"HEALTH MONITERING & RETROFITTING OF A 50 YEAR OLD BUILDING"

MAJOR PROJECT-II (4th Semester)

MASTER OF ENGINEERING

IN

STRUCTURAL ENGINEERING

Under the Guidance of:

Dr. NIRENDRA DEV
Professor & HOD
(Civil Engg. Department)
Delhi Technical University

Submitted by:

GAURAV SHARMA
(Roll No-2K15/STE/07)

Delhi Technological University

Bawana Road, New Delhi-110042

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CANDIDATE'S DECLARATION AND CERTIFICATE

This is to be declared that the project entitled **"HEALTH MONITERING & RETROFITTING OF A 50 YEAR OLD BUILDING"** is a record of work done by me under the guidance of my project guide, **Dr. Nirendra dev**, Professor, Delhi Technical University, Bawana Road, New Delhi for the partial fulfillment of the requirements of the Degree of Masters of Engineering in Civil Engineering (Structural Engineering) from Delhi Technical University, Bawana Road, New Delhi-110042

The matter embodied in this report is original and has not been submitted for the award of any other degree.

……….…………………………

Date: 24.05.2017

GAURAV SHARMA

(Roll No: 2K15/STE/07)

To the best of my knowledge, the report has reached the requisite standard and the above statement made by Mr. Gaurav Sharma bearing Roll No-2K15/STE/07 is correct.

………..…………..............

Dr. NIRENDRA DEV
(Project Guide , Professor & HOD)
Delhi Technological University
New Delhi

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(Gaurav Sharma)

ABSTRACT

It is a known fact that the Globe is facing a threat of natural disasters from time to time. With particular records based on earthquake occurrence, the consequences are loss of human lives and destruction of properties, which ultimately affects the natural economy. The occurrence of an earthquake cannot be predicted and prevented but the preparedness of the structures to resist earthquake forces become more important. Keeping the view of constant revision of the seismic zones in India, lack of proper design and detailing of structures against earthquake. So in present scenario health monitoring & strength assessment is very important and then those week structures can be retrofit to save life & money.

NDT methods of testing concrete which are quite reliable, quick, relatively inexpensive, conventional to adopt and which do not any way disturb the structure, are therefore necessary. It is worthwhile noting that in addition to fulfilling this objective, NDT methods can also be used for the detection of flaws and cracks, for locating the position of reinforcement, for testing concrete at site for early striking of form work, for quality control of concrete in precast products industry and in the evaluation of physical characteristic of concrete etc. Among the methods for NDT of concrete, two have become fairly well known namely, the rebound hammer test and the ultrasonic pulse velocity test.

In this project health monitoring & strength assessment is done on a building that is more than 50 years old using NDT, weakness in building is identified & then what retrofitting methods can be adopted.

To achieve this objective, following methodology has been adopted:

1. Rebound hammer tests were done on beams, slabs and walls .The rebound value is correlated to the compressive strength of concrete using a calibration chart, the accuracy of which however is limited by a number of factors, as the rebound is based on the surface hardness of the material. Rebound hammer readings were calibrated to determine the compressive strength of these structural components.

2. UPVT was done on beams & slab so as to determine the quality of concrete. The ultrasonic pulse method employs the principle of measuring pulses through the concrete medium. In summary the ultrasonic tests have great potential for concrete quality control particularly for establishing uniformity and detecting cracks or defects.
3. A 3D model of the school is prepared using Staad pro 2007 and the stresses in the structural component are evaluated.
4. Based on the results obtained from the field tests (UPVT & RH) and the computer model these results are compared and structural weakness is identified and based on this a suitable retrofitting technique is suggested.

NOMENCLATURE

1.	UPVT	Ultrasonic Pulse Velocity Tester
2.	RH	Rebound Hammer
3.	RCC	Reinforced cement concrete
4.	RHR	Rebound Hammer Reading
5.	V	Velocity of Ultrasonic Wave
6.	L	Path Length
7.	T'	Transit Time
8.	G	Ground Floor
9.	1^{st} F	First Floor
10.	2^{nd} F	Second Floor
11.	DL	Dead Load
12.	Z	Zone Factor
13.	I	Importance Factor
14.	R	Response Reduction Factor
15.	T_n	Natural Time Period
16.	E	Modulus of Elasticity
17.	T	Transducer
18.	r	Receiver
19.	EQX	Earthquake in X direction
20.	EQZ	Earthquake in Z direction

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CHAPTER 1

INTRODUCTION

1.1 GENERAL:

The process of determining and tracking structural integrity and assessing the nature of damage in a structure is often referred to as health monitoring. Ideally, health monitoring of civil infrastructure consists of determining, by measured parameters, the location and severity of damage in buildings as they happen.

Non-destructive testing methods have been in use in the field of concrete technology for quite some time. The conventional method of evaluating the strength of hardened concrete by loading to failure standard cubes, cylinders or prisms is well known. Although these methods served to control the quality of concrete used in structures, it may not always represent the true quality of concrete which has gone into the structure.

Even when the same concrete mix is used throughout a structure, the quality of concrete in different parts of a structural member varies for a verity of reasons. In order to determine the quality of concrete in-situ in the structure, either concrete cores are taken as decided by conational methods or some other methods such as NDT are adopted. It may not always be possible to take cores and even when it is feasible, one may have to face problems of proper matching of subsequent patch, formation of points of weakness etc.

NDT methods of testing concrete which are quite reliable, quick, relatively inexpensive, conventional to adopt and which do not any way disturb the structure, are therefore necessary. It is worthwhile noting that in addition to fulfilling this objective, NDT methods can also be used for the detection of flaws and cracks, for locating the position of reinforcement, for testing concrete at site for early striking of form work, for quality control of concrete in precast products industry and in the evaluation of physical characteristic of concrete etc.

Considerable efforts have therefore been made in the past to develop other testing methods, which are non-destructive and which permit an evaluation of the concrete quality in-situ. Among the methods for NDT of concrete, two have become fairly well known namely, the rebound hammer test and the ultrasonic pulse velocity test.

1.2 Review of Non-destructive testing of concrete

The various method of test may be classified as follows:

1. Hardness test
   a) Indentation method

   b) Rebound hammer test

2. Vibration method

   a) Continuous vibrations generated electronically

   b) Pulse of vibration at ultrasonic frequency

   c) Pulse of vibration generated mechanically at sonic frequency

3. Radioactive method

   a) Measurement of absorption of direct rays

   b) Measurement of amount of bock scatters

The application and limitation are as below:

1.2 .1 Schmidt hammer test

Schmidt found that the results of rebound test may have a standard deviation of ± 20% for low strength concrete and ±15% for high strength concrete and claimed that it was possible to assess the strength of concrete with a safety at least equal to that obtained with the crushing test of cubes. The results of the hammer test are affected by:

1. smoothness of the surface
2. Size, shape and rigidity of the specimen
3. Type of coarse aggregate
4. Surface and initial moisture content
5. Repeat test on or near the same spot
6. By striking within about 5 cm of the edge of concrete

Further, the following points may be born in mind while using the hammer:

a) The hardness varies with the depth from the surface and an accurate indication of the compressive strength can be obtained only by calibration.

b) The instrument can be calibrated separately for each attitude.

c) Small specimens should be suitably held leas they may be jerked by the blow.

d) The accuracy will be greater if a separate calibration is carried out or each particular type of concrete.

1.2.2 Resonance or vibration method

The constant determined is the resonance modulus of elasticity, the magnitude of which indicates the quality of concrete. The vibrations are produced by the driving circuit, which usually consist of a variable frequency oscillator, an amplifier and a driving unit. The range of the oscillator is usually 20-10,000 c/s.

The following points must be appreciated in performing the above test:

a) Moisture content affects the modulus of elasticity although the change is small after about 3 to 4 days of air-drying. Therefore testing is to be done after 3 or 4 days drying.

b) Oven drying even at low temperature of 38˚c reduces the modulus of elasticity. Therefore the test may not give valid results involving repeated wetting and drying of the specimen.

c) The value of E and V vary for different size of specimen.

1.2.3 Pulse or wave velocity method

In this test the velocity of propagation of a high frequency (100-200 Kcs/s) acoustical wave, which pulses through the concrete, is measured. The elastic modulus can than be calculated. Errors may be introduced in the results of these tests by the following:

1. Inaccuracy in the assumed value of the Poisson's ratio.
2. Reduction in amplitude and change in the shape of the pulse.
3. The measurement of the time interval may be affected by the intensity and direction of the hammer blow.

The ultrasonic pulse method consist of measuring the time for the onset of a longitudinal pulse of vibrations to travel between two piezo-crystal transducers placed in contact with the concrete on opposite faces. In practice frequencies of 100 to 200 KHz are used for a path of up to 2 ft. It is very much necessary that the transducer transmitting the vibrations shall be in close contact with the concrete. For specimens molded against smooth shuttering smearing the surface with oil, soap, jelly or bentonite paste will be sufficient. Rough surfaces have to be ground or if necessary cement or gypsum plaster shall be applied over the surface and smoothened with a glass or any other smooth surface.

1.3 NON DESTRUCTIVE TESTING BY REBOUND HAMMER

In 1948, a Swiss engineer, Erustschmidt developed a test hammer based on measuring the surface hardness of concrete by the rebound principle.

In due course, this NDT method has gain world- wide recognition in laboratories, at construction sites and in the precast concrete industries.

