Structural Health Monitoring by Non Destructive Techniques On Concrete

Submitted in partial fulfilment of the requirements of the degree of Bachelor of Engineering

By

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Under Guidance of
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CERTIFICATE

This is to certify that the project entitled "Structural Health Monitoring by Non Destructive Techniques On Concrete" is a bonafide work of "Shivendra Tiwari" (11CE54), "Shweta Katrekar" (12CE64), "Mustafa Girilwala" (12CE101), "Abdul Kader Shahpurwala" (12CE102), submitted to the University of Mumbai in partial fulfilment of the requirement for the award of the degree of "Bachelor of Engineering" in Department of Civil Engineering.

Prof. Hawelikar S. C. Guide Dr. Rajendra Magar (HOD)

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Project Report Approval for B. E.

This project report entitled *"Structural Health Monitoring by Non Destructive Techniques On Concrete"* by *"Shivendra Tiwari" (11CE54), "Shweta Katrekar" (12CE64), "Mustafa Girilwala" (12CE101), "Abdul Kader Shahpurwala" (12CE102)* is approved for the degree of *"Bachelor of Engineering"* in *"Department of Civil Engineering"*.

Examiners

1 ________________________

2 ________________________

Supervisors

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Chairman (Director)

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Date:

Declaration

We declare that this written submission represents our ideas in our own words and where others ideas or words have been included, we have adequately cited and referenced the original sources. We also declare that we have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in my submission. We understand that any violation of the above will be cause for disciplinary action by the Institute and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

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Abstract

The concept of non-destructive testing (NDT) is to obtain material properties "in place" specimens without the destruction of the specimens and to do the structural health monitoring. NDT using Rebound hammer, Ultra pulse velocity, Half-cell potential, core cutter, carbonation depth, rebar locator, Rapid chloride penetration test, electric resistivity meter test and vibration base analysis by data analoger are very popular and highly effective in conducting structural health monitoring. The structure can be investigated by using a visual inspection, NDT, laboratory and field test performance. In this article a review of these tests have been provided to conduct effective structural health monitoring of a RCC structure.

The estimation of mechanical properties of concrete can be carried out by several methods; destructive and non-destructive. In this context, the crushing of the samples is the usual destructive test to determine the concrete strength. The rebound hammer test and the ultrasonic device are used in the field of non-destructive tests to determine respectively the compression strength and the ultrasonic pulse velocity (UPV) in the concrete. In this work, eight concrete compositions were used to prepare cylindrical specimens (16 cm x 32 cm) by varying the water/ cement ratio and the cement dosage. An experimental study was conducted to determine the compressive strength of concrete by destructive (compression) and non-destructive (rebound hammer) tests at different ages (7, 14 and 28 days). In addition, the influence of several factors on the modulus of elasticity determined by pulse velocity test was investigated. These factors mainly included the age of concrete and the water/ cement ratio. The results showed that the difference between the resistance values obtained by destructive and non-destructive methods decreases with increasing age of concrete. The dynamic modulus of elasticity increases with the curing time of the concrete until the age of three months. In addition, a simplified expression has been proposed to estimate the rebound number from the value of the dynamic modulus of elasticity determined by pulse velocity test.

Acknowledgement

We extend our deep sense of gratitude and indebtedness to our guide **Prof. Shivaji Sarvade**, Department Of Civil Engineering, AIKTC, New Panvel for his kind attitude, invaluable guidance, keen interest, immense help, inspiration and encouragement which helped me in carrying out my present work.

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We are also thankful to the Technical Staff of the Structural Laboratory, AIKTC New Panvel for helping me during the experimental work.

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Chapter 1

1.Introduction

1.1. General

The choice of concrete as a building material in constructing large structures, whether it be in reinforced concrete or in prestressed concrete is well proven. Concrete as a material has high adaptability to satisfy many aspects in structures, such as functional, economy, maintenance, aesthetic acceptability, protection against corrosive environments, protection against fire, resistance to cyclic loading, explosion resistance, and provide better control over deflection, etc. Moreover, concrete has the advantage of four "E's" that attract the Engineers.

They are:

• Energy saving

• Economical

• Eco-friendly

The above basic considerations have opened new areas of research in concrete technology to develop newest changes to improve the material to perform to a higher degree in structures from durability point of view. Although ordinary concrete made to specification normally perform satisfactorily, it is expected that even a better product would be available in the near future owing to overall improvements in elastic modulus, flexural strength, tensile strength, impact strength and permeability. With these improved properties, one can build a highly durable structure. The emphasis now-a-days is on high performance concrete in structures to achieve higher degree of durability so that structures are built for generations and investment in infrastructural sector is successfully reduced considerably. To check 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 require 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. The purpose of establishing standard procedures for non destructive testing (NDT) of concrete structures is to qualify and quantify the material properties of in-situ concrete without intrusively examining the material properties. There are many techniques that are currently being research for the NDT of materials today. This chapter focuses on the NDT methods relevant for the inspection and monitoring of concrete materials.

The structures which have already been built do exhibit distress after a lapse of some years during its service life. Generally, the service life of structures range from 60 to 120 years, but due to various reasons the full service life of the structure cannot be realised and it needs some maintenance or repair for enhancing its service life. The causes for the distress in the structure may be due to many factors:

- Proper type of foundations not being provided complying with soil conditions
- Design inaccuracies and improper detailing of reinforcement, improper cover to reinforcement and congestion of reinforcement
- Inaccuracies in formwork, such as, dimensional inaccuracy, leaking formwork, supporting system not being rigid, etc.
- Constituent materials for concrete not complying to specifications
- Inadequate compaction of poured concrete and lack of enforcement of quality control measures during construction.

Each one of the factors mentioned above has great significance and contribute to the distress one way or the other. Engineers can realise the advantages of concrete structures only when good practices are adopted in all the phases of the construction. Concrete structures that are deficient in quality will reflect on its durability. Reinforcement corrosion will be faster and resistance to accidental fire will be reduced to a very great extent. There are number of in situ test systems which are available now. They could be used on structures to assess the quality of in situ concrete, to assess the damage due to corrosion of reinforcement, or to assess the damage to concrete and steel due to accidental fires. The in situ tests can be classified into two categories:

(I) Tests which attempt to measure some property of concrete from which an estimate of strength, durability and elastic behaviour of material may be obtained.

(ii) Tests which attempt to determine position, size and condition of reinforcement; areas of poor consolidation, voids and cracks, and the moisture content of in-place concrete.

It has been suggested (Malhotra) that unless comprehensive laboratory correlations on the field materials and mix proportions have been established between the strength parameters to be predicted, the results of Non Destructive Testing (NDT) should not be used to predict strength. As a part of overall quality assurance programme for large projects, these NDT methods have, however, proven to be unquestionably valuable.

The objective of an in-place test is to estimate properties of concrete in the structure. Very often the desired property is the compressive strength. To make a strength estimate, it is necessary to have a known relationship between the result of the in-place test and the strength of the concrete. For new construction, this relationship is usually established empirically in the laboratory. For existing construction, the relationship is usually established by performing in-place tests at selected locations in the structure and determining the strength of cores drilled from adjacent locations.

Fig. 1.0 is a schematic of a strength relationship, in which the cylinder compressive strength is plotted as a function of an in-place test result. This relationship would be used to estimate the strength of concrete in a structure based on the value of the in-place test result obtained from testing the structure. The accuracy of the strength prediction depends directly on the degree of correlation between the strength of concrete and the quantity measured by the in-place test. The user of in place tests should have an understanding of what quantity is measured by the test and how this quantity is related to the strength of concrete. The purpose of this chapter is to explain the underlying principles of the widely used in-place test methods, and to identify those factors, other than concrete strength, that can influence the test results. Additional background information on these methods is available in the references by Malhotra (1976), Bungey (1989), and Malhotra and Carino (1991).

1.2. Motivation

In recent months there are many such examples for the collapses of different residential as well as industrial structures around Mumbai region. According to NDTV reports Nearly 500 people in Kalbadevi had luck on their side when a portion of a staircase of a chawl in Kalbadevi came crashing down. The staircase of Mani Ben chawl, inside Swadeshi Market, collapsed at around 5 pm on July 24, 2015.

fig 1.1

Other such events say At least one person died while six others incurred major injuries after a large portion of a five-storey building collapsed in in Goregaon (west) in suburban Mumbai on Tuesday. One person died and five other were injured as an under-construction shanty collapsed in South Mumbai today on july 12, 2014.

1.3. Importance and need of Non-Destructive Testing

Ideally such testing should be done without damaging the concrete. The tests available for testing concrete range from the completely non-destructive, where there is no damage to the concrete, through those where the concrete surface is slightly damaged, to partially destructive tests, such as core tests and pullout and pull off tests, where the surface has to be repaired after the test. The range of properties that can be assessed using non-destructive tests and partially destructive tests is quite large and includes such fundamental parameters as density, elastic modulus and strength as well as surface hardness and surface absorption, and reinforcement location, size and distance from the surface. In some cases it is also possible to check the quality of workmanship and structural integrity by the ability to detect voids, cracking and delimitation.

Non-destructive testing can be applied to both old and new structures. For new structures, the principal applications are likely to be for quality control or the resolution of doubts about the quality of materials or construction. The testing of existing structures is usually related to an assessment of structural integrity or adequacy. In either case, if destructive testing alone is used, for instance, by removing cores for compression testing, the cost of coring and testing may only allow a relatively small number of tests to be carried out on a large structure which may be misleading.

1.4. Organisation of report

The report is organized as follows. Chapter 1 presents a brief introduction highlighting need of the study, chapter 2 presents most vital backbone of the project, i.e. literature review.Literature survey is carried out by study of various Research paper related on Structural health monitoring and condition assessment of RC structure. Chapter 3 presents methodology adopted and Chapter 4 presents a case study of structural health monitoring. Finally concluding remarks and suggestions are mentioned in the chapter 5.

