Performance Evolution and Audit of Structure by NDT Methods

Er. Neha Goyal, Er. Bhavana Arora, Dr. Sanjay Sharma, Dr. Arvind Dewangan

Abstract— **The assessment of concrete structure consist not only evaluation of its present condition but also to predict the cause of deterioration and its residual life. Hence, it is indispensable to have accurate assessment of physical, chemical and electro- chemical properties of concrete to enhance its existing life and life of the structure as well. If the cause of deterioration is predicted and a proper assessment of the structure is made, it may be economical feasible to repair the distressed structure and prolong its residual life. Number of tests need to be carried out to access the extent of distress and damages in the concrete structure and to estimate the quality/ strength of the concrete, before taking up any repair measures. These tests can be of different type which include destructive, non-destructive (NDT) or partially destructive (PDT).The main aim of this research is to highlight the importance and significance of different non- destructive testing methods employed to assess the present condition of RCC structure of different type and age. A balanced and systematic approach for the interpretation of test results based on NDT and PDT will be represented to know their present state and extent damage and deterioration present in the structure. A systematic and economical approach will also be suggested for their repair and rehabilitation measures to enhance their service life.**

Index Terms—NDT, PDT, Rebound hammer test, Ultrasonic Pulse Velocity Test.
Area : CTM- Civil Engineering

INTRODUCTION

Non-Destructive Testing (NDT) techniques can be used effectively for investigation and evaluating the actual condition of the structures. These techniques are relatively quick, easy to use, and cheap and give a general indication of the required property of the concrete. This approach will enable us to find suspected zones, thereby reducing the time and cost of examining a large mass of concrete. The choice of a particular NDT method depends upon the property of concrete to be observed such as strength, corrosion, crack monitoring etc.

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Er. Neha Goyal, Scholar M.Tech. –in Construction Technology & Mgmt., HCTM Technical Campus,Kaithal, Kurukshetra University Roll no.–17162408 ,Haryana, India
Er. Bhavana Arora, Astt. Professor CED, HCTM Kaithal-Haryana
Dr. Sanjay Sharma, Head of Dept. - Civil Engineering ,National Institute of Technical Teachers Training & Research (NITTTR), Chandigarh, India.
Dr. Arvind Dewangan, Director (Prof. in Civil Engg.)- Yognanda College of Engineering & Technology, Akhnoor Road, Jammu (J & K)

Many of NDT methods used for concrete testing have their origin to the testing of more homogeneous, metallic system. These methods have a sound scientific basis, but heterogeneity of concrete makes interpretation of results somewhat difficult. There could be many parameters such as materials, mix, workmanship and environment, which influence the result of measurements. Moreover the test measures some other property of concrete (e.g.hardness) yet the results are interpreted to assess the different property of the concrete e.g.(strength). Thus, interpretation of the result is very important and a difficult job wheregeneralization is not possible. Even though operators can carry out the test but interpretation of results must be left to experts having experience and knowledge of application of such non-destructive tests.

Variety of NDT methods have been developed and are available forinvestigation and evaluation of different parameters related to strength, durability and overallquality of concrete. Each method has some strength and some weakness. Therefore prudentapproach would be to use more than one method in combination so that the strength of onecompensates the weakness of the other. The various NDT methods for testing concrete structures are listed below –

A. For strength estimation of concrete
(i) Rebound hammer test
(ii) Ultrasonic Pulse Velocity Tester

B. For assessment of corrosion condition of reinforcement and to determine reinforcement diameter and cover
(i) Resistivity meter test
(ii) Test for carbonation of concrete
(iii) Ferro-scan

Non Destructive Evaluation (NDE) Methods
Concrete technologists practice NDE methods for
(a) Concrete strength determination (b) Concrete damage detection

Strength determination by NDE methods:
Strength determination of concrete is important because its elastic behaviour & service behaviourcan be predicted from its strength characteristics. The conventional NDE methods typicallymeasure certain properties of concrete from which an estimate of its strength and othercharacteristics can be made. Hence, they do not directly give the absolute values of strength.

