Water Resources Department
Govt. of Gujarat

Dam Safety Society,
New Delhi

Sardar Sarovar
Narmada Nigam Limited

International Conference

DAM SAFETY 2024

18-19 July 2024, Kevadia, Gujarat, India

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Workshop

on

Instrumentation of Dams including Seismic Instrumentation

16-17 July 2024

SUMMARY OF DELIBERATIONS

Organised by :

Dam Safety Society, New Delhi

In Association with

Sardar Sarovar Narmada Nigam Limited
Water Resources Department, Govt. of Gujarat

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Dam Safety Society,
New Delhi

INTERNATIONAL CONFERENCE DAM SAFETY 2024

Workshop on Dam Instrumentation including the Seismic Instrumentation

(16th to 17th July 2024), Kevadia, Gujarat, India

(Proceedings and Key Takeaway from the Technical Sessions)

The International Conference Dam Safety 2024 hosted a specialized workshop on dam instrumentation, with a particular focus on seismic instrumentation; was held from the 16th - 17th July 2024 and was organized by the Dam Safety Society. The purpose of the workshop was to address the growing importance of instrumentation in dams, which is crucial for ensuring the safety, maintenance, and proper operation of these critical infrastructures.

From (L-R); Dr. R.K. Gupta, Shri AB Pandya, Shri K.R. Parikh & Shri Vivek P. Kapadia

Given the lack of proper exposure among many officers and staff to the field of instrumentation and its maintenance, the workshop aimed to disseminate critical knowledge to engineers, dam authorities, and relevant stakeholders. The event brought together a wide range of participants, including engineers, dam owners, geologists, technicians, and representatives from government agencies and Academica.The workshop was designed with several key objectives:

- To acquaint in-service engineers, officers, and staff with the latest knowledge in dam instrumentation.
- To provide participants with an improved understanding of the principles, practices, and technologies involved in dam instrumentation.
- To expose attendees to emerging technologies and best practices in instrumentation and data management.
- To facilitate hands-on exercises and real-world scenario discussions related to both embankment and concrete dams.

Dr. R.K. Gupta Presenting Memento to Chief Guest

Workshop Content and Structure

The workshop featured a blend of presentations, exercises, equipment displays, and demonstrations. These activities were structured to provide a comprehensive overview of dam instrumentation, covering both fundamental concepts and advanced topics.

Key Topics were addressed during workshop:

- **Traditional Dam Safety Instrumentation:** Participants learned about established methods and tools for monitoring dam safety.
- **Monitoring and Assessing Structural Behavior:** The workshop emphasized the importance of using instrumentation data to evaluate the structural integrity of dams.
- **Emerging and Future Dam Safety Instrumentation and Tools:** Discussions focused on new and upcoming technologies that are poised to revolutionize dam safety monitoring.
- **Owner's Perspectives and Presentations on Data:** Dam owners shared their experiences and insights on managing and interpreting instrumentation data.
- **Seismic Instrumentation and Monitoring:** A significant portion of the workshop was dedicated to seismic instrumentation, with a focus on assessing dam performance during seismic events.
- **Equipping Existing Dams with Instrumentation:** Strategies for retrofitting existing dams with modern instrumentation were discussed.
- **Automated Data Acquisition and Management:** Best practices for automating data collection, processing, evaluation, and visualization were highlighted.
- **Case Studies:** Participants examined real-world examples of dam safety instrumentation in action.
- **Office Automation Tools:** The use of digital tools for managing recorded data was also explored.

Hands-On Exercises and Industry Engagement

A notable feature of the workshop was the hands-on exercises that allowed participants to engage in practical applications of the concepts discussed. These exercises included the planning and design of instrumentation systems, as well as data evaluation exercises.

Additionally, the workshop provided an industry session where instrumentation equipment suppliers showcased their products. This session allowed participants to interact directly with suppliers, ask questions, and gain insights into the latest tools and technologies available in the market.

Educational Discussions and Networking

The workshop emphasized the importance of educational discussions and knowledge exchange among participants, presenters, and equipment suppliers. By discussing real-world situations and challenges, attendees were able to gain a deeper understanding of how to address the complexities of dam instrumentation and monitoring.

Shri K. R. Parikh, Secretary, Narmada Water Resources Delivering the Inaugural Speech

The workshop was inaugurated by Shri K. R. Parikh, Secretary, Narmada Water Resources, Water Supply and Kalpasar Dept., Govt. of Gujarat and keynote address was delivered by Shri A. B. Pandya, President, Dam Safety Society during the Inaugural Session on 16th July 2024 at hotel Fern Sardar Sarovar Resort at Ekta Nagar, Gujarat. Shri Vivek Kapadia delivered the welcome address and focused on the need for organization of the workshop on this topic which is the need of the hour.

There was a total nos. of 13 exclusively technical sessions in two days of workshop where different aspect on techniques, technology and methodology for dam instrumentation and structural health monitoring were presented with 18 Nos. of technical presentations including case studies by different experts coming from government to renewed industries domain with multidisciplinary sectors over span of two days of the workshop activities.

Technical Session-1: ***Why Instrumentation and Why Instrumentation of Dams? Consequences of 'No Instrumentation' & Traditional Dam Safety Instrumentation*** *- Dr. R. K. Gupta, Vice President , DSS & Former Chairman, CWC.*

Dr. R.K. Gupta making the Presentation

The crucial role of Instrumentation in ensuring the safety, performance, and longevity of dams being a complex structure that hold vast amounts of water, dams are subject to a variety of stresses and environmental factors that can compromise their integrity, enables continuous monitoring, early detection of potential issues, and informed decision-making to mitigate risks.

The Key Importance of Instrumentation that provides real-time data on the structural health of the dam, enabling early detection of anomalies such as cracks, seepage, or deformation. This ensures that corrective actions can be taken before a small issue escalates into a major safety concern including the performance and operational monitoring by tracking parameters like water pressure, temperature, and vibration, instrumentation helps in understanding how the dam behaves under various conditions. This information is vital for optimizing the dam's performance and ensuring its efficient operation with necessary regulatory compliance with Preventive Maintenance and providing Disaster Preparedness in case any Risk to Failure. Without proper instrumentation, small issues that could have been easily addressed might go unnoticed, leading to catastrophic dam failures. This not only endangers lives but also causes significant economic and environmental damage.

The importance of instrumentation in dam safety cannot be overstated. It is a critical component of modern dam management, enabling real-time monitoring, early detection of issues, and informed decision-making. The consequences of not having proper instrumentation are severe, ranging from increased risk of dam failure to non-compliance with safety regulations. While traditional instrumentation has been valuable, the transition to more advanced systems is necessary to meet the increasing demands for safety, performance, and regulatory compliance in today's dam management landscape.

View of Audience

Technical Session-2: *Parameters to be monitored for dam safety & surveillance, their significance, and method of selection of an Appropriate Instrumentation' - Shri Mohan Gupta, Technical Head, AIMIL Limited.*

Shri Mohan Gupta making the presentation

Instrumentation & Monitoring is a part of detailed design for new dams and is a part of studies of probable failure modes of existing dams. Dam Design Understanding plays a very crucial role to select Instrument types, its monitoring frequency. Above all, interpretation of Instrument Monitoring is extremely critical and hence though instrument supplying & installation & monitoring is important but its interpretations & implementation in design & construction is more critical. The use of instrumentation for dam safety concerns is increasing as the technology of instrumentation and ease of use advances. Identify critical locations in Dam to be instrumented viz Design Control Parameters.

Dam safety and surveillance are critical aspects of water resource management, ensuring the long-term integrity and functionality of dam structures. Monitoring parameters such as water levels, seepage, pore water pressure, structural displacements, stress, strain, and seismic activity are essential for assessing the health of a dam. Each parameter provides insights into different potential failure modes and helps in early detection of anomalies that could lead to catastrophic events. The selection of appropriate instrumentation for monitoring these parameters is guided by the dam's design, material, location, and operational conditions. Instruments like piezometers, inclinometers, and seismographs are commonly used, with choices depending on factors such as accuracy, reliability, ease of installation, and environmental conditions. This abstract discusses the importance of monitoring key parameters, their role in maintaining dam safety, and outlines the criteria for selecting suitable instrumentation to ensure comprehensive and effective surveillance. By integrating advanced monitoring technologies with a systematic approach to instrumentation selection, dam safety can be significantly enhanced, reducing the risk of failure and ensuring the sustainability of water infrastructure.

