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Structural Assessment and Long-Term Durability Consideration of Concrete on Piers and Galleries of Chandil Dam Using Non-Destructive Test Method

S K Dwivedi[1], M Raja[2], C B Sarma[3], U S Vidyarthi [4]

[1]Scientist C, Central Soil and Materials Research Station, New Delhi, India
[2]Scientist D, Central Soil and Materials Research Station, New Delhi, India
[3]Scientist B, Central Soil and Materials Research Station, New Delhi, India
[4]Scientist E, Central Soil and Materials Research Station, New Delhi, India

Abstract:
Interaction of concrete with the persistent prevailing environmental condition will alter its material properties and cause deterioration. There are various causes of distress in the concrete structure, such as improper construction practices, post-construction expansion due to Alkali-Aggregate Reaction (AAR), corrosion of reinforcement, non-homogeneity of concrete, development of cracks due to shrinkage and thermal stresses, aging, etc., Such phenomena are very common in various elements of the dam.
The aging of concrete structures and their interactions with persistent prevailing environmental conditions will alter its material properties and cause deterioration. In spite of maintaining the best quality control, concrete may not behave as a homogeneous medium. Conducting any test in a modest way is the key factor for a true assessment of the status of the substratum. Diagnosis of the residual strength of concrete in in-situ conditions using non-destructive tests provides useful information for adopting suitable preventive measures. Deteriorations in the concrete can be broadly imaged using the ultrasonic pulse velocity technique. However, the results of ultrasonic pulse velocity depend on various factors. Such phenomena are very common in various elements of the dam.
Since prominent cracks were observed on the pier, hence the structural assessment of piers and drainage galleries of Chandil dam was required to check the quality of concrete. In this regard, Non-Destructive Tests (NDT) were conducted on piers and galleries of Chandil dam, Jharkhand, by using the Ultrasonic Pulse Velocity (UPV) method to assess the in-situ quality of concrete.

Keywords: Concrete, ultrasonic pulse velocity, non-destructive testing.

1.0 INTRODUCTION

Chandil dam is a part of Subernarekha multipurpose project. It has been constructed on the river Subernarekha near a small town called Chandil in Jharkhand state of India. The project is a tripartite initiative among the three eastern states, Jharkhand (earlier Bihar, West Bengal, and Orissa). The dam is about 720.10 meter long (of which earth part is of 300.10 meter long and the concrete part is of 420 meters long) and 56.5 meter height. The dam has a total storage capacity of 1963 hm^3. The main dam of project is located at Chandil and another reservoir is located at Icha, while two more barrages at Gauldih and Kharkai. The purpose of this project is for irrigation, industrial water, power generation and flood control. The view of Chandil dam including Subernarekha multipurpose project shown in Figure 1.

