MODERNIZATION, OPTIMIZATION AND REHABILITATION OF AGEING DAMS

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ABSTRACT

Major rural population of the Telangana state depends upon agriculture and cattle, which necessitates construction of storage reservoirs. There are certain dams, that have been constructed and functioning over 100 years. Storage dams are playing vital role in providing the range of economic, environmental, and social benefits, including recreation, flood control, water supply, hydroelectric power, waste management, river navigation, and wildlife habitat. As the dams are ageing it is prudent to adopt modern technologies for rehabilitation of these dams for their effective and optimum functioning.

1. INTRODUCTION

As per the studies carried out, generally dam failures occur during construction, or initial filling stage. During operation of existing dam, its structural components are subjected to deterioration in course of time. Each dam has unique characteristics based on its design, construction, location and Geological features. As such that every component of dam will age at a different rate in a distinct way. Some dams may remain safe for above hundred years, others may start to deteriorate even less than a decade. The average age of dams in India is now around 40 years. According to a panel on dam ageing at ICOLD's 1991 Congress, "In future attention and activity will be more and more shifted from the design and construction of new dams to the restoration of the structural and operational safety of existing dams and optimization of system".

In Telangana state, there are 184 large dams of different ages given in the table.

Age	Numbers
Above 100 years (before 1920)	18
76-100 (1921 t0 1945)	15
51-75 (1946 to 1970)	20
26-50 (1971 to1995)	23
Up to 25 years (1996 to 2006)	7
Not available	77
Under Construction	20

Source: As per NRLD

2. AGEING OF DAM

During the dam life cycle, it can be threatened by natural phenomenon such as floods, earthquakes, rock slides and deterioration of heterogeneous foundations and construction materials. In the course of time, the structure may take on anisotropic characteristics, leads to internal pressure and paths of seepage from the dam. Usually the changes are slow and not readily discernible by visual examinations.

Ageing naturally happens during the life time while performing the intended functions at desired levels, Presently, Dams in India are getting older in large number and chance of failure is expected to be in a climbing order, this requires future attention and activities for restoration of the structural and operational safety of existing dams and optimization of system.

3. EFFECTS DUE TO AGEING

The major causes of Dam failure are foundation failure, over topping, inadequate spillway, poor construction, uneven settlement, high pore pressure, embankment slips, defective materials, earthquakes, incorrect operation. Further, ageing of Dams are noticed in the form of displaced Riprap, Cracks in embankments, cracks in concrete, choking of drainage holes in dam body/ galleries, erosion of concrete in the spillway downstream.

4. EVALUATION OF AGEING DAMS

Evaluation of ageing is done by monitoring the effects and consequences of changes in structural properties and the action causing them with the implementation of Modern technologies, such as RO Vehicles, SCADA, and instrumentation. A well planned and performed monitoring program will help in early detection of ageing scenarios and provision of convenient access to all vital areas of the dam will enhance surveillance and regular maintenance.

Regular operation and maintenance as well as thorough and consistent inspection must be practiced throughout the lifetime of a dam. In addition to maintaining proper function, cost efficiency, and compliance with safety regulations, such habits can lead to the early detection of deficiencies and prevention of failure. Continuing these management activities is a simple way to extend the useful life of a dam provided a detailed Operations and Maintenance (O&M) Program that includes routine.

Evaluation program shall include the main phases of a risk assessment process: Identification of Failure Modes and Semi-Quantitative and Quantitative Risk Assessments. Risk estimations are finally used to support decision making on allocating resources for rehabilitation actions and new studies or instrumentation.

5. CONSTRAIN FOR NEW DAMS

In view of the present scenario, environmental challenges and land acquisition constrains for construction of new dams, it is inevitable to protect, maintain and rehabilitate the existing aged dams to function for the intended purpose.

6. DAM INSTRUMENTATION

Instrumentation plays a fundamental role in understanding the foundation and structural behavior both during construction and in operation of dams. A monitoring program provides the information that is necessary to develop a better understanding of the performance of the dam to reassure dam owners that the dam is performing well and to detect changes in the dam's performance. This is critical as the dam owner is directly responsible for any consequences of a dam failure. With this information, dam owners can maintain their ability to safely operate their dams.