STRUCTURAL AUDIT

Structural audit is the technical survey of the building in order to check its strength and stability. Structural audit is the first step in repairing procedure of the building. Structural audit is generally recommended for older buildings.

Structural audit was first introduced by Indian society of structural engineers. Structural audit helps in improving the safety, efficiency and gives idea about the strength of the structure by detailed technical inspection. In present study attempt have been made to carry out structural audit of the old RCC building by carrying out site inspection, performing NDT on the structure. Building is modelled and analysed using ETABS and Demand to capacity ratio is determined.

Structural Audit By ETABS Software

The innovative and revolutionary new ETABSis the ultimate integrated software package for the structuralanalysis and design of buildings. This latest ETABS offers unmatched3D object based on modelling and visualization tools, fast linear and nonlinear analytical power, sophisticated andcomprehensive design capabilities for a wedge-range of materials,and insightful graphic displays, reports, and schematicdrawings. CAD drawings can be directly converted into ETABSmodels. Design of steel and concrete frames, composite beams,composite columns, steel joists and concrete and masonry shearwalls, as is the capacity check for steel connections and baseplates. Comprehensive and customizable reports are availablefor all analysis and design output, and construction drawings offraming plans, details, and cross sections are generated for concreteand steel structures.

Need for Structural Audit

Structural audit is carried out in order to

- To increase life of property
- To know the health of building and its expected life.
- To check actual reliability of the structure.
- In order to recommend rehabilitation techniques.
- In order to highlight the critical areas and repair them immediately.

NDE Methods in Practice

Visual inspection: The first stage in the evaluation of a concrete structure is to study the condition of concrete, to note any defects in the concrete, to note the presence of cracking and the cracking type (crack width, depth, spacing, density), the presence of rust marks on the surface, the presence of voids and the presence of apparently poorly compacted areas etc. Visual assessment determines whether or not to proceed with detailed investigation.

The Surface hardness method: This is based on the principle that the strength of concrete is proportional to its surface hardness. The calibration chart is valid for a particular type of cement, aggregates used, moisture content, and the age of the specimen.

The Pull-out test:A pull out test involves casting the enlarged end of a steel rod after setting of concrete, to be tested and then measuring the force required to pull it out. The test measures the direct shear strength of concrete. This in turn is correlated with the compressive strength; thus a measurement of the in-place compressive strength is made. The test may cause damage to the specimen which needs to be repaired.

LITERATURE REVIEW

Mrs. Ayaz Mahmood, stated in his thesis, method of Non-destructive evaluation (NDE) methods are used for **(a)** detection of concrete strength (**b)** detection of concrete damage. He conducted tests on specimens and on columns, beams and on double story building's slab in NIT Rourkela by the means of ultrasonic pulse velocity and rebound hammer test. Different strength of 6 cubes were casted and conducted the compressive strength with rebound hammer and velocity. He also plotted it two graphs, one between velocity versus compressive strength and the second one between rebound hammer versus compressive strength. thereafter, they casted with the grade of M20 add m25 concrete, again rebound hammer and velocity test were conducted on these and then they compared these results with, without reinforcement tests. with the help of these results, it was witnessed that ultrasonic pulse velocity's variation was around 16. 1 % and for the rebound hammer it was around 3. 6%. after that this work performed on the real structure and got required assessment.

Denys. Breysse stated that how and why non-destructive testing, in measuring of in-situ strength of concrete is important. mainly it's by:- **(a)** clear review of existing models **(b)** data collected on in-situ and collected in Labs **(c)** illustrating real data and the development or analysis of design considerations to reproduce main pattern whereas by controlling dependable parameters main factors which influence the quality of strength estimate are known. there were two main techniques, one is UPV the another one is rebound which have preferences. it is vivid that errors in measurement have a great influence on the estimate of quality the arena real structure. suggestions and recommendations are given in the case of Son Reb combined approach.

