Effective Analysis and Usefulness of Dam Health Investigations

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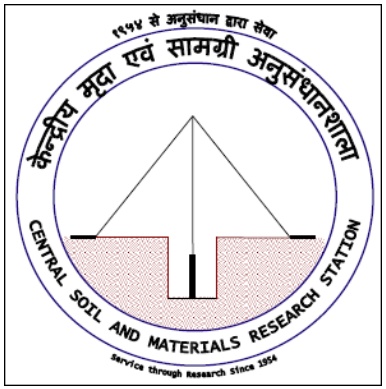

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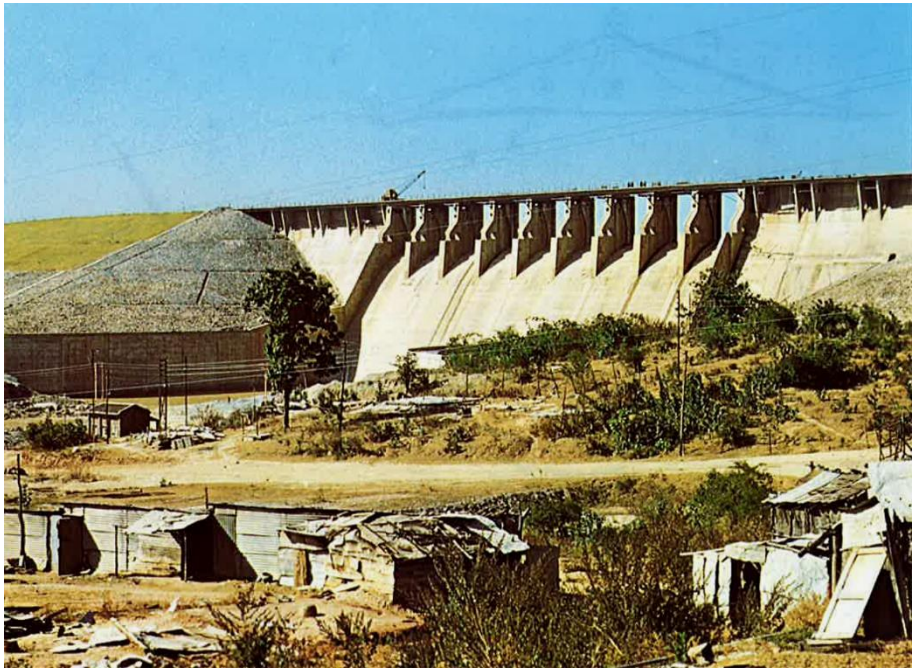
Present Study

The concrete health assessment analysis in few inspection galleries of an old dam works where minor degradation and water seepage observed (primarily from the top surface of the gallery), is presented in this study.

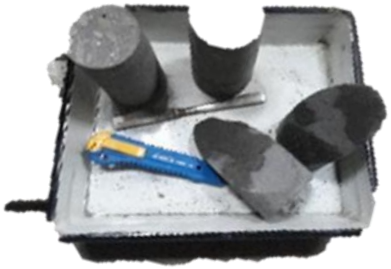


Investigations

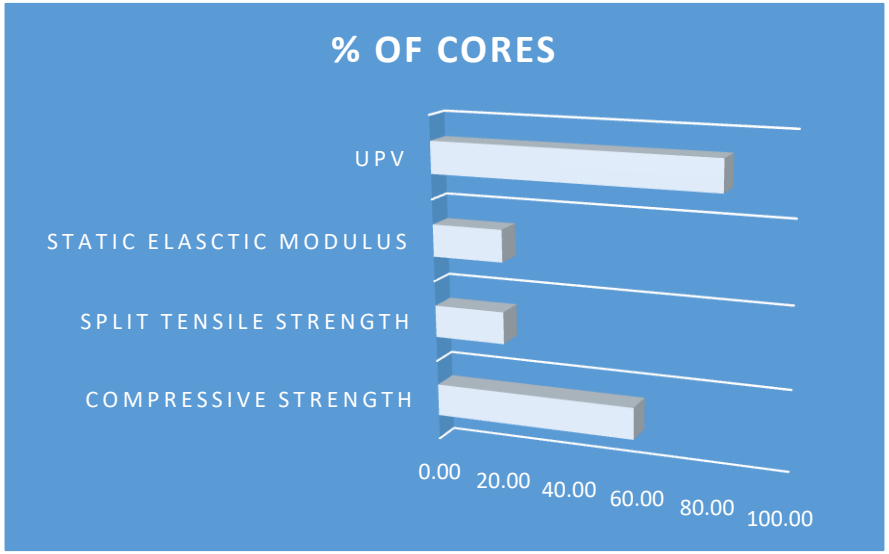
To assess the quality and strength of the concrete, NDT methods like visual examination, reading through blueprints, measuring ultrasonic pulse velocity (UPV) were utilized.

