CLIMATE-RESILIENT DAMS AND
HYDROPOWER INFRASTRUCTURE
INTEGRATING
ENVIRONMENTAL SUSTAINABILITY
IN PLANNING AND DEVELOPMENT

Nano Grouting to Arrest Heavy Water Loss Through Aging Dams Leading to Major Reduction in Carbon Foot Print

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1. HISTORY OF RANSAI DAM

1. Owner - Government of Maharashtra
2. Constructed in 2 stages - 1970 & 1981
3. Water supply to - National Armament Depot, Oil & Natural Gas Corporation, near by municipalities and villages.
4. Construction details - Rubble masonry
5. Height - 33m Length - 235m
6. 15 automatic tilting gates with inspection gallery
7. Storage capacity - 10 million cubic meters

- Mandatory to inspect the dam every year by Dam Safety organization (DSO).

- Pre and post monsoon inspections are held regularly.

- Despite the maintenance by way of periodic cement groutings, heavy losses of 200,000 m^3 water and corresponding structural deterioration were happening year after year. Evident from permeability results as given in table 1.

Department appointed a consultant in 2015 to study the site conditions and recommend remedial measures.

Various observations and tests like water intake tests, analysis of ionic contents in leakage water, pressure gradient, water level, temperature measurement, leakage and turbidity monitoring etc. were carried out in early 2017.

The summary of the tests in terms of permeability is given which makes the clear observation that test results are much above the permissible limits of 2.5 - 5 lugeons of allowed permeability as prescribed by BIS 11216-1985. (Table 1)

Lugeons definition : A unit devised to quantify the water permeability of bedrock and the hydraulic conductivity resulting from fractures - Loss of water in liters/minute/meter bore hole@1mpa pressure(10kg/cm^2)

2. LEAKAGES OF TYPICAL DAM

LEAKAGES OF RANSAI DAM

3. CONVENTIONAL METHOD OF ARRESTING SEEPAGES - CEMENTITIOUS GROUT

Grouting by using cementitious material

4. POST GROUTING LEAKAGES REOCCUR - WHY ?

- Cement is grouted with water as carrier medium. In the process the formation of hydration products and CSH binder is least due to excess w/c ratio and it is majorly fractured in microstructure.

- Cement particle size is in the range of 15000 nm (15 microns) and if one uses ultra fine cement then it is 3000 nm (3 microns)