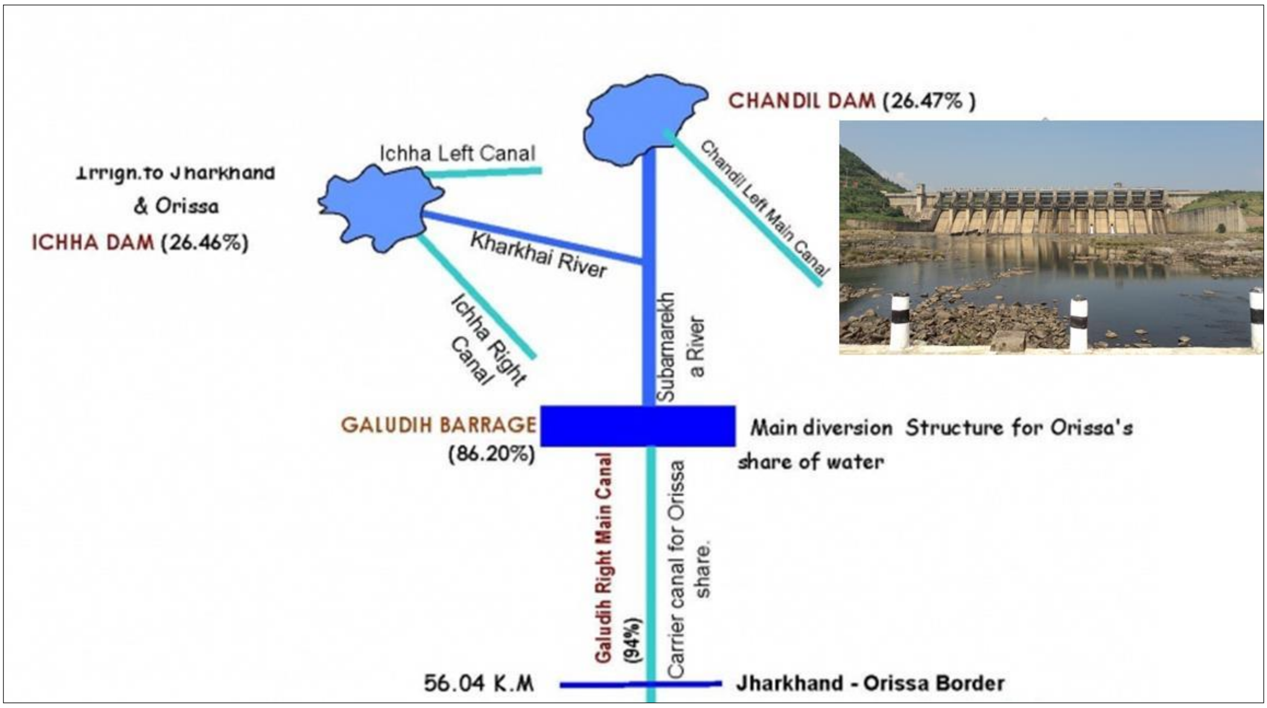


Figure 1: View of Chandil dam including Subernarekha multipurpose project

Non-destructive testing (NDT) can be applied to both old and new structures. For new structures, the principal applications are likely to be for quality control or the resolution of doubts about the quality of materials or construction. The testing of existing structures is usually related to an assessment of structural integrity or adequacy. In either case destructive testing alone is used by extracting cores for compression testing, this testing may only allow a relatively small number of tests to be carried out on a large structure which may be a chance of misleading the interpretation of results. Non-destructive testing can be used in those situations as a preliminary as an alternative core compressive strength.

As in the cases of distress to structures which are under construction and in-service have pose a problem to engineers who are associated with such structures. The various application of non-destructive testing is an assessment of the overall quality and strength of concrete, diagnosis, categorization of distressed structures, ascertaining the existing condition of the concrete, checking of efficiency of repairs, and other time-dependent studies. Hence, the need is felt to test the concrete in a structure in-situ by non-destructive testing to evaluate its condition for taking appropriate remedial measures for rehabilitation and restoration. This paper mainly covers the non-destructive testing of concrete on piers and drainage galleries of Chandil dam, Jharkhand by using the ultrasonic pulse velocity (UPV) method.

2.0 ULTRASONIC PULSE VELOCITY TEST

2.1 BASIC PRINCIPLES OF TEST

An electro-acoustical transducer in contact with one surface of the concrete under test generates pulses of longitudinal 'P' waves. A second transducer turns the vibrations pulse into an electrical signal after traveling a known path length (L) in the concrete. Electronic circuits allow the pulse's transit time (T) to be measured to be determined. The apparatus picture and pulse velocity measuring method is presented in Figure 2