From L-R; Dr. R.K. Gupta, Mr. Mohan Gupta & Dr. Sanjay Rana

Technical Session-3: *Monitoring Techniques of Structural Scanning and Health Assessment through Geophysical Investigation - Dr. Sanjay Rana, Managing Director, Parsan Overseas (Pvt.) Ltd.*

Monitoring techniques for structural scanning and health assessment through geophysical investigation offer a non-invasive and comprehensive solution, enabling early detection of issues such as seepage, internal erosion, and structural weaknesses. Traditional methods like visual inspections and invasive techniques often fall short in detecting subsurface anomalies and internal degradation. In contrast, advanced geophysical techniques provide significant advantages.

Electrical Resistivity Imaging (ERI) measures the electrical resistivity of subsurface materials to detect variations in moisture content, porosity, and water table levels. This technique is effective in identifying saturated zones and weak areas within earthen and masonry dams, using an array of electrodes to inject current into the ground and measure the resulting potential distribution. Streaming Potential (SP) measures the electrical potential generated by flowing water within porous materials, making it a valuable tool for detecting seepage paths and quantifying seepage in earthen and masonry dams. SP surveys are often correlated with resistivity imaging to identify zones of active seepage and saturated areas.

Seismic methods, including Seismic Refraction and Refraction Microtremor (ReMi)/ Multichannel Analysis of Surface Waves (MASW), measure seismic wave velocities to assess the strength and integrity of dam materials. Seismic refraction detects changes in density and saturation, while ReMi provides detailed shear wave profiles, offering insights into material strength without boreholes. These methods help determine the phreatic line and identify weak zones within the dam structure. Seismic Tomography offers high-resolution imaging of internal structures by analysing variations in P-wave velocities between dam top and galleries, or across dam faces, which is crucial for detailed assessment of anomalous areas identified in initial surveys, providing information on fractures and degradation in concrete and masonry dams.

The Ground Penetrating Radar (GPR) uses electromagnetic waves to detect subsurface objects and anomalies such as pipes, cavities, and voids. It is particularly useful for high-resolution mapping of shallow features and assessing conditions in concrete dams and stilling basins, producing radargrams that help visualize the condition of subsurface structures. Geophysical methods have been successfully applied in various dam monitoring projects worldwide. For instance, GPR

and bathymetric surveys have been used to monitor the condition of stilling basins, detecting areas of scouring and erosion that could threaten dam stability. Similarly, ERI and SP techniques have been employed to detect internal erosion and seepage in earthen and masonry dams, facilitating early intervention and repair. L-section and cross-face seismic tomography has been used to detect zones of degradation in concrete and masonry dams.

The integration of advanced geophysical techniques with traditional monitoring practices enhances the effectiveness of structural health assessments. These non-invasive methods provide detailed insights into subsurface conditions, enabling early detection and mitigation of potential issues. The continued development and application of geophysical surveys are crucial for ensuring the safety and longevity of critical infrastructure such as dams.

Paper-2 : Instrumentation and Monitoring of Reservoir: ARMAC (Automatic Reservoir Monitoring and Control) - *Shri Ramji Singh, Member DSRP Committee, NWRWS&K Dept. Gujarat State, Expert & Consultant (Instrumentation & Automation) Hydraulic & Water Resource Engineering*

Shri Ramji Singh making the presentation

Monitoring the reservoirs is a critical aspect of dam engineering, encompassing stages from investigation and planning to design, construction, and ongoing operations. Effective instrumentation and monitoring are vital to assess and understand the dam's operational behaviour, ensuring both safety and normal functionality. Comprehensive monitoring involves acquiring, evaluating, and analyzing data from the reservoir, catchment, and river basin. This process is essential for the safe and timely operation of the dam, safeguarding the structure and downstream assets and lives. Upstream monitoring, from the basin to the catchment and reservoir, provides insights into performance during peak operations. Early acquisition of precise information supports decision-making for dam owners and engineers, helping to manage operational challenges effectively. Continuous assessment of reservoir safety is necessary to understand dam behaviour throughout operations by installing different types of instrumentation and monitoring to address the specific needs of various dams, reservoirs, and river basins.

From (L-R); Mr. Ramji Singh, Dr. Sanjay Rana & Dr. Ram Worrier

Establishing an effective reservoir monitoring plan for dam operations encompasses a comprehensive approach, including survey and feasibility analysis, and communication with all stakeholders in interstate border areas. Key components involve identifying strategic, safe, and suitable locations for deploying instruments, setting up data porting and communication networks, and ensuring redundancy in power and backup systems. Additionally, safeguarding measures from physical to logical aspects are critical, alongside efficient operation and maintenance practices. Continuous improvement and process reengineering address future challenges, while third-party services in AWS and gauging stations offer scope for business in remote locations or interstate connected area, enhancing the engineered output of hydrometeorological data.

Hybrid combination sensors and instruments based on the site-specific requirements starting from AWS, AWLR, DWLR, Seismographs, Flow, Velocity and Discharge measuring equipments including Automation of Gates with an advance monitoring system like Remote Sensing Imagery and Aerial Survey reports can also be integrated into the monitoring system, providing high-resolution images for monitoring larger areas and detecting any changes over time in the catchment and reservoir. LiDAR technology can generate detailed topographic maps, assess terrain features, sediment monitoring, water quality & biodiversity monitoring and detect changes in the upstream reservoir, aiding in smart and comprehensive monitoring and management. Integrating & planning a combination of these instruments is crucial to ensure comprehensive reservoir control and monitoring. The choice of instruments depends on the specific goals and objectives of the monitoring program, reservoir characteristics, and regulatory requirements. Regular maintenance is essential to ensure accurate and reliable data, along with regular analysis to identify trends or abnormal patterns. This helps in developing a comprehensive emergency response plan based on specific monitoring triggers, ensuring a timely and organized response, even in the case of high flood probabilities.

This is achieved by designing an effective DAS/ARMAC system for a better Decision Support System (DSS) with operational management by monitoring and controlling the reservoir using Standard Operating Procedures (SOP) integrated with SCADA/IoTs for outflow discharge.

Such a system strategically helps in managing and understanding the upcoming inflow of water to the reservoir from the catchment, its volume, expected arrival time, and making advanced operational decisions to release the quantum of water for safe reservoir management.

Shri Abhinav Kumar making the presentation

Technical Session-4: *Techniques and Technology for Comprehensive Monitoring of Dams: Vibrating Wire, Pneumatic Electrical, Mechanical, and Hydraulic - Shri Abhinav Kumar, Managing Director, Record Tech Electronics, Roorkee.*

This presentation focuses on the instrumentation and monitoring techniques essential for maintaining the structural integrity and operational safety of dams. The document highlights the significance of structural health monitoring (SHM), and the various sensors and technologies utilized for comprehensive dam monitoring. Key performance metrics for SHM sensors include long-term stability, data quality, range, durability, ease of integration, maintenance requirements, reliability, accuracy, sensitivity, resolution, and power consumption. Different types of sensors such as resistive, capacitive, inductive, optical, ultrasonic, and vibrating wire sensors are discussed, along with their respective advantages and disadvantages. For instance, resistive sensors are noted for their high accuracy and cost-effectiveness but are temperature dependent and exhibit non-linearity. Similarly, vibrating wire sensors are praised for their long-term stability and low power consumption but are unsuitable for dynamic measurements.

The document also elaborates on various monitoring techniques like strain gauge monitoring, pore pressure monitoring using piezometers, use of Normal plumblines, vibration/seismic monitoring with accelerographs, environmental monitoring through weather stations, and geodetic monitoring using automatic total stations.

Shri Muthukumar Ramalingam making the presentation

Data analysis is essential for any comprehensive structural health monitoring project. This presentation briefly introduces real-time monitoring using the previously discussed sensors, as well as data acquisition systems and real-time acquisition software. It also covers trend analysis and explains how alarms and notifications are generated for relevant stakeholders in cases of excessive loading, instability, or breaches of sensor threshold values.

This presentation concludes with a case study on the Sardar Sarovar Dam demonstrates the practical application of rehabilitation work carried out after 30 years of initial installation of sensors. Overall, the presentation underscores the importance of advanced instrumentation and robust monitoring systems in ensuring the safety and effectiveness of dam operations.

Paper-2 : Importance of Regular Maintenance and Comprehensive Calibration of Dam Instruments - *Mr. Muthukumar Ramalingam, CEO, Esedios Technology Service Private Limited.*

The accuracy of data collected from well-maintained and calibrated instruments at dams has always been a topic of debate and concern. With the increasing use of technology and reliance on real-time data for decision-making, it is crucial to ensure that the data from these instruments is accurate and reliable.

