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Assessment of Aging Deterioration of Concrete using Portable Ultrasound Non-Destructive Digital Indicator Tester

NV Mahure
Email: nvmahure@nic.in

Pankaj Sharma
Email: pan2256@gmail.com

Sameer Vyas
Email: samyog78@yahoo.com

Anil Rustagi
Email: akrus1960@yahoo.co.in

BK Munjani
Email: bkmunzni@nic.in

Murari Ratnam
Email: director-csms@nic.in

Abstract **– Interactions of concrete with persistent prevailing environmental conditions will alter its material properties and cause deteriorations. Such phenomenon are very common in various elements of dams. Diagnosis of the residual strength of aging concrete of these elements necessitates their periodic health monitoring. For this purpose imaging the status of concrete using ultrasonic pulse velocity technique provides useful diagnostic tool for adopting suitable preventive measures. To monitor the effect of aging on post construction performance of concrete periodic investigations were carried out in the gallery of a hydroelectric project exposed to sulphate aggressivity. Based on visual status of concrete three different test locations were identified both on upstream as well as downstream faces of galleries and test points were en-marked. Ultrasonic pulse wave velocity across these points were observed initially in year 2008 and subsequently in year 2013. Based on these observations a comparative evaluation of residual strength is assessed which indicates aging deterioration.**

Keywords **– Concrete, Aging, Diagnostic Tool, Ultrasonic, Non-Destructive.**

I. INTRODUCTION

Aging of concrete structures and their interactions with persistent prevailing environmental conditions will alter the material properties and cause deteriorations (Fig.1).

Status 2008 Status 2013 Status 2008 Status 2013
a) Developmentof Cracks b) Exposed Reinforcement

Status 2008 Status 2013 Status 2008 Status 2013
c) Brown Patches d) Enhancement of Leaching

Fig.1. Deteriorations in concrete

In such situations instant diagnosis of problem in insitu conditions becomes mandatory. Diagnosis of the residual strength of concrete and its constant monitoring will provide useful information for adopting suitable preventive measures [4, 5, 9]. Selection of proper test method and applying it in modest way is the key factor to study the status of concrete. Using non-destructive tests (NDT) in diagnosis of defects in concrete is an efficient and versatile monitoring technique which can be safely applied in any field conditions [1, 8]. Quality of concrete can be evaluated using ultrasonic pulse velocity technique which is a NDT method of testing [2]. For assessing insitu deterioration indirect transmission of ultrasonic pulse velocity (UPV) is applied. In this method ultrasonic stress waves are propagated between two points located on the same surface. It uses the basic principle of determining time taken by an irrational pulse to travel a known distance through a concrete [3]. UPV is influenced by status of concrete [6, 7].

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II. METHOD ADOPTED

A. Ultrasound Non-destructive Test

Through an indirect transmission mode, as illustrated in Fig. 2, ultrasonic pulse velocities were measured by a commercially available Portable Ultrasound Non-destructive Digital Indicator Tester (PUNDIT) with an associated transducer pair. The nominal frequency of the transducers used for testing concrete sections is 54 kHz. The principle of ultrasonic pulse velocity measurement involves sending a wave pulse into concrete by an electro-acoustical transducer and measuring the travel time for the

Fig. 2: Indirect Transmission Mode
(T: Transducer, R: Receiver)

pulse to propagate through the concrete. The pulse is generated by a transmitter and received by a similar type of receiver in contact with the other surface. In the experimental studies, UPV across the en-marked points

was observed initially in year 2008 and subsequently in year 2013.

The concrete surface was prepared for a proper acoustic coupling by applying grease. Light pressure was applied to ensure firm contact of the transducers against the concrete surface. Knowing the path length (L), the measured travel time between the transducers (T) can be used to calculate the pulse velocity (V) using the formula V = L/T. Based on the UPV the status of concrete is assessed

Velocity Criterion for Concrete Quality Grading as per IS 13311 (Part I), 1992 Table 2

Pulse Velocity by Cross Probing, Km/sec	Concrete Quality Grading
Above 4.5	Excellent
3.5 to 4.5	Good
3.0 to 3.5	Medium
Below 3.0	Doubtful*

*According to IS 13311 (Part I), 1992, in case of doubtful quality of concrete it may be necessary to carry out further tests.

III. Equipment Used

A Portable Ultrasound Non-destructive Digital Indicator Tester (PUNDIT)

PUNDIT (Fig. 3) was used to observe the time of travel of ultrasonic wave between two fixed point at a specified distance. Waves are generated through one transducer and received by another transducer.