The Schmidt Rebound Hammer is basically a surface hardness tester with little apparent theoretical relationship between the strength of concrete and the rebound number of the hammer. However, within limits, empirical correlations have been established between strength properties and the rebound number. A section of the hammer is given in figure, it consist of a spring-controlled weight E, which slide on plunger. A , housed inside the tubular frame B. When the spring H is fully extended an automatic trigger J is engaged, thus causing the weight to strike the plunger. The weight E, as it rebound from the plunger, moves in sliding index C along the graduated scale D having least count of 10. The sliding index can be taken by pressing the button F.

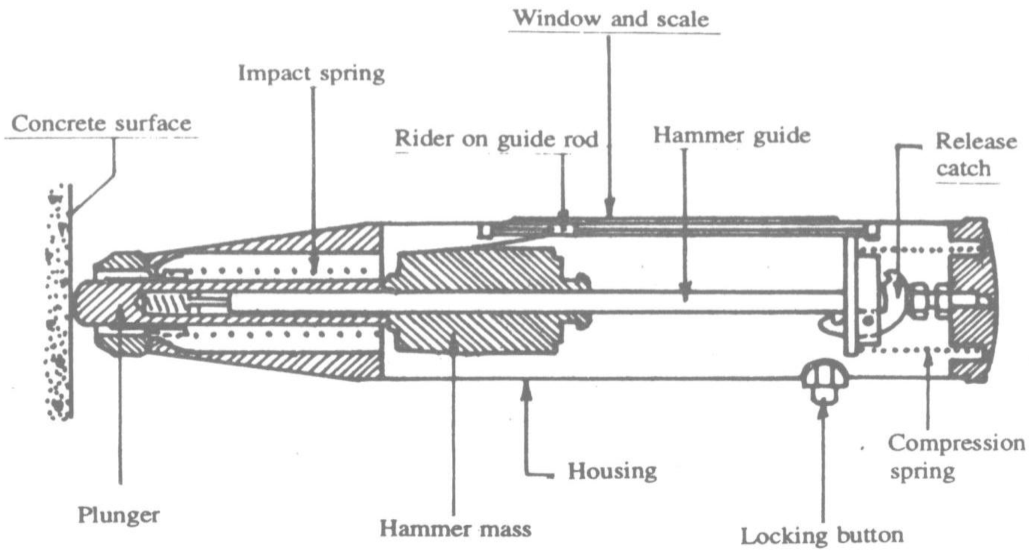


Fig. 13.1 Typical rebound test hammer

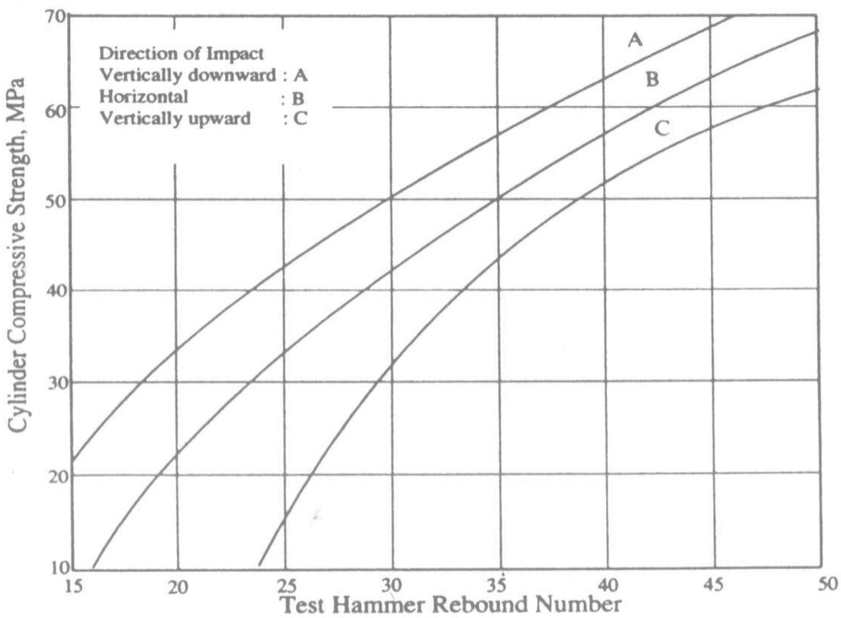


Fig .1 Relationship b/w Rebound no. & compressive strength

1.3.1. Limitation of Schmidt hammer test

Results are influenced by smoothness of surface, size, shape and rigidity of specimen, age of specimen, moisture content of specimen and by the type of aggregate.

a) Surface texture: On rough surfaces, it is advice that surface be ground smooth with a sand stone, so as to obtain a uniformly smooth surface. Surfaces made by using metal form work yields higher rebound number as compared to those which is made by using wooden form work

b) Size, Shape and Rigidity of specimen: If the concrete section or specimen is small, the measurement under the impact is lower the rebound readings and also will give considerable scatter in the result.

c) Age of specimen: For equal strength, higher rebound values may be shown for 7 days old then 28 days old specimen. This is probably due to the fact that the outer surface of concrete hardness at a faster rate (i.e. at earlier period) then the rate of gain of internal strength.

It is recommended that when old concrete is to be tested, direct correlation should be established between the rebound value and the compressive strength of a few cores taken from the structure.

d) Moisture condition of concrete: The degree of saturation of concrete and the presence of surface moisture has a profound effect on the hammer.

Well cured air dried specimens, when soaked in water and tested in saturated surface-day condition show rebound values about 5 points lower then when tested dry. Wet or dry condition can results in difference of about 10 to12 points in rebound number, in the case of old concrete around 3 yr's. Generally, it is advised that readings be taken in the field after prior saturation of the specimen several hours prior to testing and tested when surface dry.

e) Type of aggregate: Concrete made with crushed granite aggregate shows large rebound values then those made with limestone or gravel aggregate (the difference may be of the order of 100 Kg/cm^2 in strength)

1.4 Ultrasonic pulse velocity tester

A pulse of vibrations of ultrasonic frequency is used for two reasons.

(i) To give 3 pulse with a sharp onset,

(ii) To generate maximum energy in the direction of propagation of the pulse.

When the pulse is coupled into the concrete from a transducer, it undergoes reflections at the boundaries of the different material phases within the concrete. A complex system of stress waves is developed and includes both longitudinal and shears waves. The receiving transducer detects the onset of that component of the pulse which arrives earliest. This is generally the leading edge of the longitudinal vibration. Although the direction in which the maximum energy is propagated is at right angles to the face of the transmitting transducer, it is possible to detect pulses which have traveled through the concrete in some other direction it is possible to make measurements of pulse velocity by placing the two transducers on either:-

(a) Opposite faces (direct transmission)

(b) Adjacent faces (semi-direct transmission)

(c)The same face (indirect or surface transmission)

1.5 OBJECTIVE OF THE STUDY

- To evaluate the present condition of the school building through visual inspection there by identification and marking of structural & non structural cracks .
- To Conduct Rebound hammer & UPVT on structural members there by computing there compressive strength.
- To evaluate the stresses induced in the structural components by preparing a 3D model using Staad pro 2007.
- To compare the field test results with the results obtained from the staad model & based upon that appropriate retrofitting scheme is suggested.

1.6 COMPONENTS OF THE EXPERIMENTAL STUDY

Chapter-1 Contains a general introduction of the topic. It also highlights the objective of the problem.

Chapter 2 Contains the wider review on the topic of Health Monitoring & retrofitting of building. Various NDT methods have been studied for estimating the present condition of the structure.

Chapter 3 Includes methodology of NDT as well as theoretical studies. The experimental program and there process has been discussed for estimating compressive strength & Formulation of staad model as per IS codes and its results are obtained and discussed.

Chapter 4 Includes the results obtained from the experimental programs (NDT) are tabulated and discussed.

Chapter 5 Highlights and summaries the results & findings of this experimental study. Recommendations for future research work related to findings are also given in this chapter.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

There are various approaches for addressing the problem of health monitoring and damage detection in structures. The basic principle utilized is that any flaw/ damage changes some characteristic and hence the response of the structure. Researchers have proposed several techniques based on different kinds of structural characteristics or responses. The various methods reported in the literature can be broadly classified into the following categories:

(i) Global techniques: These techniques rely on global structural response for damage identification. Their main drawback is that since they rely on global response, they are not sensitive to localized damages. Thus, it is possible that some damages which may be present at various locations remain un-noticed

(ii) Local techniques: These techniques employ localized structural analysis, for damage detection. Their main drawback is that accessories like probes and fixtures are required to be physically carried around the test structure for data recording. Thus, it no longer remains autonomous application of the technique. These techniques are often applied at few selected locations, by the instincts/experience of the engineer coupled with visual inspection. Hence, randomness creeps into the resulting data.

The concept of non-destructive testing (NDT) is obtaining material properties of in place specimens without the destruction of the specimen nor the structure from which is taken. Nondestructive 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 particular NDT method depends upon the property of concrete to be observed such as strength, corrosion, crack monitoring etc.

The NDT being fast, easy to use at site and relatively less expensive can be used for:

1) Testing any number of pointes and locations

2) Assessing the actual condition of reinforcement

3) Main objective of assessment is to ensure that structure and its different parts do not fail under its loading condition.

4) Assessment is carried out so that its maximum resistance capacity can be observed.

5) Detecting cracks, voids, fractures, honeycombs and weak locations.

6) To reduce the local damage affecting the life span of structures.

7) To remove excessive vibration this causes discomfort to the people.

8) Scanning for reinforcement location, stress location.

9) Assess overall stability of the structure.

2.2 NDT Methods in Practice

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

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

The penetration technique: This is basically a hardness test, which provides a quick means of determining the relative strength of the concrete. The results of the test are influenced by surface smoothness of concrete and the type and hardness of the aggregate used. Again, the calibration chart is valid for a particular type of cement, aggregates used, moisture content, and age of the specimen. The test may cause damage to the specimen which needs to be repaired.