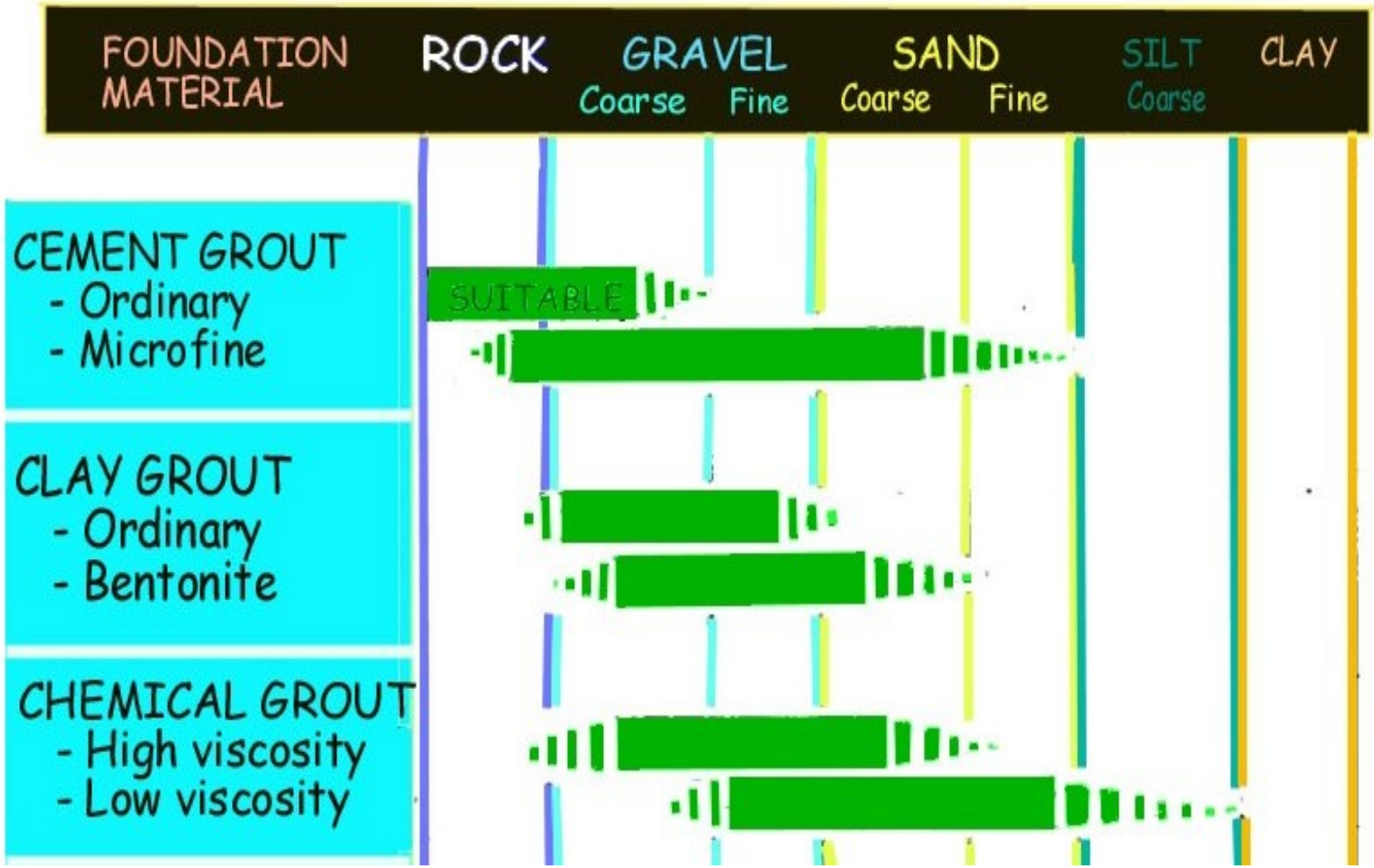
- Due to significant particle size of cement compared to voids, capillary and microcapillary diameters, restrictions are faced in the entry of the grout and does not reach till the end.

- Hence cement grouting is principally useful for blocking larger gaps and voids. Cannot effectively seal the intricate capillary/micro-capillary network which remains a major water transport route post cement grouting.