Comprehensive calibration and periodic maintenance are essential for adjusting and standardizing instruments to ensure their measurements align with known or accepted values ensuring the accuracy, and reliability of data. This process is vital as it helps reduce errors and discrepancies in the collected data. However, several field, or dam-related factors can affect the accuracy of data even from calibrated instruments.

Another significant concern is the quality of the calibration and maintenance process, whether conducted in the field or a laboratory. Inaccurate or improper techniques can result in misleading data, rendering the entire calibration process useless. It is crucial to have trained professionals who are knowledgeable about the specific instrument's calibration and maintenance process in the field or certified lab facility.

They also need to follow established standards to ensure that calibration and periodic maintenance are done correctly and accurately.

Environmental factors such as temperature variations, humidity, and electromagnetic interference can also affect data accuracy. Instruments calibrated in a controlled laboratory setting may not perform consistently when used in a different environment. Regular re-calibration in the actual environment of use can help mitigate these effects and ensure accurate data collection. This adaptability to environmental changes underscores the necessity of ongoing calibration efforts. Thus, periodic comprehensive maintenance is crucial for ensuring the accuracy, reliability, and safety of instruments used in dams. It helps detect potential issues early on and prolongs the lifespan of these instruments. Given the increasing importance of real-time dam monitoring, regular maintenance and calibration are necessary steps for ensuring their safety and functionality.

Moreover, the quality of the calibration and maintenance processes is a critical factor that influences the accuracy of dam instrumentation. Inaccurate or improper calibration techniques can lead to misleading data, undermining the entire monitoring process. It is essential to employ trained professionals who are well-versed in the specific calibration and maintenance requirements of dam instrumentation. Adhering to established standards and protocols ensures that these processes are conducted correctly and accurately, thereby safeguarding the integrity of the data.

In conclusion, the importance of regular maintenance and comprehensive calibration of dam instrumentation cannot be overstated. These practices are essential for ensuring the accuracy, reliability, and safety of data, which in turn supports effective water resource management, flood control, and power generation. By prioritizing maintenance and calibration, we can enhance the operational efficiency of dams, prevent potential failures, and ultimately contribute to the overall safety and sustainability of these critical infrastructures.

Paper-3 : Case Study on SCADA-Based Gate Automation for Comprehensive Decision Support System of Shahnehar Barrage and Its Canal Network - *Shri Rajnish Dashottar, Director, CIMCON Software (I) Pvt. Ltd*

Shri Rajnish Dashottar making the presentation

The technical paper and presentation based on the case study on Shah Nehar Barrage, a critical infrastructure in District Hoshiarpur, plays a vital role in water management and power generation in Northern India. This case study outlines the implementation of a SCADA-based gate automation system at the barrage and its associated canal network. The project, aimed at enhancing monitoring and control capabilities, integrates advanced Supervisory Control and Data Acquisition (SCADA) technology to enable real-time monitoring, automated gate operations, and comprehensive data analysis. Key components of the system include Remote Terminal Units (RTUs), Programmable Logic Controllers (PLCs), Variable Frequency Drive (VFD) panels, water level and discharge sensors, and a dual communication infrastructure for data transmission. The benefits of this system are significant, including improved operational efficiency, enhanced decision-making, strengthened security measures, and better environmental and regulatory compliance. The SCADA system has streamlined operations by reducing manual interventions, optimizing water management, and ensuring the sustainability of the barrage's operations. This case study demonstrates how the integration of advanced technology in water resource management can lead to improved efficiency, safety, and environmental sustainability at the Shah Nehar Barrage.

Technical Session-5: ***Communication and Data Transmission through Smart Loggers in Structural and Hydrometeorological Monitoring*** - *Mr. Kevin Randal, Manager Infrastructure, Campbell Scientific Inc., USA.*

Communication and data transmission through smart loggers are pivotal in enhancing the accuracy and reliability of structural and hydrometeorological monitoring systems. Smart loggers, equipped with advanced sensors VW Analysers and communication modules, facilitate real-time data collection, storage, and transmission, enabling continuous monitoring of critical parameters such as structural stress, strain, temperature, and water levels. The integration of wireless communication technologies like GPRS, GSM, and satellite links ensures seamless data transmission from remote monitoring sites to centralized data servers. This capability is crucial for timely decision-making and risk mitigation, as it allows for the early detection of potential structural issues or adverse hydrometeorological conditions. Moreover, the use of smart loggers in these monitoring systems improves data

Mr. Kevin Randal making the presentation

integrity and reduces the need for manual data collection, thereby increasing operational efficiency and accuracy. By providing a robust communication framework, smart loggers play a critical role in the real-time monitoring and management of infrastructure health and environmental conditions, contributing to the overall safety and resilience of critical assets.

At the forefront of data acquisition system manufacturing, OEM presented solutions in data communication and transmission and the effects that smart loggers have on the efficiency and reliability of monitoring systems. Whether in geotechnical or structural engineering, or environmental monitoring, the adoption of smart technologies in data transmission solutions enables reliability, optimization, efficiency gains, and the reduction of risks and operational costs. The advantages of using dataloggers with local processing and programmability outweigh the acquisition investment, especially when considering the equipment's life cycle cost, which requires lower maintenance costs. In this lecture, you will understand the different data transmission systems, what makes a datalogger smart, and why these devices bring more security and reliability to the management of structures.

Paper-2 : Meteorological and Hydrological Instrumentation for Dam Safety Monitoring - *Shri Ram Warriar, Regional Director, Seba Hydrometry GmbH & Co. Kg.*

Shri Ram Warriar making the presentation

Dam safety is a critical component of water resource management, requiring ongoing monitoring and evaluation to mitigate the risk of catastrophic failures. Advanced meteorological and hydrological instrumentation is indispensable for providing real-time data, which is essential for effective dam safety monitoring and decision-making. This paper explores the range of instruments used in dam safety monitoring, emphasizing their functions and importance. Key meteorological tools include rain gauges, weather stations, anemometers, thermometers, and snow gauges, all of which monitor weather conditions that could impact dam safety. Hydrological instruments, such as water level sensors, discharge measurement systems, and data acquisition platforms, focus on monitoring reservoir levels, inflows, and outflows to ensure the dam operates within safe limits. By utilizing these advanced tools, dam operators can proactively manage risks and maintain the structural integrity and operational safety of dams, thus safeguarding critical infrastructure.

Technical Session-6: ***Instrumentation – A Prerequisite for Ensuring Structural Safety of Dams*** - *Shri Hari Dev, Expert in Geotechnical and Rock Mechanics Engineering, Central Soil and Materials Research Station (CSMRS), New Delhi.*

Shri Hari Dev making the presentation

Instrumentation plays a pivotal role in the structural safety of dams, serving as the backbone of modern dam monitoring systems. Given the immense forces at play and the potential consequences of structural failure, the need for precise, continuous, and reliable data collection cannot be overstated. Instruments such as water level sensors, pressure transducers, strain gauges, and seismic monitors are meticulously installed to track the dam's response to various stressors, including hydrostatic pressure, seismic activity, and environmental changes. These tools measure critical parameters such as reservoir water levels, seepage through dam foundations, deformation of dam structures, and even the dynamic response of the dam to external forces like earthquakes.

The real-time data provided by these instruments enables dam operators and engineers to identify and analyze trends that could indicate emerging risks. For example, abnormal readings from piezometers, which measure the water pressure within the dam, might suggest internal erosion or potential instability, necessitating immediate investigation. Similarly, strain gauges can detect minute shifts in the dam's structure, which, if left unchecked, could lead to significant deformation or cracking.

Moreover, advanced data acquisition systems integrate this instrumentation into a centralized platform, allowing for continuous monitoring and automated alerts. This integration is crucial for timely decision-making, as it ensures that any signs of distress are promptly addressed, mitigating the risk of catastrophic failure. In essence, instrumentation not only provides a safeguard against unforeseen events but also contributes to the longevity and reliability of the dam by facilitating preventative maintenance and informed operational strategies. As dams age and environmental conditions evolve, the role of instrumentation in ensuring structural safety becomes increasingly critical, making it a non-negotiable prerequisite in dam engineering and management.

