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DAMAGE DETECTION AND IT'S REPAIR BY NDT

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Abstract - *Buildings and other structures have a certain useful life, which depends on the specifications adopted. The large numbers of monuments, which are cherished heritage structures have stood well over a period of time. But some of these have shown signs of distress due to age, aggressive natural environment/industrial pollution etc. Further, distress gets aggravated due to overloading and misuse of buildings. A few buildings have also failed due to faulty design or construction. The various causes of structural failure and the principles of rehabilitation of structures are discussed. In the proposed approach we used Damage Detection and It's Repairs and Rehabilitation Techniques in RCC Structures Using NDT 1. Ultrasonic Pulse Velocity 2. Resistivity meter For Corrosion Mapping 3. Rebound Hammer. The outcome of the project can be used as the basis for repair and maintenance works to be carried out for enhanced life and service of the structure. Structures are assemblies of load carrying members capable of safely transferring the superimposed loads to the foundations. Their main and most looked after property is the strength of the material that they are made of. Concrete, as we all know, is an integral material used for construction purposes. Thus, strength of concrete used, is required to be 'known' before starting with any kind of analysis. In the recent past, various methods and techniques, called as Non-Destructive Evaluation (NDE) techniques, are being used for Structural Health Monitoring (SHM). The concept of nondestructive testing (NDT) is to obtain material properties of in place specimens without the destruction of the specimen nor the structure from which it is taken. The use of the ultrasonic pulse velocity tester is introduced as a tool to monitor basic initial cracking of concrete structures and hence to introduce a threshold limit for possible failure of the structures. The project brings out the present state of concrete structures & the major areas where improvement is needed during its service life stage for sustainable development & also the method of carrying out Repair, Rehabilitation.*

Key Words: *Health Monitoring, Rehabilitation, Concrete Structure, NDT, Rebound Hammer Test, Methodology, Ultrasonic Pulse Velocity.*

1. INTRODUCTION

Indian construction industries structural health monitoring system 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 is more and more becoming a serious concern. Non-destructive testing (NDT) methods have a large potential to be part of structural health monitoring. Various NDT methods can be used for the assessment of existing structures, have become available for concrete structures, but are still not established for regular inspections. Therefore, the objective of this project is to study the structural health of material applicability, performance, availability, complexity and restrictions of NDT.

1.1 Background

Damage identification is carried out in conjunction with five closely related disciplines that include SHM, condition monitoring, non-destructive evaluation statistical process control and damage prognosis. Typically, SHM is associated with online global damage identification in structural systems such as buildings. CM is analogous to SHM, but addresses damage identification in rotating and reciprocating machinery, such as those used in manufacturing and power generation. NDE is usually carried out off-line in a local manner after the damage has been located. There are exceptions to this rule, as NDE is also used as a monitoring tool for in situ structures such as pressure vessels and rails. NDE is therefore primarily used for damage characterization and as a severity check when there is a priori knowledge of the damage location.

1.2 Objectives of Study

The main objectives of study area are as follows:

1. To study Mechanism of NDT in damage detection.
2. To compare out coming results as per IS 13311 code
3. To achieve rehabilitation of building on the basis detailed inspection results:
    - Faulty design of the structure
    - Improper execution and bad workmanship
    - Extreme weathering and environmental conditions
    - Ageing of the structure

1.3 Need of Study

The primary need for NDT systems on infrastructure is to ensure safety. Structural failures result in significant monetary cost and unquantifiable human loses. A correct diagnosis establishing the cause, nature and extent of damage, and the weakness or deterioration caused in the structure is very essential, since a faulty diagnosis may lead to improper selection of materials and repair techniques leading to the failure of the repaired zone again. It may also be necessary that the serviceability of the structure is checked after carrying out the necessary repairs.

1.4 Scope of Work

The scope of Structural health monitoring systems can help asset owner's transition from schedule based maintenance to condition based maintenance. The benefits of this approach are twofold: the organizations responsible for maintaining the structure can reduce maintenance cost by only conducting maintenance when it is needed and damage can be detected early for a proactive response. In this way, SHM systems both improve safety and enhance the longevity of structures.

2. LITERATURE REVIEW

2.2.1. Danish Zamanet. al (2016) In the literature, the authors focused on structural health monitoring of civil infrastructure such as building, bridge and maintaining safe and reliable civil infrastructures for daily use is important to the wellbeing of all of us. Structural health monitoring and damage identification are assuming larger and larger importance in civil engineering. Structural Health Monitoring (SHM) is defined as the use of in-situ, non-destructive sensing and analysis of structural characteristics in order to identify if damage has occurred, define its location and estimate its severity, evaluate its consequences on the residual life of the structure.