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

The rebound hammer test: The Schmidt rebound hammer is basically a surface hardness test with little apparent theoretical relationship between the strength of concrete and the rebound number of the hammer. Rebound hammers test the surface hardness of concrete, which cannot be converted directly to compressive strength. The method basically measures the modulus of elasticity of the near surface concrete. The principle is based on the absorption of part of the stored elastic energy of the spring through plastic deformation of the rock surface and the mechanical waves propagating through the stone while the remaining elastic energy causes the actual rebound of the hammer. The distance travelled by the mass, expressed as a percentage of the initial extension of the spring, is called the Rebound number. There is a considerable amount of scatter in rebound numbers because of the heterogeneous nature of near surface properties (principally due to near-surface aggregate particles). There are several factors other than concrete strength that influence rebound hammer test results, including surface smoothness and finish, moisture content, coarse aggregate type, and the presence of carbonation. Although rebound hammers can be used to estimate concrete strength, the rebound numbers must be correlated with the compressive strength of molded specimens or cores taken from the structure.

Ultra-sonic pulse velocity test: This test involves measuring the velocity of sound through concrete for strength determination. Since, concrete is a multi-phase material, speed of sound in concrete depends on the relative concentration of its constituent materials, degree of compacting, moisture content, and the amount of discontinuities present. This technique is applied for measurements of composition (e.g. monitor the mixing materials during construction, to estimate the depth of damage caused by fire), strength estimation, homogeneity, elastic modulus and age, & to check presence of defects, crack depth and thickness measurement. Generally, high pulse velocity readings in concrete are indicative of concrete of good quality. The drawback is that this test requires large and expensive transducers. In addition, ultrasonic waves cannot be induced at right angles to the surface; hence, they cannot detect transverse cracks.

Acoustic emission technique: This technique utilizes the elastic waves generated by plastic deformations, moving dislocations, etc. for the analysis and detection of structural defects. However, there can be multiple travel paths available from the source to the sensors. Also, electrical interference or other mechanical noises hampers the quality of the emission signals.

Impact echo test: In this technique, a stress pulse is introduced at the surface of the structure, and as the pulse propagates through the structure, it is reflected by cracks and dislocations. Through the analysis of the reflected waves, the locations of the defects can be estimated. The main drawback of this technique is that it is insensitive to small sized cracks.

2.3 LITERATURE REVIEW OF RESEARCH

D. Breysse (1991) This paper has been the analyzes of why and how nondestructive 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.

Ha-Won Song (1993) 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

Mhammadreza Hamidian (1996) 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%.

MR.Meltem Vatan(1997) 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.

Dias and Jayanandana (2003) used nondestructive techniques of visual inspection, perusal of drawings, ultrasonic pulse velocity measurements, cover-meter surveys, and core testing for the condition assessment; parameters required for evaluating the durability had been identified as (1) depth of carbonation; (2) cover to reinforcement; (3) chloride content; and (4) sulfate content.

Bruhwiler and Mivelaz (1999) highlighted the findings of two studies (i) investigated chloride ingress under given climatic conditions and in situ evaluation of concrete cover, (ii) used numerical models to investigate the effects of early age cracking and also determines preventive measures to be taken to limit the development of cracks.

Almir and Protasio (2000) used NDT methods to determine the compressive strength of concrete relationship between the measured mechanical or physical properties and the strength and also presented the validity of pull off, pin penetration, and UPV for assessing the concrete strength.

Rens and Kim (2007) inspected a steel bridge using several NDT methods such as visual inspection, hammer sounding, Schmidt hammer, and UPV testing including tomographic imaging; results of NDT had been used to determine areas, to be tested with local destructive tests such as compressive strength, chloride testing, and petrographic testing. Magnetic concrete cover meters are widely used to estimate the cover to steel bars.

Arash Behnia (2009) This research paper gives a comprehensive review of the acoustic emission (AE) technique for its applications in concrete structure health monitoring. Basic and established condition assessment methods for concrete structures are reviewed to configure a firm perception of AE application for enhanced performance and reliability. The AE approaches of focus are the parametric and signal analysis which can be used to develop damage evaluation criteria. Other than recent localization and source discrimination methods, applications of pivotal AE parameters such as b-value, Ib-value, AE energy, and hit are discussed herein, with highlights on the limitation of the individual parameter-based approaches when adopted on site. In addition, the introduction of new parameters such as sifted b-value, minimum b-value, and Q value is discussed as well, followed by a novel recent strategy for AE application in conjunction with tomography method to facilitate infrastructure assessment. Moreover, the key role of application of artificial intelligence methods towards damage mode identification has been highlighted.

Abo-Quadais (2005) conducted an experimental study to evaluate the effects of concrete aggregate degradation, w/c ratio, and curing time on measured UPV. Equipment used in this study was the portable ultrasonic ND digital indicating tester (PUNDIT).

Bhadauria and Gupta (2007) presented case study of deteriorated water tanks situated in the semitropical region of India. Parameters measured are concrete cover, carbonation depth, chloride concentration, compressive strength, and so forth. NDT methods used are cover meter, Phenolphthalein indicator test, Quantab test, Potentiometric Titration, Schist's hammer test, and UPV test.

Amini and Tehrani (2011) designed experimentally four sets of exposure conditions, weight and compressive strength of the samples had been measured before and after the freeze thaw cycles, and the results were analyzed.

Y. H. Su (2012) The purpose of this review article is devoted to presenting a summary of the basic principles of various optical fiber sensors, innovation in sensing and computational methodologies, development of novel optical fiber sensors, and the practical application status of the optical fiber sensing technology in structural health monitoring (SHM) of civil infrastructure.

2.4 SUMMARY

- At present a no. of NDT techniques and devices are available for strength assessment by studying the stress strain relationship of the material.

- NDT tests are also useful in assessing the concrete cover, carbonation depth, chloride concentration, compressive strength & durability , location of reinforcement.

- Nowadays optical fibers are also used as structural health monitoring systems and they are very efficient but only if correct methodology is followed in the interpretation of results .

- At least two or more NDT methods must be applied to get reliable results

& in case of huge difference b/w the results of the two NDT methods , a third method must be used to validate the result obtained .

- So I have applied two NDT methods to evaluate the present condition of the building. The strength assessment is done using rebound hammer & Upvt (Pundit).

CHAPTER 3
METHODOLOGY

3.1 INTRODUCTION:

To achieve the objective of the study, experimental as well as theoretical studies have been carried out. The health monitoring & retrofitting of a 50 year old school building has been done using NDT tests in the field there by giving the actual stresses in the structural members. A 3D model of the school building is prepared in Staad pro 2007 giving the maximum stress in the structural members. Based on these stress obtained from field tests (NDT) and from the staad model are compared and accordingly a suitable retrofitting scheme can be adopted to increase the service life of the building.

3.2 EXPERIMENTAL WORK:

Experimental work to evaluate the present strength of the school building includes the following works:

1. Finalization of the school building which might be more than 50 years old.
2. Visual inspection includes the type of structural arrangement of the building and if there any structural cracks in the building.
3. As per the requirement finalization of various NDT methods to be used to evaluate the present strength of the building.

3.1.1 STRUCTURAL ARRANGEMENT OF SCHOOL BUILDING

- This school is situated at Krishna Nagar delhi-110051 by the name of **E.D.M.C NIGAM PRATIBHA SCHOOL** It is more than 50 years old school and is said to be the first school constructed in east Delhi.

- The school building is a G+1 story and the building is having load bearing wall systems i.e slab on beam & beam are supported on brick walls. Columns are absent & in place of columns load bearing brick walls are used as a compression member.

- In place of RCC Columns brick columns have been used.

- Apart from load bearing brick walls, brick wall columns are also used In the corridor area of the school.

- The fig shows the architecture plan of the school.