V = L / T for direct transmission of pulse velocity

Where L = Path length and

T = Time

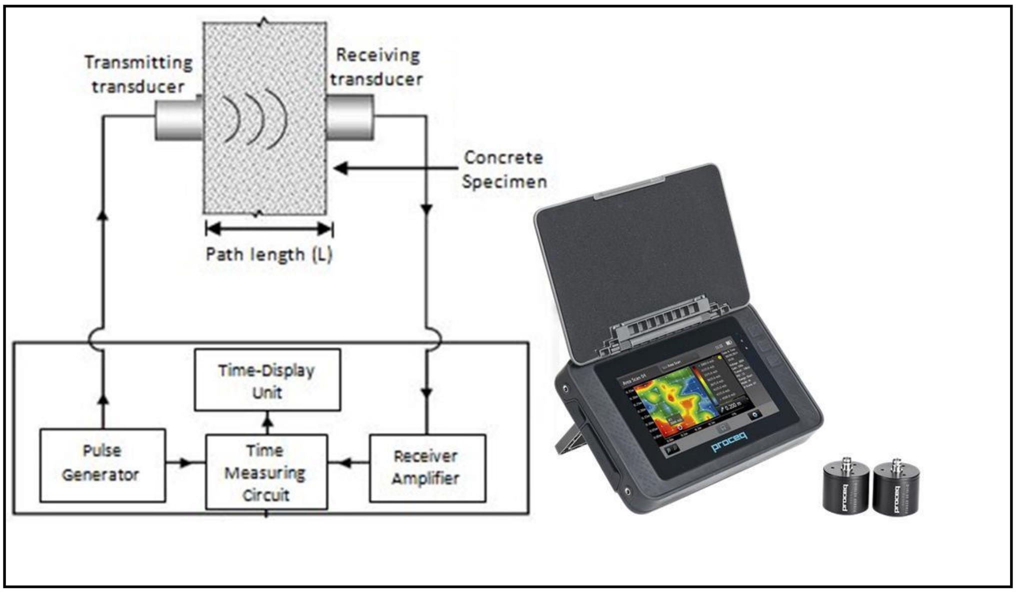


Figure 2: Ultrasonic pulse velocity test equipment (Proceq, Model- PL 200) and Pulse velocity measuring method

2.2 ACCEPTANCE CRITERIA

Ultrasonic pulse velocity tests have been employed extensively to evaluate the relative quality of in-situ concrete. It is a qualitative and relative test that does not provide the compressive strength of concrete. In general, high concrete pulse velocity readings indicate good quality.

Shocks in concrete caused by high discharge in the spillway through the gates affect ultrasonic pulse velocity readings in galleries. It is recommended to do this test during a lean period when there is either no or extremely low flow through the spillway. The following Table 1 lists the concrete quality evaluation criteria used in this study, which are recommended in IS 516 (Part 5/ Sec 1): 2018:

Table 1: Velocity Criterion for Concrete Quality Grading as per IS 516 (Part 5/ Sec 1):2018

Pulse Velocity by cross probing (km/sec)	Concrete quality grading
Above 4.40	Excellent
3.75 to 4.40	Good
3.00 to 3.75	Doubtful #
Below 3.00	Poor

In case of “Doubtful” it may be necessary to carry out further tests

3.0 PROGRAMME OF INVESTIGATION

The non-destructive tests using Portable Ultrasonic Non-destructive Digital Indicating Tester (PUNDIT, PL-200) by (Ultrasonic Pulse Velocity UPV) method were carried out on the concrete of three piers of the spillways and drainage gallery. The schematic view of pier and drainage gallery and their scanning locations are shown in Figure 3 and the number of points scanned is presented in Tables 2 and 3. Ultrasonic Pulse Velocity (UPV) tests were conducted by indirect and semi-direct methods of pulse transmission on the test points. The test points were marked on piers (i.e., Location 1: Column A, Location 2: Column B, Location 3: Between column A & column B, Location 4: Col. A (Right portion and its adjacent side) & Col. B (Left portion and its adjacent side) and drainage gallery (i.e., Location 1: U/s side, Location 2: D/s side and Location 3: Ceiling) at 30 cm center to center in horizontal and vertical path length. Measurements were taken horizontally (i.e., Row wise) and vertically (i.e., Column wise) on each pier and drainage gallery component using a path length of 30 cm.

In order to ensure proper acoustical coupling between the transducers and concrete surfaces, a thin layer of rich cement sand mortar was applied on each test point and a thin layer of ordinary grease was applied just before each measurement. Presented picture showing ultrasonic pulse velocity testing conducted on concrete at pier 1 and drainage gallery in Figure 4.