Varalakshmi V et.al(2014) analysed a G+5 storey residential building and designed the various components like beam, slab, column and foundation. The loads namely dead load and live load were calculated as per IS 875(Part I & II)-1987 and HYSD bars i.e. Fe 415 are used as per IS 1986-1985. They concluded that the safety of the reinforced concrete building depends upon the initial architectural and structural configuration of the total building, the quality of the structural analysis, design and reinforcement detailing of the building frame to achieve stability of elements and their ductile performance.

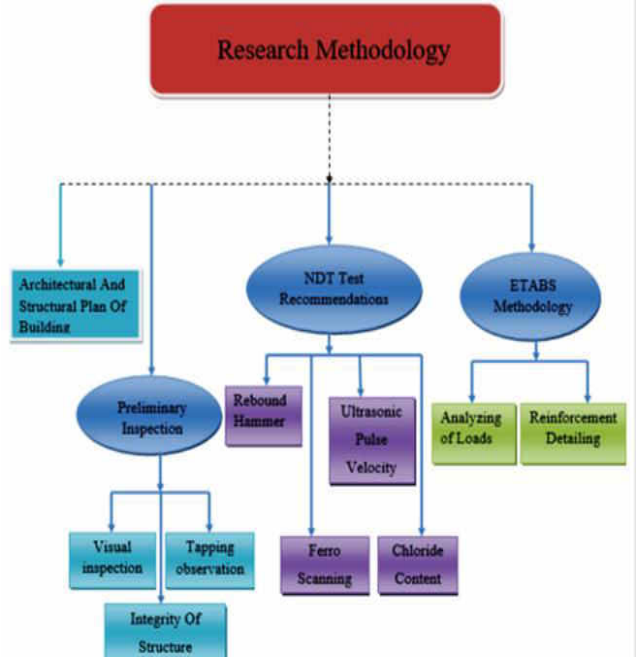
Chandrashekar et.al (2015) analysed and designed the multi-storeyed building by using ETABS software. A G+5 storey building under the lateral loading effect of wind and earthquake was considered for this study and analysis is done by using ETABS. They have also considered the chances of occurrence of spread of fire and the importance of use of fire proof material up to highest possible standards of performance as well as reliability. They suggested that the wide chances of ETABS software which is very innovative and easier for high rise buildings so that time incurred for designing is reduced.

MhammadrezaHamidian, in this research paper, authors compared two results one is conducted by the use of ultrasonic pulse velocity test and rebound hammer test on one particular specimen and previously made structure, which gives compressive strength of concrete and form comparison with the actual compressive strength which is conducted by compressive testing machine. The structural health monitoring by UPV and RSH conducted both in laboratory and on-site. The experimental examination using NDT test showed much better result and showed relation between compressive strength. UPP methods are supposed to be best

for both under construction and made structures with the accuracy ranges from ±20% whereas SRH showed ±15% to ±20 %.

RESEARCH METHODOLOGY

Thesystematicapproachfortheperformance evaluation and structural auditingofthestructureasidentifiedfrom theliteraturesurveywillbefollowed.Researchmethodologyfort heproposedprojectswillconsistof the followingsteps:-



TAPPING OBSERVATION

During this observation some of the structural members area subjected to hammer tapping and tapping sound is noted i.e. whether it is hollow or dense. A simple technique has been used effectively form any years is the cointap (or tap hammer) method. It is used to inspect composite laminates, sandwich structures, and bonded joints. Though it is cheap and simple, It is dependent upon the inspector's hearing and interpretation, the results are subject to interference from workplace noise, and this technique is unable to provide quantitative data. By instrumenting a traditional tap hammer with a force transducer and associated electronics,quantitative, objective data can be obtained simply and cheaply.