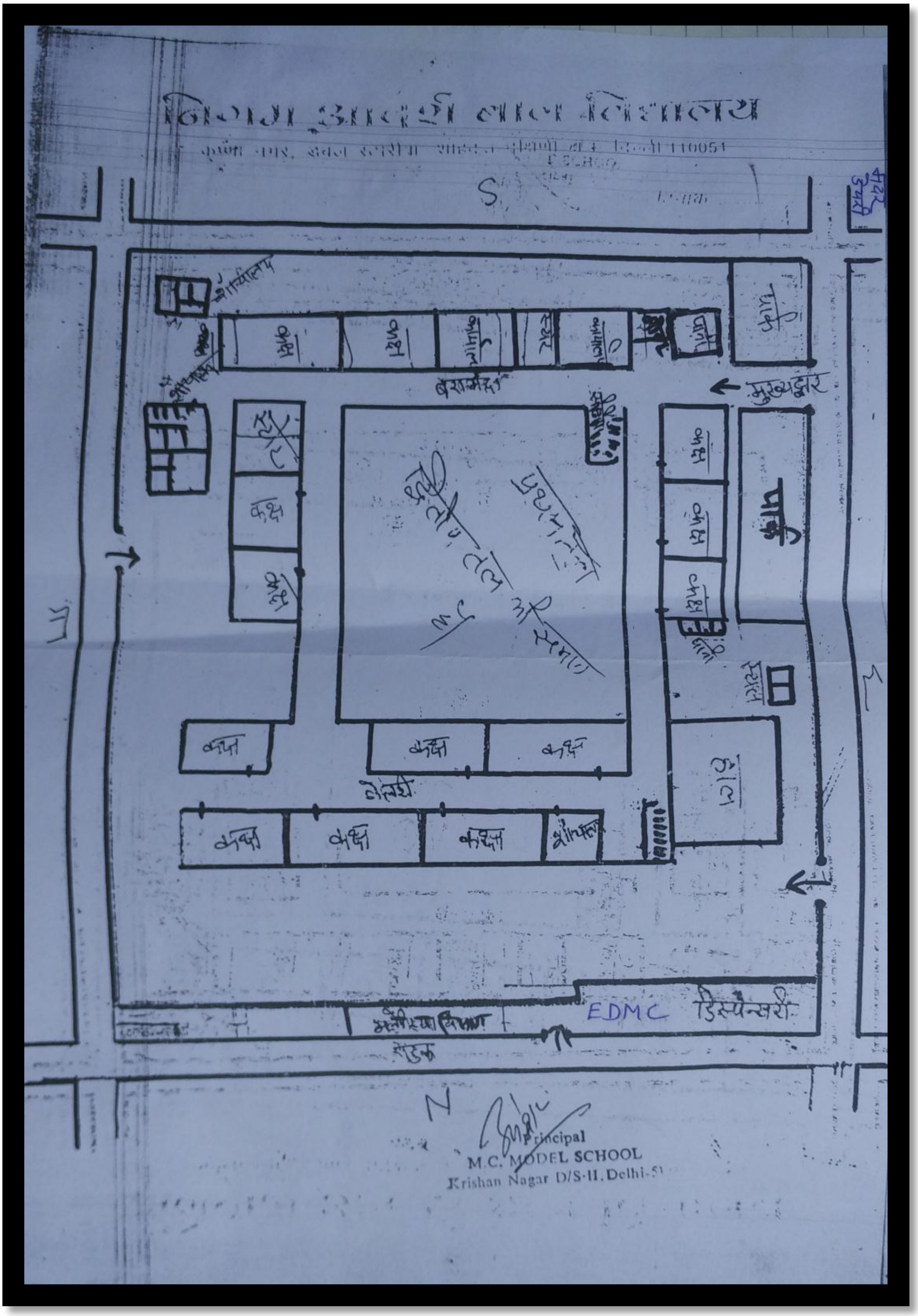


Fig.2 Architecture plan of school

3.1.2 VISUAL INSPECTION

For health assessment of the building visual inspections is a very useful method to determine the condition of the building just by inspecting i.e what is the structural arrangement of the building, what are the sizes of the structural members, are there any cracks in the building and if cracks are present then what are the causes of these cracks & the cracks are structural crack or non-structural crack. So by visual inspections we can get answers to all the above questions.

Observations made are as follows:

- The slab is around 150 mm thick with sizes of main beams (300x750) mm & of secondary beam (300x450) mm.
- The structural arrangement is shown in the fig below.
- Load bearing brick wall is 345mm thick.
- The class rooms are of size (6x7.2) m with two secondary beams are provided along the length at a distance of 2.4 m as shown in fig.
- Some structural cracks appear in the floors slabs and the cracks have travelled unto the beams.
- There are many areas where the rusting of reinforcement had caused bulging of concrete as can be seen in the pictures.

Picture 1: Entrance of school

Picture 2: Inside view of the building

Picture 3: View of open area

Picture 4: View of block A

Picture 5: Corridor Area of Block-B

Picture 6: Structural cracks in corridor area of block-C

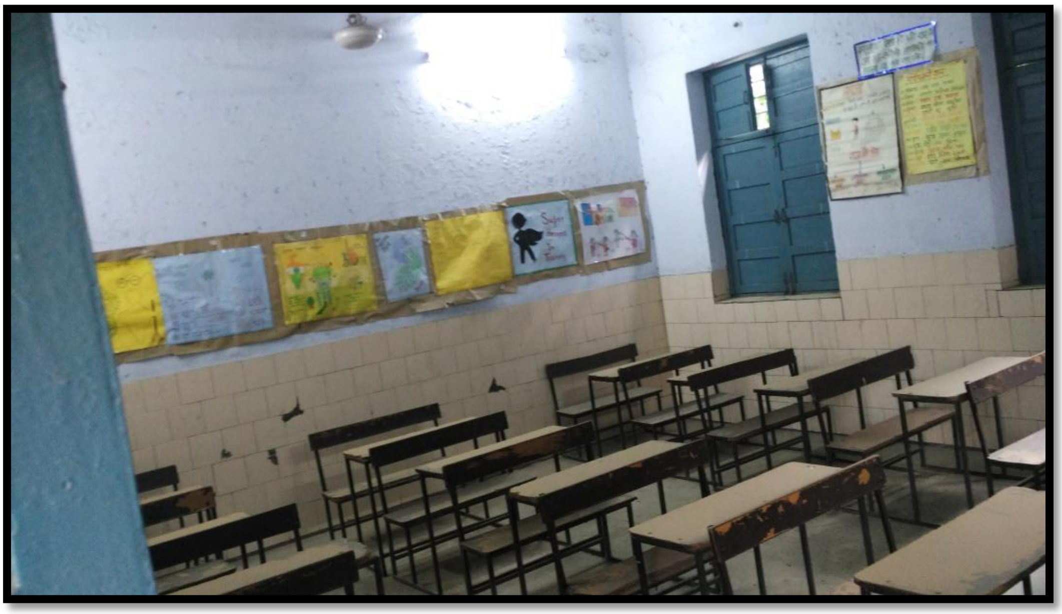
Picture 7: Spalling of concrete in the beam

Picture 8: structural Crack in the corridor at 1st floor

Picture 9: Back side view of Block B

Picture 10: View of block C from top

Picture 11: View of block-B from Top



Picture 12: Inside View Class Room

Picture 13: Location of Beams inside class rooms

Picture 14: View of Terrace of Block C

3.1.3 NDT TESTS METHODOLOGY

For strength evaluation of the school building two methods i.e Rebound hammer & UPVT are used. Rebound hammer test is done on brick walls, beams & slabs to evaluate their compressive strength.

UPVT is done on beams & slabs to confirm the quality of concrete evaluated from Rebound hammer test and to investigate any crack in the structural member i.e its location & depth. The procedures involved in taking readings are discussed below:

3.1.4 REBOUND HAMMER

Principle of Rebound hammer test:- The rebound hammer test determines the rebound of a spring loaded plunger when it is released against the surface under test. The rebound value is correlated to the compressive strength of concrete using a calibration chart, the accuracy of which however is limited by a number of factors, as the rebound is based on the surface hardness of the concrete.

Procedures for taking measurements are as below:

1. Released the plunger from the locked position by pressing it gently against a hard surface. The hammer is then ready to use.
2. To carry out the test, the plunger is pressed strongly against the concrete surface under test. This step is to be done by pressing hammer slowly without applying extra force, which may vary the actual reading.
3. This releases the spring-loaded weight from its locked position thus causing the impact. The sliding index is then read to give the rebound number.
4. In case of walls the 10 Rebound hammer reading (RHR) are taken each at top, middle & bottom portion of the wall as shown in the fig below. These readings are taken along the length of wall with distance b/w two readings is 3 meters.
5. In case of beams 10 RHR each are taken at left, right & middle portion of the beams.
6. In case of slabs 10 RHR each are taken at left, right & middle portion. Along the length of the slab panel a minimum 3 readings are taken along the length.

Rebound hammer used:- To carry out the NDT on this building a N-Type Rebound hammer is used.

FIG.3 N-TYPE REBOUND HAMMER

3.1.5 ULTRASONIC PULSE VILOSITY TESTER (UPVT)

Principal of UPVT:- A pulse of longitudinal vibrations is produced by an electro-acoustical transducer which is held in contact with one surface of the concrete under test. After traversing a known path length L in the Concrete, the pulse of vibrations is converted into an electrical signal by a receiver transducer and electronic timing circuits, to enable the transit time T' of the pulse to be measured. The pulse velocity V is given by V = L/T'.

When the pulse is coupled into the concrete from a transducer, it undergoes reflection at the boundaries of the two different material phases within the concrete. A complex system of stress waves is developed and includes both longitudinal and shears waves. The receiving transducer detects the onset of the component of the pulse which arrives earliest. This is generally the leading edge of the longitudinal vibration. Although the direction in which the maximum energy is propagated is at right angles to the face of the transmitting transducer, it is possible to detect pulse which has traveled through the concrete in some other direction.

It is possible to make measurements of pulse velocity by placing the two transducer on either:-

(a) Opposite faces (direct transmission)
(b) Adjacent faces (semi-direct transmission)
(c) The same faces (indirect or surface transmission)

These arrangements are shown the direct transmission arrangement is generally to be preferred since the maximum energy of the pulse is being directed at the receiving transducer and this gives maximum sensitivity.

Procedures for taking measurements are as below:

1. Before taking readings from UPVT the surfaces must be plain if not the surface is made plane as UPVT give acceptable results when the surface is plane.
2. The readings taken on beams are taken as Direct reading (direct transmission) i.e transducer & receiver are placed opposite to each other as shown in fig.
3. The readings on slabs are taken as Indirect reading (indirect or surface transmission) i.e transducer & receiver are placed on the same faces.
4. With distance b/w the transducer & receiver known & UPVT gives the time taken by the wave to travel through the concrete, the velocity of the wave can be calculated which give us the quality of concrete.
5. For both beams & slabs UPVT readings are taken at right side, left side and at the center. In case of slabs it is divided into 5 beams strips and readings are taken on each beam strip.