Table 2: Scanned locations on piers & number points and method adopted

S. No	Location of scanning	Method of testing/Material	No. of Points Scanned		
			Pier 1	Pier 2	Pier 3
1	Column A (Location1)	Indirect/RCC	44	46	42
2	Column B (Location 2)	Indirect/RCC	45	44	41
3	Between Col. A and Col B (Location 3)	Indirect/PCC	37	58	61
4	Col. A (Right portion and its adjacent side) and Col. B (Left portion and its adjacent side) (Location 4)	Semi direct/RCC	18	16	16

Table 3: Scanned locations on drainage gallery & number points and method adopted

S. No	Location of scanning	Method of testing/Material	No. of Points Scanned
1	Location 1	Indirect/RCC	44
2	Location 2	Indirect/RCC	22
3	Location 3	Indirect/RCC	33

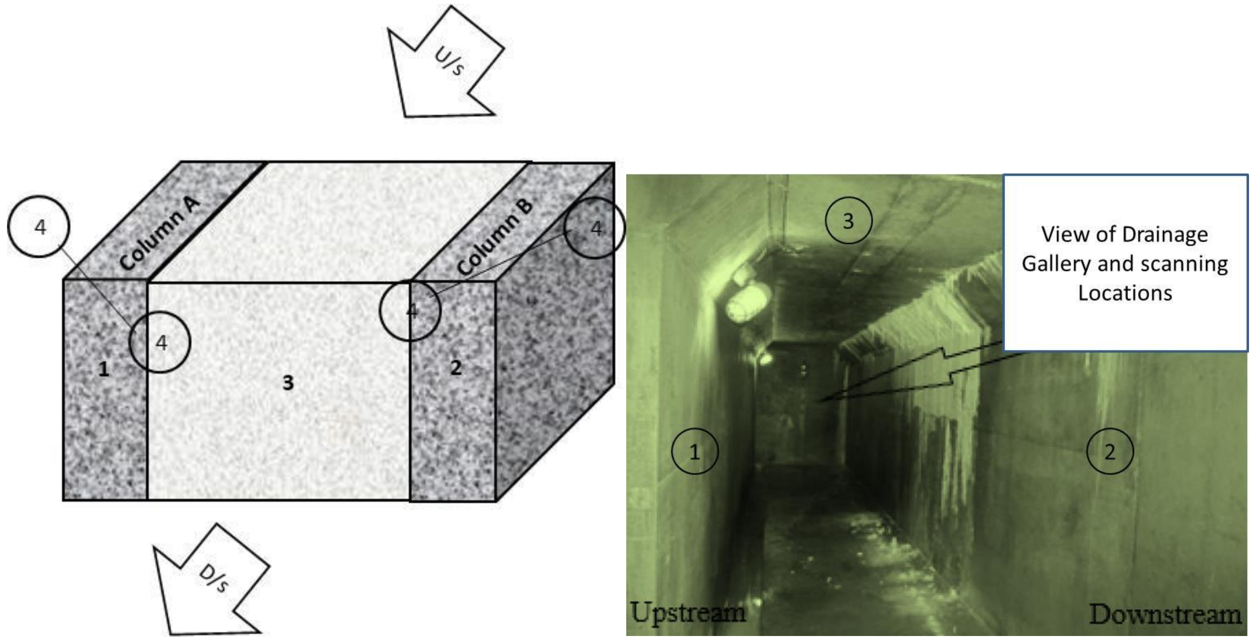


Figure 3: Scanning locations on pier and drainage gallery

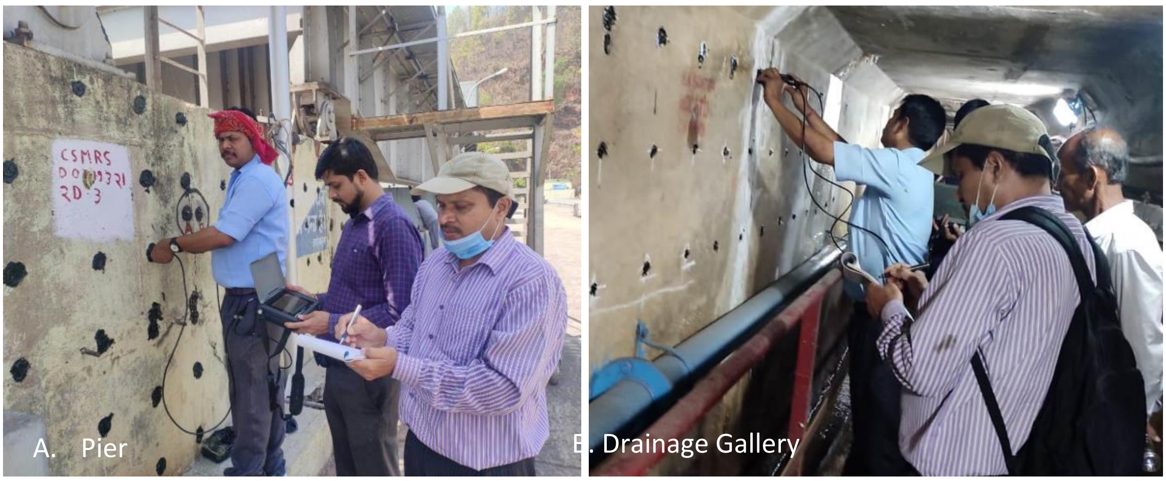


Figure 4: Ultrasonic Pulse Velocity Tests conducted on concrete of Pier 1 and Drainage gallery

4.0 DISCUSSION OF TEST RESULTS:

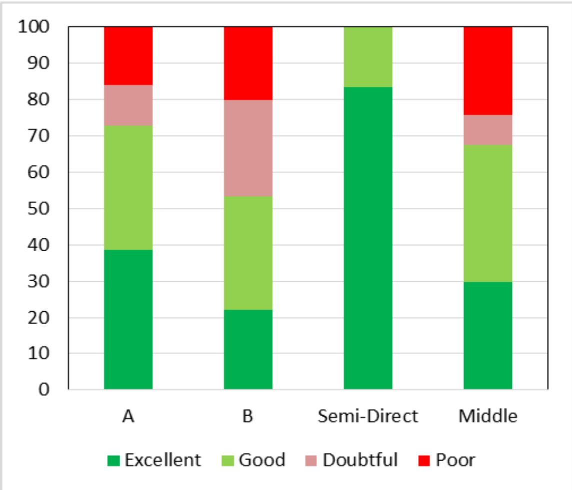
