4th International Conference on Advances in Civil Engineering 2018 (ICACE 2018)
19 –21 December 2018
CUET, Chittagong, Bangladesh
www.cuet.ac.bd

EVALUATION OF IN-SITU MECHANICAL PROPERTIES AND QUALITY OF CONCRETE STRUCTURES BY NON-DESTRUCTIVE TESTING

M. M. Ali[1*], M. Z. Ali[2], A. A. Saeem[3]& M. S. Ahmed[2]

[1]*Department of Civil Engineering, Bangladesh Army University of Engineering & Technology, Qadirabad Cantonment, Natore-6431, Bangladesh.*
E-mail:mmali19bd@gmail.com
[2]*Department of Civil Engineering, Chittagong University of Engineering & Technology (CUET), Chittagong-4349, Bangladesh. E-mail:mdzobaearali8630@gmail.com*
[3]*Bangladesh Army*
**Corresponding Author*

ABSTRACT
The non-destructive testing (NDT) of various components of reinforced cement concrete structures is becoming increasingly important for both economic and safety reasons in Bangladesh perspective. The modern NDT methods have received growing attention during recent years, especially to study the mechanical properties and quality characterization of damaged constructions made of concrete. There are many non-engineered constructions of reinforced concrete (RC) buildings which have been constructed without any consideration to resist earthquake forces or without following current code of earthquake resistance design. A quick NDT assessment could be a good approach for safety measurement of buildings within considerable cost for such type of seismically deficient buildings. In this study, a five (5) storied RCC building was selected and assessed its mechanical properties and quality of concrete through NDT. To investigate the mechanical properties of existing concrete structures against different loading patterns, several non-destructive tests such as Ferro-scanner, Rebar detector, Ultrasonic device, rebound hammer have been introduced. The present work deals with different NDT techniques for the assessment of the quality of existing old concrete structures and key findings obtained from the analysis of the surveyed data.

Keywords: RCC; NDT; Ferro-Scanner; Ultrasonic Device; Rebound Hammer Test.

INTRODUCTION

Non-destructive testing is the process by which the inspection or evaluation of materials and structural components are performed without destroying the serviceability of the structural system. Due to their simple operating system NDT are widely used to determine uniformity, strength, durability and other properties of concrete structures. The modern NDT techniques have a much more authenticity to integrity assessment of existing structures before re-strengthening work. According to the international norms and regulations any building that are going to be designed should have sufficient physical and strength properties to meet the required ultimate strength during their full design life (Samia, 2012). The modern NDT are widely accepted to diagnose the strength properties, quality, surface absorption, surface hardness and reinforcement details (location, size and spacing) embedded in concrete without damaging any part of the concrete structures (IS 13311, 1992, Jones 1969, IAEA, 2002). NDT techniques also determine the lack of bonding with reinforcing bars, location of in-built piping, wiring, ducting and the extent of defects such as cracks, corrosion, honeycombing, voids etc. (IS 13311, 1992, IAEA 2002). NDT is carried out to determine the suitability of existing concrete structures for its intended use. The major applications of NDT are to investigate the mechanical properties or checking adequacy of structural elements for old existing concrete structures (IS 13311, 1992). For new concrete structures, the quality control of construction are the principal applications of NDT. The main objectives of this study were to study the mechanical properties of existing old concrete structural elements, to determine the reinforcement details (location, size and spacing) in the members of concrete structure and to evaluate the quality of in built concrete.