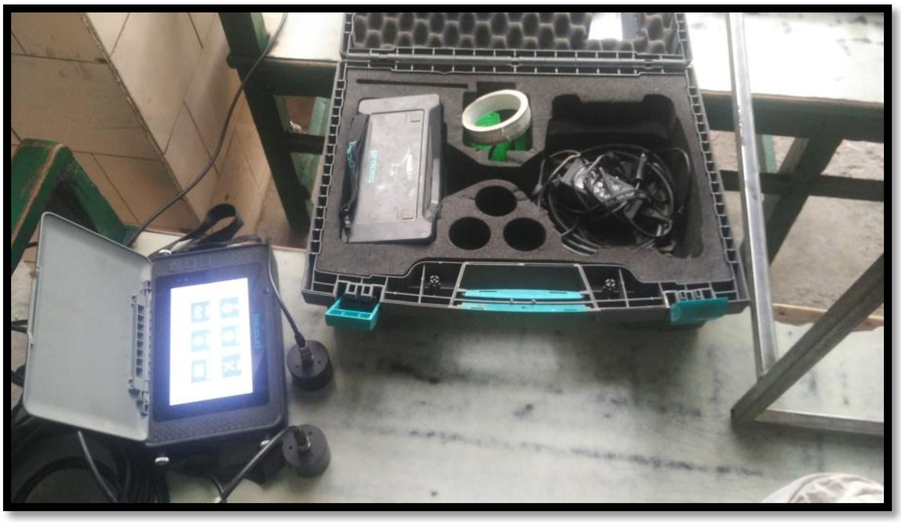


Fig 4: UPVT USED

3.3 GENERATING 3D MODEL

To compute the stresses in the structural members of the school building a 3D model is generated using Staad pro 2007.All the properties of the structural members are kept same as the building is in actual i.e the sizes of beams , slab , thickness of walls etc.

3.3.1 METHODOLOGY

The school building is a G+1 structure with class rooms at ground floor and 1st floor.This structure is supported on brick walls with thickness of 345mm throughout. Slab is being supported on beams with beams resting on brick wall. In generating this staad model the main objective is to generate a model of building which gives the results as they actually are i.e to generate a model as close as the structure is in original & get the stresses in all the structural members.

3.3.2 STRUCTURAL PARAMETERS & CALCULATIONS

The loading applied in the model are as per IS: 875 part-1&2 IS: 1893 & IS: 456. The loading applied are dead load, Live load & Earthquake load. The loading calculations are given below:

Dead load calculation

1. For slabs: - slabs are 150 mm thick & floor finishing of 75 mm.

   DL of slab :- (.150*25+.075*24)=6.15 KN/m^2

2. Terracing load: - terracing of 100mm is provided on the terrace roof.

   Terracing load: - (.100*20) =2KN/m^2

3. For walls :- brick wall is of 350mm thick with 12 mm thick plaster

   DL of wall :- (.35*20*3+.012*21) = 21.25KN/m

4. Apart from the mentioned above dead loads, DL of structural members like beams, columns & walls are applied as self-weight.

Live load considered

Live load applied is as per IS 875 part -2, so live load taken are as following:-

Class rooms	-	4 KN/m^2
Corridor	-	4 KN/m^2
Staircase	-	4 KN/m^2
Toilets	-	2 KN/m^2
Store room	-	4 KN/m^2
Terrace	-	1.5 KN/m^2

Earthquake load

In this model earthquake loading is considered with following factors considered:

Zone factor (Z) - Zone: IV, 0.24

Importance factor (I) - 1

Response reduction factor (R) - 1.5

Type of soil - soft soil

The fundamental natural time period is calculated using the relation as given below:

$$T_n = .09h/(d)^{1/2}$$

Material Property Considered

The material property considered in generating the staad model for various structural members as defined as follows:

For Beams/Slabs

Grade of concrete: M15

Size of beams: (300*450) mm & (300*750) mm

Thickness of Slab: 150 mm

E: 21.718 KN/mm^2

Density: 25 KN/m^3

For walls

Thickness of Wall: 350mm

The walls are modeled as a plate element with property as below

E: 7 KN/mm^2

Poisson's Ratio: .21

Density: 21 KN/m^3

The above mentioned parameters & properties are input in the staad model and then the model is run for analysis to calculate the stresses in the structural members.