2.2.2. KondapalliHarshadaet al (2015) The study of SHM analysis can be used on the educational building of their college in this case study For the present work of Structural Health Monitoring based on Non Destructive Testing we have considered a 5-storey educational building which is nothing but the R-Block of Usha Rama College of Engineering & Technology. It has an age of 8 years.

2.2.3.Mohan D. Aggarwalet al (2008) In this paper author studied on the real time SHM Monitoring author focused on sensory material used for SHM. Those technologies include techniques and devices such as bi-metal strain gauges, fiber optic sensors, and the more labor intensive visual inspection of micro cracks made visible with dye penetrate.

2.2.4.A. D'Alessandro et al(2013) In this paper author focused on the effective monitoring of a structure can lead to cost-effective maintenance and can enhance occupants' safety. A distributed monitoring system can better identify, localize and quantify incipient damages and variations of the structural behavior compared to a sparse utilization of off-the-shelf sensors.

2.2.5.J.Vcelak, A.Vodickaet al(2017) In this paper author focused on smart building monitoring, Modern building has several monitoring and control systems which should cooperate together to achieve energy saving while keeping indoor comfort and healthy environment. The overall building management systems (BMS) provides an integrated way to gather data from the building and issue control commands to the installed technology.

2.2.6. MohammadrezaHamidian et al. (2014) The concept of nondestructive testing (NDT) is to obtain material properties of "in place" specimens without the destruction of the specimens and to do the structural health monitoring. Ultrasonic pulse velocity (UPV) used together with Schmidt Rebound Hammer (SRH) tests give a combined test method for health assessment by a suitable correlation between these two tests along with test by compressive testing machine.

2.2.7. KaziJabedAkram et al (2016) The efficiency of a parallel plate capacitor for the detection of moisture concentration in concrete structure is proposed in this paper. As the presence of moisture in the concrete structure deteriorate the health of the structure, therefore its presence should be correctly examined. In this paper, the effect of moisture on the electrical properties such as impedance, capacitance, phase angle, dissipation factor of concrete is thoroughly studied. A fly ash brick has been taken in order to analyze the performance of the proposed methodology.

2.2.8. Y. DONG et al. (2012) The chapter begins by discussing the requirement for performance assessment of FRP rehabilitated structures by NDT/NDE methodologies. The general classification of NDT techniques are introduced, followed by the concept of structural health monitoring (SHM) as related to the real-time performance monitoring of the rehabilitated structures.

2.2.9. Won-Jae Yi, et al. (2017) Critical structures such as aircrafts, buildings, dams and buildings require periodic inspections to ensure safe operation. Reliable inspection of structures can be achieved by combining ultrasound non-destructive testing techniques with other sensors (for example, temperature sensor and accelerometers).

2.2.10. Divya P. Goswami et al. This review paper analyzes why and how nondestructive testing (NDT) measurements can be used in order toassess on site strength of concrete. It is based on (a) an in-depth critical review of existing models; (b) an analysis of experimental data gathered by many authors in laboratory studies as well as on site, (c) the development and analysis of synthetic simulations designed

in order to reproduce the main patterns exhibited with real data while better controlling influencing parameters.

3. METHODOLOGY

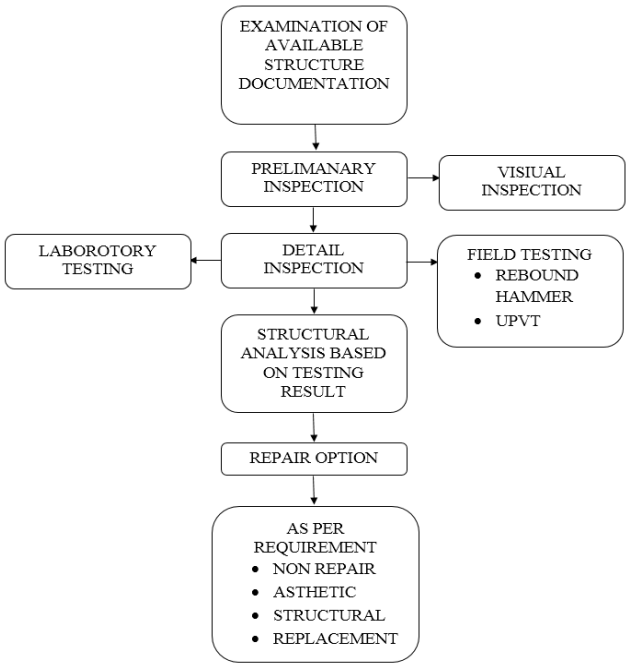

Fig. 01 Research Methodology

3.1 Rebound Hammer

Before commencement of a test, the rebound hammer should be tested against the test anvil, to get reliable results. The testing anvil should be of steel having Brinell hardness number of about 5000 N/mm2. The supplier/manufacturer of the rebound hammer should indicate the range of readings on the anvil suitable for different types of rebound hammer.

