



## Non-Destructive Testing For Residential Buildings - A Case Study

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**Abstract:** Reinforced concrete that has been used for a long time should be evaluated to determine the current strength, durability and to know how long it can withstand all possible loads. Poor quality of reinforced concrete will cause discomfort to customers, safety will be affected and strength will be reduced. In the present study, we are using existing Sector20 Residential Buildings is taken as the case study. Municipal Corporation Chandigarh has its Single story residential houses for its staff. It is occupied and investigated for their strength and quality. Non-destructive testing (NDT) of concrete members was used for characterization of material and assessment of functional structures without impairing their functions and performances. The Pulse velocity test and Rebound hammer tests were used to determine the current strength and also the properties of the concrete. From the data it was found that the building has strength range is from 100 to 110 kg/cm<sup>2</sup> compressive strength in the current condition. The test results have been interpreted, and finally assessed the overall concrete quality and integrity. Based on the test results, it was found that the quality of concrete is poor mainly due to voids, honeycombing, and carbonation of concrete. Chandigarh being in seismic zone 1V the seismic features as required are not present in the structure. The wide diagonal cracks are also present in the wall of houses. Necessary repair measures if done may be costly and require expertise work. The houses are 40 years old and lived its useful life.

**Keywords:** Rebound hammer, compressive strength, honeycombing, Non-Destructive Testing (NDT)

### I. Introduction

Structures are assemblies of load carrying members capable of safely transferring the superimposed loads to the foundation. To keep a high level of structural safety, durability, and performance of the infrastructure in each country, an efficient system for early and regular structural assessment is urgently required. The quality assurance during and after the construction of new structures and after reconstruction processes and the characterization of material properties and damage as a function of time and environmental influences are more and more becoming a serious concern. Looking into the above requirements, there is a need of testing of hardened concrete of new structures as well as old structures, to assess the actual condition of structures. Non-Destructive Testing (NDT) techniques can be used effectively for investigation and evaluate the actual condition of the structures. Non Destructive Testing was conducted on Municipal Corporation Chandigarh which was a Single story residential house. The condition survey assessed the quality of concrete by using ultrasonic technique and Hammer rebound method. The carbonation depth was determined by use of Phenolphthalein test. The visual examination was carried out to find out/ locate the dampness, cracks and other defects in the buildings.

In-situ NDT studies for diagnostic purposes start with field observations composed of mapping of decay forms with visual analyses and IR scanning. Quantitative analyses are shaped for data acquisition on site and at laboratory taken from representative sound and problem areas in structures or laboratory samples. Laboratory analyses are needed to support in-situ examinations and to establish the standard/reference data for better interpretation of the in-situ data. In order to enhance the accuracy of non-destructive investigations, particularly the in-situ ones, there is necessity of using more than one NDT testing method and supporting the in-situ investigation with laboratory tests.

### II. Literature review

The abstract of most related and the latest literature are summarized here. Literature from e-journals was accessed through internet whose websites are given in the reference section.

V. R. Chethan, M. R. Gowda (2018) showed that Poor quality of reinforced concrete will cause discomfort to customers, safety will be affected and strength will be reduced. Existing Polytechnic building belonging to AdichunchanagiriShikshana Trust, Chikmagalur was taken as the case study. The Ultrasonic Pulse Velocity (UPV) and Rebound Hammer tests for the two grades of concrete cast in the laboratory viz: M20 and M25 for evaluating the compressive strength. K. V. Ganesh1, M. S. Priya (2017) concluded that Nondestructive testing has achieved

an important place in the Quality Assurance of hardened concrete and the evaluation of existing concrete structure with regard to their strength & durability. M. P. Ismail (2017) recommended that Visual, rebound hammer, advanced ultrasonic and thermography methods are the minimum NDT methods to cover the required parameter for assessing the structural integrity of the concrete building. N. L. Jagtap<sup>1</sup>, P. R. Mehetre (2015) observed that the Ultrasonic Pulse Velocity Results with direct, semi-direct and indirect methods indicates the maximum readings are below 3km/sec and between 3.0 km/sec to 3.5km/sec.