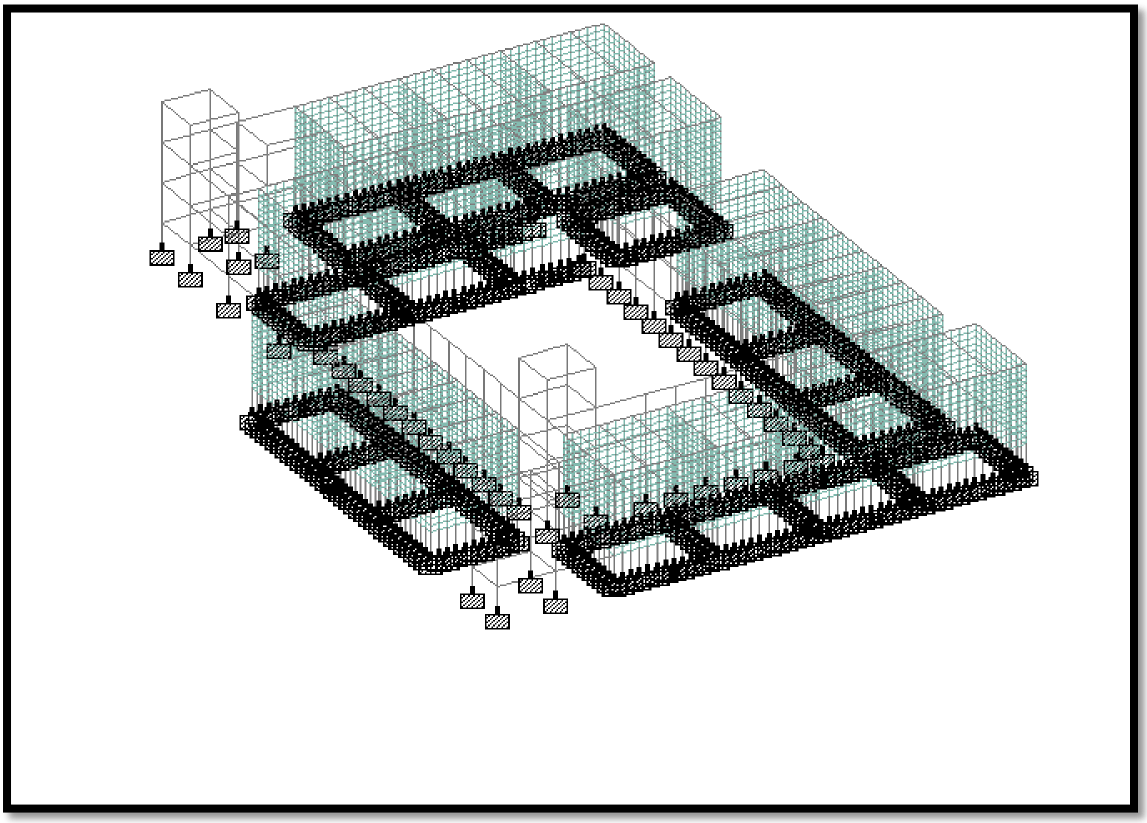


Fig.5 3D Model of the building

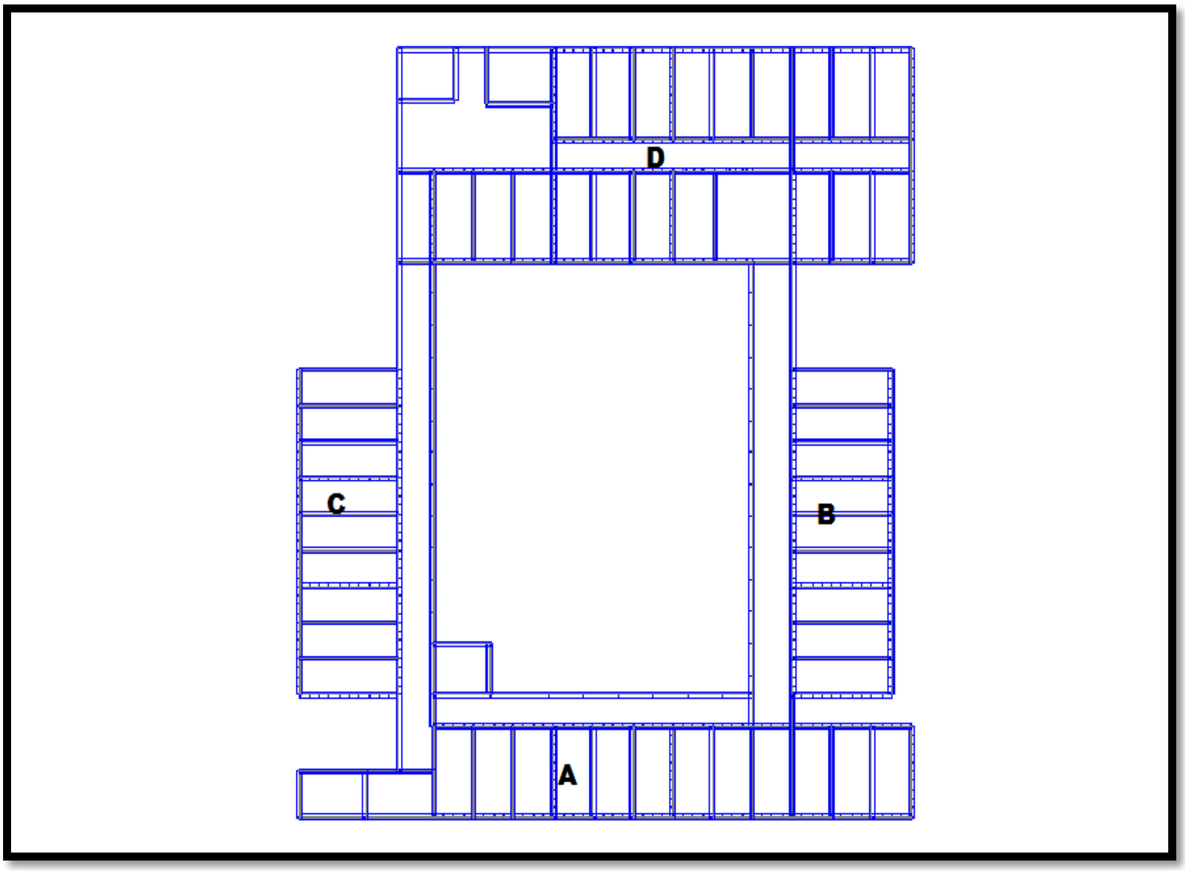


Fig.6 Plan of the building

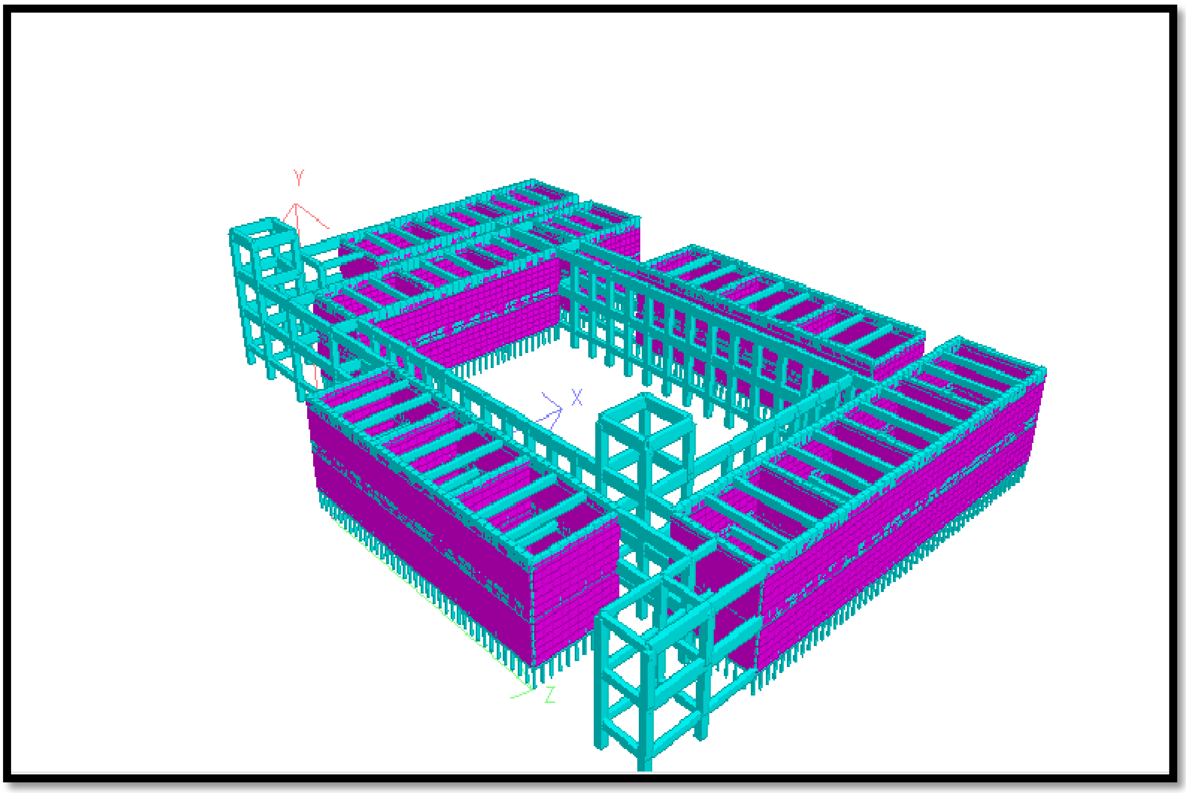


Fig.7 3D view of the building

CHAPTER 4

RESULTS AND DISCUSSION

The experimental work is carried out using Rebound Hammer & UPVT on the structural members i.e beams, slabs & walls. The whole building is divided into 4 Blocks as A, B, C & D.

4.1 Rebound Hammer Readings

Rebound hammer test has been carried out to check the surface hardness of concrete or getting range of compressive strength of concrete. The rebound hammer readings obtained are tabulated below for beams, Slabs & walls.

4.1.1 Rebound Hammer Readings for walls

Rebound Hammer (RM) Tests were done on all the walls & the test location are shown in the fig.8

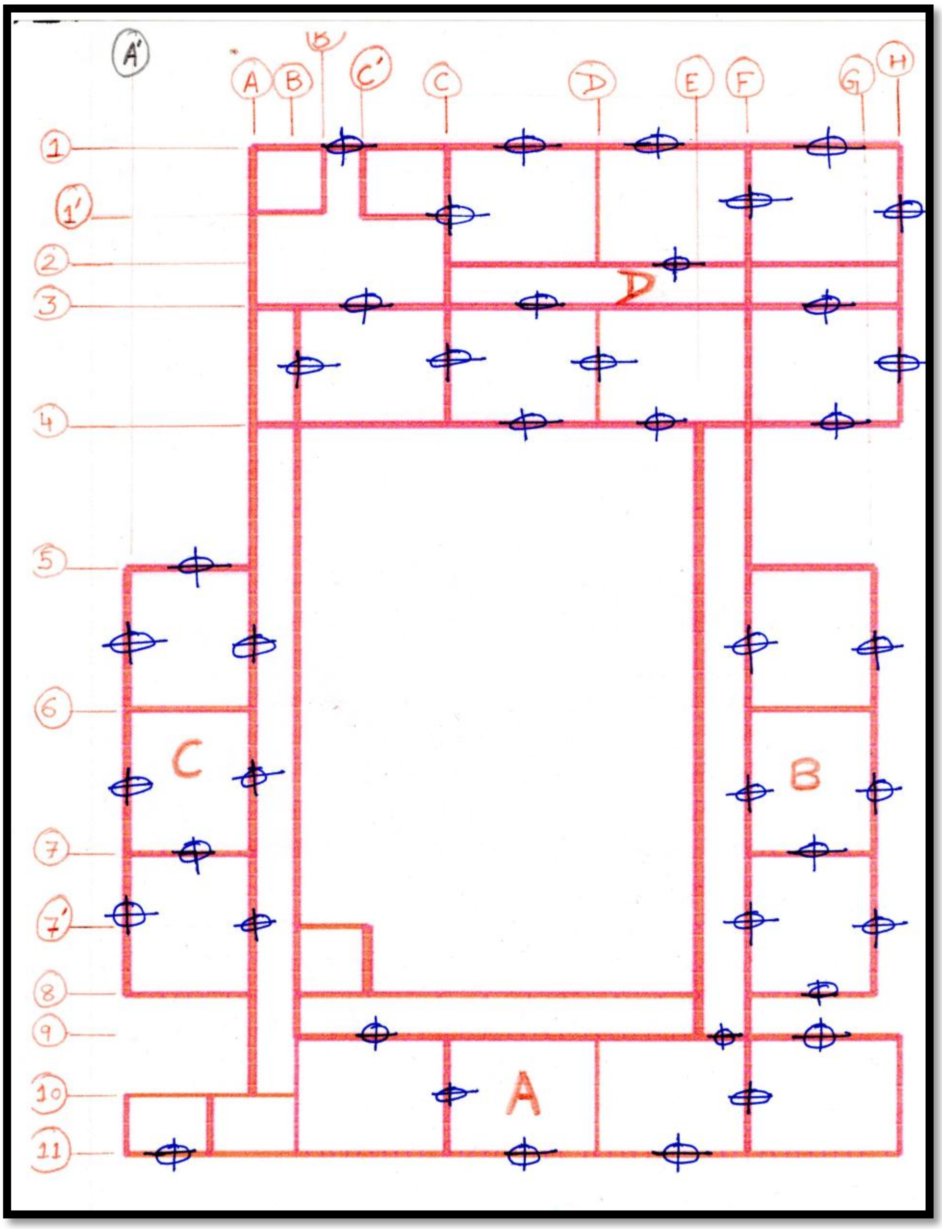


Fig. 8 Plan showing test points of brick wall

S.NO	BLOCK	FLOOR	GRID WISE LOCATION OF WALL	RM Reading			Avg. RM READING
				TOP	Middle	Bottom	
1	A	Gr.FL	A’-A&11	26	26	26	26
2	A	Gr.FL	A-C&9	24	26	28	26
3	A	Gr.FL	C&11-9	26	22	24	24
4	A	Gr.FL	C-D&11	24	22	22	23
5	A	Gr.FL	D-F&11	24	24	24	24
6	A	Gr.FL	F&11-9	22	24	24	23
7	A	Gr.FL	E-F&9	24	22	26	24
8	A	Gr.FL	F-G&9	24	24	24	24
9	B	Gr.FL	F-G&8	26	22	22	23
10	B	Gr.FL	F&7’	26	26	26	26
11	B	Gr.FL	G&7’	24	26	28	26
12	B	Gr.FL	F-G&7	26	22	24	24
13	B	Gr.FL	F&7-6	24	22	22	23
14	B	Gr.FL	G&7-6	24	24	24	24
15	B	Gr.FL	F&6-5	22	24	24	23
16	B	Gr.FL	G&6-5	24	22	26	24
17	C	Gr.FL	A’&7’-7	24	24	24	24
18	C	Gr.FL	A&7’	26	22	22	23
19	C	Gr.FL	A’-A&7	24	24	24	24
20	C	Gr.FL	A’&7-6	22	24	24	23
21	C	Gr.FL	A&7-6	24	22	26	24
22	C	Gr.FL	A’&6-5	24	24	24	24
23	C	Gr.FL	A&6-5	26	22	22	23

