CONDITION ASSESSMENT AND FORMULATION OF STRATEGY FOR REHABILITATION OF INDUCED DRAUGHT COOLING TOWER (IDCT) WALLS

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Abstract

Concrete is considered as a durable material but it is still potentially vulnerable to deterioration, unless certain precautions are taken. Number of tests, either non-destructive testing (NDT) or partially destructive testing (PDT) are to be carried out to assess the extent of deterioration and to estimate the quality/strength of concrete, before formulating any repair measures. This paper discusses the condition assessment of induced draught cooling tower (IDCT) walls by non-destructive and partially destructive testing methods. The importance and significance of different tests employed to assess the present condition of IDCT walls are highlighted. The assessment consists of visual inspection, NDT & PDT using ultrasonic pulse velocity tester, IR Thermography, half-cell potential measurement, concrete powder sample collection, core samples extraction, etc. The in-situ investigations are planned in such a way that both qualitative and quantitative evaluation of the mechanical and durability parameters of the cooling tower (CT) walls of IDCT can be assessed. Based on the investigations and interpretation of test results, the prevailing condition of the IDCT walls has been evaluated. Repair and rehabilitation measures have been suggested to improve the quality and integrity of concrete which would enhance the service life of the wall panels of IDCT.

***Keywords**: Condition assessment, CT walls, deterioration, NDT, PDT, IRT, rehabilitation*

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1. INTRODUCTION

Concrete structures require a closer inspection, not only immediately after construction but also periodically at a regular interval. The quality control measures during construction generally consist of workability tests on fresh concrete and cube compressive strength of concrete samples after some specified days of curing. It is a well known fact that the results of the above tests do not reflect the true quality of the concrete existing in the structure because the quality of concrete in the structure depends on many factors such as method of mixing, transporting, placing, compacting and curing. While concrete members with certain amount of defects can satisfy the requirements relating to strength and serviceability, such concrete may not satisfy durability requirements. Assessment of quality of concrete is necessary to ensure that the quality of execution is satisfactory and also to identify any deficiencies so that they can be rectified. This can be achieved only by conducting some in-situ tests on the structures besides visual inspection. The in-situ tests are either non-destructive or partially destructive and have been developed with the primary objective of evaluating the condition of in-situ concrete[1,2]. Rebound hammer test, Pull-out and Pull-off tests, Ultrasonic pulse velocity (UPV) test, Core sampling and testing, Cover thickness survey, Carbonation test, IR Thermography, etc., are mostly used for the assessment of existing concrete structures[2-4]. It is to be noted that all non-destructive test methods have inherent strengths and weaknesses. The concrete is heterogeneous in nature, hence, the efficiency and quality cannot be established just by doing one single test[3]. It is often advantageous to use more than one method to make the reliable assessment. This paper discusses the condition assessment of induced draught cooling tower (IDCT) walls carried out by non-destructive testing (NDT) methods such as visual inspection, UPV, IR Thermography and partially destructive testing (PDT) methods such as core sampling, concrete powder sampling, half-cell potential measurements. The main aim of the paper is to highlight the importance and significance of different tests carried out to assess the present condition of CT walls. A strategy for repair and rehabilitation is also proposed to address the cause for dampness and to arrest the dampness in order to enhance the service life of the structure.

2. DESCRIPTION OF THE STRUCTURE

The IDCT is a nine cell reinforced concrete (RC) framed structure consisting of columns and beams. The main function of IDCT is to reduce the temperature of hot water stream by extracting heat from water and emitting it to the atmosphere[5]. The space between peripheral beams and columns is covered with RC walls of 130mm thickness and space between cells is covered with wall of 100mm thickness. M30 grade concrete was proposed to be used for construction of IDCT walls. Fig. 1 shows the typical photograph of IDCT. Seawater is being used for condenser cooling.

3. INVESTIGATIONS CARRIED OUT

During the visual inspection of IDCT, dampness is noticed on the outer face of the RC walls at many places between upper (water channel) and lower beams. Construction deficiencies are noticed and openings are found at junctions between RC wall and top beam. Number of patch repair works especially at shuttering lifts/joints and honeycombs at many places, uneven RC wall surface, etc. are noticed. In RC walls, the cover thickness to reinforcement is not uniform. At some places very low cover thickness (4-5mm) and rust stains are also observed. The poor quality of construction can be visually evidenced by non-uniform cross-section and cover thickness, exposure of the rebars, nonalignment of the column with the wall, etc. In view the observations during visual inspection, a comprehensive test programme is planned for the condition assessment of CT walls. The tests carried out are:

- Ultrasonic pulse velocity test for assessing the integrity and quality
- Core sampling and testing for water absorption and evaluation of compressive strength
- Carbonation test for the qualitative assessment of carbonation depth of concrete
- Half-cell potential and resistivity measurements to assess the activity of corrosion of rebars
- Concrete powder samples for quantitative estimation of chloride contents and
- Infrared Thermography (IRT) to identify the areas of seepage/dampness

3.1 Ultrasonic Pulse Velocity (UPV) Test

UPV test is basically a wave propagation test and consists of transmitting ultrasonic pulses of 54 kHz frequency from transmitting transducer to the receiving transducer through concrete medium and measuring the transit time. The equipment used is known as PUNDIT LAB+. UPV test has been carried out on grid points of selected RC wall portion in a systematic way. Transmit time is measured at each grid point and the velocity is calculated by dividing the thickness of the member by the transit time. Fig. 2 shows the UPV test in progress. Generally, UPV varies with the denseness of concrete, the presence of voids, cavities, cracks, etc. which affect the wave propagation resulting in lower pulse velocities.

