Stability Analysis of Machine Foundation By Non-Destructing Testing For Koradi Thermal Power Plant

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Abstract- *Non-destructive testing is a form of testing to be carried out on various construction members and materials without causing any permanent damage to them. As NDT is used in concrete, it can also be used very effectively for foundation members and materials. This paper covers case study of NDT on concrete as well as elements of foundation. Concrete has been used in construction industry for its compressive strength and for protection of reinforcement of steel. NDT is used to test concrete by two methods namely, surface testing technique and through testing technique. In surface testing Schmidt Hammer, pull out tester etc. are carried out and compressive strength is determined by using imperial formula or graph. In through testing technique ultrasonic pulse velocity, half-cell potential test etc. are the techniques are used.*

I. INTRODUCTION

It is often necessary to test concrete structure after the concrete has hardened to determine whether the structure is suitable for its designed use. Ideally such testing should be done without damaging the concrete. The test available for testing concrete range from the completely non- destructive, where there is no damage to the concrete, through those where the concrete surface is slightly damaged, to partially destructive tests, such as core tests and pullout and pull off tests, where the surface has to be repaired after the test. The range of properties that can be assessed using non-destructive tests and partially destructive tests is quite large and includes such fundamental parameters as density, elastic modules and strength as well as surface hardness and surface absorption, and reinforcement location, size and distance from the surface. In some cases it is also possible to check the quality of workmanship and structural integrity by the ability to detect voids, cracking and delamination.

Non- destructive testing 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 material or construction. The testing of existing structures is usually related to an assessment of structural integrity or adequacy. In either case, if destructive testing alone is used, for instance, by removing cores for compression testing, the cost of coring and testing may only allow a relatively small number of tests to be carried out on a large structure which may be misleading. Non-destructive testing can be used in those situations as a preliminary to subsequent coring.

Typical situation where non-destructive testing may be useful are as follows.

[1] Quality control of pre-cast units or construction in situ.
[2] Removing uncertainties about the acceptability of the material supplied owing to apparent non-compliance with specification.
[3] Conforming or negative doubt concerning the workmanship involved in batching, mixing, placing, compaction or curing of concrete.
[4] Monitoring of strength development in relation to formwork removal, cessation of curing, prestressing, load application or similar purpose.
[5] Location and determination of the extent of cracks, voids, honeycombing and similar defects within a concrete structure.
[6] Determining the concrete uniformity, possibly preliminary to core cutting, load testing or other more expensive or disruptive tests.
[7] Determining the position, quantity or condition of reinforcement.
[8] Increasing the confidence level of a smaller number of destructive tests
[9] Conforming or locating suspected deterioration of concrete resulting from such factors as overloading, fatigue, external or internal chemical attack or change, fire, explosion, environmental effects.
[10] Monitoring long term changes in concrete properties.
[11] Providing information for any proposed change of use of a structure for instance or for change of ownership.

II. BASIC METHODS FOR NDT OF CONCRETE STRUCTURE

The following methods, with some typical applications, have been used for the NDT of concrete.

[1] Visual inspection, which is an essential precursor to any intended non-destructive test. An experienced civil or structural engineer may be able to establish the possible cause of damage to a concrete structure and hence identify which of the various NDT methods available could be most useful for any further investigation of the problem.
[2] Schmidt/rebound hammer test, used to evaluate the surface hardness of concrete.
[3] Carbonation depth measurement test, used to determine whether moisture has reached the depth of the reinforcing bars and hence corrosion may be occurring.
[4] Cover meter testing, used to measure the distance of steel reinforcing bars beneath the surface of the concrete and also possibly to measure the diameter of the reinforcing bars.
[5] Ultrasonic pulse velocity testing, mainly used to measure the sound velocity of the concrete and hence the compressive strength of the concrete.
[6] Half cell electrical potential method, used to detect the corrosion potential of reinforcing bars in concrete.

