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Dam Safety Instrumentation

P. R. Bamane[1], Dr.S. S. Valunjkar[2]
[1] *PG Student, Government College of Engineering, Karad,Maharashtra, India*
[2] *Professor, Civil Engg Dept, Government College of Engineering, Karad,Maharashtra, India*

Abstract: - *In most of the cases, the materials are tested in laboratories and designs are based on assumptions that the same results will be met with, during actual construction. As there are always large variations in materials, their properties, construction methods and their control, the actual product defers from the original assumptions. In this paper, instruments required to check the behaviour and stability of dams are discussed with their necessity, use and operation. These instruments prove to be much useful in proper maintenance of dam, and hence they should be installed under the guidance of experts at appropriate places in the dam. A conclusion has been arrived that there should be close co-operation between the designers, instrumentation specialist, expert analysis and site authorities to achieve the goal of instrumentation.*

I. INTRODUCTION

While designing dams, number of factors, parameters is assumed. In most of the cases, the materials are tested in laboratories and designs are based on assumptions that the same results will be met with, during actual construction. As there are always large variations in materials, their properties, construction methods and their control, the actual product defers from the original assumptions. This can be found out by many methods. The engineer must know how the actual constructed dam behaves against the assumptions made. Necessary help from various instruments embedded in a dam body is taken for satisfying structural behavior. This instruments are devices to measure and / or control the variables on each depends the functioning of a structure or a system or the operation of a process.

The principal objectives of a geotechnical instrumentation plan may be generally grouped into four categories: first, analytical assessment; second, prediction of future performance; third, legal evaluation; and fourth, development and verification of future designs.Instrumentation achieves these objectives by providing quantitative data to assess groundwater pressure, deformation, total stress, temperature, seismic events, leakage, and water levels. Total movements as well as relative movements between zones of an embankment and its foundation may also need to be monitored. A wide variety of instruments may be utilized in a comprehensive monitoring program to ensure that all critical conditions for a given project are covered sufficiently.

Instrumentation in dam is necessary for verification of design assumptions, construction technique & modifies design. Data collected from instrument can be extremely valuable in determination of specific cause of failure. By instrumentation constant watch over the performance of the structure during service & obtain timely warnings in respect of distress spots. Safety in dam can be assist by instrumentation.

Recent dam failures in various part of world inspire significant interest in monitoring various parameters as a means for ensuring adequate margin of safety. As per IS specification basic parameters like pore pressure, displacement, seepage, strains, stresses, dynamic load, uplift pressure, temperature can study with the help of instrumentation.

In India there are about 4291 large dams. Out of these 1529 dams are in Maharashtra. There are about 40 Dams are instrumented. The approximate cost of these instruments worked out to 1% of total construction cost. In unusual circumstances it may be 2to 3%.

II. INSTRUMENTATION PLANNING

A. Failure Of Dam

1. Overturning of dam
2. Sliding of dam

3. Crushing of dam
4. Tension failure of dam

Various causes of dam failure in percentage are listed below:

Sr.	Cause	Percentage failure
1	Foundation failure	40
2	Inadequate spillway	23
3	Poor construction	12
4	Uneven settlement	10
5	High pore pressure	05
6	Acts of war	03
7	Embankment slips	02
8	Defective materials	02
9	Incorrect operation	02
10	Earthquakes	01

B. Instruments in Dam

Following table shows the instruments used to obtain parameter:

SR.NO.	PARAMETER	INSTRUMENT
A	Pore Water Pressure	1. Open stand pipe piezometer 2. Pneumatic piezometer 3. Vibrating wire piezometer
B	Surface Displacement	1. Tiltmeter 2. Surface extensometer
C	SEEPAGE	1. "v " notch weir- large Discharge
D	STRESS	1. Total Pressure Cells 2. Jack-Out Total Pressure
G	DYNAMIC LOADS	1. Seismometer
I	UPLIFT PRESSURE	1. For Structures on Permeable Foundation Instruments. 2. Instruments For Structures On Rock Foundations.