1.5. Special Credit.

It gives us immense pleasure to acknowledge and express our sincere gratitude to **Mr.Ashish Srivastava and Structech Consultant Engineers Pvt. Ltd.** for allowing us to work with the firm on the project. The study presented here is carried under his supervision at site. We are deeply indebted towards him and his team members for their kind support and valuable guidance during the entire work.

Chapter 2

2. Literature review

2.1. General

Here in this chapter we will be discussing about three different sub topics. In the very first unit we will discuss an overview of Structural Health Monitoring. In the next one we will discuss about different concepts and literatures given by the researchers.

2.1.1. Structural Health Monitoring

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. This testing approach may be used to assess the uniformity and relative quality of the concrete, to indicate the presence of voids and cracks, and to evaluate the effectiveness of crack repairs. It may also be used to indicate changes in the properties of concrete, and in the survey of structures, to estimate the severity of deterioration or cracking. Decreases in ultrasonic waves speeds over time can reveal the onset of damage before visible deficiencies become evident. This allows inspectors and engineers to implement repair recommendations before minor deficiencies become safety hazards.

2.1.2. Structural Health Monitoring using Non-Destructive Testing

The quality of new concrete structures is dependent on many factors such as type of cement, type of aggregates, water cement ratio, curing, environmental conditions etc. Besides this, the control exercised during construction also contributes a lot to achieve the desired quality. The present system of checking slump and testing cubes, to assess the strength of concrete, in structure under construction, are not sufficient as the actual strength of the structure depend on many other factors such as proper compaction, effective curing also. Considering the above requirements, need of testing of hardened concrete in new structures as well as old structures, is there to asses the actual condition of structures. 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. The subsequent testing of structure will largely depend upon the result of preliminary testing done with the appropriate NDT technique. The NDT being fast, easy to use at site and relatively less expensive can be used for

(i) Testing any number of points and locations
(ii) Assessing the structure for various distressed conditions
(iii) Assessing damage due to fire, chemical attack, impact, age etc.
(iv) Detecting cracks, voids, fractures, honeycombs and weak locations
(v) Assessing the actual condition of reinforcement

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 where generalization 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 for investigation and evaluation of different parameters related to strength, durability and overall quality of concrete. Each method has some strength and some weakness. Therefore prudent approach would be to use more than one method in combination so that the strength of one compensates the weakness of the other.

2.2 Literature review

Literature survey is carried out by study of various Research paper related on Structural health monitoring and condition assessment of RC structure

2.2.1 Mr. Ayazmahmood in this thesis Non-destructive evaluation (NDE) methods are used for,(a) Concrete strength determination and (b) Concrete damage detection. Rebound hammer testand Ultra-sonic pulse velocity testhave be done on specimens and the column, beams and slabs of two double storied buildings in NIT Rourkela. 6 Cubes were cast, targeting at different mean strengths, and then tested by rebound hammer and UPV and get Predicted compressive strength by help of Rebound numbers and Velocity. Also plot the graph between rebound number vs. compressive strength and velocity vs compressive strength. Then after M-20 and M- 25 concrete grade beam were casted. Again Rebound hammer and UPV tested on beams for comparative analysis to know the effect of reinforcement on the test Then after compare the without reinforcement and with reinforcement results, the maximum variation for Rebound value is 3.6%where in case of Ultrasonic Pulse Velocity the maximum variation is 16.1%.Therefore the variations are well within the tolerable limits. Then after rebound hammer and UPV were tested on actual structure and got existing condition of the structure.

2.2.2 D. Breysse in this paper has been analyzes why and how non destructive testing (NDT) measurements can be used in order to assess 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. The key factors influencing the quality of strength estimate are identified. Two NDT techniques (UPV and rebound) are prioritized and many empirical strength-NDT models are analyzed. It is shown that the measurement error has a much larger influence on the quality of estimate than the model error. The key issue of calibration is addressed and a proposal is made in the case of the SonReb combined approach.

2.2.3 Ehiorobo J.O in this paper authors carried out structural monitoring, periodic measurement of displacements, strains, stresses and damage evaluation (e.g. crack width) and vibration characteristics and mainly visual inspection of the structure. To detect the various crakes and also measuring the width of cracks, to show the layout of that structures. In this papers also using various non-destructive test to detect the cracks and to evaluate the existing condition of the structure. The cracks within the building vary in width from 0.75mm to 31.50mm. As some of the cracks along the wall are more than 25mm, it means that the stability of the building is already being impaired.

2.2.4 Ha-Won Song in this paper authors have focus on corrosion and have worked on detecting corrosion for different structures such as bridges, buildings and others structure locating around the coastline area. Authors also emphasize on structural Health monitoring, electrochemical techniques, durability maintenance and repair of structures. For measurement of the corrosion rate of reinforcing steel in concrete, many electrochemical and non-destructive techniques are available for monitoring corrosion of steel in concrete structures. Rebar corrosion on existing structures can be assessed by different methods such as, Visual inspection Open circuit potential (OCP) measurements,. Surface potential (SP) measurements, Concrete resistivity measurement, Galvan static pulse transient method Embeddable corrosion monitoring sensor, Cover thickness measurements, Ultrasonic pulse velocity technique, X-ray, Gamma radiography measurement, Infrared thermograph Electrochemical etc. Sensors are also used on structures exhibiting corrosion as part of a rehabilitation strategy to assess the effectiveness of repairs and to determine the future repair cycle.

2.2.5 KatalinSzilágyi Present paper introduces the SBZ-model developed by the authors of the paper which is a phenomenological constitutive model for the rebound surface hardness of concrete as a time dependent material property. The model covers the following empirical material laws: relationship between the water–cement ratio and the compressive strength of concrete at the age of 28 days; development of the concrete compressive strength in time; relationship between the compressive strength of concrete and the rebound index at the age of 28 days; the development of carbonation depth of concrete in time; the influence of carbonation depth of concrete on the rebound index.

2.2.6 MhammadrezaHamidian in this research paper authors used Rebound hammer test and Ultrasonic pulse velocity test on specimen and existing structure and got compressive strength of concrete and comparison along with actual compressive strength which is obtain from compressive testing machine. The structural health monitoring by NDT methods comprised of UPV and RSH (Schmidt Rebound Hammer) were carried out in laboratory and site. The experimental investigation using NDT methods showed that a good correlation exists between compressive strength, SRH and UPV. The SRH offers method of achieving concrete strength with accuracy of ±15 to ±20 parent and the UPV method is a perfect instrument for both existing structures and those under construction with accuracy within ±20%.

2.2.7 M. Torres-Luque in This paper highlights the importance of chloride content measuring, and also summarizes the state of the art of non-destructive and in situ techniques for measuring chloride content into concrete structures. These techniques have been developed over the past twenty years, and they have been shown as good alternatives in durability field. They are based on three methods: electrical resistivity (ER), ion selective electrode (ISE) and optical fiber sensors (OFS). Although other NDTs have been proposed such as electrochemical impedances spectroscopy, grounding penetrating radar and capacitive methods, until now, there is not enough results about their performance, accuracy, robustness, and chemical stability. Consequently, research efforts should focus on the improvement of the accuracy of these NDTs under in-field exposure conditions.

2.2.8 Kumavat H.R. The paper present case study include the use of various Non-Destructive Test (NDT), to evaluate the concrete quality of building age was 8 years. NDT used such as Ultrasonic pulse velocity, half-cell potential, carbonation depth, rebar locator, cover meter and core sampling. Initially, the structure deteriorates due to cyclic temperature variations, physical causes and aggressive chemical attack due to the environment. The research paper also focus on standard testing procedure of NDT and sequence of operation for obtaining accuracy as well as the problems created during the testing and the limitations of the tests are considered. In building structure it was observed that the half-cell potential reading of concrete beam is 15% more than the concrete column, the reading is shift in between 200mv to 500mv. There was 50 to 75% of probability of corrosion in beam member, due to shifting towards more negative values getting chances of corrosion of reinforcement.

2.2.9 MR.MeltemVatan in this research paper to identify the potential seismic risk in existing historic buildings for hazard mitigation, disaster preparedness and prior knowledge of potential hazards. Seismic risk evaluation is based on safety assessment which requires qualitative and quantitative data. This data is necessary before making any intervention decision. The qualitative data is visual inspection of decays, structural damages and deteriorations; and the quantitative data requires laboratory tests, structural analysis etc. Obtaining the quantitative data is detailed method, which necessitates specialists and takes more time and money. The fact that there are so many historic buildings and a few specialists on this field it is very important to make condition survey based on visual inspection as a first step of safety assessment procedure.

2.2.10 Mehdi Modares in this work, a new method with a hybrid experimental/analytical framework for condition assessment and life prediction of existing structures is developed. This objective hybrid framework combines experimental structural measurements (e.g., results from non-destructive tests or routine performance and/or inspection data for structure's response) and theoretical structural uncertainty analyses (interval finite element method). This method uses the structural measurements, with consideration of uncertainties, in structural uncertainty analyses, for estimating the condition of a structure. Application of structural measurement data, integrated with an enhanced structural analysis scheme, and with consideration of uncertainties provides the necessary information to make decisions regarding inspections, rehabilitation and repairs.

2.3. Aim of the study

To analyze the structure in respect of its strength and durability without destructing it, using Rebound Hammer, Ultrasonic pulse Velocity Test, Carbonation test and Half Cell Potentiometer Test. These Non Destructive Instruments were then used to test the columns, beams and slabs.

2.4. Objectives

1) To check the strength of existing buildings, to assess the strength of concrete, corrosion of steel inside the concrete, integrity of concrete and durability of concrete.

2) To check Ph and Carbonation of concrete to assess the life of the structure and possibility of corrosion because of lowering ph value.

