International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 2 Issue 7, July - 2013

Strength Assessment And Restoration Of Rc Structures By Structural Health Evaluation - Case Study

Namitha R Jain **Mr . K. N. Vishwanath**

1. *PG student, Dayananda Sagar College of Engineering, Bengaluru, Karnataka, India*
2. *Associate Professor, Civil Engineering, Dayananda Sagar College of Engineering, Bengaluru.*

ABSTRACT

Non-Destructive Evaluation (NDE) techniques, are being used for Structural Health Evaluation. 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. The various methods and techniques, called as NDT.

In recent years, innovative NDT methods, which 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 applicability, performance, availability, complexity and restrictions of NDT.

1.0 Introduction

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. The existing Residential building owned by Mr. Nasir Ahmed located at HSR Layout BANGALORE is a RC framed structure with infilled masonry walls. The building comprises of basement, ground and three upper floors only. The floor slab and roofing system comprises of RC slab with beams supported on columns and footings. On conducting various tests it is found that columns were purely executed and the core tests were failing. Later on considering design checks it was found that some columns were deficient of certain percentage of reinforcement. Hence restoration measures are to be adopted.

2.0 Literature Review

A paper entitled **"State-Of-The-Art Non-Destructive Methods For Diagnostic Testing Of Building Structures"** anticipated development trends by **J. Hoła, K. Schabowicz** was studied.[1] The paper presents a survey of state-of-the-art non-destructive diagnostic techniques of testing building structures and examples of their applications. Much attention is devoted to acoustic techniques since they have been greatly developed in recent years and there is a clear trend towards acquiring information on a tested element or structure from acoustic signals processed by proper software using complex data analysis algorithms. Another trend in the development of non-destructive techniques is towards assessing characteristics other than strength in elements or structures, particularly the ones made of concrete or reinforced concrete.

A literature work on **"Site Remediation Techniques Supporting Environmental Restoration Activities"** by **D.M. Hamby**. [2] Ann Arbor, MI 48109-2029 U.S.A was identified. The literature contains a number of books, articles, and federal documents on various remediation techniques available for environmental restoration activities. However, a single document that is a compilation of the majority of methods utilized by United States federal agencies and the private sector for environmental remediation is not known to exist. The purpose of this paper, therefore, is to provide a comprehensive overview of the techniques and methods available for environmental remediation. It is not intended to provide in-depth detail for any one technique, but rather to serve as initial guidance for remedy selection alternatives and to act as a catalyst in option-specific literature searches

A paper on **"Integration of Non-Destructive Testing In Concrete Education"** by **Amir Mirmiran[3]** says that, A two-year laboratory improvement and course development project was funded by the NSF for implementation at the University of Central Florida (UCF). Feedback from alumni and local engineering firms indicated the need for a comprehensive concrete lab and field experience. Previously, concrete experiments were limited and combined with other construction materials in a 1-credit Structures Laboratory, which was offered at least one semester prior to the concrete course.

An another journal on **"Non-destructive testing to investigate corrosion status in concrete status"** by **Nicholas J Carino**[4] was reviewed and the gist was with the growing rate of deterioration in the nation's infrastructure, the necessity for including non-destructive testing (NDT) and field instrumentation in engineering curriculum has become more apparent than ever before. Implementation of a National Science Foundation project for enhancing concrete laboratory with NDT and instrumentation modules is discussed. The new laboratory significantly increased student's interest in, and learning from the course. A national survey of civil engineering programs showed that less than 1 out 12 schools include NDT methods in their labs.

A paper by **Hertlein B.H.,** on **"Role of Nondestructive Testing in Assessing the Infrastructure Crisis"** [5] was reviewed and the focus of this project was to improve the quality of undergraduate concrete education by enhancing the concrete laboratory to include new modules for NDT and instrumentation. The new laboratory significantly increased student's interest in, and learning from, the concrete course work. A national survey of civil engineering programs across the country showed that less than 1 out 12 schools include NDT methods in their concrete laboratories.