MATERIALS AND METHODS

Basic Information of Assessed Building

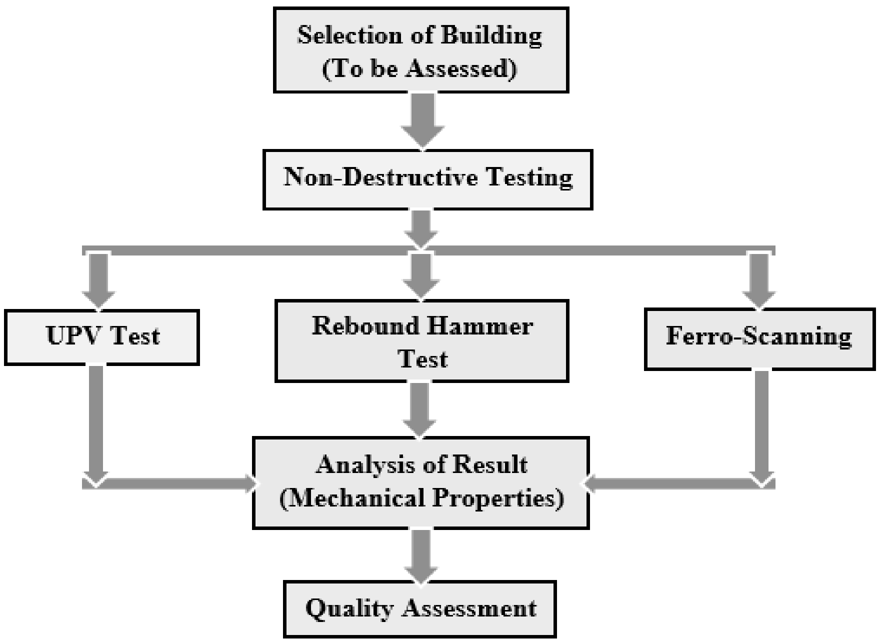
The assessed building was a garments factory building located in Dhaka, the capital of Bangladesh. The basic information of the assessed building are given in Table 1.

Table 1: Basic Information of Assessed Building

Information	**Description**
Structural System	The structural system of main production building is RCC Beam-Column frame system and foundation system is isolated column footing.
Area of Floor	Total building area: 30,000 sft.
Number of Stories	Five storied RCC building
Year of Construction	2005
Construction Materials	Concrete (with brick chips and steel)

Methodology

The step by step approaches for evaluation of mechanical properties and quality of in built concrete are given as follows:



Application of Schmidt RH Test

Standard Schmidt rebound hammer (RH) test is the most widely applied surface hardness procedure. Swiss engineer Ernst Schmidt developed the test in 1948 and is known to as the Schmidt RH (Kolek, 1969). While testing the rebounded hammer counts a rebound number under the impact of concrete surface and the compressive and flexural strength of concrete can be determined from the established empirical correlations between the rebound number and the strength of concrete. Small rebound number (RN) indicates the weak concrete surface at which corrosion may occur. However, several key factors affect the test results of concrete such as surface smoothness, type of coarse aggregate and cement, geometric properties, age and moisture condition of concrete and carbonation of the concrete surface (Malek and Kaouther, 2014). While conducting hammer test, it is necessary to place the hammer in perpendicular direction to the concrete surface to be tested (Malek and Kaouther 2014, IS 13311, 1992). Fig. 1 shows the details of the equipment.

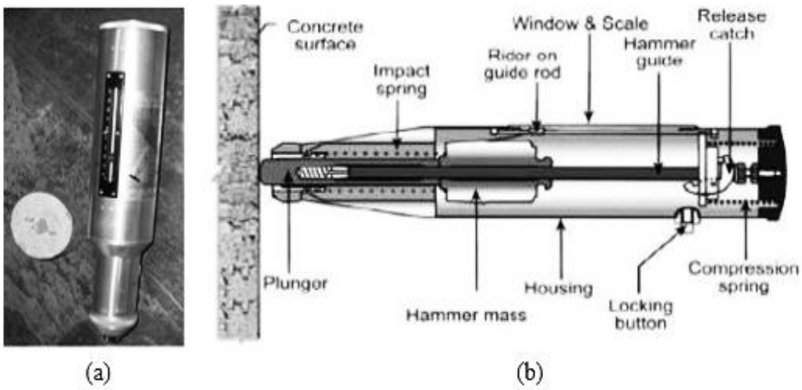


Fig. 1: (a) Schmidt Hammer (b) Different Parts of Schmidt Hammer.