Fig.3. Portable Ultrasound Non-destructive Digital Indicator Tester Equipment (PUNDIT)

IV. Observations

Investigations were carried out at 3 locations selected on the basis of various visual defects (Table 1).

Table 1: Details of Test locations

Location	Face	Year	Number of observation points	Presentation of Observations
A	US	2008	50	Fig 4, 5
		2013	50	
	DS	2008	50	Fig. 6, 7
		2013	50	
B	US	2008	50	Fig. 8, 9
		2013	50	
	DS	2008	50	Fig. 10, 11
		2013	50	
C	US	2008	50	Fig. 12, 13
		2013	50	
	DS	2008	50	Fig. 14, 15
		2013	50	

V. Result and Discussion

Legend used in graphical presentations

- UPV in Year 2008
- UPV in Year 2013
- ----- Below 3 Doubtful Status of Concrete
- ----- Between 3 to 3.5 Medium Status of Concrete
- ----- Between 3.5 to 4.5 Good Status of Concrete
- Above 4.5 Excellent Status of Concrete

A. Location A

The results of UPV recorded in year 2008 and year 2013 for scanned area on upstream face of gallery is presented in Fig. 4. Based on the observed UPV the overall status of concrete in year 2008 and year 2013 is presented in Fig. 5.

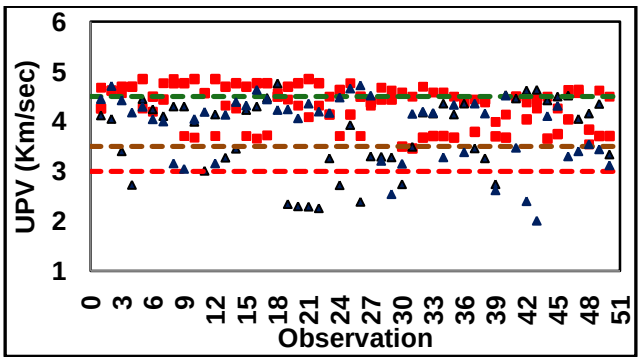
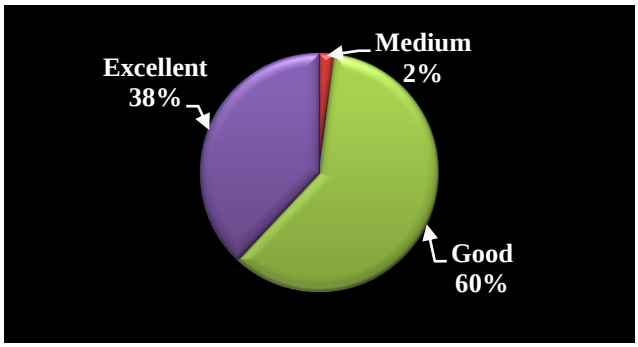
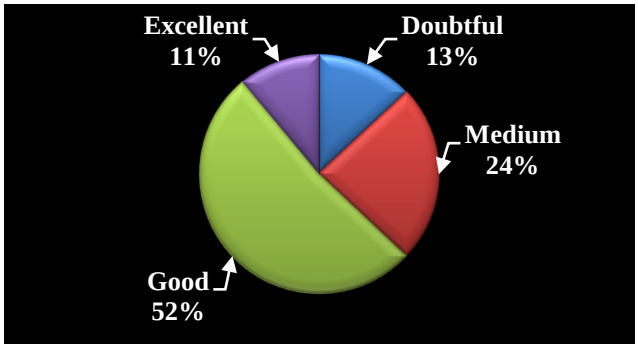


Fig.4. UPV - Upstream Face



In Year 2008



In Year 2013

Fig.5. Status of Concrete on Upstream Face

On visualising Fig. 5 it is clearly evident that in the scanned area on the upstream face concrete has undergone deterioration.

The results of UPV recorded in year 2008 and year 2013 for scanned area on the downstream face of gallery is presented in Fig. 6. Based on the observed UPV the overall status of concrete in year 2008 and year 2013 is presented in Fig. 7.

