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ABOUT JOURNAL

INCOLD Journal is a half yearly journal for fully-reviewed qualitative articles on aspects of the planning, design, construction and maintenance of reservoirs, dams and barrages, foundation and scientific aspects of the design, analysis and modelling of dams and associated structures.

In addition to the information on the research work on the relevant subjects, the journal shall provide information on the related technical events in India and abroad such as conferences/training programmes/exhibitions etc. Information related to ICOLD activities shall also be highlighted.

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Secretary General

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Editorial

Greetings from INCOLD, New Delhi.

At the outset, let me convey our best wishes for Happy and Prosperous New Year 2019.

Global declines in water storage are increasingly troubling. With greater hydrological variability due to climate change, more storage will be vital to provide the same level of security of water, food and energy. Water storage is a fundamental protection from the impacts of a changing climate, safeguarding the supply of water, and the water–food–energy nexus, even during extended drought. For thousands of years, dams have stored water to irrigate crops, control flooding, supply water for industrial and household use, and generate hydroelectric power – contributing enormously to food security, human development and economic growth. These days, many dams serve more than one function, but remain the primary mechanism for coping with the variability of water supply and demand. During the last century, more than 45,000 dams higher than 15 m have been constructed worldwide, creating a combined storage capacity estimated to be between 6700 and 8000 km^3, representing 17 per cent of global annual runoff.

Security of water, food and energy are inextricably linked. For example, approximately 50 per cent of all large dams worldwide are used for irrigation. Without sufficient water storage, irrigated agriculture (the largest user of water at the global level, contributing 40 per cent of the world’s food) is at the mercy of changing patterns of rainfall and runoff. Understanding water storage issues is essential for successfully managing water resources. At the simplest level, it is a matter of ‘inflow (water supply) less outflow (water demand) equals change in storage’. But it is particularly important to understand whether storage declines relate to reducing supply, increasing demand, or both. Key factors influencing storage are greater variability of inflows due to climate change, increased demand due to population growth, reduced net storage due to sedimentation, and less dam construction occurring worldwide due to environmental and social impacts. The effects of climate change are predicted to increase and to result in greater magnitude and frequency of hydrological extremes, such as prolonged droughts and significant floods. With prolonged drought, inflows for storages will reduce. If demand remains the same, stress on existing water storages will increase.

Keeping in view the above, Indian Committee on Large Dams and Central Board of Irrigation and Power in Technical Collaboration with Central Water Commission and in association with BBMB, THDC, NHPC, NEEPCO organized two days Conference on “Storage Dams for Water Security and Sustainable Development” on 24-25 October 2018 at New Delhi to focus on the various issues connected with the creation of more no. of storage to meet the water demand with greater hydrological variability due to climate change and level of security of water, food and energy.

I thank all the authors for their valuable contributions. I also take this opportunity to thank all the members of the Editorial Board for helping us in our endeavour and providing us with their valuable suggestions in bringing out this journal.

We request all the water and dam professionals’ readers to contribute technical papers/articles, news etc. which would be of interest for publishing in the subsequent issues of the journal. We also request for the comments /suggestions of the readers so as to improve the utility of the journal.

V.K. Kanjlia
Secretary General
Indian National Committee on Large Dams

Hydraulic Design Considerations of Spillways and Energy Dissipators for Hydropower Projects in Himalayan Region

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ABSTRACT

The Himalayas have the largest concentration of glaciers outside the polar region. In the face of global warming, there is clear evidence that Himalayan glaciers have been melting at an unprecedented rate in recent decades. These in turn give rise to an increase in the potential threat of glacial lake outburst floods occurring. Because of fragile geology and steep Slopes, soil erosion rate is high during snowmelt and monsoon. Sudden discharge of large volumes of water with debris from the lakes potentially causes glacial lake outburst floods (GLOFs) in valleys downstream. These in turn give rise to an increase in the potential threat of glacial lake outburst floods occurring.

The rapid altitudinal variations with swift flowing perennial rivers have made Himalayan region a natural haven for large-scale hydro power production. Considering the experience of silting of dams and damages to power plants, the trend has changed to design the Himalayan hydropower projects as run-of-the-river schemes utilizing the stream flow as it comes without any permanent storage. Innovative designs of orifice spillways in the form of low-level sluices in the body of the dam or a spillway with a breast wall have been evolved based on the concept of reservoir flushing with minimal impact to the environment. A number of hydroelectric projects in India, Bhutan and Nepal are being planned in the Himalayan regions. It has become necessary for the project planners and designers to account for the GLOF also along with the Probable Maximum Flood (PMF) due to rainfall for deciding the spillway capacity of projects.

Special considerations are required for design of suitable energy dissipator, since the spillway has to surpass both the flood and the sediment. Ski-jump bucket is found to be the most suitable form of energy dissipator because of its obvious advantage during flushing operation. The sediment passes down the spillway with supercritical flow without deposition and churning in the bucket. Fortunately, steep bed slopes of the rivers result in low tail water depth permitting this type of energy dissipator. If the geological conditions are not favourable, a hydraulic jump stilling basin may have to be adopted. Because of the requirement of passing silt-laden flows, use of energy dissipating appurtenances like chute and baffle blocks is not advisable. Cylindrical end - sills are generally preferred for easy movement of sediment out of the basin. A concrete apron downstream of the end sill is required to protect the spillway against undermining due to scour during transition action from hydraulic jump to flip action and vice versa. Provision of roller bucket is generally avoided as an energy dissipator due to likelihood of abrasion damage of the bucket due to churning of sediment.

The present paper describes various hydraulic design considerations while designing the spillway and energy dissipator for run-of-the river projects in Himalayan region. It is also emphasized that although no design procedures are readily available for such type of spillways, experience from the hydraulic model studies and prototype to evolve suitable layout of spillways and energy dissipators provide useful guidelines.

1. INTRODUCTION

India has so far constructed about 4700 large dams and another 390 projects are under construction[1]. The dam building activities over the years have been concentrated in the ideal and easy sites. This leaves the geologically and topographically complex and difficult sites for future activities. These sites have been identified mainly in the Himalayan and North Eastern regions. High mountains, deep narrow valleys, complex geological strata with occasional problems of stability of hill slopes and generally high levels of seismicity characterize the Himalayan terrain. These rivers have very steep bed gradient in the range of 1 in 60 to 1 in 100. These give rise to flash floods and huge amounts of sediment load. This sediment would ultimately settle in the reservoir resulting in the reduction of live storage capacity. In order to utilize the high heads and discharge available in this region for power generation this sediment should be flushed regularly. The overflow spillways using conventional methods i.e. high head storage dams for river valley projects in Himalayan regions are not suitable. The ongoing and future dam building activity involves more complex flows with unprecedented flash floods causing high velocity flows and associated problems of turbulence, cavitation and air entrainment. Some spillways are also designed considering the flash floods caused by Glacial Lake Outburst Flood (GLOF). Due to potential impacts of climate change on glacier dynamics, catastrophic GLOF may increase future flood risks for infrastructure and population. This is particularly relevant in view of the current development of hydropower projects in Himalaya. These flash floods also contribute to the major part of the sediment in glacierized catchments. In such complex hydrological scenario, assessing the hydraulic performance of spillways with sediment flushing facility would be of vital importance. As per data collected by ICOLD on failure of large dams, nearly 35% of dams have failed globally due to causes related to inadequate spillway capacity and hence this becomes a major concern in Dam safety programme. This paper describes the various issues related to glacial melting leading to contribution of GLOF to the design flood, floods with severe sedimentation and consequent change in the design of spillway & energy dissipator and role of hydraulic model studies in assessing and optimizing the overall hydraulic parameters of spillway.

1.1 Himalayan Water Resources for Hydropower Generation

Himalaya forms the most active and interactive snow-land-ocean atmospheric system. The landscape of the Himalaya is founded on an immature geology and on unconsolidated rock systems, Problems thus arising are compounded by the heavy rainfall and fast moving streams, and as a result the geomorphology of the Himalaya has changed and will continue to change. The available estimates show that the water yield from a high Himalayan catchments is roughly double that from an equivalent one located in peninsular India and this is mainly due to additional inputs from snow and ice melt contributions from high altitudes. Longer availability of water in the high altitude region will be helpful in generating cheap hydroelectric power and maintaining the greenery thereby reversing the environmental degradation of the mountain system as the entire water conductor system including powerhouse are located in the underground. The only structure located on the surface is diversion dam.

Hydropower potential of Himalayan river systems is about 78% of the total Indian hydropower resources. This potential of Indus, Ganga and Brahmaputra river basins is assessed to be 19,988; 10,715 & 34,920 MW at 60% load factor respectively. Several studies have shown that hydropower has small share in environmental degradation which can be largely compensated by environmental protection measures[2]. It may be pointed out that the developed countries the world over have tapped hydro resources before moving to fossil fuels. It is high time, the country focus on hydropower to ensure its energy security. It is well recognized that hydro power constitutes the cleanest and cheapest source of power generation in India even after the recent enormous increase in the costs of equipment and civil infrastructure. In addition to the development of the hydro power potential in India, Government of India is also facilitating Government of Bhutan to develop its hydro power potential of 30,000 MW, about a fifth of India's own potential.

1.2 Impact of Himalayan Glaciers, Glacial Lakes and GLOF on design of Spillway

The Himalayas have the largest concentration of glaciers outside the polar region. These glaciers are a freshwater reserve for nine major river systems in Asia – a lifeline for almost one-third of humanity. The climatic change/variability in recent decades has made considerable impacts on the glacier life cycle in the Himalayan region. As a result, many big glaciers melted, forming a large number of glacial lakes. Due to an increase in the rate at which ice and snow melted, the accumulation of water in these lakes started increasing. Sudden discharge of large volumes of water with debris from these lakes potentially causes glacial lake outburst floods (GLOFs) in valleys downstream. These in turn give rise to an increase in the potential threat of glacial lake outburst floods occurring. A number of hydroelectric projects in India, Bhutan and Nepal are being planned in the Himalayan regions. It has become necessary for the project planners and designers to account for the GLOF also along with the Probable Maximum Flood (PMF) due to rainfall for deciding the spillway capacity of projects. Table 1 shows the magnitude of GLOF considered for various hydropower projects in Himalaya in addition to Probable Maximum Flood (PMF) for which hydraulic model studies for spillways were carried out or being referred for studies at CWPRS, Pune.

Table 1: Magnitude of GLOF and PMF for various projects in Himalayan region

Sl. No.	Name of the Project	PMF in m^3/s	GLOF in m^3/s	PMF + GLOF m^3/s	Percentage of GLOF wrt PMF
1	Punatsangchhu-I H.E. Project, Bhutan	11,500	4,300	15,800	37.4
2	Punatsangchhu-II H.E. Project, Bhutan	11,723	4,300	16,023	36.7
3	Etalin H.E. Project, Dri Limb, Ar. Pradesh	11,811	1,170	12,981	9.9
4	Etalin H.E. Project, Tangon Limb, Ar.Pradesh	10,218	2,143	12,361	20.97
5	Arun-III H.E. Project, Nepal	8,880	6,830	15,710	76.91
6	Chamakharchhu H.E. Project, Bhutan	9,406	5,112	14,518	54.35
7	Kwar H.E. Project, J & K	10534	620	11,154	5.88
8	Mangdechhu H.E. Project, Bhutan	6,900	3,715	10,615	53.84

Approximately 15,000 glaciers (covering an area of 33,340 sq. km), and 9000 glacial lakes throughout Bhutan, Nepal and Pakistan, as well as selected river basins in China and India were documented in a baseline study conducted earlier by ICIMOD, UNEP, and the Asia Pacific Network for Global Change Research (APN). GLOF events have adversely affected Nepal and Bhutan in the recent past and to date over 200 potentially dangerous glacial lakes have been documented across the Himalayan region[3]. A GLOF event of 1985 originating from Dig Tsho, a glacial lake in the Khumbu Himal, Nepal, destroyed the Namche Small Hydel Project and caused extensive damage downstream. GLOFs have caused damage across national borders; outbursts originating in China have impacted areas in Nepal, India, and Bhutan[4]. June 2013 floods in Uttarakhand also have big GLOF component[5]. The Nathpa Jhakri Hydroelectric Project situated in Himachal Pradesh is world's one of the largest run-of-the-river schemes and has dealt successfully since its commissioning in 2000 the frequent flash floods of large magnitudes due to accurate warning system so that sufficient time is available for proper assessment of flood and depleting the Nathpa reservoir in anticipation of heavy inflows and timely operation of spillway gates. The GLOF of the order of 4500 m^3/s was observed on 26th June, 2005 due to breach of artificial lake formed on Parechu river (in Tibet region). Since necessary measures had already been taken, no major damages occurred for the project. During the floods river carried lot of silt, boulders, gravel, & trash etc. and the intake gates of water conductor system of powerhouse was closed to avert damages to the Power House in Jhakri. Urgent action by the international community to develop even better scientific understanding of the consequences of global climate change on GLOF and to take the corrective and precautionary measures is required. Hydrological models have been developed to calculate discharge and flood arrival times in downstream areas. Monitoring of glacial lakes in poorly accessible mountain locations using satellite-based techniques is also explored as a basis for monitoring and prioritization of disaster mitigation efforts.

Monitoring and tracking of the lakes in West and North Sikkim has revealed that quite a few of them are expanding due to accelerated glacial retreat and melting due to climate change impacts. In addition, new lakes have also developed due to glacier retreat and melting. During the retreat the glaciers leave behind moraines (accumulation of boulders, stones or other debris) in the valley. Moraine-dammed lakes were observed from 1965 to 2010 using satellite imageries in Teesta and Rangit basins of Sikkim[6].

Modeling and prediction of the motion and reach of GLOFs is very difficult due to following reasons[7]:

- The knowledge about the onset of the process is often limited (properties of dam, type of dam breach, understanding of process chains and interactions).
- The volume of water involved in the outburst flood is unclear. The lake bathymetry is often unknown and may change rapidly. Furthermore many lakes burst out within a short time after their development without being detected as potential source of hazard [8]. Continuous monitoring is required to keep updated on the existing hazards.
- Uncertainties related to erosion and deposition is a big unresolved issue. Erosion of the dam and the bed as well as concomitant deposition can strongly change the rheology and the moving volume of the flow. These changes have a direct impact on the spreading and reach.

Considering all these points, it has to be concluded that up to now, no well suitable modelling approaches do exist for GLOFs, as these represent highly variable phenomena and often exhibit a behaviour in between debris flows and floods. Figure 1 gives the Schematic representation of a Glacial Lake Outburst Flood.

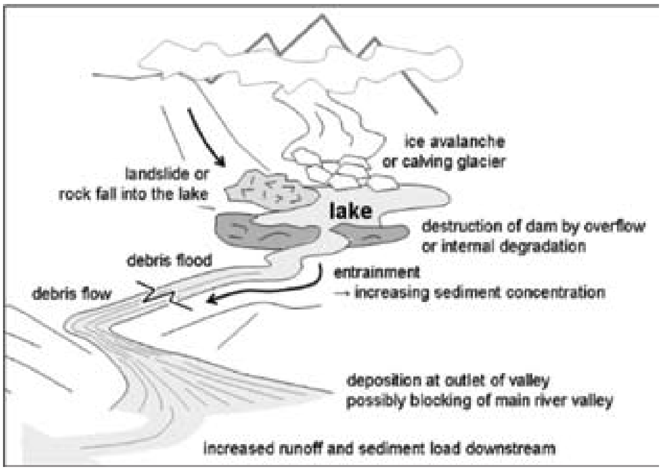

Fig. 1 : Schematic representation of a Glacial Lake Outburst Flood

Glacier-dam failures have produced the largest documented historic and prehistoric flood-peak discharges known on Earth. The most dangerous glacier dams are formed when tributary-valley glaciers block main valleys and form large lakes behind them. Temperate glacier dams usually fail by erosion of sub-glacial or englacial tunnels under or through the ice dam, aided by the hydrostatic pressure of water behind the ice dam. Cold polarice dams fail most commonly by overtopping and erosion of a channel in the ice[9].

2. DESIGN PHILOSOPHY OF SPILLWAYS IN HIMALAYAN REGION

The major causes that are responsible for floods and flash-floods in Himalayan Rivers are:

1. Cloudburst in the catchment of the river.
2. Heavy rainfall in the upper reaches of the river.
3. Sudden breach or bursts of glacial lakes.
4. Landslides leading to obstruction of flow and change in the river course.
5. Tectonic movement leading to slope failure and landslides

These rivers carry heavy sediment load during monsoon and snow melt in summer, which has to be efficiently managed to ensure long term sustainability of hydropower projects. Conventional design viz. high ogee spillways in storage dams are not suitable to deal with floods carrying heavy sediment. Considering the experience of silting of dams and damages to power plants, the trend has changed to designing run-of-the-river schemes which utilizes the stream flow as it comes without any large storage. Elaborate desilting arrangements are also envisaged before the silt laden water enters the power plant. The trend is to utilize low level outlets for managing floods, sediment flushing as well as for reservoir depletion. The provision of sluice spillway has to be appropriately planned to facilitate to perform these tasks. Flushing used to be carried out previously by providing small sluices at very low level. However, it was realized that these sluices were effective only locally. Also, there was a tendency of choking of sluices within a short period. Innovative designs of spillways have been evolved based on the concept of flushing. Recent trends in designing the spillways is by modifying the low level sluices with due consideration for flushing [10]. Orifice spillways (Breastwall / sluice spillway) are thus evolved over last few years to cater for both flood disposal and flushing of sediments. The main parameters affecting the performance of orifice spillway are; head over the opening, size of the sluice barrel and entrance shape of the sluice bellmouth. The hydraulics of orifice spillway changes with the varying reservoir levels. The flow is free flow for reservoir water levels below the top of the roof of the sluice. For higher water levels the flow is orifice flow. The crest profile is required to be designed for orifice (pressurized) flow. Figure 2 shows the definition sketch of orifice spillway.

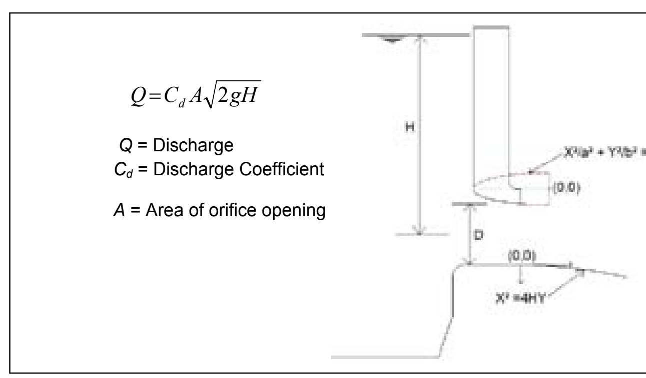

Fig. 2 : Definition sketch of Orifice Spillway

It has been experienced from the physical model studies that the flow through sluice barrel do not get fully developed and that flow separation takes place on the sluice roof profile resulting in negative pressure for high head spillways. Such high head sluice spillways should be checked against presence of sub-atmospheric pressures on the bellmouth roof to avoid cavitation damage. Sometimes, upper nappe of the jet does not follow the sluice roof profile or breastwall bottom profile conforming to quarter of an ellipse resulting in decreased discharging capacity as shown in Photo 1. In such situation, the modified roof profile conforming to part of quarter of an ellipse gives better results as shown in Photo 2. The roof profile has not been standardized with respect to the upstream head because of many hydraulic and structural parameters such as thickness of breast wall and piers, bottom profile of spillway, width of the opening and sediment flushing requirements etc. There is a need for evolving hydraulically efficient roof profile of bellmouth transition for high head sluice spillways, as sluice roof is susceptible for cavitation damage.

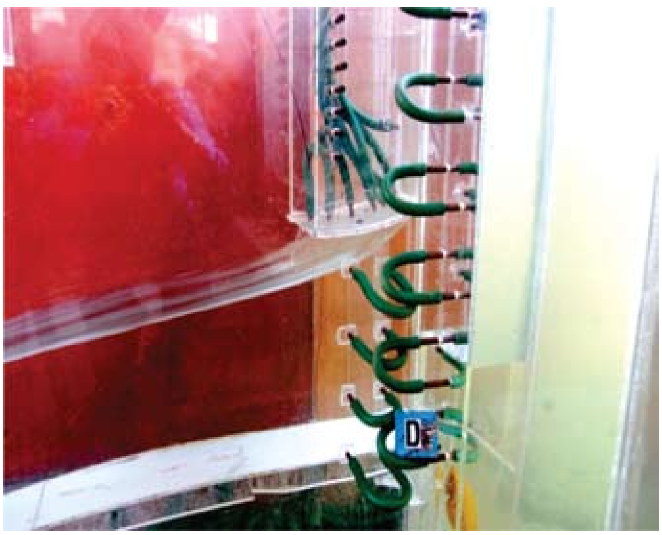

Photo 1: Upper nappe of jet not following the sluice roof profile

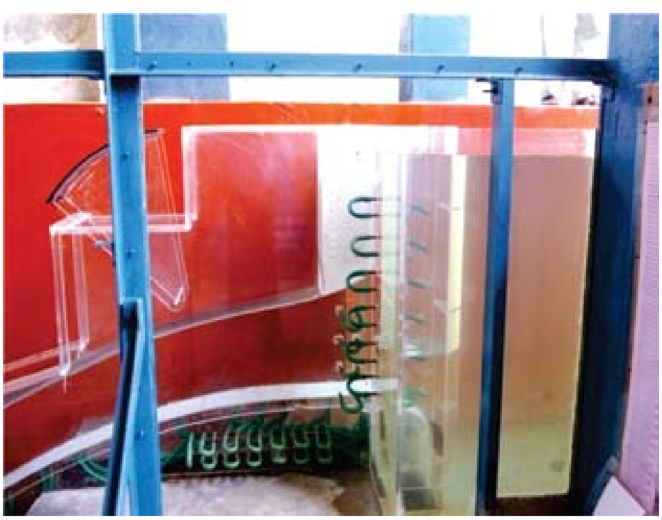

Photo 2 : Upper nappe of jet follows the sluice roof profile

Orifice spillways necessitate some special design considerations. Breast walls have to bear the upstream water head with beams or slabs spanning between and fixed with two piers. As such, the breast wall and both the piers have to be constructed as a single structural unit. The construction joint is, therefore, provided at the center of each pier, except the end piers. Thus, a single pier is virtually a combination of two full piers separated by a construction joint, and a typical spillway monolith is composed of two piers and breast wall. In a standard overflow spillway without breast wall, construction joints are provided at the center of the monolith. Special care is also required regarding the top seal of the radial gate in ensuring water tightness. The larger velocities associated with the high heads may increase the potential for cavitation and erosion damage to the structure. Adequate protection measures should be taken during the construction of the sluice barrel and breastwall spillway, to withstand the erosive power of the silt laden water while flushing the reservoir and flood routing, by way of special type of concreting (poly impregnated concrete) or providing steel lining along the discharge channel of the spillway.

Based on site-specific constraints of geological and topographical considerations, innovative spillways are evolved. For example, rock fill or concrete faced rock fill dams are designed due to weak geology for the diversion dam. In such cases the spillway is provided along the banks of the reservoir. Long chutes instead of short spillway are provided for discharging the flow in the river downstream as in the case of Kishanganga and Dhauliganga H. E. projects. Tunnel spillways are often provided when the river gorge is narrow and the discharge to be passed is not large enough for designing a two tier spillway. Tunnel spillway can also be provided for diverting silt laden flows, e.g. Parbati-III project. Many a times diversion tunnels used during construction stage of the dam are converted in to spillway tunnels, e.g. Dhauliganga project, Tehri project.

2.1 Two Tier Spillways

The river gorges are narrow and the discharges to be passed through spillway are high. Therefore, designing an orifice spillway becomes difficult. Multi-tier spillways have evolved to overcome this difficulty. Two/ three orifice spillways and an overflow spillway on the top form a multi-tier spillway as shown in Fig. 3. The energy dissipator for these spillways may be common or independent. One such spillway has been designed for PMF of 60,315 m^3/s and studied at CWPRS for Lower Siang Dam spillway in Arunachal Pradesh. A common energy dissipator in the form of stilling basin has been provided for both the orifice and overflow spillway. The design has been evolved on a sectional model to solve the complex flow problems at the junction of the spillways. Photo 3 shows view of the sectional model in operation.

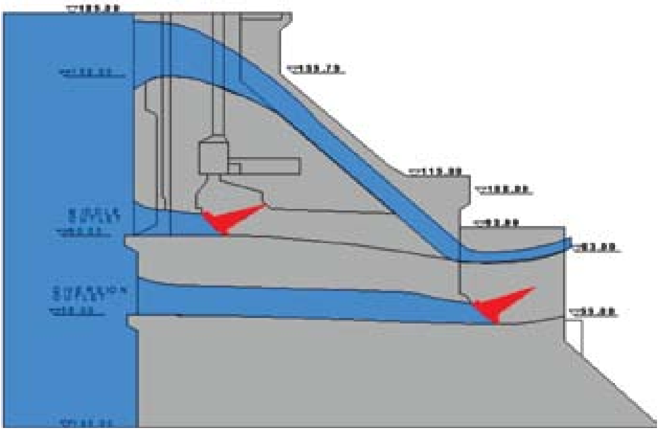

Fig.3 : Cross section of typical Multi-Level Spillway

Photo 3 : View of the sectional model

Sometimes, based on techno-economic feasibility considerations, power intake and power house structure and tailrace channel has to be provided in the body of dam, if fragile geology of Himalaya does not permit independent layout for power intake, water conductor system and huge underground power house cavern. This type of two-tier spillway and dam foot power house has been considered for Siang Lower run-of-the river H. E. Project in Arunachal Pradesh. The project envisages construction of 86 m high concrete gravity dam across river Siang to generate power of 2700 MW utilizing a net head of 55 m.