3) Damage assessment of buildings and structures because of wear and tear, unexpected loadings on the structure and ageing factor.

2.5. Scope

In place tests are performed typically on concrete within a structure in contrast to tests performed on moulded specimens made from the concrete to be used in the structure. Historically, they have been called *non-destructive tests* because some of the early tests did not damage the concrete. Over the years, however, new methods have developed that result in superficial local damage. Therefore, the terminology *in place tests* is used as a general category that includes those which do not alter the concrete and those which result in minor surface damage. The important characteristic of these tests is that they measure the properties of the concrete in a structure. In this report, the principal application of in-place tests is to estimate the compressive strength of the concrete. In-place tests can be used to estimate concrete strength during construction, so that operations can be performed safely or curing procedures can be terminated. They can also be used to estimate concrete strength during the evaluation of existing structures. These two applications require slightly different approaches, so parts of this report are separated into sections dealing with *new* and *existing* construction.Only one colony has been selected for the study and only using Rebound Hammer, Ultrasonic pulse Velocity Test, Carbonation test and Half Cell Potentiometer Test

Chapter 3

3. Methodology

3.1. General

Following are the methods and application of NDT

- Schmidt/rebound hammer test, used to evaluate the surface hardness of concrete.
- Half-cell electrical potential method, used to detect the corrosion potential of reinforcing bars in concrete.
- Carbonation depth measurement test, used to determine whether moisture has reached the depth of the reinforcing bars and hence corrosion may be occurring.
- Permeability test, used to measure the flow of water through the concrete.
- Penetration resistance or Windsor probe test, used to measure the surface hardness and hence the strength of the surface and near surface layers of the concrete.
- Cover meter testing, used to measure the distance of steel reinforcing bars beneath the surface of the concrete and also possibly to measure the diameter of the reinforcing bars.
- Radiographic testing used to detect voids in the concrete and the position of stressing ducts.

- Sonic methods using an instrumented hammer providing both sonic echo and transmission methods.
- Topographic modelling, which uses the data from ultrasonic transmission tests in two or more directions to detect voids in concrete.
- Impact echo testing, used to detect voids, delimitation and other anomalies in concrete.
- Ground penetrating radar or impulse radar testing, used to detect the position of reinforcing bars or stressing ducts.
- Infrared thermograph, used to detect voids, delimitation and other anomalies in concrete and also detect water entry points in buildings.
- Ultrasonic pulse velocity testing, mainly used to measure the sound velocity of the concrete and hence the compressive strength of the concrete.

3.2. Visual Inspection

It can often provide valuable information to the well trained eye. Visual features may be related to workmanship, structural serviceability, and material deterioration and it is particularly important that the engineer is able to differentiate between the various signs of distress which may be encountered. These include for instance, cracks, pop-outs, spelling, disintegration, colour change, weathering, staining, surface blemishes and lack of uniformity. Extensive information can be gathered from visual inspection to give a preliminary indication of the condition of the structure and allow formulation of a subsequent testing programmed.

3.2.1.Tools and equipment for Visual Inspection

Measuring tapes or rulers, markers, thermometers, anemometers and others. Binoculars, telescopes, bore scopes and endoscopes or the more expensive fibre scopes may be useful where access is difficult. A crack width microscope or a crack width gauge is useful, while a magnifying glass or portable microscope is handy for close up examination. A good camera with the necessary zoom and micro lenses and other accessories, such as polarized filters, facilitates pictorial documentation of defects, and a portable colour chart is helpful in identifying variation in the colour of the concrete. A complete set of relevant structural drawings.

3.2.2. Applicaions of Visual Inspecion

For existing structures, presence of some feature requiring further investigation is generally indicated by visual inspection, such as weathering, chemical attack, mechanical damage, physical deterioration, abuse, construction deficiencies or faults and many others.

3.3. Methodology adopted for SHM

3.3.1. Rebound hammer method

The surface hardness method consists essentially of impacting the concrete surface in a standard manner. This is achieved by activating a mass by a given energy and measuring the indentation or rebound. The most commonly and widely used instrument is a “Rebound Hammer”. There are several types of hammers having varying impact energy from 0.07 kgm to 3.0 kgm. The high impact energy is used for mass concrete, road pavements and airport runways. The low impact energy hammers (0.07 to 0.09 kgm) are used for small and low strength materials.

The test procedure consists of applying the hammer on the concrete surface and observing the rebound reading indicated by a rider over a scale. Before applying the hammer, the surface of the concrete is cleaned and smoothened. A minimum of 10 readings should be obtained on a given point and average is determined. If more than 2 readings differ from the average by 7 units, entire set of readings are to be discarded and again readings are taken afresh. The procedure for determining the rebound values has been specified in ASTM C805-85 and also in the latest ASTM specifications. Although the rebound hammer provides a quick and inexpensive means of checking the surface hardness, it has many serious limitations, which should be recognised beforehand. The main factors that affect the readings are:

- Size and age of concrete

- Surface texture
- Concrete mix characteristics
- Stress state and temperature
- Carbonated concrete, and
- Moisture content.

It should be noted that the rebound values reflect the concrete quality up to a depth of 50 mm in the member. The calculation of "coefficient of variation" may yield an indication on the surface hardness of concrete. Fig. 1 shows a hammer test in progress.

3.3.1.1 Applications

The application of surface hardness measurements can be used for:

- checking the uniformity of concrete
- comparing a given concrete with a specified requirement

3.3.2. Ultrasonic Pulse Velocity

The object of this method is basically to measure the velocity of the pulses of longitudinal waves passing through concrete. The velocity of an ultrasonic pulse is influenced by the properties of concrete which determine its elastic stiffness and mechanical strength. Thus the variations in the pulse velocity values reflect a corresponding variation in the state of concrete under test. There is a reduction in the pulse velocity if the concrete under test has low compaction, voids or damaged material. The pulse velocity increases or decreases as the concrete matures or deteriorates or changes with time. However, based on the pulse velocity values, one can assess the quality of concrete in a structure. Assuming that the ultrasonic pulse velocity values (UPV value) of more than 4.5 km/sec represents excellent quality of concrete, the following criteria is adopted for certification qualitatively as per IS 13311.

The pulse velocity measurements may be used to establish:

i) the homogeneity of the concrete
ii) Presence of cracks, voids, and other imperfections
iii) Changes in the structure of concrete which occur with time/assessment of concrete deterioration due to fire, mechanical or chemical attack

iv) The quality of the concrete in relation to standard requirements

v) Quality of one element of concrete in relation to another

vi) The values of dynamic module/ elastic module of concrete. The test consists of transmitting longitudinal waves produced by an electro-acoustical transducer from one side of the concrete, and receiving the signal from the other side and measuring the transit time (T) of the pulse using electronic timing circuits. The path length (L) of the pulse is measured and velocity (V) is calculated as V = L/T

The measuring equipment consists of an electrical pulse generator, a pair of transducers, an amplifier, and an electronic timing device for measuring the time interval elapsed between the onset of a pulse generated at the transmitting transducer and the onset of its arrival at the receiving transducer. The transducers are of Piezo-electric type with natural frequencies ranging between 10 KHz and 200 KHz. Transducers with natural frequencies between 20 KHz and 150 KHz are the most suitable for use in concrete.

There are three ways in which the transducers can be arranged and UPV values may be determined depending on the accessibility of the exposed sides of a concrete member. They are shown schematically in Fig. 2. Determination of crack depth by using ultrasonic tester is also illustrated in Fig. 3.

Since the transverse reinforcement lying in the member in the path of the pulse influences the UPV, suitable correction have to be effected for the apparent velocity. Fig. 4 shows a ultrasonic pulse velocity test being conducted on a RC column.

3.3.2.1 Reliability and Limitations

The ultrasonic pulse velocity technique has been found to be a valuable and reliable method of examining the interior of a body of concrete in a truly non-destructive manner. The equipment (for example, PUNDIT, V-meter) is robust, reasonably cheap, easy to operate, and reliable even under site conditions. The operators must be well trained and should be aware of the factors affecting the readings. It is equally important that results are properly evaluated and interpreted by experienced engineers, who are familiar with the technique. The least reliable application of this technique is for strength estimation of concrete. The factors influencing calibrations are so many, that even under ideal conditions with specific calibration, it is unlikely that 95% confidence limits of better than + 20% can be achieved for an absolute strength prediction for in place concrete. However, a qualitative assessment is easily possible on a structure with UPV scanning at a large number of locations. ASTM C597 gives the standard test method for pulse velocity through concrete.

can be cut including reinforcements, if any, by using these machines. The cores can be tested for compressive strength, chemical analysis, petro graphic examination and evaluation of physical parameters. The strength testing of cores provide almost a direct evidence on the quality of concrete as it exists on the structure. It is however necessary to exercise caution in interpreting strength test results of cores as a number of factors, such as diameter of the core, slenderness ratio (l/d), core location, presence of reinforcement and curing condition influence the final results and the relation with cube strength.

3.3.3. Carbonation test

Carbonation of concrete is associated with the corrosion of steel reinforcement and with shrinkage. However, it also increases both the compressive and tensile strength of concrete, so not all of its effects on concrete are bad. Carbonation is the result of the dissolution of CO_2 in the concrete pore fluid and this reacts with calcium from calcium hydroxide and calcium silicate hydrate to form calcite ($CaCO_3$). Aragonite may form in hot conditions. Within a few hours, or a day or two at most, the surface of fresh concrete will have reacted with CO_2 from the air. Gradually, the process penetrates deeper into the concrete at a rate proportional to the square root of time. After a year or so it may typically have reached a depth of perhaps 1 mm for dense concrete of low permeability made with a low water/cement ratio, or up to 5 mm or more for more porous and permeable concrete made using a high water/cement ratio.