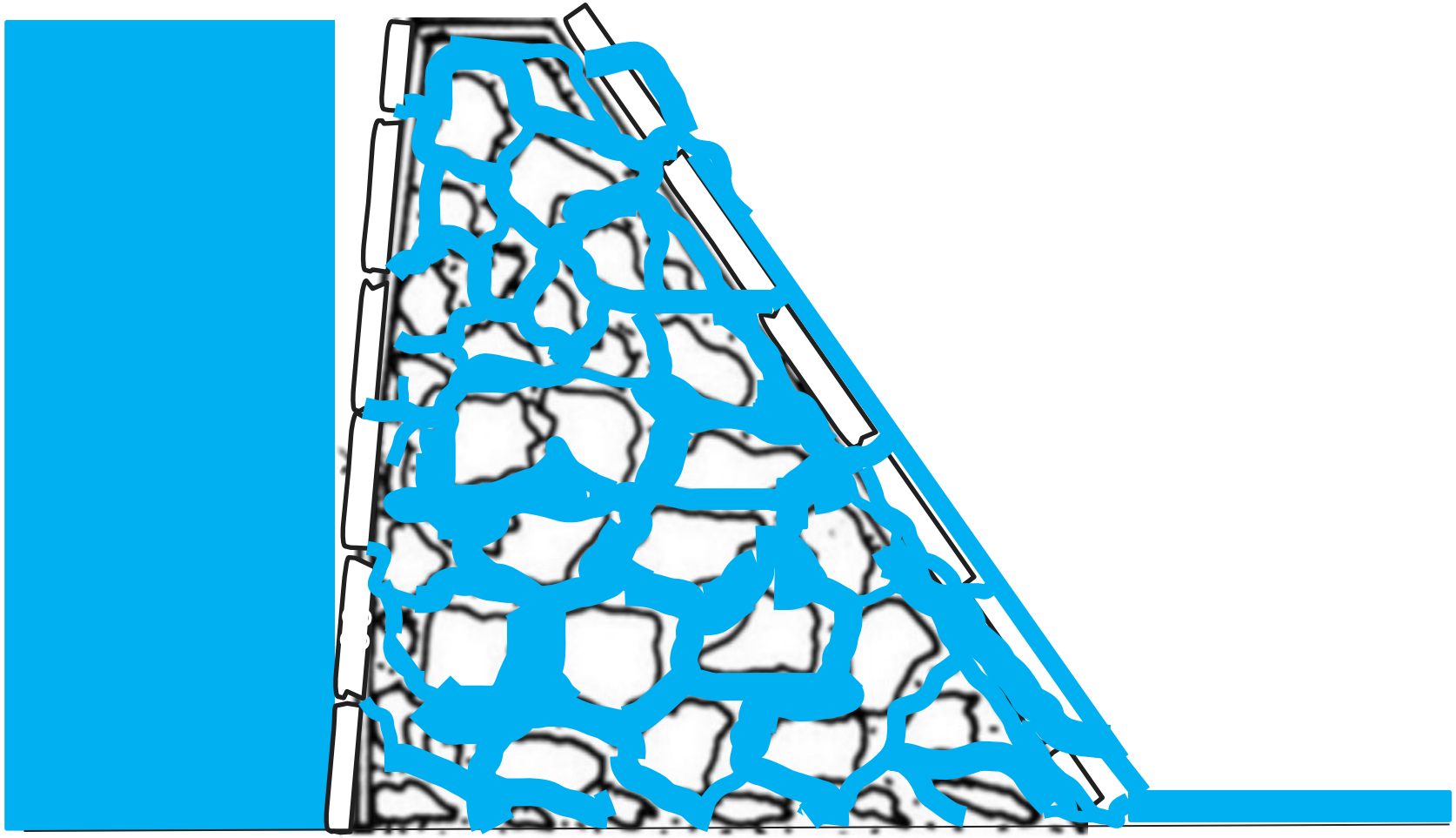
- The washout can be measured from the analysis of seepage water for ions, turbidity, alkalinity and pH.

- Ideally we need a freely flowing liquid material through the intricacies of the matrix and subsequently convert itself into impermeable solid achieving the dual objective of converting the residual gaps into monolithic mass with special binding properties.