3. SPECIAL CONSIDERATIONS FOR DESIGN OF ENERGY DISSIPATORS

The factors that govern the choice of the type of energy dissipator are hydraulic considerations, topography, geology, type of dam, layout and other associated structures, economic comparisons, frequency of usage etc. In Himalayan regions the topography is normally steep, fragile geology, high intensity of rain, high level of seismicity etc. cause high load of sediments. Since the spillway has to surplus both the flood and sediment, special considerations are required for design of suitable energy dissipators[10]. The various types of conventional energy dissipators and special considerations are discussed in the following paragraphs:

3.1 Ski Jump Bucket

Usually ski-jump bucket is found to be the most suitable energy dissipator because of its obvious advantage as there is no churning of sediment in the bucket. The sediment passes down the spillway with supercritical flow without deposition in the bucket. Fortunately, steep bed slopes of the rivers result in low tail water depth permit this choice of energy dissipator. In Himalayan region the rock is fragile and due to this there is possibility of uncontrolled scour and landslides in the vicinity of impact of ski-jump jet. Therefore, preformed plunge pools are necessary to avoid these hazards. Design of plunge pool thus becomes an important aspect of the energy dissipator which involves deciding the location and dimensions of plunge pool. The extent of maximum scour needs to be assessed for deciding the depth of plunge pool.

3.1.1 *Necessity of Model Studies for Scour Studies*

The mechanism of scour of rocky bed due to impact of high velocity jet is apparently almost impossible to simulate in a scale model and therefore, practical simulation is adopted in the model depending upon objective of study. The bed material is reproduced in its disintegrated form, which can be carried downstream by the flow. In most cases the bed material selected as sand-gravel mix regardless of size that would result from the disintegration of rock. The sand is filled in the probable scour location from river bed level to the bed level below the anticipated ultimate scour. The water is allowed to flow over it for specified time and then the scour profile is observed. Though the studies are qualitative in nature, the past experiences show that the ultimate scour is realized in the prototype after many years of operation as the rock get fragmented and behaves as non-cohesive material.

3.1.2 *Location and Sizing of Plunge Pool*

The water and scour profiles for entire range of discharges and reservoir water levels observed on the model provide a comprehensive picture of ski jump jet and scour profiles. These studies play important role in deciding the location and size of plunge pool. Scour pit is usually formed downstream of the point of impingement of ski-jump jet. The scour envelope for un-gated and gated flow conditions are shown in Figures 4a and 4b respectively. The plunge pool can be preformed, unlined or lined depending upon the site conditions. Provision of lined plunge pool seems to be impracticable; however, it needs to be adopted in extremely fragile geology. Transverse slopes on both the flanks of plunge pool may be decided based on geological conditions prevailing at site. The ski-jump jet is also likely to spread laterally in the downstream directions and would also abrade along the side slopes. Therefore, suitable bank protection measures are necessary to protect the excavated banks.

3.1.3 Necessity of Divide Walls

The provision of divide walls up to the bucket lip also plays key role in deciding the scour as it eliminates the possibility of thick rooster tails. These rooster tails are one of important reason for generation of sprays. Damage had occurred in Salal project due to the spray hazard. Photo 4 shows the spillway operating and damage due to spray.

The divide walls also help in controlled operation of spillway. In lean floods the jet can be kept away from the river banks by operating only central bays. This also facilitates the maintenance of some spans while others are operating. Such arrangement is suggested in Subansiri lower project as shown in Photo 5. In Tala dam spillway, Bhutan also the provision of divide wall up to the lip has been suggested. Photo-6 shows the flow conditions downstream of spillway before and after provision of divide walls.

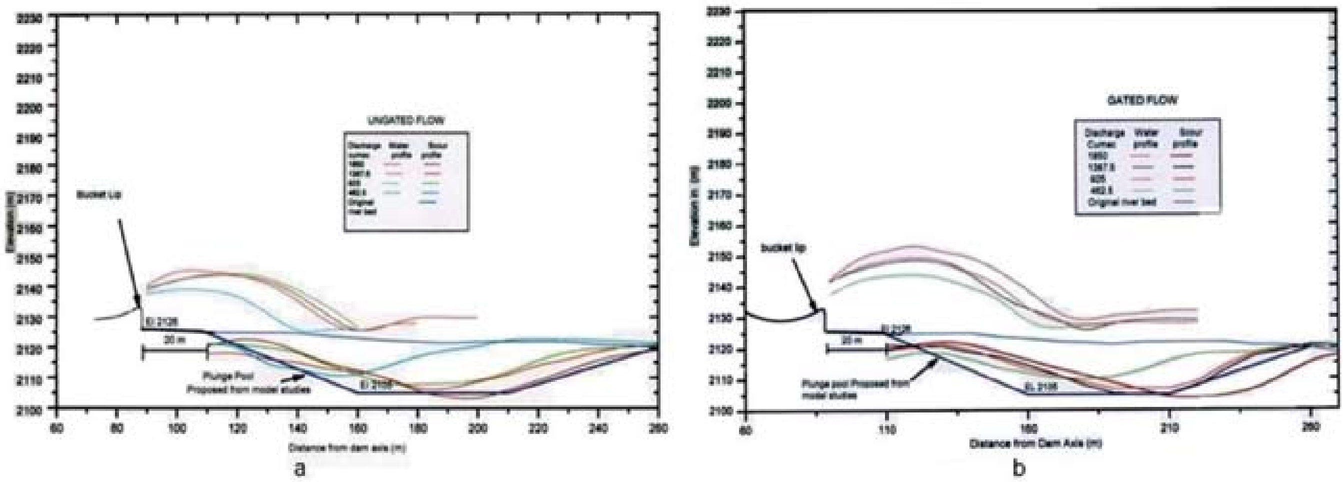

Fig. 4 : A typical Configuration of plunge pool based on Scour Envelopes

Photo 4 : Spray generation and subsequent failure of bank in Salal project

Photo 5: Spillway Operation with divide walls up to lip

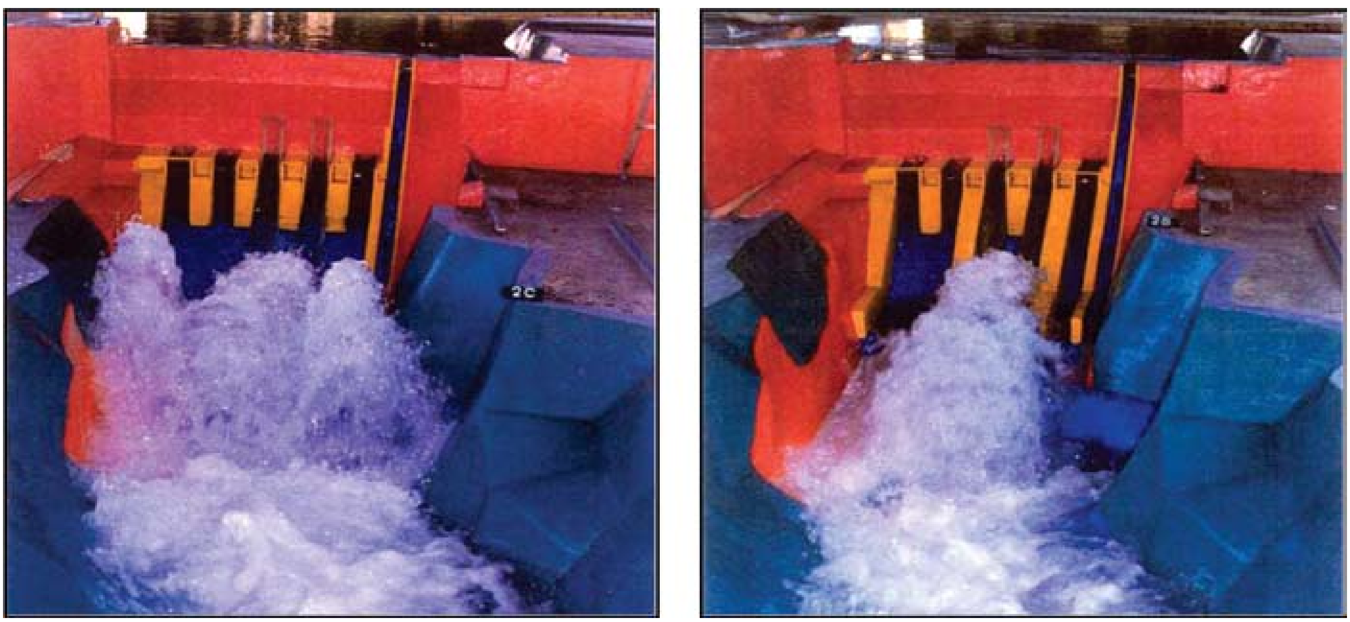

Photo 6 : Spillway Operation with and without divide walls

It is necessary to protect the toe of the dam from undermining due to the flow cascading over the lip of the bucket by providing a concrete apron downstream of the ski-jump bucket. During construction stages of the spillway, the flow over the partly completed spillway blocks would cascade over the lip of the bucket. After completion of the spillway, cascading flow would occur at the beginning and end of the operation of spillway. In order to avoid undermining of the toe of the bucket due to cascading flow, concrete aprons are necessary. The apron may have to be properly anchored and keyed into the rock at the downstream end. Ski jump type energy dissipator has successfully been provided in many projects like Nathpa Jhakari, Tala, Chamera-I, Dhauliganga, Ranganadi, Salal and proposed in projects like Subansiri, Myntdu, Punatsangchuu-I & II.

3.2 Stilling Basin

If tail water levels and geological conditions are not favourable for ski-jump bucket type energy dissipator, a hydraulic jump type stilling basin may have to be adopted. As the spillway is to serve dual purpose of flood as well as sediment disposal, the critical issue involved in the design of stilling basin is satisfying both the requirements. The high unit discharge of the order of 200 $m^3/s/m$ to 300 $m^3/s/m$, passing down a low head spillway results in low Froude number conditions. The stilling basin for the Froude number in the range of 2.5 - 4.5 is rather difficult to design to ensure satisfactory performance for the entire range of discharges. The stilling basin has to cater for dual needs of energy dissipation as well as flushing of sediment. Because of the requirement of passing silt-laden flows, use of energy dissipating appurtenances like chute and baffle blocks is not advisable. The resulting basin is excessively long and often deep-seated due to higher sequent depth or sound rock foundation below the general river bed, making it vulnerable to deposition by silt during flushing operation. Deeply seated stilling basins are necessary for satisfactory hydraulic action whereas the floor of the stilling basin should be high so as to flush the sediment out of the basin. Lots of trials are required to finalize the stilling basin floor level to satisfy these conflicting requirements. The studies for Chamera-II project illustrate this feature. In such a contradictory requirement, there is always danger of abrasion to the floor of the basin, so also silting of the basin during low flows. This silting may prove to be very dangerous as the hydraulic jump may not form in the stilling basin due to insufficient sequent depth. The jump will sweep out of the basin and would form in the downstream, causing lots of scour. Photo 7 shows the deposition of the silt in the stilling basin after flushing on Chamera – II H.E. Project. However, these sediments can be flushed out with spillways discharging at high reservoir water levels with partial gate operation before sediment becomes consolidated. Estimation of hydro-dynamic forces on training walls of deep seated stilling basins shall be required for the structural design.

Photo 7 : Silt deposition in the stilling basin

Experience with stilling basin of Chamera–II project shows that a trade-off is desirable between the hydraulic efficiency of energy dissipation and the self-cleansing potential of the stilling basin during flushing operation. Cylindrical end sills are generally preferred for easy movement of sediment out of the basin as shown in Figure 5.

Another major drawback of the stilling basin is that it requires huge excavation for placing the stilling basin

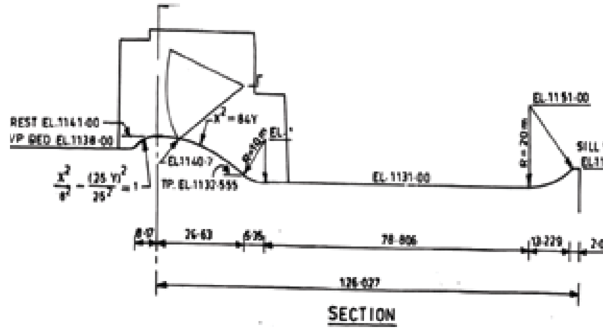

Fig. 5 : Cross section of spillway with stilling with cylindrical endsill

floor. High training walls are required for the stilling basin. Estimation of hydro-dynamic forces on deep seated stilling basin floor and training walls shall be required for the structural design.

3.3 Roller Bucket

Roller bucket is designed when the tail water is greater than 1.1 times the sequent depth necessary for the formation of hydraulic jump in stilling basin (IS 7365-1985) and river bed rock is sound. The energy dissipation in this type occurs mainly in the bucket by the formation of surface roller over the bucket moving counter clockwise and ground roller downstream of the bucket moving clockwise. The design of roller bucket is complex and there are several limitations to the design and operation of this type of energy dissipator. Damages to the roller bucket are also reported at several projects[12]. A major problem with the solid roller bucket is damage to the bucket due to churning of material brought from the downstream especially due to unequal operation of spillway spans setting up horizontal eddies downstream of bucket. The picked up material causes abrasive damage to the bucket. Dressing of river bed 1 to 1.5 m below the bucket lip and cleaning the loose material after construction and each monsoon is essential. However, this aspect is not given sufficient attention. Build up of tail water level is another important aspect for the formation of roller or else the roller bucket acts as ski jump bucket causing excessive scour downstream Several spillways with solid roller bucket have been reported to be damaged due to above aspects.

The abrasion damage is expected to be more when this type of dissipator is provided downstream of an orifice spillway which flushes the sediment out of the reservoir. Also, the experience from model studies for Teesta Low Dam Project Stage IV has shown that it is very difficult to turn 8-10 m thick jet for formation of surface roller. The thick jet results due to high discharge intensity which is a characteristic of orifice spillways in Himalayan region. Thus, provision of roller bucket is avoided due to above cited reasons.

3.4 Combination of the Ski Jump Bucket and Stilling Basin

In some cases, head-discharge-tail water combination for the full operating range of the structure do not provide single type of energy dissipator design, a composite type energy dissipator with a horizontal apron terminating with low circular end sill is found to be satisfactory[11]. A concrete apron downstream of the end sill as shown in Figure 6 is required to protect the spillway against undermining due to scour during transition from hydraulic jump to flip action and vice versa. Another alternative would be to isolate a few spans of the spillway on the flanks with apron at higher level for flushing out sediment as shown in Figure 7. These spans would function with hydraulic jump under sweep out condition, for small discharges of the order of average annual flow, during flushing operation. The central spans would cater to the normal discharges. Such arrangement has been provided for Chukha dam spillway, Bhutan.

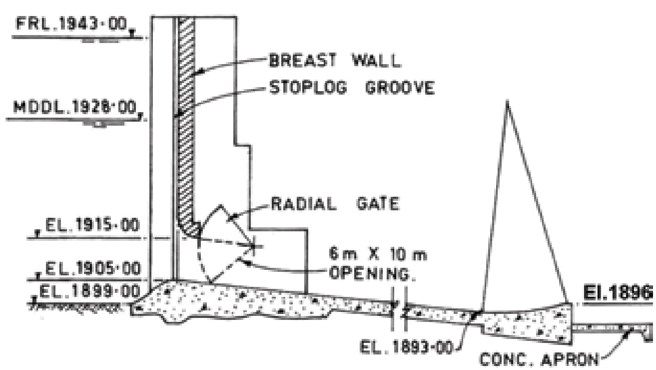

Fig. 6 : Spillway cross section of Chukha dam spillway[11]

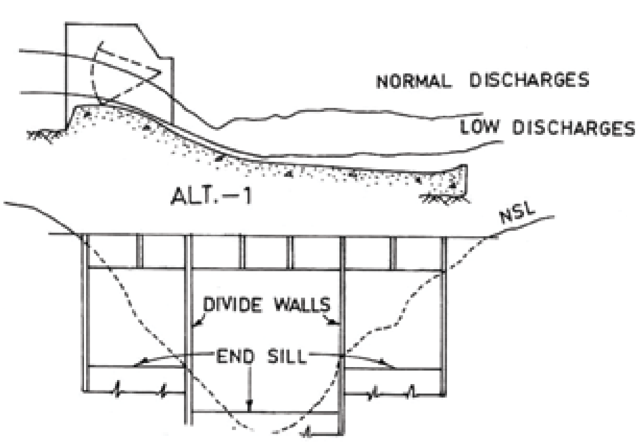

Fig. 7 : Provision of spans at different levels[11]

4. CONCLUSIONS

Considering the experience of siltation of dams and damages to power plants in Himalayan hydropower projects, the trend has changed to designing run-of-the-river schemes which utilizes the stream flow as it comes without any permanent storage being provided. Innovative designs of orifice spillways in the form of low-level sluices in the body of the dam or a spillway with a breast wall have been evolved based on the concept of reservoir flushing with minimal impact to the environment. The review of design of spillway and energy dissipators for the spillways in Himalayan region has revealed the following important issues:

1. Orifice spillways (Breastwall / sluice spillway) are recommended to cater for both flood disposal and flushing of sediments.
2. Special considerations are required for design of suitable energy dissipator for spillways in Himalayan region, since the spillway has to surplus both the flood and the sediment. Usually ski-jump bucket is found to be most suitable for energy dissipation because of its obvious advantage as there is no churning of sediment in the bucket. Another reason for choosing this type is saving in cost due to short length.
3. Pre-formed plunge pools are recommended downstream of ski-jump buckets to avoid uncontrolled erosion of river bed and banks. Design of plunge pool for its location, size and shape is decided based on scour studies on physical models. The ski-jump jet is likely to spread laterally and abrade the side slopes. Therefore, suitable bank protection measures are necessary to stabilize bank slopes.
4. Provision of divide walls up to the bucket lip eliminates the possibility of thick rooster tails which cause spray hazards leading to landslides due to saturation of hill slopes. The divide walls also help in controlled operation of spillway. In lean floods the jet can be kept away from the river banks by operating only central bays.
5. If tail water levels are higher, stilling basin may have to be adopted as energy dissipator. Because of the requirement of passing silt-laden flows, use of energy dissipating appurtenances like chute and baffle blocks is not advisable. Cylindrical end sills are generally preferred for easy movement of sediment out of the basin. Deep seated stilling basins are necessary for satisfactory hydraulic action whereas the floor of the stilling basin should be high so as to flush the sediment out of the basin. In such a contradictory requirement, design of stilling basin becomes very complicated. Estimation of hydro-dynamic forces on

stilling basin floor and training walls of deep seated stilling basins shall be required for the structural design.

6. The design of roller bucket is complex and there are several limitations to the design and operation of this type of energy dissipator. Its performance is extremely sensitive to tail water level. The sediment can cause abrasive damage to the bucket by churning action. As the spillway is designed for dual functions of passing flood and sediment, the choice of this type of energy dissipator is ruled out for spillways in Himalayan region.

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Life is more precious than gold, but not as precious as freshwater

Anthony T.Hincks

Geodetic Technology for Dam Structure Monitoring

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ABSTRACT

In India Dams ensure fresh water storage and availability of water throughout the year for irrigation, hydroelectric generation, flood control, fisheries etc. Rightly called as "Temples of Modern India", these dams have been instrumental in managing water resources optimally. Soon after Independence India saw a sudden jump in the number of dam projects to boost agrarian and allied economies. Like every other structure dams also have a life span and it continuously withstand the natural pressure throughout its life hence it becomes important to measure the health parameters of a dam structure on a continuous basis. Dam's storage also gives rise to micro seismicity and induce small earthquakes in a localized region due to the seepage of water in the layers beneath the reservoir. Such mild tremors could cause intense movement of the dam structure apart from other factors like pour water pressure in upward direction. Pour water pressure along with hydrostatic pressure due to reservoir on the wall can result in the movement of entire structure in 3D and non uniform deformation of the dam wall. Geodetic surveying techniques and instrumentation like precise Total Stations and DGNSS can monitor the deformation and shifting of the wall in real time on continuous basis. Geodetic controls are established in near by stable area are used as point of reference to measure the deformation of selected points. Now a day's software and mathematical techniques are available to combine the data from optical total station and DGNSS to ensure the reliability of the measurements.

WHAT IS DAM MONITORING?

Monitoring is the process of taking measurements on to a structure over a period of time, with a sole purpose of detecting changes in the size, shape or behavior of the structure.

Monitoring involves installation of a lot of devices or sensors on and around the Dam structure. These sensors generate a lot of data over time. Monitoring process entails extraction of meaningful "TRENDS" from this data. These trends define the behavior and movement of dam structures, which in turn gives a better insight to the dam authorities to know their structure better. Every monitoring situation is different and so the choice of the suitable tools will also differ from dam to dam. However trend analysis is one request which is common to all monitoring applications. Typically a dam experiences movements that can occur either upstream or downstream. Dam movements can also be seasonal (summer/ winter/ rains), diurnal (effects of sunlight) or even hourly (effects of hydrostatic pressure).

GEODETIC TECHNOLOGY FOR DAM MONITORING

The geodetic technology for monitoring includes Optical Total Station, DGNSS and Seismic Sensor/ accelerometer with DGNSS. The data from all the sensors can now be combined together with trend analysis in web/ cloud and desktop based software solutions. The aim of the technology is to provide the analysis without human intervention in real time with a provision to issue alarms in case of any critical change. The basis concept on which the monitoring systems work is measurement of Displacement, Velocity and Acceleration of the structure movement. All the geodetic sensors combined together provide these values.

Optical Total Station

Trimble has developed S Series automated optical total station with 0.5" of angular accuracy and distance accuracy of 1mm+1ppm at an array of reflective prisms permanently mounted on a structure as shown in Fig 1.

The total station observes multiple points and provides the observation data which is absolute positions of the prisms calculated using angles and distances to the prism from its station setup. The data is provided to centralized location running Trimble 4D control software which does the analysis and provides trends to the user.

Differential Global Navigation Satellite System

Differential GNSS is used to set up geodetic controls and provides redundant measurement to the optical total station and can be used with and without total station. The GNSS receiver monitors the absolute position of the points continuously and provides the shift with time. GNSS is also useful to find the tectonic movement in the area around the dam structure. The accuracies of DGNSS and Optical rotation stations are similar hence the combination of reading becomes possible using Trimble 4D control software. Trimble provides NetR9 permanent GNSS stations which can log data up to 50Hz to study

Fig 1: Total Station and prisms installation on a Dam

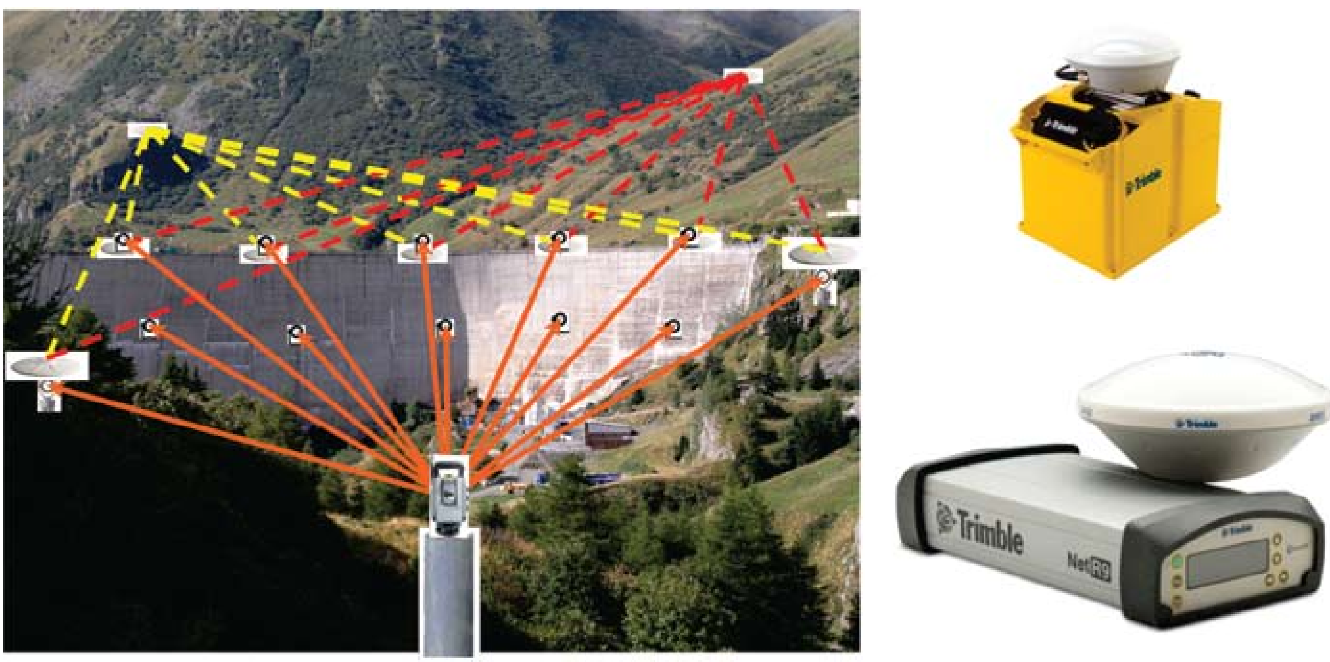

Fig 2: Installation of DGNSS and OpticalTotal Station

the vibrations in the area. These receivers are typically used at dam locations where line of sight is not available for a Total station installation. Typical installation is shown in Figure 2.