A paper on **" Inspection and monitoring planning for RC structures based on minimization of expected damage detection delay"** by **Sunyong Kim, Dan M. Frangopol** [6] shows that deterioration mechanism of reinforced concrete (RC) structures under corrosion is highly dependent on environment and material properties. Uncertainties in structural damage occurrence and propagation due to corrosion should be considered in a rational way using a probabilistic approach. In this study, such an approach is proposed to establish a life-cycle optimum inspection plan under uncertainty. This plan leads to cost-effective maintenance interventions, considering uncertainties associated with damage occurrence/propagation and inspection methods. Uncertainties associated with prediction of damage occurrence time are considered by using the Monte Carlo simulation.

A journal on "**Structural health monitoring of underground facilities – Technological issues and challenges"** by **S. Bhalla , Y.W. Yang , J. Zhao , C.K. Soha**[7] shows driven by the scarcity of land, many urban planners are seriously considering underground space to meet residential, commercial, transportation, industrial and municipal needs of their cities. Besides saving land resources, the benefits offered by underground structures include safety against earthquakes and hurricanes, and freedom from urban noise. However, owing to their unique design and construction, they call for rigorous structural health monitoring (SHM) programmes during construction and operation, especially when important structures are located nearby on the ground surface.

A paper by **Mousumi Majumder, Tarun Kumar Gangopadhyay, Ashim Kumar Chakraborty, Kamal Dasgupta, D.K. Bhattacharya** on "**Fibre Bragg gratings in structural health monitoring—Present status and applications"** [8] says that In-service structural health monitoring (SHM) of engineering structures has assumed a significant role in assessing their safety and integrity. Fibre Bragg grating (FBG) sensors have emerged as a reliable, in situ, non-destructive tool for monitoring, diagnostics and control in civil structures. In this article, the recent research and development activities in structural health monitoring using FBG sensors have been critically reviewed, highlighting the areas where further work is needed.

A journal on **Structural health monitoring and reliability estimation** by **F. Necati Catbas, Melih Susoy, Dan M. Frangopol** [9] says that the main objective of this study is to present the reliability estimation studies for the main truss components as well as the entire structural system of a long span truss bridge which is the longest in its category in the USA. It is possible to assess the safety level of a long span bridge by using a probabilistic approach in terms of its component and system reliability indices. However, most of the older long span bridges were designed based on allowable stress design and it is not possible to quantify their reliability.

2.1 Objectives

This project work regarding strengthening and restoration of an RC structure is taken up with the following objectives:

1. To identify the strength of the existing building using NDT tests.
2. To locate the damages found in the structure.
3. To check the available percentage of reinforcement in RC Structures to that with the percentage of reinforcement which was calculated for that structure.
4. To provide the best available restoration measures to strengthen the damage structure.

3.0 Methodology

The various NDT methods for testing concrete structures are listed below
In order to evaluate the structural soundness of the building following tests are to be resorted:
1.Dimensional measurement of building
2.Non-destructive test to assess the quality / strength of in-situ concrete

- Rebound hammer test on RC Slab and bricks
- Ultrasonic Pulse Velocity Test

3.Covermeter studies to map the peripheral reinforcement and thickness of the cover concrete in RC members
4.Half-cell potential measurement test on RC members
5.Corbonation test on RC members
6.Chemical analysis on concrete samples

- Chloride determination test in concrete samples.
- Sulphate determination test in concrete samples.
- Determination of pH level in concrete.

7.Compressive strength test to assess the strength of bricks.
8.Verification of mortar in masonry joints of load bearing walls.