Compressive strength, splitting tensile strength, elastic modulus, density, were all determined via core testing.

Investigation-statics



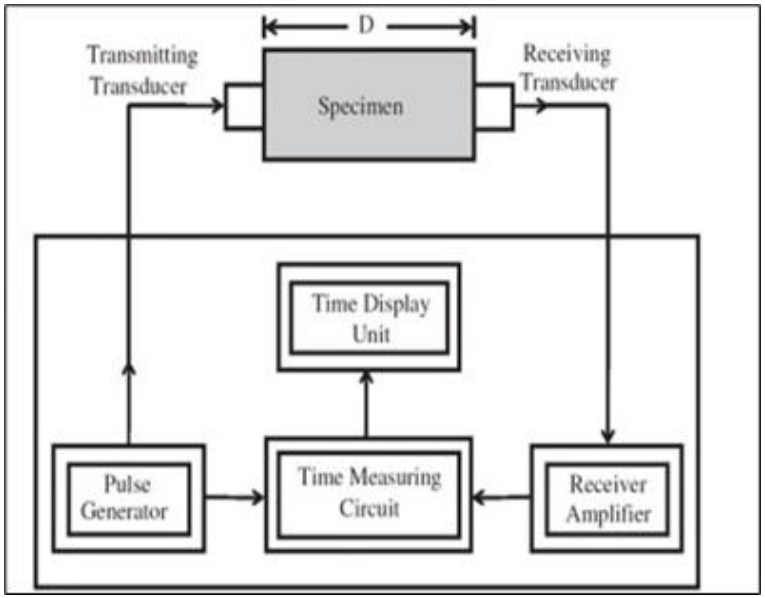
- Due to the structural issues in anticipation, limited number of cores could be extracted.
- The extracted cores range in size from 175 to 315 mm in length (l/d ranging from 2 to 3).
- The corelations were analysed in the light of established research findings.



Ultrasonic Pulse Velocity Tester (UPV)

UPV measurements on cores were performed in accordance with IS 516 (Part 5/Sec 1) and ASTM C 597 by positioning the probes (24 kHz) directly on opposing faces of the core.