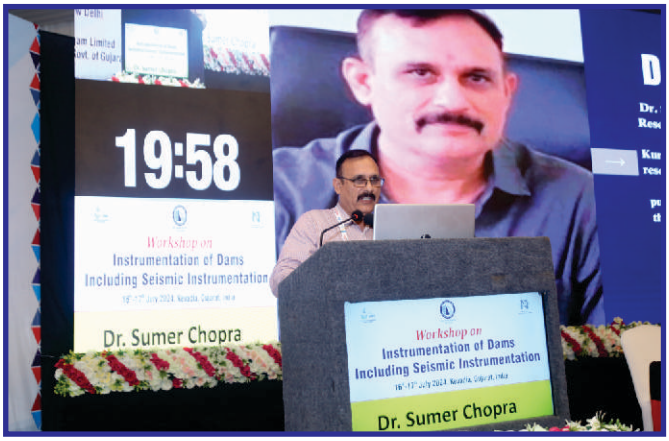
Industrial Session-7: *Industrial Demonstration of Various Types of Instruments & Portable Sensors, Calibration: Surveying Instruments, Tools, and Techniques under Industries Connect from OEM's Corner's CAMPBELL SCIENTIFIC, AIMIL, CARPI, PARSAN, SMEC, DYNASORE, CIMCON, CANARYSAUTOMATION, I4-MARINE & More*

Shri Vivek P. Kapadia Chairing the Session

During the 2-day of Workshop of Instrumentation and remaining 2 Days of Dam Safety Conference under the banner of DSS2024 "Industries Connect," participants were offered a comprehensive, hands-on demonstration of various state-of-the-art geotechnical, hydrometeorological instruments, portable sensors, data loggers, calibration systems, ROV (Remotely Operated Vehicle) underwater cameras, and other essential surveying and mapping instruments. The event was designed to provide industry professionals, engineers, researchers, and students with practical insights into the latest tools and techniques used in modern geotechnical and hydrometeorological studies, with an emphasis on enhancing structural safety and environmental monitoring.

The said "Industries Connect" event demonstrated and provided participants with a deep understanding of the latest geotechnical, hydrometeorological, and surveying instruments and techniques on geophysics and geophysical investigations. The hands-on demonstrations allowed attendees to engage directly with the tools and technologies that play a crucial role in ensuring the structural safety of dams and the effective management of water resources. By integrating these advanced instruments into their monitoring and maintenance practices, dam operators and engineers can proactively address potential issues, thereby safeguarding these critical infrastructures against failure and ensuring the safety of structures and saving the downstream communities.

Technical Session-8: *Seismic Instrumentation and Monitoring of Dams, Cases and Examples of sardar Sarovar Dam - Dr. Sumer Chopra, Director General, Institute of Seismological Research (ISR), Govt. of Gujarat.*



Dr. Sumer Chopra making the presentation

The stability and safety of dams are critical concerns in civil engineering and disaster management. Seismic instrumentation and monitoring play a crucial role in ensuring the structural integrity of dams, particularly in seismically active regions. Seismic instrumentation is essential for understanding the dynamic behaviour of dams during earthquakes. It forms an integral part of dam safety monitoring systems, providing outputs that help assess damage and determine necessary upgrading works. The primary benefits include understanding the dynamic behaviour of the dam's response to earthquake loading, continuous safety assessment, maintenance, and risk reduction, improving design and maintenance with data from seismic recordings to verify design parameters and guide maintenance and reinforcement activities, and early warning systems where seismic sensors detect early signs of structural stress or damage, allowing for timely interventions to prevent catastrophic failures.

Types of seismic instrumentation include strong motion accelerographs, which record strong ground motion and resulting dam vibrations, and seismographs, which determine local seismicity before construction and detect changes in seismicity level during and after the reservoir filling. The purposes of seismic monitoring are to identify the location and depth of earthquake epicentres relative to the dam, measure magnitude, frequency characteristics, and focal mechanisms of earthquakes, assess the mode of occurrence of future earthquakes, and evaluate the dam's behaviour during and after seismic events.

A minimum of four strong motion accelerographs i.e. on Crest, Abutment, Foundation and free field), each recording three components of motion, supported by a broadband seismic observatory are recommended to ensure comprehensive monitoring of dams. The plan of action includes planning and installation, which involves conducting detailed assessments to identify potential seismic hazards, designing an instrumentation plan that includes types and locations of sensors, and installing sensors and data acquisition systems at strategic locations. Monitoring and data collection involve continuous real-time monitoring of seismic activity and structural responses, recording and storing seismic data for subsequent analysis, and using remote telemetry systems for data transmission. Data analysis and interpretation involve processing seismic data to identify patterns and anomalies, evaluating the impact of seismic events using advanced modelling techniques, and generating reports on dam performance and potential risks based on seismic data.

The benefits of seismic instrumentation include evaluation of the dam's functioning during and after earthquakes, detecting subtle trends in the dam's performance with long-term data, enabling rapid response with automated monitoring and alarming systems, improving understanding of seismic hazards and their impact on the dam, verifying design parameters against actual dynamic behaviour, and assessing damage and determining necessary upgrades.

Successful seismic monitoring of dams has been implemented in many dams in India such as Tehri dam, Koyna dam, Indira Sagar dam, and in Gujrat state for dams like Navagam Dam (Sardar Sarovar), Dharoi Dam, Kadana Dam, Panam Dam etc. Seismic instrumentation is a critical component of comprehensive dam safety monitoring. It provides valuable quantitative data to understand seismic hazards, evaluate dynamic performance, and ensure the ongoing safety and integrity of dams. Implementing robust seismic monitoring systems as per CWC guidelines, and dam safety act can significantly reduce the risk of dam failures, protecting lives and property downstream.

Paper-2 : Seismic Monitoring of Dams, Embankments and Water Retaining Bodies *- Shri Vinod Kumar Taamar, Managing Director, Pinnacle Geosystems, New Delhi.*

The seismic monitoring of dams and water retaining bodies are a critical aspect of dam safety and risk management, ensuring the structural integrity and operational reliability of these crucial infrastructures. This process involves the prefeasibility analysis, site survey, deployment of advanced instruments such as Broad Band Seismographs (BBS) and Strong Motion Accelerographs (SMA) strategically positioned on and around the dam structure, essential to ensure the safety, stability, and functionality of these critical structures allowing for the early detection of stress or damage by understating, recording and analysing the dynamic behaviour of structural response in case of earthquake.

Shri Vinod Kumar Taamar making the presentation

These instruments continuously record seismic activity, capturing data on ground movements and structural responses to both minor tremors and significant seismic events. The collected data is further analysed to assess the dam's ability to withstand seismic forces, identify potential vulnerabilities, and guide the implementation of necessary reinforcement or mitigation measures. This proactive approach enables engineers to assess the dam's condition, implement timely maintenance or reinforcement measures, and optimize emergency response plans. Additionally, seismic monitoring helps in understanding the dynamic behaviour of the dam and surrounding geological conditions, contributing to improved design standards and risk mitigation strategies. Ultimately, it safeguards downstream communities, protects valuable water resources, and ensures the long-term operational efficiency of the dam.

Shri A.B. Pandya intervention after the presentation

The process for seismic monitoring of dams involves a systematic approach to collect, analyze, and interpret seismic data to ensure the dam's structural integrity and safety including Selection and Installation of Instruments, Capacity, strategically defined locations at dams, foundation, abutments and surrounding area, designing and establishing the communication network to ensure accurate data collection and timely acquisition, Filtering Noise, Identifying Seismic Events including processing and analysis, setting up the Threshold Setting and Automated Alarm or Tigger System for decision making, providing Power good signals with proper backup, load and balancing regular maintenance and calibration, data Integration, plotting, reporting and visualizations to provide a clear understanding of the dam's seismic performance over time in case of emergency preparedness.

Effective seismic monitoring enables proactive management, helping to prevent catastrophic failures, ensuring the safety of downstream communities, and maintaining the dam's operational efficiency.

Technical Session-9: **"Geodetic: Integrated Modern Approaches to Structural Health Monitoring in Dams and Apparent" -** *Shri Praveen Pillai, Sales Manager- Geospatial, Trimble Inc.*

Shri Praveen Pillai making the presentation

The Geodetic techniques have become integral to modern approaches in Structural Health Monitoring (SHM) for dams, providing precise and continuous measurements critical for assessing the stability and integrity of these massive structures. The integration of geodetic methods, such as GPS/GNSS, InSAR (Interferometric Synthetic Aperture Radar), and terrestrial laser scanning, allows for the accurate monitoring of deformations, displacements, and potential subsidence or uplift of dam structures. These techniques offer high-resolution spatial data, enabling the detection of even minute shifts that could indicate underlying structural issues. By combining these geodetic tools with traditional sensors and data acquisition systems, engineers can create a comprehensive SHM framework that not only tracks the physical behavior of the dam in real-time but also enhances predictive maintenance strategies. This integrated approach facilitates proactive management, ensuring the longevity and safety of dams by providing early warnings of potential failures or the need for repairs, thus safeguarding downstream communities and resources.

