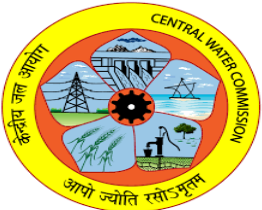




Indian National Committee
on Large Dams

INTERNATIONAL DAM SAFETY CONFERENCE



Central Water Commission

Effective measure to control seepage in masonry gravity dams – A case study

R. VIGNESWARAN, SCIENTIST B

Central Water and Power Research Station,

Pune, Maharashtra, India

100 years and beyond ...



10-12 October 2022 at Jaipur, Rajasthan (India)



Indian National Committee on Large Dams

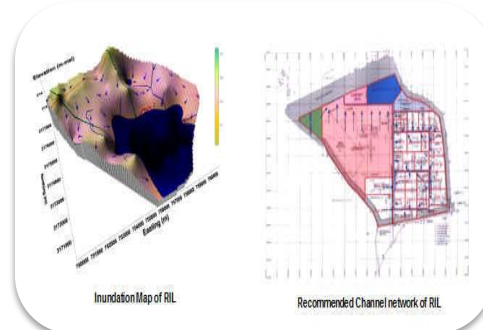
INTERNATIONAL DAM SAFETY CONFERENCE



CWPRS- one of the foremost organisations in the world in the field of hydraulics and allied research
Estd: 1916



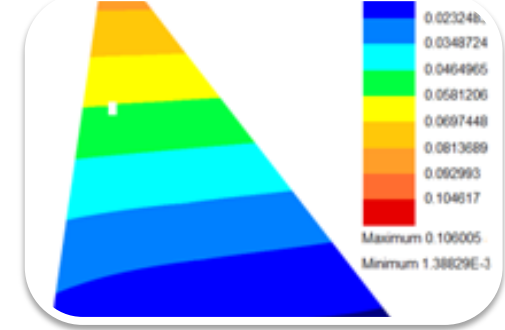
River Engineering



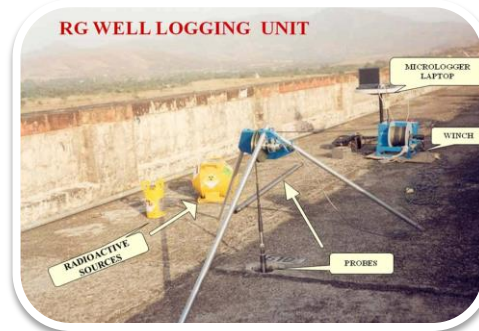
River & Reservoir Modelling



Coastal & Offshore Engineering



Foundation & Structures



Applied Earth Sciences



Reservoir & Appurtenant Structures



Instrument Calibration & Testing Services

10-12 October 2022 at Jaipur, Rajasthan (India)



Indian National Committee
on Large Dams

INTERNATIONAL DAM SAFETY CONFERENCE



Repair- To provide protection and making up the deficiencies.



Rehabilitation - To restore the distressed structures to normal serviceability levels.



Strengthening - To improve the load carrying capacity as a whole or part thereof to its original level that had been lost

The objective of rehabilitation is to reinstate the

- structural integrity,
- improve durability,
- prevent leaching of materials,
- restore water tightness, and
- improve the appearance of structure



INTERNATIONAL DAM SAFETY CONFERENCE



CAUSES OF SEEPAGE/ LEAKAGE

- Masonry dams exhibit leakages/seepage due to **moisture absorption**, **temperature effect**, **poor quality construction**, **leaching of cementitious material**, **excessive pore pressure**, **cracking**, **design deficiency** and **ageing effect** etc.
- The leakages/seepages affect **structural stability** of the dam due to development of high pore pressure, reduction in mass density and strength parameters
- To restore the structural integrity of the dam and make the distressed structure serviceable again, various methods are adopted either one or in combination



