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A Review on Structural Health Monitoring using NDT

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Abstract: Any structure is always designed as per the IS regulations and Standards; however they are always not followed during the actual construction process. This tends to symptoms such as deterioration and prompting early restoration and repair work. The corrosion of the RCC structures is always considered as one of the major concern hence periodic monitoring and maintenance is mandatory. Over the period of time as the structure gets older, it exhibits the distress in the form of cracking, delamination, corrosion, fracturing etc. To prevent such causalities and anticipate preventive measures structural health monitoring is one of the essential step. These deteriorated structures can be rehabilitated using various forms of admixtures and new materials for the repair. Non-destructive Testing (NDT) has been used to assess the structure's properties and is useful in the inspection and monitoring of existing structures.

Keywords: Non-destructive testing, Rebound Hammer test, Ultrasonic Pulse velocity test, Repair, Rehabilitation

1. INTRODUCTION:

Structural health monitoring identifies and evaluates all key areas, as well as recommending quick corrective and preventative actions. The appropriate actions are subsequently taken to increase the structure's performance and restore the required function. As a result, it is critical to conduct a structural examination of existing structures and to promptly implement maintenance and repair work, which will result in the building's longevity and occupant safety.

In recent years, non-destructive techniques (NDT) and monitoring methods are performed on concrete structures to examine the properties of structures. The primary goal of NDT techniques is to assess the materials' quality and integrity. Non-destructive methods are used to test building materials such as concrete and reinforcing corrosion, and can be done both during construction and later on in the structure's life cycle. NDT has been used to evaluate the structure's properties and plays an important

part in the inspection and monitoring of existing structures. NDT is to obtain the material properties of in place specimens, without the destruction of neither the specimen nor the structure from which it is taken.

1.1 STRUCTURAL AUDIT:

Structural audit is the inspection or examination of a building to assess its strength in order to increase its service life, safety, and efficiency. The overall health and performance of a building is determined by its quality and maintenance, and exposure to the environment can have a substantial impact on its health.

1.1.1 Destructive Testing:

Tests are carried out until the specimen's failure in destructive testing (or destructive physical analysis, DPA) in order to understand a specimen's performance or material behaviour under varying stresses. Non-destructive testing is more difficult to do, produce more information, and interpret than destructive testing. Destructive testing is most appropriate and cost-effective for mass-produced goods because the expense of destroying a small number of specimens is insignificant. When only one or a few products are to be produced, destructive testing is usually not cost effective (for example, in the case of a building).

1.1.2 Non-Destructive Testing:

A non-destructive test is one that is used to verify the integrity of a material, component, or building without hurting or destroying it." NDT is used to determine the strength of structural members in an existing structure or during construction. A variety of non-destructive evaluation tests for concrete members are available to determine in-situ strength and quality of concrete. These tests can also be used to assess damage to RCC structures that have been subjected to corrosion, chemical attack, or fire for other reasons. Non-destructive testing is divided into two categories: in-situ field testing and laboratory testing.

There are several types of NDT for concrete structures; however they are chosen based on their durability and application. These tests can be fully non-destructive or somewhat destructive, with little impact on the concrete structure's strength and durability.

ULTRASONIC PULSE VELOCITY TEST:

The ultrasonic pulse velocity test on concrete is a well-known NDT for determining concrete homogeneity. With this ultrasonic test on concrete, the following can be determined:

• Quantities assessment or concrete strength gradation in various structural member locations and plotting the same

• Determination of any discontinuity in cross section, such as a crack; depth of surface crack.

Table no.1: Quality of concrete in structures in terms of the ultrasonic pulse velocity (AS PER IS 13311(PART 1): 1992)

UPV Value km/sec. (V)	Concrete quality
Greater than 4.00	Excellent
Between 3.50 and 4.00	Good but porous
Between 3.00 and 3.50	Medium
Between 2.50 and 3.00	Poor
Between 2.00 and 2.50	Very poor and low integrity
Less than 2.00	No integrity, large voids suspected

REBOUND HAMMER TEST:

The Schmidt rebound hammer is primarily a surface hardness test, with little obvious theoretical relationship between concrete strength and the hammer's rebound number. The rebound hammer method can be used for;

a) Assessing the appropriate co-relations between rebound index and compressive strength to estimate the expected compressive strength of concrete.

b) Concrete uniformity evaluation.

c) Evaluating concrete quality in reference to industry standards.

d) Comparing the quality of one concrete element to that of another. This method can be used to differentiate between dubious and acceptable elements of a structure or to compare two different structures with higher confidence.

Table no. 1: Quality of concrete for respective average rebound number (AS PER IS 13311(PART 1): 1992)

Average Rebound Number	Quality of Concrete
greater than 40	Very good hard layer
30 to 40	Good layer
20 to 30	Fair
less than20	Poor concrete
0	Delaminated

1.2 Need of Structural Audit:

1. Extend the life of the structure.
2. To save the lives of the people inside the building.
3. Locate and repair any damaged areas of the building as soon as possible.
4. To determine whether or not the structure is fit for human habitation.

2. LITERATURE REVIEW:

This includes a detailed study of various research works and literature related to various NDT techniques, some structural auditing case study and articles related to maintenance, repair and retrofit of RCC structure.

