SAFETY INSPECTION OF DAMS IN INDIA

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ABSTRACT

An unsafe dam constitutes a hazard to human life, environment including flora fauna, riverine ecology and public assets. Therefore, safety of dam is a matter of great concern to the general public and it becomes a responsibility of dam owners to take necessary steps to ensure the safety of dams. India ranks third in the World after China and USA in terms of the number of dams. As per National Register of Large Dams 2019, India has more than 5334 constructed large dams out of which 75% are more than 20 years old and average age of these dams is approximately 40 years. In India, invariably Safety inspections of existing dams are conducted at periodic intervals, usually during pre-monsoon and post-monsoon period, and after any extreme event such as a large flood or an earthquake by State Govts. The methods and requirements vary for the several types of dams and for routine periodic inspections and post-event inspections. The Central Water Commission (CWC) has, as part of institutional strengthening, prepared guidelines, and manuals for inspection of dams. Dam Safety Bill, 2019 emphasizes need for uniform dam safety procedures to provide surveillance, inspection, operation and maintenance of the specified dam and setting up of institutional mechanism for prevention of dam failure related disaster. In this paper, the prescribed procedure for inspection of dams in India will be discussed.

Keywords *: safety, inspection, monitoring, surveillance*

1. OVERVIEW OF DAM SAFETY INSPECTION

In India, water is the State subject. Safety and maintenance of dams primarily rests with owners which are invariably the State Govts., Central and State power generating PSUs. Dam owners are generally carrying out the Scheduled inspection (generally i.e. pre-monsoon, post-monsoon inspections), comprehensive dam safety evaluation and special inspection of their dams to identify deficiencies or areas that need monitoring or immediate attention, and assess the safety of the dam and ascertain whether the dam system is performing as expected or not. Officials of DSO, CWC, too inspect the dams to address the specific issues and provide technical assistance. Dam owners are expected to submit their inspection report/ health status report of all the large dams to DSO, CWC for the examination, compilation and data base. Dam owners while submitting these inspection report are now being encouraged to upload the same on Dam Health and Rehabilitation and Monitoring Application (DHARMA), a web based tool developed under ongoing Dam Rehabilitation and Improvement Project (DRIP).

The primary goal of DSO, CWC is to encourage and assist the advancement of dam safety practices that will help to ensure operation of dams to their full capacities and intended purpose, and also to reduce the risk to lives and properties from consequences of both structural and operational dam incidents and failures. "*Guidelines for Dam Safety Inspection of Dams*" published by the DSO, CWC in January 2018 forms the basis of this paper.

2. DAM SAFETY INSPECTION PROGRAM:

Dam safety inspections are conducted to ensure proper operation and maintenance; to discover unsafe conditions and determine why they exist; to recommend remedial measures to mitigate the deficiency or defect that will safeguard the structure and appurtenances.

2.1 Types of Inspections:

Four types of dam safety inspections are carried out for all dams, regardless of their hazard classification:

(a) Scheduled Inspections: Scheduled inspections are generally carried out during pre and post monsoon period in India and are performed to gather information on the current condition of the dam and its appurtenant works. This information is then used to establish needed repairs and repair schedules, and to assess the safety and operational adequacy of the dam. Scheduled inspections are also performed to evaluate previous repairs. These inspections minimize long-term liability costs and extend the life of the dam.

(b) **Comprehensive Evaluation Inspections:** In comprehensive evaluation inspections detailed examination of the all component of dam is carried out through an independent panel of experts constituted for the purpose of determining

the conditions of specified dam and its reservoir. A comprehensive evaluation inspection of a dam typically consists of, but not limited to the following components:

(i) review and analysis of available data on design , construction, operation, maintenance and performance of structure.

(ii) general assessment of hydraulic and hydraulic conditions with mandatory review of design floods as specified by the regulations.

(iii) general assessment of seismic safety of specified dams with mandatory site specific parameters study in certain cases as specified by the regulations .

(iv) evaluation of operation , maintenance and inspection procedures; and

(v) evaluation of any other conditions which constitute a hazard to the integrity of the structure.

Such inspection shall be compulsory in case of :-

(a) major modification to the original structure of design criteria;

(b) discovery of an unusual condition of the dam or reservoir rim; and

(c) an extreme or hydrological or seismic event

(c) Special Inspections: Special inspections may need to be performed to resolve specific concerns or conditions at the site on an unscheduled basis. These inspections are usually made before or immediately after the dam or appurtenant works have been subjected to unusual events or conditions, such as an unusually high pool level, rainstorm, or a significant earthquake.

