A comprehensive insight into Warna dam's instrumentation

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Abstract:
Instrumentation in the dam is essential because it monitors the dam's health during construction, operation as well as maintenance phases and gives early warnings if any problems occur. It ensures the dam's secure running and functionality which results in financial gain and increased public safety. This paper is focused on the limitations of existing instrumentation on Warna dam and finding out the solutions for those limitations according to standard guidelines of Central Water Commission given about minimum desirable instrumentation and advancements in instrumentation. This was done by investigating existing records of the dam. From the detailed investigation of instrumentation, it is found that seismometers are not installed in the dam body. Therefore, the installation of seismometers that come under minimum desirable instrumentation is proposed. Also, it is necessary to update all the instruments except the automatic water level recorder, meteorological instruments, v- notches. It is also recommended to install data loggers and an automatic data acquisition system.

Keywords: *Instrumentation, dam, Embankment, piezometers, Seismic, safety*

I. Introduction:

Instrumentation is the utilization of specialized equipment to collect essential scientific observations of designed behavior. Retaining water securely is a dam's main function. The reservoir, however, during the monsoon period, could endanger people and property in the downstream area. Gradually growing structural strain within a dam and its base is the reason for the disastrous failure of a dam. With the proper instrumentation, a surveillance plan can identify signs of dam distress. Utilizing specialized equipment to collect vital scientific observations of designed behavior is known as instrumentation.
Gradually growing structural strain within a dam and its base is the reason for the disastrous failure of a dam.

A decent dam safety program should focus on an efficient instrumentation and tracking program, as well as routine inspection. Benefits can only be realized if the instruments are reliable, data are collected, processed, and analyzed quickly, and values are compared to known design parameters and past performance. Numerous kinds of instruments can be used to gauge the physical factors required to assess the performance and safety of dams.

Even though only a small percentage of dams experience issues, it is difficult to know which ones will due to the highly unpredictable nature of the structures and the countless possible variations in environmental factors that could influence the safety of a dam or ancillary structures. Consequently, any dam that may have an impact on public safety should have fundamental instruments to inspect vital signs.

The majority of the instruments on the Warna dam need to be updated due to their non-functionality. Therefore, it is important to analyze the existing condition of instruments and determine which are needed to install based on the limitations of existing instrumentation. It is also necessary to install data loggers for effective data collection. A different option to manual readings for dam safety monitoring is the use of data loggers.

II. Methodology:

Warna dam is a composite dam having an Earthen Dam of 837 M. and a Masonry dam of 743 M (including a spillway). It comes under the Warna irrigation project which is a major project under construction across the Warna River in Krishna Basin near Chandoli Village in the Sangli district of Maharashtra.

Salient features of dam :

1. Name of dam: Warna dam
2. Name of river: Warana river
3. Location:
   Near village: Chandoli
   Tal. Shirala
   Dist. Sangali
4. Catchments Area:
   A. Main Dam: 301 Sq.km.
   B. Pick up weir: 88.91 Sq.km.
   C. Average annual precipitation: 762 mm
5. Dam & Reservoir:
   A. Gross Storage: 974.188 Cumec
   B. Live Storage: 779.348 Cumec
6. Type of Dam: A. Main Dam: Earthen Dam in the gorge with gated spillway on Warana river And Masonry dam on left and right sides with canal gates
7. Height of Dam:

From River Bed	From foundation
77 m	88.80 m

8. Length of dam:
   a) Earthen dam: 837 m
   b) Masonry dam: 743 m
   c) Total length: 1580 m
9. Spillway:
   Gated spillway having 4 numbers of radial gates of size 12m X 8m
10. Outlets
   a) Low-level irrigation outlet: The layout consists of four openings each of size 1.80 m X 2.40 m each converging into separate conduits of size 1.80 m X 4.00 m
   b) High-level irrigation outlet: The layout consists of three openings each of size 1.9 m X 2.40 m. Each opening converges into a separate conduit size of 1.9 m X 3.1 m
   c) River outlet: It is provided with a single opening of size 1.53 X 2.13 m
   d) Right bank irrigation outlet: The pipe conduit of diameter 600 mm conforming to grade 1 is provided
   e) Emergency gate: On the upstream end a bell mouth opening of size 0.9 m X 0.9 m is provided in which the emergency gate is fixed which will be operated by screw stem hoist arrangements
   f) Power outlet: Warana Irrigation project envisages the construction of a powerhouse for the generation of elastic energy. The total installed capacity is 16 MW. (Two units of 8 MW each)

   The size of the intake is 4.6 m X 6.95 m bell mouth in shape which further joins a circular penstock of 4.6 m diameter trash rack arrangement in two bays provided at the upstream face of the opening.
11. Canals:
   a) Main canal:
      Length = 26 km
      Discharge= 56.10 Cumec
   b) Left bank canal
      Length= 70 km
      Discharge= 30.47 Cumec
   c) Right bank canal
      Length=117 km
      Discharge= 24.86 Cumec
      12. Command area= 4772 hectares

Table number 1: Existing instrumentation on Warna dam

Name of instrument	No. of instruments proposed			No. of instruments installed	Functional status
	R.D.10 00 M	R.D.6 35 M	R.D.10 00 M	R.D.635 M	
1) Embankment type piezometer (Twin tube)	50	21	50	21	Non-functional
2) Foundation-type piezometer (Twin tube)	12		12		Non-functional
3) Pore pressure transducers.	26	12	26	12	Non-functional
4) Earth pressure cells	18	5	18	5	Non-functional
5) Casegranda type piezometer	4	7	4	7	Non-functional
6) Inclinometer	3	3	1		Non-functional
7) Seismometers	5			5	Functional
8) Automatic water level recorder	1			1	Functional
9) V-notches	16				Functional