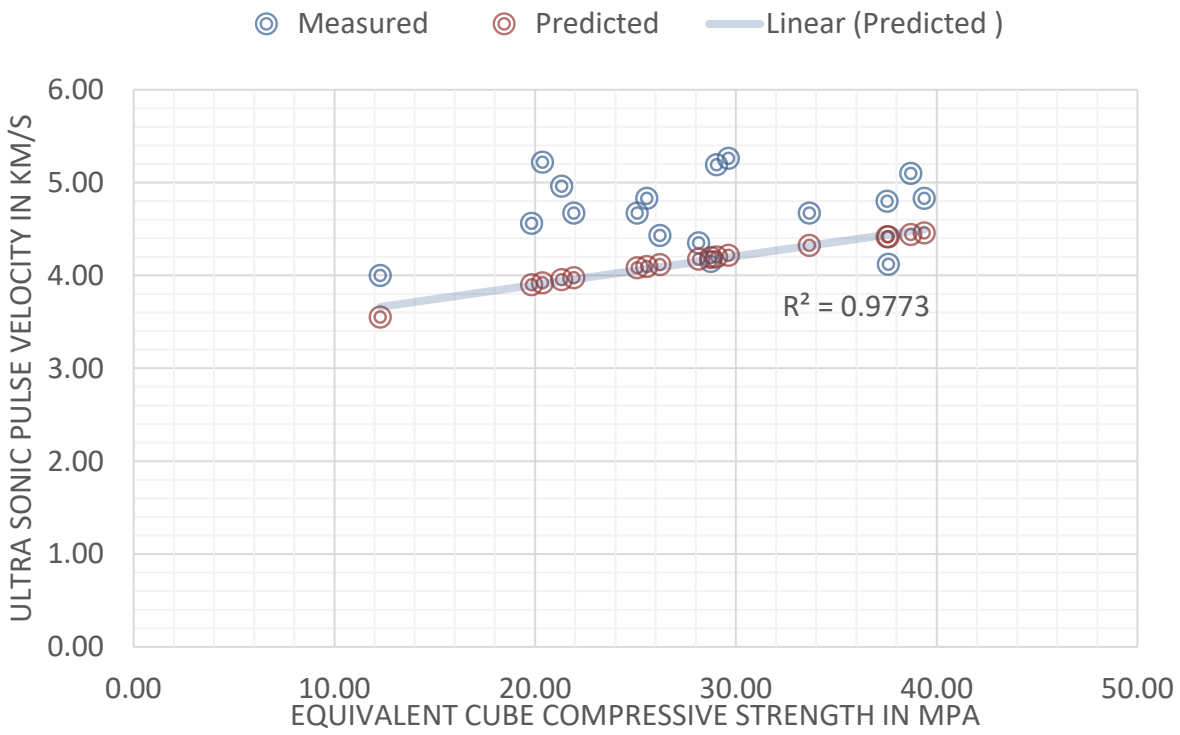
P-wave Transducers					
24 kHz Ø50 mm x 95 mm		154 mm	≈ 77 mm	154 mm	» Concrete: Very coarse aggregate and large objects (several meters)
54 kHz Ø50 mm x 46 mm		68.5 mm	≈ 34 mm	69 mm	» Concrete » Wood » Rock
150 kHz Ø28 mm x 46 mm		24.7 mm	≈ 12 mm	25 mm	» Fine grained material » Refractory bricks » Rock (NX cores)
250 kHz Ø28 mm x 46 mm		14.8 mm	≈ 7 mm	15 mm	» Fine grained material » Refractory bricks » Rock » Use on small samples
500 kHz Ø57 mm x 32 mm		7.4 mm	≈ 3 mm	7 mm	» Fine grained material » Refractory bricks » Rock » Use on small samples
54 kHz Ø50 mm x 100 mm		68.5 mm	≈ 34 mm	69 mm	» Concrete: Rough and rounded surfaces (no couplant required) » Wood » Rock (heritage sites)



$V = 2178.7 f_{ck}^{0.1948}$ Hong's Equation(2014)

Where V = Ultrasonic Pulse Velocity in km/s

f_{ck} = Compressive strength in MPa



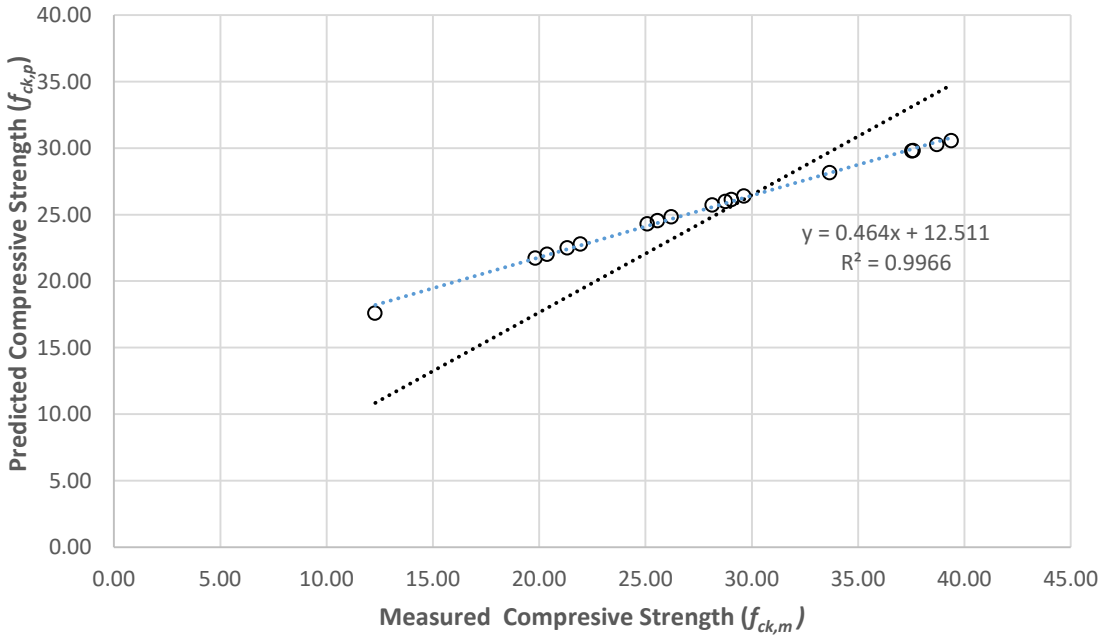
The measured mean pulse velocity of the cores was 4.72 km/s, which is considered to be "excellent."