III. TESTING AT KORADI THERMAL POWER STATION

ULTRASONIC PULSE VELOCITY TEST:A pulse of longitudinal vibration is produced by an electro-acoustical transducer, which is held in contact with one surface of concrete under test. When pulse generated is transmitted into concrete from transducer, it undergoes multiple reflections at boundaries of different material phases with concrete. A complex system of stress waves develop, which include both longitudinal and shear waves and propagate through concrete. The first wave to reach the receiving transducer is longitudinal waves, which is converted into electrical signal. The time required by the waves to pass through denser material is less and that through material which has less density would relatively none. Thus time required to pass through dense or well compacted concrete would be less as compared to the concrete specimen having high degree or porosity. IS 13311(Part-1),1998 mentioned the following concrete quality gradation and also mentions that in case of indirect probing the velocity is less as compared to the velocity that in case of direct probing and difference is 1Km/sec.

UPV Test: As discussed earlier, it is possible to arrange the transducer in 3 possible combinations.

1) Opposite faces(Direct probing)
2) Adjacent faces(Semi-direct probing)
3) Same faces(Indirect probing)

Before starting the test one has to first determine the method of probing and then proceed for marking the position on the surface of structure to be tested. These points are to be smoothened using carborandum stone/grinding wheel etc. Grease or liquid soap is applied to the points to ensure perfect contact of the transducer to the concrete surface. Grease is applied to transducer and their faces are connected to each other and a reading zero is set. Transducer is held at the previously marked positions and reading of time required to travel the pre-determined length is noted. Velocity (Km/sec) =Distance in mm/Time (us) for indirect method, the code mentions (Art. 5.1)"The Indirect velocity is invariably lower than direct velocity on the same concrete element. The difference may vary depending on the quality of concrete under test. For good quality concrete, a difference of about 1.0km/sec. May generally be uncounted.

REBOUND HAMMER TEST: I.S. 13311 (Part II), 1998 the rebound hammer is principally a surface hardness tester works on the principle that the rebound of an elastic mass depends on the hardness of surface against which the mass impinges. Rebound hammer test gives us a tentative idea about the surface strength of concrete. Is suggest a variation of 25% (between the strength of specimen tested by RBH and by convention method) as the results of RHB are affected by factors like surface and internal moisture, carbonation of concrete, age of concrete, type of aggregates etc. More moisture gives less rebound number more carbonation implies more rebound number etc. The hammer is pushed hard against concrete surface, the body of the hammer is allowed to move away from the concrete unit the latch connects the hammer mass to the plunger. The plunger is then held at right angles to the concrete surface and the body is pushed hard against the concrete. During the rebound, the slide indicator travels with the mass and stops at maximum distance the latch reaches after rebounding. With the help of button provided on the mass the reading is locked (also the plunger and the mass get locked).this reading is the rebound number. Testing can be done by holding the hammer at vertically upwards or downwards or at horizontal positions. The estimated compressive strength is obtained by reading the graph Rebound no. Vs. Compressive strength. Graphs are given for different positions in which is held. i.e. upwards, downwards and horizontal.

COVER TEST: The physical principle involved can either be by utilising eddy current effects or magnetic induction effects. Cover meters with magnetic induction, a multirole search head is used with lower operating frequency that the eddy current type device. In both type instruments, both the orientation and proximity of the metal to the search head affect the meter reading. It is therefore possible to locate reinforcing bars and determine their orientation. Set the cover reading displayed on the screen by involving the cover meter on a slab/column, whose reinforcement is open and measurable by tape. This process is calibration and can be done by pressing the re-calibration button provided on the instrument. Then the place instrument where the cover is to be measured. A beep is heard and a –ve sign is displayed on the left side of instrument and cover is read in inches and cms.

