one set spillway stop logs was done. Measures included replacement of corroded horizontal stiffeners, zinc metallizing and repair of rubber seals. New 84 Ton capacity gantry crane with one set of stoplog elements (7 nos.) was also provided. Pier and pier grooves were also repaired.

Figure 8. Narayanpur dam new gantry crane and set of stop logs.

Figure 9. Replacement of 136 gates at KRS dam.

At Krishina Raja Sagar (KRS) dam, Karantaka replacemnt of 136 gates and 2 ganntry cranes is currently ongoing. The KRS dam is over 100 years old dam with many gates/hoists not-working or have structural defects & suffer heavy leakages. Replacement of 136 gates and 2 gantry cranes currently ongoing including provision of automatic control of gates through SACADA. This activity is critical for hydrologic ensuring safety of the dam.

3.2 Structural Safety Measures

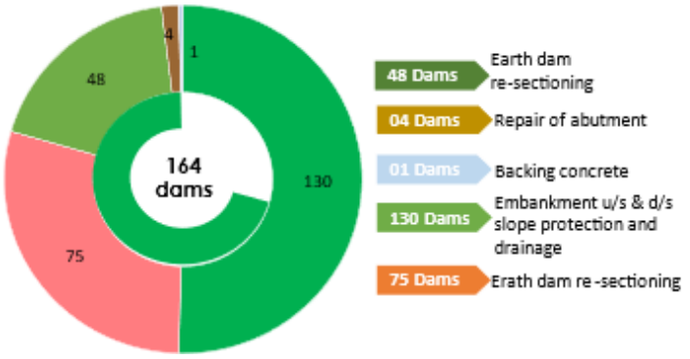

Figure 10. Structural safety measures under DRIP.

Out of the 198 dam projects under DRIP, a total of 164 dams have taken up various rehabilitation measures to improve and ensure the structural safety of the dams. The main measures include embankment dam rese-sectioning, repair of embankment upstream and downstream slope protection, masonry/concrete dam reaming of porous and foundation drains, masonry/concrete dam backing concrete, repair of abutments, etc. (Figure 10).

Among the major structural safety measures taken up in DRIP project, highlights of very few examples are discussed below.

At Pechiparai dam a backing concrete was constructed to ensure strutural safety. The Pechiperai dam is one of the oldest dams built during 1895–1906. The existing dam was found unsafe under seismic loading conditions and a backing concrete was provided. The backing concrete was designed and constructed considering appropriate bonding level between the existing dam and backing concrete. With this measures that dam is safe against seismic loading as per current practice.

Figure 11. Pechiparai dam backing concrete.

Figure 12. Mallaghata dam re-sectioning.

Mallaghata dam is one of the very old dams in Karanataka which was constructed in 1907. To ensure structural safety, the embankment dam was re-sectioned by changing the downstream slope below RL 95.5 m from 1V:2H to 1V:2.5H plus a 3.0 m wide berm at. RL 95.5 m. To safely drain any possible seepage through the dam, a rock toe was provided. The upstream slope was also re-sectioned from 1V:1.5H to 1V:2H by providing additional rockfill/riprap over the existing riprap.

3.3 Seepage Control Measures

Out of the 198 dam projects under DRIP, a total of 71 dams have taken up various rehabilitation measures to control seepage through the dams and foundation. The main measures include masonry dam raking and pointing of u/s face with UV resistant high strength mortar; dam body grouting of masonry/concrete dams and u/s face geomembrane; grouting of embankment dam dam/ foundation and provision of cut-off, etc. (Figure 13).

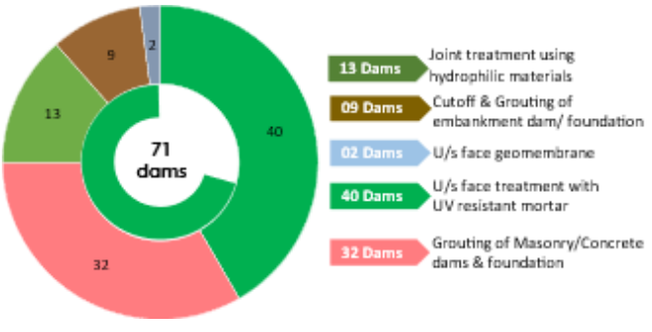

Figure 13. Seepage control measures under DRIP.