Eq. Cube Compressive Strength (IS 516, IS 14858)

Statistical Summary of Equivalent Cube Compressive Strength (in MPa)

Maximum:39.39; Minimum: 12.29; Mean:27.95;Standard Deviation:7.643; COV:27.34%

Rouf's et al equation: $f_{ck} = 2.016 \exp(0.61V)$

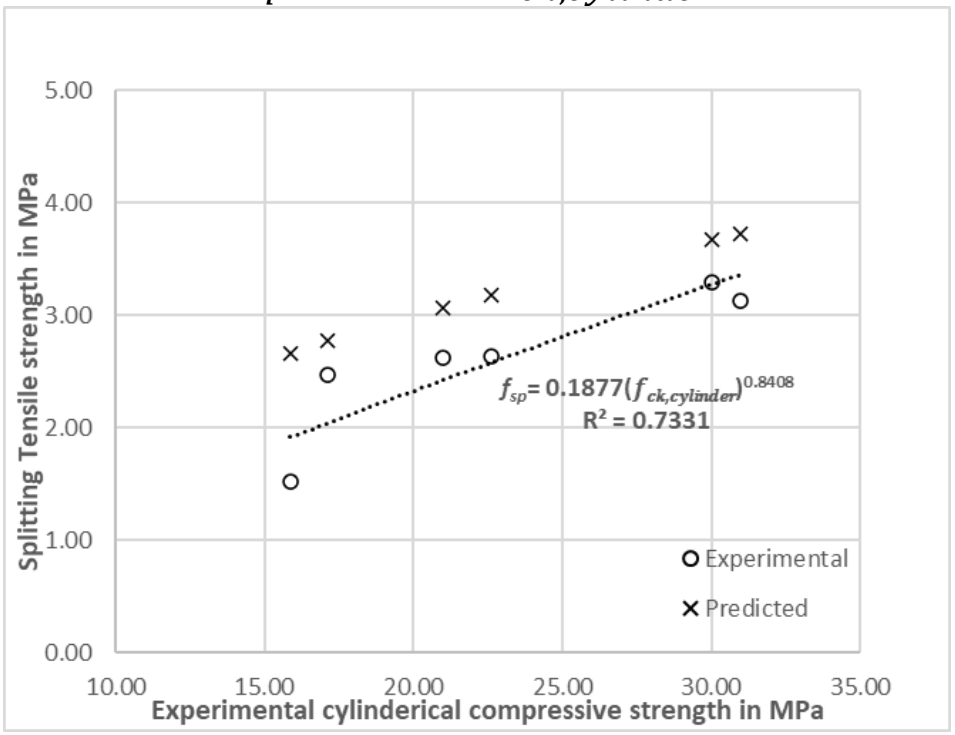


Split Tensile Strength (IS 5816, IS 14858)