3.3.3.1 Testing for carbonation

The affected depth from the concrete surface can be readily shown by the use of phenolphthalein indicator solution. This is available from chemical suppliers. Phenolphthalein is a white or pale yellow crystalline material. For use as an indicator it is dissolved in a suitable solvent such as isopropyl alcohol (isopropanol) in a 1% solution. The phenolphthalein indicator solution is applied to a fresh fracture surface of concrete. If the indicator turns purple, the pH is above 8.6. Where the solution remains colourless, the pH of the concrete is below 8.6, suggesting carbonation. A fully-carbonated paste has a pH of about 8.4.The phenolphthalein indicator solution is applied to a fresh fracture surface of concrete. If the indicator turns purple, the pH is above 8.6. Where the solution remains colourless, the pH of the concrete is below 8.6, suggesting carbonation. A fully-carbonated paste has a pH of about 8.4. In practice, a pH of 8.6 may only give a faintly discernible slightly pink colour. A strong, immediate, colour change to purple suggests a pH that is rather higher, perhaps pH 9 or 10. Normal concrete pore solution is saturated with calcium hydroxide and also contains sodium and potassium hydroxide; the pH is typically 13-14. Concrete with a pore solution of pH 10-12 is less alkaline than sound concrete but would still produce a strong colour change with phenolphthalein indicator. It therefore follows that the indicator test is likely to underestimate the depth to which carbonation has occurred. In confirmation of this, microscopy - either optical microscopy using thin-sections, or scanning electron microscopy using polished sections - shows carbonation effects at greater depths than indicated by phenolphthalein indicator. Nevertheless, this test is very useful as a means of making an initial assessment - it is quick, easy and widely used.

3.3.4. Half cell potentiometer test

Principle & Procedure :

The instrument measures the potential and the electrical resistance between the reinforcement and the surface to evaluate the corrosion activity as well as the actual condition of the cover layer during testing. The electrical activity of the steel reinforcement and the concrete leads them to be considered as one half of weak battery cell with the steel acting as one electrode and the concrete as the electrolyte. The name half-cell surveying derives from the fact that the one half of the battery cell is considered to be the steel reinforcing bar and the surrounding concrete. The electrical potential of a point on the surface of steel reinforcing bar can be measured comparing its potential with that of copper – copper sulphate reference electrode on the surface. Practically this achieved by connecting a wire from one terminal of a voltmeter to the reinforcement and another wire to the copper sulphate reference electrode. Then generally readings taken are at grid of 1 x 1 m for slabs, walls and at 0.5 m c/c for Column, beams.

The risk of corrosion is evaluated by means of the potential gradient obtained, the higher the gradient , the higher risk of corrosion. The test results can be interpreted based on the following

If the concrete surface has dried to the extent that it is dielectric, then pre wetting of concrete is essential especially for Cement Silos, Exposed roof slab. The Quality of the cover concrete, particularly its moisture condition and Contamination by carbonation and / or chlorides may affect the results.

Chapter 4

4.1. General

Report on survey carried out for structural stability in assistance with ashish srivastava sir, director of structech consultant engineers pvt. ltd. name of building is Indian Oil Corporation Limited. Indian Oil Nagar, Shivaji Nagar, Chembur – Mankhurd Link Road, Govandi. Mumbai – 400 043. India and the owner of the same is Indian Oil Corporation Limited. Indian Oil Nagar, Shivaji Nagar, Chembur – Mankhurd Link Road, Govandi. Mumbai – 400 043. India. This construction was carried out in 1989 – 1992 years. The total area of the colony is approximately 251 Sq.mts. Mentioned floor to floor height in plan of the building is 3.5 mts. And the general depth of the slab is 110mm. total height of the building is 10.5 mts. and the soil strata is known to be hard murrum.

4.2 Visual Inspection

As per the structural survey carried out on the said buildings, located at Indian Oil Corporation Limited. Indian Oil Nagar, Shivaji Nagar, Chembur – Mankhurd Link Road, Govandi. Mumbai – 400 043. India. , the following points were noted down.

1. Plaster : The building plaster is in bad condition due to which rusting of reinforcing bar have taken place & there is heavy leakage from the external walls inside the building, which is creating unhygienic conditions for the residents of the building, which may lead to bad health of the residents & is seriously deteriorating the stability of the structure.

   Cause: These are surface cracks, this may have taken place due to shrinkage, because of use of rich mortar, sand used is too fine, inadequate curing or lack of bond with background or sulfate attack.

fig 4.1

fig 4.2

2. Roof terrace: The water proofing done to the terrace is in bad condition, which is causing leakage in the building below roof terrace.

   Cause: Cracks in roof terrace generally result in leakage of rain water through. The main cause of cracking is due to thermal & moisture movements.

3. Walls: The following types of cracks were noted in the walls as follows.

a. Vertical cracks in the top of slabs at corners of a building

   cause: This is due to shrinkage of R.C.C roof slab on initial drying, as well as thermal contraction, which exerts an inward pull on the walls in both directions. Since near the corners the walls cannot deflect because of interaction of the two walls at right angles to each other, bending in walls in portion away from corners, has caused vertical cracks about one unit away from the corners.

fig 4.3

b. Vertical cracks below opening in line with window jambs :

Cause: These cracks are due to vertical shear caused by differential strain in the lightly loaded masonry below the opening & heavily loaded portion of wall having no opening.

c. Vertical cracks around opening :

Cause: These cracks are caused by drying shrinkage & thermal movement in a building & occur around openings because of weakening in the walls as well as floor section occurring at the portion of the building.

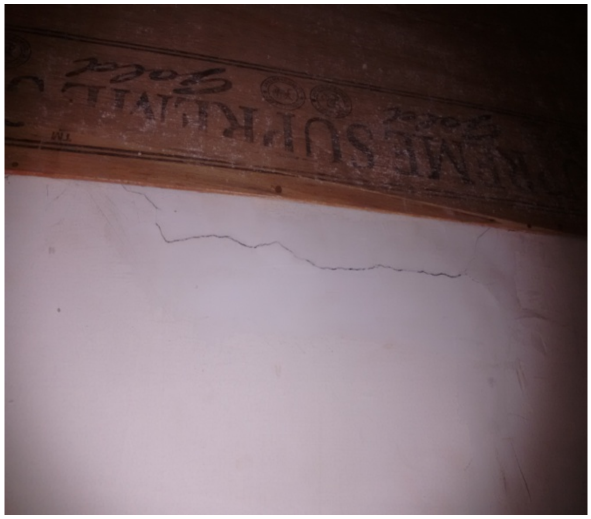

Fig 4.4

d. Horizontal cracks in the storey below slab level :

Cause: These cracks are due to deflection of slab & lifting up of edge of the slab, combined with horizontal movement in the slab due to shrinkage.

Fig 4.5

e. Horizontal cracks at windows lintel or sill level :

Cause: These cracks are due to pull exerted on the wall by the slab because of drying shrinkage & thermal contraction. This pull results in bending of the wall which causes cracking at a weak section, that is, at the lintel or sill level of the window opening.

f. Vertical cracks at the junction of r.c.c column & masonary :

Cause: These cracks are due to differential strain between R.C.C member & masonry because of elastic deformation, shrinkage & creep in R.C.C column.

Fig 4.6

fig 4.7

g. Ripping cracks at the ceiling level in cross walls :

Cause: These cracks are due to relative movement between the R.C.C roof slab & the cross wall, movement of R.C.C slab being due to thermal expansion & contraction because of inadequate thermal insulation or protective cover on the roof slab.

h. Diagonal cracks over R.C.C lintels spanning large openings:

Cause: These cracks are due to drying shrinkage of in-situ RCC lintels.

i. Horizontal cracks in panel walls :

Cause: These cracks occur if the walls are built too tightly between the beams of RCC frame. These cracks are caused by compressive forces on the wall on account of shortening of R.C.C due to elastic deformation, shrinkage & creep. These cracks are aggravated by irreversible moisture expansion of brickwork if bricks are used soon after taking out of the kiln.

Fig 4.8

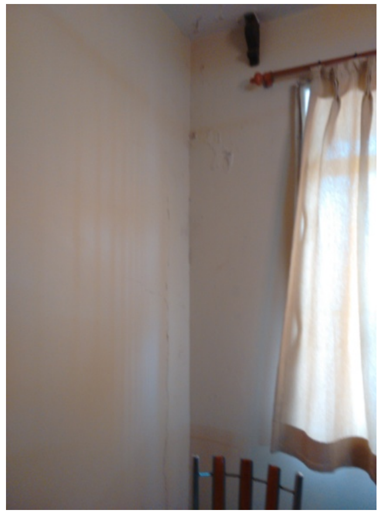

fig 4.9

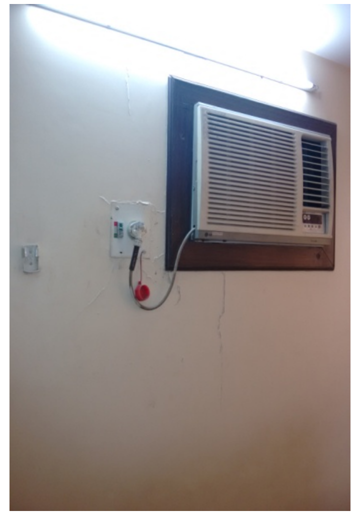

fig 4.10

4. RCC Members : The following points were noted in RCC members.

a. Straight cracks in concrete columns, parallel to reinforcement accompanied by spalling of cover and exposure of reinforcement at places in full height of building :
   Cause: The cracks are due to corrosion of reinforcement & would occur if concrete in question is not sufficiently dense & moisture from source has been causing continuous dampness in the affected portion.

b. Straight cracks in concrete beams at places in all floor parallel to reinforcement accompanied by spalling of cover and exposure of reinforcement at places :
   Cause: The cracks are due to corrosion of reinforcement & would occur if concrete in question is not sufficiently dense & moisture from source has been causing continuous dampness in the affected portion.

c. Straight cracks in concrete slab in corridor parallel to reinforcement accompanied by spalling of cover and exposure of reinforcement at first slab level, also at second & third floor level:

   Cause: The cracks are due to corrosion of reinforcement & would occur if concrete in question is not sufficiently dense & moisture from source has been causing continuous dampness in the affected portion.

d. Straight cracks in concrete slab parallel to reinforcement accompanied by spalling of cover and exposure of reinforcement at some locations at first slab level, also at second & third slab level:

   Cause: The cracks are due to corrosion of reinforcement & would occur if concrete in question is not sufficiently dense & moisture from source has been causing continuous dampness in the affected portion.

e. Straight cracks in concrete waist slab of staircase parallel to main reinforcement accompanied by spalling of cover and exposure of reinforcement at all level:

   Cause: The cracks are due to corrosion of reinforcement & would occur if concrete in question is not sufficiently dense & moisture from source has been causing continuous dampness in the affected portion.

f. Straight cracks in concrete slab of stair room parallel to main reinforcement accompanied by spalling of cover and exposure of reinforcement at top level:

   Cause: The cracks are due to corrosion of reinforcement & would occur if concrete in question is not sufficiently dense & moisture from source has been causing continuous dampness in the affected portion.