From the literature review, it was seen that Non-destructive testing can help in determining whether these structures are being set up without following the code of practice.

### III. Objectives

The objectives of the overall investigation are:

1. To assess the existing quality and allowable characteristic strength of concrete in the slab, beam and column elements, so that the same can be utilized for overall structural safety appraisal of the structure if required. Besides, in case of any inadequacy in the concrete quality being revealed, suitable remedial measures can also be suggested
2. To diagnose the causes of the distress so as to undertake suitable remedial measures for rehabilitation if possible of the structure taking account of the causes.
- 3.

### IV. Methodology

The methods that were followed in this project are further given below.

#### Methodological Approach

- ◆ To identify the cause of the damage and the source of the problem.
- ◆ To determine the extent of the damage.
- ◆ To determine material properties.
- ◆ To assess the safety and serviceability of the structure.
- ◆ To provide recommendations on remedial and preventive measures.
- ◆ To estimate the cost of repair or replacement.

A typical investigation involves the following processes:-

- ◆ Inspecting the site, with special attention to potential safety hazards.
- ◆ Studying the design, construction details, and loading history of the structure.
- ◆ Planning a condition survey.
- ◆ Executing the condition survey.
- ◆ Laboratory testing of material samples secured from the structure.
- ◆ Analyzing and interpreting the acquired data.
- ◆ Load testing individual members, if necessary.

The different methods for inspecting concrete structures may be simply classified as:

- ◆ Visual
- ◆ Mechanical/physical inspection
- ◆ Chemical analysis, and
- ◆ Electrochemical testing

The strength, the integrity of concrete, the presence of cracks and delamination, the following tests are used:

(i) Surface Hardness tests - Rebound Hammer (IS: 13311- part 2, 1992)

The rebound hammer is commercially known as Schmidt Hammer. The testing can be carried out on a grid pattern marked on the structure. This grid pattern will be useful for further tests such as Ultrasonic Scanning, Potential Resistivity, and Corrosion Rate measurements.

(ii) Ultrasonic Pulse Velocity Tests Assessment on condition of concrete can also be made using Ultrasonic Pules Velocity test method. Generally, a concrete member will be divided into well-defined grid points of the spacing of 250 -300mm and pulse velocities can be determined using standard instruments. A systematic scanning can give useful information on the condition of concrete and the method helps to identify locations which are corrosion- prone.

(iii) Determination of reinforcement bar cover ihe cover is obtained by Cover Meter

(iv) Carbonation: Carbonation has been identified with the help of phenolphthalein. The concrete is alkaline in nature and the phenolphthalein gives pink color when it comes in its contact. If the carbonation has taken place, the concrete will not turn pink.

## V. Non Destructive Testing

### Visual Examination

A total of 220 number flats were surveyed and examined thoroughly for visual defects viz. dampness, cracks, functional defects, corrosion etc. The category of flats and their numbers are as follows. LIG group C Flats which were 98 in number was visually examined. Below is the result. Visual examination of houses

The visual examination of houses was carried out in the following sequence:

- (i) Preparation of line diagram.
- (ii) Marking of various rooms.
- (iii) Marking of walls.
- (iv) Individual defects have been listed house wise giving the location already described (inline diagram).
- (v) Tabulation of the report of visual defects is given in the sequence, (As per Annexure 1).
- (vi) Common defects found in various blocks are reported below observations.

### Common Defects

- (i) Leakage and seepage in all houses
- (ii) Dampness around the CI pipes in kitchen and bathroom.
- (iii) Dampness in all the walls and roof of bath and W.C.
- (iv) Chajjajs of all the houses are in bad condition, joint cracks, plaster cracks, and exposed bars can be seen.
- (v) Ground settlement in kitchen and bath
- (vi) Dampness in walls
- (vii) Cracks from the sill level of the window to bottom in some houses
- (viii) Water-proofing on Roof has deteriorated.

These are some common defects, which are visible.