III. CASE STUDY- TILARI DAM

SALIENT FEATURES OF DAM:

1. NAME OF DAM: TILARI DAM
2. NAME OF RIVER: TILARI RIVER
3.Location:
Near village Tillariwadi
Tal. Sawantwadi
Dist. Sindhudurg
4. Catchments Area:
A. Main Dam : 301.27 Sq.km.
B. Pick up weir : 88.91 Sq.km.
C. Av. Rainfall : 5588mm to 2280mm
5. Dam & Reservoir:
A. Gross Storage.
1. Main dam : 462.17 M cum
2. Pick up weir : 2.025 M cum
B. Live Storage.
1. Main Dam : 447.29 M cum
2. Pick up weir : 1.845 M cum

6. Type of Dam:
A. Main Dam: Earthen Dam in gorge with gated spillway on Tilaririver in saddle on left Bank.
B. Pick up weir on : Masonary pick-up weir with KhararíNalla gated spillway.

7. Height of Dam:

	From River Bed	From foundation
A. Main Dam :	71.35 m	73.35 m
B. Pick up weir :	12.52 m	15.40 m

8. Length of Dam:

	Total Length	Earthen	Masonary
A. Main Dam :	900 m	900 m	---
B. Saddle Dam :	300 m	172 m	128 m
C. Pick up weir :	274 m	99 m	175 m

D. Irrigation cum Power Outlet Tunnel with Power House: Length : 900 m
Type : D Type segmental arch fully lined
E. Spillway:
1. Saddle Dam: Gated spillway having 4 nos of radial gates of size 12 m X 6.5 m each.
2. Pick up weir : Gated ogge having 7 Nos. of radial gates of size 12 m X 5 m

9. Outlets:
A. Main Dam :Irrigation cum Power Outlet Tunnel with Power House of capacity of 10 MW.
B. Pick up weir :-
Right side :1. For Irrigation
2. For Hydro Power Generation of 200 KW.

10. Hydro Electric Generation:
A. Main Dam : 10 MW.
B. Pick up weir : 0.2 MW.

11. Canals:

	Total	**Maharashtra**	**Goa**
A. RightBank Canal :	60Km	25	35
Discharge : 14.5 cumecs			
B. Left Bank Canal :	71Km	22	49
Discharge : 32.56 cumecs			

12. Command Area:

	Irrigable
Maharashtra state:	6676 hect.
Goa state :	16978 hect.
Total :	23654 hect.

A.INTRODUCTION
Tilari interstate project is a major irrigation project and is a joint venture of government of Maharashtra and gov.of Goa. Tilari is a west flowing river originates from Sahyadri rages. In Chandgad taluka of Kolhapur District. An earthen dam is being constructed across Tilari river near village Tilariwadi.Taluka Sawantwadi in Maharashtra state.

Following are major components of project:-
1. Constructing an earthen dam across Tilari river near village Tilariwadi.Taluka Sawantwadi.
2. Masonary –Dam with gated spillway in saddle near village konal.
3. A pick up weir on Khararinalla, near village Terwanmedhe, to utilize the Tail Race release of Tilari Hydro Electronic Project. A small power house 1 x 200 Kw at Terwanmedhepick up weir is also proposed.
4. Irrigation cum power outlet tunnel, which includes construction of power house with an installed capacity of 10MW.
5. Main canals viz. left bank canal 71 kms and right bank canal 60 kms in length.
6. Distribution system to cover the command area.

Total 23654 hect. Area will be benefited in Maharashtra and Goa. The administrative approval is accorded by Govt. of Maharashtra in March 1979. Revised cost of the project at R.S.R. 1993-94 IS Rs. 488.33.corores.

B.NECESSITY OF INSTRUMENTATION

The behaviour of this dam will have to be monitored carefully particularly with reference to the following points:

1. The casing soils are low in permeability and their performance in sudden draw down condition on u /s side needs to be watched.
2. The pore pressure within the body of dam on other zones would be of interest.
3. The dam is located in highly seismic zone, with this point of view and even otherwise,the vertical settelement of dam as well as its horizontal spread on u /s and d /s needs to be monitored, particularly in its early life
4. The behaviour of dam for comparision with design assumptions is to be observed.
5. The Tilari dam lies in heavy rainfall zone both in quantum and intensity. It would be interesting to a certain as to how far does the heavy rainfall affect the saturation of d /s slope even after provision of pitching, backed by quarry spalls on d /s slope.
6. To watch performance of horizontal filters proposed in d /s casing zone to reduce pore pressure with the body of dam.
7. The horizontal filter mat of 1.20 m thk. Has been provided on d/sside. The performance of the same needs to be watched.