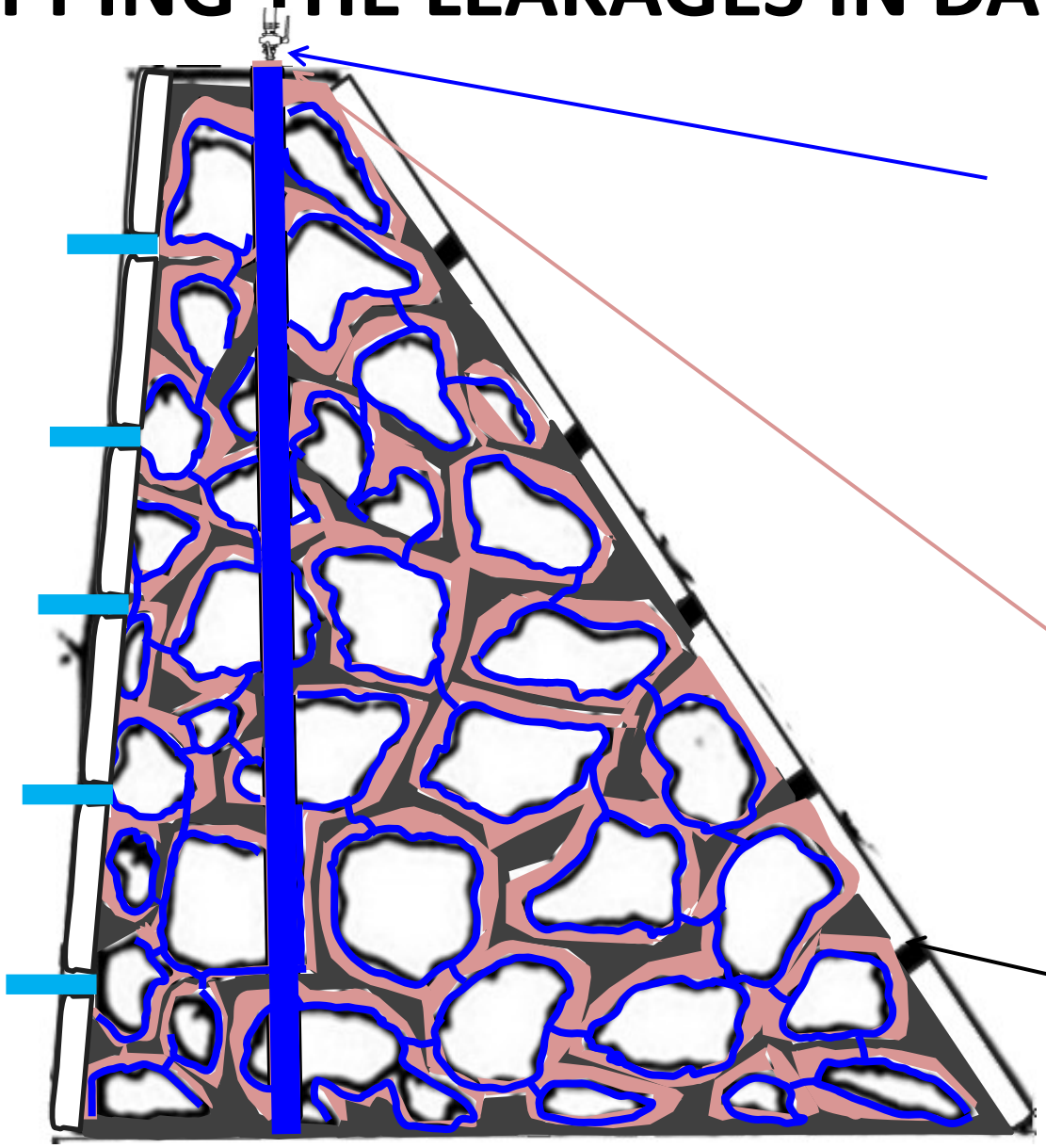
5. TYPES OF GROUT AND THEIR PENETRATION



ANATOMY OF LEAKAGES THROUGH BODY OF THE DAM



STOPPING THE LEAKAGES IN DAMS



Filling of remaining voids
Inorganic Nano Grout
Sungeogrout

Operation 3

Cementitious Grout.

Operation 2

Repointing with
Polyplug

Operation 1

6. CORRECTIVE METHODOLOGY

The recommendations were made by the consultants in collaboration with our material scientists.

Corrective method - Executed in 2017

i. Inject cement slurry to fill the larger gaps, pores, voids, tubings etc. This grout is mixed along with shrinkage compensating and w/c reducing agent - Sunplex. Allow to set.

ii. Inject nano grout subsequently, which enters as free flowing liquid of water consistency and precipitates resulting in bonding firmly the co-matrix of a) Original dam core & b) Freshly injected and set cementitious grout. On precipitation it works as a micro filler cum binding agent.

COMPARATIVE SIZES OF GROUTING

15,000 nm

10 to 15 nm

Sungeogrout

3,000 nm

iii. The working time was engineered as per the depth and other requirements of the interiors of dam which is an operational convenience.

iv. Post grouting water intake tests (BIS 11216-1983[1]) were carried out to assess the effect of the treatment. (Table 1).

The discernible improvement in extent of impermeability is discussed further which is supported by laboratory results wherever required.