Dam safety monitoring is a worldwide statutory requirement. The long-term performance of a dam is a necessary factor in the evaluation of dam safety. Diurnal and seasonal effects, changes in hydrostatic pressure and related water seepage affect the health of dams. Wall deflection, settlement and heaving, rate of water flow, seepage, temperature, vibration, stress, strain, and other significant parameters require monitoring to detect changes in the performance of the dam. Catastrophic dam failure will threaten life and property downstream. The safe functioning of a dam is an important matter of economic benefit and public safety.

Monitor dam operations to flag potential failures and make informed decisions to mitigate production risks. Trimble Monitoring's consistent, reliable data enables safety and operational efficiency and insights to support a safe working environment, maintain productivity and reduce waste. The importance of a well-planned monitoring installation as an essential component of the maintenance and operation of a dam, particularly in an aging structure where early warning signs of failure may be detected, is widely accepted and in many countries, enforced by legislation.

Dr. Selva Balan making the presentation

Paper-2 : "Techniques in Designing an Efficient SCADA System for Canal and Barrage Automation-Case studies from India" - *Dr. Selva Balan, Joint Director, Central Water and Power Research Station (CWPRS), Government of India.*

Designing an efficient SCADA (Supervisory Control and Data Acquisition) system for canal and barrage automation involves several critical techniques to ensure robust, reliable, and responsive control. Firstly, the system architecture should be designed with scalability and modularity in mind, incorporating a hierarchical structure that includes field devices, local control units, and a central control station. Advanced communication protocols such as Modbus, OPC, or DNP3 should be employed to ensure seamless data exchange between these layers, minimizing latency and maximizing data integrity. The integration of real-time data acquisition from sensors and actuators is essential for accurate monitoring and control; hence, the SCADA system must be capable of handling high-frequency data inputs and performing real-time analytics. Additionally, incorporating redundancy and failover mechanisms at both the hardware and software levels can significantly enhance system reliability and uptime. The user interface should be designed for intuitive operation, with customizable dashboards and alerts that provide operators with clear, actionable insights. Moreover, implementing advanced cybersecurity measures is crucial to protect against potential threats and ensure the integrity of the automated control processes. Finally, regular maintenance and updates, including system testing and validation, are vital to adapt to evolving operational requirements and technological advancements, ensuring that the SCADA system remains efficient and effective over time.

Paper-3 : Geodetic Monitoring of Sardar Sarovar Dam – A Case Study - Shri K. Sudhakar, Scientist, National Institute of Rock Mechanics (NIRM), Bengaluru.

Shri K. Sudhakar making the presentation

The Geodetical monitoring of the Sardar Sarovar Dam, one of the largest and most significant hydroelectric projects in India, provides critical insights into the structural health and stability of this massive infrastructure. This case study explores the application of geodetic techniques for the monitoring and assessment of the dam's structural integrity. Utilizing advanced geodetic tools such as Total Stations, GPS (Global Positioning System) networks, and laser scanning, the study aims to track and analyse deformations, movements, and potential displacements of the dam structure. The integration of these geodetic methods offers high precision and spatial resolution, enabling real-time monitoring of the dam's performance under various operational conditions. By systematically collecting and analysing geospatial data, the study evaluates the dam's structural behavior, identifies areas of concern, and assesses the effectiveness of maintenance and reinforcement strategies. The results underscore the importance of continuous geodetic monitoring in ensuring the safety and longevity of large-scale dam infrastructures, highlighting how these techniques contribute to informed decision-making and proactive management of potential structural issues. The case study also talks and advocating about an advancement and adoption of new mapping techniques using GNSS and DFOS.

Technical Session-10: DFOS-Future Trends & Advance Monitoring Techniques in Structural Instrumentation: Balancing Safety, Efficiency, and Sustainability and Case Studies, Best Practices and Examples of Instrumentation in Existing Dams - Dr. Ajay Kumar Jha, CEO Nexhenhitech, Fibris Terre Systems GmbH-Trusted Partner, Berlin, Germany.

Dr. Ajay Kumar Jha making the presentation

Real-time structural health monitoring of large civil structures, such as dams, is crucial due to the significant economic and social consequences associated with structural failures. As existing dams age and new ones become more sophisticated, there is a pressing need for precise detection methods to better understand dam structural behaviour. Conventional monitoring systems, utilizing sensors like extensometers, piezometers, and temperature sensors, offer valuable data but are limited by technical biases, loss of sensitivity, and environmental degradation. These sensors often struggle with accuracy and calibration in harsh conditions.

To address these limitations, Distributed Fiber Optic Sensing (DFOS) technology has emerged as a superior alternative. DFOS provides high-resolution, spatially dense measurements over long distances with exceptional accuracy and precision. It enables real-time, electromagnetic interference-immune monitoring, offering advancements in temperature and strain measurement with accuracies down to 0.1¡C and micro-meters, respectively. DFOS employs both time domain-based and frequency domain-based interrogators, with the latter providing cleaner, more reliable data. Notably, the Distributed Temperature and Strain Sensing (DTSS) technology under DFOS allows for simultaneous monitoring of both temperature and strain using a single interrogator.

The advantages of DFOS over conventional systems include a comprehensive understanding of dam structures, enhanced detection of crack development and movement, and extensive monitoring of deformation and leakage. DFOS technology facilitates a more detailed and reliable assessment of dam health, surpassing the capabilities of traditional monitoring systems and offering crucial insights for maintaining structural integrity and safety.

Technical Session-11: Data Analytics - Automated Data Acquisition, Plotting & Processing, Evaluation, Interpretation, and Inference - Shri Mohan Gupta, Technical Head, AIMIL Limited.

The Instrumentation/Monitoring, Quantum computing, artificial intelligence, augmented reality, and machine learning - what's the one common thread that binds all these trendsetting technologies of tomorrow? It's the increasing prominence of data. Data they generate, and data they feed upon. But without expert interpretation, that data in its raw form has little value.

Data analytics has gone from being mere numbers in Excel sheets. Data analytics, the gap between analytics leaders and laggards has widened like never before. Mastering the skill of resource optimization is crucial, particularly when it comes to deploying technologies like Right Instrumentation & monitoring.

Automated data acquisition systems in dam monitoring significantly enhance the efficiency and accuracy of data collection from various sensors and instrumentation. By leveraging advanced technologies such as Internet of Things (IoT) devices and real-time telemetry, these systems ensure continuous data capture, minimize human error, and facilitate timely updates, thus supporting prompt decision-making and response.

Following acquisition, sophisticated software tools plot and process the data, generating real-time visualizations such as graphs and charts for parameters like water levels, strain, and temperature. Advanced processing algorithms handle large datasets, performing noise reduction and trend analysis to maintain data clarity and integrity.

From (L-R); Shri Mohan Gupta & Dr. M.K. Sinha

In the evaluation phase, automated analytical tools employ statistical methods and machine learning techniques to assess the processed data, identifying patterns and anomalies. This proactive approach enables early detection of potential issues such as structural weaknesses or unusual behaviour.

Data interpretation further transforms raw data into actionable insights through the application of complex algorithms and models. This stage provides a detailed analysis of dam performance and conditions, elucidating the implications of observed changes on structural integrity and operational efficiency.

Finally, the inference phase involves drawing conclusions from the interpreted data, with automated tools generating reports and predictive models. These outputs aid stakeholders in making informed decisions regarding dam operations and maintenance, leveraging historical and real-time data to enhance strategic planning and risk management of dam infrastructure.

Shri A. B. Pandya making the presentation

Technical Session-12: Codal Provisions, Authentic Guidelines by Other Institutions, and matching the pace with Advancement - *Shri A. B. Pandya, President, DSS.*

Codal provisions and authentic guidelines play a critical role in ensuring the safety, reliability, and efficiency of dams and water-retaining bodies. In India, the Codal provisions are primarily outlined in the "Indian Standard Code of Practices , which provides comprehensive guidelines on various aspects such as design, construction, and maintenance of dam structures. Similarly, the Central Water Commission (CWC) and the Dam Safety Organization (DSO) issue specific guidelines and safety protocols to ensure adherence to national standards. These provisions encompass structural design, hydraulic analysis, seismic considerations, and routine inspections, aiming to mitigate risks and enhance the durability of dam infrastructure.

Globally, various institutions and organizations set authentic guidelines for dam engineering and safety. The International Commission on Large Dams (ICOLD) offers guidelines that address design, construction, and operational practices for large dams. The United States Bureau of Reclamation (USBR) and the Federal Energy Regulatory Commission (FERC) provide detailed standards and safety protocols that are widely recognized and adopted internationally. These guidelines are instrumental in setting benchmarks for structural integrity, hydrological analysis, and operational safety, ensuring that dam projects meet international best practices and standards.