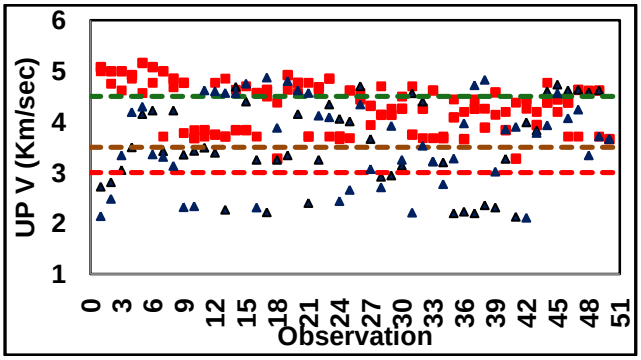
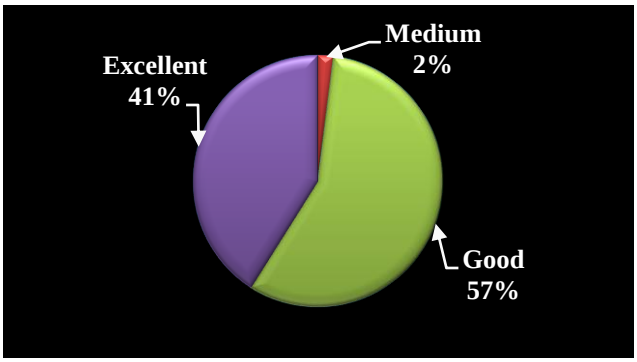
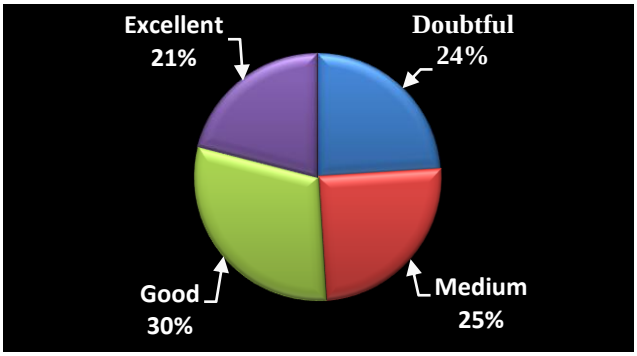


Fig.6. UPV – Downstream Face



In Year 2008



In Year 2013

Fig.7. Status of Concrete on Downstream Face

On visualising Fig. 7 it is clearly evident that in the scanned area on the downstream face concrete has undergone deterioration

B. Location B

The results of UPV recorded in year 2008 and year 2013 for scanned area on upstream face of gallery is presented in Fig. 8. Based on the observed UPV the overall status of concrete in year 2008 and year 2013 is presented in Fig. 9.

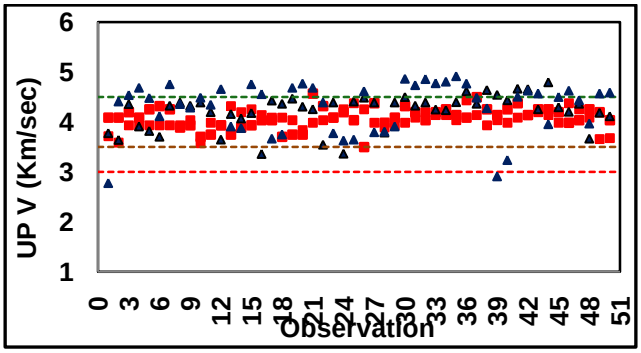
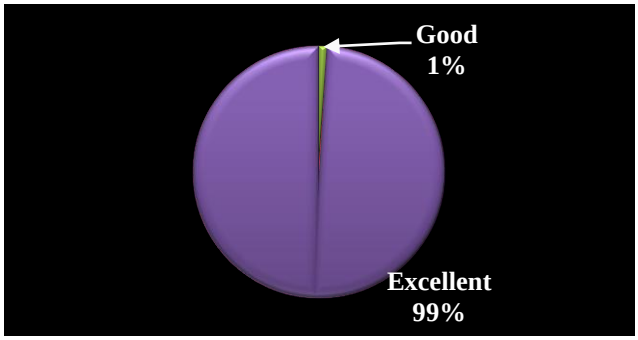
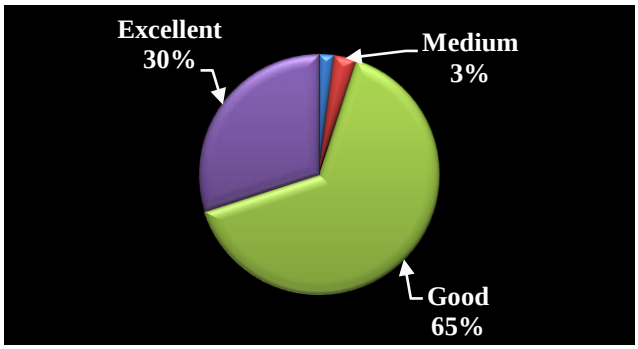


Fig.8. UPV - Upstream Face



In Year 2008



In Year 2013

Fig.9. Status of Concrete on Upstream Face

On visualising Fig. 9 it is clearly evident that in the scanned area on the upstream face concrete has undergone deterioration.

