SEEPAGE CONTROL IN MASONRY DAMS WITH MODERN TECHNOLOGY USING INNOVATIVE TECHNIQUES AND EXECUTION METHODOLOGIES : CASE STUDY : THE BHAVANISAGAR DAM, TAMIL NADU, INDIA

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ABSTRACT

Dams have played a vital role in the history of civilization and serve the people from the time immemorial. We know that dams are instrumental and strategic infrastructures in the modern development of Irrigation and Hydropower, besides helping in flood management as well. Tamil Nadu is one of the States in India having significant number of dams and there is a constant need to strengthen and maintain the dams to ensure that Dam structures and systems are properly maintained by regular monitoring and rehabilitation. Hydraulic structures like masonry or concrete dams are normally designed not only to curtail the loss of stored water through seepage, but also to withstand the uplift pressure of water, as it seeps through them. It is well known that no dam can be totally impervious. Dam Engineers need to ensure that the seepage through the dam is well within the acceptable limits. The prime challenges in the maintenance of dams are mainly related with the adoption of innovative technologies, technically & structurally sound maintenance measures besides compliance of economically viable and fully sustainable interventions. The work of rehabilitation and improvement of Bhavanisagar Dam in Tamilnadu has been executed at an estimated cost of Rs.1971 lakh under Dam Rehabilitation and Improvement Project (DRIP) which was funded by the World Bank and monitored by the Central Project Management Unit, CWC. The main scope of this project is to strengthen the masonry & earthen portion of the dam to the fullest extent to upkeep the safety aspects and effective functioning towards sustainable development, which ultimately leads to safeguard and stabilize the cultivable command area and increasing the food production. Rehabilitation to Masonry Dam which includes the upstream face treatment with Poly Ironite Ceramic Cementitious (PICC) mortar utilizing crystalline technology or equivalent cementitious material was carried out in this Project. The outcome of this technically sound intervention with modern technology using innovative techniques and execution methodologies adopted in the rehabilitation work has proved its successfulness in seepage control in the masonry segment of the dam structure.

Keywords *: impervious, innovative technologies, command area, sustainable development, crystalline technology*

1. PREAMBLE

Dams have played a vital role in the history of civilization and serve the people from the time immemorial. We know that dams are instrumental and strategic infrastructures in the modern development of Irrigation and Hydropower, besides helping in flood management as well. They also play a key role in the service domains of drinking water supply, industrial water supply, aquaculture, recreation and navigation to certain extent.

In our Tamil Nadu State, we have already harvested about 97% of surface water by way of construction of major, medium and small dam structures, in addition to the existing and newly created Tank systems. As such, there is no scope in creating megascopic hydraulic infrastructures towards water resources development in Tamil Nadu, except for creation of micro level miniature rain water harvesting infrastructures such as check dams, sub surface dykes, percolation ponds, etc.

In the present context, our prime focus is to safeguard the existing dams, which are considered as the hydraulic temples of modern India, for its enhanced strength and stability towards extending their life span. Since the dams are the lifeline of the irrigation and hydropower systems, up-keeping of these vital structures is the fresh need of the hour.

2. CAUSES OF DAM FAILURES

The incident of failures demonstrates that depending on the type of dam, the cause of failure may be classified as:

- hydraulic failures (for all types of dams)
- Failures due to seepage.

  (i) through foundation (all except arch dams)

  (ii) through cracks/joints failures in upstream side of masonry Portion

  (ii) through body of dam (embankment dam)
- Failures due to stresses developed within structure.

3. REMEDIAL MEASURES FOR SEEPAGE IN MASONRY DAMS

- *Geo-membrane* - jacketed with geo-membrane
- *Guniting* - flowable concrete is pressed on u/s surface. Guniting appears to have an edge over pointing, as work is quicker and management of quality control is better. But guniting shall not be considered as a preventive measure and can be considered as a remedial measure since it acts as an additional line of defense.
- *Upstream face treatment* -In pointing process, voids in between the stones are first filled with stone chips by placing cement mortar as binding material, the joints are filled with mortar extending on both sides of joint. Damaged/ deteriorated pointing should be repaired with modified repair mortars like epoxy mortar, polymer modified mortar etc.