The means and methods available to measure phenomena that can lead to dam failure include a broad spectrum of instruments and procedures, ranging from simple to complex. Any program of dam safety instrumentation must be properly designed and be consistent with all project components including prevailing geotechnical conditions at the dam and considering revised hydrologic and hydraulic factors present both before and after the project is in operation.

7. CONTROL MEASURES

Prevention and mitigation of ageing shall be achieved through periodical inspections, collection and analysis of the instrumentation data at regular intervals and conducting non destructive investigations to evaluate the condition of existing dams.

Good practice in terms of monitoring the behaviour of a dam should comprise the following as a minimum:

- Sufficient monitoring equipment in good order to be provided to allow a basic understanding of the behaviour of the dam.
- Measurement data to be carried out daily and regularly evaluated.
- The dam should be inspected regularly and independent advice should be called for when unusual behaviour is noted.

8. ROLE OF STATE DAM SAFETY

As an advisory body, the state dam safety officers along with experts shall be conducting periodical inspections for all the large dams in the state. Health reports of all the dams and emergency action plans for the dams are being prepared. Remedial measures for the distressed conditions of the dams reported are being suggested and implemented.

Generally, the earthen dams are subjected for settlement, longitudinal and transverse cracks, seepage on downstream, piping through foundation, sand boils. As an example, seepage through the embankment of earth dam pertaining to Akkampally balancing reservoir and Mid Manair reservoir are studied and remedial measures are suggested.

9. CASE STUDY 1

Akkampally balancing reservoir is located in Akkampally village ,Nalgonda district of Telangana state .The source of water for AKBR is from foreshore of Nagarjuna Sagar Reservoir, water is being lifted from +145.00 via Puttamgandi pump house to delivery cistern (+ 248.00) with a head of 103m. AKBR reservoir is filled up through a link channel by gravity. The main purpose of AKBR is to pump water to the Hyderabad city for its water needs, in addition to the ayacut of 2.7 Lakh acres. (refer Drawing No. 1)

AKBR is an earthen dam 4990m long with maximum height of 22 m in deep gorge portion. The reservoir was constructed in 1996 and has a storage capacity of 1.5 TMC with 4 vents of size 6.0X 2.5 m to discharge 500 cusecs water daily. The controlling levels provided in the reservoir are FRL +245.00, MWL+246.00 and TBL + 249.00.

9.1 Earth Dam Section (Refer Drawing No. 2)

The earth dam was designed as a homogeneous section with clayey sand (SC) type of soils along with upstream slope. The earth dam has been provided 1 m thick vertical & horizontal sand filters along with 0.45 thick upstream riprap, 0.2 thick metal & 0.3 thick sand inverted filters to dissipate upstream pore pressures incase of drawdown conditions. Stability analysis has been carried out as per BIS: 7894 1978 and the required section was adopted, the profile of dam section is enclosed in annexure. It has a head regulator @ KM. 1.403 and has a water spread area 5.915 sqm.

9.2 Distress Noticed

The major distress noticed in the AKBR project is the seepage problem, which has started since 2016 and efforts are made to overcome it. The seepage has appeared on downstream berms and slopes with an increase in the water level above +242.00m, where there is no sign of seepage when the reservoir level is at +238.00m and below i.e., MDDL. Slushy conditions are appeared on the 2nd berm +235.00 with water flowing through the chute drain. Chute drains are under dilapidated conditions and deep rooted vegetation on upstream and downstream side of the earth dam are observed.

9.3 Challenges

The main challenge in front of SDSO team was that, without depleting the reservoir remedial measures have to be taken up, as this is a source of drinking water for HMWSSB, Hyderabad and for the Nalgonda district.

9.4 Investigation Carried Out

The Expert team from the dam safety organization has inspected in 2016 and suggested to carryout Geophysical investigations to find out seepage path, location, wet patches and cavities inside the earth dam.