Ultrasonic Pulse Velocity (UPV) tests were conducted on the concrete of three piers and a drainage gallery, the results are summarized in Table 4 and a graphic representation of the quality categorization is illustrated in Figure 5.

At locations 1, 2, 3, and 4 on Pier 1, UPV testing was conducted 44, 45, 37, and 18 points, respectively. The four locations on pier 1 had an average velocity that varied between 3.55 km/second to 4.69 km/second and 53.3% to 100% of the test results were good to excellent.

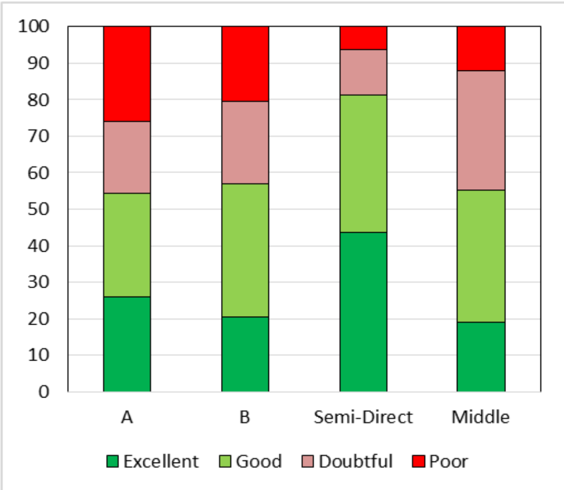
At locations 1, 2, 3, and 4 on Pier 2, UPV testing was conducted 46, 44, 58 and 16 points, respectively. The four locations on pier 1 had an average velocity that varied between 3.56 km/second to 4.27 km/second and 54.3% to 81.3% of the test results were good to excellent.

At locations 1, 2, 3, and 4 on Pier 3, UPV testing was conducted 42, 41, 61 and 16 points, respectively. The four locations on pier 1 had an average velocity that varied between 3.50 km/second to 4.29 km/second and 61.0% to 87.5% of the test results were good to excellent.