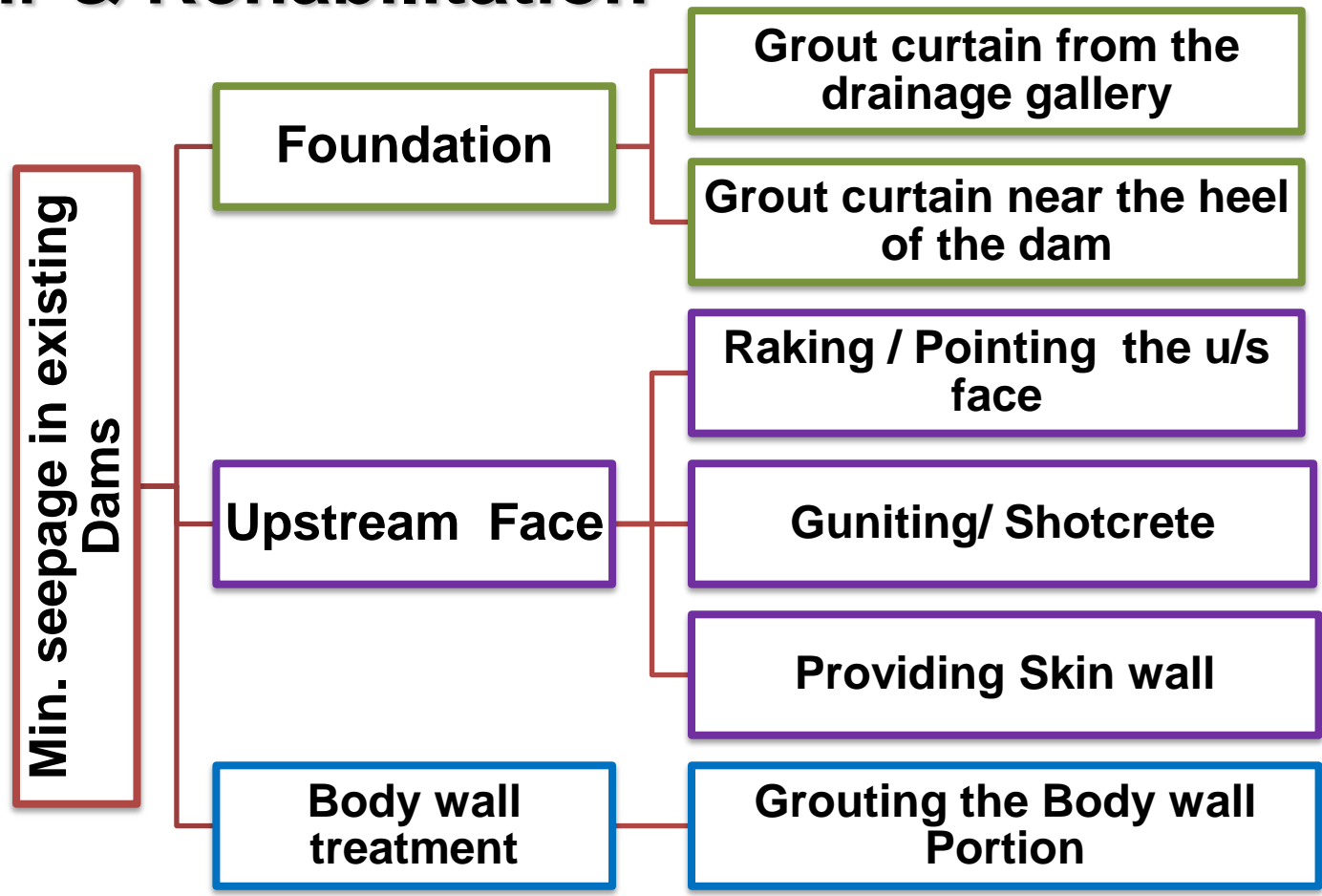
INTERNATIONAL DAM SAFETY CONFERENCE



Repair & Rehabilitation

For gravity dams, distress is seldom attributed to a single factor and therefore knowledge of **possible cause of distress, its diagnosis, repair material and technique is essential.**

Economically viable options to impart effective functionality, **durability and safety** to the existing structure