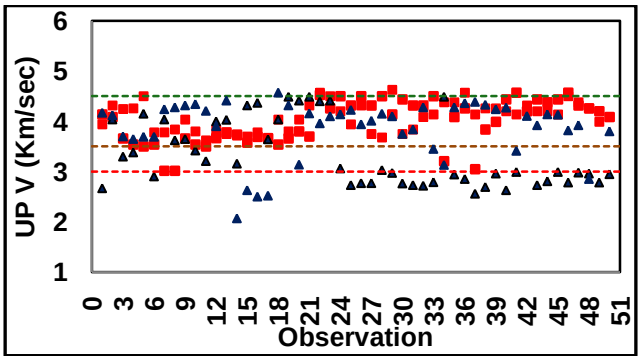
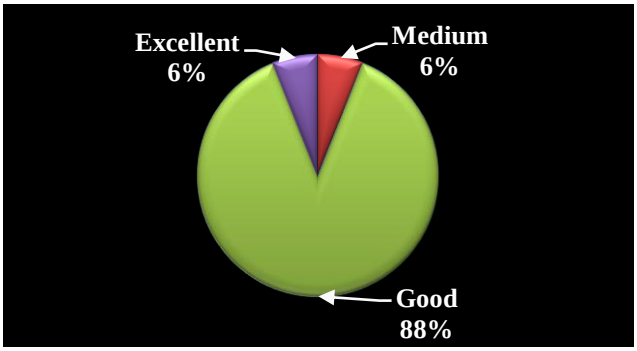
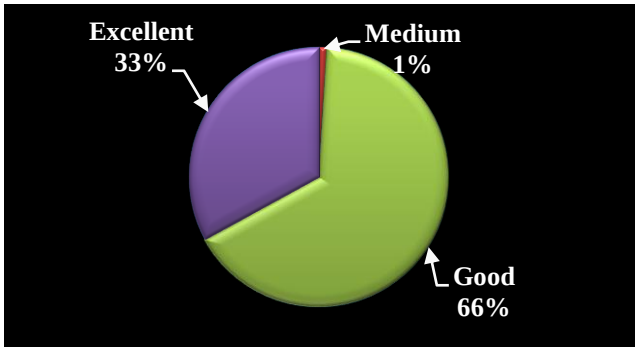


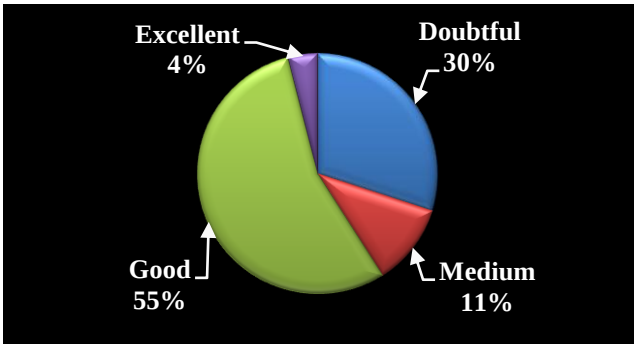
Fig.10. UPV – Downstream Face



In Year 2008

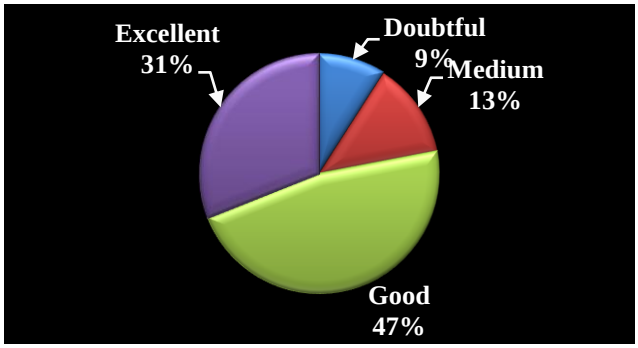


In Year 2008



In Year 2013

Fig.11. Status of Concrete on Downstream Face



In Year 2013

Fig.13. Status of Concrete on Upstream Face

The results of UPV recorded in year 2008 and year 2013 for scanned area on the downstream face of gallery is presented in Fig. 10. Based on the observed UPV the overall status of concrete in year 2008 and year 2013 is presented in Fig. 11. On visualising Fig. 11 it is clearly evident that in the scanned area on the downstream face concrete has undergone deterioration.