(d) Informal Inspections: An informal inspection, is a continuing effort by on-site personnel (dam owners/operators and maintenance personnel) performed while carrying out their regular duties on daily basis. Informal inspections give a continuous surveillance of the dam and are critical to the proper operation and maintenance of the dam.

3. INSPECTION ITEMS

3.1 Concrete Structures in General

(a) Concrete Surfaces - The condition of the concrete surfaces should be examined to evaluate the deterioration and continuing serviceability of the concrete.

(b) Structural Cracking - Concrete structures should be examined for structural cracking resulting from overstress due to applied loads, shrinkage and temperature effects or differential movements.

(c) Movement - Horizontal and Vertical Alignment Concrete structures should be examined for evidence of any abnormal settlements, heaving, deflections or lateral movements.

(d) Junctions - The condition at the junction of the structure with abutments or embankments should be determined.

(e) Drains - Foundation, Joint, Face All drains should be examined to determine that they are capable of performing their design function.

(f) Water Passages - All water passages and other concrete surface subject to running water should be examined for erosion, cavitation, obstructions, leakage or significant structural cracks.

(g) Seepage or Leakage - The faces, abutments and toes of the concrete structures should be examined for evidence of seepage or abnormal leakage, and records of flow of downstream springs reviewed for variation with reservoir pool level. The sources of seepage should be determined, if possible.

(h) Monolith Joints - Construction Joints All monolith and construction joints should be examined to determine the condition of the joint and filler material, any movement of joints, or any indication of distress or leakage.

(i) Foundation - Foundation should be examined for damage or possible undermining of the downstream toe.

(j) Abutments - The abutments should be examined for sign of instability or excessive weathering.

3.2. Embankment Structures

(a) Settlement - The embankments and downstream toe areas should be examined for any evidence of localized or overall settlement, depressions or sink holes.

(b) Slope Stability - Embankment slopes should be examined for irregularities in alignment and variances from smooth uniform slopes, unusual changes from original crest alignment and elevation, evidence of movement at or beyond the toe, and surface cracks which indicate movement.

(c) Seepage - The downstream face of abutments, embankment slopes and toes, embankment structure contacts and the downstream valley areas should be examined for evidence of existing or past seepage. The sources of seepage should be investigated to determine cause and potential severity to dam safety under all operating conditions.

The presence of animal burrows and tree growth on slopes which might cause detrimental seepage should be examined.

(d) Drainage Systems - The slope protection should be examined to determine whether the systems can freely pass discharge and that the discharge water is not carrying embankment or foundation material. Systems used to monitor drainage should be examined to assure they are operational and functioning properly.

(e) Slope Protection - The slope protection should be examined for erosion-formed gullies and wave formed notches and benches that have reduced the embankment cross-section or exposed less wave resistant materials. The adequacy of slope protection against waves, currents and surface run-off that may occur at the site should be evaluated. The condition of vegetative cover should be evaluated where pertinent.

3.3. Spillway Structures

Examination should be made of the structures and features, including bulkheads, flashboards and fuse plugs of all service and auxiliary spillways which serve as principal or emergency spillways for any condition, which may impose operational constraints on the functioning of the spillway.

(a) Control Gates and Operating Machinery - The structural members, connections, hoists, cables and operating machinery and the adequacy of normal and emergency power supplies should be examined and tested to determine the structural integrity and verify the operational adequacy of the equipment where cranes are intended to be used for handling gates and bulkheads, the availability, capacity and condition of the cranes and lifting beams should be investigated. Operation of control systems and protective & alarm devices such as limit switches, sump high water alarms and drainage pumps should be investigated.

(b) Unlined Saddle Spillways - Unlined saddle spillways should be examined for evidence of erosion and any conditions which may impose constraints on the functioning of the spillway. The ability of the spillway to resist erosion due to operation and the potential hazard to the safety of the dam from such operation should be determined.

(c) Approach and Outlet Channels - The approach and outlet channels should be examined for any conditions which may impose constraints on the functioning of the spillway and present a potential hazard to the safety of the dam.

(d) Stilling Basin (Energy Dissipaters) - Stilling basins, including baffles, flip buckets or other energy dissipaters should be examined for any conditions which may pose constraints on the ability of the stilling basin to prevent downstream scour or erosion · which may create or present a potential hazard to the safety of the dam. The existing condition of the channel downstream of the stilling basin should be determined.

3.4 Outlet Works

The outlet works examination should include all structures and features designed to release reservoir water below the spillway crest through or around the dam.

(a) Intake Structure - The structure and all features should be examined for any condition which may impose operational constraints on the outlet works. Entrances to intake structure should be examined for conditions such as silt or debris accumulation which may reduce the discharge capabilities of the outlet works.