Indian National Committee
on Large Dams

INTERNATIONAL DAM SAFETY CONFERENCE



Dam Rehabilitation & Improvement Project



Central Water Commission

CASE STUDY - DHAMNI DAM, PALGHAR, MAHARASHTRA

- River : **Surya River**, Palghar Dist, Maharashtra
- Masonry gravity dam with height of 58.08 m and length of 623 meters
- Dam Construction **1990**
- Due to **ageing** distresses in the form of **heavy seepage and leaching of mortar** have been observed



10-12 October 2022 at Jaipur, Rajasthan (India)

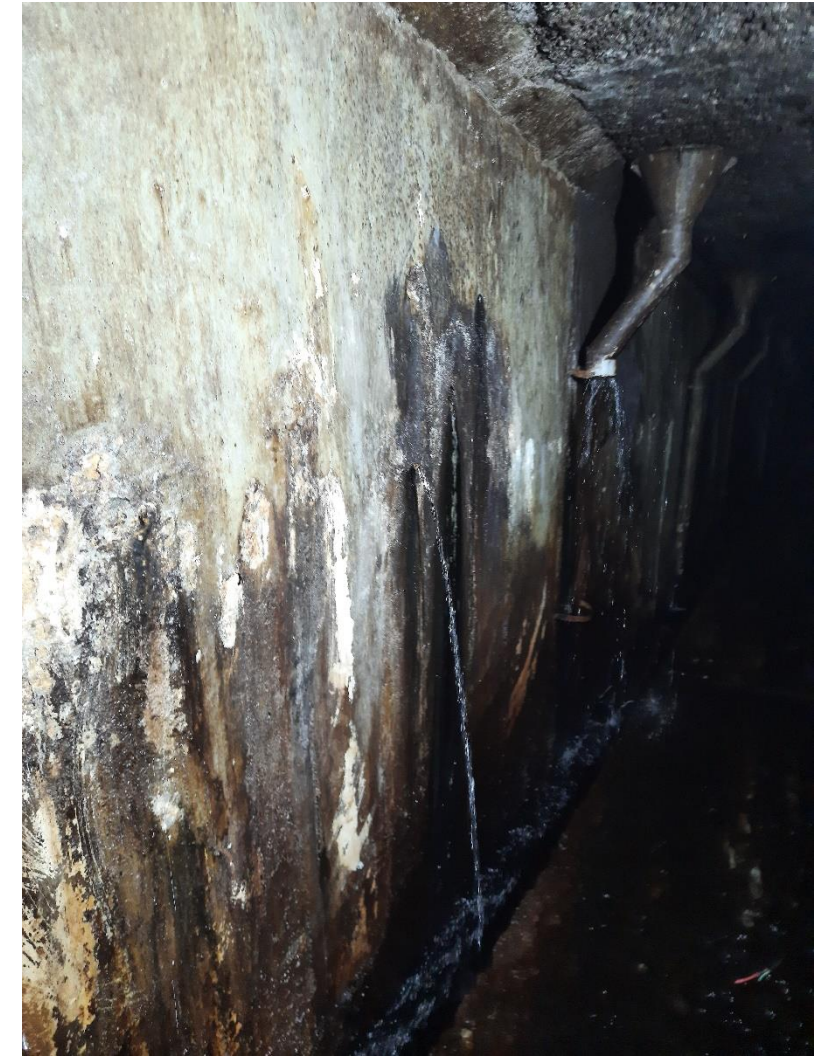


Indian National Committee
on Large Dams

INTERNATIONAL DAM SAFETY CONFERENCE



Central Water Commission



10-12 October 2022 at Jaipur, Rajasthan (India)



Indian National Committee
on Large Dams

INTERNATIONAL DAM SAFETY CONFERENCE



Central Water Commission

DAM BODY GROUTING

- **Grouting the body of dam** is one of the effective cures for most of the dams and has been successfully implemented for reducing seepage in so many dams all over world.
- Presently no **specific BIS code** exists for the design grout mix for dam body grouting.
- **Grout Mix Design** is dependent on pattern, size and continuity of the cavities/fissures, quantity of seepage water flow and desirable enhancement of mass density towards improvement in strength requirement of dam body