NON-DESTRUCTIVE TESTINGOFCONCRETE ELEMENTS

Non-destructive testing of various concrete elements at different locations was carried out for find -ing the quality of concrete and other defects. Following major tests were conducted.

- ReboundHammer Test
- UltrasonicPulse VelocityTest
- Ferro-Scanning Test
- Ferro Scanner is a device used to locate reinforcing bars and estimates the diameter and depth of cover. This device is based on interactions between the bars and low-frequency electromagnetic fields. The physical principle that is employed is that of electromagnetic induction, whereby and alternating magnetic field induces an electrical potential in an electrical circle intersected by the field.

The test for reinforcement scanning is done with help of HILTI PS 200 Ferroscan, a portable system for detecting rebar in concrete structures. HILTI PS 200 Ferroscan record the depth and positions of rebars over long stretches and obtain average coverage and statistics. The major analysis and conclusion is done on the computer on the analysis software to produce reports of the data recorded which is further submitted to the Structural Consultant for Preparation of Structural Drawing and thereby establishing the Stability of the Structure. The limitations of this test are interferences may occur in images due to scraps of reinforcement in concrete, tie wires where rebars cross, aggregates with Ferro magnetic properties.

The results have been presented in a tabular form. The rebound hammer values, ultrasonic pulse velocity test values and ferro-scanning test result as determined by tests on different locations.

VISUAL INSPECTION AND OBSERVATION

Visualexaminationisthe starting pointofinspection.Cracks, ruststaining,andspallingare the mostobvious defectswhich canbeidentified.Often thelocation ofthesecangive agood indicationofthecauseoftheproblem,butanopen mindmustbekeptatthisstageuntilfurther investigationisundertakentoconfirmtherootcause.Ifvisualinsp ectionofastructuresuggests that a problem may be present, an in-depth examination should be carried out.

PRINCIPLE

The method is based on the principle that the rebound of an elastic mass depends on the hardness of the surface against which mass strikes. When the plunger of rebound hammer is pressed against the surface of the concrete, the spring controlled mass rebounds and the extent of such rebound depends upon the surface hardness of concrete. The surface hardness and therefore the rebound is taken to be related to the compressive strength of the concrete. Therebound value is read off along a graduated scale and is designated as the rebound number of rebound index. The compressive strength can be read directly from the graph provided on thebody of the hammer

INSTRUMENT	AVERAGE REBOUND NUMBER	QUALITY OF CONCRETE
Schmidt Hammer N-TYPE	Greater than 40	Verygood hard layer
	30 to 40	Good layer
	20 to 30	Fair
	Less than20	Poor concrete
	0	Delaminated

Table: QUALITY OFCONCRETE COVER PURPOSE

This test gives a measure of the surface hardness of the concrete surface. Although there is no direct relationshipbetweenthismeasurementofsurfacehardnessandstrength,anempirical relationship exists.

Rebound hammer isthe best known methodsof comparing the concrete indifferent parts of a structureandindirectlyassessingconcretestrength.Therebound hammershouldbeconsidered as a means of assessing variations of strength within a structurerather than an accurate means of assessing the strength.

ULTRASONIC PULSE VELOCITY TESTER

Ultrasonic instrument is handy, battery operated and portable instrument used for assessing elastic properties or concrete quality. The apparatus for ultrasonic pulse velocity measurement consists of the following

A. Electrical Pulse Generator
B. Transducer- one pair
C. Amplifier
D. Electronic Timing Device

Although thereisnofundamentalrelationshipbetween pulsevelocityandstrength,an estimationof strengthcanbe obtainedbycorrelation.The methodhasperhapsagreater potentialforcomparingknownsoundconcretewithaffected concrete.Ultrasonicpulse velocityisameansofassessingvariationsin theapparentstrengthofconcrete.Thequality gradationofconcrete can beappraisedatbestqualitatively as `excellent', `good', `medium' or`doubtful'. Themeaningsoftheterm`excellent',`good',`medium'and`doubtful' are based onultra-sonic pulsevelocity measuredat site andareas perthenomenclatureofIS13311(part-1): 1992.