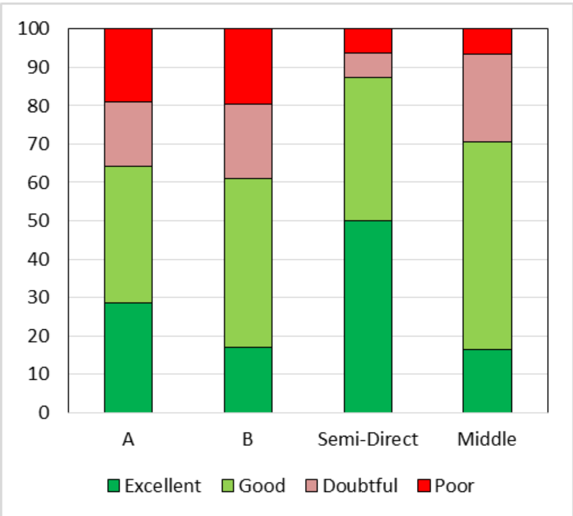
At locations 1, 2, and 3, the drainage gallery was scanned 44, 22, and 33 points, respectively. All three locations on the drainage gallery showed average velocities between 3.79 km/second to 4.14 km/second and 67.6% to 77.3% of the test results were considered good to excellent.



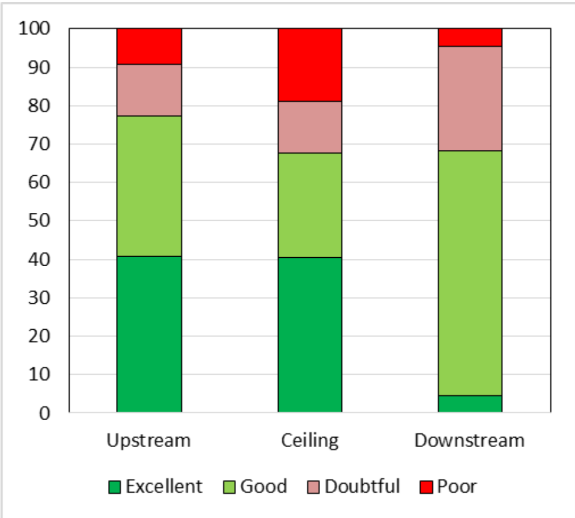
Pier 1



Pier 2



Pier 3



Drainage gallery

Figure 5: Ultrasonic pulse velocity tests results and categorization of the quality as per IS code of piers (1, 2 & 3) and drainage gallery

Table 4: Ultrasonic Pulse Velocity Tests of piers (1, 2 & 3) and drainage gallery

Structural Component	Location	No. of Scanned	No.of Points falling in category as per IS Code 516				Velocity (m/s)		
			Excellent	Good	Doubtful	Poor	Max	Min	Average
Pier 1	1	44	17	15	5	7	5795	1288	4082
	2	45	10	14	2	9	5604	623	3637
	3	37	11	14	3	9	5604	462	3553
	4	18	15	5	-	-	5174	4234	4696
Pier 2	1	46	12	13	9	12	5033	402	3563
	2	44	9	16	10	9	5249	432	3658
	3	58	11	21	19	7	5752	938	3773
	4	16	7	6	2	1	5197	2693	4271
Pier 3	1	42	12	15	7	8	5977	1758	3908
	2	41	7	18	8	8	4928	854	3506
	3	61	10	33	14	4	5075	2400	3911
	4	16	8	6	1	1	5042	2929	4291
Drainage gallery	1	44	18	16	6	4	5387	431	4144
	2	22	1	14	6	1	4454	2539	3790
	3	33	15	10	5	7	5514	1726	3964

5.0 CONCLUSION:

1. UPV test results of Pier 1 are falling from good to excellent in the range of 53.3% -100%, and 0.0% to 46.7% is doubtful to poor quality. The average velocity of locations 1, 2, 3 and 4 of pier 1 is around 3992 m/s.
2. UPV test results of Pier 2 are falling from good to excellent in the range of 54.3% -81.3%, and 18.8% to 45.7% is doubtful to poor quality. The average velocity of locations 1, 2, 3 and 4 of pier 2 is around 3816 m/s.
3. UPV test results of Pier 3 are falling from good to excellent in the range of 61.0% -87.5%, and 12.5% to 39.0% is doubtful to poor quality. The average velocity of locations 1, 2, 3 and 4 of pier 3 is around 3904 m/s.
4. UPV test results of drainage gallery are falling from good to excellent in the range of 67.6% -77.3%, and 22.7% to 32.4% is in doubtful to poor quality. The average velocity of locations 1, 2 and 3 of the drainage gallery is around 3966 m/s.

Acknowledgments

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