Structural health monitoring is the process of applying a damage identification technique for civil engineering infrastructure in this study (SHM). Damage is defined as changes made to a system that has a negative impact on its present or future performance. SHM, condition monitoring, non-destructive

evaluation, statistical process control, and damage forecasting are five closely related disciplines that are used in damage identification. Significant future developments of this technology will come by multi-disciplinary research efforts, studying fields such as structural dynamics, signal processing, motion and environmental sensing and smart materials. [1]

This study intends to boost knowledge about the health inspection of existing concrete buildings among civil engineers, residents, and building owners and also determines the strength and durability of a structure in order to extend its life or service life span. Structural audit generally done periodically by professional expert act immediately through recommendation provided in audits reports. The sorts of problems, nature of the problems, and environmental circumstances all influence the success of repair and retrofit. The effective requirement of retrofitting is implemented on the auditing problem so enhance the property of structure. [2]

Structural audit is used to find out appropriate remedial measures can be recommended for all structure defect and damages so that to find out the damages non –destructive test is required. This kind of testing allows the material or component to be tested without losing its utility. This paper concludes that the structural audit is generally recommended for older building. Structural auditing assists in the improvement of building safety, efficiency, and strength and durability. NDT method helps is testing integrity of concrete or structural member through outs its life span. The main cause of damage of the structural member is due to corrosion. Corrosion in the structural member is seen due to dampness and linkage from the slabs, crack in the wall. [3]

The purpose of this test was to analyse delamination in concrete utilising an ultrasonic pulse velocity test. For this two slabs specimen are used having size 150mm and 300mm thickness consist delamination of varying size. To establish the characteristics of concrete, direct and indirect transmission methods were used in the test. The indirect method was used to calculate parameters such as dynamic young's modulus and dynamic Poisson's ratio, whereas the direct method was utilised to calculate concrete's compressive strength. [4]

Structural health monitoring is a necessary step for regular monitoring of a structure. Nondestructive Testing (NDT) has been used to evaluate the characteristics of the structure and plays a good role in the inspection and monitoring of the existing buildings. Ultrasonic pulse velocity, rebound hammer, and

rebar locator test was used on this building to identify the quality and strength of the concrete structure. [5]

Retrofitting reinforced concrete (RC) bridge columns with steel or fiber-reinforced polymer (FRP) composite jackets has proven to be beneficial in improving seismic performance of the structures. However, only a few studies on the behavioural features of restored RC columns with steel or FRP jackets have been done too far. The comparative performance of restored RC columns with steel and CFRP jackets is described in this research. The impact of the transverse reinforcement ratio on steel behaviour and CFRP repair is also examined. Monotonic and cyclic load tests are conducted on nine RC column specimens with different repairing strategies and transverse reinforcement ratios to compare the ultimate and the hysteretic behaviours. Both steel and CFRP jacket repairs can greatly boost the ductility and ultimate capacity of damaged columns, according to the tests. For columns with a lower transverse reinforcement ratio, steel jacket repaired columns have a higher energy dissipation capability than CFRP jacket repaired columns. It is also observed that the location of plastic hinge region goes up as the transverse reinforcement ratio of RC columns increases. [6]

The rebound hammer test was used in this research to determine the compressive strength of recycled aggregate concrete. The rebound hammer test is used to measure the relative compressive strength of concrete and to find relative surface weakness in cover concrete. Casting cubes were tested under the controlled condition. [7]

The major mechanical parameters of concrete for assessing the flexural and shear stiffness of concrete elements are the modulus of elasticity and Poisson's ratio. Although steel fibres are beginning to be approved in modern building codes, such standards do not include formulae for determining the elasticity modulus and Poisson's ratio of Fiber Reinforced Concrete (FRC). The findings of this study revealed that choosing the right dynamic test design (direct or semi-direct) is critical because the predicted outcomes are dependent on setup. It is also necessary to identify the wave types logged by the test equipment, because Vp, Vs or Vr velocities must be known for determining the modulus of elasticity or the Poisson's ratio of fiber reinforced concrete. [8]

This paper provides an overview of many innovative and cost-effective retrofitting strategies for strengthening damaged structures. Existing structures' seismic behaviours are influenced by design flaws, construction flaws, increased loads, additional performance demands, and so on. The necessity to

update and fortify these seismically inadequate structures has been highlighted by recent earthquakes. Retrofitting is one of the most effective ways to make an existing building safe against future earthquakes or other natural disasters. Retrofitting decreases an existing structure's vulnerability to damage during a future earthquake. It tries to reinforce a structure in order to meet the current seismic design criteria. A significant amount of research work has been carried out in recent years to develop various strengthening and rehabilitation techniques to improve the seismic performance of structures. [9]

The author has been developing two softwares, ETABS and MATLAB software were applied to develop and optimal plan that involved minimal repair costs and maximum safety, it has been used two methods for corrosion damaged reinforced concrete column retrofitting. The following are the significant objectives of this project:

- To optimize the reinforcement process considering the cost of concrete and reinforcement.
- To compare the cost of a column for different concrete strengths (fc) and retrofitting methods.

In case study two type of retrofitting methods are applied to 20 % critically corroded column the results are follows:

- Considering safety factors, applying externally –bonded still plate yields about 40% growth in comparison to concrete jacketing retrofitting which means implementing steel plate are safer than used concrete jacketing retrofitting.

- Considering all parameter's, the concrete jacketing retrofitting shows approximately 70% decreasing total cost which makes the more economical compare to other methods. [10]

3. CONCLUSION:

The above papers conclude that health monitoring is becoming increasingly important for any structure, as its ultimate goal is to be able to inspect the structure throughout its working life in order to reduce maintenance requirements and downtime.

There are bylaws that specify the time period after which any structure must be audited.

Visual examination, coupled with non-destructive evaluation techniques, is currently the primary way for assessing the health of structures.

There is a third option, which is destructive testing, but this renders the structure component useless. As a result, it is rarely utilised.

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