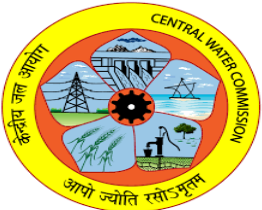
Dams Grouted

- Warasgaon dam
- Temghar dam
- Bhatsa dam
- Domihira dam
- Radhanagari dam
- Pagara dam
- SakhyaSagar dam
- Hemavathy dam
- Talakalale dam



Indian National Committee
on Large Dams

INTERNATIONAL DAM SAFETY CONFERENCE



Central Water Commission

Laboratory experimentation for selection of suitable cementitious grout system

- Suitable grout mix design is essential to achieve desirable results towards controlling seepage
- To check the performance of the grout by conducting various tests in laboratory before conducting trial application

1. Flowability Test by Marsh Cone Apparatus
2. Settlement/ Segregation test
3. Gelification test
4. pH value
5. Compressive strength



Indian National Committee on Large Dams

INTERNATIONAL DAM SAFETY CONFERENCE



Laboratory Tests

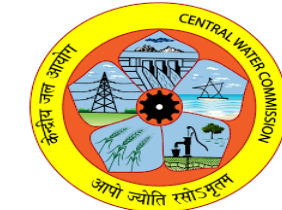


10-12 October 2022 at Jaipur, Rajasthan (India)



Indian National Committee
on Large Dams

INTERNATIONAL DAM SAFETY CONFERENCE



Central Water Commission

Efficacy test for selection of suitable cementitious grout system

- **1 cub.m** of masonry blocks have been cast using lean cement mortar and the blocks have been cured for a period of 28 days
- The grout application was carried out in the masonry blocks by using **grout pumps** by applying a pressure upto 2 kg/cm^2

1. Non Destructive Tests on Masonry blocks
2. Water Loss Test
3. Compressive strength on extracted cores

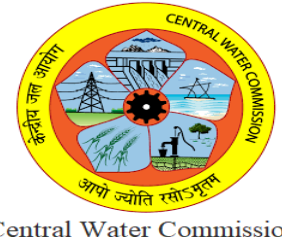


10-12 October 2022 at Jaipur, Rajasthan (India)



Indian National Committee on Large Dams

INTERNATIONAL DAM SAFETY CONFERENCE



Field Tests

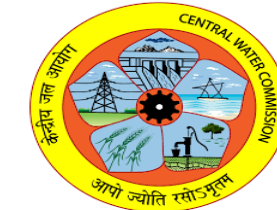


10-12 October 2022 at Jaipur, Rajasthan (India)



Indian National Committee on Large Dams

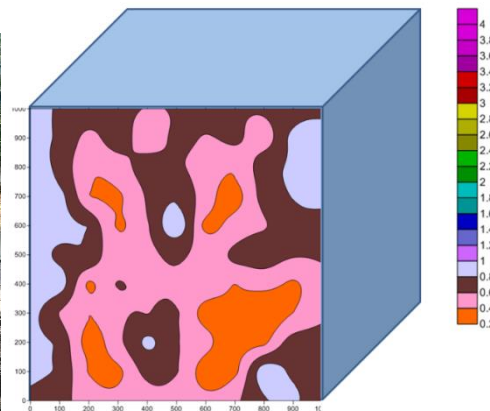
INTERNATIONAL DAM SAFETY CONFERENCE



Central Water Commission

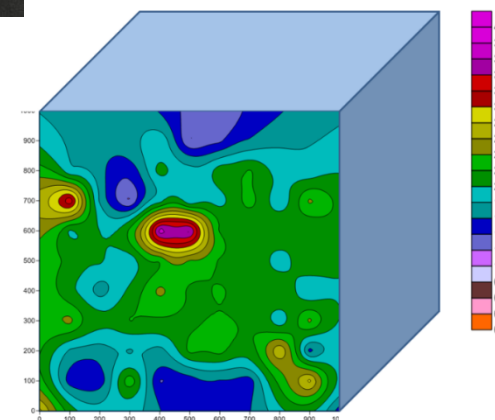
Assessment of Improvement in Quality of Masonry Blocks through Non Destructive Tests

- Non destructive tests on masonry blocks by **ultrasonic pulse velocity** method have been carried out to evaluate the improvement in quality of masonry after grouting.
- The ultrasonic pulse velocity test has been conducted on all **four faces of masonry blocks** at three levels in vertical and horizontal direction in all masonry blocks at **pre and post grouting stages**.