3.2 Core Sampling and Testing

Concrete core samples are collected from different locations of the selected RC wall and Column using a portable core cutting machine. Fig. 3 shows the extraction of core from the RC wall. To determine the effect of carbonation, 1.0% phenolphthalein solution is sprayed on to the extracted core samples at site[7]. Later, the extracted core samples are dressed in the laboratory using the concrete cutting machine. After dressing, water absorption and the compressive strength of the cores are determined in the laboratory. The core compressive strength is corrected for its height to diameter ratio. The equivalent cube strength is obtained by multiplying with the value 1.25.

3.3 Electrochemical parameters

Corrosion is basically an electrochemical phenomenon, measurements of electrochemical parameters such as half-cell potential and resistivity of concrete are helpful to identify the proneness of corrosion of rebars[3,11]. In this investigation, half-cell potentials with reference to copper-copper sulphate electrode are measured for selected members. Also, concrete resistivity measurements are made with Wenner four probe resistivity meter and typical resistivity measurement is shown in Fig. 4. The powder samples are also collected from different locations and the chloride content present in the concrete is determined in the laboratory.

3.4 IR Thermography (IRT) Imaging

In the present investigation, IR thermography is carried out on the identified wall panels, before and during the charging of IDCT. For this, one Cell of IDCT is stopped from charging for few days and IR thermographic images are obtained under dry condition. It is observed that even under dry condition, there is a presence of moisture at the joints between the wall panel and the column as well as at the construction joint. During charging of the Cell, IR thermographic images are again taken at regular intervals from the beginning of charging in order to capture the possible locations of the seepage entry. IR thermal images are taken at regular intervals in the wall panels till the outer surface of the wall panel becomes completely wet. Fig. 5 shows the IR thermography image of the bottom portion of the wall panel.

4. DISCUSSION ON TEST RESULTS

During visual inspection, dampness and seepage of water is noticed at many places of the CT wall between the upper and lower beams. Construction deficiencies are also noticed at many places. A large variation of concrete cover to rebars is observed which may affect the long term durability of the structure.

Based on UPV test results, the quality grading of concrete in terms of quality and integrity is assessed as per IS 13311 (Part 1)[6]. It is noted that nearly 50% of test locations (grid points) in the selected portion of RC wall recorded (i) unstable reading (USR) and (ii) the velocity less than 3.0km/sec; indicate poor quality concrete possessing excessive voids, honeycombs, flaw, local defect, etc. In remaining locations, the velocity is about 3.5km/sec and indicate that the concrete quality grading is good. However, the coefficient of variation is very high (more than 50%). The UPV results of the selected Column are in the range 4.23 to 4.44km/sec and indicates that the quality of concrete is good.

The carbonation depth obtained from extracted core samples at different locations of RC wall and Column is not significant and found to be in the range of 10-12mm. It is observed that the equivalent cube compressive strength of concrete is in the range of 7.0 MPa to 28.6 MPa indicating large variation in strengths. As per Clause 17.4.3 of IS 456:2000, concrete in the member represented by a core test shall be considered as acceptable if the average equivalent cube strength of the cores is equal to at least 85 percent of the cube strength of the grade of concrete ($0.85 \times 30 = 25.5$ MPa; M30 is the design grade of concrete) and no individual core shall have a strength less than 75 percent ($0.75 \times 30 = 22.5$ MPa; M30 is the design grade of concrete)[8-10]. The water absorption levels in the core samples observed are higher than the normal values (4%) for concretes made of granite/basalt aggregates[7].

The half-cell potentials observed are in the range of -330 to -870mV in the selected Column and -299 to -508 in RC wall. At most of the locations of the Column, the potentials are more negative than -500mV near to GL and in the range of -330 to -530mV at Level 1 (top tier beams). The more negative values at GL portion could be due to nearby storage water. The observed half-cell potentials indicate that the probability of corrosion is more than 90% or certain[12]. The resistivity of concrete is in the range of 3 to 6 kΩcm in RC wall and 7 to 40 kΩcm in the Column indicating early chance of corrosion initiation. At many locations, the chloride content present at the rebar position is more than the threshold limit (0.4% by weight of cement), indicating probability of occurrence of corrosion risk due to chloride ions[13].

IR thermographic study reveal that significant dampness was observed during the charging in the entire wall panel. With the progression of time, the appearance of observation is more prominent. It is to be noted that the presence of flaws is not limited to a certain zone and distributed all over the wall panel. Further, the joint regions of the column and the wall panel is found to be bad, causing more seepage. From the IRT study, it is observed that the quality of the wall panels is such that it is unable to arrest the seepage of water from inside to outside wall. The reason may be due to the poor construction quality, especially at junction between the column and wall panel which can be visually evidenced by non-uniform cross-section and cover thickness, nonalignment of the column with the wall, etc.