Application of UPV Test

The modern ultrasonic pulse velocity (UPV) techniques provides an easy means of estimating the strength, quality and the uniformity of in built concrete by measuring the propagation speed of ultrasonic waves. The location of defects, cavity inside structures, depth of fractures and the strength of old concrete can also be determined by UPV test (Alexandre et Al., 2013). This ultrasonic device essentially consists of an amplifier, time measuring device, electrical pulse generator and two transducers (Jones 1969, Alexandre et Al., 2013). Fig. 2(a) shows an ultrasonic concrete testing instrument.

Fig. 2: (a) Ultrasonic Concrete Testing Instruments (b) Hilti PS 200 Monitor and Scanner Device.

Ferro Scan

Ferro scan is portable, non-destructive steel reinforcement detection system using electromagnetic pulse. It can reduce costly effort to drill, cut or physically break concrete surface to find out the bar. The position, depth and diameter of rebar in existing concrete structure can be determined using Ferro scan. The key elements of the system are the scanner and the monitor. After scanning a structure data has been transferred to the monitor. Collected data can be analyzed by monitor or in a PC using PS 200 software's. Maximum depth of scanning is 180 mm (at 36 mm rebar diameter) where rebar diameter range 6 - 36 mm. Depending on the mode of scan used and the range of depth, the accuracy of the measurement of depth for reinforcement is ±1 mm. Fig. 2(b) shows monitor and scanning device produced by Hilti Corporation, 2011.

RESULTS AND DISCUSSIONS

The evaluation of in-place mechanical properties and quality of concrete structures were performed by UPV, Hammer test and Ferro scanning of structural members along with checking of foundations, taking dimensions and removing plasters at different locations of the building for conforming reinforcement details.

Test result of UPV

Total UPV test at **16** points in different locations of the selected structure was performed to examine the strength of concrete. The data obtained from the UPV test are given in Table 2.

Table 2: Data of UPV Test

ID	Member		UPV Results		V (m/s)
	Type	**Location**	**Size/Distance (mm)**	**Time (micro second)**	
1.	Column	4F	343.5	94.2	3646
2.	Beam	4F	345.1	87.4	3949
3.	Column	3F	331.4	89.6	3699
4.	Beam	3F	332.6	85.9	3872
5.	Column	2F	326.9	91.6	3569
6.	Column	2F	355.6	85.4	4164
7.	Beam	2F	341.2	86.6	3940
8.	Beam	2F	341.8	87.8	3893
9.	Beam	1F	339.2	87.4	3881
10.	Column	1F	340.5	91.5	3721
11.	Beam	1F	338.5	88.6	3821
12.	Column	1F	342.5	83.4	4107
13.	Column	GF	342.5	87.3	3923
14.	Column	GF	340.5	91.2	3734
15.	Beam	GF	336.6	89.6	3757
16.	Column	GF	336.8	90.4	3726

The quality of concrete based on UPV value may be interpreted by the general guidelines for concrete quality as shown in Table 3 (Nikhil et al., 2015, CPWD Handbook 2002, IS 13311, 1992). Generally, higher pulse velocity represents the higher quality and durability of concrete and lower pulse velocity represents the lower quality concrete (Alexandre et Al., 2013).

Table 3: Quality interpretation of Concrete based on UPV Value

Concrete Quality	V (m/s)
Very Good	> 4000
Good, But May Be Porous	= 3500 to 4000
Poor	= 3000 to 3500
Very Poor	= 2500 to 3000
Very Poor and Low Integrity	= 2000 to 2500
No Integrity, Large Voids Suspected	< 2000 and Reading Fluctuating

From the assessment, the UPV value was found above 3500 m/sec for beams and columns at different locations of the selected structure and ranged from 3569 m/sec to 4164 m/sec (as shown in Table 2). So, the quality of concrete was found to be good based on UPV value (from Table 3).