Accordingly, the geophysical investigations are carried out, for detecting seepage paths and location inside the earth dam without disturbing or depleting the upstream water level. It was found that the saturated zones have started from EL 240 and extend all the way down to full dam body extent. The resistivity imaging and streaming potential methods are used for the investigations. The results was categorized zone wise i.e., Zone-I(dam top location) ,Zone –I(Ds location), Zone -2 (dam top location) ,Zone –2(Ds location). This is useful in identifying the location, path of the problem in earth dam.

9.5 Remedial Measures

The following remedial measures were proposed based on the above investigations and Site inspections (Refer Drawing No.3):

1. HG line based on seepage levels is arrived as around 1 in 6 at FRL and for this a 500 mm thick sand filter in d/s profile after stripping up to 500 mm thick ,thus totally 1000 mm thick to bring HG Line well within the body of the earth dam.
2. The berm width has been increased to 11.0 m in addition to the existing berm of width 5.0 m at first berm level +242.00.
3. The berm width has been increased to 7.5 m from 7.0 m at second berm level +235.00 along with a rise in berm level to + 238.00.
4. By Heightening the rock toe from existing level of +229.700 to +233.45 i.e., height of 3.6m, so as to impart more stability and also to drain seepage water.
5. To provide a 300 mm thick riprap over 200 thick graded metal and 200 thick graded sand, to protect against rain / wind in lieu of proposing turfing.
6. Turfing is proposed on the downstream slopes of the embankment to protect from slippage.

9.6 Present Status of the Earth Bund

The strengthening works are under progress with the above recommendations to minimize the seepage.

10. CASE STUDY : 2

10.1 Introduction

The Mid Manair reservoir (MMR)is the balancing Reservoir on Flood Flow Canal from SRSP at km.122.00.The reservoir is proposed across Manair river connecting Manwada(V) , Boinpally(M),on left side and Kandikatkur(V),Illanthakunta(M) on right side. The MMD was constructed with a water storage capacity of 25.873 TMC. Mid Manair Reservoir receives water from SRSP-FFC & also from Kaleshwaram Lift Scheme, will be supplied to Lower Manair Dam for drinking and irrigation needs of Karimnagar district and to united Warangal, Medak and Ranga Reddy districts. The MMR is renamed recently as Sri. Raja Rajeswara Reservoir.

10.2 Reservoir Particulars

Mid Manair is a balancing reservoir with TBL +323.000 M, FRL +318.000 M, MDDL +309.900 M, T.W.L. + 294.500 M, Free board 5 mts., Earth bund (L/S)=5.4765 Kms, NOF & Spillway 0.555 Kms, Earth bund (R/S) 4.6185 Kms, L/S Guide Bund (D/S) is 650 M, R/S Guide Bund (D/S) is 650 M, filter:1.50 m thick inclined sand chimney filter adjacent to hearting on d/s side. 1m thick horizontal sand filter on d/s side.

10.3 Distress Noticed

FRL of the reservoir is +318.00m, TBL of the reservoir is +323.00m .While impounding the reservoir with water (first filling of the reservoir with pumped water of Kaleshwaram scheme), when water level is at +312.0 m, it was observed that there is some seepage & sand boils occurred along with piping on d/s side in the toe drain & also at 10 to 30 mts away from the d/s toe of the earth dam in the reach between KM 2.450 to KM 2.700. Stripped level is around +299.0 m at that location. Height of the water column at the time of leakage / piping is around 13 mts. The water emanating on the d/s side is turbid (Photograph:7) .

10.4 Challenges

The main challenge in front of Engineers is that, in view of urgency expressed with a view to fill the reservoir at the earliest, remedial measures have to be taken up immediately with the available information, as this is an important reservoir which will feed many reservoirs which in turn serves lakhs of acres of ayacut & also caters the needs of drinking water to many districts.

10.5 Investigations carried out

The site has been inspected by Senior Engineers to assess the situation for suggesting suitable measures on top priority. During inspection, it was informed by the local people that previously there was a stream crossing at that location. The water level in the reservoir was depleted to +301.500 m to reduce the seepage & piping effect on d/s side. Preliminary field investigations reveals that there is an overburden clayey layer of around 4 mts followed by 1m to 1.5m thick (clay + lime) band and further followed by murrum / SDR.