4. APPROACH TO REHABILITATION PROBLEM

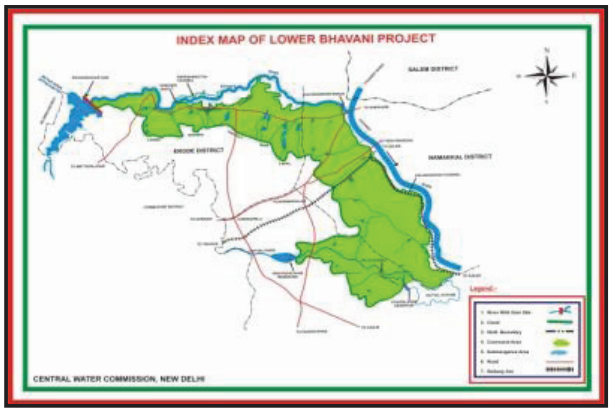
- Identification of cause of damage/distress
- Estimation of short and long term effect of the distress on the structural safety.
- Planning of rehabilitation program to ensure the continued project benefits.
- Pre application studies in laboratory for selection of suitable material.
- Carrying out the actual rehabilitation work.

In this paper, a case history of Lower Bhavani Project Dam (Bhavanisagar Dam), Tamil Nadu, India was taken wherein the seepage controlling technique method was followed and done using the methodology of "Upstream Face Treatment of Masonry Dam"

5. ABOUT THE PROJECT

The Lower Bhavani Project (LBP) is the first major Irrigation Project executed in India after independence. It was executed during 1948 -1955 at a cost of about Rs.1034 Lakh in the first Five Year Plan. The Bhavanisagar Dam is the largest Earthen Dam of its kind in the Tamil Nadu State measuring 8780 meters in length, in which Masonry Spillway Structure for a length of 464 meters is located in the river bed portion. The Bhavanisagar is the second largest reservoir in Tamil Nadu with a water spread area of 75.35 Sq.KM and a storage capacity of 929 Million Cubic Meters (32.80 TMC-ft).The Bhavanisagar Dam is constructed across the Bhavani River just below the confluence point of River Bhavani and River Moyar and located in the Erode District at about 16 KM west of Sathyamangalam Town and about 36 KM North-East of Mettupalayam Town, through which an extent of 1,00,060 Ha of irrigated command area is getting benefitted now.

The masonry dam which is located in the central portion of the dam across the river for a length of 464M and 62.18 M from the lowest foundation level consists of ogee curve spill way section of 120.70M in profile length for discharging surplus water to a depth of 6M over the spill way crest. In the masonry portion, a drainage gallery of size 1.52 x 2.13 M has been provided with three Exits, two on the left and right flanks and the third at the center portion adjacent to the guide wall separating the spillway and the river sluices. These galleries facilitate inspection inside the dam, besides enabling further maintenance. Three numbers of V notches are provided in the drainage gallery at various sill levels for



monitoring the seepages.

Figure 1 : Location Map

Figure 2 : Aerial view

Figure 3 : Front view

6. REHABILITATION OF BHAVANISAGAR DAM

Tamil Nadu is one of the States in India having significant number of dams and there is a constant need to strengthen and maintain the dams to ensure that Dam Structures and Irrigation Systems are properly maintained by regular monitoring and rehabilitation.

The prime challenges in the operation and maintenance of dams are mainly related with the adoption of innovative technologies, technically & structurally sound maintenance measures besides compliance of economically viable and fully sustainable engineering interventions.

Hydraulic structures like masonry or concrete dams are normally designed not only to curtail the loss of stored water through seepage, but also to withstand the uplift pressure of water, as it seeps through them or through their foundations. While the water seeps the built up structures, it gradually erodes the material of the construction even modifying its chemical composition to some extent, and may create voids, thereby rendering it structurally unsafe over time and leading to increasing water loss. (Mohanakrishnan, 2010)

It is well known that no dam can be totally impervious. Dam Engineers need to ensure that the seepage through the dam is well within the acceptable limits. If seepage measured is high, in order to maintain the dam against the ill effects of excessive seepage, suitable remedial measures need to be taken on priority basis.