Table number 2 : Meteorological instruments onWarna dam

Sr. No.	Name of the Meteorological instruments	No	Location	Since when installed	Current status (in working condition or not)
1	2	3	4	5	6
1.	Rain gauge on Dam (Ordinary)	1	D/s. of Dam	June 1975	Yes
	Rain gauge in the catchment (ordinary)	3	Dhalake, Dhangarwada & Patharpunj	June 2003	Yes
1.	Rain gauge on Dam (Self-recording)	1	D/s. of dam	June 2003	Yes

2.	Rain gauge in the catchments (self-recording)	3	Dhalake, Dhangarwada & Patharpunj	June 2003	Yes
3.	Pan evaporate meter	1	D/s of Dam near Chandoli (Bk.)	1985	Yes
4.	Wind velocity recorder	1	D/s of Dam near Chandoli (Bk.)		Yes
5.	Wind direction recorder	1	D/s of Dam near Chandoli (Bk.)		Yes
6.	Wet and dry bulb thermometer (For humidity)	1	D/s. of the dam near Chandoli (Bk.)	1985	Yes

Table number 3: Parameters measured by respective instruments

Serial number	Instruments	Parameters
1	Embankment type piezometer	Pore water pressure
2	Foundation-type piezometer	Uplift and Pore water pressure
3	Pore pressure transducers	Pore water pressure
4	Earth pressure cells	Uplift pressure
5	Casegranda type piezometer	Groundwater pressure and soil pressure
6	Inclinometer	Foundation movement, soil settlement
7	Seismometers	Dynamic loads
8	Automatic water level recorder	Water level
9	V-notches	Seepage

III. Results:

The premises of Warana dam lies in Zone IV. As the catchment is close to Koyana and From from the experience Koyana earthquake, the authorities have established five seismological stations at Waranawati, Kokrud, Sakhrpa, Marathwadi, Chikhali to monitor seismic activities. These seismic instruments identify the average seismic activity, epicenter, and intensity of earthquakes.

Scientists who are examining the seismic activity caused by the Koyna-Warna lakes, which are 165 kilometers from Pune and close to Karad, have found that the epicenters of recent tremors are moving southward and focusing on the vicinity of Warna reservoir. However, it has been discovered that in recent decades, the majority of earthquakes with an origin at a depth of 2–8 km have been moving from the Koyna reservoir to the Warna reservoir. This could be a sign of the faultline shifting in that direction. (Marar, 2017)

The project area is prone to seismic activities, a fact known since the design stage of various components of dam.

Out of the 5 seismological lab sites, only two labs of seismology are operative.

1. Seismometers over the sites are too old.
2. They are analog-type and operated on a battery source.
3. There is no trained staff to handle these Seismometers.

- At least four seismometers should be set at the dam's abutment, crest, and foundation, and at a free position at least three to four times the dam's height. (Central Water Commission, Ministry of Water Resources, River Development & Ganga Rejuvenation Government of India, 2018)
- Seismic instruments aren't installed in the dam.
- Foundation piezometers, Embankment piezometers, Casagrande piezometers, Earth pressure cells, Inclinometers, Pore pressure cells, Uplift Pressure cells are non-functional. (Government of Maharashtra, Water Resource Department, 2021)
- These instruments are installed during years 1980 to 1990. (Maharashtra Krishna Valley Development Corporation, Water Resource department, Pune, Government of Maharashtra,2013)

If no major flaws are found, upgradation of the monitoring system every 10 to 15 years needs to be done. (Central Water Commission, Ministry of Water Resources, River Development & Ganga Rejuvenation Government of India, 2018)

Casagrande piezometer, Earth pressure cells, Inclinometer, Pore pressure cells, Uplift Pressure cells are non-functional and need to be updated.

Hydraulic twin-type piezometers i.e., Foundation type piezometer and embankment-type piezometer cannot be installed in boreholes drilled into the body of the dam and foundation.

IV. Conclusion

1. Digital strong motion accelerometers need to be installed at the abutment, crest, and foundation of a dam and a free location at least 3 to 4 times the height of the dam.
2. Casagrande piezometer, Earth pressure cells, Inclinometer, Pore pressure cells, Uplift Pressure cells are non-functional. Hence, they need to be updated.
3. Seepage measurement is done using V-notches. This manual method involves errors. A fiber optic temperature technology for seepage measurement is suggested to use to monitor seepage by reducing human errors and reducing labor.
4. It is recommended to install data recorders to automatically record and monitor environmental factors throughout time, allowing measurements, recording evaluations, and validation of the conditions.

5. The following instruments need to be automated:
    1. Piezometers
    2. Total pressure cells
    3. Pore pressure transducer
    4. Pressure transducer can also be used
    5. Piezometers and observation wells to be automated by placing pressure sensors down standpipes
    6. In hydraulic piezometer devices, pressure sensors may be built into the lines.
    7. Staff meters are to be replaced with pressure sensors when using weirs and flumes.
    8. Inclinometers
    9. Seismic alarms that alert to trembling associated with earthquakes
6. Seepage measurement is done using V-notches. This manual method involves errors. A fiber optic temperature technology for seepage measurement is suggested to monitor seepage by reducing human errors and reducing labor. This can be done by inserting temperature sensors inside existing standpipes.
7. Seepage measurement using the manual method can also be done using the temperature method. In this method temperature in standpipes is measured manually. Even if it is not possible to install temperature sensors, then it is suggested to measure the temperature manually in standpipes.

V. Future Scope

Reservoir and tail water levels affect the water pressure in or under an embankment. Therefore, water pressure can be analysed by getting reservoir and tail water levels and can be compared with water pressure readings obtained from instruments. Purchase and installation cost analysis of instruments can be done.

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