Seismo-Geodetic Sensors

The Trimble Kestrel System provides the user with high rate GNSS and accelerometer data, full epoch-to-epoch measurement integrity and, using the Trimble Seismo Geodetic App, the ability to create a combined GNSS and accelerometer stream (200 sps high resolution displacement time series) in real-time. It combines true accelerations and displacement observations from GNSS installed on board. The unit instantaneously processes displacements and transmits to a central location for trend analysis. The accelerometer records triaxial movements and helps in creating the complete movement profile of the structure.

Trend Analysis and Decision Making

While the sensors mentioned above are physically located at the dam site, their data is seamlessly transmitted using standard communication protocols to a central server or a cloud based set up for further analysis. Trimble 4D Control is a complete monitoring and trend analysis system suitable for deployment on large dams. Apart from the capability of continuous monitoring of data from sensors on the dam, it also carries out comparative analysis of the data via a web interface, issues alarms on changes that are detected and monitor data from even third party

Fig. 4 : Schematic workflow of the monitoring process

sensors installed at the dam. It comprises of sensors, data acquisition and processing software, SQL database and web interface. It allows the user to visualize all sensors installed and their live data feed. The schematic below shows the workflow of the entire monitoring process.

CONCLUSION

Indian dams are ageing day by day and hence a robust preventive maintenance program is the need of the hour. With geodetic monitoring system dam authorities can square in at the problems at the dam structure. The solution has been designed to create or follow the standard workflow of structural monitoring. Trimble has created a team of experts to consult the government for dam monitoring installations. We have value added partners to support the customers globally.

BIOGRAPHICAL DETAILS OF THE AUTHOUR

Munish Malhotra Handles the structural monitoring projects at Trimble Navigation India Pvt Ltd. He has been working with the company for last 6 years and is instrumental in Geodetic DAM Monitoring projects across SAARC countries and had also executed GNSS & Seismic related projects for National Geophysical Research Institute, Hyderabad, India Meteorology Department, New Delhi and INCOIS Hyderabad. He is currently working as Regional Manager for SAARC countries in Trimble in India.

Geophysical Techniques for Inspecting Dams (Concrete, Masonry, Earthen) and Spillways

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ABSTRACT

As large dams age, it becomes increasingly important to determine the condition of their material and to track changes in this condition over time. Inspections of concrete, masonry and earthen dams, dikes and spillways often require testing to evaluate for leakage paths, soil settlement/voiding, or weakened deteriorated concrete/ masonry.

NDT uses geophysical testing methods (ground penetrating radar, 2D/ 3D electrical resistivity imaging, streaming potential) to identify potential leakage paths under earthen dams, dikes and concrete spillways. Sonic/ultrasonic impact echo, cross-face sonic tomography and GPR non-destructive testing methods are used to identify voided areas under spillways. Sonic/ultrasonic pulse velocity, cross-face sonic tomography, MASW and impact-echo measurements are also used to determine the condition and integrity of dam and spillway concrete.

Although long recognized that dams need periodic inspection and monitoring, it has only been recently recognized that geophysical surveys can supplement the results of standard inspection and monitoring techniques. Geophysical surveys have been performed on a number of dams around the world, including India, and have yielded extremely useful insight into dam conditions. The choice of right tool, timing of such investigation and deliverables expected are, however, not very well defined at the moment.

Present paper defines available NDT tools and techniques applicable to earthen, masonry and concrete dams, presents guidelines for selection of appropriate method and establishes the investigation methodology.

1. INTRODUCTION

Sub-surface imaging by means of geophysical survey is a powerful tool for subsurface mapping which historically has been under-utilized world-over. Continuing improvements in survey equipment performance and automation have made large area surveys with a high data sample density possible. Advances in processing and imaging software have made it possible to detect, display, and interpret small geological features with great accuracy. This has made dam geophysics extremely attractive, especially due to the fact that dams do require periodic condition monitoring using non-destructive tools.

In the event of a dam failure, the economic loss as well as the potential hazard to life and property could be enormous. Typical dam safety surveillance consists of visual inspections supported by limited instrumentation. However, the problems in dams can become quite advanced before the problem is detected via these means. Recently, interest has grown regarding the use of non-intrusive geophysical techniques to facilitate early detection of anomalous seepage, piping, internal erosion and other degradation issues.

Geophysical methods are sensitive to contrast in the physical properties in the subsurface. Different methods respond to different physical properties, like material strength, material conductivity (linked to water saturation), fluid movement (seepage), change in density etc. The application of geophysical methods to dams enables detection of problems in early stages and hence can become part of dam safety surveillance program.

Geophysical techniques, by virtue of their non-invasive and non-destructive nature, offer an excellent solution for investigation or regular monitoring of dams, and detection of anomalous conditions which might snowball into major problems if left untreated.

Various geophysical methods are available to investigate the problems of earthen, masonry, concrete or composite dams:

- Leak path detection
- Internal Erosion
- Identification of zone of water accumulation
- Cavity/ sinkhole
- Concrete degradation

No single geophysical technique can uniquely solve the problem due to a large overlapping of physical properties in various subsurface materials. To date, the use of geophysical methods to investigate dams has produced mixed results, partly because the application of these methods is not well-understood and partly because false positives cannot be tolerated. That is the reason why it becomes important to use a combination of geophysical methods to uniquely resolve the problem. Choosing the right tool/ technique to address to a specific problem is critical for success of a geophysical program. A detailed geophysical investigation plan must be worked out in consultation with the client, to address to critical issues. The right combination of various available tools should be chosen to resolve the problem in unique manner.

Surveys which are both successful and cost-effective must satisfy a number of basic requirements. They must be implemented using appropriate and properly configured survey equipment. The data sampling strategy and density must be matched to the spatial resolution and statistical requirements of the survey. Monitoring the quality of data while in the field is mandatory, and post survey data processing must be both appropriate and mathematically sound.

The chosen geophysical contractor should have experienced personnel and advanced instruments to carry out high resolution geophysical surveys for geotechnical investigations. The survey methodology and tools to be used should be decided in consultation with the client and depending on site conditions and objectives of survey. A technical report describing the work, including high resolution maps with detailed interpretation, should be presented to the client upon completion of analysis.

2. CONCRETE DAMS

The elements that are of the most concern, because they are the most critical structural elements of the dam, include the spillway concrete, spillway sub-grade, dam wall concrete, and interiors of thin arch dams.

Because of the large mass of concrete in dams and spillways and the long expected life of these structures, they are susceptible to degradation mechanisms that can start as minor problems and be present for years. These mechanisms include freeze-thaw damage on the downstream face and crown, seepage under and around outflow pipes and spillways, slow-developing cracks in the dam interior, and erosion due to water flow and weathering.

The presence of initial degradation tends to accelerate future problems. For example, surfaces damaged by the freeze-thaw cycle tend to hold more moisture than undamaged surfaces, thus leading to greater damage during future freeze-thaw cycles. In addition, small cracks in the dam face become stress concentrators that lead to deeper cracking. Cracks that seep can lead to erosion and cracking as a result of the action of the water. And seepage under a spillway or around an outflow pipe slowly erodes the sub-grade, leading to faster flow rates and even greater erosion.

Periodic inspection is a dam owner's best defence against these threats. However, visual inspections often only reveal problems that have developed into major degradation. In addition, some types of damage – such as voids under a spillway slab or cracking in the dam interior – are difficult or impossible to uncover using only visual means.

This is where non-destructive evaluation (NDE) techniques enter the picture. NDE methods use sound waves, radio waves, and other types of low-level energy to penetrate the concrete. These methods can be used to locate a void under a spillway; measure the depth and severity of freeze-thaw or other surface damage; and create an image slice through the interior of a dam to show cracks, de-bonded joints, and other degraded zones. Most of these evaluations can be performed without dewatering the dam, and all are completely non-destructive and nonintrusive.

Many NDE methods can be used to investigate the condition of concrete elements in a dam. These methods include impact echo, slab impulse response, Multi-spectral analysis of surface waves (MASW), ground penetrating radar (GPR), and acoustic/ sonic tomography (AT).

In particular, three techniques are most useful in dam investigations. The first is MASW, which is used to measure the condition of concrete vs. depth from the test surface, as well as to measure the depth of cracks. The second is GPR, which is used to map out voids and water seepage paths under a spillway, as well as to provide information on the spacing and depth of any reinforcing in the concrete. The third is AT, which uses sound wave transmission through a thin-arch dam to create a tomographic image slice from the upstream to downstream faces.

2.1 MASW

First introduced in GEOPHYSICS (1999), the multichannel analysis of surface waves (MASW) method is one of the seismic survey methods evaluating the elastic condition (stiffness) of the ground. MASW first measures seismic surface waves generated from various types of seismic sources—such as sledge hammer—analyses the propagation velocities of those surface waves, and then finally deduces shear-wave velocity (Vs) variations below the surveyed area that is most responsible for the analysed propagation velocity pattern of surface waves. Shear-wave velocity (Vs) is one of the elastic constants and closely related to Young's modulus. Under most circumstances, Vs is a direct indicator of the ground strength. After a relatively simple procedure, final Vs information is provided in 1-D, 2-D, and 3-D formats.

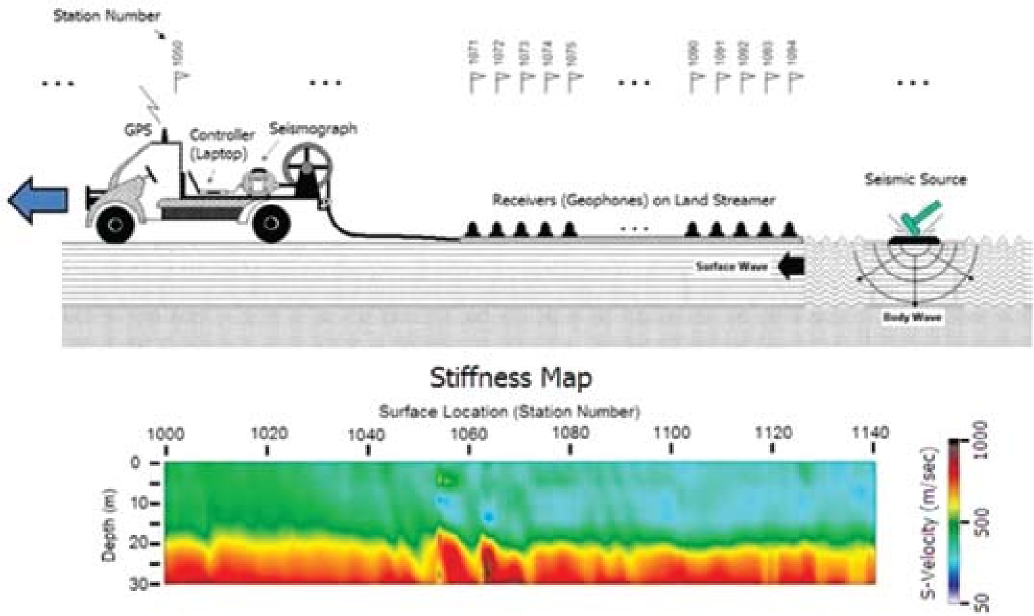


Fig.1: Field setup and results of MASW

The test provides an excellent tool to determine strength of concrete within the dam body.

2.2 Ground Penetrating Radar

The GPR method involves moving an antenna across a test surface while periodically pulsing the antenna and recording the received echoes. Pulses are sent out from the GPR computer driving the antenna, at a frequency range cantered on the design centre frequency of the antenna. Antenna centre frequencies used in NDE investigations vary widely, depending on the structural geometry and the information desired. To locate rebar or detect voids under thin slab-type spillways, a 900 to 1,500 mega-Hertz (MHz) antenna typically is used. For thicker slabs or other thick concrete elements, antennae with a centre frequency of 400 MHz or lower often are selected. Lower-frequency antennae allow for deeper penetration, but at the sacrifice of resolution.

The electromagnetic wave pulses propagate through the material directly under the antenna. Some energy reflects back when the wave encounters a change in electrical impedance, such as at rebar or an air-filled void. The antenna receives these echoes, which are amplified and filtered in the GPR computer, then digitized and stored. A distance wheel records scan distance across the test surface, and embedded features can be located as a given distance from the scan start position. For repetitive scanning, a standard survey is designed and adhered to as field conditions allow to minimize mistakes and maximize data quality.

A non-destructive investigation recently was conducted on the spillway slab of a small dam in the southern U.S. This 50-foot-wide concrete slab had unknown reinforcing and showed evidence of settlement and distortion. In addition, there were small water flows near the base and sides of the spillway that were presumed to be a result of flow under the spillway slab. The owner requested the NDE to examine the concrete slab and its sub-grade support conditions. Objectives of this investigation were to locate any reinforcing and to map out voids under the slab for subsequent mitigation. As part of this investigation, a set of GPR scans was performed across the spillway, at 5-foot intervals down the length of the structure. These scans showed clear evidence of water-filled voids under the spillway. They also showed the presence of rebar in the slab concrete, at nominal 12-inch centres.

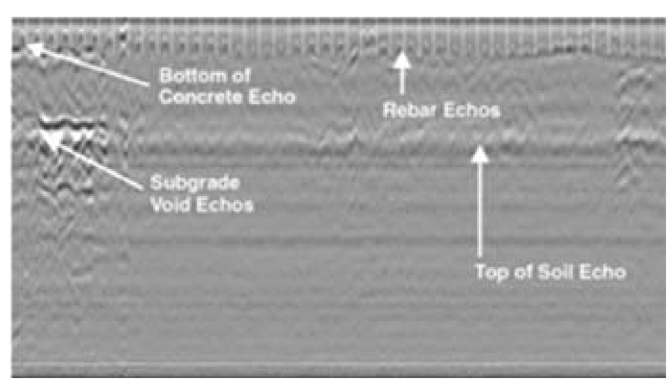


Fig.2 : Typical GPR results

2.3 Seismic Tomography

Unlike other methods discussed till here, used from the surface of Dam or Ground, Seismic Tomography is conducted between a pair of boreholes or between upstream and downstream face of the Dam, to provide high resolution details of internal structure. The resulting tomogram shown physical property of each unit cell of dam body. In a concrete dam the information can be interpreted in terms of fractures, weathered concrete etc., as shown in Figure 3:

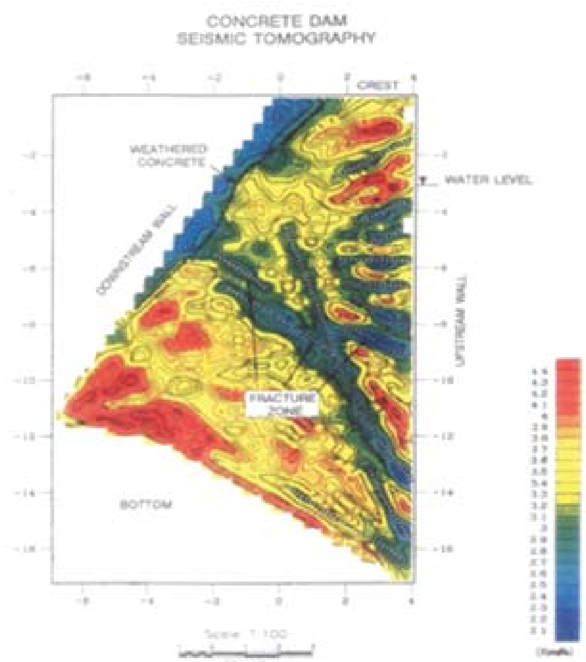


Fig. 3: Seismic Tomography Across Faces of a Concrete Dam

3. MASONRY DAMS

The techniques discussed for concrete dams above are equally applicable for masonry dams. Additional techniques of Electrical Resistivity Imaging, Streaming Potential and ReMi (Refraction Micro-tremor) provides invaluable information on seepage paths, water saturation and material strength of masonry. Acoustic/ sonic tomography results, when concerted to density, provide information on material loss due to leaching and grout quantification.

3.1 Electrical Resistivity Imaging

The direct current resistivity method has well-established data acquisition and interpretation techniques for standard survey configurations. The method uses pairs of electrodes to inject current into the ground and measure the resulting electrical potential distribution. Its application to dam seepage investigations is two-fold. The method may be used to monitor spatial and/or temporal variations in electrical resistivity in response to changing soil conditions caused by internal erosion and anomalous seepage. The method also may be used to characterize the electrical resistivity of the subsurface for the purposes of interpreting SP data.

The method can also be used to detect changes in resistivity with time, which may be linked to the development of internal erosion in the core of the embankment.

The results of electrical surveys carried out on the crest of a dam are presented as vertical sections showing the electrical properties of the dam materials. Electrical currents travel along preferential pathways in the most conductive materials such as dam core composed on fine grained materials. ***The method provides picture of internal resistivity distribution of the dam structure, identifying areas of water saturation in the dam body, and thus identifying the zones of water accumulation and wetting.***

2D Resistivity Imaging uses an array of electrodes (typically 64) connected by multicore cable to provide a linear depth profile, or pseudosection, of the variation in resistivity both along the survey line and with depth. Switching of the current and potential electrode pairs is done automatically using a relay box. The computer initially keeps the spacing between the electrodes fixed and moves the pairs along the line until the last electrode is reached. The spacing is then increased and the process repeated in order to provide an increased depth of investigation. In this way a profile of resistivity against depth (‘pseudosection’) is built up along the survey line.

The modelled results are displayed as scaled resistivity-depth pseudosection as illustrated below in Fig. 4. Blues represent areas of low resistivity whilst reds are relatively higher. The wedge shape of the plot illustrates the gradual reduction in the amount of data acquired as the current and potential electrode spacing are increased.

The method can be applied in two ways.

1. Resistivity investigations as a onetime survey may detect spatially anomalous zones along the dam, and can be used to investigate suspected structural weaknesses.
2. Long-term resistivity monitoring make use of the seepage-induced seasonal variation inside the embankment to detect anomalies not only in space, but more importantly in time, by studying deviations from the time-variation pattern. The second approach is more powerful as repetition of measurements provides additional evaluation possibilities for seepage analysis. However, the monitoring approach is also more demanding as installations are necessary as well as long-term instrumentation.

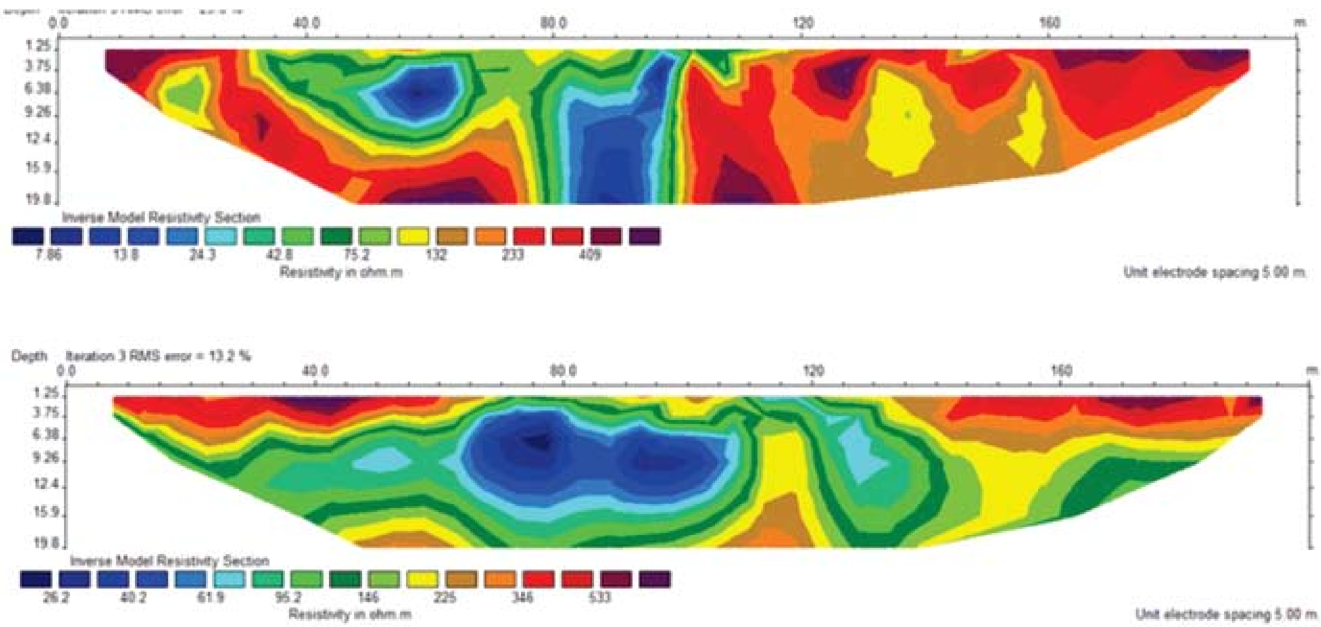


Fig. 4: Electrical Resistivity Section Showing Zone of Saturation (Blue)

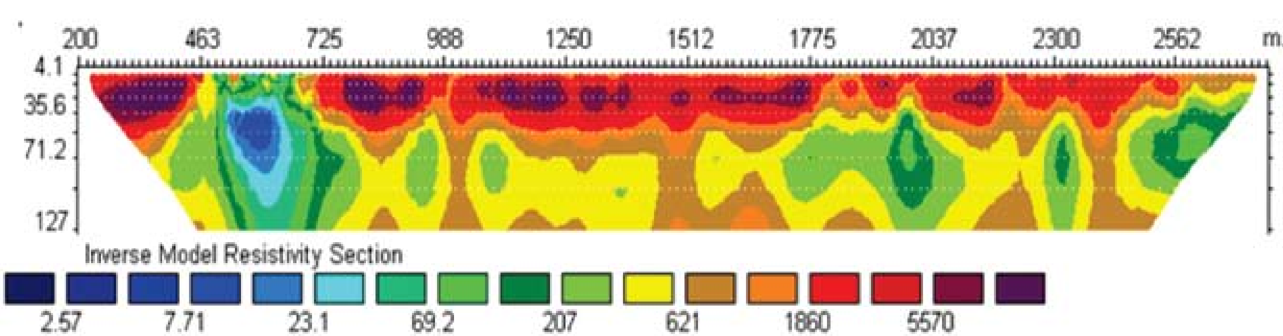
3.2 Streaming Potential Survey

The streaming potential method consists of measuring the electrical potential by flowing water within a structure or subsurface. Self-potential (SP) is a passive technique that measures naturally occurring electrical potentials in the ground. This is the only one of these geophysical techniques that responds directly to fluid flow. Water flowing through the pore space of soil generates electrical current flow. This electrokinetic phenomenon is called streaming potential and gives rise to SP signals that are of primary interest in dam seepage studies.

SP is measured by determining the voltage across a pair of non-polarizing electrodes using a high-impedance voltmeter. This inexpensive and deceptively simple data acquisition procedure requires special care and attention in order to reliably interpret and correct for sources of electrical noise that can mask the signal of interest. All noise sources – including time-varying telluric currents associated with solar and atmospheric activity, stray currents, and the corrosion of buried metal – must be recognized and measured. These noise sources can mask the relatively small signals associated with seepage anomalies. For this reason, telluric measurements and magnetic surveys should be carried out to assist in interpreting the SP data. Typically, SP anomalies on the order of tens of millivolts are associated with seepage anomalies of interest, although anomaly amplitudes largely depend on site-specific conditions.

Interpretation of SP measurements to infer seepage patterns and concentrated seepage flows ranges from simple qualitative to more advanced quantitative numerical modelling approaches.

Most common application of SP study is to identify the zones in the dam body through which seepage is taking place. The results are correlated with resistivity sections. An example of such correlation is shown below in Fig. 5 wherein zone of saturation in dam body, as noted in electrical resistivity imaging section, shows a profound negative SP development.