The Government of Tamil Nadu has accorded Administrative Sanction for the work of Rehabilitation and Improvement of Bhavanisagar Dam in Sathyamangalam Taluk of Erode District at an estimated cost of Rs.1971 Lakh under Dam Rehabilitation and Improvement Project (DRIP) which was funded by the World Bank and monitored by the Central Project Management Unit, Central Water Commission, India.

The main scope of this project is to strengthen the masonry & earthen portion of the dam to the fullest extent to upkeep the safety aspects for a sustainable development and effective functioning which ultimately leads to safeguard and stabilize the cultivable command area and increase in food production.

In the above rehabilitation project, works such as rehabilitation of chutes and parapet walls, rehabilitation of service roads and dam bund roads, upstream face treatment work to the masonry portion, renewal and repairs to Hydro Mechanical components, up gradation of electrical installations etc., have been taken up for execution.

7. REHABILITATION TO MASONRY DAM

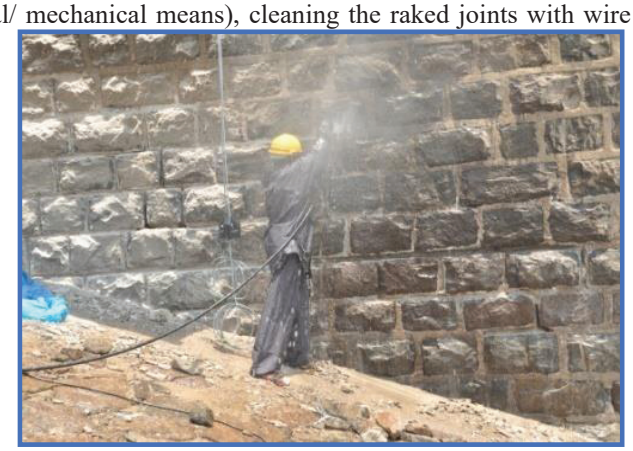
Rehabilitation to Masonry Dam which includes the upstream face treatment with Poly Ironite Ceramic Cementitious (PICC) mortar utilizing crystalline technology or equivalent cementitious material was carried out in this Project. This treatment comprised the following work components as narrated below.

A. Reaming

Reaming (i) the existing vertical shaft of 200 mm dia by rotary drilling from dam top to the drainage gallery level and (ii) the existing vertical drainage shaft of 200 mm dia inside the drainage gallery using sophisticated machineries, equipment, consumables, cleaning the drainage shafts, etc. complete complying with standard specifications

B. Surface Preparation

Raking out the horizontal and vertical joints of RR masonry in the upstream face of dam to remove all the loose pointing using hand grinding machine with diamond wheel (manual/ mechanical means), cleaning the raked joints with wire



brush followed by compressed air and water jets with variable pressure of 30 – 250 bars, drying the raked joints.

Figure 4 : Surface Preparation- During Execution

Figure 5 : Surface Preparation (Water Jet)- During Execution

C. Cavity Filling

Providing and filling the deeper cavities of the RR masonry which are beyond 5 cm and up to 18 cm using non-shrink, cementitious micro concrete mixed with water at ratio 0.16 to fill the gaps where normal access is restricted and to achieve proper compatibility and placement without vibration. The micro concrete shall contain no-chloride admixture and provides minimum compressive strength of 40 N/mm² in 7 days & 50 N/mm² in 28 days when tested in 70.7mm

cube. The product shall have controlled expansion characteristics of 1 to 4% when tested as per ASTMC 827 – 1987.

Figure 6 : Application of cavity Filling- During Execution

D. Injection Grouting

Treating the internal cavities up to 1metre deep in the RR masonry using injection pressure grouting by drilling hole of 25mm dia and 300mm deep in triangular pattern at inclined position. Fixing PVC nozzles of 12mm dia& 200mm deep using quick setting cement. Mix OPC 43 grade cement with water in ratio 0.35 - 0.4 as per the consistency required and by adding polymer rubber based latex @ 1 liter per bag of cement and plasticized expanding non shrink grout admixture @ 225 grams per bag of cement and grouting the same by using 2.812 kgf/Sq.cm (40 psi) grouting pump. The grouting

material shall give minimum compressive strength of 35 N/mm² in 28 days when tested in 10cm cube. On completion

of grouting, the top portion of the PVC pipe shall be cut and sealed with cement putty.