## VI. Rebound Hammer

The results of Rebound Hammer showed in Table No 1, that the quality of concrete is poor and not adequate for safety aspects of the structure. The mean compressive strength for each of the structural element was  $> 25\text{N/mm}^2$  which is the minimum acceptable compressive strength of concrete.

| S. No. | House No. | Rebound Numbers |    |    |    |    |    | Compressive Strength (f) (N/mm <sup>2</sup> ) |
|--------|-----------|-----------------|----|----|----|----|----|-----------------------------------------------|
| 1      | 2720      | 15              | 14 | 16 | 16 | 16 | 18 | 12                                            |
| 2      | 2721      | 4               | 16 | 13 | 14 | 16 | 17 | 12                                            |
| 3      | 2722      | 12              | 16 | 16 | 18 | 13 | 16 | 11                                            |
| 4      | 2723      | 12              | 14 | 16 | 17 | 12 | 14 | 12                                            |
| 5      | 2724      | 13              | 18 | 18 | 16 | 13 | 18 | 12                                            |
| 6      | 2725      | 12              | 13 | 14 | 16 | 13 | 18 | 12                                            |
| 7      | 2726      | 12              | 13 | 15 | 14 | 12 | 16 | 12                                            |
| 8      | 2727      | 11              | 17 | 13 | 14 | 12 | 16 | 12                                            |
| 9      | 2748      | 12              | 12 | 14 | 14 | 12 | 14 | 11                                            |
| 10     | 2749      | 11              | 12 | 14 | 14 | 12 | 12 | 11                                            |
| 11     | 2750      | 14              | 14 | 12 | 12 | 14 | 14 | 11                                            |
| 12     | 2751      | 12              | 12 | 14 | 14 | 12 | 14 | 11                                            |
| 13     | 2752      | 11              | 12 | 14 | 14 | 12 | 12 | 11                                            |
| 14     | 2753      | 14              | 14 | 12 | 12 | 14 | 14 | 11                                            |
| 15     | 2754      | 12              | 13 | 15 | 14 | 12 | 16 | 12                                            |
| 16     | 2755      | 11              | 17 | 13 | 14 | 12 | 16 | 12                                            |
| 17     | 2756      | 12              | 12 | 14 | 14 | 12 | 14 | 11                                            |
| 18     | 2757      | 12              | 13 | 15 | 14 | 12 | 16 | 12                                            |
| 19     | 2758      | 16              | 18 | 18 | 16 | 16 | 18 | 12                                            |
| 20     | 2759      | 16              | 18 | 18 | 16 | 18 | 18 | 12                                            |
| 21     | 2760      | 12              | 13 | 15 | 14 | 12 | 16 | 12                                            |
| 22     | 2761      | 11              | 17 | 13 | 14 | 12 | 16 | 12                                            |
| 23     | 2762      | 16              | 18 | 18 | 16 | 16 | 18 | 12                                            |
| 24     | 2763      | 14              | 16 | 16 | 16 | 18 | 12 | 15                                            |
| 25     | 2764      | 16              | 13 | 14 | 16 | 17 | 12 | 4                                             |
| 26     | 2765      | 16              | 16 | 18 | 13 | 16 | 11 | 12                                            |
| 27     | 2766      | 14              | 16 | 17 | 12 | 14 | 12 | 12                                            |
| 28     | 2767      | 18              | 18 | 16 | 13 | 18 | 12 | 13                                            |
| 29     | 2768      | 13              | 14 | 16 | 13 | 18 | 12 | 12                                            |
| 30     | 2769      | 13              | 15 | 14 | 12 | 16 | 12 | 12                                            |
| 31     | 2770      | 17              | 13 | 14 | 12 | 16 | 12 | 11                                            |
| 32     | 2771      | 12              | 14 | 14 | 12 | 14 | 11 | 12                                            |
| 33     | 2772      | 12              | 14 | 14 | 12 | 12 | 11 | 11                                            |
| 34     | 2773      | 14              | 12 | 12 | 14 | 14 | 11 | 14                                            |
| 35     | 2774      | 12              | 14 | 14 | 12 | 14 | 11 | 12                                            |
| 36     | 2775      | 12              | 14 | 14 | 12 | 12 | 11 | 11                                            |