CARBONATION TEST: A small hole is drilled gradually about 5mm deep at a time with the help of electrically operated drill machine and the dust is collected on a non-absorbent, chemically inert sheet of metal or tile. A small quantity of phenolphthalein is sprayed on the dust. The minimum depth at which the colour changes (pink/purple) is the depth of carbonation. Theoretical depth of Carbonation can be derived as follows. $C = (y^{0.5} * R\ (4.6x-1.76))/\sqrt{7.2}$

Where,

C= carbonation depth
Y=age of building in years
X=water cement ration
R= α^{β} – depends upon the surface coating whether the concrete is in external or internal service system.

HALF CELL ELECTRIC POTENTIAL METHOD: Half cell electric potential method for assessing the risk of corrosion of reinforcing steel bars. In this method, the potential of an embedded reinforcing bar is measured as compared to a reference half cell placed on the concrete surface. Half cell is usually a copper sulphate cell. The concrete functions as an electrolyte and risk of corrosion of the reinforcement in the immediate region of the test location may be related empirically to the measured potential difference. The relevant code for this test is ASTMC 876-91.Risk of corrosion against potential difference readings.

Potential Difference (mv)	Chance of rebar being corroded
Less than -500	Visible evidence of corrosion
-350 to -500	95%
-200 to -350	50%
More than -200	5%

IV. SUMMARY OF TEST CONDUCTED

REBOUND HAMMER TEST: IS 13311PART II

16 readings were taken. The highest and lowest three are discarded. Ten are taken on record and average is taken. From the graph, the corresponding strength is evaluated. However, as per IS the actual strength could be +-25% of the value derived from the graph. To error on safer side, the estimated strength is chosen as value derived from the graph - 25%. Thus, estimated compressive strength is recorded (i.e. after deduction).

Sr. No	Details	Rebound No	Avg. Rebound no	Estimated Comp. Strength
1	TG Column U:5	52,50,50,56,54,56,54,52,52,54	53	51
2	TG Column U:6	52,44,56,44,48,52,46,54,40 42,43	52	49.5
3	TG Column U:7	52,54,54,54,52,48,50,52,52,50,50,54	52	49.5
4	PA Fan 6A	29,30,29,32,30,38,30,29,29,30	31	21.0
5	PA Fan 6B	29,29,29,35,34,36,36,29,34,29	32	21.5
6	PA Fan 5A	32,30,36,28,30,28,28,30,32,32	31	21.0
7	PA Fan 5B	32,34,30,28,28,34,30,32,30,28	31	20.25
8	ID Fan 6A	40,40,40,36,34,36,36,32,36,36	37	28.50
9	ID Fan 6B	32,38,36,32,32,34,34,40,36,34	35	25.5
10	FD Fan 7A	32,32,36,38,36,38,38,40,38,36	36	27.0
11	FD Fan 7B	36,34,36,32,32,40,46,46,38	37	28.50
12	CW Plant	42,44,48,46,38,40,40,40,44,42	42	34.50

COVER TEST

Sr. No	Details	Cover in mm	Minimum Cover
1	PA Fan 5A	62,55,50,55,60,55,50,50,50,50,55,65	45
2	FD Fan 5A	60,60,55,60,50,55,55,50,60,55	50

CARBONATION TEST (BASED ON ASTM – C-865)

Sr. No	Details	Depth Observed	Max. Depth
1	TG Columns	22,10,15,18,10,15,15,18,20,20	22
2	TG Columns	10,15,15,10,15,15,10,15,10,10	15
3	PA Fan 5A	50,45,40,40,40,50,40,40,45,40	50
4	FD Fan 5B	45,40,38,42,40,45,35,40,45	45
5	ID Fan 6A	15,10,10,10,22,20,18,15,18,20	22
6	ID Fan 6B	25,25,20,20,22,20,20,22,20,25	25
7	ID Fan 7A	20,25,25,30,25,30,25,20,20,25	30

ULTRASONIC PULSE VELOCITY TEST

Velocity Km/sec	Concrete gradation quality
Below 3.0	Doubtful
3.0-3.50	Medium
3.50-4.50	Good
Above	Excellent

PA Fan 5A (Indirect): Path Length 200mm

Sr. No	Points	Times (μ s)	Velocity (Km/sec)	Concrete quality gradation
1	1	92	3.17	M
2	2	90	3.22	M
3	3	94	3.12	M
4	4	66	4.03	G
5	5	82	3.43	M
6	6	98	3.04	M
7	7	80	3.50	G
8	8	70	3.85	G
9	9	98	3.04	M
10	10	96	3.08	M

FD Fan 5A Indirect: Path length 200mm.