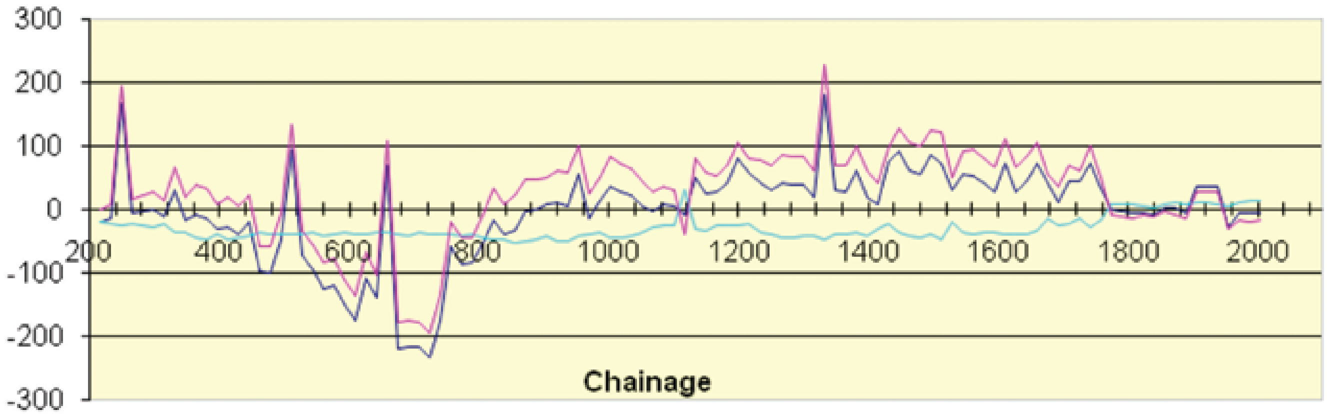


Fig. 5: SP Results along with Resistivity Section

3.3 Seismic Tomography

Seismic Tomography is an excellent tool to examine anomalous areas in high resolution, providing detailed properties along the section where it is conducted. It should, however, be chosen based on initial results of surface geophysical methods conducted all along the dam length, as it provides information only across the investigated plane. Typical results obtained from seismic tomography across a plane in masonry dam are as shown in Figure hereunder (velocity has been converted to density based on standard empirical relationships):

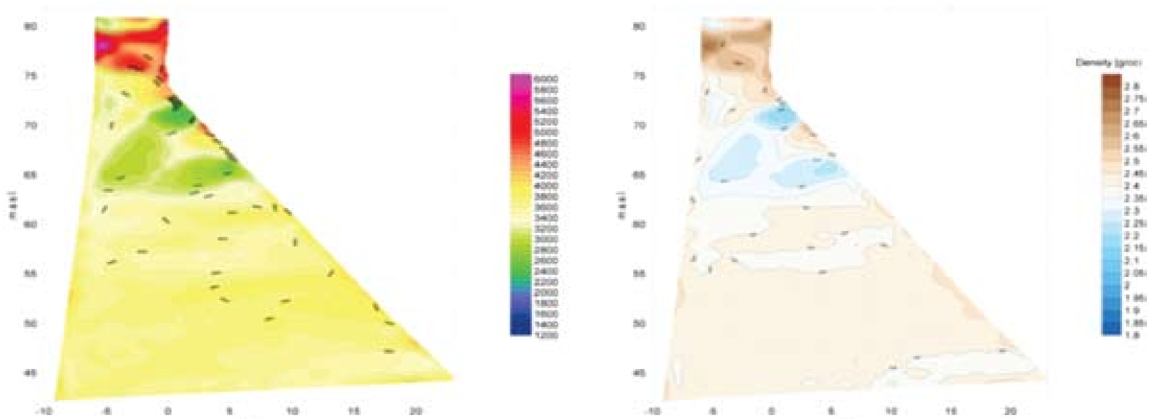


Fig.6 : Seismic Tomography Across Faces of a Masonry Dam

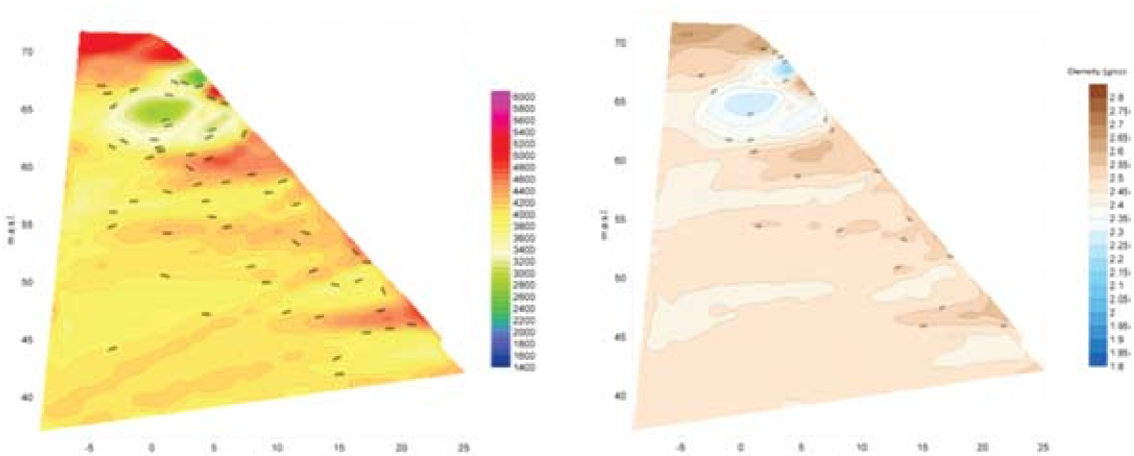


Fig. 7 : Seismic Tomography across Spillway of a Masonry Dam

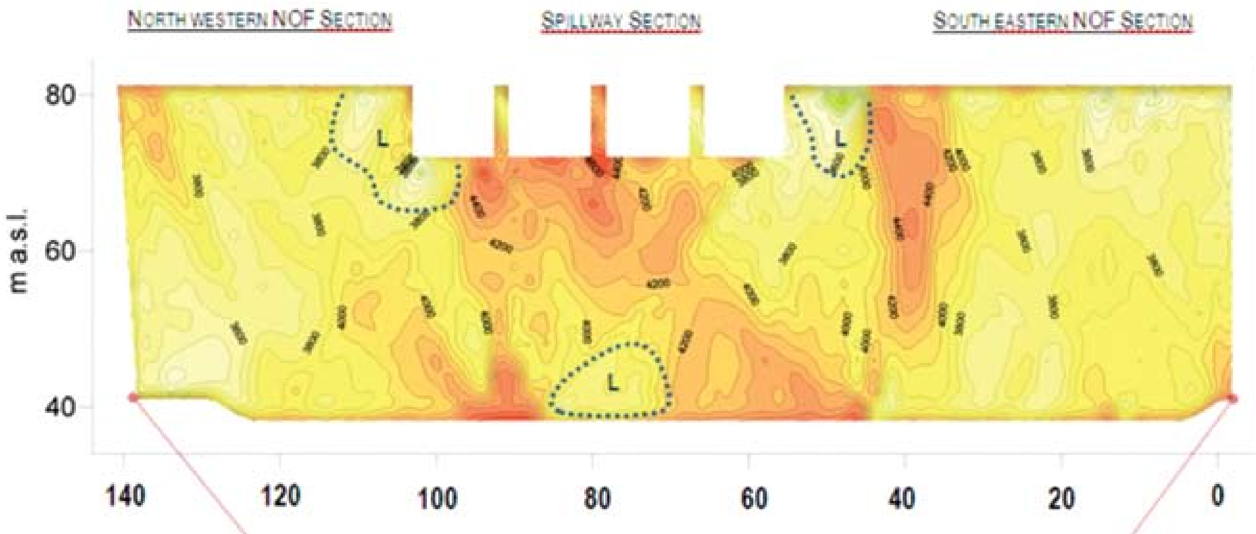


Fig.8 : Seismic Tomography between Gallery & Dam Top

Seismic tomography also allows similar investigations in spillway section, as shown in Fig. 7.

Another application of seismic tomography is from dam gallery to dam crest, or between dam galleries (in case of multiple galleries). This provides a high resolution information on material properties along the length of the dam in gallery portion. The example (Fig. 8) shows results of seismic tomography conducted between dam gallery and dam top.

Typically, tomography images are analysed to look at the velocity changes within the concrete. Areas with lower velocity correspond to weaker, less dense concrete, while those with higher velocities are considered to be sound concrete. The results also can show areas with cracking damage or other discontinuities.

3.4 Refraction Micro Tremor (ReMi)

Innovative technique of ReMi (Refraction Micro-tremor) has distinct edge over MASW and SASW in terms of logistics, execution and results. ReMi can be performed under the same layout as used for seismic refraction, to obtain excellent shear wave velocity profiles of subsurface.

ReMi is a new, proven seismic method for measuring in-situ shear-wave (S-wave) velocity profiles. It is economic both in terms of cost and time. Testing is performed at the surface using the same conventional seismograph and vertical P-wave geophones used for refraction studies. The seismic source consists of ambient seismic “noise”, or micro-tremors, which are constantly being generated by cultural and natural noise. Because conventional seismic equipment is used to record data, and ambient noise is used as a seismic source, the ReMi method is less costly, faster and more convenient than borehole methods and other surface seismic methods, such as SASW and MASW used to determine shear-wave profiles. Depending on the material properties of the subsurface, ReMi can determine shear wave velocities down to a minimum of 40 meters (130 feet) and a maximum of 100 meters (300 feet) depth.

The ReMi method offers significant advantages. In contrast to borehole measurements. ReMi tests a much larger volume of the subsurface. The results represent the average shear wave velocity over distances as far as 200 meters (600 feet). Because ReMi is non-invasive and nondestructive, and uses only ambient noise as a seismic source, no permits are required for its use. ReMi seismic lines can be deployed within road medians, at active construction sites, or along highways, without having to disturb work or traffic flow. Unlike other seismic methods for determining shear wave velocity, ReMi will use these ongoing activities as seismic sources. There is no need to close a street or shut down work for the purpose of data acquisition. And a ReMi survey usually takes less than two hours, from setup through breakdown. These advantages sum to substantial savings in time and cost. Moreover the method provides more accurate results compared to conventional effort of picking up shear waves from records which more often than not lead to errors.

Refraction Micro-tremor (ReMi) provides detailed S wave profiles of subsurface, providing a detailed insight into material strength (independent of water saturation). Fig. 9 is a typical example from a masonry dam, clearly showing weak blocks after chainage 265 m (Blue low velocity zones). The rock interface is visible as red interface.

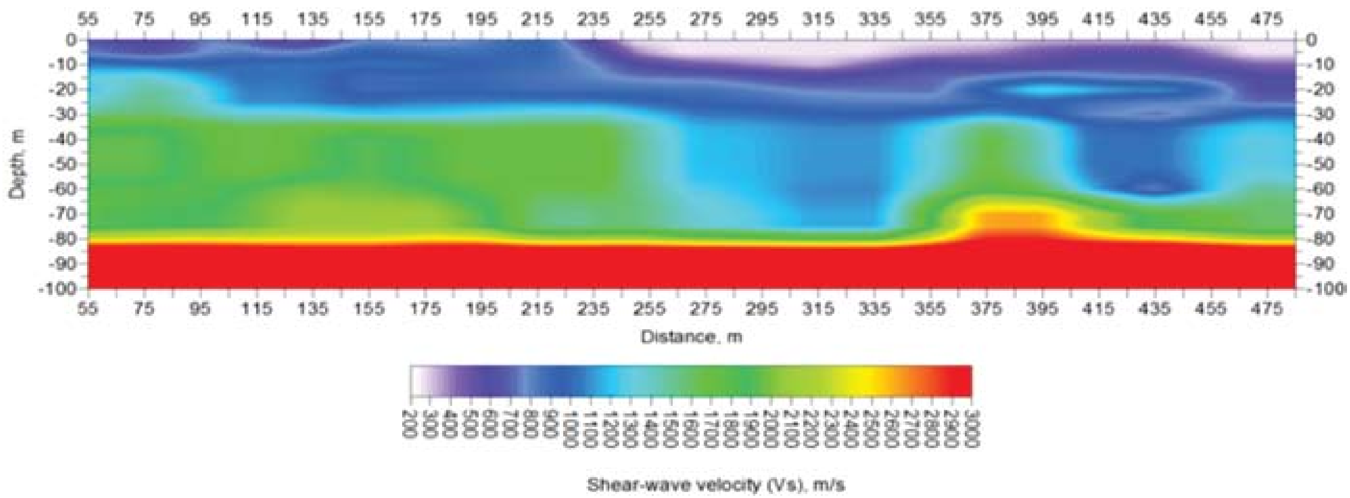


Fig. 9: ReMi Results on a Masonry Dam Showing Weak Zone

4. EARTHEN DAMS

Techniques of Electrical Resistivity Imaging and Streaming Potential as discussed earlier are primary investigation tools for Earthen Dams. In addition, seismic refraction tomography provides valuable information on bedrock status and foundation flows, if any.

4.1 Seismic Refraction Tomography

The seismic refraction method detects changes in lateral- seismic velocity and/or layer thickness. Seismic techniques are extremely useful since seismic velocity is generally the most sensitive to slight changes in density and saturation in the types of materials commonly used in dams.

The common seismic technique used for dam investigation is seismic refraction method. A standard seismic refraction line is laid out using 24 geophones at 5m intervals. Energy is input into the ground at various points located along the seismic line, resulting in a 2D velocity model of the subsurface.

A minimum of seven shot points are used for each spread. These include two far shots on either side of the spread, to provide the true seismic velocity of the "sound" rock, two end shots to obtain reciprocal times, and three mid shots within the profile to obtain lateral velocity variation in the top layer(s) (overburden).

The length of geophone spread depends upon the required depth of investigation and the dimensions of any subsurface features that are to be mapped. A length of approx. three to four times the depth of investigation is used. A geophone spacing of 5 m with 24 channels spread is adequate for detailed mapping of subsurface conditions to a depth of approx. 30m. The geophone spacing can be further increased for greater depth of investigation, if required.

The compressional wave velocity is affected by many conditions. However, in sediments (or compacted soil) the primary factors affecting the compressional wave velocity are density, porosity and saturation. In lithified materials (rock), factors such as cementation, fracturing, alteration and stress generally have a greater effect on the velocity. Fig. 10 hereunder show typical results obtained from Seismic Refraction Tomography, with blue to red representing increasing seismic velocity, and red line representing the bedrock topography.

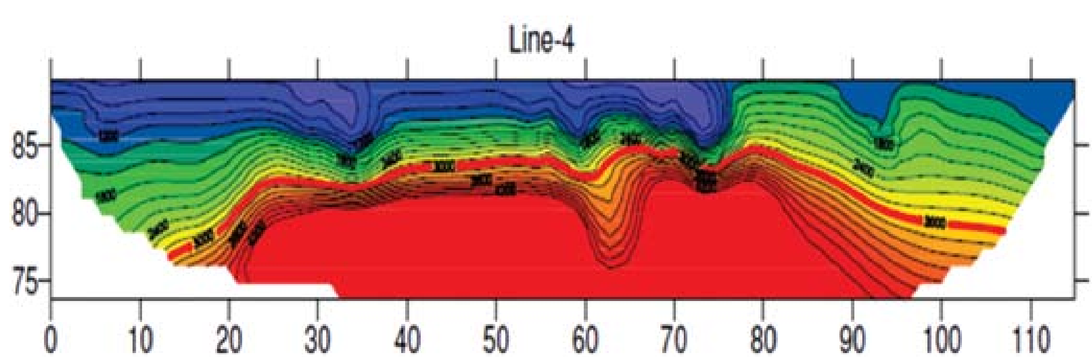


Fig. 10: Geophysical Methods for Common Dam Problems

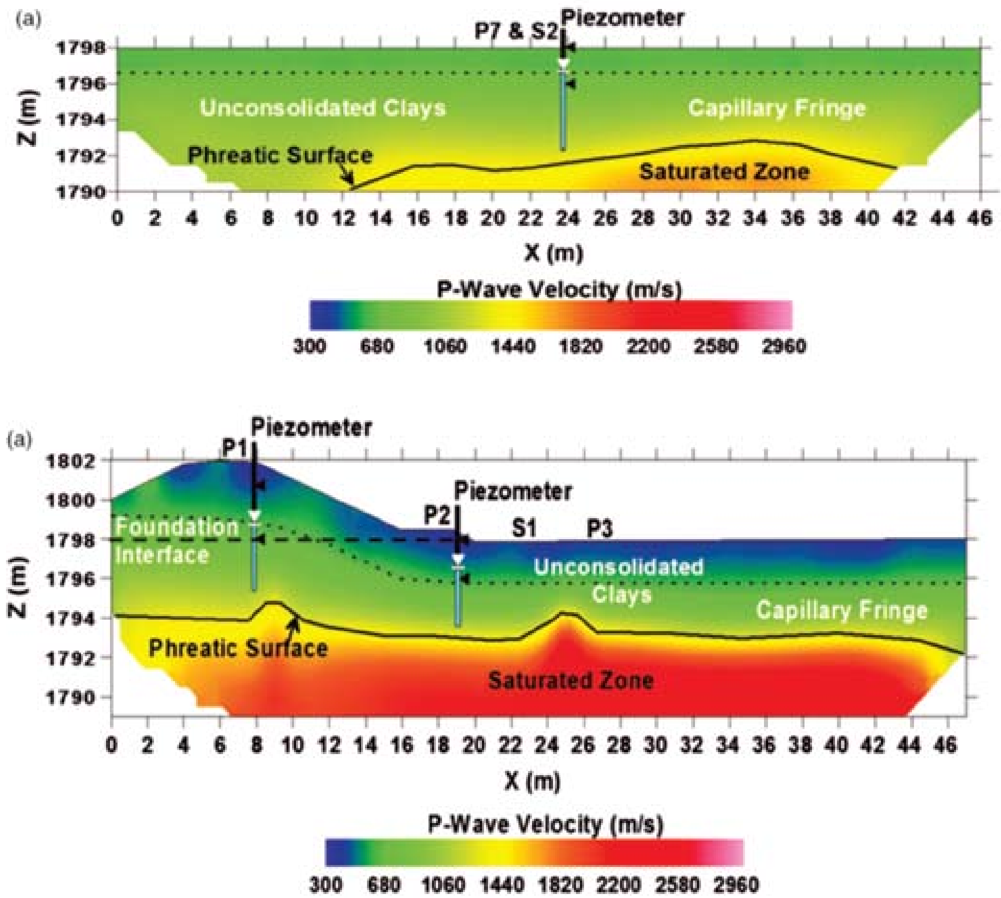


Fig. 11: Seismic Refraction Results

Seismic Refraction results can also be used to determine Phreatic line. Fig. 11 show typical results obtained from seismic refraction.

5. DAM GEOPHYSICS- CONSIDERATIONS

To date, the use of geophysical methods to investigate seepage in dams has produced mixed results, partly because the application of these methods is not well understood and partly because false positives cannot be tolerated. Although geophysical anomalies are easily detected, often what these anomalies represent and their implications are not clear. The application of geophysical methods to dams is in its early stages, and adapting geophysical techniques to geotechnical investigations and dam safety surveillance requires more refinement to answer specific engineering questions.

Geophysical methods are useful as non-destructive remote sensing tools that can provide information over large volumes as compared to point measurements. However, the anomalies of interest that are associated with dams often are very small. The effectiveness of geophysical techniques to detect changes in seepage conditions is improved through repeating surveys or adopting a long term monitoring approach. In addition, application of more than one geophysical technique will provide added confidence in the interpretation and detection of anomalous features. Not recognizing some of the fundamental relationships between various parameters and carrying out a onetime survey without supporting information could lead to misleading and often disappointing results. The results, therefore, need to be interpreted jointly by geophysicists and dam engineers, to derive maximum benefits.

For dam safety applications, SP and resistivity methods generally appear to hold more promise than seismic methods as nonintrusive techniques applied at the surface of a dam. However, in specific settings, cross-hole seismic techniques could prove indispensable for acquiring high resolution data in anomalous zones. Although the understanding of the SP and resistivity methods as applied to dams has come a long way in recent years, more research is required and interpretation needs special care. It is imperative that the dam owner and practicing engineer recognize the limitations and the care required in planning, executing, and interpreting the results. Geophysical data interpretation is non-unique and should be constrained by incorporating all available site information and integrating the interpretation of complementary data sets. Thus, strong cooperation between the geophysicist and engineer is essential to improve the interpretation and usefulness of the results.

6. DAM GEOPHYSICS- WHEN?

It is desirable to have a 'base line' data of dam soon after completion of dam. For older dams, this time is 'now'. Availability of this base line data makes it possible to compare periodic measurements and detect 'changes' in physical properties, which are much easier to interpret than one time measurement values. Under 'normal' conditions, such measurements should be repeated every couple of years as a routine dam inspection program.

It is almost always desirable to conduct a well designed geophysical investigation program before designing any rehabilitation program. The information obtained at a fraction of cost of the complete rehabilitation program, provides invaluable information on internal conditions, helping an optimal design and saving on costs and time. The investigation program then should be conducted after rehabilitation, to confirm success of rehabilitation.

7. CONCLUSIONS

Dam geophysics is still in its early days. It holds a great potential as health check and monitoring tool for dams of all types, provided the geophysical program is well designed, executed and interpreted. A strong cooperation between the geophysicist and engineer is essential to improve the interpretation and usefulness of the results. The principal objective of a geophysical investigation is usually to measure material properties, and locate anomalies in dams based on contrast in physical properties. Usually it is best to utilize more than one geophysical method to remove ambiguity to the extent possible. The objectives of investigation program must be well defined, and then the geophysical program should be designed involving primary and secondary tools/ techniques.

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Even though this generation still believes in the miracle working power of God, they must no longer wait for God to bring water from the rocks, but rather construct dams, water systems, subdue the power of the ocean thereby give glory to God almighty"

Sunday Adelaja

Constructing Storage Dams – Lessons Learnt from Raising of Sardar Sarovar Dam and Gujarat

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Narmada Control Authority, Ministry of Water Resources,
River Development & Ganga Rejuvenation, Government of India

ABSTRACT

Water is essential for everybody's life, living and livelihood. It is this unique reach, which makes water a most effective means to achieve inclusive growth. It fulfils most basic human and ecological needs and is indispensable to almost all economic activities, including agriculture, energy production, industry, and mining. But its availability varies widely in time and space which makes storage dams a necessity. With impacts on health, gender equity, education and livelihood, water management, Storage Dams and water resources projects are crucial to sustainable economic development and the alleviation of poverty. Since beginning of the civilization, water resources projects have contributed towards all round development of the region. But sometimes these projects lack holistic approach thereby inviting criticisms for skewed and lopsided developments along with concerns for environment and displacement of inhabitants of the submergence area. While the command area benefit from irrigation, water supply, etc., people from submergence area not only lose their land and/or livelihood but also their social networks. Similarly, implementation of environment safeguard measures and resettlement & rehabilitation measures often raise several questions. In the process, the opportunity for inclusive growth is not utilized fully. There is a need to learn from implementation of large projects, such as Tehri HE Project, Sardar Sarovar (Narmada) Project, etc., so that proper policy perspectives emerge towards achieving inclusive growth. These experiences and best practices were also corroborated during consultation meetings for National Water Policy (2012), which helped in evolving some policy recommendations in this regard. This paper makes an attempt to present these best practices and policy prescriptions so that project authorities may adopt these and make large water resources projects more beneficial and contribute towards achieving inclusive growth.

Keywords: *storage dams, Environmental Safeguard Measures, Inclusive Growth, National Water Policy, Resettlement & Rehabilitation, Water Resources Projects.*

1. INTRODUCTION

Inclusive growth, in simple words, implies participation of people from different groups –gender, ethnicity, religion–and across sectors–agriculture, manufacturing industry, services, in the economic growth process and its outcomes. Water has the potential to contribute towards inclusive growth since it touches everybody's life, living and livelihood. Water is not only fundamental to life and essential component of environment for living but also a vital resource for economic activities for livelihood. Water is necessary for food production and optimum water management improves food productivity, which is vital for ensuring food security and social harmony. Water produces energy (hydropower) and is required for energy generation (cooling). At the same time, energy is needed for water extraction and pumping. Water is also central to climate and the consequences of likely climate change. Therefore, World Economic Forum (2011) rightly observes that "water security is the gossamer that links together the web of food, energy, climate, economic growth and human security challenges".

2. SIGNIFICANCE OF STORAGE DAMS

Storage dams are necessary to provide a reliable source of water for short or long periods to capture spring runoff for use by in the dry summer months. In India due to monsoonal climate and inherent variability of availability of water in time and space, storage dams are more essential for providing water, food and ultimately, national security.

Irrigation accounting for 75% of the use (source: www.nlwra.gov.au/atlas). China, one of the fastest growing economies in the world, has per capita reservoir storage capacity of 2,000 m^3 per annum through dams, and an actual storage of nearly 360 m^3 per capita. This is in spite of the great technological advancements made by most of these countries in improving water use efficiencies, particularly in sectors such as irrigation and industry. When compared to these impressive figures, India, which is still developing, has a per capita storage of only 210 m^3 per annum. Though a much higher level of withdrawal of nearly 600 m^3 per capital per annum is maintained by the country, a large percentage of this (231 BCM per annum or nearly 217 m^3 per capita per annum) comes from groundwater draft. But, there are increasing evidences to suggest that this won't be sustainable. Many semi-arid areas are already facing problems of groundwater over-draft, with serious socioeconomic and ecological consequences as discussed in the recent work by Kumar (2007). Ethiopia, the poorest country in the world, has a per capita storage of 20 m^3 per annum. These facts also strengthen the argument that economic prosperity that a country can achieve is a function of available water storage per unit of population. The per capita water storage and the per capita GDP (ppp adjusted) for a group of 22 countries is given in Figure 5. One can see a strong relationship between level of storage development and country's economic prosperity. The R square value is 0.55 and the coefficient is significant at one per cent level. Such a relationship is understandable.