3.2 Ultrasonic Pulse Velocity Tester

The equipment should be calibrated before starting the observation and at the end of test to ensure accuracy of the measurement and performance of the equipment. It is done by measuring transit time on a standard calibration rod supplied along with the equipment. A platform/staging of suitable height should be erected to have an access to the measuring locations. The location of measurement should be marked and numbered with chalk or similar thing prior to actual measurement (pre decided locations).

3.3Audit and Repair Development Model

A Norm According to the model bye-law no. 77 for co-operative housing societies, it is mandatory that if the age of a building is 15 to 30 years, a structural audit must be carried out once in five years and for buildings older than 30 years it should be carried out once in three years. One may, however, go for it even earlier if one suspects the condition of the building to be bad. Perhaps monsoon/ post monsoon is the best time to commission a structural audit since the seepage is more evident at that time. The certificate, issued by a structural engineer registered with BMC, will have to be submitted within a year after a building completes 30 years. For any corrective repairs suggested by the commissioner, the owner or occupants will be asked to submit the structural stability certificates again after a specific period suggested by him.

3.4 Case Study

3.4.1. R.C.C. Building Information

Basic Information	
Type of Structure -	**RCC Building of P+6 floors**
Address -	**Pune**
Type of Structure –	**RCC**

No of wings & stories - 6 storied (4 flats from 1st to 6th floor each and having no flats at ground floor) No & type of apartments - 24 flats

Description of Building

Year of construction-Oct 1992

Age- 27 years

Effects of monsoon - Yes

Fig. 02 Spelled cover concrete & exposed cover Reinforcement (Ref. Google)

3.4.5. Observations

External

- The Building is of RCC frame and brickwork / block masonry. RCC Columns and Beams show corrosion based cracks at many places.
- The exterior face of the building shows cracks, crazing, and delamination in plaster.
- Beam & column adjoining to wall delamination is noticed at various places on the facade of the building.
- All these defects propagate to seepage and leakages. Seepage near any R.C.C. member's leads to further propagation of defects like rebar's corrosion, etc.
- Other important problem in the building appears to be the seepages from the dead walls & entire exteriors, more prominent on the south & west sides of the building. The level of damage is more on the account of the south west sides due to atmospheric direction of monsoon.
- Due to these problems, the condition of the building appears to be quite leaky and structural distress is observed in most of the corner columns & beams.

4. APPLICATION OF NDT

Structural health monitoring is at the forefront of structural and materials research. Structural health monitoring systems enable inspectors and engineers to gather material data of structures and structural elements used for analysis. Ultrasonic can be applied to structural monitoring programs to obtain such data, which would be especially valuable since the wave properties could be used to obtain material properties as well as structural health. His purpose of the course is to provide students with a fundamental and practical understanding on concrete repair technology, repair materials, and repair philosophies. A large number of reinforced concrete (RC) structures are deteriorating, often prematurely, and need remedial measures to reinstate their safety and/or serviceability. Consequently, the need for repair and protection has grown considerably in recent years. While costs associated with repair of deteriorating concrete structures can be substantial, costs resulting from poorly designed or executed repairs may be even higher.

5. RESULTS AND DISSCUSSION

5.1. Rebound Hammer Test

5.1.1. Preparation of Specimen:

6 cubes were cast, targeting at different mean strengths. Further, the cubes were cured for different number of days to ensure availability of a wide range of compressive strength attained by these cubes. Size of each cube was 150×150×150 mm.

5.1.2 Testing of specimen:

10 readings (rebound numbers) were obtained for each cube, at different locations on the surface of the specimen. The cube was divided into grid blocks of equal spacing and 10 points were marked at equal intervals for taking the Rebound Hammer test.

The cubes were then given a load of 7 N/mm^2 (as specified by the IS CODE 13311) in the Compression Testing Machine and the Rebound Values were obtained. The cubes were then loaded up to their ultimate stress and the Breaking Load was obtained.