As advancements in technology and engineering continue to evolve, it is imperative for Codal provisions and guidelines to keep pace with these developments. In India, there is an increasing emphasis on incorporating modern technologies such as advanced monitoring systems, remote sensing, and data analytics into dam safety practices. Innovations like Distributed Fiber Optic Sensing (DFOS) and real-time telemetry are becoming integral to structural health monitoring and predictive maintenance.

Globally, similar advancements are being adopted to enhance the safety and performance of dams. The integration of smart technologies, such as Internet of Things (IoT) devices and artificial intelligence (AI), is transforming how dam infrastructure is monitored and managed. These advancements facilitate more accurate data acquisition, real-time analysis, and predictive maintenance, thereby improving the overall safety and efficiency of water-retaining bodies.

To align with these advancements, it is crucial for Codal provisions and guidelines to be periodically updated and revised. This includes integrating new technologies, addressing emerging risks, and adopting innovative practices that reflect the latest advancements in dam engineering and safety. By doing so, the industry can ensure that dam infrastructure remains robust and resilient in the face of evolving challenges and technological progress.

Technical Session-13: ***Panel Discussion, QA, and Valedictory Session within Speakers & Moderator: Shri A. B. Pandya, Panel Chairperson & with Key Panel Members (Shri Mohan Gupta, Dr. Selva Balan, Mr. Kevin Randall and Shri Vinid Tammar).***

Overview of Panel Members' Technical Elaboration on Dam Instrumentation and Monitoring

From (L-R); Shri A. B. Pandya, Shri Mohan Gupta, Mr. Kevin Randall, Dr. Selva Balan and Shri Vinod Tammar

In recent panel discussions on dam instrumentation and monitoring, experts have shared valuable insights into the integration of advanced technologies for enhancing dam safety. The panel comprised specialists from diverse fields, including structural engineering, hydrology, data analytics, and instrumentation. Each member contributed technical elaborations on the current state of dam monitoring systems and the critical role of data analytics.

One key insight discussed was the importance of real-time monitoring systems, advancement in SHM, such as Distributed Fiber Optic Sensing (DFOS), which offer high-resolution, spatially distributed measurements of temperature and strain. Panel members highlighted that DFOS technology enables precise detection of structural anomalies and deformation, which is crucial for early intervention and preventive maintenance. The use of such advanced sensors can significantly improve the accuracy of structural health assessments and provide continuous data that is immune to electromagnetic interference, thus enhancing overall dam safety.

Another critical aspect covered was the integration of data analytics in dam monitoring. The panel emphasized that data analytics plays a pivotal role in transforming raw sensor data into actionable insights. Advanced data processing techniques, including machine learning algorithms and statistical models, are employed to analyze large datasets, identify trends, and detect anomalies. This analytical approach supports proactive decision-making by predicting potential issues before they escalate, thereby ensuring timely maintenance and reducing the risk of catastrophic failures.

The discussions also addressed the need for harmonizing traditional monitoring methods with modern technological advancements. Experts noted that while conventional sensors and instrumentation remain valuable, their limitations - such as sensitivity degradation and calibration challenges—necessitate the adoption of new technologies. The panel advocated for a hybrid approach that combines established practices with innovative solutions to achieve a comprehensive monitoring strategy.

Group Photograph at the end of Panel Discussions

Overall, the panel's discussions underscored the critical role of integrating advanced instrumentation with robust data analytics to enhance the safety and reliability of dam infrastructure. By leveraging cutting-edge technologies and sophisticated analytical tools, stakeholders can ensure more accurate and reliable monitoring, leading to improved risk management and greater confidence in dam safety protocols.

Conclusion

The Dam Safety 2024 workshop on dam instrumentation, including seismic instrumentation, successfully fulfilled its objectives by providing a platform for knowledge dissemination, practical learning, and industry engagement. The event was a valuable experience for all attendees, from novices to seasoned professionals, and highlighted the critical role of instrumentation in ensuring dam safety.

The workshop underscored the need for continuous learning and adaptation to emerging technologies in the field of dam safety. Participants were left with a richer understanding of the factors that influence the accuracy and reliability of dam instrumentation data, as well as a greater appreciation for the challenges and opportunities in this essential area of engineering.

Dam Safety Society,
New Delhi

TAKEAWAYS FROM THE WORKSHOP

1. For quantification of the health parameters of dams, a well organized instrumentation programme is an essential ingredient.

2. Instrumentation is needed throughout the lifecycle of dams. During construction and initial reservoir cycles, it is required for confirmation of design assumptions and effectiveness of measures adopted. In the later parts of operation cycles, safety assurance becomes prime focus. For assessing monitoring needs, Potential Failure Modes that warrant attention are required to be kept in view.

3. Apart from the structural and hydraulic behaviour instrumentation, network of hydro-meteorologic instrumentation for efficient and timely inflow forecasting in real time is an essential ingredient for operational safety of dams.

4. Types and technology for the instruments vary with the type of dam, parameter to be measured and location where it is to be measured. Hence, planning an instrumentation programme has to be in step with the design processes for new dams.

5. Providing fresh instrumentation in existing dams poses special challenges due to accessibility of the locations where the parameter is to be measured. However, seepage, uplift/ pore pressures, displacements and monitoring of cracks and seismic responses can be installed beneficially even for existing dams.

6. Various technologies exist for sensor design. The vibrating wire technologies are currently being preferred for instrumentation in dams. Other specialized technologies based on fibre optics are also coming up and need serious investigation as to their suitability.

7. Well-designed data acquisition and information systems are necessary to monitor performance of the dam. The real time SCADA are required for safe and reliable operations of dams.

8. For dams with large number of gates and outlets, SCADA systems should have real time data display, historical data storage and alert and alarm management components are required. Sufficient redundancy through parallel channels of verification like CCTV cameras and manual over rides need be built in to meet extreme emergencies.

9. In concrete/ masonry dams, the plumb line installations are often not successful. Utilization of other vertical openings like shafts can be beneficially used for restoring these measurements.

10. Use of precision survey methods with modern instruments like total stations, DGPS and SATNAV techniques make it possible to monitor the deformations with reliability and precision. There is a need to provide skill set to the project personnel for executing such observation programme.

11. A number of new technologies have emerged for hydrological and meteorological observations. The new techniques are claimed to be robust and more precise. However, calibration with the conventional modes of measurements should be carried out to correlate with the standard instrumentation for recording and utilizing data with a common baseline.

12. With the increasing frequency of intense events, the hydrological instrumentation networks should also be considered an essential part of dam safety assurance programme.

13. Unattended water level, snow and discharge measurement systems are important for the advance warnings of Glacial Lake Outburst Floods (GLOF). Such networks as a common utility should be implemented wherever significant developments like hydropower, tourism or population centers are located in target areas in Himalayan regions. Such networks should have facilities of disseminating the information on a wide basis and also be maintained and operated as a common good utility, jointly owned.

15. To reducing the down time of the real-time instruments at dam, through the use of maintenance log data & statistical algorithms and machine learning techniques, dam owners can identify the likelihood of future sensor performance trends and downtime.

16. Fibre optic sensors are witnessing a rapid development trend. While time domain reflection methodologies are being taken up for use, a mix of methods for better assessing the parameters of interest like deformation/ strain have been developed. More work and test implementation of such techniques are needed to develop alternative methods of measurement for existing dams.

17. Using digital signal processing techniques, the signal input from the vibrating wire sensors can be improved. Elimination of frequency noise introduced due to environmental factors and other interference can permit better reliability of the instrumentation observations. Techniques employing real time Fast Fourier Transforms are being built in hybrid mode in new readouts. Such readouts can be tried.

18. It is necessary that a systematic database is established for all the instrumentation programme right from the time of construction and initial installation. Modern IT based tools and industry standard RDBMS should be gainfully established. The application should have extensive facilities for presenting the observations in a graphical form for rapid assessment and analysis.

Dam Safety Society,
New Delhi

About Dam Safety Society

Dam safety assurance and rehabilitation has been addressed in the country at union government level since 1979 and had been getting addressed at the states level in various degrees of maturity. However, the dialogue was confined at the Government department levels. With the promulgation of the Dam Safety Act 2021, the importance of assuring the safety of dams all through the country has been legally enforced. With this, the scope of dialogue has encompassed not only the state and the union government departments and units but has also brought in the dam owners in all the sectors. There are special demands of the dam safety assurance and rehabilitation for which a special class of service and solution providers exist. Thus, there is a considerable expansion of the stakeholder groups in respect of dam safety. A need was felt that all the stakeholder communities need be brought under a neutral platform where the technical, logistical and prioritization issues can be discussed and collation of experiences generated is achieved for common good of the sector. A platform to preserve and exchange the knowledge base in respect of dam safety is required to be established for this growing discipline. Therefore, a group of interested senior professionals came together to formally establish the society in July, 2

International Conference DAM SAFETY 2024

The dam safety conference was conceived as a regular forum for exchange of ideas specific to the dam safety and water resources asset management areas. The conference was divided into 7 exclusively technical sessions where different aspects of the dam safety assurance were addressed. A total of 36 papers were presented over a span of two activity filled days.