C. Location C

The results of UPV recorded in year 2008 and year 2013 for scanned area on upstream face of gallery is presented in Fig. 12. Based on the observed UPV the overall status of concrete in year 2008 and year 2013 is presented in Fig. 13. On visualising Fig. 13 it is clearly evident that in the scanned area on the upstream face concrete has undergone deterioration.

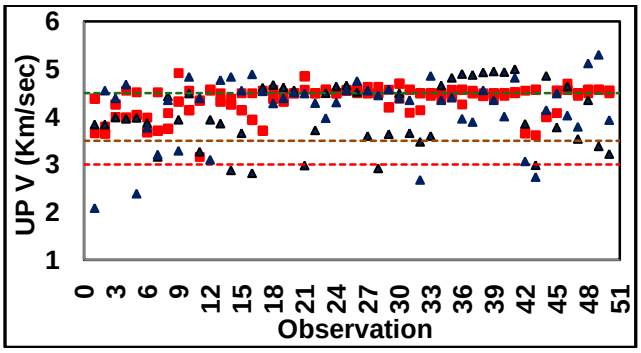


Fig.12. UPV - Upstream Face

The results of UPV recorded in year 2008 and year 2013 for scanned area on the downstream face of gallery is presented in Fig. 14. Based on the observed UPV the overall status of concrete in year 2008 and year 2013 is presented in Fig. 15.

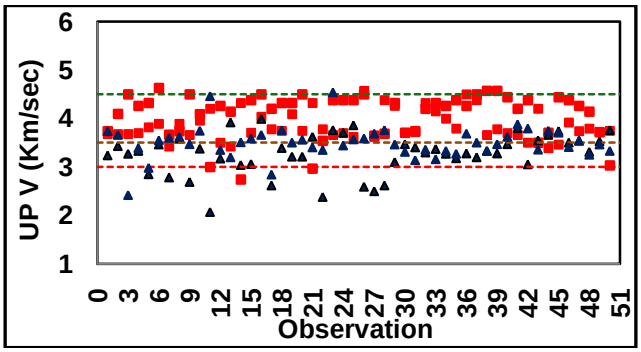
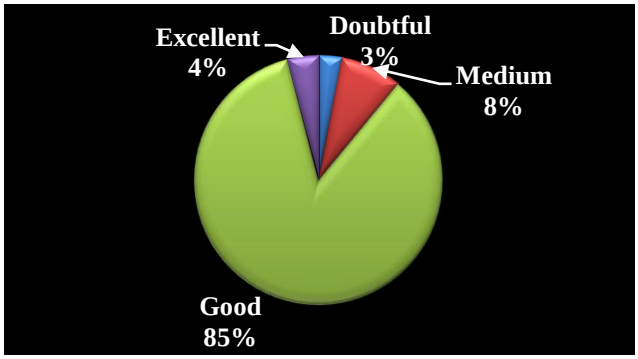
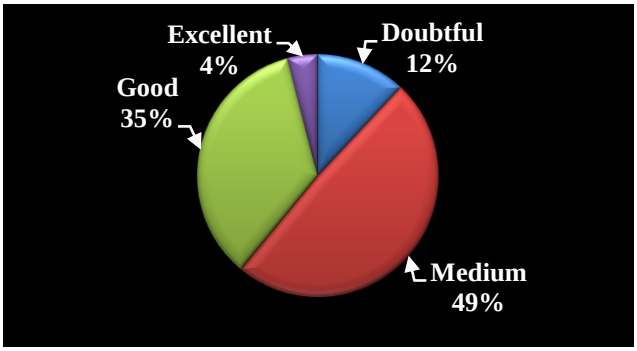


Fig.14. UPV – Downstream Face



In Year 2008



In Year 2013
Fig.15. Status of Concrete on Downstream Face

On visualising Fig. 15 it is clearly evident that in the scanned area on the downstream face concrete has undergone deterioration

VI. Conclusion

Interactions of concrete with persistent aggressive environmental conditions will alter its material properties and cause deteriorations. Diagnosis of the residual strength of aging concrete necessitates its periodic health monitoring. Ultrasonic pulse velocity technique provides useful and an efficient diagnostic tool for imaging the status of concrete. The outcome of the investigation clearly reveal the effect of aggressive hydro-environment causing aging deteriorations of concrete in a period of almost 5 years.

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Author’s Profile

NV Mahure
Age 52 years. 25 years research experience in the field of civil engineering with special reference to concrete, concrete chemistry and environmental impacts on concrete structures. Presently working as a Senior Scientist at Central Soil and Materials Research Station, New Delhi. Have 80 technical papers to his credit in various national and international journal and conferences. Permanent member of ISCMS.