S.NO	BLOCK	FLOOR	GRID WISE LOCATION OF WALL	RM Reading			Avg. RM READING
				TOP	Middle	Bottom	
24	C	Gr.FL	A'-A&5	24	24	24	24
25	D	Gr.FL	B&4-3	22	24	24	23
26	D	Gr.FL	B-C'&3	24	22	26	24
27	D	Gr.FL	C&4-3	24	24	24	24
28	D	Gr.FL	C-D&4	26	22	22	23
29	D	Gr.FL	C-D&3	24	24	24	24
30	D	Gr.FL	D&3-4	26	26	26	26
31	D	Gr.FL	D-E&4	24	26	28	26
32	D	Gr.FL	F-G&4	26	22	24	24
33	D	Gr.FL	F-G&3	24	22	22	23
34	D	Gr.FL	H&4-3	24	24	24	24
35	D	Gr.FL	C&1'	22	24	24	23
36	D	Gr.FL	B-C'&1	24	22	26	24
37	D	Gr.FL	C-D&1	24	24	24	24
38	D	Gr.FL	D-E&1	26	22	22	23
39	D	Gr.FL	F-G&1	24	24	24	24
40	D	Gr.FL	F&1'	22	24	24	23
41	D	Gr.FL	H&2-1'	24	22	26	24

S.NO	BLOCK	FLOOR	GRID WISE LOCATION OF WALL	RM Reading			Avg. RM READING
				TOP	Middle	Bottom	
42	D	Gr.FL	D-E&2	24	24	24	24
43	A	1ST.FL	A'-A&11	26	22	22	23
44	A	1ST.FL	A-C&9	24	24	24	24
45	A	1ST.FL	C&11-9	22	24	24	23
46	A	1ST.FL	C-D&11	24	22	26	24
47	A	1ST.FL	D-F&11	24	24	24	24
48	A	1ST.FL	F&11-9	26	22	22	23
49	A	1ST.FL	E-F&9	24	24	24	24
50	A	1ST.FL	F-G&9	26	26	26	26
51	B	1ST.FL	F-G&8	24	26	28	26
52	B	1ST.FL	F&7'	26	22	24	24
53	B	1ST.FL	G&7'	24	22	22	23
54	B	1ST.FL	F-G&7	24	24	24	24
55	B	1ST.FL	F&7-6	22	24	24	23
56	B	1ST.FL	G&7-6	24	22	26	24
57	B	1ST.FL	F&6-5	24	24	24	24
58	B	1ST.FL	G&6-5	26	22	22	23
59	C	1ST.FL	A'&7'-7	24	24	24	24
60	C	1ST.FL	A&7'	22	24	24	23
61	C	1ST.FL	A'-A&7	24	22	26	24
62	C	1ST.FL	A'&7-6	24	24	24	24
63	C	1ST.FL	A&7-6	26	22	22	23

S.NO	BLOCK	FLOOR	GRID WISE LOCATION OF WALL	RM Reading			Avg. RM READING
				TOP	Middle	Bottom	
64	C	1ST.FL	A'&6-5	24	24	24	24
65	C	1ST.FL	A&6-5	22	24	24	23
66	C	1ST.FL	A'-A&5	24	22	26	24
67	D	1ST.FL	B&4-3	24	24	24	24
68	D	1ST.FL	B-C'&3	26	22	22	23
69	D	1ST.FL	C&4-3	24	24	24	24
70	D	1ST.FL	C-D&4	26	26	26	26
71	D	1ST.FL	C-D&3	24	26	28	26
72	D	1ST.FL	D&3-4	26	22	24	24
73	D	1ST.FL	D-E&4	24	22	22	23
74	D	1ST.FL	F-G&4	24	24	24	24
75	D	1ST.FL	F-G&3	22	24	24	23
76	D	1ST.FL	H&4-3	24	22	26	24
77	D	1ST.FL	C&1'	24	24	24	24
78	D	1ST.FL	B-C'&1	24	22	22	23
79	D	1ST.FL	C-D&1	24	26	28	26
80	D	1ST.FL	D-E&1	24	24	24	24
81	D	1ST.FL	F-G&1	26	22	24	24
82	D	1ST.FL	F&1'	22	24	24	23

S.NO	BLOCK	FLOOR	GRID WISE LOCATION OF WALL	RM Reading			Avg. RM READING
				TOP	Middle	Bottom	
83	D	1ST.FL	H&2-1'	24	26	28	26

Some of the picture while taking Rebound Hammer readings on brick wall is shown below:

Picture 15: Rebound Hammer reading in Block A

4.1.2 Rebound Hammer Readings for Beams

Rebound Hammer (RM) Tests were done on the beams & the test location are shown in the fig.9

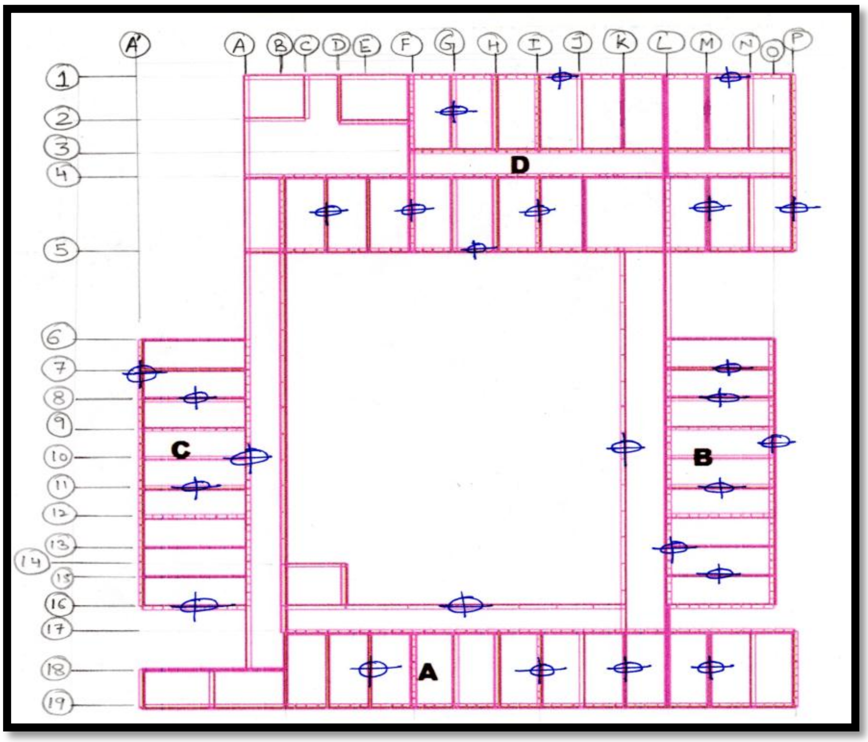


Fig 9: Plan showing test points of Beams

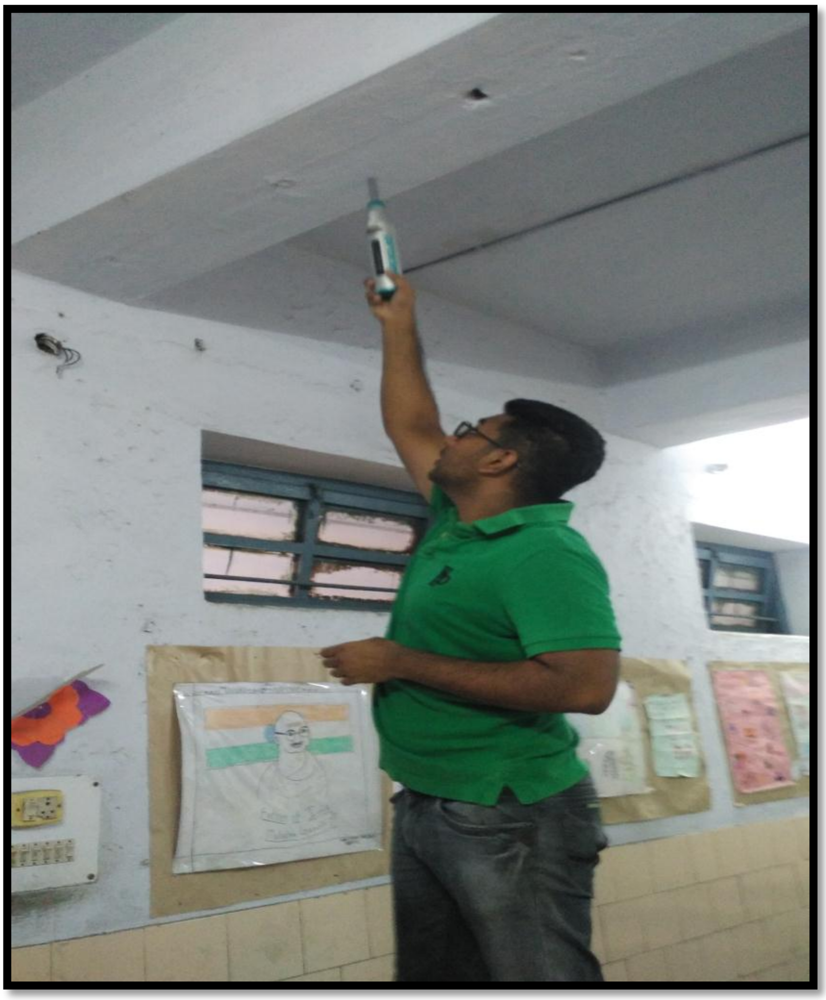
S.NO	BLOCK	FLOOR	BEAM SIZES (mm)	GRID WISE LOCATION OF BEAM	RM Reading			Avg. RM READING
					Right	Middle	Left	
1	A	1ST.FL	300x450	E&19-17	28	28	30	29
2	A	1ST.FL	300x450	I&19-17	28	28	28	28
3	A	1ST.FL	300x450	K&19-17	30	30	32	31
4	A	1ST.FL	300x450	M&19-17	28	28	30	29
5	A	2nd.FL	300x450	E&19-17	28	28	30	29
6	A	2nd.FL	300x450	I&19-17	32	32	30	31