|    |      |    |    |    |    |    |    |    |
|----|------|----|----|----|----|----|----|----|
| 37 | 2776 | 14 | 12 | 12 | 14 | 14 | 11 | 14 |
| 38 | 2777 | 13 | 15 | 14 | 12 | 16 | 12 | 12 |
| 39 | 2778 | 17 | 13 | 14 | 12 | 16 | 12 | 11 |
| 40 | 2779 | 12 | 14 | 14 | 12 | 14 | 11 | 12 |
| 41 | 2780 | 12 | 14 | 14 | 12 | 12 | 11 | 11 |
| 42 | 2781 | 14 | 12 | 12 | 14 | 14 | 11 | 14 |
| 43 | 2782 | 13 | 15 | 14 | 12 | 16 | 12 | 12 |
| 44 | 2783 | 17 | 13 | 14 | 12 | 16 | 12 | 11 |
| 45 | 2784 | 12 | 14 | 14 | 12 | 14 | 11 | 12 |
| 46 | 2785 | 13 | 15 | 14 | 12 | 16 | 12 | 12 |
| 47 | 2786 | 18 | 18 | 16 | 16 | 18 | 12 | 16 |
| 48 | 2787 | 18 | 18 | 16 | 16 | 18 | 12 | 16 |
| 49 | 2788 | 18 | 16 | 16 | 18 | 18 | 12 | 16 |
| 50 | 2789 | 13 | 15 | 14 | 12 | 16 | 12 | 12 |
| 51 | 2790 | 17 | 13 | 14 | 12 | 16 | 12 | 11 |
| 52 | 2791 | 18 | 18 | 16 | 16 | 18 | 12 | 16 |
| 53 | 2792 | 12 | 14 | 14 | 12 | 12 | 11 | 11 |
| 54 | 2793 | 14 | 12 | 12 | 14 | 14 | 11 | 14 |
| 55 | 2794 | 13 | 15 | 14 | 12 | 16 | 12 | 12 |
| 56 | 2795 | 17 | 13 | 14 | 12 | 16 | 12 | 11 |
| 57 | 2796 | 12 | 14 | 14 | 12 | 14 | 11 | 12 |
| 58 | 2797 | 13 | 15 | 14 | 12 | 16 | 12 | 12 |
| 59 | 2798 | 18 | 18 | 16 | 16 | 18 | 12 | 16 |
| 60 | 2799 | 18 | 18 | 16 | 18 | 18 | 12 | 16 |
| 61 | 2816 | 14 | 12 | 12 | 14 | 14 | 11 | 14 |
| 62 | 2817 | 12 | 14 | 14 | 12 | 14 | 11 | 12 |
| 63 | 2818 | 12 | 14 | 14 | 12 | 12 | 11 | 11 |
| 64 | 2819 | 14 | 12 | 12 | 14 | 14 | 11 | 14 |
| 65 | 2820 | 13 | 15 | 14 | 12 | 16 | 12 | 12 |
| 66 | 2821 | 17 | 13 | 14 | 12 | 16 | 12 | 11 |
| 67 | 2822 | 12 | 14 | 14 | 12 | 14 | 11 | 12 |
| 68 | 2823 | 13 | 15 | 14 | 12 | 16 | 12 | 12 |
| 69 | 2824 | 18 | 18 | 16 | 16 | 18 | 12 | 16 |
| 70 | 2825 | 18 | 18 | 16 | 18 | 18 | 12 | 16 |
| 71 | 2826 | 13 | 15 | 14 | 12 | 16 | 12 | 12 |
| 72 | 2827 | 17 | 13 | 14 | 12 | 16 | 12 | 11 |
| 73 | 2828 | 18 | 18 | 16 | 16 | 18 | 12 | 16 |
| 74 | 2829 | 14 | 12 | 12 | 14 | 14 | 11 | 14 |
| 75 | 2830 | 12 | 14 | 14 | 12 | 14 | 11 | 12 |
| 76 | 2831 | 12 | 14 | 14 | 12 | 12 | 11 | 11 |
| 77 | 2832 | 14 | 12 | 12 | 14 | 14 | 11 | 14 |
| 78 | 2833 | 13 | 15 | 14 | 12 | 16 | 12 | 12 |
| 79 | 2834 | 17 | 13 | 14 | 12 | 16 | 12 | 11 |
| 80 | 2835 | 12 | 14 | 14 | 12 | 14 | 11 | 12 |
| 81 | 2836 | 13 | 15 | 14 | 12 | 16 | 12 | 12 |
| 82 | 2837 | 14 | 12 | 12 | 14 | 14 | 11 | 14 |
| 83 | 2838 | 12 | 14 | 14 | 12 | 14 | 11 | 12 |
| 84 | 2839 | 12 | 14 | 14 | 12 | 12 | 11 | 11 |
| 85 | 2840 | 14 | 12 | 12 | 14 | 14 | 11 | 14 |
| 86 | 2841 | 13 | 15 | 14 | 12 | 16 | 12 | 12 |
| 87 | 2842 | 17 | 13 | 14 | 12 | 16 | 12 | 11 |
| 88 | 2843 | 12 | 14 | 14 | 12 | 12 | 11 | 11 |
| 89 | 2844 | 14 | 12 | 12 | 14 | 14 | 11 | 14 |
| 90 | 2845 | 13 | 15 | 14 | 12 | 16 | 12 | 12 |
| 91 | 2846 | 17 | 13 | 14 | 12 | 16 | 12 | 11 |
| 92 | 2847 | 12 | 14 | 14 | 12 | 14 | 11 | 12 |
| 93 | 2848 | 13 | 15 | 14 | 12 | 16 | 12 | 12 |
| 94 | 2849 | 14 | 12 | 12 | 14 | 14 | 11 | 14 |
| 95 | 2850 | 12 | 14 | 14 | 12 | 14 | 11 | 12 |
| 96 | 2851 | 12 | 14 | 14 | 12 | 12 | 11 | 11 |
| 97 | 2852 | 14 | 14 | 12 | 12 | 14 | 11 | 10 |
| 98 | 2853 | 12 | 12 | 14 | 14 | 14 | 11 | 10 |