7. CASE STUDY - SOME VISUALS

Leakages Through Body of Ransai Dam

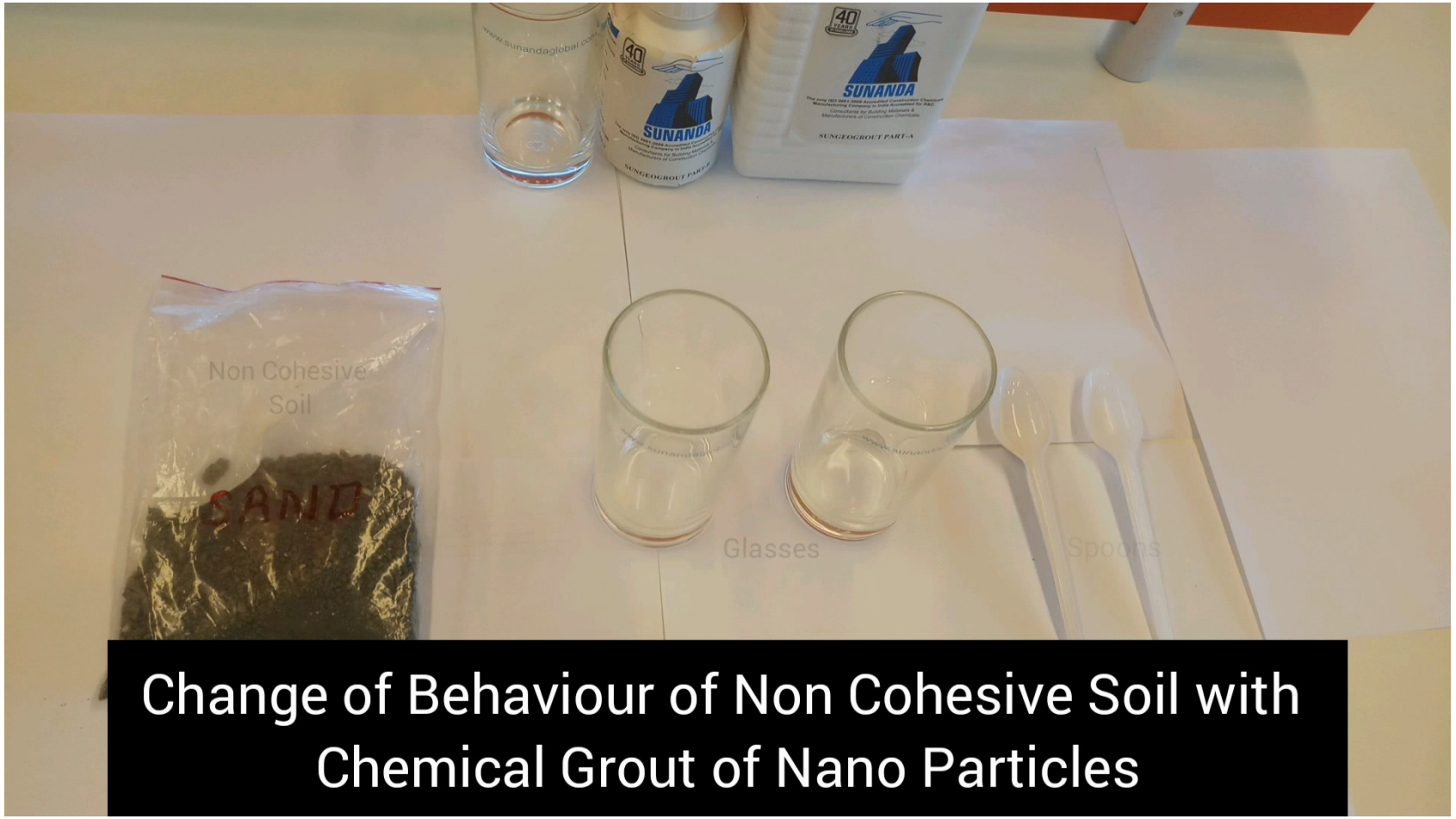
Leakages Through Body of Ransai Dam

Leakages in the Inspection Gallery - Pre 2017

Cement Grouting

Mixing - Sungeogrout

Sample Demo - SUNGEOGROUT



Grouting using Sungeogrout

8. SITE TEST RESULTS

WATER LOSS IN LUGEONS		
Before Grouting	**Cement Grouting**	**Cement Grouting + SUNGEOGROUT**
82.404	15 to 20	1.18