The seepages in Toe drain measures with V-notches located at 2.497 Km and 2.532 Km every day during filling and are well within the limits at +301.500m.

To have an expert opinion on prevailing slushy condition upto 100mtrs D/s of the Toe drain from Km.2.450 to Km.2.700, expert committee along with the Geo - Technical professor from NIT have visited the site and suggested preliminary measures of providing Relief wells at suitable location and further suggested to carry out the geophysical investigations with an expertise agency to analyze the problem for taking up suitable remedial measures from Km.2.450 to Km.2.700 at possible locations.

10.6 Field Observations

The sub strata in the D/s side are exhumed along with the Toe drain in order to ascertain the extent of soft seam below the bund. Form these excavations; it is observed that the soft seam is present within the toe drain only. The open pit excavations made at about 10m from the outer end of the toe drain within the bund revealed that the substrate is stiff and no soft seams are noticed.

10.7 Remedial Measures

The Committee after studying the Geo Physical investigations and Sub Strata condtions, the following remedial measures are proposed:

1. New positive cut off trench at a distance of about 20 mts from the u/s toe of the earthen dam along with curtain grouting if required into rock based on site conditions is suggested .Clay blanket of 1.0m to 1.5m thick connected to positive cut off shall be laid upto 100 mts from the u/s side toe of the earth dam. If the clay strata already exists on the u/s side, gaps if any remaining shall be filled with clay blanket of 1.0m thick 30cm thick gravel/random material shall be laid over the clay blanket .The C.O.T. keyed into 1.0m continuous impervious strata or hard impervious rock. This is to minimize or avoid any seepage to the main C.O.T.as per site conditions.

2. Grouting is to be carried out from the TBL into the existing COT with cement & Bentonite. The curtain grouting shall be in the rock below the existing COT to strengthen and to arrest any seepage through fissures or joints which may have developed after the construction of earth Dam.
3. Trench of 22mts x 5Mts x 250 mts. filled with GW/SP/SW with filters of 500 mm thick graded metal & 500 mm thick graded sand is proposed as a part of soil stabilization near d/s toe after removing the existing slushy soils and function as a additional filter.
4. New rock toe along with toe drain etc shall be constructed utilizing the material from the existing Rock Toe which would be removed.
5. 150m dia vertical sand drains at 6mts c/c staggered shall be proposed on the existing d/s base width of the connected to the horizontal filter to relieve inbuilt pore pressures.
6. Existing berm at +311.000m is increased by 5m and a loading berm of 5m is proposed at +306.00m.This is proposed to nullify any expansive action of the foundation soils.

Based on the above remedial measures, the Chief Engineer, Central Design Organization has issued drawings and accordingly the execution is carried out.

11. PRESENT STATUS OF THE EARTH BUND:

With the above remedial measures action has been taken up and work is completed to arrest the seepage and reservoir is filled up to the F.R.L, presently maintaining regular watch and ward at that distressed section.