5.2. Calibration Tests

5.2.5. Calibration test results of sample No. 5

Following table shows rebound hammer no. taken at different points on sample no. 1 along with compression tests result.

Table 5.1

Dead Load	=	150	KN
Breaking load	=	710	KN
fck Predicted	=	36.2	N/mm^2
fck Actual	=	31.5	N/mm^2

The following graph is obtained between the Predicted Compressive Strength by the Rebound Hammer and the Actual Compressive Strength:

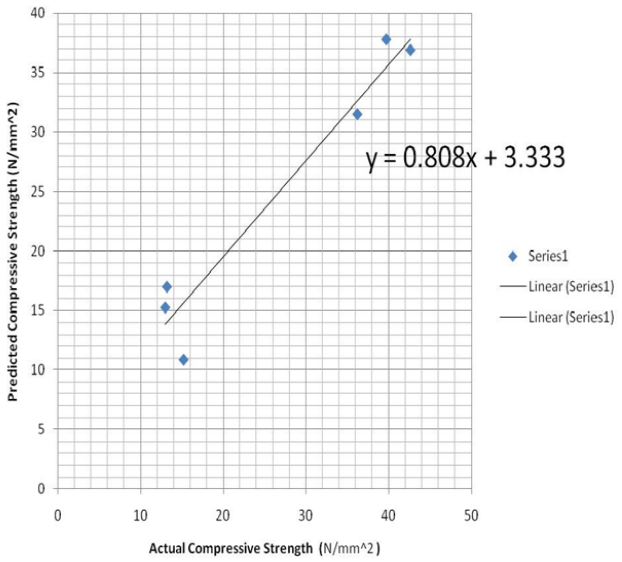

Fig. 03: Calibration Graph for Rebound Hammer with its Equation

5.3 Ultrasonic Velocity Testing Machine

Preparation of Specimen: 9 cubes were cast, targeting at different mean strengths. Further, the cubes were cured for different number of days to ensure availability of a wide range of compressive strength attained by these cubes. Size of each cube was 150×150×150 mm.

5.3.1. Testing of Specimen: 3 readings of Ultrasonic Pulse Velocity (USPV) were obtained for each cube. The cubes were then given a load of 7 N/mm^2 (as specified by the IS CODE 13311) in the Compression Testing Machine and the USPV were obtained.

The cubes were then loaded up to their ultimate stress and the Breaking Load was obtained.

The following graph is obtained between the Compressive Strength and the Ultrasonic Pulse Velocity:

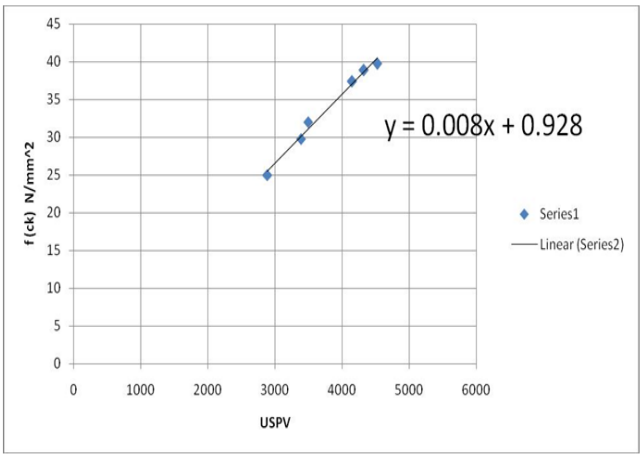

Fig. 05 Graph obtained for USPV Testing

This graph can now also be used to approximately predict the Compressive Strength of Concrete. Although it gives fairly approximate results but it should be verified with some other tests like the Rebound Hammer test.

Pictures during taking readings:

Picture 1: Rebound Hammer NDT Testing on Column

6. CONCLUSIONS

1. In summary, ultrasonic pulse velocity tests have a great potential for concrete control, particularly for establishing uniformity and detecting cracks or defects.

2. At the junction of beams and columns the results seems more accurate and proper, this is because of proper compaction and attention given during casting as it is junction of beam and column joint compared to other area.

3. Also, when compare all NDT results taken over slab then strength of concrete at edges is **8% -10**% higher than the center of slab. In case of column there is variation of **35% - 40**% in strength; at the base of the column it is higher as compaction occurred due to weight of the column.

4. Measurements were not accurate and representative when compared to the cubes used to construct the plots. The use of the combined methods produces results that lie close to the true values when compared with other methods.

5. The final results were compared with Rebound Test and Ultrasonic pulse velocity test which actual results obtained from samples extracted from existing structures and find out best methods for NDT.

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