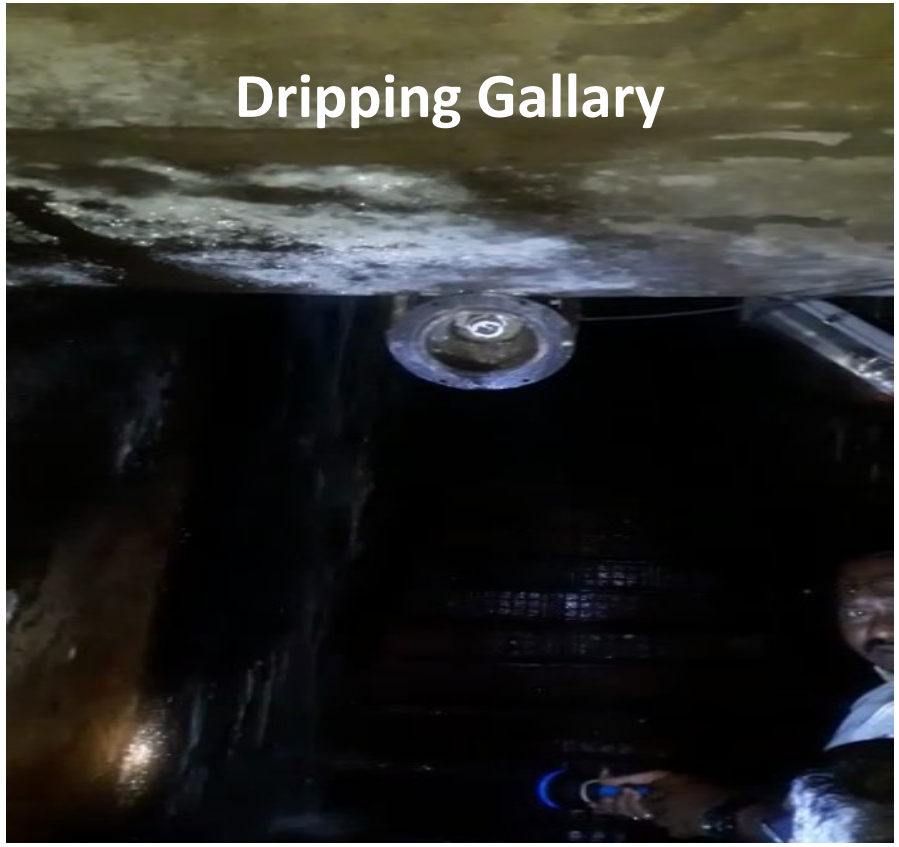
Loss of 82 liters/minute/1 meter height

Reference:- MIDC field staff

8. SITE TEST RESULTS

Lugeons - It is the water loss in liters per minute per meter depth of the drill hole under a pressure of 10 atmosphere maintained for 10 minutes in a drill hole of 46 to 76 mm diameter and 1 meter length.(IS 11216-1983)

WORK DONE - 2017



Year 2017
Before Treatment - Leakages

Year 2017
After Treatment - No Leakages

NO LEAKAGES
IN INSPECTION GALLARIES - 2023 & 2026

2023
Still - No Leakages

2026
Still - No Leakages

CONTINUED

Table 1 - WATER INTAKE TEST
(NON OVERFLOW SECTION) before and after Grouting

Sr. No.	Bore hole number and chainage in meters	Water loss before grouting (lugeons)	Water loss after grouting (lugeons)
1	**BH8 (RD -63.1)**	15	**0.00**
2		14	**0.00**
3		24	**0.00**
4		92	**0.02**
5		72	**0.02**

BH - Borehole
RD - Reduced Distance

CONTINUED

Sr. No.	Bore hole number and chainage in meters	Water loss before grouting (lugeons)	Water loss after grouting (lugeons)
1	**BH9 (RD-66.10)**	08	**0.37**
2		02	**0.36**
3		43	**0.07**
4		30	1.31
5		73	1.18
6		69	**0.39**
7		120	**0.00**

BH - Borehole

RD - Reduced Distance

Sr. No.	Bore hole number and chainage in meters	Water loss before grouting in lugeons	Water loss after grouting in lugeons
1	**BH12 (RD-75.10)**	08	**0.37**
2		17	**0.12**
3		14	**0.28**
4		114	**0.87**
5		02	1.18
6		22	**0.00**
7		06	**0.00**
8		04	**0.00**
9		57	**0.00**

BH - Borehole

RD - Reduced Distance

Sr. No.	Bore hole number and chainage in meters	Water loss before grouting in lugeons	Water loss after grouting in lugeons
1	**BH13 (RD-78.10)**	48	**0.15**
2		14	**0.37**
3		16	**0.37**