Pre-grouting stage – 2000m/s

Post-grouting stage - 3000m/s





Indian National Committee on Large Dams

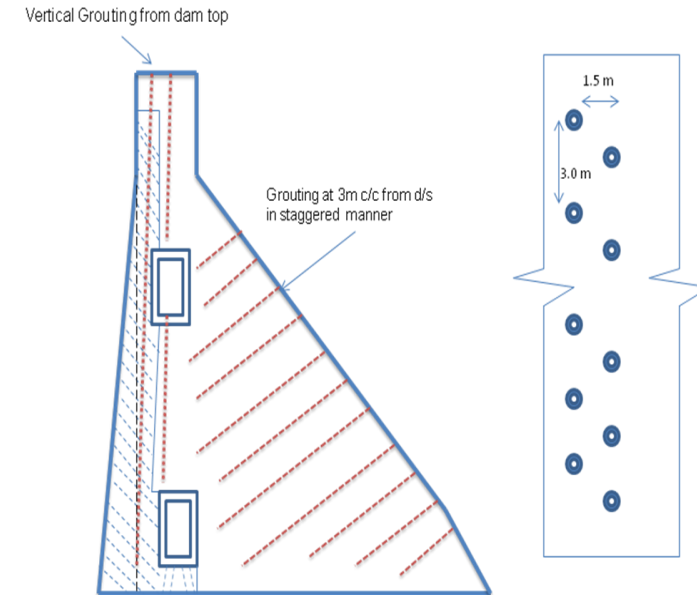
INTERNATIONAL DAM SAFETY CONFERENCE



Central Water Commission

Grouting Methodology Suggested

- At first stage, it has been suggested to carry out vertical grouting from the dam top
- Second line of grouting may be carried out by drilling the grout holes at a distance of 1.50 m
- The tertiary stage grouting if required may be carried out after assessing the **efficacy of primary and secondary stage grouting**
- For grouting from the downstream side, the downward inclined hole drilling in transverse direction on downstream faces at a suitable angle (45°) to cover the maximum thickness of masonry of the dam



10-12 October 2022 at Jaipur, Rajasthan (India)



Indian National Committee
on Large Dams

INTERNATIONAL DAM SAFETY CONFERENCE



SHOTCRETING or GUNITING

- The Shotcrete is the most effective process of **repairing concrete work** which has been damaged due to inferior work or other reasons
- It is also used for **providing impervious layer**.
- Shotcrete is a mixture of Portland cement, sand, additives and water, shot into the place by compressed air. The size of aggregate is restricted to less than 10mm.

Surface preparation

Fixing of wire mesh

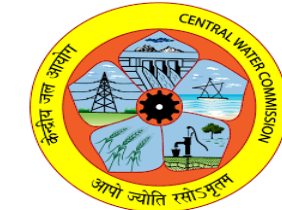
Shotcrete operation

- IS 13645 :1993 Guniting the upstream face of masonry dams**



Indian National Committee
on Large Dams

INTERNATIONAL DAM SAFETY CONFERENCE



Central Water Commission

DAM BODY SHOTCRETING

- Properly applied shotcrete is a structurally **sound and durable construction material** which exhibits excellent bonding characteristics to existing concrete, rock, steel, and many other materials.
- It can have **high strength, low absorption, good resistance** to weathering, and resistance to some forms of chemical attack.
- Physical properties of sound shotcrete are **comparable or superior** to those of conventional concrete or mortar having the same composition