5. Rendering or plastering on concrete background :

   Cause: These crazing or cracking may occur either due to shrinkage or due to heavy stress in the member. Shrinkage cracks occur if mortar used is too rich or wet, if curing has been inadequate, if sand used is too fine & if rendering/plastering is done long after casting of concrete.

Fig 4.11

4.3 Ultra Sonic Pulse Velocity Test

The ultrasonic pulse is generated by an electro acoustical transducent, when the pulse is induced into the concrete from a transducer; it undergoes multiple reflections at the boundaries of the different material phases within the concrete. A complex system of stress waves 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 of the materiel through which they pass & depends only on its elastic properties, pulse velocity method is a convenient technique for investigating structural concrete.

The underlying principle of assessing the quality of concrete is that comparatively higher velocities 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, the pulse strength is attenuated & it passes around the discontinuity, thereby making the path length longer. Consequently, lower velocities are obtained. The actual pulse obtained depends primarily upon the materials and mix proportions of concrete. Density and modulus of elasticity of aggregate also significantly affect the pulse velocity.

The reading from the test is given as follows:

Table 4.1

SR. NO.	LOCATION	MEMBER	DISTANCE (MM)	TIME, MICRO SEC	VELOCITY, KM/SEC	METHOD
BUILDING-C						
1	Ground floor, C-01	Column	230	62.4	3.7	Direct
2	Ground floor, C-04	Column	300	126.3	*2.4	Indirect
3	Ground floor, CT-03	Column	300	134.4	*2.2	Indirect
4	Ground floor, CT-04	Column	300	214.4	*1.4	Indirect
5	Ground floor, CT-05	Column	300	101.4	*3.0	Indirect
6	Ground floor, C-06	Column	300	99.3	*3.0	Indirect
7	Ground floor, C-08	Column	300	141.2	*2.1	Indirect
8	Ground floor, C-09	Column	300	104.2	*2.9	Indirect
9	Ground floor, CT-06	Column	300	136.2	*2.2	Indirect
10	Ground floor, C-11	Column	300	99	*3.0	Indirect
11	Ground floor, C-12	Column	300	97.7	*3.1	Indirect
12	Ground floor, C-13	Column	300	118	*2.5	Indirect
13	Ground floor, CT-07	Column	300	141.7	*2.1	Indirect

14	Ground floor, C-15	Column	300	95.1	*3.2	Indirect
15	Ground floor, CT-10	Beam	300	169.1	*1.8	Indirect
16	Ground floor, C-18	Column	300	103.1	*2.9	Indirect
17	Ground floor, CT-08	Column	300	170.1	*1.8	Indirect
18	Ground floor, CT-09	Column	300	169.2	*1.8	Indirect
19	Ground floor, C-21	Column	300	152.9	*2.0	Indirect
20	Ground floor, C-20	Column	300	181.2	*1.7	Indirect
21	Ground floor, CT-01	Column	300	96.6	*3.1	Indirect
22	Ground floor, CT-02	Column	300	119.6	*2.5	Indirect
23	Ground floor, CT-03 to 04	Beam	230	88.6	2.6	Direct
BUILDING-C						
24	Ground floor, CT-01 to opp side	Beam	300	125.8	*2.4	Indirect
25	Ground floor, C-05 to C-06	Beam	300	127.5	*2.4	Indirect
26	Ground floor, C-09 Beam	Beam	300	152.4	*2.0	Indirect
27	Ground floor, CT-06 Beam	Beam	150	56.8	2.6	Direct
28	Ground floor, C-11 Beam	Beam	300	135.5	*2.2	Indirect
29	Ground floor, C-13 to 14	Beam	250	90.4	2.8	Direct

30	Ground floor, C15 to Meter Room	Beam	250	97.1	2.6	Direct
31	Room No. 101 Hall	Column	300	112.4	*2.7	Indirect
32	Room No. 101 Hall	Beam	300	130.4	*2.3	Indirect
33	Room No. 102 Hall	Column	300	179.4	*1.7	Indirect
34	Room No. 102 Hall	Beam	300	126.5	*2.4	Indirect
35	Room No. 103 Hall	Column	300	119.5	*2.5	Indirect
36	Room No. 103 Hall	Beam	300	139.6	*2.1	Indirect
37	Room No. 104 Hall	Column	300	180.6	*1.7	Indirect
38	Room No. 104 Hall	Beam	300	165.1	*1.8	Indirect
39	Room No. 203 Hall	Column	300	175.8	*1.7	Indirect
40	Room No. 203 Hall	Beam	300	169.5	*1.8	Indirect
41	Room No. 204 Hall	Column	300	111.5	*2.7	Indirect
42	Room No. 204 Hall	Beam	300	156.8	*1.9	Indirect
43	Room No. 301 Hall	Column	300	165.8	*1.8	Indirect
44	Room No. 302 Hall	Column	300	125.7	*2.4	Indirect
45	Room No. 304 Hall	Column	300	175.6	*1.7	Indirect
46	Room No. 304 Hall	Beam	300	165.6	*1.8	Indirect
47	Room No. 402 Hall	Column	250	119.6	2.1	Direct
48	Room No. 402 Hall	Beam	300	126.9	*2.4	Indirect
BUILDING-C						
49	4th floor staircase	Beam	180	88.4	2.0	Direct

	beam					
50	Room No. 404 Hall	Column	300	175.5	*1.7	Indirect
51	Room No. 404 Hall	Beam	300	169.3	*1.8	Indirect
52	Room No. 502 Hall	Column	300	135.6	*2.2	Indirect
53	Room No. 502 Bedroom	Column	180	126.3	1.4	Direct
54	Room No. 504 Bedroom	Column	300	175.4	*1.7	Indirect
55	Room No. 601 Hall	Column	300	169.3	*1.8	Indirect
56	Room No. 604 Bedroom (GH-10)	Column	300	112.2	*2.7	Indirect
57	Room No. 701 Bedroom (GH-07)	Column	180	121.6	1.5	Direct
58	Room No. 702 Bedroom (GH-02)	Column	300	179.5	*1.7	Indirect
59	Room No. 703 Bedroom (GH-05)	Column	300	189.5	*1.6	Indirect
60	Room No. 704 Bedroom (GH-02)	Column	180	126.5	1.4	Direct
BUILDING-E						
61	ET-01	Column	300	123.7	*2.4	Indirect
62	E-01	Column	300	125.5	*2.4	Indirect
63	ET-07	Column	300	152.7	*2.0	Indirect
64	E-22 to E-17	Column	300	160.3	*1.9	Indirect

65	E-04	Column	300	178.3	*1.7	Indirect
66	E-06	Column	300	151.2	*2.0	Indirect
67	ET-05	Column	300	117.2	*2.6	Indirect
68	ET-05	Column	230	76.6	3.0	Direct
69	E-05	Column	300	165.4	*1.8	Indirect
70	E-06	Column	300	151.3	*2.0	Indirect
71	ET-04	Beam	230	75.9	3.0	Direct

BUILDING-E						
72	E-07	Beam	300	165.3	*1.8	Indirect
73	E-08	Beam	300	145.2	*2.1	Indirect
74	ET-03	Beam	300	119.3	*2.5	Indirect
75	ET-02	Beam	300	106	*2.8	Indirect
76	E-09	Beam	300	126.3	*2.4	Indirect
77	ET-13	Beam	300	155.4	*1.9	Indirect
78	E-11	Beam	300	156.2	*1.9	Indirect
79	ET-12	Beam	300	177.7	*1.7	Indirect
80	ET-11	Column	300	145.8	*2.1	Indirect
81	E-13	Beam	300	158.4	*1.9	Indirect
82	E-14	Column	300	164.2	*1.8	Indirect
83	E-15	Column	300	154.3	*1.9	Indirect
84	ET-10	Column	300	145.1	*2.1	Indirect