The sessions of the conference were

Inaugural Session

The conference and exhibition were inaugurated by Shri Mukesh Puri, IAS, Managing Director, Sardar Sarovar Narmada Nigam Ltd.(SSNNL), Shri CV Nadpara, Director (Dams) and Sh. P C Vyas, Director (Canals). Shri A.B. Pandya, President, Dam Safety Society and Former Chairman, Central Water Commission welcome the dignitaries, invitees and participants of the conference. He mentioned that soon after formation of the society, it was felt that there is a need to have a regular dedicated platform for the entire cross section of dam safety professionals, to familiarize themselves with the advances and practices in dam safety assurance and rehabilitation. Dam safety assurance requires deployment of technologies and services that span over wide inter-disciplinary spectrum. Conventional conferences addressing the basic disciplines are not able to focus on them. Therefore, the platform should provide an opportunity amongst various service providers and suppliers to showcase their products and services specific to dam safety assurance and management.

Inaugural Session

Plenary session: Emerging challenges in dam safety management and global best practices

The session was chaired by Dr. M.K. Sinha, Chairman, Godavari River Management Board. Following key-note presentations were made in the session:

- Global Best Practices in Dam Safety Management - Enrique Cifres
- Dam safety Assurance - A. B. Pandya
- Dam safety Issues and Relevance of Dam Rehabilitation and Improvement Project - Rakesh Kashyap

The International Conference on Dam Safety was inaugurated by Managing Director, SSNNL.

Plenary Session
Dam safety assurance- strategies to follow A.B. Pandya

Mr. Pandya highlighted the relevance of dams in Water Food and Energy (WFE) nexus and mentioned that in 2020, low carbon footprint Hydropower gave 17% of global electricity generation. Irrigated areas account for roughly 24% of croplands worldwide, but produce about 40% of the world's food. The only sustainable means of storing large volumes of annually replenishable water is the reservoirs created by dams. Among the single purpose dams, 48 % are for irrigation, 17% for hydropower, 13% for water supply, 10% for flood control, 5% for recreation and less than 1% for navigation and fish farming. Multipurpose dams perform all these functions simultaneously.

Shri A. B. Pandya making the presentation

Why Dam Safety

While giving the brief background about the Dam Safety, he mentioned that the Dams are very costly infrastructure built at great expense and effort and are a public asset. Dams enable management of an everlasting water resource and are required to last forever. With the change in environment, age and usage pattern, the continued operation of a dam requires systematic review and upgradation at regular intervals. Dam safety is an asset management discipline relying on science and technology and has components of public administration. Dams do pose hazard if not maintained or managed properly. Management of risk is also covered by the dam safety discipline. Being linked to public safety and benefit assurance, Governance structures are needed to implement and supervise the activities under the dam safety

Issues and challenges

While focusing on the issues and challenges in dam safety, he mentioned that we have started working on dam safety since long, the approach has been voluntary and owner specific (Anecdotal). Enactment of dam safety act 2021 has created a necessity for establishment of a standard implementation strategy (New Situation). Some approaches have been generated through the world bank assisted programmes like DSARP and DRIP, but continuation of these approaches beyond the tenure of the programme is challenging (Sustainability). Similar situations are also felt the world over as the hazard awareness increases. (Unified Approach)

He has highlighted some of the Major areas

Management and Administration

Dams Portfolio creation and management

Inventorization, operational databases, hierarchical responsibility definitions
Inspection and Surveillance Programme, Reporting
Setting up programmes, monitoring parameters, reporting requirements, data analysis
Follow up and escalation processes
Assessment of needs, mobilization of expertise, course determination, financial and logistical need definition
Mobilization of logistics and human resources
Infrastructure and logistics

Technology
Rehabilitation Standards
Performance standards for processes and materials
Analytical Methodologies and Risk Quantification
Evaluating environmental loads, Performance simulation under revised loads, Probability of failures/ incidents
Specialized Investigative and surveillance technologies
In-situ and laboratory investigations for materials, performance monitoring
Specific Construction materials and techniques; Infrastructure and logistics; Emerging Scientific Areas such as Climate Change - Changes in yield and flood patterns for the reservoirs, Effects of extreme temperatures on dam components, and Decreasing dry weather flows and impact on structures like energy dissipators; Analytical Methodologies and Risk Quantification; Visualizing new situations of flood formation and emergency action plans; Considering downstream development projections in EAP and Handling changes reservoir operations in safety protocols

Leveraging Climate funding for dam safety
Financing dam safety programmes, Sustainable Revenue Models for safety assurance costs
Feasibility assessment of various revenue streams, implementation, investments required
Finance mobilization based on risk based prioretisation
Estimating finance requirements, priority based allocation, emergent requirements
Special procurement processes for unique products and services
Limited/ proprietary products and services acquisition process, special conditions of procurement and payment
Development and nurturing sinking funds for the assets

Stakeholder participation
Awareness creation amongst key management personnel
Explanation of emerging situations, generating awareness about consequences
Facilitation of resources generation through political and bureaucratic support
Need awareness of the resources requirements, Implications of deprival of resources for safety assurance
Generation of responses in affected domains
Land and development plans, Impact awareness on investments in affected areas
Communication channels for hazard mitigation
Public safety awareness for dam operations
Transboundary cooperation

Capacity and Skills
- Setting up information base
  - Documentation about the assets, key operational parameters and procedures, safety historical records
- Knowledge infrastructure
  - Collation and compilation of knowledge as gained from operations, identification of knowledge sources, adoption of specific processes, participation in standardization exercises, building and maintaining expert resources base
- Operational skill building
  - Building skills for extreme situation operations, setting up practices and manuals specific to the structure, nurturing expertise and upgradation of expertise
- Mobilization of logistics and human resources

Infrastructure and logistics

Keynote address on Dam safety: insights and thoughts- Enrique Cifres

Dr. Cifres while giving the brief background about the dam safety mentioned about the Dam Safety Pillars. Such as Emergency planning is of utmost importance for all dams; adequate training of operators; sharing lessons learned benefits the entire industry; an international perspective to dam safety can be enlightening; a comprehensive dam safety approach will allow minimization of risks and A dam owner has the ultimate responsibility for its dam.

He also mentioned that the role of regulatory authorities is paramount for safety; ageing vs obsolescence - Functional modification of dams in operation; Functional or structural modification of dams under operation and Structural remedial of old dams. He also focused on Hydrological safety which is Very rare events but still possible and also shown some concerns about classical methods; Climate Change impact; Parametric analysis. Just modifying few point it's possible to re-assess probability function and identify the impact of one parameter as sea temperature that governs storm depths.

Modernizing methodologies. Repeating classical studies with CC data changes is not enough. Assuming that the revision of hydrology entails the admission, in many cases, of greater risks than estimated. Establishing margins of uncertainty in the design of hydraulic structures is recommended. Updating studies with consideration of Climate Change relevant parameters. Foreseeing investments to face flood risk evolution due to CC by means of infrastructure updating. Complementing with non-structural measures, such as RTWS and Emergency Action Plans

Hazard Creep or risk creep, caused by changes in the basin that may result in changes to a dam classification. New development constructed downstream of a dam, or upstream development or deforestation that increases runoff, can result in higher potential consequences. **Classification may vary**

Monitoring hazard creep.

As a standard operating procedure, dam owners **should review** the EAP and inundation maps

periodically and update as needed.
any updates to inundation maps, evacuation plans to include new buildings or other occupied assets within the inundation area.
Local government officials should minimize damage through *prudent development.*
The state dam safety regulator should complete hazard creep analyses for dams and *reclassify* them as needed.
Property owners and other stakeholders should be kept informed about a dam with the potential to impact their property due to spillway release, flood control storage release, or catastrophic failure and any changes of its hazard potential classification in order to make informed decisions. (INFORMAR)
Design, inspection, and maintenance requirements should also be **reviewed** and updated as necessary.
Mitigating hazard creep.
Sensible land use planning can help reduce or eliminate hazard creep. Zoning regulations, building codes, and floodplain management ordinances can be adapted to guide **development away from inundation areas**, elevate
Structures
Relocating potential at-risk development away from inundation areas or developing property prudently.