To reduce initially observed seepage at

Figure 14. Porthimund dam u/s face treatment.

Porthimund dam, Tamilnadu, the masonry dam upstream face racking and pointing of upstream face of the masonry dam was carried out using UV resistant, high strength, non-shrink Polymer cementitious. Moreover, failed contraction joint water-stops were repaired using hydrophilic sealants. The downstream face of the dam was also raked and repointing with 1:3 ratio cement mortar.

At Servalar dam, Tamilnadu, to reduce initially observed seepage, left flank and overflow section upstream face of the masonry dam was treated using geomembrane water- proofing. On the right flank non-overflow section racking and pointing as well as contraction joint water-stop treatment was carried out. These measures stopped leakage of water on downstream face and gallery leakage reduced from 742.65 L/min to 28.96 L/min at reservoir level near FRL.

Figure 15. Servalar dam geomembrane treatment

3.4 Dam Safety Basic Facilities

In addition to structural deficiencies, dam safety basic facilities were also absent in many dams. Out of the 198 dam projects under DRIP, a total of 178 dams have taken up various dam safety basic facilities. These include repair and construction of all-weather access roads and roads for access to sections of the dams; critical equipment for O&M and for emergency situations; provision of low-voltage electrical supplies in inspection and drainage galleries, improved lighting and security for external areas, standby generators for emergency operation of spillway gates, and inspection launches.

4 NON-STRUCTURAL MEASURES

In addition to the structural measures discussed above, several non-structural measures have also been undertaken under DRIP that are also critically important for ensuring safety of the dams. The different non-structural measures are implemented under DRIP are discussed below.

4.1 Technical Guidelines and Manuals

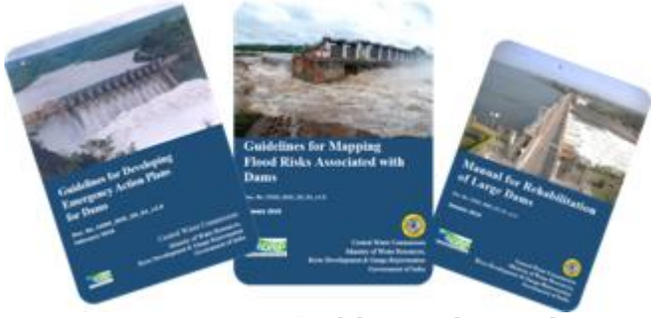

Figure 16. DRIP Guidelines and Manuals

As the practices of dam safety is varying from State to State and from organization to organization in absence of any legislation, the CWC is making all out possible efforts for evolving unified practices of dam safety across the Country to maintain uniform standards by pooling the expertise available across the world. In regard, six guidelines and manuals were published during the 2018 International Dam safety Conference (IDSC) in Trivandrum, Kerala. five more guidelines and manuals were published in 2019 and four more are currently at advanced stage of preparation, which will make the total 14 manuals & guidelines.

4.2 Emergency Action Plans (EAP)

Under DRIP, safety encompasses all aspects of the health of the dam; from structural repairs or modification to development of Emergency Action Plans (EAPs); all working to reduce risks to downstream population, minimize economic damages and ensure sustainable performance and efficiency of the dams. To date 222 dam breach analysis (DBA) are carried out, 195 EAPs prepared and out of which 185 published. Following preparation of EAPs, stakeholders' consultations are being conducted and 85 consultations have so far been conducted.