85	E-16	Column	300	143.1	*2.1	Indirect
86	E-18	Column	230	79.6	2.9	Direct
87	ET-08	Column	300	151.6	*2.0	Indirect
88	ET-09	Column	300	103.2	*2.9	Indirect
89	E-20	Column	230	79.6	2.9	Direct
90	E-20 to 21	Beam	300	153.6	*2.0	Indirect
91	E-18 to Meter Room	Beam	230	129.3	1.8	Direct
92	E-16 to Meter Room	Beam	230	97.4	2.4	Direct
93	E-15 Beam	Beam	230	90.4	2.5	Direct
94	E-09 to ET-02	Beam	230	84.3	2.7	Direct
95	ET-08	Beam	300	167.9	*1.8	Indirect
BUILDING-E						
96	Room No. 101 Hall	Beam	300	165.8	*1.8	Indirect
97	Room No. 101 Hall	Column	300	157.9	*1.9	Indirect
98	Room No. 103 Hall	Column	300	109.8	*2.7	Indirect
99	Room No. 103 Hall	Beam	300	110.4	*2.7	Indirect
100	Room No. 203 Hall	Column	300	167.4	*1.8	Indirect
101	Room No. 203 Hall	Beam	300	172.1	*1.7	Indirect
102	Room No. 204 Hall	Column	300	102.7	*2.9	Indirect
103	Room No. 204 Hall	Beam	300	113.3	*2.6	Indirect
104	Room No. 301 Hall	Column	300	143.6	*2.1	Indirect

105	Room No. 301 Hall	Beam	300	110.1	*2.7	Indirect
106	Room No. 303 Hall	Column	300	132.4	*2.3	Indirect
107	Room No. 303 Hall	Beam	300	146.5	*2.0	Indirect
108	Room No. 401 Hall	Column	300	151.6	*2.0	Indirect
109	Room No. 401 Hall	Beam	300	146.2	*2.1	Indirect
110	Room No. 403 Hall	Column	300	151.2	*2.0	Indirect
111	Room No. 403 Hall	Beam	300	147.4	*2.0	Indirect
112	Room No. 501 Hall	Column	300	174.3	*1.7	Indirect
113	Room No. 501 Hall	Beam	300	134.7	*2.2	Indirect
114	Room No. 503 Hall	Column	300	170.4	*1.8	Indirect
115	Room No. 503 Hall	Beam	300	176.3	*1.7	Indirect
116	Room No. 602 Hall	Column	300	169.5	*1.8	Indirect
117	Room No. 602 Hall	Beam	300	168.6	*1.8	Indirect
118	Room No. 604 Hall	Column	300	132.1	*2.3	Indirect
119	Room No. 604 Hall	Beam	300	141.4	*2.1	Indirect
BUILDING-E						
120	Room No. 702 Hall	Column	300	148.8	*2.0	Indirect
121	Room No. 702 Hall	Beam	300	152.3	*2.0	Indirect
122	5th Floor Staircase Beam	Beam	150	96.5	1.6	Direct
123	2nd Floor Staircase Beam	Beam	150	92.4	1.6	Direct

124	6th Floor Staircase Beam	Beam	150	90.4	1.7	Direct
125	7th Floor Staircase Beam	Beam	150	65.3	2.3	Direct
126	Water Tank Column	Column	180	98.3	*1.8	Indirect
127	4th Floor Staircase Beam	Column	300	138.4	*2.2	Indirect
BUILDING-D						
128	D-01	Beam	250	103.1	2.4	Direct
129	D-01	Column	300	164.2	*1.8	Indirect
130	DT-12	Column	230	64.5	3.6	Direct
131	D-02	Column	300	143.2	*2.1	Indirect
132	D-03	Column	300	123.6	*2.4	Indirect
133	D-02 to 04	Beam	300	126.7	*2.4	Indirect
134	DT-01	Column	230	119.5	1.9	Direct
135	D-06	Column	300	173.2	*1.7	Indirect
136	D-07	Column	230	83.2	2.8	Direct
137	DT-03	Column	230	118.8	1.9	Direct
138	D-09	Column	300	157.3	*1.9	Indirect
139	DT-02	Column	300	73.6	*4.1	Indirect
140	D-10	Column	300	175.4	*1.7	Indirect
141	D-11	Column	230	89.5	2.6	Direct
142	D-11	Beam	230	110	2.1	Direct

BUILDING-D						
143	D-12	Column	300	120.4	*2.5	Indirect
144	D-13	Column	300	95.8	*3.1	Indirect
145	D-12 to 13	Beam	300	188.1	*1.6	Indirect
146	DT-04	Column	230	127.1	1.8	Direct
147	DT-05	Column	230	95.4	2.4	Direct
148	DT-5	Beam	230	95.7	2.4	Direct
149	D-15	Column	300	134.5	*2.2	Indirect
150	DT-07	Column	300	133.1	*2.3	Indirect
151	DT-06	Column	230	97.8	2.4	Direct
152	DT-06	Beam	230	87.5	2.6	Direct
153	D-15 to 16	Beam	230	144.6	1.6	Direct
154	DT-08	Column	300	111.4	*2.7	Indirect
155	DT-08	Beam	230	84.3	2.7	Direct
156	D-17	Column	230	97.1	2.4	Direct
157	DT-08 to D-17	Beam	230	117.5	2.0	Direct
158	D-18	Column	300	112.4	*2.7	Indirect
159	DT-09	Column	230	84.3	2.7	Direct
160	DT-10	Column	230	87.6	2.6	Direct
161	D-21	Column	230	82.4	2.8	Direct
162	D-22 to DT-11	Beam	300	129.5	*2.3	Indirect

163	DT-11	Column	230	89.4	2.6	Direct
164	D-05	Beam	230	83.9	2.7	Direct
165	Room No. 101 Hall	Column	300	97.4	*3.1	Indirect
166	Room No. 101 Hall	Beam	300	121.3	*2.5	Indirect
167	Room No. 103 Hall	Column	300	136.4	*2.2	Indirect
168	Room No. 103 Hall	Beam	300	138.8	*2.2	Indirect
BUILDING-D						
169	Room No. 203 Hall	Column	300	143.4	*2.1	Indirect
170	Room No. 203 Hall	Beam	300	147.8	*2.0	Indirect
171	Room No. 303 Hall	Column	300	131.5	*2.3	Indirect
172	Room No. 303 Hall	Beam	300	145.6	*2.1	Indirect
173	Room No. 403 Hall	Column	300	156.3	*1.9	Indirect
174	Room No. 403 Hall	Beam	300	147.4	*2.0	Indirect
175	Room No. 504 Hall	Column	300	143.4	*2.1	Indirect
176	Room No. 504 Hall	Beam	300	148.5	*2.0	Indirect
177	Room No. 402 Hall	Column	300	146.5	*2.0	Indirect
178	Room No. 402 Hall	Beam	300	106.3	*2.8	Indirect
179	Room No. 603 Hall	Column	300	194.3	*1.5	Indirect
180	Room No. 603 Hall	Beam	300	158.4	*1.9	Indirect
181	Room No. 604 Hall	Column	300	160.5	*1.9	Indirect
182	Room No. 604 Hall	Beam	300	166.2	1.8	Indirect
183	Room No. 702 Hall	Column	300	142.9	*2.1	Indirect

184	Room No. 702 Hall	Beam	300	162.3	*1.8	Indirect
185	Room No. 701 Hall	Column	300	138.4	*2.2	Indirect
186	Room No. 701 Hall	Beam	300	132.5	*2.3	Indirect
187	Water Tank	Column	300	162.7	*1.8	Indirect
188	7th Floor Staircase Beam	Beam	300	165.4	*1.8	Indirect
189	5th Floor Staircase Beam	Beam	300	144.5	*2.1	Indirect
190	3rd Floor Staircase Beam	Beam	300	146.7	*2.0	Indirect
191	1st Floor Staircase Beam	Beam	300	123.8	*2.4	Indirect
192	Room No. 204 Hall	Column	300	124.7	*2.4	Indirect
193	Room No. 204 Hall	Beam	300	175.8	*1.7	Indirect

VELOCITY CRITERION FOR CONCRETE QUALITY GRADING:

Table 4.2

SR. NO.	PULSE VELOCITY BY CROSS PROBING (KM/Sec)	CONCRETE QUALITY GRADING

1	ABOVE 4.5	EXCELLENT
2	3.5 TO 4.5	GOOD
3	3.0 TO 3.5	MEDIUM
4	BELOW 3.0	DOUBTFUL

CONCLUSION: The concrete in question is on the verge of satisfactory condition & is fit for the stability of the structure.

4.3 Rebound Hammer Test

"Good concrete is such an excellent classic building material that it would have had to be invented at once had it not existed for a long time"

This is the most frequently used method for testing the concrete & structural components. The rebound test is done as the test hammer will hit the concrete at a defined energy. Its rebound is dependent on the hardness of the concrete and is measured by test equipment. By reference to the conversion tables, the rebound values can be used to determine the compressive strength.

Fig 4.12

Table 4.3

SR. NO.	LOCATION	MEMBER	DISTANCE MM	AVERAGE OF REBOUND NUMBER (REBOUND INDEX)	ESTIMATED COMPRESSIVE STRENGTH N/mm2	METHOD
BUILDING-C						
1	Ground floor, C-01	Column	300	46	49.6	Horizontal
2	Ground floor, CT-02	Column	300	44	46.8	Horizontal
3	Ground floor, CT-02	Column	300	41	42.6	Horizontal