Test result of Rebound Hammer

Rebound hammer was used in columns & beams located at different floors to evaluate the elastic properties or strength of concrete. Rebound hammer test was performed at 16 points in different locations of the selected structure. An average of 12 impacts was considered for each concrete surface. The data obtained from the rebound hammer test are given in Table 4.

Table 4: Data of Rebound Hammer Test

ID	Member		12 Values of Rebound	Average R Value
	Type	Location		
1.	Column	4F	37, 31, 31, 35, 34, 30, 32, 30, 31, 36, 37, 38	33
2.	Beam	4F	45, 43, 49, 42, 38, 45, 36, 42, 38, 42, 48, 40	42
3.	Column	3F	38, 36, 49, 37, 40, 40, 46, 43, 42, 38, 40, 39	40
4.	Beam	3F	40, 38, 35, 42, 38, 49, 38, 39, 47, 32, 37, 41	40
5.	Column	2F	34, 32, 36, 29, 30, 28, 32, 26, 27, 30, 29, 37	31
6.	Column	2F	38, 40, 34, 36, 35, 42, 26, 46, 28, 40, 40, 38	38
7.	Beam	2F	32, 29, 40, 42, 42, 32, 32, 40, 40, 32, 34, 35	36
8.	Beam	2F	42, 42, 28, 48, 29, 38, 48, 28, 32, 28, 30, 38	36
9.	Beam	1F	30, 28, 35, 32, 30, 27, 38, 35, 34, 33, 31, 35	32
10.	Column	1F	35, 29, 34, 35, 31, 40, 36, 36, 30, 42, 38, 28	34
11.	Beam	1F	28, 32, 36, 38, 38, 28, 35, 39, 40, 35, 34,33	35
12.	Column	1F	40, 44, 32, 42, 38, 44, 38, 43, 49, 45, 42, 39	42
13.	Column	GF	34, 35, 31, 31, 38, 32, 40, 50, 32, 34, 30, 31	34
14.	Column	GF	32, 28, 34, 39, 18, 18, 32, 34, 30, 36, 30, 36	31
15.	Beam	GF	32, 31, 32, 32, 32, 35, 37, 34, 33, 40, 36, 41	33
16.	Column	GF	38, 38, 52, 38, 32, 32, 39, 42, 33, 39, 38, 34	37

The quality of concrete based on average rebound number may be interpreted as shown in Table 4. For the concrete made with the same coarse aggregate, higher RN value represents higher compressive strength of concrete while the lower RN value represents lower compressive strength of concrete.

Table 5: Average Rebound Number and Quality of Concrete (CPWD Handbook, 2002).

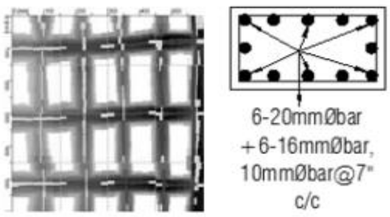
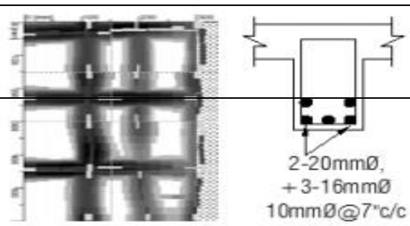
Quality of Concrete	RN (average)
Very Good Hard Layer	Greater than 40
Good Layer	From 30 to 40
Fair	From 20 to 30
Poor Concrete	Less than 20
Very Poor and/or Delaminated	0

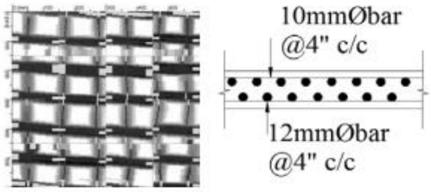
From the assessment it was found that average rebound value ranged from 31 to 42 (as shown in Table 4) for beams and columns at different locations of the selected structure. So, the quality of concrete was found good to very good hard layer (from Table 5).