#### **Ultrasonic Pulse Test:**

1. The results of the Ultrasonic Test using Pulse velocity of 1000m/sec on concrete elements showed that the quality of concrete was poor.

#### **Carbonation Test:**

1. Holes were drilled and wherever carbonation has set in, the phenolphthline does not show pinkish color. It was possible to establish the depth up to which carbonation was set in. It was found that concrete members were fully carbonated with  $\text{ph} < 8.5$ .

## VI. Conclusion and Suggestion:

Based on the results of various Non-destructive testing, foundation condition and site observations the following was concluded and was suggested -

- 1) The integrity and stability of the existing masonry houses are in very bad condition and unsafe for occupancy.
- 2) Repair/Strengthening of existing masonry houses are possible but it requires extra cost .effective repair of the structure depends on contractors ability. However, if the cost of repair works out to be more than 30% than that of the cost of reconstruction it is advisable to demolish the existing building and reconstruct the same by incorporation of earthquake resistant measures in buildings.
- 3) Cracks had developed from foundation to top of the houses due to differential settlement.
- 4) All the masonry houses are about 40 years old and served its useful service life.
- 5) Chandigarh is in Seismic Zone –IV, these masonry houses are in usages are not designed for seismic forces. The structures are not having plinth beams, lintel ties and vertical bends to resist earthquake forces.

The test results have been interpreted, and finally assessed the overall concrete quality and integrity. Based on the test results, it was found that the quality of concrete is poor mainly due to voids, honeycombing, and carbonation of concrete. Chandigarh being in seismic zone 1V the seismic features as required are not present in the structure. The wide diagonal cracks are also present in the wall of houses Necessary repair measures if done may be costly and require expertise work. The houses are 40 years old and lived its useful life.

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