RANGE AND LIMITATIONS OF SCHMIDT REBOUND HAMMER TEST

Although the rebound hammer does provide a quick, inexpensive method of checking the uniformity of concrete, it has some serious limitations. The results are affected by:

1. *Smoothness of the test surface*

Hammer has to be used against a smooth surface, preferably a formed one. Open textured concrete cannot therefore be tested. If the surface is rough, e.g. a trowelled surface, it should be rubbed smooth with a carborundum stone.

2. *Size, shape and rigidity of the specimen*

If the concrete does not form part of a large mass any movement caused by the impact of the hammer will result in a reduction in the rebound number. In such cases the member has to be rigidly held or backed up by a heavy mass.

3. *Age of the specimen*

For equal strengths, higher rebound numbers are obtained with a 7 day old concrete than with a 28 day old. Therefore, when old concrete is to be tested in a structure a direct correlation is necessary between the rebound numbers and compressive strengths of cores taken from the structure. Rebound testing should not be carried out on low strength concrete at early ages or when the concrete strength is less than 7 MPA since the concrete surface could be damaged by the hammer.

4. *Surface and internal moisture conditions of concrete*

The rebound numbers are lower for well-cured air dried specimens than for the same specimens tested after being soaked in water and tested in the saturated surface dried conditions. Therefore, whenever the actual moisture condition of the field concrete or specimen is unknown, the surface should be pre-saturated for several hours before testing. A correlation curve for tests performed on saturated surface dried specimens should then be used to estimate the compressive strength.

5. *Type of coarse aggregate*

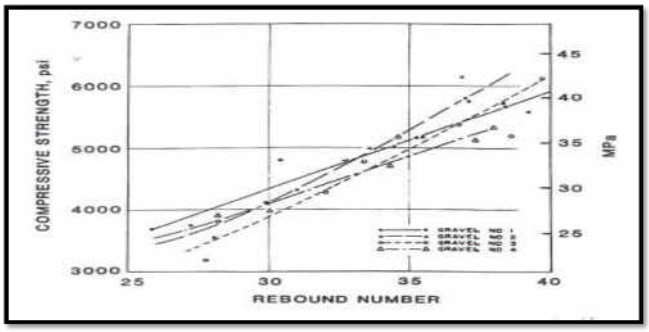
Even though the same aggregate type is used in the concrete mix, the correlation curves can be different if the source of the aggregate is different. An example is shown in Fig. 4.5 where correlation curves for four different sources of gravel are plotted.

6. *Type of cement*

High alumina cement can have a compressive strength 100% higher than the strength estimated using a correlation curve based on ordinary Portland cement. Also, super sulphated cement concrete can have strength 50% lower than ordinary Portland cement.

7. *Carbonation of the concrete surface*

In older concrete the carbonation depth can be several millimetres thick and, in extreme cases, up to 20 mm thick. In such cases the rebound numbers can be up to 50% higher than those obtained on an uncarbonated concrete surface.



ULTRASONICPULSE VELOCITY

The ultrasonic pulse is generated by an electro acoustical translucent, when the pulse isinduced into the concrete from a transducer; it undergoes multiple reflections at theboundaries of the different material phases within the concrete. A complex system of stresswaves is developed which includes longitudinal (Compression) shear (transverse) & surface(Rayleigh) waves. The receiving transducer detects the onset of the longitudinal waves,which is fastest. Because the velocity of the pulse is almost independent of the geometry ofthe materiel through which they pass & depends only on its elastic properties, pulse velocitymethod is a convenient technique for investigating structural concrete. The underlying principle of assessing the quality of concrete is that comparatively highervelocities are obtained when the quality of concrete in terms of density, homogeneity &uniformity is good. In case of poorer quality, lower velocities are obtained. If there is crack,void or flaw inside the concrete, which comes in the way of transmission of the pulses, thepulse strength is attenuated & it passes around the discontinuity, thereby making the pathlength longer. Consequently, lower velocities are obtained. The actual pulse obtaineddepends primarily upon the materials and mix proportions of concrete. Density and modulusof elasticity of aggregate also significantly affect the pulse velocity.