(b) Operating and Emergency Control Gates - The structural members, connections, guides, hoists, cables and operating machinery, including the adequacy of normal and emergency power supplies should be examined and tested to determine the structural integrity and verify the operational adequacy of the operating and emergency gates, valves, bulkheads and other equipment. In case of existing arrangement does not conform to present design guidelines and practices, then adequacy of strength and required factor of safety need to be checked to ensure prevention of any untoward incidence.

(c) Conduits, Sluices, Water Passages, etc. - The interior surfaces of conduits should be examined for erosion, corrosion, cavitation, cracks, joint separation and leakage at cracks or joints.

(d) Stilling Basin (Energy Dissipater) - The stilling basin or other energy dissipater should be examined for conditions which may impose any constraints on the ability of the stilling basin to prevent downstream scour or erosion which may create or present a potential hazard to the safety of the dam. The existing condition of the channel downstream of the stilling basin should be determined by soundings.

(e) Approach and Outlet Channels- The approach and outlet channels should be examined for any conditions which may impose constraints on the functioning of the discharge facilities of the outlet works, or present a hazard to the safety of the dam.

(f) Drawdown Facilities - Facilities provided for drawdown of the reservoir to avert impending failure of the dam or to facilitate repairs in the event of stability or foundation problems should be examined for any conditions which may impose constraints on their functioning as planned.

3.5 Safety and Performance of Instrumentation

Instruments which have been installed to measure behaviour of the structures should be examined for proper functioning. The available records and readings of the installed instruments should be reviewed to detect any unusual performance of the instruments or evidence of unusual performance or distress of the structure. The adequacy of the installed instrumentation to measure the performance and safety of the dam should be determined.

(a) Headwater and Tail-water Gauges - The existing records of the headwater and tail-water gauges should be examined to determine the relationship between other instrumentation measurements such as stream flow, uplift pressures, alignment and drainage system discharge with the upper and lower water surface elevations.

(b) Horizontal and Vertical Alignment Instrumentation (Concrete Structures) - The existing records of alignment and elevation surveys and measurements from inclinometers, inverted plumb bobs, gauge points across cracks and joints, or other devices should be examined to determine any change from the original position of the structure.

(c) Horizontal and Vertical Movement, Consolidation and Pore-water Pressure Instrumentation (Embankment Structures) - The existing records of measurements from settlement plates or gauges surface should be examined to determine the movement history of the embankment. Existing piezometer measurements should be examined to determine if the pore-water pressures in the embankment and foundation would under given conditions impair the safety of the dam.

(d) Uplift Instrumentation - The existing records of uplift measurements should be examined to determine if the uplift pressures for the maximum pool would impair the safety of the dam.

(e) Drainage System - Instrumentation The existing records of measurements of the drainage system flow should be examined to establish the normal relationship between pool elevations and discharge quantities and any changes that have occurred in this relationship during the history of the project.

(f) Seismic Instrumentation - The existing records of seismic instrumentation should be examined to determine the seismic activity in the area and the response of the structures to past earthquakes.

3.6 Reservoir

The following features of the reservoir should be examined to determine to what extent the water impounded by the dam would constitute a danger to the safety of the dam or a hazard to human life or property.

(a) Shore Line - The land forms around the reservoir should be examined for indications of major active or inactive landslide areas and to determine susceptibility of bedrock stratigraphy to massive landslides of sufficient magnitude to significantly reduce reservoir capacity or create waves that might overtop the dam.

(b) Sedimentation - The reservoir and drainage area should be examined for excessive sedimentation of recent developments in the drainage basin which could cause a sudden increase in sediment load thereby reducing the reservoir capacity, with attendant increase in maximum outflow and maximum pool elevation.

(c) Potential Upstream Hazard Areas - The reservoir area should be examined for features subject to potential backwater flooding resulting in loss of human life or property at reservoir levels up to the maximum water storage capacity including any surcharge storage.

(d) Watershed Runoff Potential - The drainage basin should be examined for any extensive alternations to the surface of the drainage basin such as changed agriculture practices, timber clearing, railroad or highway construction or real estate developments that might extensively affect the runoff characteristics. Upstream projects that could have impact on the safety of the dam should be identified.

3.7 Downstream Channel

The channel immediately downstream of the dam should be examined for conditions which might impose any constraints on the operation of the dam or present any hazards to the safety of the dam. Development of the potential flooded area downstream of the dam should be assessed for compatibility with the hazard classification.