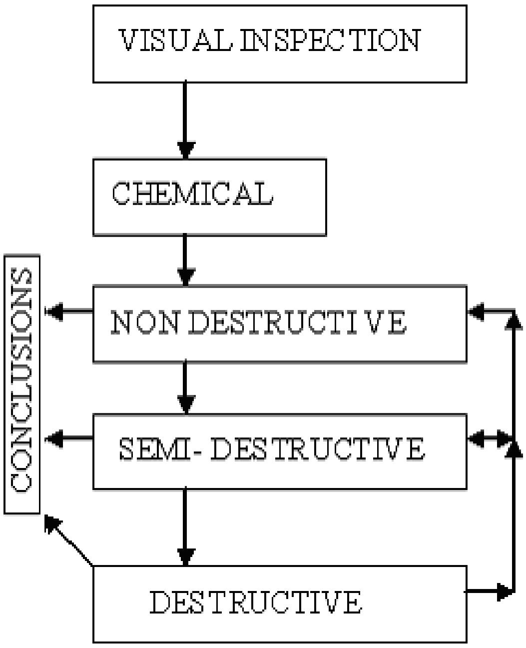

Fig., 1 Test selection procedure

1. **Dimensional measurement of structural members:**

As the relevant drawings were not made available, a detailed physical measurement was carried out at site, in order to obtain the dimensions of the various members for making layout drawings of the building.

2. **Non-destructive tests to assess the quality / strength of in-situ concrete in RC members:**
   Ultrasonic Pulse Velocity test on RC Columns & Beams: Ultrasonic Pulse Velocity test was conducted on RC columns and beams at random at all accessible regions of the building in all the blocks. The test was conducted using **"PUNDIT"** (Portable Ultrasonic Non-destructive Digital Indicating Tester).
   Rebound Hammer test on RC Slab: Rebound Hammer test was carried out on the RC slabs at random to assess the surface hardness / quality and strength of in-situ concrete in all the blocks. The tests were conducted using **Schmidt Rebound Hammer.**
3. **Cover meter studies to assess the thickness of cover concrete in RC members:**Cover meter test was carried out on RC members at random, in order to assess the thickness of cover concrete provided for embedded peripheral rebars.

4. **Half-Cell Potential Measurement test on RC members.**
   Half-Cell Potential Measurement test was carried out on RC members at random using Copper-Copper-Sulphate-Half-Cell to estimate the probability of corrosion in reinforcing bars. The test was conducted using **CANIN** equipment.
5. **Carbonation test on RC members:**
   Carbonation test was carried out on RC members at random using **phenolphthalein indicator** in 0.1 N methyl alcohol solution to assess the extent of carbonation in cover concrete.
6. **Chemical analysis on concrete samples:**

a. **Chloride Determination test in concrete samples.**
   Chloride determination test is carried out on concrete to estimate the level of chlorides in the concrete. The presence of higher amount of chlorides in concrete surrounding the reinforcement will result in corrosion of rebars. The quantity of chlorides in concrete is determined generally by chemical analysis.The results of chloride content test in concrete indicate that the level of chlorides in RC members should be within the permissible limit of **0.6 kg/cum.**

b. **Sulphate determination test in concrete samples**
   Sulphate determination test in concrete is carried out to estimate the level of sulphates in the concrete. The presence of higher amount of sulphates in concrete will result in reaction of calcium present in cement with sulphates, resulting in deterioration of concrete.

c. **Determination of pH level in concrete.**
   The level of pH in fresh concrete is generally in the range of 12 to 14. Due to carbonation, the pH value of concrete will be reduced considerably. When the pH value falls below about 10, the alkalinity of the concrete will not be adequate to protect the rebars against corrosion.

4.0 Results and Discussions

Following are the step-by-step measures for the proposed strengthening of deficient footings and r.c. columns.

- The existing plaster and debonded cover concrete if any on footings/ r.c.column surface shall be removed completely by gentle chipping and surface to be cleaned with air and water jet.
- Exposed reinforcement if shall be thoroughly cleaned with wire brush / buffing wheel to remove corrosion scale, dust etc. as per specification.
- 24 mm dia, 100 mm deep holes shall be drilled in footing / ceiling slab for fixing column bars and cleaned with air and water jet .
- 8 mm dia shear connectors shall be fixed in 12 mm dia drilled holes on column surface using polyester resin anchor grout.
- Proposed reinforcement as detailed in drawing shall be fabricated and fixed into the drilled holes of footing / ceiling slab and tied to the shear connectors.
- 75 mm thick, M30 grade concrete encasement shall be provided as per specification using slurry tight shuttering. (The shuttering of columns shall be de-shuttered only after a period of 72 hours).

On carrying out the recommended strengthening measures effectively by an experienced agency under the supervision of experienced personnel, the deficient R.C footings and columns of basement and ground floor will be rendered normal and bear the expected loads.

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