Water storage infrastructure reduces risks, and improves water security.

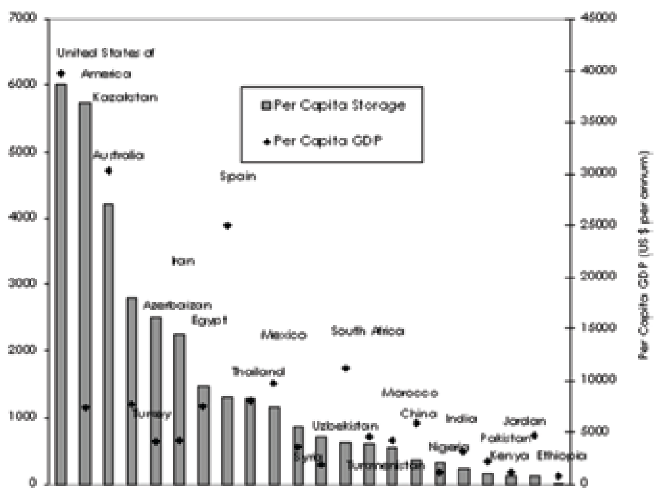

Fig. : Per Capita GDP & Dam Storage in Selected Countries

Thus, Storage dams and water resources development have important roles in improving the access to and use of water, the two pre-requisites for improving the water situation (expressed in terms of SWUI) of a region, though intensive water development in river basins might reduce indicators on the water environment front. The amount of storage that needs to be created to improve access to and use of water depends on the type of climatic conditions. In temperate and cold climates, the demand of water for irrigation, which is the largest user of water in most regions with agricultural base, would be negligible when compared that in tropical and hot climates. Hence, the storage requirements would be much lower, mainly limited to that for meeting domestic/ municipal water needs and water for manufacturing. Hence, it makes logic to explore links between storage development for meeting various human needs and economic growth only in tropical and hot climates. The sheer scale of water infrastructure in rich countries is not widely appreciated (HDR, 2006: pp155). Many developed regions of the world that experience tropical climates had high water storage in per capita terms. The United States, for instance, had created a per capita storage capacity of nearly 6000 m^3. In Australia, the 447 large dams alone provide a per capita water storage facility of nearly 3,808 m^3 per annum or a total of 79,000 MCM per annum. Aquifers supply another 4,000 MCM per annum. Against this, the country maintains a use of nearly 1,160 m^3 per capita per annum for irrigation, industry, drinking and hydropower, with Water resources projects have contributed significantly in development of civilizations world over. Shah and Kumar (2008) illustrated the role of large storages in development and economic growth, particularly for poor and developing countries. Their analysis of data from 145 countries shows that improvement in water situation of a country determines the progress in human development and economic growth of a country. The sustainable water use index (SWUI), which captures attributes, viz., access to and use of water, water environment and human resource capacities in water sector, to a great extent, determines the human development index (HDI), driving economic growth. While the relationship between SWUI and HDI is linear, that between SWUI and per capita Gross Domestic Product is exponential. The paper argued that building large storages would be crucial improving the overall water situation of a country, as the widely talked about alternatives such as intensive use of groundwater, virtual water trade and small-scale water harvesting suffer from many limitations. Large dams are important for human development and economic growth.

However, large water resources projects are often criticized for skewed and lopsided development and for environmental and resettlement reasons. The catalytic role of water resources projects in socio-economic developments have seldom been analysed and publicized. The policies of environment safeguard measures and resettlement & rehabilitation are generally good but implementation on ground needs improvement. It is not intended to discount these criticisms. In fact, the criticismshave helped in identifying lacuna, for which policy initiatives have been taken from time to time so that water resources projects can contribute towards inclusive growth. The consultation meetings held with parliamentarians, academia, professionals, corporate leaders, civil societies, non-government organizations and Panchayati Raj institutions for drafting National Water Policy (2012) and the lessons learnt from implementations of Narmada Projects, etc., have brought out the concerns and the best practices. This paper makes an attempt to present these best practices and policy prescriptions so that project authorities may adopt these and make storage dams and large water resources projects more beneficial and contribute towards achieving inclusive growth.

3. WATER RESOURCES PROJECTS – INSTRUMENTS OF ALL - ROUND DEVELOPMENT

Whenever we talk of contribution of water resources projects, the role of Bhakra Beas Project comes in front of all of us. In fact, this Project has been credited for bringing green revolution. Malik (2006) analysed Bhakra Beas Project using Social Accountability Matrices (SAM) based multiplier model to examine whether investments in large water resources development projects, such as multipurpose dams, benefits all sections of society, including the poor and the landless, thereby serving a major mechanism for combating poverty. The study found that increased availability of water for irrigation resulted in higher agricultural output. The gross irrigated area during the forty year period (1996-97 over 1955-56) increased by about 220%, i.e., from 3.2 million hectare (MHa) to 10.3 MHa. The increase in irrigated area from the Bhakra system and other sources led to significant increase in food grain production in Punjab and Haryana; availability of water for industry, household enterprises and drinking for households and livestock; and generation of hydro power. Moderation of floods reduced flood damages significantly. These changes in availability of additional food grains and electricity in Bhakra system have led to a number of other benefits in the benefited region, namely, 100 percent rural electrification in Punjab and Haryana, widespread installations of private wells, a very significant reduction in poverty, overcoming problems of recurrent floods etc. The modelling study showed that the Bhakra dam project generated significant indirect or downstream effects in the State of Punjab and estimated the multiplier value as 1.90, which implies that for every rupee (100 paisa) generated directly by the project, another 90 paisa was generated in the region as downstream or indirect effects. These multipliers include the effects of inter-industry linkages as well as the consumption induced effects but do not include the benefits reaped in by other players such as immigrant labour etc. If it were possible to account for these impacts as well, the value of multiplier would perhaps be much larger than estimated. Further, the investment in the Bhakra Dam has provided income gains to agricultural labour households that are higher than those for the average households.

Another important dam, which has courted several controversies and legal cases, is the Sardar Sarovar (Narmada) Project, Gujarat. The Project Authority, i.e., Sardar Sarovar Narmada Nigam Limited commissioned a study to Institute for Resource Analysis and Policy, Hyderabad to analyze the socio-economic and environmental impacts of the Sardar Sarovar Project. The study found the indirect economic impacts as reduced energy cost of production and supply of water for domestic and municipal uses, with the replacement of groundwater based sources by Narmada canal based pipeline in rural and urban areas, estimated to be around Rs. 85.77 crore per annum for an population of about 24 million people; and the ability of men and women to reach their work site on time, and increase in their employment opportunities. The indirect economic benefits of producing clean energy through hydropower, which can defer the investments in fossil fuel based power generation, thereby saving the cost of capturing emitted carbon, is worked out to be more than 160 crore rupees annually. All these benefits and impacts are realized with just one third of the designated command areas receiving Narmada water, and a lesser percentage of the planned villages receiving drinking water supplies from Narmada canal based drinking water scheme. Some of the direct and indirect economic benefits are likely to magnify in proportion to the increase in irrigated area from canals and increase in coverage of drinking water supply schemes. The multiplier effects of irrigation that are likely to magnify over a period of time would essentially come from growth in agro processing industries such as rice and flour mills and cold storages. This would ultimately have a huge poverty reduction impact across Gujarat.

These two case studies amply demonstrate the positive contributions of large water resources projects not only in terms of direct benefits from irrigation, hydropower, drinking and industrial water supplies, but also for indirect benefits in terms of increased economic activities, overall human development, improved health, etc. Thus, water resources projects have the potential of achieving inclusive growth.

4. MAJOR CHALLENGES IN CONSTRUCTION OF STORAGE DAMS

Any development initiative has its share of challenges and large water resources projects have equally larger challenges. Effective and successful project management depends primarily on how effectively these challenges are addressed and mitigated. Following major challenges have been expressed time and again;

(a) Land Acquisition

With most of the optimal sites having been used up, we have very limited choice for constructing water resources development projects. Huge population pressure, further, compounds the problems in land acquisition, which has proved to be the biggest challenge in water resources development projects. The Government of India has enacted “The Right to Fair Compensation and Transparency in Land Acquisition, Rehabilitation and Resettlement Act, 2013 (also Land Acquisition Act, 2013)” regulating land acquisition and laying down the procedure and rules for granting compensation, rehabilitation and resettlement to the affected persons in India. Often the provisions of land acquisition are taken as cost prohibitive without recognizing that water resources projects yield multiple benefits and if all benefits, direct and indirect, are taken into account then the efforts and the costs would appear to be worth undertaking.

(b) Inequity

Water resources projects tend to increase inequity. While the people in submergence area lose their land and livelihood, with which they are socially, economically, culturally and overall emotionally associated, people in the command area derive most of benefits from the project. This inequity is often the root cause of the resistance of the project affected families, which manifests in opposition for the project.

(c) Engineering Centric Approach

Water resources projects are generally planned and implemented as an engineering project without recognizing their socio-economic inter-linkages. In fact, lack of agronomical logistics, participatory management, skill development, capacity building and other aspects of inclusive growth, limit the benefits from water resources projects and accordingly, their acceptability in the society. The Central Water Commission's Guidelines (2010) for "Submission, Appraisal and Clearance of Irrigation and Multipurpose Projects" and the Central Electricity Authority's Guidelines (2012) for "Formulation of Detailed Project Reports for Hydro Electric Schemes, their Acceptance and Examination for Concurrence", do not make it mandatory to consider aspects of inclusive growth in planning of the water resources projects.

(d) Corruption

Another major concern is corruption and more so in the society. The moment a project is conceived; people flock towards submergence area and indulge into all practices, including litigations, to get included in the list of project affected families for the sake of getting some compensation. The Oversight Group (2006) constituted by the Government of India for the Sardar Sarovar Project had reported that population of 22 villages demonstrated an extraordinary increase between the census of 1991 and 2001, by as much as 140 per cent in respect of population and 162 per cent in respect of households, whereas in other villages, population has shown negative growth between the two census. As a result, the genuine project affected persons get marginalized and suffer from unscrupulous processes. The corruption in implementation agencies impacts the quality of works and mars the good efforts towards proper implementation of environment safeguard measures and resettlement & rehabilitation.

(e) Poor Implementation of Environment Safeguard Measures and Resettlement & Rehabilitation

The policies and guidelines for implementation of environment safeguard measures (ESM) and resettlement & rehabilitation (R&R) are generally good on paper but their implementation raises many questions. The stipulation of public hearing; social impact assessment; environment impact assessment; statutory clearances under Forest (Conservation) Act, 1980; Environment (Protection) Act, 1986; Wild Life (Protection) Act, 1972;Panchayats (Extension to Scheduled Areas) Act, 1996; Scheduled Tribes and Other Traditional Forest Dwellers (Recognition of Forest Rights) Act, 2006; Right to Fair Compensation and Transparency in Land Acquisition, Rehabilitation and Resettlement Act, 2013; techno-economic appraisal; investment clearance, etc., provides enough checks to ensure proper provisioning for ESM and R&R and their implementation. However, the process of implementation of ESM and R&R is so complex with inter and cross linkages that much remains wanted on the ground.

(f) Judicial Delays

The implementation of water resources projects often get delayed with substantial time and cost over-runs due to delays in settlement of litigations in courts. Many unscrupulous elements tend to take advantage of these procedural delays. Justice delayed is justice denied and it is more true in case of water resources projects. As such, the genuine project affected persons do not get due compensation in time, the people in command area also do not get the benefit of development. The opportunity of inclusive growth gets delayed or even lost due to judicial delays.

5. LESSONS LEARNT AND POLICY PRESCRIPTIONS

Water resources projects have great potential for achieving inclusive growth as brought out in para 2 above. These act as catalyses in accelerating socio-economic developments. However, the concerns mentioned in para 3 above have been proving as limitations and there is an urgent need to adopt best practices for achieving inclusive growth. Some of the best practices and policy prescriptions are given below;

(a) Integrated Water Resources Management

National Water Policy (2012) recognizes inter-disciplinary nature of water resources projects and proposes that they should be planned considering social and environmental aspects also in addition to techno-economic considerations in consultation with project affected and beneficiary families. The integrated water resources management (IWRM) with emphasis on finding reasonable and generally acceptable solutions for most of the stakeholders should be followed for planning and management of water resources projects.

The Central Water Commission's Guidelines (2010) for "Submission, Appraisal and Clearance of Irrigation and Multipurpose Projects" and the Central Electricity Authority's Guidelines (2012) for "Formulation of Detailed Project Reports for Hydro Electric Schemes, their Acceptance and Examination for Concurrence" do not explicitly make it mandatory that the projects should conform to River Basin Master Plan prepared on the basis of IWRM principles. The Ministry of Water Resources, River Development & Ganga Rejuvenation has taken the initiative to prescribe this in draft National Water Framework Bill and the draft River Basin Management Bill, which are at consultation stage.

The Supreme Court, in the case of Alaknanda Hydro Power Co. Ltd. Vs Anuj Joshi & Ors. in Civil Appeal Nos.6746-6747 of 2013, etc., also recognized the need for study of the cumulative impact of the various projects in a region and vide order dated August, 13, 2013, directed for "comprehensive" environment and ecological impact report of 24 hydroelectric power projects to be established on Alaknanda and Bhagirathi river basins in Uttarakhand. Thus, there is an urgent need to prescribe preparation of River Basin Master Plans, according to which water resources projects should be planned.

(b) Holistic Planning with All Costs and Benefits

Water Resources Projects are planned taking all costs including costs on resettlement & rehabilitation and environment safeguard measures, such as catchment area treatment, compensatory afforestation, etc. But only direct benefits due to increased crop productivity and production of high value crops are considered in the Benefit Cost Analysis. Other benefits, such as tourism development, improved transport connectivity, consequential developments in agronomical logistics, participatory management, skill development, capacity building and other aspects of inclusive growth of the region should also be accounted for. Therefore, water resources projects should be holistic planned with appropriate linkages with tourism development, improved transport connectivity, consequential developments in agronomical logistics, participatory management, skill development, capacity building, etc.

(c) Special Purpose Vehicle for Environment Safeguard Measures and Resettlement & Rehabilitation

Environment Safeguard Measures (ESM) and Resettlement & Rehabilitation (R&R) of large water resources projects are generally carried out by the Project Authority itself. This creates conflict of interest since Project authority is of ten focused on speedy project execution and ESM and R&R take back seats. Also, the people who implement ESM and R&R, generally don't live in the affected areas and so are not familiar with the local conditions, needs and other community and ecological issues. Given this, it is better to set up a Special Purpose Vehicle (SPV) before project implementation begins. The SPV could be run by concerned line departments, such as Forest, Tribal Welfare, etc., under guidance of or in close association with local NGOs and elected representatives, so that local concerns get addressed and the SPV becomes truly representational. The money required for these should be set aside by the Project Authority and placed at the disposal of SPV at the beginning of the Project. This would bring local partnership, transparency and accountability and would serve as an institutional mechanism to address the failure that we have seen in ESM and R&R implementation.

The Government of Gujarat has set up in 1992, the Sardar Sarovar Punarvasvat Agency (SSPA) for implementing the Resettlement and Rehabilitation (R&R) activities of the Sardar Sarovar Project Affected Families (PAFs) in Gujarat. While implementing the activities, SSPA recognized that resettlement and rehabilitation are two different issues. Resettlement is more concerned with the change in geographical location and the provision of basic infrastructure in the new habitat, Rehabilitation is more concerned with the empowerment of PAFs, so that they can get assimilated and prosper in their new settlements. The SPV approach would ensure that PAFs are not only resettled but also rehabilitated.

(d) Grievance Redressal Authority

Resettlement process is quite litigation prone. From the time project is conceived, even outsiders move to the affected areas for getting registered as project affected persons. Many persons claim project affected status and file suits in local courts for more and more compensation. Often these litigations take considerable time delaying the land acquisition and consequently project execution resulting into delayed benefits and high cost over-runs. The setting up of Grievance Redressal Authority (GRA) headed by a retired High Court or District Judge in case of Narmada Projects has proved to be of great help since majority of the claims and counter-claims get resolved locally. It also acts as an appeal mechanism for the redressal of grievances of the PAFs. According to this mechanism, if a displaced person is aggrieved by the decision from any of the rehabilitation officers in respect of R&R process, he/she may appeal to the concerned GRA for proper resettlement within a limited period. The implementing agency has to comply with the directions of the GRA. The opinion of GRA becomes the basis for giving permission for engineering works, such as, raising of the dam. The institution of GRA has instilled the system of judicial review in the implementation of R&R, checked corruption to some extent, reduced the number of litigations and also helps the Project Authority get the confidence of general public and Courts.

(e) Recurring Benefit Sharing

Recurring benefit sharing by the project affected persons to make them feel as partners in progress is very essential. The very nature of dam construction involves displacement from submergence area and benefits in the command area. While analyzing the benefit sharing issues, Egre (2007) emphasized the necessity to take innovative measures to indemnify the affected people and to share the economic advantages of the projects. From the ethical and social justice point of view, it is logical that part of the proceeds return to the local populations affected by the project.

Most of present compensation package comprise one time settlement with no plans for the future to ensure social and economic security to future generations. Land based rehabilitation in command area is the preferred mode so that PAFs continue to get the shelter and livelihood, which land provides, but often Government cultivable land is not available. Further, displacing other people to resettle PAFs does not make logical sense. Recognizing this aspect, many States have been announcing better and more liberal compensation packages including annuity for the land acquisition. In Sardar Sarovar (Narmada) Project, all major sons (and all major daughters in Maharashtra) of PAFs have been considered as separate families and given compensation accordingly. This ensured compensation to at least immediate next generation. In case of hydropower projects, 1% of power generated is allocated for local area development. Theseforms of recurring benefit sharing not only ensure social security for PAFs, but also make them feel as partners in progress.

(f) Pari-passu Completion

Large water resources projects have large challenges, which areinter-dependent with cross and inter linkages, making their resolution difficult before hand or in afixed time frame. Therefore, it is always better to have civil construction *pari-passu*with implementation of ESM and R&R. The environment clearance order for Tehri, Sardar Sarovar (Narmada) Project, etc., specifically provided that compilation of present status, formulation of action plans for ESM and R&R and their implementation would be scheduled in such a manner that their execution is pari-passu with the construction, failing which the engineering works would be brought to a halt. The Courts have also endorsed this and has been directing completion of ESM and R&R at least 6 months prior to raising of the dam to the corresponding height. This approach has worked well in both Tehri HE Project and Sardar Sarovar (Narmada) Project, ensuring balanced progress of engineering works with ESM and R&R and also not forcing resettlement much ahead of actual requirements. The National Water Policy (2012) also recommends that all components of water resources projects should be planned and executed in a pari-passu manner.

(g) Use of Technology and Transparent Approach

There is an urgent need to promote use of technology in planning and implementation of water resources projects and for ESM and R&R. This facilitates proper documentation bringing transparency and avoiding unnecessary litigations. In case of Sardar Sarovar (Narmada) Project, survey in some parts of the submergence area in Madhya Pradesh could not be done due to local resistance, and list of PAFs was prepared on mere visual inspection (nazaria survey). This has led to several allegations of omissions in the list of PAFs. The present day technology, particularly with the CARTOSAT 2 satellite, allows capturing of objects of more than 1 meter size in the satellite imagery. This would allow complete capturing of all households, roads, trees, etc., thereby avoiding possibility of manipulation. LiDAR (Light Detection And Ranging) surveys permit generation of contour with interval less than 0.2 meters and accurate delineation of submergence areas on the ground.

Another important advancement in technology has been in the field of hydrodynamic modeling, which permits scenario analysis in backwater studies, inundation mapping and reservoir operations. Often due to inaccurate studies, either people, not resettled get submerged or the 'resettled' people do not get impacted during filling and/or operation of the reservoir. As a result, genuine PAFs do not get compensation but undue people receive the compensation. This issue had also come to the fore during filling of Indira Sagar (Narmada) Project and the Madhya Pradesh High Court directed for review of back water levels. Thus, latest advancement in technology should be used not only in design and construction of large water resources projects but also in planning and implementation of ESM and R&R. All such studies should be put in public domain and presented during public hearings.

The inter-State agreements included in the Award of the Godavari Water Disputes Tribunal (1980) stipulates construction of Model villages with facilities/amenities, etc., at the cost of the Project before submergence actual takes place. This is very important so that PAFs actually see what they are actually getting. In fact, arranging physical visits by PAFs to such R&R villages have facilitated resettlement process in case of Narmada Projects.

(h) Emphasis on Skill Development and Livelihood

The developments associated with water resources projects bring new economic activities and social transformations as well. Therefore, the traditional skills no longer remain remunerative and attract new generations. A survey carried out by the Narmada Valley Development Department, Government of Madhya Pradesh in finding causes for fake registration of lands revealed that some of the PAFs did not buy actually the land and diverted the Special Rehabilitation Package as they no longer want to continue with agriculture. In changed circumstances when they are newer and more remunerative opportunities, PAFs may be more interested in skill development and enhanced livelihood opportunities rather than confined to traditional way of living. In fact, some of the rehabilitation amount and share of the project benefits could be more productively utilized in setting up Industrial Training Institutes (ITIs), agro-based industries' skill development, etc., which would bring inclusive growth in the region.

6. CONCLUSION

Since beginning of the civilization, the potential of water resources projects to bring all round development has been well established. At the same time, they are limited sites where dams can be built and such opportunities should not be lost merely due to concerns of environment and resettlement. Water resources projects must be made multi-purpose and not restricted to, say only hydro-power as run-off-the-river scheme, to avoid environment and resettlement issues. The limitations and the concerns, which have come to fore from the experiences of implementations of water resources projects, need to addressed and mitigated. The potential for inclusive growth must be fully exploited, as also recommended by the National Water Policy (2012) that all water resources projects, including hydro power projects, should be planned to the extent feasible as multi-purpose projects with provision of storage to derive maximum benefit from available topography and water resources.

In 1954, while inaugurating the Bhakra Nangal dam, the then Prime Minister Jawaharlal Nehru christened it as the 'Temple of Modern India'. People's faith in these temples needs to be preserved, which can be done only through achieving inclusive growth. It is hoped that the Project Authority would adopt the suggested policy prescriptions and make large water resources projects more beneficial and contribute towards achieving inclusive growth.

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Storage Dams for Sustainable Development "Need for Storage Dams for Future Water Security" with Reference to Development of Proposed Water Resources Projects in Indravati Sub Basin


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ABSTRACT

Water resources engineers and planners have realized the importance of integrated water resources planning, development and its management at basin and state levels in order to optimize the use of renewable water resources potential available for sustainable development. In the Indian subcontinent the maximum concentrated runoff is available during the month of June-September. Indian summer monsoon contributes about 80% of the annual precipitation during June-September and remaining 20% during October-May. This rainfall pattern is mostly erratic and unevenly distributed in different parts of the country. Sometimes, non monsoon rains also defers and create acute water scarcity in many parts of India resulting crop failure and also fail to support the increasing water requirement. The suitable sites for construction of Dams and Reservoirs are gift of nature and can not be created. Indravati sub basin in the state of Chhattisgarh and Maharashtra offers excellent suitable sites for creation of reservoirs supported by abundant water availability. Indravati sub basin is a part of the Godavari Basin. The Godavari Basin is the 2^{nd} largest river basin in India after Ganga basin and it accounts for approximately 10% of the geographical area of the country. The Godavari Water Dispute Tribunal Award allocated utilization of Water available in Godavari basin between the beneficiary states. Nearly 4 decades have been passed, since the Godavari Water Dispute Tribunal Award (GWDTA) came in force in the year 1980. In the present paper authors have highlighted the importance of the construction of Storage Dams across proposed suitable sites in Indravati Sub-Basin to ensure future water security and consequently play a key role in poverty elimination.

Water is an essential element and basic requirement for sustainability of any living organism including humans for their existence. Of late, water resources engineers and planners have realized the importance of integrated water resources planning, development and its management at basin and state levels in order to optimize the use of renewable water resources potential available for sustainable development and ensuring water availability for irrigation, power, municipal and industrial usages.

The typical monsoon climate in Indian subcontinent plays an important role for water resources planning and development which is characterized by large scale reversal of the prevailing wind, giving very two distinct seasons:

(a) Summer: in summer moist air is carried northwards from the Indian Ocean over the Indian subcontinent resulting rains. **(b) Winter:** in winter cool and dry air is carried southwards from subcontinent. Thus the year is divided in to **wet** and **dry** Season. In addition a short north-east monsoon affects the south east coastal states of India[1]. The present day climatic characteristics and problems are thus rooted in the Physical environment and in their long and intricate history[2]. Indian summer monsoon contributes about 80% of the annual precipitation during June-September and remaining 20% during October-May. This rainfall pattern is mostly erratic and unevenly distributed in different parts of the country. Sometimes deficit non monsoon rains create acute water scarcity in many parts of India. This often fails to support the increasing water requirement during summer in draught prone areas.

In view of above, it is inevitable to store surplus water during monsoon by creating large reservoirs, wherever favorable natural sites for construction of dams are available. This storage may be utilized during non monsoon or lean periods to meet drinking water, agriculture and other needs. Under prevailing climatic and geographical conditions the only solution for sustainable development is creation of large reservoirs to ensure water security. Water security will play a key role in poverty elimination.