Sr. No	Points	Times (μ s)	Velocity (Km/sec)	Concrete quality gradation
1	1	112	2.78	D
2	2	170	2.17	D
3	3	123	2.62	D
4	4	94	3.12	M
5	5	100	3.00	M
6	6	98	3.04	M
7	7	198	2.04	D
8	8	78	3.56	G
9	9	86	3.32	M
10	10	92	3.17	M

TG Column U-5 Direct: Path length 1000mm

Sr. No	Points	Times (μ s)	Velocity (Km/sec)	Concrete quality gradation
1	A1	246	4.06	G
2	A2	250	4.0	G
3	A3	282	3.54	G
4	A4	240	4.16	G
5	B1	250	4.00	G
6	B2	298	3.35	M
7	B3	295	3.38	M
8	B4	251	3.98	G
9	C1	248	4.03	G
10	C2	274	3.64	G
11	C3	258	3.87	G
12	C4	252	3.96	G
13	D1	240	4.16	G
14	D2	292	3.42	M
15	D3	292	3.42	M
16	D4	248	4.03	G

HALF CELL POTENTIAL TEST BASED ON ASTM – C- 876

Potential Difference (mv)	Chance of rebar being corroded
Less than -500	Visible evidence of corrosion
-350 to -500	95%
-200 to -350	50%
More than -200	5%

Sr. No	Details	Reading
1	RWP	-415,-375,-360
2	RWP	-300,-320,-470
3	Cooling Tower	-266,-296,-242
4	Cooling Tower	-304,-317,-342
5	Settling Tank (ETP)	-165,-148,-110

CONCRETE SAMPLE FOR CHEMICAL ANALYSIS

Parameter	Method Reference
P_H	I.S.456:2000 & APHA 21st Ed.2005,4500-H+-B
Total Acid Soluble Chloride (Cl)	I.S.456:2000 & USEPA/SW 846/9253
Total Water Soluble Sulphate (So_3)	I.S. 456:2000 & USEPA/SW 846/9038

Sr. No	Location	P_H	Total Acid Soluble Chloride (Cl) (g/kg)	Total Water Soluble Sulphate (So_3) (% by mass of concrete)
limit	......	.....	0.6kg/m^3 of concrete	4% by mass of concrete
1	PA Fan 5A	10.5	0.611	0.13
2	ID Fan 6B	11.9	0.532	0.051
3	PA Fan 7B	8.7	0.108	0.012
4	ID Fan 7B	10.3	0.192	0.030
5	ID Fan 5B	12.5	0.133	0.054
6	TG Column	12.3	0.133	0.023
7	B.F.P. Column	11.0	0.154	0.057

V. CONCLUSION

Rebound Hammer Test & Ultrasonic Pulse Velocity Test: The rebound test indicates the surface hardness and its results are rather indicative, hence the results are not be viewed independently and read along with UPV results, visual observations and general performance of the structure for its intended use. It may also be noted that the carbonated concrete shows higher rebound number whereas the moist concrete shows less rebound number. IS suggests a variation of ± 25%.PA fans, ID fan 5&6 appear to have lesser compressive strength. This could happen on account of the surface treatment, greasy surface etc. The UPV results show 'medium' grade concrete. The overall impression, based upon the tests indicates 'medium' quality gradation concrete and warrants no immediate attention. The test cannot be performed on those foundations, where the machine is running. The vibration of the machine causes interference and delivers exceptionally high results.

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[7] *ASTM –C- 876- For Half Cell Potential Test*