Figure 17. Emergency Action Plan (Hirakud Dam)

4.3 O&M Manuals

Operation and Maintenance (O&M) manuals have been prepared as per the latest guideline published under DRIP. O&M manuals for Almatti dam, KaWRD with 26 spillway gates, hydraulic hoisting systems; for Maithon dam, DVC with 12 spillway gates, rope-drum hoisting system and no stop logs; and Ashoknal dam, OWRD with ungated spillway were first prepared as pilot O&M manual to be used as references by dam projects. The O&M manuals is a detailed set of written descriptions with step-by-step procedures for ensuring that the dam is safely operated, frequently inspected and properly maintained. It also includes O&M manual budget that needs to be updated annually. To date 203 O&M manuals have been prepared out of which 200 were reviewed and 146 were finalized and published.

Figure 18. Pilot O&M Manuals

4.4 DHARMA (Dam Health and Rehabilitation Monitoring Application))

DHARMA is a web-based asset management software to support the effective collection and management of asset and health data for all large dams in India. Activities completed to date include development and launch of 7 modules and 2 analysis tools; capture of dam inspection, O&M, instrumentation, investigations and EAP data in Asset Health Module. Overall progress in Data entry is approximately 75% for DRIP dams. In addition, training of over 1000 users in the 9 DRIP Agencies and 4 non-DRIP Agencies has been conducted.

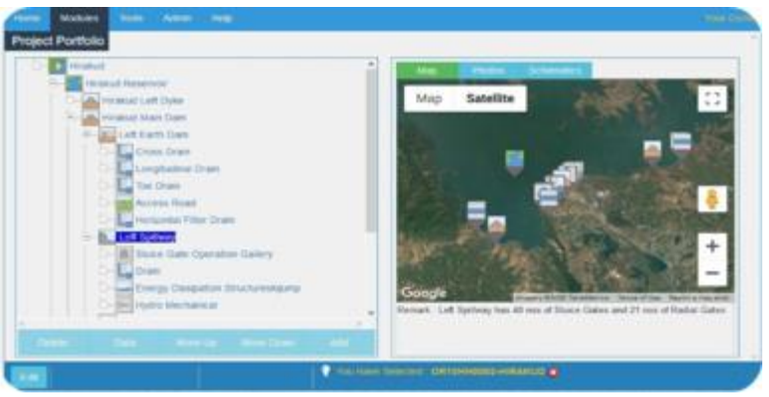

Figure 19. DHARMA Data Entry Platform

4.5 Dam Safety Conferences

Dam Safety Conferences provide a forum for exchange of expertise, experience among dam professionals around the world to address the dam safety concerns and provide an opportunity to learn about the international development in the technology of dam safety management. In the regard, DRIP project successfully conducted two International Dam Safety Conferences (IDSC) in 2018 Trivandrum, Kerala and in 2019 in Bhubaneswar, Odisha as well as three National Dam Safety Conferences (NDSC) in 2015 in Chennai, Tamil Nadu; in 2016 in Bengaluru, Karnataka; and in 2018 in Roorkee, Uttarakhand.

Figure 20. Dam Safety Conferences

5 THIRD-PARTY QUALITY CONTROL

Establishing an effective Construction Supervision and Quality Assurance (CS&QA) system in a Construction Project is most important to ensure that Works are executed with a high level of quality and comply with agreed Contract requirements. In DRIP Project, a three-tier mechanism was used to take care of CS&QA, which is very important for any rehabilitation work. In this case, the Contractor as 1st party is responsible for execution of the Works pursuant to Contract conditions; the Implementing Agency (IA) as 2nd party is responsible for day-to-day CS&QA issues and contract management; and, CPMU has been assigned as 3rd party for CS&QA activities.

In line with this, CPMU conducts regular 3rd party construction site visits (CSV) and quality control tests that play a key role in the successful implementation of the works. To date, a total of 1,092 construction site visits have been conducted to all projects under the 9 IAs. A total of 605 different third-party quality control tests have also been carried out during these site visits with 86% successful results and 14% failed results that were recommended for rectification. Third-party tests include looking at the engineering properties of materials (soil, aggregate, cement, steel, GI wire, etc.), embankment degree of compaction, and concrete tests. The tests on concrete include cube, core and non-destructive tests (NDT).