4	Ground floor, C-04	Column	300	35	34.2	Horizontal
5	Ground floor, C-06	Column	300	36	35.6	Horizontal
6	Ground floor, C-08	Column	300	32	30.0	Horizontal
7	Ground floor, C-11	Column	300	33	31.4	Horizontal
8	Ground floor, C-12	Column	300	36	35.6	Horizontal
9	Ground floor, C-13	Column	300	36	35.6	Horizontal
10	Ground floor, C-15	Column	300	32	30.0	Horizontal
11	Ground floor, C-17	Column	300	37	37.0	Horizontal
12	Ground floor, C-21	Column	300	33	31.4	Horizontal
13	Ground floor, C-20	Column	300	38	38.4	Horizontal
14	Ground floor, CT-03	Column	300	37	37.0	Horizontal
15	Ground floor, CT-04	Column	300	31	28.6	Horizontal
16	Ground floor, CT-05	Column	300	38	38.4	Horizontal
17	Ground floor, CT-06	Column	300	34	32.8	Horizontal
18	Ground floor, C-18	Column	300	31	28.6	Horizontal
19	Ground floor, CT-07	Column	300	39	39.8	Horizontal
20	Ground floor, CT-08	Column	300	36	35.6	Horizontal
21	Ground floor, CT-09	Column	300	37	37.0	Horizontal
22	Ground floor, CT-10	Beam	300	36	35.6	Horizontal
23	Ground floor, C-01	Beam	300	36	35.6	Horizontal
BUILDING-C						
24	Ground floor, C-03	Beam	300	35	34.2	Horizontal

	to C-04					
25	Ground floor, CT-05 to C-06	Beam	300	35	34.2	Horizontal
26	Ground floor, CT-06 to opp. side	Beam	300	34	32.8	Horizontal
27	Ground floor, C-09	Beam	300	34	32.8	Horizontal
28	Ground floor, C-13 to C-14	Beam	300	31	28.6	Horizontal
29	Ground floor, C-15 to meter room	Beam	300	34	32.8	Horizontal
30	Ground floor, CT-06	Beam	300	31	28.6	Horizontal
31	Room No. 101 Hall	Column	300	34	32.8	Horizontal
32	Room No. 101 Hall	Beam	300	33	31.4	Horizontal
33	Room No. 102 Hall	Column	300	33	31.4	Horizontal
34	Room No. 102 Hall	Beam	300	31	28.6	Horizontal
35	Room No. 103 Hall	Column	300	34	32.8	Horizontal
36	Room No. 103 Hall	Beam	300	35	34.2	Horizontal
37	Room No. 104 Hall	Column	300	38	38.4	Horizontal
38	Room No. 104 Hall	Beam	300	36	35.6	Horizontal
39	Room No. 203 Hall	Column	300	33	31.4	Horizontal
40	Room No. 203 Hall	Beam	300	34	32.8	Horizontal
41	Room No. 204 Hall	Column	300	36	35.6	Horizontal
42	Room No. 204 Hall	Beam	300	35	34.2	Horizontal

43	Room No. 302 Hall	Column	300	35	34.2	Horizontal
44	Room No. 302 Hall	Beam	300	32	30.0	Horizontal
45	Room No. 304 Hall	Column	300	42	44.0	Horizontal
46	Room No. 304 Hall	Beam	300	30	27.2	Horizontal
47	Room No. 402 Hall	Column	300	33	31.4	Horizontal
48	Room No. 402 Hall	Beam	300	36	35.6	Horizontal
BUILDING-C						
49	Room No. 404 Hall	Column	300	32	30.0	Horizontal
50	Room No. 404 Hall	Beam	300	34	32.8	Horizontal
51	Room No. 502 Hall	Column	300	27	23.0	Horizontal
52	Room No. 502 Hall	Column	300	34	32.8	Horizontal
53	Room No. 504 Bed Room	Column	300	36	35.6	Horizontal
54	Room No. 604 Bed Room (10)	Column	300	33	31.4	Horizontal
55	Room No. 701 Bed Room (07)	Column	300	35	34.2	Horizontal
56	Room No. 702 Bed Room (02)	Column	300	32	30.0	Horizontal
57	Room No. 703 Bed Room (GH-05)	Column	300	30	27.2	Horizontal
58	Room No. 704 Bed Room (GH-02)	Column	300	35	34.2	Horizontal
59	Water Tank	Column	300	27	23.0	Horizontal

60	5th floor staircase beam	Beam	300	31	28.6	Horizontal
61	4th floor staircase beam	Beam	300	34	32.8	Horizontal
BUILDING-D						
62	Ground floor, D-01	Column	300	38	38.4	Horizontal
63	Ground floor, D-02	Column	300	41	42.6	Horizontal
64	Ground floor, D-03	Column	300	39	39.8	Horizontal
65	Ground floor, DT-01	Column	300	35	34.2	Horizontal
66	Ground floor, DT-06	Column	300	36	35.6	Horizontal
67	Ground floor, DT-07	Column	300	37	37.0	Horizontal
68	Ground floor, DT-02	Column	300	36	35.6	Horizontal
69	Ground floor, DT-03	Column	300	38	38.4	Horizontal
70	Ground floor, D-09	Column	300	39	39.8	Horizontal
71	Ground floor, D-10	Column	300	38	38.4	Horizontal
BUILDING-D						
72	Ground floor, D-11	Column	300	40	41.2	Horizontal
73	Ground floor, D-12	Column	300	38	38.4	Horizontal
74	Ground floor, D-13	Column	300	40	41.2	Horizontal

75	Ground floor, DT-04	Column	300	38	38.4	Horizontal
76	Ground floor, DT-05	Column	300	40	41.2	Horizontal
77	Ground floor, D-15	Column	300	40	41.2	Horizontal
78	Ground floor, DT-06	Column	300	36	35.6	Horizontal
79	Ground floor, DT-07	Column	300	42	44.0	Horizontal
80	Ground floor, DT-08	Column	300	40	41.2	Horizontal
81	Ground floor, D-17	Column	300	41	42.6	Horizontal
82	Ground floor, D-18	Column	300	39	39.8	Horizontal
83	Ground floor, DT-09	Column	300	40	41.2	Horizontal
84	Ground floor, DT-10	Column	300	40	41.2	Horizontal
85	Ground floor, D-21	Column	300	40	41.2	Horizontal
86	Ground floor, D-11	Column	300	40	41.2	Horizontal
87	Ground floor, D-12	Column	300	40	41.2	Horizontal
88	Ground floor, D-03 to 04	Beam	300	36	35.6	Horizontal
89	Ground floor, D-01 to opp. side	Beam	300	35	34.2	Horizontal
90	Ground floor, D-05	Beam	300	35	34.2	Horizontal

91	Ground floor, D-15 to16	Beam	300	34	32.8	Horizontal
92	Ground floor, DT-08 to opp. side	Beam	300	35	34.2	Horizontal
93	Ground floor, DT-13 to 12	Beam	300	35	34.2	Horizontal
94	Ground floor, DT-05	Beam	300	34	32.8	Horizontal
95	Ground floor, D-11	Beam	300	36	35.6	Horizontal
BUILDING-D						
96	Ground floor, DT-06	Beam	300	35	34.2	Horizontal
97	Ground floor, DT-08 to D-17	Beam	300	34	32.8	Horizontal
98	Ground floor, D-22 to DT-11	Beam	300	32	30.0	Horizontal
99	Room No. 101 Hall	Column	300	35	34.2	Horizontal
100	Room No. 101 Hall	Beam	300	32	30.0	Horizontal
101	Room No. 103 Hall	Column	300	32	30.0	Horizontal
102	Room No. 103 Hall	Beam	300	33	31.4	Horizontal
103	Room No. 203 Hall	Column	300	34	32.8	Horizontal
104	Room No. 203 Hall	Beam	300	32	30.0	Horizontal
105	Room No. 303 Hall	Column	300	34	32.8	Horizontal
106	Room No. 303 Hall	Beam	300	31	28.6	Horizontal

107	Room No. 403 Hall	Column	300	35	34.2	Horizontal
108	Room No. 403 Hall	Beam	300	32	30.0	Horizontal
109	Room No. 504 Hall	Column	300	32	30.0	Horizontal
110	Room No. 504 Hall	Beam	300	31	28.6	Horizontal
111	Room No. 402 Hall	Column	300	36	35.6	Horizontal
112	Room No. 402 Hall	Beam	300	31	28.6	Horizontal
113	Room No. 603 Hall	Column	300	32	30.0	Horizontal
114	Room No. 603 Hall	Beam	300	27	23.0	Horizontal
115	Room No. 604 Hall	Column	300	32	30.0	Horizontal
116	Room No. 604 Hall	Beam	300	32	30.0	Horizontal
117	Room No. 702 Hall	Column	300	33	31.4	Horizontal
118	Room No. 702 Hall	Beam	300	30	27.2	Horizontal
119	Room No. 701 Hall	Column	300	32	30.0	Horizontal
BUILDING-D						
120	Room No. 701 Hall	Beam	300	30	27.2	Horizontal
121	7th Floor Staircase Beam	Beam	300	32	30.0	Horizontal
122	5th Floor Staircase Beam	Beam	300	30	27.2	Horizontal
123	Water Tank Column	Column	300	31	28.6	Horizontal
124	Room No. 204 Hall	Column	300	33	31.4	Horizontal
125	Room No. 204 Hall	Beam	300	30	27.2	Horizontal

126	3rd Floor Staircase Beam	Beam	300	30	27.2	Horizontal
127	1st Floor Staircase Beam	Beam	300	27	23.0	Horizontal
BUILDING-E						
128	Ground floor, E-01	Column	300	39	39.8	Horizontal
129	Ground floor, ET-01	Column	300	41	42.6	Horizontal
130	Ground floor, E-04	Column	300	42	44.0	Horizontal
131	Ground floor, E-06	Column	300	44	46.8	Horizontal
132	Ground floor, E-05	Column	300	41	42.6	Horizontal
133	Ground floor, E-07	Column	300	45	48.2	Horizontal
134	Ground floor, E-08	Column	300	46	49.6	Horizontal
135	Ground floor, ET-02	Column	300	43	45.6	Horizontal
136	Ground floor, E-09	Column	300	43	45.6	Horizontal
137	Ground floor, ET-03	Column	300	43	45.6	Horizontal
138	Ground floor, ET-04	Column	300	43	45.6	Horizontal
139	Ground floor, ET-05	Column	300	44	46.8	Horizontal
140	Ground floor, ET-06	Column	300	44	46.8	Horizontal
141	Ground floor, ET-07	Column	300	43	45.4	Horizontal
142	Ground floor, E-20	Column	300	43	45.4	Horizontal
SR. NO.	LOCATION	MEMBER	DISTANCE MM	AVERAGE OF REBOUND NUMBER	ESTIMATED COMPRESSIVE	METHOD