3.8 Operation and Maintenance Protocols

(a) Reservoir Regulation Plan - The actual practices in regulating the reservoir and discharges under normal and emergency conditions should be examined to determine if they comply with the designed reservoir regulation plan and to assure that they do not constitute a danger to the safety of the dam or to human life or property. Inspection team shall check the availability of Reservoir Operation Manual during Normal as well as Exigencies etc.

(b) Maintenance - The maintenance of the operating facilities and features that pertains to the safety of the dam should be examined to determine the adequacy and quality of the maintenance procedures followed in maintaining the dam and facilities in safe operating condition. Inspection team shall also examine the availability of Operation and Maintenance Manual, Safety Manual etc. along with annual budget requirement sought by dam manager and the

annual budget allocations done by authority. Availability of all this information shall be reflected appropriately in the Inspection Report

3.9 Disaster Management Plan

All large dams are supposed to have operational disaster management plan in place along with standard operating protocol procedures during any exigency. The Plan needs to confirm latest guidelines for Development of Emergency Action Plans (EAP) for Existing dams. Inspection team may review the document as per the standard guidelines. Also, Inspection team may also take stock of situation whether annual mock drill, pre-monsoon security and safety mock drill is conducted with all stakeholders. It is also important to review the implementation part of these plans, whether an effective coordination mechanism exist with all disaster management agencies at district, State and National level in the available Plan.

3.10 Security Arrangement for Dam and Dam Appurtenances

All dams of national importance are supposed to have a fool proof security arrangement in place to ensure security of dam and appurtenances from any kind of man-made threats. Inspection team may interact with security in charge in place, may review the Standard Operating protocols of this system. This arrangement shall be reflected in Inspection Report.

3.11 Basic Dam Facilities

The basic dam facilities covers the approach roads to dam, access roads to dam top as well as road to downstream stilling basin arrangement, Guest House, proper lighting within the dam complex as well as inside the various drainage galleries, proper power back up arrangement (DG set etc.) , house, adequacy of staff quarters for permanent staff deputed to dam site during normal as well as flood season, public conveniences, proper signage at appropriate locations including proper numbering of blocks inside the inspection as well as drainage galleries along with proper elevations, central control room housing SCADA and Surveillance system along with instrumentation monitoring etc. need to be reviewed by inspection team and shall be reflected in the Inspection Report.

4. DOCUMENTATION OF INSPECTION

It is important for the dam owner/operator to keep log books, history sheets and records throughout the entire life of the dam. Accurate records can better illustrate the dynamic nature of the structure and will help pinpoint problems. The dam owner should create a permanent file in which to keep inspection records, including documentation of actions taken to correct conditions found in the inspections.

4.1 Method of Documentation

(a) Inspection Checklist: It is wise to complete a checklist for comprehensive evaluation inspections and scheduled inspections. Each type of inspection may have its own checklist format, and the format used for an inspection may be predetermined by the owner or CDSO. Format for schedule inspection check list is given in the Appendix B as Part 2a of the Guideline[1]. A checklist will not typically be needed for informal and special inspections.

(b) Field Sketches: The field sketch is intended to supplement the information recorded on the inspection checklists; however, it should not be used as a substitute for clear and concise inspection checklists. Problems and their location can be recorded on the field sketch.

(c) Inspection Report Form: Current CDSO regulations require the completion and submittal of a Scheduled Dam Safety Inspection Report Form (shown in Appendix B of the Guideline[1]) for comprehensive evaluation inspections on high hazard dams. A detailed written report incorporating the Inspection Report Form, a summary of findings, recommendations, conclusions, photographs, and other supporting data must be prepared for comprehensive evaluation inspections.

(d) Photographs: Inspection photographs can be vitally important. Over time, photographs serve to provide a pictorial history of the evolving characteristics of a dam.

(e) Voice Recorder: Tape recorders, especially the micro recorders, can be convenient when it is difficult to write while an inspector is observing field conditions.

(f) Others: Monitoring Data, Inspection Notes, Global Positioning Sensors (GPS) and Smart phones and Laptop Computers etc.

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5. CONCLUSION

Dams are critical infrastructure constructed with large investments for multipurpose uses such as irrigation, power generation, flood moderation and supply of water for drinking and industrial purposes. Other physical assets, such as, Hydro power plants, irrigation network, drinking and industrial network, municipal supplies etc., are also linked with the dams. Safety of the dams is a very important aspect which has to be given priority on a continuous basis for safeguarding the national investment and the benefits derived by the nation from the projects. In addition, an unsafe dam (with high possibilities of failure and sudden release of huge quantities of stored water) constitutes a hazard to human life, ecology and public and private assets including crops, buildings, canals and roads. Therefore, safety of dam is a matter of great concern to the general public and becomes a national responsibility to take necessary steps to ensure the safety of dams.

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