C.TYPES OF INSTRUMENTS TO BE INSTALLED:

1. Piezometers for observing pore pressure in embankment and foundation

a. Foundation piezometers
b. Embankment piezometers
c. Vibrating wire type piezometers
d. Pneumatic type piezometers
e. Casagrande type porous tube piezometers.

2. Earth pressure cells for observation of stresses in dam.
3. Surface settelement plugs for measuring embankment movements.
4. Peak recordingaccelerographs to measure the ground acceleration duration earthquake.
5. Seismoscope to determine displacement relative velocity and acceleration response of dam to earthquake.

D.SELECTION OF CROSS SECTION OF DAM FOR INSTRUMENTATION.

In view of present position of work it is proposed to provide the instrumentation at following locations.

I. R.D. 950.00 m
II. R.D. 445.00 m

The depths of overburden at the above locations are 8.0 m and 1.0 m respectively

E.PIEZOMETERS:

It is proposed to provide piezometers both in foundation as well as in embankment.

F.FOUNDATION PIEZOMETERS:

The foundation piezometers should be located slightly above the top of rock. These are spaced at a distance of 60 m,c/c. Alternative piezometers in foundation are associated with pneumatic type and Vibrating wire type piezometers.

G.EMBANKMENT PIEZOMETERS

The embankment piezometers are proposed in the heating zone at the vertical interval of about 12 m and horizontal spacing of 20 m. The piezometers in u /s and d /s casing zone have been proposed at spacing of 20 m and at vertical interval of 12 m. It will thus indicated the control of placing of hearting and casing soils exercised during construction. It also indicates the behaviour of horizontal sand filters provided. Vibrating wire type piezometers and pneumatic type piezometers are to be located alternately on both the sides of inclined filter.

H.CASAGRANDE TYPE POROUS TUBE PIEZOMETERS.
These are installed at R.D. 950m in d /s part of dam and are intended to give information regarding the effectiveness of both, inclined sand filter and intermediate horizontal filter mat and pore pressure developed near the base in d /s casing zone.

I.TERMINAL WELL:
Pore pressure observations are to be taken in terminal well of 4 m x 5 m size at d s of rock toe. The floor of terminal well shall preferably be located 5.0 m. above teil water level so as to be accessible at all times.
Efficient lighting and ventilation arrangement should be provided.

J.EARTH PRESSURE CELLS
Earth pressure cells placed little above G.L. and at intermediate levels at a spacing of 40 m. in u /s casing zone and in hearting zone. They are installed by the side of piezometers. So that effective earth pressure can be obtained.

K.SURFACE SETTELEMENT PLUGS
Surface settelement plugs installed between R.D.315 m to R.D. 815 m at interval of 100 m and at R.D. 950 M. The locations of settelement plugs are to be generally keep on both sides of berm.

L.SEISMIC INSTRUMENTS:
a. Force balance type accelerograph.
b. Peak recording accelerograph.
They are located at intermediate points in between locations of force balance type accelerograph.
Sesmoscope: They are installed on natural ground.
In short, instrumentation in Tilari Dam will give an excellent opportunity for checking various design assumptions made and parameters assumed in the stability analysis

IV. CONCLUSION

- The purpose of the instrumentation program and underlying geotechnical and structural problems that create the need for instrumentation must be clearly defined.
- The instrumentation program must be so comprehensive and carefully planned to include measurements of all the quantities which are essential in the problem to be studied..
- The data collected must be reduced to a convenient form and the results must be available to the concerning authorities without unnecessary delay.
- There should be close co-operation between the designers, instrumentation specialist, expert analysis and site authorities to achive the goal of instrumentation.
- We can obtain real significance of various parameters used in a design and thereby modify procedure and criteria leading to increase the economy and safety.
- We can obtain constant watch over the performance of the structure and timely warnings we can save life of many peoples, farms and various structures in city.

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