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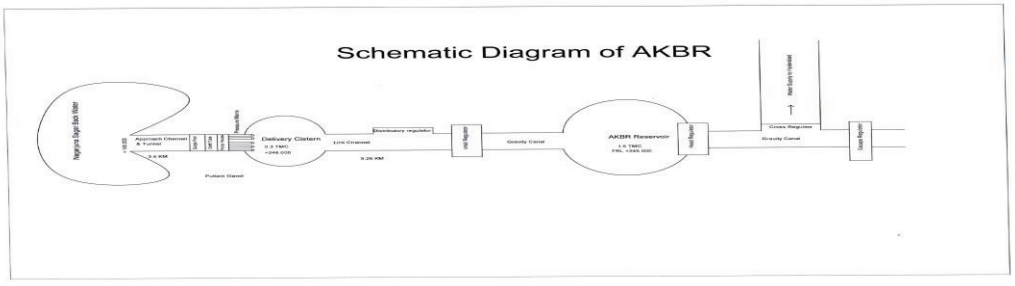
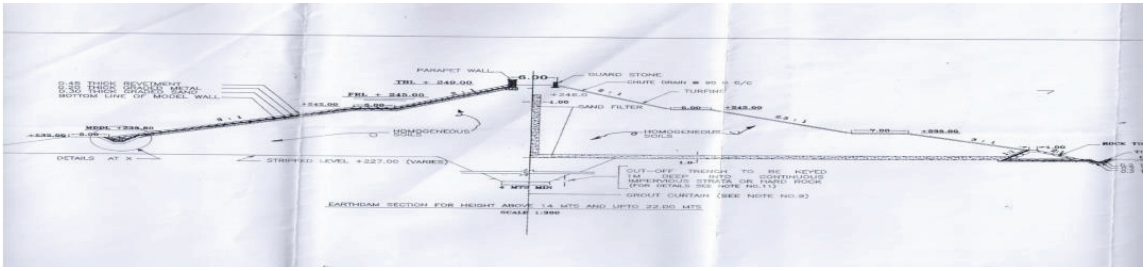
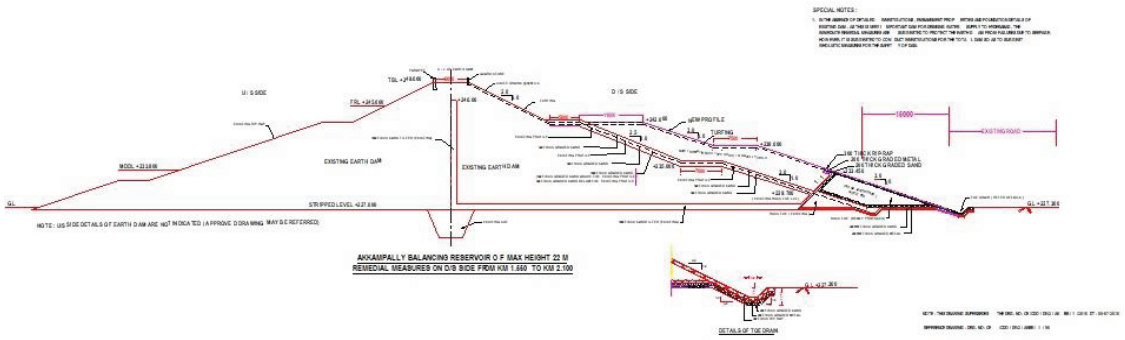
ANNEXURES



Drg. 1 : Schematic Diagram



Drg. 2 : Existing Earth Dam



Drg. 3 : Downstream Remedial Measures, Site Photographs during Execution:

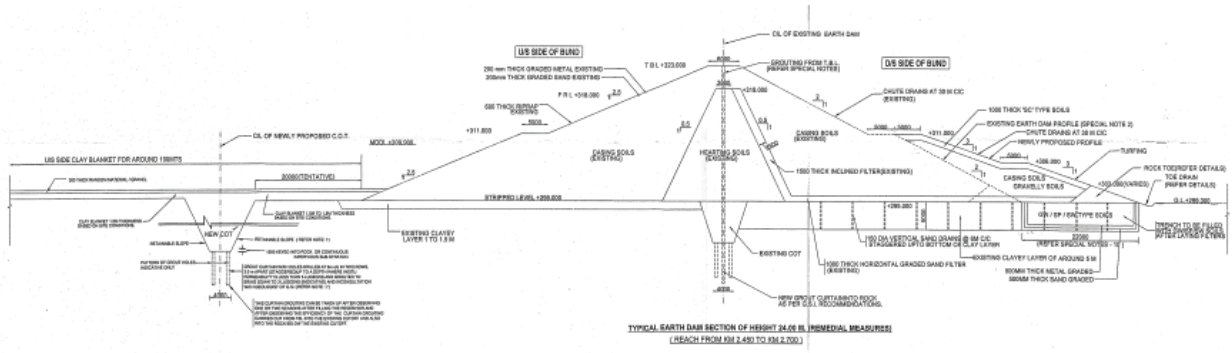
Photograph 1

Photograph 2

Photograph 3

Photograph 4

Drawing showing the Remedial Measures for Mid Manair Reservoir in the Reach from Km.2.450 to 2.700



Photograph 5

Photograph 6

Photograph 7

Photograph 8