Figure 7 : Drilling Hole- During Execution

Figure 8 : PVC Nozzle Insertion- During Execution

Figure 9 : Water Permeability Test- During Execution

Figure 10 : Cement Grouting Test-During Execution

E. Application of Pointing Mortar

Providing and filling the pointing mortar in the horizontal and vertical joints of RR masonry in the upstream face of Dam to an average depth of 2 times the thickness of joint, (25mm thick and 50mm depth) by applying a priming coat with solvent free epoxy bonding agent inside the joints with a brush and filling properly these joints with "shrinkage controlled non shrink, abrasion resistant, UV resistant, polymer modified cementitious high specification repair mortar system" mixed with water in the ratio of 0.16, which should prove fully adequate and will give compressive strength of minimum 45 N/mm² in 7 days & 70 N/mm² in 28 days; tensile strength of minimum 4 N/mm² in 28 days; flexural strength of minimum 9 N/mm² in 28 days, permeability less than 5mm, Water Absorption less than 2%, Rapid Chloride

permeability < 1800 coulombs and nicely pointed. On completion of the pointing treatment, a single component

transparent silicone based repellent coating is provided as a sealer coat by brush or spray application.

Figure 11 : Epoxy Pointing Coat- During Execution

Figure 12 : Application of Pointing Mortar- During Execution

Figure 13 : Application of Pointing Mortar - After Execution

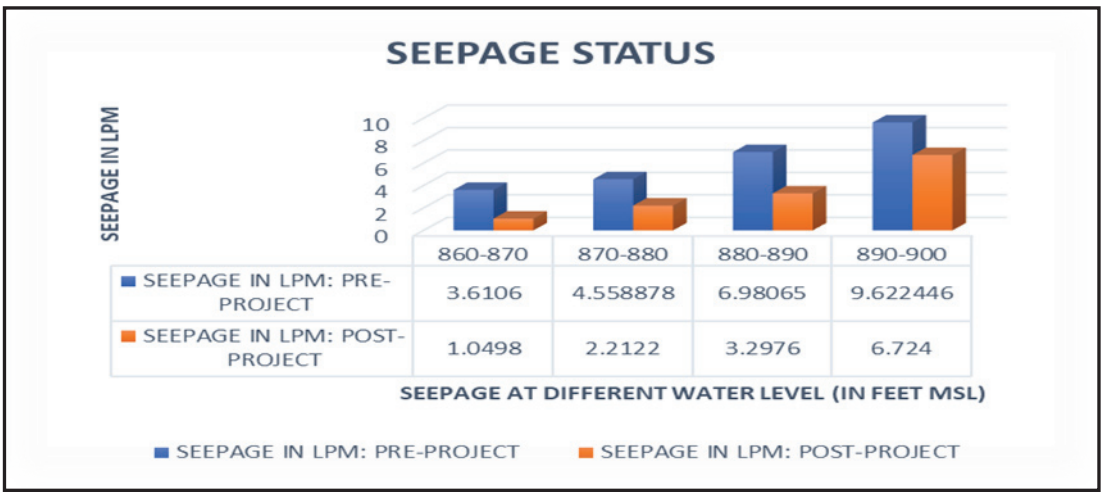
Figure 14 : Application of Pointing Mortar - After Execution

8. CONCLUSIONS

The dams are national property constructed for the development of the national economy. The safety of the dam is a very important aspect for safeguarding the national investment and the benefits derived by the nation from the project. In addition, an unsafe dam constitutes a hazard to human life and property in the downstream reaches. The safety and health of the dams and their appurtenant structures are important aspects to be focused for ensuring public confidence in the continued accrual of benefits from the national investment made as well as to protect the downstream area from any potential hazard. (CWC, CDSO, 2017)

As the dams being the strategic infrastructures of national importance, the present engineering community is developing knowledge in the construction and maintenance management with respect to updated technical and practical perspectives. The rehabilitation carried out to the masonry dam which includes the upstream face treatment with Poly Ironite Ceramic Cementitious (PICC) mortar utilizing crystalline technology or equivalent cementitious material seems to be a technically sound intervention.

The embedded modern technology using innovative techniques and execution methodologies has proved its successfulness



in seepage control in the masonry segment of the dam structure, to a tune of 30% – 71% reduction of seepage at different storage levels.

Graph : Seepage Status before & after Rehabilitation

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