NEED FOR HARNESSING WATER RESOURCE POTENTIAL OF INDRAVATI SUB BASIN

Indravati River is one of the major tributary of the Godavari River which contributes significant inflows during monsoon to the Godavari River. It originates from the Eastern Ghat of Dandakaranya range at an elevation 914.40 m in Kalahandi district of Odisha and flows across Chhattisgarh state and meets Godavari near Somnoor sangam at an elevation of 82.3 m in Maharashtra. The Indravati Sub Basin lies between Latitude 18°27'00" N to 20°27'00" N and Longitudes 80°05'00" E to 83°07'00" E and drains a total area of 41655 sq. km. having total length of 536 km from its origin to confluence with Godavari.

Indravati sub basin is a part of the larger Godavari Basin. The Godavari Basin is the 2nd largest river basin in India after Ganga basin and it accounts for approximately 10% of the geographical area of the country. The Godavari Water Dispute Tribunal Award has already allocated utilization of Water available in Godavari basin between the beneficiary states. Nearly 38 years have been passed, since the Godavari Water Dispute Tribunal Award (GWDTA) became reality in the year 1980, wherein all party states Madhya Pradesh (now MP & CG), Odisha and Andhra Pradesh (now AP and Telangana) have unanimously and amicably agreed to comply with the GWDT Award in its letter and spirit. As such the beneficiary states of Chhattisgarh and Maharashtra may use their share of water from Indravati Basin.

Table 1: Indravati Sub Basin at a Glance

S. No.	State	River Length in km	Catchment Area in sq km
1	Odisha	164	7448
2	Common Between Odisha and Chhattisgarh	10	-
3	Chhattisgarh	233	26514
4	Common Between Chhattisgarh and Maharashtra	129	7703
	TOTAL	**536**	**41665**

It may be observed that large variation in the annual rainfall along the course of River Indravati in its Basin is noteworthy. The occurrence of about 90% rainfall during monsoon season without any interceptions ultimately drains it in to ocean in the Bay of Bengal. As a result the lower reaches of Godavari are frequently and severely affected due to huge uncontrolled floods during rainy season. While, during non monsoon periods plains of Marathwara and parts of Vidharva of Maharastra state are suffering from frequent droughts. Both these extreme conditions make life of the people miserable because of huge wastage of valuable replenishable water resources of the basin. The dispersion of annual rainfall in Indravati sub basin is shown in Table 2.

Table 2: Distribution of Annual rainfall in Indravati Basin

S. No.	Region	Minimum Rainfall (mm)	Average Rainfall (mm)
1	Upper Indravati River	1366	1588
2	Chhattisgarh - Middle and lower Indravati River	1400	1588
3	Maharastra - Upper and middle Godavari	645	770
4	Wardha	955	1055
5	Lower Godavari (from Parnhitta to Sea)	1137	1143

(**Ref: DPR Vol-I Main Report of Bodhghat Project -2007*)

It can be inferred from the above table that major part of Indravati Basin receives good rainfall as compared to parts of Maharashtra which ensures adequate water availability in the basin. The vast untapped water resources potential available in the Indravati sub basin is yet to be utilized by the state of Chhattisgarh and by Maharashtra for economical hydropower, irrigation, navigation and other usages. The development of proposed water resources projects in the valley will eventually resolve water scarcity, enable flood control and ensure sustainable future development in the region.

HYDROPOWER POTENTIAL OF INDRAVATI RIVER IN CHHATTISGARH

The drop in Indravati River in the state of Chhattisgarh up to border with Maharashtra state is 303.50 m. therefore it offers number of sites suitable for construction of Hydropower Projects by creation of large storage reservoirs across the river in cascade. The locations of these natural and already identified storage hydropower projects sites are marked on the imagery placed at Fig. 1.

The hydropower potential offered by various identified sites and their main feature in Indravati sub Basin are presented in Table 3.

Major Dams and Reservoirs in the Basin: The Bodhghat Hydropower Project is one of the major project proposed in the state of Chhattisgarh having live storage capacity of 3715.4 Million Cum at FRL 466.50 m. The non consumptive use of water for generation of hydropower by Bodhghat project will act as mother reservoir and benefit all the downstream hydropower stations and enhance their power potential significantly. It is pertinent to note that installed capacity of Kutru-II HEP is 3 x 50 MW i.e. 150 MW with provision of 5 penstocks out of which 2 penstocks are kept dummy as proposed (3*) and 3 penstocks shall be utilized to generate 50 MW power each and additional 2 penstocks shall be utilized later on, thus final installed capacity will be 5 x 50 (250 MW) (4*) after completion of Bodhghat HEP. This shows the additional benefit that Bodhghat may generate besides flood absorption and ensuring supply of water during lean periods. The implementation of Bodhghat HEP is stalled even after obtaining all statutory clearances from Central / State government. The WAPCOS Limited, revised DPR in Nov. 2007 and the project cost worked out to be Rs. 3771.86 crores with levelised tariff as Rs. 7.00 per KWh which is on higher side as compared to prevailing average tariff, but this higher cost of generation can be justified on the grounds the benefits it will pass on to downstream projects.

The Bhopalpatanam is the largest reservoir in the cascade across Indravati having live storage capacity of 8421 Million Cum. at FRL 200.254 m. It is an interstate project to be constructed by Chhattisgarh and Maharashtra in which Chhattisgarh has 55% share and 45% share shall be of Maharashtra state. Contributions of regulated releases from all upstream projects will further benefit all downstream projects proposed across River Godavari in terms of flood, sedimentation control and water availability during non monsoon period for power generation and irrigation. Proposed HEP sites in cascade on Indravati sub basin are shown in Fig. 2.

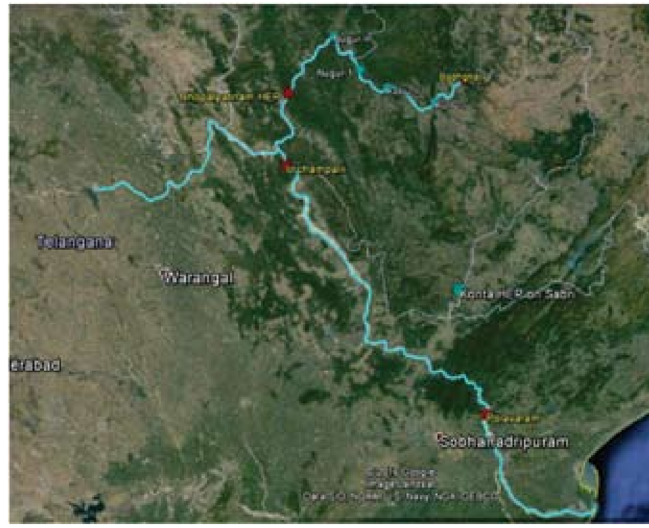

Fig. 1

Water Availability: The water availability studies carried out for the Bodhghat HEP is presented in Table 4. This shows that sufficient quantity of water is available in the Indravati River, which is essential for sustainable development:

Table 3

S. No	Project	FRL (m)	Submergence Area (ha)	Head (m)	Installed Capacity (MW)	Annual Energy Generation (GWh)	Remarks
1	Matnar	-	-	-	60	-	About 300 m U/s of Chittrakot Fall in CG
2	Bodhghat	466.50	17281.00	91	500	1258.75	HEP in CG
3	Kutru-I	347.00	6530.50	24	150	280.32	HEP in CG
4	Kutru-II	317.00	13037.23	38	150	530.46	HEP in CG
5	Nugur-I	273.70	14617.00	32.7	170	313.97	HEP in CG
6	Nugur-II	240.00	30600.00	39	150	493.00	HEP in CG
7	Bhopalpatanam	200.25	71174.00	71.75	975*	2496.00	HEP interstate MS and CG (45%:55%)
8	Kotri-Nibra	-	-	-	150**	44MW (Firm)	HEP interstate MS and CG on Tributary
	Total	**-**			**2305**		

(-) Data not available with the authors.

(*) Installed capacity of Bhopalpatanam HEP 6x125 MW + 3x75 MW = 975MW (CG share 536 MW, MS Share 439 MW) Ref; Project Report- Kutru-II, Vol-1 PP-59 MPEB Jan-1981.

(**) Installed capacity of Kotri-Nibra HEP 3x50 MW = 150MW Ref; Project Report- Kutru-II, Vol-1, PP-59 MPEB, Jan-1981.

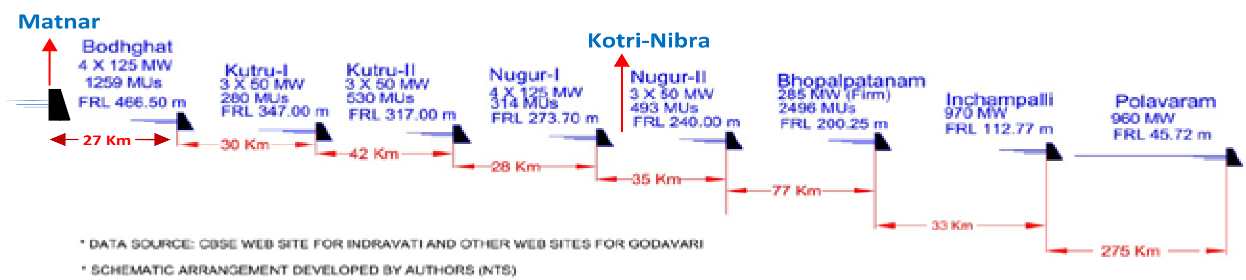

Fig. 2

Table 4

S. No.	Dependability	Bodhghat HEP (in MCM)*
1	Yield at 50% Dependability	4939.25
2	Yield at 75% Dependability	3812.01
3	Yield at 90% Dependability	3141.73

Notes: (*) Worked out as per CWC Guide lines for Bodhghat Project (Ref-5).

Long Term Benefits from the Proposed Water Resources Project in Indravati Sub Basin

1. The construction of large Dams and Reservoirs are planned, designed and constructed to store maximum possible Runoff available during the year particularly in monsoon. The water resources projects indentified in Indravati sub basin shall be able to meet various water requirements for water security.
2. The hydropower generated from the proposed projects will improve the Hydro-thermal mix of the Western Grid favorably, which is essential for the grid stability. The hydro thermal mix of the western grid at present is 11:89 (CEA Mar-2018) which is much below the desired ratio of 40:60.
3. Hydropower generated will bring industrial development in the undeveloped areas and will generate employment during implementation of the projects and thereafter.
4. The large storage reservoirs created will store rain water during monsoon which may be utilized for irrigation and other purposes by installing pumping facilities to supply water at higher elevations of Marathwada and Vidharva region of Maharashtra. The renewable hydropower generated from these storage schemes shall be economically and effectively utilized in the development of agriculture, domestic and industrial sectors.
5. Particularly the construction of Bodhghat Project will pave the way for the development of down-stream Projects namely Kutru-I, Kitru-II, Nugur-I, Nugur-II and Bhopalpatnam. This will invite attraction of private power project developers as a result of improved economic viability of projects in Indravati sub_basin.
6. The implementation of these projects will enormously contribute effectively and economically if implemented in totality. This will also control flood and sedimentation of downstream and improve power generation and agricultural output.
7. The utilization of natural and replenishable water resources will reduce dependency on coal based power generation and significantly contribute to the environmental concerns which are essential for sustainable development.
8. The implementation of proposed projects will bring infrastructural developments and accelerate the progress of the undeveloped region. The administrative presence of government for project development shall help in controlling the Naxalite activities in the region and consequently restore peace and harmony.

CONCLUSION

The large storage schemes can only be developed on the naturally available suitable sites, which are technically feasible and economically viable. The proposed natural sites for large dams and reservoirs in Indravati Sub Basin have been identified on the basis of suitability for construction of these major projects. It is worthwhile to mention that suitable sites identified are gift of the nature as these cannot be created. It is obligatory on the part of water resources planners and engineers to optimally harness these natural assets for larger benefit of the nation. At present very small number of suitable sites are available in India. Therefore such excellent sites for construction of large dams and storage reservoirs proposed in the Indravati sub basin, which are both technically feasible and economically viable, shall be implemented for sustainable development and future water security.

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BIOGRAPHICAL DETAILS OF THE AUTHORS

Er. G.L. Dwivedi, graduated in Civil Engineering from Government Engineering College Jabalpur M.P. in the year 1988. While posted in Rabi Avanti Bai Lodhi Sagar Project (Bargi Dam) across River Narmada near Jabalpur, got opportunity to join WRDTC University of Roorkee in the year 1989, for pursuing Postgraduate Degree course in Water Resources Development. Acquired P.G. (Dip) in 1990 and M.E. (WRD) in January-1991. Subsequently posted in Indira Sagar Project in the year 1993 when the construction of Dam was started and rendered his services to Narmada Valley Development Authority and Narmada Hydroelectric Development Corporation (a JV of NVDA & NHPC) till November-2004. After leaving Government Job, he got an opportunity to serve Jindal Power Limited (JPL) and was appointed as AGM (Civil) for Construction of Dam across River Kurket for meeting raw water requirement for 1000 (4 x250) MW Thermal power plant and also worked for 4x600 MW Thermal Power Plant, both situated near Village Tamnar in Raigarh district of Chhattisgarh. He served JPL in various capacities from Nov-2004 to June-2015 and resigned from services of JPL as Sr. General Manager (Water Systems). Having expertise in Dam Hydro, Thermal power and water systems construction and project management. He is a life member of MIWRS and FIE (India) and is also annual member of INCOLD. Presently he is self employed and working as Sr. Consultant with his associates.

Er. Rajesh Shrivastava Graduated in Civil Engineering in 1982 and Post Graduated (Structural Engg) from Govt. Engineering College Jabalpur. He worked in Madhya Pradesh State Electricity Board (MPSEB) for 28 years from 1983 to 2011 in various disciplines and capacities. During initial period of service he was posted on various proposed hydro power project sites in Bastar District of erstwhile Madhya Pradesh, which provided ample opportunities to learn various technical as well as practical aspects of hydro power projects. He took voluntary retirement from Board's Services in the year 2011, while his 12 years service was remaining, to pursue independent Engineering Design and Consultancy for Water Resources and Structural Projects.

During his service in MPSEB he was closely associated with identification of potential sites for Hydro Power Projects and preparation of their Detailed Project Reports (DPR's) including obtaining clearances from Ministry of Environment and Forest and other statutory agencies and Central Government. He also worked for Engineering Design of Hydro Power Projects, obtained approvals of construction drawings from Central Water Commission (CWC) and monitored execution of projects.

He is presently engaged in consultancy services for Water Resources Projects, Feasibility Studies and structural designs of large civil structures, hydro, thermal, industrial, commercial and residential projects independently.

Rivers, ponds, lakes and streams -
They all have different names, but they all contain water.
Just as religions do - They all contain truths.

Experience Gained During Full-Scale RCC Trial Embankment Construction at TLDP-IV

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Hindustan Construction Company Ltd., Mumbai

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Design & RCC Consultant, Malaysia

1. INTRODUCTION

1.1 Project Background

Built with roller compacted concrete dam (RCCD) technology, Teesta Low Dam Project–IV (TLDP-IV) is a 160 MW (4X40 MW) project in West Bengal, India. The non-overflowing 196 m long right bank section consists of 45 m high roller compacted concrete (RCC) dam. This is the third RCC project in the country and has been built in 196-days.

Typically, full-scale trial (FST) is undertaken after completing initial phase of concrete mix design, materials' preparations, equipment preparations and assembling requisite manpower and before commencing the actual construction. FST is significant because it provides practical insights into the preparedness for undertaking RCCD construction, which requires "military discipline". FST usually aims at commissioning and optimizing plant, equipment and machinery workings, assessing and establishing construction methodologies, assessing suitability of designed mixes and most importantly training of all personnel involved in construction. This paper describes the significance, execution and benefits of conducting full-scale trial (FST) by constructing full-scale trial embankment (FSTE). Since RCC requires "military-discipline" and is constructed in a monolithic continuous way, it is important that teams executing such projects are fully aware of the preparedness for undertaking a 24/7 operation. Adapting to such discipline requires arduous preparations and integration of almost all the functions.

1.2 Mix Design Program: Lab

Laboratory mix design for RCC was undertaken almost a year ahead of actual construction schedule. Considerations of aspects other than materials is essential in RCC mix design since RCC is not just a material but also a construction method. This involved optimizing the crusher operations, arranging logistics for continuity of procured materials such as boulders for aggregates, cement, fly ash and admixtures, preparing the concrete mixers, the conveying systems, etc.

Based on scores of trials with different permutations and combinations, the following mix designs were finalized:

(i) 43 Grade OPC @ 85 kg/cum

(ii) Class F fly ash @ 135 kg/cum

(iii) Aggregates @ 2095 kg/cum

(iv) Water @ 118 – 126 kg/cum

(v) Retarders – two different makes, by weight of binder
  - (a) A: @ 0.15 – 0.40 %,
  - (b) B: @ 0.40 – 0.90 %

The non-segregating RCC mix was designed for a Vebe time ranging between 10-18 s and for a characteristic compressive strength of 15 MPa at 180-days.

2. FULL SCALE TRIAL EMBANKMENT

2.1 Purposes

The primary purpose of FSTE is to review the overall preparedness (refer Figure 1) for RCC dam construction. This is further divided as follows:

(i) Training

Training at all levels from laborers through the construction manager is essential, since RCC requires "military-discipline" for its execution. Training involves preparation, production, equipment operations, quality, safety, monitoring and most importantly developing team-spirit and tenacity to work 24/7

(ii) Materials
  - (a) Aggregate feeding and cooling systems and associated cycle times
  - (b) Production cycle times
  - (c) Transportation fleet management
  - (d) Mix behaviours and optimal water requirements
  - (e) Production of Grout enriched vibratable RCC (GEVR)
  - (f) Retarder behaviour w.r.t. setting time
  - (g) Field strength development of mixes w.r.t. lab results

(iii) Construction
  - (a) Formwork cycle time and cleaning
  - (b) Receiving of concrete and tire washing arrangements
  - (c) Spreading and leveling of concrete

- (d) Face treatments and GEVR application
- (e) Compaction optimization
- (f) Density measurement
- (g) Curing
- (h) Exposure time and joint treatments
- (i) Contraction joint and plate insertion
- (j) Water stops

(iv) Quality

- (a) Assurance systems
- (b) Controls

(v) Safety

Safety is at the core of RCC operations as a slight neglect could lead to major accident or loss of life

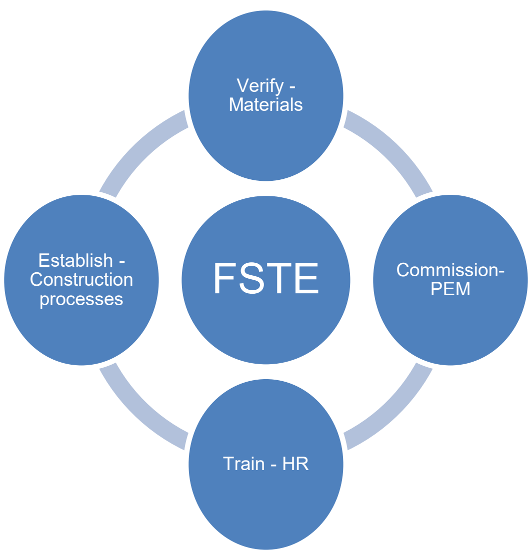


Fig. 1 : Core Objectives of FSTE Construction

2.2 Embankment

The schematic layout of the FSTE was selected in a manner to resemble close to the actual construction procedure and sequencing. Figure 2 shows the schematic layout of the FSTE outlining the division of each layer and number of layers and formwork locations.

The plan area of first three layers was 50 m × 10 m and this was then sub-divided into four blocks viz.

- (i) Block-A (South-East side)
- (ii) Block-B (South-West side)
- (iii) Block-C (North-East side) and
- (iv) Block-D (North-West side)

Formwork was utilized in two stages first to support first three layers and second to demonstrate the stepping. See Figure 3 for a pictorial representation. This picture is taken at the beginning of RCC-FSTE construction and illustrates the preparatory works done. FSTE construction used RCC volume of approximately 600 cum in a plan area of 500 sq.m (divided in 4 blocks) and was conducted in 4 nos. of layers (300 mm each) over 5 days.

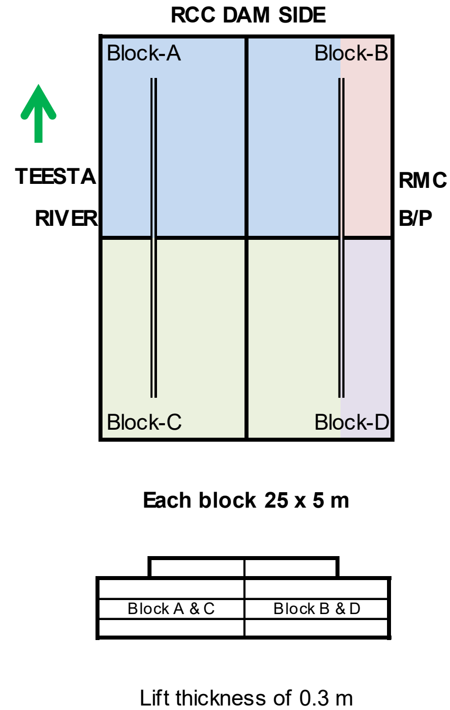


Fig. 2 : Schematic layout of FSTE (NTS)

Fig. 3 : FSTE site in perspective. Blocks are indicated

2.3 Schedule

The FSTE was undertaken in January 2013, when the ambient temperature was ranging between 8-22 deg. C.

2.4 Materials

OPC and fly ash procured from one source each were used. Aggregates consisted of four distinct fractions viz. -50/+25 mm, -25/+12.5 mm, -12.5/+5 mm and -5/+0 mm.

Chilling plant was used for aggregate cooling for the former two fractions. Water was chilled along with ice, the quantity of which was computed based on the required placement temperature of 15 deg. C. Two different retarders viz. A & B were tried.

2.4.1 *Mixes*

In order to have focused learning and swifter interpretations of material behaviours, a mix design was finalized and the two blocks were divided longitudinally for each retarder.

2.4.2 *Exposure Times*

Depending on ambient temperature, the contract specified the joint type and exposure time (Figure 4). In case of FSTE construction, different layers were allowed to have different exposure times with an objective of having learnings on all joint types and respective treatments.

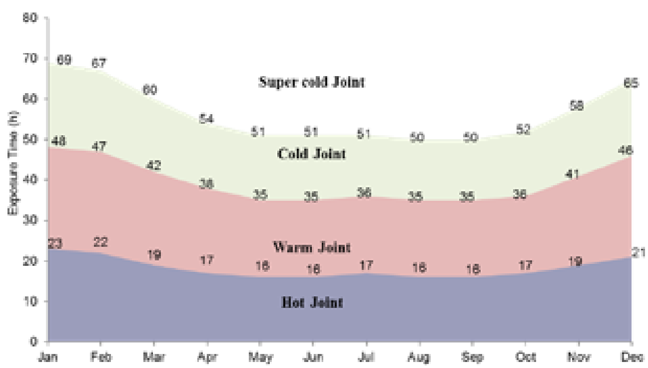


Fig. 4 : Joint type and exposure times

2.4.3 *Other Materials*

PVC water-stops were used along with the fixing. The arrangement made during FSTE resembled with the one required in actual dam construction. Artificial joint creator/ contraction joint creating galvanized iron (GI) plates were inserted using GI plate inserters. Formwork performance was also observed.

2.5 Plant – Equipment – Machinery (PEM)

RCC production and placement is a series of chain-like synchronized events and processes, each having its definitive role in successfully and holistically delivering RCC. Following is a summary of significant PEM used for FSTE

(i) A three-stage crusher was utilized to produce grading and shape controlled aggregates in four fractions. The aggregates produced in the aggregate crushing and screening plant were conveyed through the inundation-cum-cooling system to the batching plant through a web of conveyors and storage-in-line silos

(ii) For achieving required placement temperature, a water-chilling unit capable of feeding chilled water was installed and commissioned much ahead of commencement of FSTE. The chilled water was used for two purposes viz. aggregate cooling and concrete mixing

(iii) The flaked ice required for reducing the concrete temperature was produced by ice making and flaking plants. Each concrete batching plant (B/P) was equipped with two units of ice plants potent to produce the required quantity of ice for each plant

(iv) Three numbers of 120 m^3/hr. fully automated, twin-shaft batching plants were installed and commissioned before commencing FSTE

(v) A fleet of dump trucks was used for transporting RCC from the batching plant to FSTE site

(vi) The tire washing arrangement ensured that the truck moves on RCC without contaminating RCC construction

(vii) The grout required for GEVR production was produced at site in a vertical drum mixer. Measured quantities of OPC and water were added to produce a grout with w/c ratio of 0.50

(viii) After reaching the required location, the RCC was dumped in regulated small mounds for minimizing dozing efforts. The spreading of dumped RCC was accomplished with a dozer, the crawling track of which were washed on the washing grill and the dozer was then marched on used truck tires. In order to reduce the potential for segregation and to follow lane discipline and regulate the spread of RCC, the dozer blades were fitted with wings at each end. Laser guided dozing system.