The reading from the test is given as follows:

Table 4.2 ULTRASONICPULSE VELOCITY TEST RESULTSOFHotel King Castle

Sr. No.	Location/ Grid	UPVValues		Avg. UPV	Method of Testing	Final UPVResultsDirect Proportionate Velocity(IS, 5.4.1 13311 part)	Quality
Ground Floor							
1.	ColumnC-1	2585	2897	2891	Indirect	3325	Medium
2.	Column C-2	2250	3120	2685	Indirect	3088	Medium
3.	Column C-3	2903	2447	2675	Indirect	3077	Medium
4.	BeamB-1	2685	2875	2780	Indirect	3197	Medium
1st Floor							
5.	Column C-4	2614	3014	2814	Indirect	3236	Medium
6.	Column C-5	2372	3002	2687	Indirect	3090	Medium
7.	Column C-3'	2678	2685	2682	Indirect	3084	Medium
8.	Column C-6	2937	2706	2822	Indirect	3245	Medium
9.	Column C-7	2990	2967	2979	Indirect	3226	Medium
2nd Floor							
10.	Column C-8	2350	2876	2613	Indirect	3005	Medium
11.	Column C-9	2743	3058	2901	Indirect	3336	Medium
12.	Column C-10	3026	2545	2786	Indirect	3204	Medium
13.	BeamB-2	3752	3356	3554	Indirect	3554	Good
3rd Floor							
14.	Column C-11	3012	2999	3006	Indirect	3457	Medium
15.	Column C-12	2358	3025	2692	Indirect	3096	Medium
4Th Floor							
16.	Column C-13	2695	2550	2623	Indirect	3017	Medium
17.	Column C-14	3598	3489	3544	Direct	3544	Good
18.	Column C-15	3712	3644	3478	Direct	3478	Medium
19.	Column C-16	3385	3142	3264	Direct	3264	Medium
20.	Column C-17	3166	3358	3262	Direct	3262	Medium

CONCLUSION

- There is no unique relation between hardness and strength of concrete but experimental data relationship can be obtained from a given concrete.The relationship is dependent upon factors affecting the concrete surface such as degree of saturation, carbonation, temperature, surface penetration and location, and type of surface finish.
- This is just a traditional fact to follow that this tests can only be performed on the aged structure but now, it is evident that conducting tests on newly made structures also provide a considerable amount of outcomes.
- Popular currently used techniques have been presented, detailed and illustrated.
- Non-destructive testing methods are based on correlation of particular concrete characteristics to strength.
- No single technique can be treated as superior to others.
- Discrimination cannot easily be done, as the basis for correlation of strength to concrete characteristics is different in different techniques.
- More than one technique may have to be employed based on the situation and results
- have to be carefully interpreted applying a very sound engineering judgment

- The pulse velocity method is an ideal tool for establishing whether concrete is uniform. It can be used on both existing structures and those under construction.
- Ultrasonic pulse velocity tests have a great potential for concrete control, particularly for establishing uniformity and detecting cracks or defects. Its use for predicting strength is much more limited.

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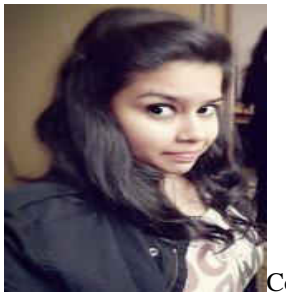

Corresponding Author Er. Neha Goyal is a scholar of M.Tech. in Haryana College of Tech. & Management, Kaithal.