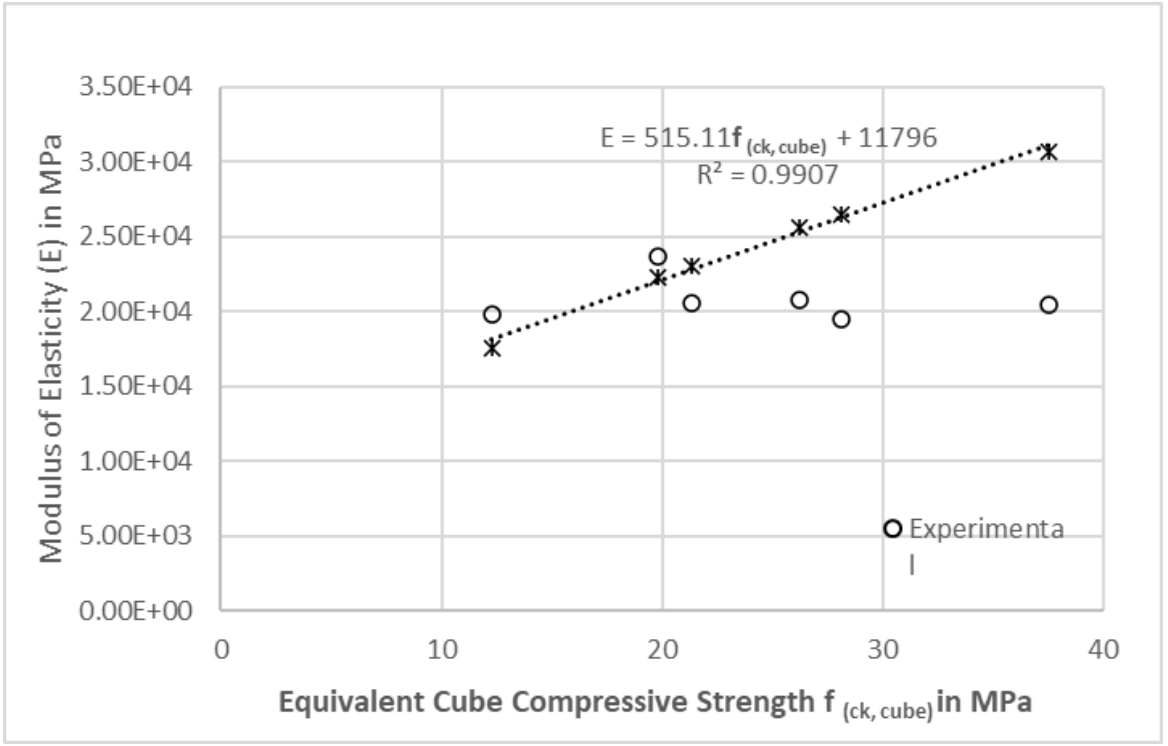
Statistical summary of split tensile strength (in MPa)

Maximum: 3.30; Minimum:1.53; Mean:2.62; Standard Deviation:0.622; COV:23.77%

As per ACI 318-2014: $f_{spt} = 0.67\ (f_{ck,cylinder})^{0.5}$



Modulus of Elasticity (IS 516)



Entity (MoE)	All Cores (GPa)
Maximum	23.7
Minimum	19.5
Mean	20.8
Standard Deviation	1.50
Coefficient of Variation (COV)	7.20%

Entity (Density)	All Cores (Kg/cum)
Maximum	2440
Minimum	2260
Mean	2363
No. of Cores	24
Standard Deviation	47.956
Coefficient of Variation (COV)	2.03%

Results and Discussion

- ✓ The present study focuses on combination of non-destructive and destructive investigations to have a fair idea of dam health.
- ✓ The mean value of UPV provides a good estimate of concrete quality, which can be termed as excellent following the acceptance criteria.
- ✓ The density test findings show that the calculated mean density falls roughly within the range of typical concrete.
- ✓ The experimental split tensile strength varied linearly with respect to the cylindrical compressive strength.
- ✓ It was also envisaged to establish a correlation between modulus of elasticity versus predicted and experimented values of eq. cube compressive strength. However, the experimental test values of modulus of elasticity showed variations more than permissible limits w.r.t. predicted values.
- ✓ Though, it is important to notice that a better linear variation was observed while comparing the predicted UPV (as per Hong's equation) versus experimental UPV to eq. cube compressive strength.

Conclusion

- To reinforce the investigations and accuracy of collected data, the experimental data has been compared and analyzed in the light of established correlations, empirical formulas and established findings of other researchers.
- The present investigations and analysis of test results facilitated the project authority to have a better outlook on existing concrete properties like compressive strength, tensile strength modulus of elasticity and density. The test results obtained by these investigations could be utilized to establish mathematical model for repair and rehabilitation program.
- Exhaustive investigation of old structures is required before taking up repair and rehabilitation of the structure, as huge fund is involved in the work. To reinforce the investigative analysis subject to availability of cores, additional investigations including the **DIN water permeability test, rapid chloride penetration test, cut and pull-out test, corrosion monitoring** etc. could also be performed.

INCOLD
Indian National Committee on Large Dams

INTERNATIONAL DAM SAFETY CONFERENCE

DRIP
Dam Rehabilitation & Improvement Project

Central Water Commission

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