BH - Borehole

RD - Reduced Distance

Sr. No.	Bore hole number and chainage in meters	Water loss before grouting in lugeons	Water loss after grouting in lugeons
1	**BH22 (RD-105.10)**	7	**0.02**
2		10	**0.12**
3		26	**0.59**
4		04	**0.59**
5		06	**0.59**

BH - Borehole

RD - Reduced Distance

Sr. No.	Bore hole number and chainage in meters	Water loss before grouting in lugeons	Water loss after grouting in lugeons
1	**BH3 (RD-214.74)**	63	**0.59**
2		50	**0.00**
3		34	**0.61**
4		95	**0.36**
5		92	1.13
6		73	1.13
7		86	**0.39**
	Average water loss lugeons	**43.92**	**0.515**

BH - Borehole
RD - Reduced Distance

9. INTERPRETATION

i. We have developed special nano grout which is having thorough access due to its ‘solute in solution’ size, anywhere in the intricate microstructure of the capillaries as well as in the voids which are otherwise partially filled with over-hydrated discontinuous cement slurry.

ii. Insoluble inorganic non toxic impermeable precipitate is formed and works as a binder for unhydrated cement and all size aggregates of dam. It also blocks all the capillaries and micro capillaries in the microstructure of matrix resulting into longer lasting impermeable structure.

iii. Falling head permeability test measurements further explains the reduction in seepage to almost zero lugeons.

The test was done in accordance with ASTM D 2434 as well as IS 2720 Part 17-1986. The coefficient of permeability of untreated soil was 1.49×10^{-4} cm/sec which was reduced to 1.075×10^{-5} cm/sec after the nano grout chemical treatment. This would reduce the seepage through earthen dams, by the order of more than 10 which is significant.

10. CONCLUSION

i. Chemical grouting is an established, effective technique of soil stabilization.

ii. Nano-particles of the grout improve the penetration capability of the grout

iii. It is possible to explore various combinations of chemical grout reactants to enter into micron, nano and sub-nano particle zones. The success of this case is the result of such extensive trials with various reactants in laboratory.

iv. Entering into the nano zone enhances the performance of the grout in terms of unconfined compressive strength. As a result chemical grouts can be injected into dam masses containing voids that are too small to be penetrated by cementitious or other contemporary grouts containing suspended solid particles. This enhances the residual strength of the dam structure.

v. Chemical Grouts, once reacted, become a material analogous to sandstone and hence have no detrimental effect on the soil and ground water and hence totally green material. It has great binding factor.

vi. Chemical grouting improves the physical properties of soil significantly. Direct shear tests, California bearing ratio and falling head permeability tests[7] have shown substantial improvement which are directly useful for the strengthening of the Dam along with seepage control.

vii. Latest observations done by Dam Safety Organization (DSO) at the end of 6 years found to be without any seepage based on the conditions in the inspection gallery. DSO does the inspection visually and the permeability trials are mandatory only in the case of seepage.

viii. Finally important observation about reduction in carbon footprint. Scientists, industries and other stake holders have understood the meaning, impacts and interrelated trade offs meant by the term “Water-Energy nexus”.

Raw water collection, treatment and supply of drinking water, collection and treatment of waste water, final disposal of the treated waste water and the resultant sludge, altogether contribute to GHG emissions.

All the equipments in various operations are operating on power throughout the year on 24 hours basis. Hence the power consumption is the major source of carbon emissions.

xi. For example 13% electricity in the US is used for water related operations.

It is reported that every cubic meter of water consumed is responsible for 10.6kgs of carbon emissions which in other words means every cubic meter of water lost unused entails the unnecessarily accounted avoidable carbon footprint.

In the present case at the annual loss of 220,000 m^3 of water before the treatment of the dam, the corresponding carbon footprint due to loss was somewhere in the range of 2 millions plus kilograms of CO_2 emission. The same was saved in last 6 years of successful operation post nano grouting treatment. This amounts to avoiding of whopping 14 million kilograms of CO_2.

xii. The possible cumulative magnitude when extrapolated across the geographies depends on number of old dams in respective countries.

It will be an astronomically larger number and impact on ENVIRONMENTS - which is avoidable.

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