				(REBOUND INDEX)	STRENGTH N/mm2	
BUILDING-E						
143	Ground floor, ET-08	Column	300	44	46.8	Horizontal
144	Ground floor, ET-09	Column	300	48	52.4	Horizontal
145	Ground floor, E-18	Column	300	41	42.6	Horizontal
146	Ground floor, E-16	Column	300	44	46.8	Horizontal
147	Ground floor, ET-10	Column	300	45	48.2	Horizontal
148	Ground floor, E-15	Column	300	46	49.6	Horizontal
149	Ground floor, E-14	Column	300	48	52.4	Horizontal
150	Ground floor, E-13	Column	300	44	46.8	Horizontal
151	Ground floor, ET-11	Column	300	47	51.0	Horizontal
152	Ground floor, ET-12	Column	300	46	49.6	Horizontal
153	Ground floor, E-11	Column	300	46	49.6	Horizontal
154	Ground floor, ET-13	Column	300	39	39.8	Horizontal
155	Ground floor, E-09 to ET-02	Beam	300	38	38.4	Horizontal
156	Ground floor, E-08	Beam	300	35	34.2	Horizontal
157	Ground floor, E-05	Beam	300	36	35.6	Horizontal
158	Ground floor, E-22 to ET-07	Beam	300	36	35.6	Horizontal
159	Ground floor, E-20 to E-21	Beam	300	31	28.6	Horizontal

160	Ground floor, E-18 to Meter Room	Column	300	33	31.4	Horizontal
161	Ground floor, E-16 to Meter Room	Beam	300	36	35.6	Horizontal
162	Ground floor, E-15 to opp. side	Column	300	37	37.0	Horizontal
163	Room No. 101 Hall	Column	300	33	31.4	Horizontal
164	Room No. 101 Hall	Beam	300	32	30.0	Horizontal
165	Room No. 103 Hall	Column	300	33	31.4	Horizontal
166	Room No. 103 Hall	Beam	300	32	30.0	Horizontal
BUILDING-E						
167	Room No. 203 Hall	Column	300	31	28.6	Horizontal
168	Room No. 203 Hall	Beam	300	33	31.4	Horizontal
169	Room No. 204 Hall	Column	300	34	32.8	Horizontal
170	Room No. 204 Hall	Beam	300	31	28.6	Horizontal
171	Room No. 301 Hall	Column	300	36	35.6	Horizontal
172	Room No. 301 Hall	Beam	300	34	32.8	Horizontal
173	Room No. 303 Hall	Column	300	34	32.8	Horizontal
174	Room No. 303 Hall	Beam	300	36	35.6	Horizontal
175	Room No. 401 Hall	Column	300	36	35.6	Horizontal
176	Room No. 401 Hall	Beam	300	32	30.0	Horizontal

177	Room No. 403 Hall	Column	300	36	35.6	Horizontal
178	Room No. 403 Hall	Beam	300	32	30.0	Horizontal
179	Room No. 501 Hall	Column	300	32	30.0	Horizontal
180	Room No. 501 Hall	Beam	300	33	31.4	Horizontal
181	Room No. 503 Hall	Column	300	34	32.8	Horizontal
182	Room No. 503 Hall	Beam	300	31	28.6	Horizontal
183	Room No. 604 Hall	Column	300	34	32.8	Horizontal
184	Room No. 604 Hall	Beam	300	30	27.2	Horizontal
185	Room No. 602 Hall	Column	300	31	28.6	Horizontal
186	Room No. 602 Hall	Beam	300	31	28.6	Horizontal
187	Room No. 702 Hall	Column	300	35	32.2	Horizontal
188	Room No. 702 Hall	Beam	300	34	32.8	Horizontal
189	Water Tank Column	Column	300	31	28.6	Horizontal
190	6^{th} Floor Staircase Beam	Beam	300	27	23.0	Horizontal
BUILDING-E						
191	7^{th} Floor Staircase Beam	Beam	300	28	24.4	Horizontal
192	5^{th} Floor Staircase Beam	Beam	300	27	23.0	Horizontal
193	4^{th} Floor Staircase Beam	Beam	300	26	21.6	Horizontal
194	2^{nd} Floor Staircase Beam	Beam	300	27	23.0	Horizontal

CONCLUSION: The compressive strength of the structure in question is satisfactory & is fit for the stability of the structure.

4.4 Half Cell Potential Test

Corrosion is the most harmful factor which affects the structure. Corrosion occurs due to the reaction of the Cao with Co2 and forms CaCo3 which further reacts with moisture present in the concrete and forms CaHCo3 which is most reactive and finally it reacts with the sulphate which is present in cement and other ingredients in concrete, as sulphate turns the concrete in acidic range due to which the concrete gets carbonated and finally it affects the reinforcement and it starts to get corrosive, due to which the reactive formulation begins in the structure. This is one aspect when the corrosion has started to take place but it is up to what extent?. To find that the position of corrosion the half cell potentiometer can be used which gives the flow of current in "mv", from which it can be evaluated whether there is inactive corrosion, active corrosion or no corrosion. This is an instrument in which one cell contains Copper Sulphate or Silver Nitrate solution which is connected with the meter & other end is connected with a clean rubber reinforced pad in concrete, prior to that the concrete is brought under saturated wet condition so that the current passes from the meter & could be received by the reinforcement and the cell to be bought in contact of concrete surface to make complete circuit. The reading can be noted down in "mv", this reading in "+mv" shows no corrosion, reading between 0 to 150 mv means uncertainty of corrosion.

- 0.15 V to 0.250 V - Inactive Corrosion.
- 0.250 V & above - Active Corrosion.

Table 4.4

SR. NO.	LOCATION	MEMBER	READING VOLTS (-V)	READING VOLTS (-V)	READING VOLTS (-V)

1	GROUND FLOOR	COLUMN-1	0.165	0.146	0.151
2	GROUND FLOOR	COLUMN-2	0.169	0.170	0.169
3	GROUND FLOOR	COLUMN-3	0.182	0.188	0.186
4	GROUND FLOOR	COLUMN-4	0.191	0.189	0.190
5	GROUND FLOOR	COLUMN-5	0.186	0.185	0.183

CONCLUSION: The Corrosion in the columns in question is within satisfactory limits for the stability of the structure.

4.5 Carbonation Test

Carbonation test on column No "1, 2, 3, 4 & 5" on Ground floor was carried out using phenolphthalein solution which indicated that at different depth & the color was pink. So concluded that the concrete has not been carbonated.

CONCLUSION: The concrete has not been carbonated in the columns in question is satisfactory & is fit for the stability of the structure.

Fig 4.13

Chapter 5

5. Conclusion

5.1 General

Based on the studies and tests carried out following conclusions and recommendations are made.

5.2 Inferences from each Test

Conclusion from UPV Test: The concrete in question is on the verge of satisfactory condition & is fit for the stability of the structure. Conclusion from Rebound Hammer Test: The compressive strength of the structure in question is satisfactory & is fit for the stability of the structure. Conclusion from Half Cell Potentiometer Test: The Corrosion in the columns in question is within satisfactory limits for the stability of the structure. Conclusion from Carbonation Test: The concrete has not been carbonated in the columns in question is satisfactory & is fit for the stability of the structure.

5.3 Remedies for visual Inspections

The following works are proposed to be carried out for the repairs & rehabilitation of the plant:

1. R.C.C. MEMBERS:
    a. SLABS: The slabs for the proposed repairs & rehabilitation can be repaired as per the remedial measures scheduled below for Hollowness & Cracks, However for the Rebar, Corrosion Related, Stress Related, Carbonation of Concrete & corrosion in rebar in slabs, the best way to repair it is to recast the slab in position.
    b. BEAMS: The beams for the proposed repairs & rehabilitation can be repaired as per the remedial measures scheduled below. Also the repair scheme for the rebar in beam is scheduled after removal of the spawlling or cover.
    c. COLUMNS: The column for the proposed repairs & rehabilitation can be repaired as per the remedial measures scheduled below. Also the columns in questions have to be Jacketed all around from the plinth level to the top level.

2. BRICK WORK : The brick work in question is in satisfactory condition & it does not require any repairs to it. The minor crack in the walls can be rectified by re-plastering the surface.
3. PLASTERING: It is proposed to remove the existing plaster over the wall & redo the same. Also it is proposed to plaster all the Existing R.C.C member so as to protect them from direct atmospheric deterioration.
4. WATER PROOFING : It is proposed to redo the existing waterproofing, wherever applicable so as to avoid any further leakages from the exposed roof slabs.
5. FLOORING: It is proposed to provide a new flooring surface of approx. 3mm of Epoxy, also providing proper slope in the floor to direct the Rain Water to the Strom water gutters.
6. GRATING: It is proposed to rectify the corrosion in grating by the following:
    a. Cleaning the corroded surface of the grating by rust remover & washing it clean by water.
    b. Providing rust converter primer cum rust inhibitor coating to the surface area.
    c. Providing Coal tar based Epoxy coating or Polyurethane Colour Coating to the surface area.
7. SHEETING: Replacing the existing damaged Colour Coated GI sheets & replacing all existing AC sheets with new colour coated GI sheets.
8. PAINTING: Painting the Sand faced surface by providing 100% Acrylic Electrometric single component of 200micron DFT paint having more than 400% elongation & repainting the steel faced surface by the same method as adopted in Grating.

5.4 Future scope.

Structural Health monitoring is a very important aspect as day by day structures are degrading in strength due to aggressive environment and age of the buildings. In order to avoid loss of human lives and financial loss a detailed health monitoring mechanism shall be formed for each individual structure since each one is unique. The project shall be extended to develop a health monitoring mechanism for ARKP and AIKTC campus and structures in and around Panvel.

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