(ix) Compaction was achieved with 10 MT vibratory rollers. Small rollers and plate compactors were used for compacting the GEVR near the faces

(x) Curing was done through regulated – fog nozzle

(xi) For joint treatment, different types of tractor-mounted road brushes were arranged

(xii) Nuclear density gauges were organized for measuring the density of compacted RCC.

After selecting the location for constructing FSTE, the site was cleared, cleaned and prepared for laying leveling concrete. Leveling concrete was placed as a first step towards constructing FSTE.

Two layers of leveling concrete mixture was used in preparing a course of leveling concrete for FSTE along with the required ramps for equipment movements. Once leveling concrete attended enough strength for carrying construction load, it was green cut to specified roughness level. Vertical formwork assemblies/ framed structure was raised on two sides – one side representing the upstream side while the other representing downstream. The third side form was the one planned for block joint. Water stop assembly was then fixed and adequate lighting arrangement was made so that work could be performed in an unhindered manner.

3. OBSERVATIONS AND LEARNINGS

3.1 Formwork

Three modules of brand-new formworks were designed viz. for upstream, for downstream and for block forming. Formwork consisted of faceplate fixed with the truss-based supporting structures (Figures 5 & 6). Anchor rods were designed for holding the formworks and to withstand the lateral and dynamic pressure of the rolling and compacting equipment. The concrete surfaces was mostly used as operating platform.

Since the formwork team was new to handling stepping formwork, it took few cycles for them come to speed. FSTE helped in identifying the cycle times for handling of formwork. Properly installing anchor bolts properly and subsequently removing these also had a learning curve.

3.2 Cleaning

Cleaning to the degree that RCC operation requires needs special training. Since contamination of preceding layer could lead to formation of a weak joint, hence extreme care has to be taken in this regard. Additionally, the dump trucks and other equipment moving on RCC surface had to wash tires before entering into RCC area. Even the human resources entering into RCC have to water clean their safety shoe before entering into RCC.

A High Pressure Water Pump for washing of the equipment's has been deployed at FSTE area. Further, to avoid contamination of the FSTE area with dirt from the equipment, an elevated steel ramp has been placed at the entrance-point of the FSTE so that any equipment before entering the concrete surface is washed and thoroughly cleaned on the ramp with the high pressure water pump arrangement.

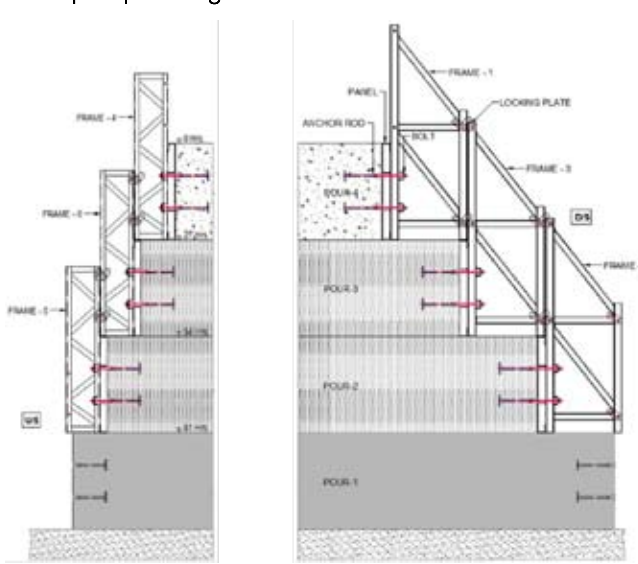


Fig. 5 : Upstream and downstream formworks

Fig. 6 : Upstream and downstream formworks (step) as used in FSTE and the anchor bolts

3.3 Safety

RCC construction is equipment intensive. Maneuvering of construction equipment and other resources has to be critically planned and executed during construction. A smaller RCC dam has different challenges than a larger one. FSTE construction taught the equipment operator and the construction team the significance of working in confined spaces, using of reverse horns in equipment and most importantly to look for each other's safety. One of the important aspects of RCC construction is also how safely the equipment is operated and maintained. This is important because all the equipment are fueled and maintained on the RCC-in-construction.

3.4 Production & Transportation

RCC for FSTE was produced in 120 cum/h capacity twin-shaft batching and mixing plant. The plant was calibrated and checked for various mixing sequences, retarder dose, and ability to deliver uniform, non-segregating mixture and for its productivity. FSTE also helped calibrate the temperature formulae for arriving at the production and placement temperature correlations of concrete. Based on the input material and produced concrete temperatures, the temperature calculation formulae were calibrated to suite the local conditions.

High-pressure water washed dump truck were used for transporting RCC. To regulate the flow of RCC and to follow the lane-spread, the end-dump trucks were fitted with temporary tapers (Figure 7). The tapers actually regulated the flow of RCC being dumped and thus reduced segregation and spreading tendency of RCC.

Fig. 7 : Dump trucks fitted with tapers and tire cleaning operations

3.5 Workability

The consistence of RCC was measured using Vebe time, both at the production and placement locations. Since it was wintertime and it took only 10-15 min for RCC to be transported from production plant to site, there were minimal changes in the vebe consistence. Some samples were however retained for longer time to establish correlations between Vebe consistency retention and time. This helped in monitoring production during regular construction. A consistent and homogeneous mix was retained through a series of measures in terms of production, transportation, dozing and compaction. The teams were trained to appreciate the importance of having a homogeneous mixture in front of the dozer.

3.6 Spreading and Levelling

After tire washing, the dump trucks were systematically and sequentially backed to the respective dumping locations by trained and assigned backsmen. After reaching the required location, RCC was dumped in regulated small mounds (Figure 8) for minimizing dozing efforts.

Dozer of adequate capacity spread the dumped RCC. The crawling track of dozer were washed on the washing grill and the dozer was then marched on used truck tires (Figure 9). In order to reduce the potential for segregation, to follow lane discipline and regulate the spread of RCC, the dozer blades were fitted with wings at each end (Figure 9).

In order to minimize the dozer movement on uncompacted RCC, guide the dozing thickness and rapidly achieve spreading, a laser guide system was installed on the dozer (Figure 10). It was regulated by an established guide station outside the body of FSTE in a vibration free area at a sufficient elevation.

Fig. 8 : Regulated dumping of RCC from dump trucks

Fig. 9 : Dozers fitted with wings

Fig. 10 : Laser guided dozing system

3.7 Compaction

For compaction of RCC, different types of rollers and compactors were used depending on maneuverability, compactive force requirement, accessibility and nature of compaction requirements.

3.7.1 *Large Vibratory Rollers*

Two nos of 10 MT vibratory rollers were used in an alternating fashion for compacting RCC (refer Figure 11), excluding the GEVR area. Both the rollers were pre-calibrated for similar frequency and amplitude. This was done with an objective of having consistent and uniform compaction. The sequence and nature of passes were optimized during FSTE along with the roll-pass chart.

Fig. 11 : 10 MT vibratory roller under operation

3.7.2 *Small Vibratory Rollers*

Two nos. of small (2.5 MT) calibrated rollers were used during FSTE (Figure 12). These were utilized in finishing off RCC layer, where accessibility to large vibratory rollers was difficult and in locations which demanded gentle (yet complete) compaction effort to be applied.

Fig. 12 : 2.5 MT vibratory roller under operation

3.7.3 *Plate Compactors*

Plate compactors (Figure 13) were used for compacting areas where GEVR was placed, in areas where vibratory rollers could not reach and effectively compact and for finishing purposes.

Fig. 13 : Use of plate compactor on GEVR

3.8 Waterstops & GI Plates

PVC waterstops were used along with the fixing assembly as shown in Figure 14. The arrangement made during FSTE resembled with the one required in actual dam construction. The application of water-stops and the compaction of RCC around it were observed very carefully, since a poorly compacted zone could lead to leakages.

Artificial joint creator/ contraction joint creating GI plates were inserted using GI plate inserters. The GI plates had a J shaped bent at one end. These plates were carefully inserted vertically in compacted RCC.

Fig. 14 : Water-stop assembly

3.9 Joints & Treatments

Fully compacted, uncontaminated and clean layer of RCC was used for laying the subsequent layer. Four major joint types were carefully arrived at based on the modified maturity factor (MMF) in degree C. The prescribed treatments that were tested are summarized in Table 1 along with the range of MMF as applicable during the FSTE. Figure 15 shows one such joint treatments being done during FSTE.

Table 1 : Joint Types, treatment and MMF range

S. N.	Joint Type	Treatment	Typical MMF Range
1	Hot	No treatment, except ensuring fully compact, clean and uncontaminated surface	150 – 570
2	Warm	Soft brush brooming, vacuum cleaning and ensuring below layer as above	570 – 1190
3	Cold	Hard brush brooming, vacuuming while ensuring below layer as in warm joint	1190 – 1700
4	Super cold	Exposing aggregate followed by vacuuming and grouting	1700+

Fig. 15 : Warm joint treatment using soft brush

3.10 MMF & Exposure Time

The MMF was used in computing the maturity of concrete. This is because the concrete will not develop any strength below 12 deg C (Neville, 2004) and this is taken as the datum. Each hour, the average air temperature was measured and added with 12 to obtain a number, which was cumulatively added to get the MMF at a particular time. This was used to arrive at MMF range w.r.t. exposure time and hence the joint treatment required.

3.11 Facing

The GEVR was placed close to the formwork upto a distance of 500 mm away from the formwork. GEVR placement preceded RCC placement in the lanes. L-shaped steel meter-sticks were used in forming the RCC-bunds wherein pre-mixed grout (at w/c of 0.50) was transported through pipes, measured and poured in each bund. Figure 16 shows an illustrative picture taken during FSTE. Similar approach was taken at the concrete-rock interfaces and near the inspection gallery.

Fig. 16 : Meter stick form for preparing GEVR bund

3.12 Internal Contraction Joints

Artificial joint creator/ contraction joint creating GI plates were inserted using GI plate inserters. The GI plates had a J shaped bent at one end. These plates were carefully inserted vertically in compacted RCC (see Error! Reference source not found.). (Figure 17)

Fig. 17 : GI plates layed before insertion

3.13 Quality

The key to quality RCC construction is to visualize and implement each operational component with the end-product in mind. All the equipment checks, preparedness checks, cleaning, etc. form a part of quality assurance program.

Quality control involved the following:

(i) Checking of formwork line-level, oiling, cleaning and alignment

(ii) Monitoring of temperatures – raw materials, ambient and concrete

(iii) Production consistency – cohesiveness, homogeneity, workability

(iv) Laying consistency – no segregation during spreading and leveling

(v) Compaction and density

(vi) Setting time of concrete

(vii) Joint treatment requirement – measurement of MMF

(viii) Compressive strength measurement – accelerated and normally cured

(ix) Curing of concrete

(x) For each layer the levels of finished concrete were checked and it was assured that the compacted thickness of RCC was within ± 5 mm

Two calibrated nuclear desiometers were used for measuring the moisture content and fresh density of concrete. The density was measured (Figure 18) immediately after completion of compaction. During the initial stages, roll-pass chart was developed to optimize the compaction effort required to achieve the required degree of compaction.

Fig. 18 : Nuclear densiometer in use

3.14 Training

Training was imparted to various engineers, supervisors and labourer gangs. A sampling of the salient ones is listed in Table 2.

Table 2 : Sampling of training to various cadres of personnel

S. N.	Activity	Shift-1	Shift-2	Engineers	Supervisors or operators	Laborers
1	Base preparation, cleaning & leveling concrete	●	●	●	●	
2	Green cutting, cleaning and surface preparation of concrete	●	●		●	●
3	Formwork fixing and cycle time	●	●	●	●	
4	Equipment cleaning and preparation	●	●	●	●	●

5	B/P (Materials management and co-ordination)	●	●	●	●	
6	Production quality control	●	●	●	●	
7	Dumping of RCC	●	●		●	
8	Spreading of RCC with laser guidance system	●	●	●	●	
9	Level measurement and checks	●	●	●	●	
10	GEVR – placement and compaction	●	●		●	●
11	RCC compaction & compaction control	●	●	●	●	
12	Site quality control	●	●	●	●	
13	RCC surface monitoring for various joints	●	●	●		
14	Various types of joint surface preparations	●	●	●	●	
15	GI plate insertion	●	●		●	●
16	Water stops' placement with GEVR	●	●		●	●
17	Curing of RCC	●	●	●	●	
18	Co-ordination and synchronization of RCC activities	●	●	●	●	

4. SUMMARY

In general, the FSTE provided training on the scope and nature of operations required for RCC construction. While fulfilling the intended objectives, following formed the core learnings of constructing FSTE:

(i) Leveling concrete was to be carefully done while balancing between the construction schedule and the concrete set times. This was with an objective of avoiding over using of green cutting as a transitioning step

(ii) The formwork fixing requires meticulous works in terms of alignment. Care would have to be taken during formwork removal, while regulating and observing the strength gain of concrete.

(iii) Optimization and fine-tuning of dozing and leveling operations helped improvise the speed

(iv) GEVR placement and compaction operations wherever required would have to be meticulously performed

(v) Road brush applications for inter-layer jointing were well-learnt. Similarly GI sheet insertion and compaction of adjacent areas was done to satisfaction

(vi) Placement of water-stops was done methodically along with the learning the compaction around the water-stops

(vii) Compaction of RCC was done with large vibratory rollers. The roll-pass charts were developed and it was observed that two static followed by six dynamic passes were adequate for reaching the required degree of compaction

(viii) Curing was done using fog sprays and was found satisfactory

(ix) Layer-wise MMF were monitored to keep a track on the types of inter-layer joints. This information was used during construction.

(x) The lab designed RCC mixture performed well and was found to be user-friendly. It had the required workability and achieved the required compacted densities. The retardation of concrete setting with both the admixtures was found to be satisfactory in the then existing cold climate. Compressive strength developed followed closely the values obtained during the lab trials

DAMS INDIA 2018

Conference on Storage Dams for Water Security and Sustainable Development

24-25 October 2018, New Delhi

Global declines in water storage addition are troubling to Policy makers. With greater hydrological variability due to climate change, additional storage will be vital to provide the same level of security of water, food and energy. Water storage is a fundamental protection from the impacts of changing climate, safeguarding the supply of water, and the water–food–energy nexus, even during extended drought. For thousands of years, dams have stored water to irrigate crops, control flooding, supply water for industrial and household use, and generate hydroelectric power – contributing enormously to food security, human development and economic growth. These days, many dams serve more than one function, but remain the primary mechanism for coping with the variability of water supply and demand. During the last century, more than 45,000 dams of height 15 m and above have been constructed worldwide, creating a combined storage capacity estimated to be between 6700 and 8000 km^3, representing 17 per cent of global annual runoff. Security of water, food and energy are inextricably linked. For example, approximately 50 per cent of all large dams worldwide are used for irrigation. Without sufficient water storage, irrigated agriculture (the largest user of water at the global level, contributing 40 per cent of the world's food) is at the mercy of changing patterns of rainfall and runoff. Understanding water storage issues is essential for successfully managing water resources. At the simplest level, it is a matter of 'inflow (water supply) less outflow (water demand) equals change in storage'. But it is particularly important to understand whether storage shortage relate to reducing supply, increasing demand, or both. Key factors influencing storage are greater variability of inflows due to climate change, increased demand due to population growth, reduced net storage due to sedimentation, and less dam construction occurring worldwide due to environmental and social impacts. The effects of climate change are predicted to increase and to result in greater magnitude and frequency of hydrological extremes, such as prolonged droughts and significant floods. With prolonged drought, inflows for storages will reduce. If demand remains the same, stress on existing water storages will increase.

Keeping in view the above, Indian Committee on Large Dams and Central Board of Irrigation and Power in Technical Collaboration with CWC and in association with BBMB, THDC, NHPC, NEEPCO, SJVNL organized two days

Conference on "Storage Dams for Water Security and Sustainable Development" on 24-25 October 2018 at New Delhi to focus on the various issues connected with the creation of more number of storage to meet the water demand with greater hydrological variability due to climate change and level of security of water, food and energy. The conference was sponsored by Trimble Navigation India Pvt. Limited

The conference was inaugurated by Shri A.K. Bhalla, Secretary to Govt. of India, Ministry of Power. Shri Bhalla briefly touched about the position of global water storage vis-à-vis India's water storagwe where rainfall is only for 3 months period. He stressed the need for creation of more storage project to meet the water security demand. The other issues which Shri Bhalla focussed are survey & investigation of water storage projects, environmental issues, public awareness about the benefits of dams; sedimentation problem in Himalayan rivers and capacity building of young professionals. He also highlighted the importance of participation of more dam professionals in ICOLD activities and events and ICOLD cooperation to resolve problems in difficult area of dam engg. Development. He has also highlighted about the recent geological disaster problem – blockage of river water. The other dignitaries who addressed the gathering during the inaugural session are Shri D.K. Sharma, President, INCOLD and Chairman, Bhakra Beas Management Board welcomed the dignitaries and the participants from the State Govt.. The other dignitaries who addressed the gathering during the inaugural session are **Dr. Michael F. Rogers, PE, P. Eng, PMP,** President, International Commission on Large Dams; **Shri D.V. Singh,** Chairman and managing Director, THDC India Limited; **Shri Balraj Joshi**, Vice President, INCOLD & Chairman and Managing Director, NHPC Limited; **Shri Syed Masood Husain,** Chairman, Central Water Commission; **Mr. Michel de Vivo,** Secretary General, International Commission on Large Dams. Shri V.K. Kanjlia, Secretary General INCOLD and Secretary, CBIP proposed the Vote of thanks at the end of the session.to the dignitaries, sponsors and the audience during the inaugural session.

During the two days conference deliberations, the following papers were presented by the national and international dam professionals in the different Technical sessions.

PLENARY SESSION

- A Summary and update of the Oroville Dam spillway incident of 2017 - *Michael F. Rogers, President, ICOLD, USA*
- Dam safety management in a trans-boundary river: Eastern Nile Countries' Approach - *Michael Abebe, VP-ICOLD and Chairperson: ETCOLD and Regional WR and Dam safety Coordinator (ENTRO), Addis Ababa, Ethiopia*

- Uncertainty analysis in design of hydraulic structures - *Ali Noorzad, Ph.D., P.Eng., VP, ICOLD and President, IRCOLD*
- Dam safety: Lessons from recent incidents and accidents - *Michel LINO, Vice-Président de la CIGB*

Technical Session I – Storage Dams for Sustainable Development

- Hydro-Québec experience on ACED – *Dr. Jean-Pierre TOURNIER, ICOLD Vice President – America Zone & Conseiller Expert -Aménagements hydroélectriques*
- Education and training in dam engineering – *Prof. Dipl.-Ing. Dr. Gerald Zenz, ICOLD Vice President and University Chair of Hydraulic Engineering and Water Resources Management– Austria*
- Need for storage dams for future water security – *A.B. Pandya, Secretary General, ICID*
- Water Security and Climate change outlook in respect of storage projects – *D.K. Sharma, President, INCOLD & Chairman, BBMB*
- Storage dams for water security, food, energy and flood control – *Dr. R.K. Gupta, Member Secretary, Polavaram Project Authority, MOWR*

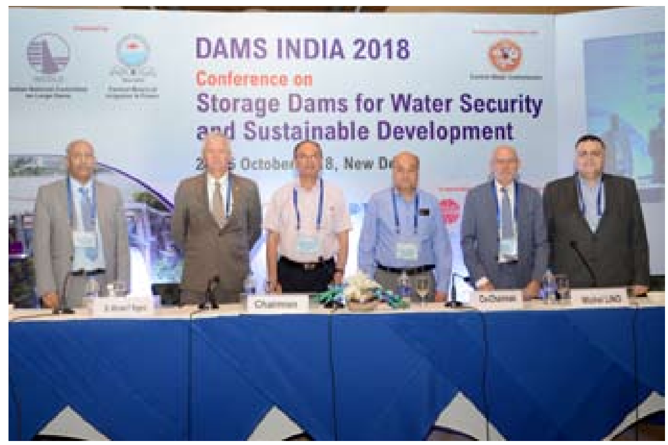
Technical Session II– Innovation engineering of water storage projects

- Asset conservation including sedimentation management *R. K. Vishnoi, Vice President, INCOLD & Executive Director- Designs, THDC India Ltd.*
- Innovation engineering of river water storage projects for sustainable development – *Dr. D.V. Thareja*
- Inter basin transfer of water - Importance of storage dams.– *M.K. Srinivas, Director General, NWDA*
- Constructing storage dams – Lessons learnt from raising of Sardar Sarovar Dam, Gujarat - *Dr. Mukesh Kumar Sinha and Suman Sinha, Narmada Control Authority*

THURSDAY, 25TH OCTOBER 2018

Technical Session III – Dam Safety Assessment and Risk Management

- Dam safety and instrumentation – *Gulshan Raj, Chief Engineer, Dam Safety, Central Water Commission*
- Diagnosis and restoration a distressed dam – Case Study of Gujarat – *Vivek P. Kapadia*
- Hydraulic model studies for sediment management by drawdown flushing run-of-the river hydroelectric project - *Neena Issac, P.S. Kunjeer, S.A. Kamble and Dr. V.V. Bhosekar, CWPRS, Pune*
- Design aspect of dam without joints: Chamera III Power Station - *Narendra Kumar, Y K Chaubey,, S C Joshi, and Sankhadip Chowdhury*



- Reservoir operation guidelines of Mangdechhu dam ensuring safety of the structure - *Balraj Joshi, Keshav Deshmukh, Rajeev Baboota , and Manjusha Mishra, NHPC Limited*

Technical Session IV – Dam Rehabilitation

- Strengthening of overflow section of Koyna Dam – A case Study - *R.V. Panse, and R.N. Thakre, WRD, Pune*
- Why not small dams attain assured success: Experience of Gujarat – *Vivek P. Kapadia, Chief Engineer, Narmada, water Resources, Water Supply and Kalpsar Dept., Govt. of Gujarat*
- Soft and erodible foundation rock in Pare concrete gravity dam, Arunachal Pradesh - *Ranendra Sarma and V.K. Singh, North Eastern Electric Power Corporation Limited*
- Hydraulic design considerations of spillways and energy dissipaters for hydropower projects in Himalayan region – *Dr. M.R. Bhajantri, R.R. Bhate and V.V. Bhosekar, CWPRS*

Technical Session V – Other Issues

- Geophysical techniques for inspecting dams (concrete, masonry, earthen) and spillways – *Dr. Sanjay Rana, Managing Director, PARSAN Overseas Pvt. Ltd., New Delhi*
- Environmental aspects of Water Resources Projects - *Amrendra Kumar Singh, Chief Engineer (Environment Monitoring Organisation) CWC, New Delhi.*
- Geodatic technology for dam structure monitoring - *Munish Malhotra, Trimble Navigation India Pvt. Limited*
- Sediment management in hydropower projects – *Narendra Kumar, Keshav Deshmukh, Rajeev Baboota , and Bharti Gupta, NHPC Limited*
- Importance of flood forecast in reservoir operation for flood management. – *Sharat Chander and Ritesh Kumar on behalf of Mr. Y.K. Sharma, Member – RM, CWC*
- Need for storage dams for future water security with reference to development of proposed water resources projects in Indravati Sub Basin - G.*L. Dwivedi, and Rajesh Shrivastava, Consultant Water Resources*

CONCLUDING SESSION

The concluding session was chaired by Shri D.K. Sharma, President, INCOLD and Chairman, BBMB. The other dignitaries who addressed the professionals during the concluding session are Shri R.K. Vishnoi, Vice President, INCOLD and Executive Director-Designs, THDC Limited. Shri D.K. Sharma summarized the discussions and highlighted the various issues emerged during the two days deliberations of the conference.

More than 175 national and international dam professionals attended the conference participated to stimulate the debate on the challenges met and the lessons learnt with the advancement of technology adopting modern designs and methods of construction with accent on safety of these structures as it is considered imperative to derive economic benefits.

Short Course on Earthquake and Dam Safety

(Seismic Aspects of Dam Design and Dam Safety)

12-13 November 2018, New Delhi

Dr. Martin Wieland lightening the lamp

The Committee on Seismic Aspects of Dam Design is one of ICOLD's oldest technical committees, which at present comprises dam and earthquake experts from 34 different countries from all continents. The Committee was created in 1968 and celebrates its 50th anniversary in 2018. Guidelines on the following seismic aspects of dams have been published:

(i) different seismic hazards affecting storage dams, such as fault movements in the footprint of dams, and reservoir-triggered seismicity,

(ii) seismic design criteria,

(iii) dynamic analysis of dams,

(iv) conceptual guidelines for earthquake-resistant design of dams and design of appurtenant structures, and

(v) seismic monitoring and inspection of dams after earthquakes,

These guidelines, listed below, represent the international state-of-the-art in the seismic design, construction and safety assessment of large storage dams, i.e.