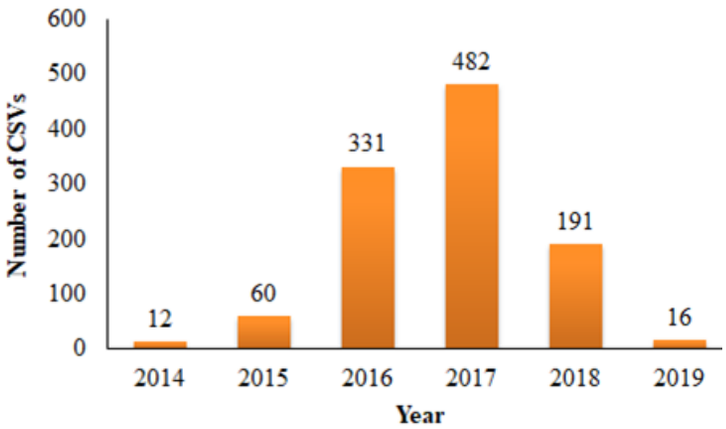

Figure 21. Construction Site Visits (CSVs)

6 LESSONS LEARNT

Over the course of the DRIP the following important lessons have been learnt that will be very useful input for the upcoming 10-year DRIP phase II and III projects.

Preparatory Stage: It needs standardized formats in advance for preliminary proposal submission by

States, DSRP Inspection Report, DSRP composition, Design Flood Review, Project Screening Template and Standard Procurement Document, Empaneled Pool of Experts, continuous training and support by CWC.

Adequate Delegation of Financial Powers: It needs adequate delegation of financial powers up to working levels and field levels to minimize the approval stages and payment stages for fast and feasible execution of rehabilitation activities. The concerned Procurement Committees shall meet minimum once in a month for the approval.

Advance Planning and Approval for High-Risk Rehabilitation Activities: Advance planning is required to take up important rehabilitation activities like de-silting of reservoir, construction of additional spillway. The all investigations, feasibility report, rate analysis to firm up cost, bid document, EIA and EMP approval, R&R activities etc. shall be handled meticulously with rational timelines and desired outcomes.

Resource Identification and Assignment: High end technical activities like dam break analysis, inundation mapping, integrated reservoirs operations, numerical modelling, preparation of EAPs, O&M manuals etc. a technical competent group of officials shall be identified and may be assigned all these activities with appropriate technical trainings to execute these soft activities.

Bankable Tender Preparation: The tender document for any proposed rehabilitation work shall be drafted rationally based on required investigations to minimize cost variation along with feasible Qualification Criteria, Technical Specifications and BQS, payment milestones, completion time etc. to ensure timely completion with minimum litigation matters.

Contract Management Experience: The officials dealing with contract management shall have adequate experience of contract management otherwise it will invite matters related to undue delay in technical and financial evaluation up to contract award, matters related to time extension, cost variation, unreasonable claims by contractor, court cases and arbitrations, etc.

CS and QA Mechanism: In order to ensure that all important rehabilitation works shall be executed as per given technical specifications and bill of quantities to meet the end objectives, very effective Construction Supervision and Quality Assurance (CS&QA) team shall be at three level i.e. contractor, dam owner and CWC to carry out this assignment timely and advise for corrective actions as and when required.

Appropriate Capacity Building: All agencies must give due weightage to various kind of trainings for their staff and officials and it shall be ensured that right kind of training and at appropriate time shall be given to have long term sustainability of their intended objectives for optimum benefits from existing assets.

Monitoring Mechanism: Each Agency must have right kind of monitoring mechanism so that activities can be monitored, and corrective actions can be taken. It is desired that Scheme review shall be done by Principal Secretaries/ CMD monthly to ensure successful implementation of Scheme.

Quality Human Resources in SPMU: SPMU is the single window arrangement at State Level to steer the Scheme. It shall be explored that competent officials shall be posted with good service period alongwith minimum transfer, as these carry the institutional memory to ensure successful implementation of Scheme.