Ferro-Scanning

The reinforcement details using Ferro-scanner for beam and column are shown in Table 6.

Table 6: Details of Reinforcement using Ferro-Scanner

Location and Member Type	Reinforcement Details	Image from Ferro-Scanner
GF Column (22" X 12")	**Along 22" face:** Main Reinforcement: 3-Ø20mm + 2- Ø16mm Tie Bar: Ø10 mm @ 7" c/c **Along 12" face:** Main Reinforcement: 2-Ø20mm + 1- Ø16mm Tie Bar: Ø10 mm @ 7" c/c	
	Column Strip: Main Reinforcement: 2-Ø20mm + 3- Ø16mm Tie Bar: Ø10 mm @ 7" c/c	

GF Beam (12" X 15")	**Middle Strip:** Main Reinforcement: 2-Ø20mm + 3- Ø16mm Tie Bar: Ø10 mm @ 7" c/c	
1th Floor Slab (6")	**Slab (Bottom):** Ø12 mm @ 4" c/c	
	Slab (Top): Ø10 mm @ 4" c/c	

The detail Ferro-scanning was performed to evaluate reinforcement details (to know the existing rebar diameter, quantity & spacing) of column, beam & slab. As built analysis was performed by remodeling the structure using powerful finite element based structural design software package CSI Etabs V9.7.4. It was found from the analysis results that the selected structure had sufficient structural strength to resist BNBC loadings and load combinations.

CONCLUSIONS

In this study, an overview of NDT and the evaluation of the in situ mechanical properties of reinforced concrete structures by NDT are presented in a simple. To ensure safety and credibility of concrete structures NDT plays an extreme role in each stage of construction. The integrity of structure throughout its design life can also be determined by NDT techniques. A series of non-destructive tests have been performed to evaluate the in situ mechanical properties of concrete structures due to its easy execution system and minor disruption to the occupants. The NDT has a great technical importance for quality and condition assessment of existing concrete structures and evolved in great savings of cost and time. However, the optimal in situ NDT techniques must be routinely adopted to diagnose and evaluate the concrete structures which enable accurate, reliable and cost-effective inspection of buildings during its whole useful life.

REFERENCES

Alexandre, B J, Gloria, G M, and Augusto, G (2013). Compressive strength evaluation of structural lightweight concrete by non-destructive ultrasonic pulse velocity method. 2013.

Handbook on Repair and Rehabilitation of RCC Buildings. CPWD, Government of India, New Delhi. 2002.

IAEA (International Atomic Energy Agency, 2002). Guidebook on non-destructive testing of concrete structures. Training Courses Series, Vol.17, Vienna.

IS 13311(1992). Code of Practice for Non Destructive Testing of Concrete – Methods of Test Part: 1 Ultrasonic Pulse Test, Bureau of Indian standards (BIS), New Delhi, January 1992.

IS 13311(1992). Code of practice for Non Destructive Testing of concrete – methods of test part: 2 Rebound Hammer test, Bureau of Indian standards (BIS), New Delhi, January 1992.

Jones, R. (1969). A review of the non-destructive testing of concrete. London: Institution of Civil Engineers.

Malek, J and Kaouther, M (2014). Destructive and Non-destructive Testing of Concrete Structures. *Jordan Journal of Civil Engineering,* Volume 8, No. 4, 2014.

Nikhil L. Jagtap, Mehetre P R (2015). Study on Retrofitted RCC Building by Different NDT Methods. *IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE).* Volume 12, Issue 3 Ver. I (May - Jun. 2015), PP 85-89.

Samia H, Mohamed NG, (2012). Application of the Combined Method for Evaluating the Compressive Strength of Concrete on Site. Open Journal of Civil Engineering, 2012, 2, 16-21.