Dams Shotcreted

- Warasgaon dam
- Temghar dam
- Bhatsa dam
- Bhandardara dam
- Radhanagari dam
- Warna dam

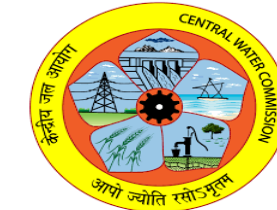


Indian National Committee
on Large Dams

INTERNATIONAL DAM SAFETY CONFERENCE



Dam Rehabilitation & Improvement Project



Central Water Commission

Laboratory Tests

1. **Slump Test:** to determine (wet) uncured shotcrete consistency.
2. **Compression Test:** to measure cured shotcrete compression strength.
3. **Early Strength, Partial-beam Compression Test:** to measure cured shotcrete compression strength.
4. **Permeability Test:** to measure cured shotcrete for water penetration.



10-12 October 2022 at Jaipur, Rajasthan (India)



Indian National Committee
on Large Dams

INTERNATIONAL DAM SAFETY CONFERENCE



Field Tests

1. Slump Test
2. Test on Extracted Cores
3. Overcoring and Direct tension pull test : to measure cured shotcrete adhesion strength
4. Round determinate panel Flexure test : to measure cured shotcrete load capacity and toughness.
5. Permeability Test



10-12 October 2022 at Jaipur, Rajasthan (India)



Indian National Committee
on Large Dams

INTERNATIONAL DAM SAFETY CONFERENCE



Shotcrete methodology

- The upstream surface should be well chipped
- The chipped surface need to be cleaned by using air water jet so as to remove all loose material, sand pockets etc.
- 25 mm diameter anchor bar 1.50 m. long in staggered pattern and grouted.
- M.S. welded wire mesh of size 100x100x4 mm is placed at about 20 mm from the cleaned upstream face by using cover block and fixed firmly with the help of the anchor pins
- The prepared surface is again cleaned by air water jet thoroughly.
- Continuous curing by surface saturation should be carried out upto 14 days.
- During Shotcreting nozzle distance should be kept of 0.9 m away from surface and be perpendicular during application in elliptical shape.



10-12 October 2022 at Jaipur, Rajasthan (India)



Indian National Committee
on Large Dams

INTERNATIONAL DAM SAFETY CONFERENCE



Central Water Commission

EFFICACY OF GROUTING AND SHOTCRETING IN DAM BODY

- Before grouting and shotcreting → 197 LPS
- After partial grouting and shotcreting → 41 LPS i.e about 77% reduction in seepage has been observed



10-12 October 2022 at Jaipur, Rajasthan (India)



Indian National Committee
on Large Dams

INTERNATIONAL DAM SAFETY CONFERENCE



Central Water Commission

Conclusion

1. Dam body grouting and shotcrete using proper mix design is a well proven, **economical and effective tool to control seepage** and improve structural integrity of the distressed masonry dams.
2. **Design of cementitious grout mix** is important and necessarily be done by conducting laboratory tests on different materials. After conducting the suitability tests in laboratory by using many mix proportions, a suitable design mix is arrived at for carrying out grouting in the field.
3. Nearly **Six shotcrete mix designs** have been evaluated in laboratory before arriving at a Final suitable design mix shotcrete.
4. Due to dam body grouting and shotcrete in upstream face of Dhamini dam in Maharashtra, the seepage/leakage through the dam portion has been observed to be reduced considerably. The overall seepage rate has reduced from **197 lps to about 41 lps** after the successful grouting and shotcreting.

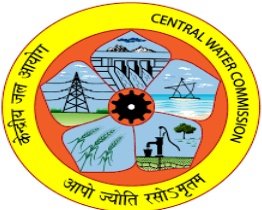
10-12 October 2022 at Jaipur, Rajasthan (India)



INCOLD

Indian National Committee
on Large Dams

INTERNATIONAL DAM SAFETY CONFERENCE



Central Water Commission



Thank You

www.cwprs.go.in

10-12 October 2022 at Jaipur, Rajasthan (India)