Based on the combination of observations and test results, it can be said that the overall quality and integrity of concrete at the selected areas of CT walls is found to be poor. In view of this, it is opined that, localized/patch repair at joints or discontinuous regions, etc. may not be sufficient to make the IDCT structure more durable and water tight. Therefore, a thorough comprehensive and effective repair methodology is needed.

5. REPAIR METHODOLOGY

A thorough comprehensive and effective repair scheme needs to be adopted on the wall panels of IDCT for improving the quality and integrity of concrete, followed by effective water proofing procedures. To fulfill the requirements, the repair procedure is proposed in two stages; (i) improving the quality and integrity of wall panels and columns and (ii) water proofing of wall panels and joints[14]. To improve the quality, integrity and strength of concrete in the entire stretch of RC walls, grouting is recommended from the inner face of the IDCT. This may be extended for columns and beams, where, large area of voids/honeycombs is observed. The grouting can be done by cement slurry followed by epoxy grouting. After successful completion of the grouting, a step by step water proofing procedure, shall be followed. The water proofing procedure consists of combination of applying acrylic based polymer modified water proofing systems and glass fiber mesh over it to ensure the durability of the waterproofing membrane system.

6. SUMMARY AND CONCLUDING REMARKS

A detailed systematic and comprehensive test program followed for the condition assessment of IDCT walls is presented. This include visual inspection, NDT and PDT. Based on the observations of visual inspection and test results, it has been concluded that the overall quality and integrity of concrete at selected portions of IDCT walls is found to be improved. Detailed repair methodology is suggested for improving the quality, integrity, water tightness and over all durability of IDCT walls.

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FIGURES

Fig.1 Typical view of IDCT

Fig. 2 UPV Test in Progress

Fig. 3 Core extraction in progress

Fig. 4 Typical resistivity measurement

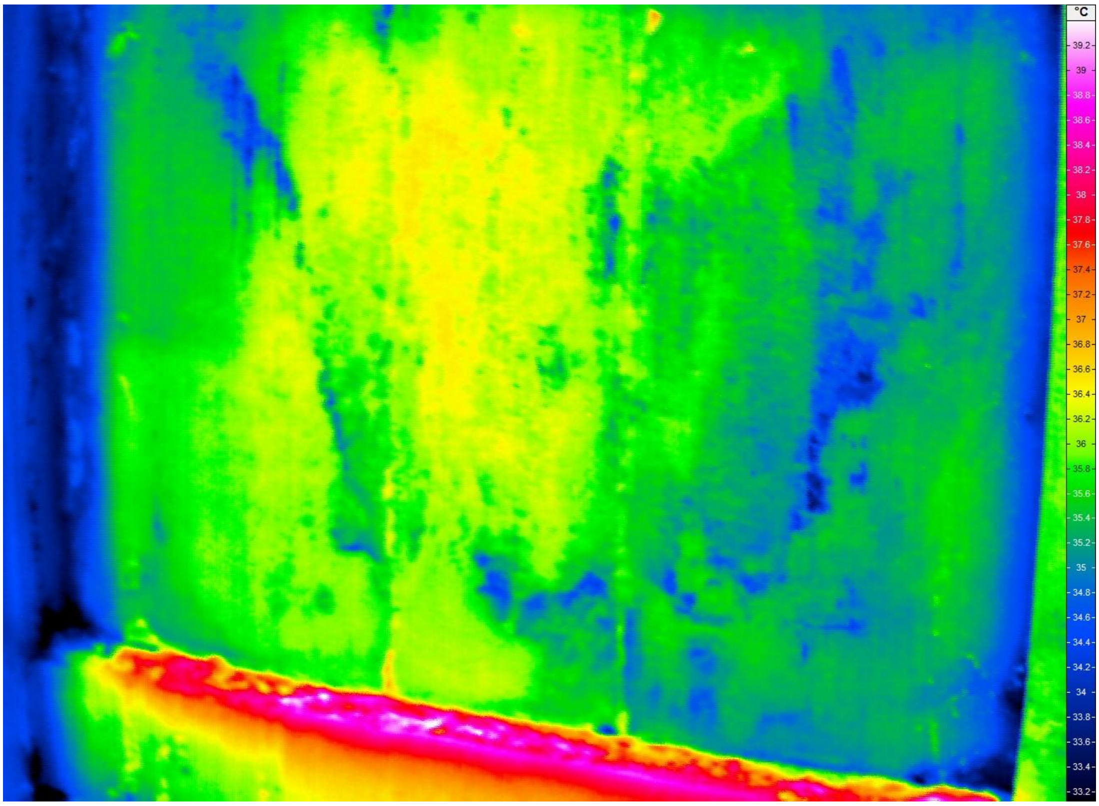

Fig. 5 IRT image of bottom half of the wall panel 60min after charging