Lack of legal framework : a challenge to face in many countries

Despite policies aimed at reducing risk, potential flood damage is increasing (assets and human), due to the lack of guarantee in the control of social dynamics outside the dam.

D.K. Sharma

Regulatory and Policy Intervention for Speedy Harnessing of PSPs

Dr. D.K. Sharma making the presentation

Policy makers and civil society have to recognise the crucial role of dams and Pump Storage Plants in energy transition and climate change adaptation. Construction of pump storage, storage based and pondage based sustainable hydropower to achieve the net zero pathway has to be prioritised and implemented on fast track.

- ō Dam Safety relies on a strong National Governance (Dam Safety Act in India)
- ō Dam safety is a personal duty and a sacred responsibility to the dam engineers
- ō Failures and incidents provide valuable lessons and advance
- ō Dam safety management is a daily activity and a long-term commitment for many generations of those associated with dams

- ß With the increasing global warming, losses or damages are becoming very difficult to avoid. Adaptation strategies do not prevent all losses and damages even though they are implemented effectively. Implementation of adaptive measures depend upon capacity and effectiveness of governance and decision making processes. Overall findings of the study highlight the need to implement adaptive/mitigation strategies ensuring the water security of

TAKEAWAYS FROM THE CONFERENCE

1. Reduction and minimization of the risk is the fundamental aim of dam safety. Lack of legal framework is a challenge in many countries. Role of regulatory authorities is paramount for safety.
2. Structural integrity of dams is keystone to dam safety. Surveillance, maintenance, inspection and monitoring on a sustained basis right from the construction stage onwards is essential. Growth of natural hazard risks will have to be accounted for with the growing age of the dams.
3. Emergency action planning is of utmost importance for all dams. Very rare events but still possible can not be ignored.
4. India has almost 1300 dams older than 50 years out of a total of 6138 large dams. This poses a challenge of safety assurance of great magnitude. Dam safety act 2021 and various measures taken thereunder are playing a vital role in generating awareness and setting up mechanisms for safety assurance. DRIP series of programmes are playing vital role in establishing procedures and providing financial and technological help.
5. The dam safety programme will have to be sustainable. For achieving this, various aspects like management and administration, science and technology, finances and revenue models, capacity and skills and stakeholder involvement will be necessary. It will have to be a strategy-based approach.
6. A rational selection of storm considering the storm track, topographic and meteorologic influencing factors of storm centering and storm transposition limits need to be decided carefully in order to obtain a reliable levels of PMP depths over the sub-catchments and consequent PMF estimate through a detailed sensitivity analysis.
7. Significant climate trends have an impact on dam safety and water management. Increased extreme precipitation events will necessitate larger spillway capacities and robust quick acting infrastructure to prevent dam failures.
8. Large reservoirs are capable of absorbing significant (>80%) of peak inflows and thereby reducing the flood risk to downstream by efficient operation strategies like robust inflow forecast, periodical review of operation procedures can ameliorate the climate change effects.
9. Intense and infrequent rainfall events in arid areas pose a difficult compromise between conservation and flood management policies. Protection to downstream areas can endanger the safety of dam. Efficient real time inflow forecasting and training in large flood management to dam operators can help.
10. Re-assessing the flood risk to old dams involves changes in flood assessment approaches from those adopted in past. The flood risk of a large number of dams experiences increases commencing from 20% to >100%. Use of PMP atlas and standardized procedures with a basin based rationalization of flood risk provides reliable estimates.
11. Geophysics is playing a critical role in defect investigations and rehabilitation planning. There are a large number of technique based tools available. However, selection of an appropriate set of tools is important to deliver desired information to the dam engineer. In order to tackle about 6000 dams for safety evaluation, geophysics can be beneficially utilized with proper guidance and correlation with site conditions.
12. Creating wider awareness of the geophysical techniques with correlation with physical tests of the parameters by standard tests to arrive at dam-wide assessment of properties and phenomena like strength variations and seepage paths.
13. A successful instrumentation programme like that at Bhakra dam provides continued information about performance of the dam and is valuable for dam safety assurance. Observations like uplift, deflections in horizontal and vertical directions and correlation with models provide valuable insights. Annual observation reports should be prepared and meticulously examined.

14. Established strong motion accelerographs in the dams in Himalayan region provide valuable information about the ground motions during earthquakes of various magnitudes. A comprehensive database of historical records need be developed at the national level integrating all such instrumentation across the dam owning agencies. Generation of Ground Motion Prediction Equation parameters can be made in Indian geology context using such data. The approach adopted by NHPC may be expanded in this aspect for optimizing our design parameters.
15. Measurements like seepage, settlement and displacement (internal as well as external and across crack like features) are valuable parameters for assessing Potential Failure Modes (PFMs) for a dam. Trends noticed over a continued programme provide early warnings and scope to implement failure prevention measures.
16. Using modern IT tools, User Interfaces can be built integrating structural and hydrological safety parameters. Such interfaces can beneficially integrate dams in a cascade for a comprehensive emergency action programme. However, the models to be selected for implementing such Decision Support Systems should be appropriate.
17. In-situ and laboratory tests on the samples of the materials of the dam provide quantitative information and should be integrated into a safety evaluation programme. Simulation tests in laboratories provide useful information about possible performance of a repair measure.
18. A measurement programme should commence right from the time of installation of an instrument in the body of the dam during construction. Construction stage performance monitoring goes a long way in ensuring a safe dam for posterity.
19. Rehabilitation of a distressed dam is a specialized exercise involving grouting, structural modifications and various other techniques. Control of leakages from the body of the dam is a frequent problem needing provision of membranes, shotcrete and grouting.
20. Geosynhetics can be beneficially used for prevention of erosion and improving hydraulics of the dam components. For erosion prevention, armoured section of geotextiles is comparable to conventional provision of concrete blocks.
21. Techniques like borehole logging and nuclear density probes provide useful information about the state of material within body of the dam.
22. Spillway glacis and energy dissipator erosions can lead to severe impact on safety of the dam. Restoration with specialized material duly integrated with the existing structure is very important. Such restoration should be preceded with regular inspections and reporting.
23. Underwater repairs to the dam upstream face and other components is a valuable tool. Use of trained divers, specialized epoxy materials and Remote Operated Vehicle based inspections are essential part of the programme. Role of experienced agencies become important in executing such programme. Considerable developments in under water works like inspection, drilling and grouting need be exploited as per requirements.
24. Site specific seismic hazard assessment approach adopted by National Committee on Seismic Design parameters provides for minimization of subjectivity in assessment and is in line with international practices.
25. Hazard classification is being graded in line with the hazard potential as indicated by the storage and hydraulic heads behind the dam. A suitable mix of Probability and Deterministic methods coupled with rational assessment of causative mechanism is recommended to be adopted.
26. Evaluating stability of existing embankment dams can be carried out by deformation assessment methods like those of Newmark sliding block theory approach. The methods need evolution and more applications to arrive at standard guidelines. Numerical method applications for embankment dams require special care as the assumptions about the behaviour need to take into account nature of soils.
27. Risk informed decision making is a discipline developed earlier in different fields and is being increasingly applied in the dam safety areas. Potential Failure Mode Analysis is based on the inspections and field and desk studies but assignment of indices to the assessments is a

subjective area. Risk prioritization based on these methods will have to be rationally evaluated in a comparative fashion taking into account application of similar standards across the dam population.

28. PVC geomembranes are flexible, durable with long life and are capable of providing effective sealing against the seepage in dams. Anchorage and sealing of joints should be properly designed and implemented at site. Case studies need be documented and disseminated for guidance of other engineers. Under water installation of the membrane is an upcoming application which has to be tried in India as well.
29. Robotics and AI based applications for image processing have a potential for dam safety surveillance and rapid assessment of the conditions of the dam surfaces. The method can feed into digital twin concepts based approaches. For a large population, these techniques may prove useful in reducing turnaround times. More applications are needed in India.
30. Acoustic Emission techniques are useful for defect location in massive and heavily reinforced structures. Applications at Polavaram dam have provided useful insights in the application of the techniques. Further developments and applications are needed.
31. Exceedance Probability Inundation maps for emergency action planning are useful decision support tool for flood operation of dams. Apart from the dam failure analysis, inundation mapping need be carried out for extreme flood events handled without a breach.
32. Maintenance and revival of instrumentation in a dam is a difficult exercise and success rates are limited. Some of the surface accessible instruments have better chances of revival than the embedded ones. Innovative techniques have to be employed for such revival. Costs of a renewed minimum instrumentation programme vis-ṛ-vis the revival costs should be compared.

Group Photograph

Exhibition

Audience