Bulletin 52 (1986): Earthquake analysis procedures for dams,

Bulletin 112 (1998): Neotectonics and dams,

Bulletin 113 (1999): Seismic observation of dams,

Bulletin 120 (2001): Design features of dams to resist seismic ground motion, Bulletin 123 (2002): Earthquake design and evaluation of structures appurtenant to dams,

Bulletin 137 (2011): Reservoirs and seismicity,

Bulletin 148 (2016): Selecting seismic parameters for large dams, and

Bulletin 166 (2016): Inspection of dams following earthquakes

Among these guidelines, Bulletin 137 provides information on reservoir-triggered seismicity (RTS), a hazard unique to large storage dams, which is often a key dam safety argument brought forward by opponents against new dams. For properly designed and constructed dams, RTS is not a new safety concern. However, the publication with the greatest long-term impact on the seismic design and safety assessment of existing dams is Bulletin 148, which includes the concept of two earthquake levels for dams and safety-critical elements, i.e. the Operating Basis Earthquake (OBE) and the Safety Evaluation Earthquake (SEE). The safety-critical elements are the spillway and low level outlets, which are needed to control the reservoir level after the SEE or for lowering the reservoir for repair works or for increasing the safety of a dam. This is new. Bulletin 120 complements Bulletin 148 as it includes conceptual features for the seismic design of dams, which are extremely important, as it is well known that it will be difficult to have a structure to perform well during an earthquake, when the basic seismic design concepts are not observed.

Dr. Martin Wieland addressing the participants

Mr. D.K. Sharma, addressing the participants

Dr. G.P. Patel, addressing the participants

Dams were the first structures designed against earthquakes, on a worldwide basis, starting in the 1930s. At that time, the ground shaking was the main seismic hazard and was represented by a seismic coefficient of typically 0.1, almost irrespective of the seismic hazard at the dam site, which was often unknown. The seismic analysis was done with the pseudo static method, ignoring the dynamic characteristics of dams. Because of its simplicity, this method is still in use today, although it has become clear that this method is obsolete following the observations made during the 1971 San Fernando earthquake. The pseudo static method is also not compatible with current seismic guidelines (Bulletin 148) and, therefore, this obsolete method shall no longer be used for the safety checks of large storage dams. Using the pseudo static concept, the seismic load case was very seldom the governing one. This has changed by using today's rational concepts for seismic hazard analyses and dynamic analyses of dams. The earthquake load case has become the dominant one for most dams.

Since the formation of the seismic committee, the magnitude 8 Wenchuan earthquake of May 12, 2008 that occurred in Sichuan province, China, was the most important earthquake for dam engineers as it damaged some 1580 dams. Most of them were small earth dams, but also some large dams were damaged. The main lesson from this earthquake was that the seismic hazard is a multi-hazard. Thousands of mass movements occurred in the mountainous epicentral region. Mass movements that can be triggered by strong earthquakes are often ignored or the hazard is assessed using criteria, which are different from those used for the dam body. Based on the past experience, it is obvious that dams are not inherently safe and can be damaged by strong earthquakes. The most vulnerable dams are those, which are poorly constructed and/or designed. Still a lot of work is required in order to ensure that all dams comply with modern seismic safety criteria, which is the main concern of the Committee. One of the main tasks of the Committee is to promote good practice in dam engineering, which includes the dissemination of the international state-of-the-art. This is also the objective of this short course.

A view of the audience

The main developments in the seismic design of dams, which have taken place during the last 50 years and which was addressed in this short course, is as given below:

From pseudo static to dynamic seismic analysis of dams.

From seismic coefficient to Safety Evaluation Earthquake ground motion.

From single ground shaking hazard to multiple seismic hazards.

From safety factors to rational seismic performance criteria.

Further, the safety of dams and their potential risks to their downstream region, particularly in seismically active areas, are serious concerns for governments, owners of dams and affected communities. There is an increasing awareness in recent times, not only among the engineers but also among the general public, about safety of dams already constructed as well as those planned for construction. It has been recognized that dam safety aspects particularly of the existing dams, are not receiving much attention needed, especially in view of the fact that a number of these old/existing dams are ageing, leading to gradual natural degeneration. Even safety of some of the dams which have been constructed in the recent past or which are under construction may become questionable, if the flood characteristics or seismicity of the area has undergone a change. The performance of the old dams need to be analyzed keeping in view the latest technology. Hence, the need has been felt to review the procedures and the criteria of dam design with the objective of establishing the best assurance of dam safety within the limitations of present state-of-the art technology/practices.

There is a need to create awareness amongst engineers, scientists, dam professionals, contractors etc about the procedures in working out appropriate seismic design parameters utilizing the State-of-the technology/practices followed globally. In this effort, Indian Committee on Large Dams (INCOLD), Central Board of Irrigation & Power, and DRIP under the aegis of ICOLD organized the above short course on “Earthquake and Dam Safety” on 12th -13th November 2018 in the Conference Hall of CBIP, Malcha Marg, Chanakyapuri at New Delhi – 110021.

The short course was inaugurated by Shri Devendra Kumar Sharma, President, INCOLD and Chairman, Bhakra Beas management Board. The other dignitaries who addressed during the inaugural session are Dr. Martin Wieland, and Dr. G.P. Patel Director – WR, CBIP.

The short course offered a good scope for interchange of experiences to facilitate exposure of state of art technology in all aspects of earthquake and dam safety management, especially considering participation of eminent Dam expert Dr. Wieland Martin, Chairman, ICOLD Committee on Seismic Aspects of Dam Designs from Switzerland.

The following lectures were delivered by Dr. Martin Wieland during the two days deliberations of the short course:

- 50 Years of ICOLD Committee on Seismic Aspects of Dam Design
- ICOLD’s Revised Seismic Design and Performance Criteria for large storage dams
- Seismic hazards of large storage dams

- Reservoir-triggered seismicity and effect on seismic design criteria for large storage dam projects
- What seismic hazard information the dam engineers need from seismologists and geologists?
- Models of Earthquake Ground Shaking Used in Seismic Design and Safety checks of Large Dams
- Performance criteria for Rockfill Dams subjected to multiple seismic hazards
- Criteria for the selection of dam types in areas of high seismicity
- Application of Pseudo-static analysis in seismic design and safety evaluation of embankment dams
- Dynamic stability analysis of a Gravity Dam subject to the safety evaluation earthquake
- Designs aspects of Deriner Dam
- Long-term Dam Safety Monitoring of Punt dal Gallarch Dam in Switzerland
- Seismic safety analysis of new and aged dams considering Dam-Reservoir-Foundation Interaction – Prof. Damodar Maity
- Seismic safety aspects of gated spillways of large storage dams
- The effects of the 1990 Manjil earthquake on Sefid Rud Buttress Dam
- Seismo-tectonic features at Rudbar Lorestan Dam in Iran and Reservoir slope stability during first impoundment

100 participants from Central and State Govt.. as well as private dam building agencies, Planners, Designers, Scientists, Researchers, Engineers, Geologists, Regulatory Bodies, Developers, Contractors, Consultants and Students working in hydropower Engineering, Dam Design, Hydropower Development, Environmental Engineering, and Structural Hydraulics. consultants, academicians, participated in the deliberations of the short course.

A view of the audience

87th Annual Meeting - Ottawa, Canada

9-14 June 2019

CDA ACB

Contribute your knowledge to 2019's leading conference on dams. We invite you to submit an abstract for a technical paper or poster to be presented at the International Commission on Large Dams, June 2019 in Ottawa, Canada.

Theme : Sustainable and Safe Dams Around the World

Deadline: September 29, 2018

Visit the ICOLD 2019 website for additional information

Tony Bennett
Co-chair, ICOLD 2019 Organizing Committee

Johanne Bibeau
Co-chair, ICOLD 2019 Organizing Committee

PROGRAM-AT-A-GLANCE

Saturday, June 8 : CDA Short Courses

Sunday, June 9
Meeting: ICOLD Officers
Meeting: ICOLD Officers and CDA Organizing Committee
City Tour, CDA Short Courses

Monday, June 10
Meeting: ICOLD Officers and Technical Committee Chairs
Technical Workshops: Presented by ICOLD Committees
Meetings: ICOLD Regions
Meeting: Young Engineers Forum
Optional Daytime Events
City Tour, Welcome Reception

Tuesday, June 11
Meetings: ICOLD Technical Committees (Open to observers)
Optional Daytime Events, Exhibition
Exhibitors Reception, Young Professionals Networking

Wednesday, June 12
International Symposium
Exhibition, Optional Daytime Events, Cultural Evening

Thursday, June 13
International Symposium
Exhibition, Technical Tours (Half and full day options)

Friday, June 14
ICOLD General Assembly
Partner Seminars
Optional daytime events, Banquet & Closing Ceremony

Saturday, June 15
Study Tours

REGISTRATION FEE

REGISTRATION CATEGORY	**Early** *until March 31*	**Regular** *As of April 1*
Full Delegate : ICOLD Member Country	$1,550	$1,695
Full Delegate : ICOLD Non-member Country	$1,950	$1,950
Technical Delegate only	$1,195	$1,295
Young Engineer & Student	$895	$995
Accompanying Persons First complete the registration for the ICOLD delegate. This person's reference number is required to register.	$650	$650
Exhibitor : Link to register will be sent once booth has been confirmed.	$750	$750

ICOLD 2019, CIGB 2019

Annual Meeting/Symposium Secretariat
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info@icold-cigb2019.ca

ICOLD gets Technical about Climate Change

Emmanuel Grenier is the Public Relations Officer for the ICOLD gives an insight into the work being carried out by its technical committee on climate change.

The ICOLD Technical Committee on Global Climate Change and Dams, Reservoirs and the Associated Water Resources was first established in 2008. Climate change was of course a subject already discussed inside ICOLD but until now, we were relying mainly on the work of the Intergovernmental Panel on Climate Change (IPCC) and we were arguing in favour of hydropower because of the weak emissions of greenhouse gases of this power-producing technology. The commission decided that, with the climate change becoming real, there was a need for studying the way dam operators could adapt to its consequences.

The goal was of course not to repeat the content of the IPCC Reports, but to work on what it meant for dam operators and to make concrete recommendations for professionals.

Getting Technical

The Technical Committee on Climate Change group together 17 members named by the national committees of different countries, plus 21 co-opted members or corresponding members, chosen for their specific competences and skills. Those experts come from the main dam building nations: USA, China, Iran, Spain, France, Canada, Japan, Norway, Spain, South Korea, etc. That is a typical composition of a Technical Committee of ICOLD.

The mandate received from ICOLD General Assembly was to:

- Collect and review the guidance and policies currently used in planning for the impacts of global climate change on dams, reservoir, and the associated water resources.
- Assess the role of dams and reservoirs in adapting to the effects of global climate change, and determine the threat posed by global climate change to existing dams and reservoirs.
- Recommend measures designed to mitigate against or adapt to the effects of global change on water storage facilities. Such recommendations would be developed in light of scientific predictions of future climate changes; possible impacts from factors such as: increased or decreased precipitation, a change in the rate of evapo-transpiration, water quality, erosion, and siltation, prolonged drought, flooding.
- Publish an ICOLD position paper and guidelines for climate change and dams, reservoirs and the associated water resources. These documents would be used by the ICOLD membership, governments, the United Nations, the World Bank and other organizations in need of guidance with respect to water resource protection and development.

After beginning its work, the technical committee has decided to add an objective to the bulletin: Provide up-to-date information about the potential of greenhouse gas emissions associated to reservoirs and related water systems existence and operation.

There has been one publication already, which is available on ICOLD's website in a preprint format. (https://www.icold-cigb.org/GB/publications/bulletins.asp) called Global Climate Change, Dams, Reservoirs, and Related Water Resources. There is also the publication of the Rabat Recommendations. Before the COP 22 meeting in Marrakech, the Moroccan government organised in Rabat, in July 1996, a pre-conference event was s dedicated to water. A workshop was co-organized by ICOLD, the Moroccan Committee on Large Dams and the Technical Committee on Climate Change, on the subjects dams and climate change.

Remain active

The committee will remain active to address climate change related problems and to disseminate knowledge and good practice examples of adaptation of reservoir management to climate change consequences. It has decided to structure its work in following three complementary themes:

- Theme 1: Climate-induced Water shortage and Drought Management
- Theme 2: Flood risk evolution associated to climate change
- Theme 3: Assess the role of hydropower in climate change mitigation and new energy mix

So far, it has not yet been decided which Theme will be dealt first. The basis of the work is to start with case studies that could clearly illustrate each theme and derive generic guidelines based on these actual examples.

An important part of our work is presenting regional case studies of adaptation to climate impact. We have case studies that cover different climatic situations around the world ranging from the arid regions of south-east Australia and west Texas in the USA, to the temperate climate of Japan, tropical Guyana and the alpine region of France. In various parts of the world the impacts of climate change are significantly different and the problems encountered are of course also different.

The Committee is working on all the topics that seem appropriate in the framework of its mandate. For example, although it was not mentioned initially in the Terms of Reference voted by the General Assembly of ICOLD, the committee thought it was necessary to discuss the GHG emissions from dams and reservoirs, because it is something often raised by dam opponents and it is a subject which need clarifications and rational discussions.

On this chapter, we have discussed the possibilities of reducing GHG emissions from reservoirs and here are our three main conclusions:

- We need to favour smaller reservoir surface/water volume ratio and consequently short residence time and less organic matter flooded;
- When measuring GHG emissions, all pathways should be taken into account (diffusion, ebullition, degassing) and a particular attention should be towards measuring methane and determining net GHG
- GHG emissions should be considered right from the conception phase. If the water intake to the power turbines is located near the surface of the reservoir or through flexible gates drawing water mostly from the surface of the reservoir, the risk of downstream degassing of methane is much lower. If water to the turbines is fed from the oxygen-depleted water closer to the bottom of the reservoir (hypolimnion), dissolved methane may be carried with the water and degassed downstream of the power plant. The use of bottom gates for releasing water or flushing the reservoir may also increase the risk of downstream methane emissions for the same reason. Hydro operations ensuring that water stays inside the reservoir for short periods of time will reduce the risk for emitting GHG.

INCOLD News

HUNDREDS MISSING IN LAOS AFTER DAM COLLAPSE UNLEASHES BILLIONS OF CUBIC METRES OF WATER ON VILLAGES

The dam was built by a joint venture led by South Korean companies, with Thai and Lao partners

A hydroelectric dam collapsed in southeastern Laos, leaving an unknown number of people dead and hundreds missing, state media said on Tuesday. Rescue efforts were underway as top government officials rushed to the site and public appeals were launched for aid.

MORE SOUTHEAST ASIAN DAM DISASTERS LIKELY UNLESS FUNDERS ENSURE HIGHER STANDARDS

Stakeholders attend the Mekong River Commission’s fifth regional forum on hydropower dam projects in the Lao capital Vientiane, Sept. 20, 2018.

The Lao dam disaster in July that resulted in heavy flooding in two provinces that left at least 40 people dead and displaced 7,000 others has drawn both regional and international attention to the potential dangers of Southeast Asia’s current dam-building spree.

With plans for 11 large dams either proposed or under construction on the mainstream of the lower Mekong River in Laos and Cambodia, and for about 120 dams on Mekong tributaries by 2040, more disasters are likely to occur, experts say.

Some observers of the hydropower boom have expressed concern over whether project funders and donor countries, also known as international development partners, could be doing more to ensure that dam builders and governments adhere to construction and technical standards in order to avert disasters from shoddy or questionable work.

Observers have also raised questions about whether funders and donors could be doing more to ensure that communities affected by dam projects receive enough money and assistance to compensate them for property and livelihoods lost when they are forced to relocate for dam projects.

UK SUMMER 'WIND DROUGHT' PUTS GREEN REVOLUTION INTO REVERSE

Britain’s long heatwave threw the country’s green energy revolution into reverse and pushed up carbon emissions this summer, leading experts to stress the need for a diverse energy mix. The weather proved a boon for staycations, garden centres and solar panel owners, but windfarms suffered. They usually provide four times as much power as solar each year.

EUROPE DROUGHT REVEALS 'HUNGER STONES' IN CZECH RIVER

A drought in the Czech Republic is causing a major river to dry up and expose rocks which are some of the oldest hydrological landmarks in Central Europe. While the drought might prove a boon for some researchers, high temperatures and low rainfall in other parts of Europe are expected to cause higher food prices.

TWO MILLION RISK HUNGER AFTER DROUGHT IN CENTRAL AMERICA: UN

7 Sept, 2018

Poor harvests caused by drought in parts of Central America could leave more than two million people hungry, the World Food Programme (WFP) said, warning climate change was creating drier conditions in the region. Lower than average rainfall in June and July has led to major crop losses for small-scale maize and bean farmers in Central America's "Dry Corridor", which runs through Guatemala, El Salvador, Honduras and Nicaragua.

KANGAROOS AND EMUS SWARM INTO CITIES AS DROUGHT WORSENS: AUSTRALIA

Wild animals and birds are heading towards towns and cities in a hunger-fuelled mass migration as Australia suffers its worst drought in decades. Mobs of camels rampaged through wheat farms in Western Australia after walking hundreds of miles in search of food and water.

They had never been seen so far south before. Huge numbers of kangaroos are racing through inner suburbs of Canberra, having fled farmlands to the west where grass has run out.

MORE AFGHANS DISPLACED BY DROUGHT THAN CONFLICT: REPORT

13 Sept, 2018

A total of 275,000 people have been displaced by drought in western Afghanistan - 52,000 more than the number uprooted by conflict this year - with over two million threatened by the effects of water shortages, the United Nations said. Reports from the U.N. and aid charities described farmers lacking seeds to sow following crop failures in some areas and livestock dying for the want of anything to eat.

DROUGHT BITES IN THE EAST AS ABARES FORECASTS 12PC CUT TO GRAIN PRODUCTION: AUSTRALIA

A rough winter for grain growers on the east coast has led the Australian government commodity forecaster, ABARES, to predict a 12 per cent drop in winter grain production from last year's total. The latest crop report is tipping winter production — including wheat, barley, canola, pulses and oats, among others — to yield 33.2 million tonnes. Overall, the harvest is nine per cent below the 20-year average.

DIVERSE FORESTS ARE STRONGER AGAINST DROUGHT

Diversity is strength, even among forests. In a paper published in Nature, researchers led by University of Utah biologist William Anderegg report that forests with trees that employ a high diversity of traits related to water use suffer less of an impact from drought. The results, which expand on previous work that looked at individual tree species' resilience based on hydraulic traits, lead to new research directions on forest resilience and inform forest managers working to rebuild forests after logging or wildfire.

MEDIUM-HEIGHT TREES SURVIVE DROUGHT BEST

4 Sept, 2018

Forests with canopy heights of around 18 metres are more resistant to the effects of severe drought than those with shorter and taller trees, according to researchers in China and the US. In the past, studies have disagreed on whether forests with lower or higher canopies will be more likely to make it through prolonged spells of hot, dry weather. The discrepancy has made it difficult for forest managers, who need to know which tree heights to encourage to ensure the highest growth and survival rates during extreme drought.

CITIES WARNED TO IMPROVE WATER BASIN RESILIENCE TO PREVENT DROUGHTS, FLOODS

The report "Cities Alive: Water for People" claims that cities need to expand their water infrastructure to include the entire river basin on which they depend. It finds that while the world's 100 largest cities occupy less than 1 percent of the planet's land area, the basins they depend on cover over 12 percent and serve almost a billion people. Water basins are vital for supplying cities with water as well as collecting all the surface water and groundwater in the area.

DROUGHT-HIT AUSTRALIAN FARMERS FORCED TO SLAUGHTER LIVESTOCK

From cooling showers for cows to airport runways designed for higher sea levels, businesses and parts of Australia's A$2.7 trillion ($2 trillion) pension industry are starting to find ways to live with rising temperatures. Australia's latest climate casualties are its farmers, who are being forced to slaughter livestock and watch crops wither amid one of the worst droughts on record. Economists estimate the drought could cut as much as 0.75 per cent from gross domestic product growth.

DROUGHT MAY COST CHINA US$47 BILLION A YEAR AS TEMPERATURES RISE, STUDY FINDS

Drought conditions could cost China US$47 billion per year in economic losses – more than double the current estimate – if global temperatures rise by 1.5 degrees Celsius above the pre-industrial baseline, according to a Chinese study. Those losses could climb a lot higher – to US$84 billion, or about five times this year's level – if the global average temperature goes up by 2 degrees, Chinese Academy of Sciences researchers found.

DRIEST EVER SEPTEMBER DEEPENS AUSTRALIA'S DROUGHT

Australia had its driest September on record last month, and though spring rains are forecast this week across parts of the continent's east that has seen the worst drought in years, the season is predicted to offer little relief from the dry weather. The country's east coast has recorded less than a fifth of its typical rainfall over the last three months to September and is barren, with winter crops failed and graziers buying in grain to feed their herds.

Events

Sr. No	Description	Dates	Country	websie
1	Hydropower Caspian & Central Asia	13 Feb - 14 Feb 2019	Tbilisi, Georgia	Email: events@ vostockcapital.com
2	NWHA Annual Conference	20 Feb - 22 Feb 2019	Portland, OR, USA	www.nwhydro.org/events-committ...
3	Hydropower & Stations	19 Mar - 20 Mar 2019	Tucson, AZ, USA	URL: www.ceati.com/ events/conferenc...
4	Water Power week in Wahsington	April1 to 3	Washington D.C	www.waterpowerweek. com/
5	2019 USSD Conference and Exhibition	8 April -11 April 2019	Chicago, Illinois -- Hilton Chicago Hotel	www.ussdams.wildapricot. org
6	ASDSO West Regional Conference	25 Mar - 27 Mar2019	Westminster, CO, USA	URL: damsafety.org/ training-center/...
7	WORKSHOP: Digitalization in Hydropower	25 Apr - 26 Apr2019	Graz, Austria	URL: www.vgb.org/en/ digitalization_...
8	World Hydropower Congress	14 May - 16 May2019	Paris, France	URL: congress. hydropower.org
9	ICOLD 2019 Annual Meeting	9 Jun - 14 Jun2019	Ottawa, Ontario, Canada	
	URL: www.icold-cigb2019.ca			
10	Dam Europe2019	27June-28June	London	/www.henrystewart conferences.com/ DAME urope2019/
11	HydroVision 2019	23 Jul - 25 Jul 2019	Portland, OR, USA	URL: www.hydroevent. com/future-even...
12	Dam Safety 2019	8 Sep - 12 Sep 2019	Orlando, FL, USA	URL: damsafety.org/ training-center/...
13	ICOLD 2019 - 11th ICOLD European Club Symposium	2 - 4 October 2019	Crete, Greece	http://www.globalevents.gr/
14	Canadian Dam Association Conference and Exhibition	6-10 October 2019	Calagary,Alberta Canda	www.Cda.ca
15	NZSOLD/ANCOLD 2019 Combined Conference	10-11 OCTOBER 2019	Australia	www.ancold.org.au
16	Dam Safety 2020	20 Sep - 24 Sep 2020	Palm Springs, CA, USA	URL: damsafety.org/ training-center/...
17	HydroVision 2020	14 Jul - 16 Jul 2020	Minneapolis, MN, USA	URL: www.hydroevent. com/future-even...
18	24th ICID International Congress + 71st IEC Meeting	22 Sep - 28 Sep2020	Sydney, NSW, Australia	www.icid2020.com.au
19	HydroVision 2022	12 Jul - 14 Jul2020	Denver, CO, USA	www.hydroevent.com/ future-even...

Aims & Scope

INCOLD Journal is a half yearly journal of Indian Committee on Large Dams (INCOLD) which is involved in dissemination of the latest technological development taking place in the field of dam engineering and its related activities all over the world to the Indian dam/hydropower professionals.

The aim of the journal is to encourage exchange of ideas and latest technological developments in the field among the dam engineering Professionals. The journal is for fully-reviewed qualitative articles on planning, design, construction and maintenance of reservoirs, dams and barrages and their foundations. The articles cover scientific aspects of the design, analysis and modelling of dams and associated structures including foundations and also provides information relating to latest know how in the field of construction technology for the related works. In addition to the information on the research work on the relevant subjects, the journal provides information on the related technical events in India and abroad such as conferences/ training programmes/ exhibitions etc. Information related to ICOLD (International Commission on Large Dams) activities such as ICOLD Congresses, its technical symposia, workshops, technical lectures, technical bulletins are also highlighted for the benefit of INCOLD members.

The original unpublished manuscripts that enhance the level of expertise and research in the various disciplines covered in the Journal are encouraged. The articles/technical papers are peer reviewed by editorial Board consisting of renowned experts before publication. The Journal has both print and online versions. There are no publication charges on the author.

V.K. Kanjlia
Secretary General
Indian Committee on Large Dams

Subscription Information 2019/ (2 issues)

Institutional subscription (Print & Online)	:	Rs. 900/US$75
Institutional subscription (Online only)	:	Rs. 600/US$50
Institutional subscription (Print only)	:	Rs. 600/US$50
Membership for 10 Years (Print only)	:	Rs. 5,000
Membership for 10 Years (Print & Online)	:	Rs. 8,000

Recent ICOLD Technical Bulletins

Bulletin 107 (1997) Concrete dams, control and treatment of cracks : Review and case histories.
Bulletin 108 (1997) Cost of temporary and permanent flood control in dams.
Bulletin 109 (1997) Dams less than 30 m high.
Bulletin 110 (1997) Impact of cost of rules, criteria, specifications and contractual issues.
Bulletin 111 (1998) Dam break flood analysis.
Bulletin 112 (1998) Neotectronics and dams.
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