S.NO	BLOCK	FLOOR	BEAM SIZES (mm)	GRID WISE LOCATION OF BEAM	RM Reading			Avg. RM READING
					Right	Middle	Left	
7	A	2nd.FL	300x450	K&19-17	28	32	32	31
8	A	2nd.FL	300x450	M&19-17	32	32	30	31
9	B	1ST.FL	300x450	L-O&15	30	30	28	29
10	B	1ST.FL	300x450	L-O&13	28	28	30	29
11	B	1ST.FL	300x450	L-O&11	28	28	28	28
12	B	1ST.FL	300x450	L-O&8	32	30	30	31
13	B	1ST.FL	300x450	L-O&6	28	28	30	29
14	B	2nd.FL	300x450	L-O&15	28	28	30	29
15	B	2nd.FL	300x450	L-O&13	32	32	30	31
16	B	2nd.FL	300x450	L-O&11	30	30	30	30
17	B	2nd.FL	300x450	L-O&8	28	28	26	27
18	B	2nd.FL	300x450	L-O&6	28	28	32	29
19	C	1ST.FL	300x450	A'-A&16	28	28	30	29
20	C	1ST.FL	300x450	A'-A&11	28	28	28	28
21	C	1ST.FL	300x450	A'-A&10	32	32	30	31
22	C	1ST.FL	300x450	A'-A&8	28	28	30	29
23	C	2nd.FL	300x450	A'-A&16	28	28	30	29
24	C	2nd.FL	300x450	A'-A&11	30	32	30	31
25	C	2nd.FL	300x450	A'-A&10	32	28	30	30
26	C	2nd.FL	300x450	A'-A&8	28	26	32	29
27	D	1ST.FL	300x450	C&5-4	32	32	30	32
28	D	1ST.FL	300x450	F&5-4	30	32	30	31

S.NO	BLOCK	FLOOR	BEAM SIZES (mm)	GRID WISE LOCATION OF BEAM	RM Reading			Avg. RM READING
					Right	Middle	Left	
29	D	1ST.FL	300x450	I&5-4	32	32	30	31
30	D	1ST.FL	300x450	P&5-4	32	32	30	32
31	D	1ST.FL	300x450	G&3-1	28	26	32	29
32	D	1ST.FL	300x450	K&3-1	32	32	30	32
33	D	2nd.FL	300x450	C&5-4	28	28	30	29
34	D	2nd.FL	300x450	F&5-4	28	28	30	29
35	D	2nd.FL	300x450	I&5-4	32	32	30	31
36	D	2nd.FL	300x450	P&5-4	34	32	30	32
37	D	2nd.FL	300x450	G&3-1	28	28	26	27
38	D	2nd.FL	300x450	K&3-1	28	28	28	28
39	A	1ST.FL	300x750	G-H&16	30	34	34	33
40	A	2nd.FL	300x750	G-H&16	34	32	30	32
41	B	1ST.FL	300x750	K&10-9	32	32	30	32
42	B	1ST.FL	300x750	O&10-9	34	34	34	34
43	B	2nd.FL	300x750	K&10-9	34	32	30	32
44	B	2nd.FL	300x750	O&10-9	32	32	30	31
45	C	1ST.FL	300x750	A'&8-7	32	32	30	31
46	C	2nd.FL	300x750	A'&8-7	28	26	32	29
47	D	1ST.FL	300x750	G-H&5	32	32	30	31
48	D	1ST.FL	300x750	I-J&1	34	32	30	32
49	D	1ST.FL	300x750	M-N&1	28	26	32	29
50	D	2nd.FL	300x750	G-H&5	32	32	30	31

S.NO	BLOCK	FLOOR	BEAM SIZES (mm)	GRID WISE LOCATION OF BEAM	RM Reading			Avg. RM READING
					Right	Middle	Left	
51	D	2nd.FL	300x750	I-J&1	30	30	32	31
52	D	2nd.FL	300x750	M-N&1	28	28	30	29

Some of the picture while taking Rebound Hammer readings on beams is shown below:



Picture 16: RH Reading of beam in block D

4.1.3 Rebound Hammer Readings for Slabs

Rebound Hammer (RM) Tests were done on slabs & the test location is shown in the fig.10

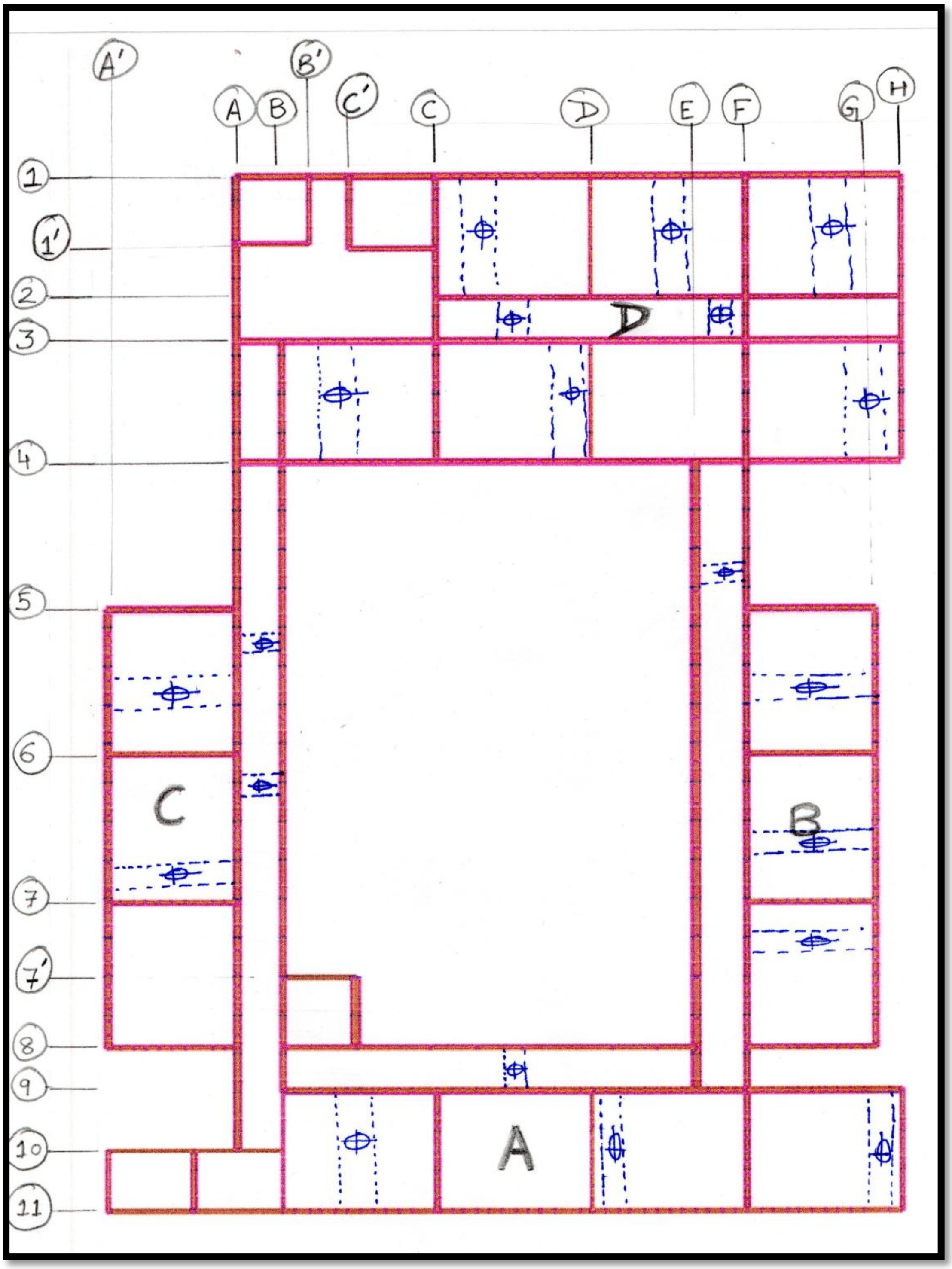


Fig 10: Plan showing test points of slabs

S.NO	BLOCK	FLOOR	Thickness (mm)	GRID WISE LOCATION OF SLAB	RM Reading			Avg. RM READING
					Right	Middle	Left	
1	A	1st.FL	150	A-C&11-9	28	28	32	29
2	A	1st.FL	150	C-D&11-9	32	28	30	30
3	A	1st.FL	150	D-F&11-9	28	28	30	29
4	A	1st.FL	150	F-H&11-9	28	28	30	29
5	A	2ND.FL	150	A-C&11-9	30	30	30	30
6	A	2ND.FL	150	C-D&11-9	28	26	32	29
7	A	2ND.FL	150	D-F&11-9	32	32	30	32
8	A	2ND.FL	150	F-H&11-9	28	28	30	29
9	B	1ST.FL	150	F-H&8-7	30	28	30	29
10	B	1ST.FL	150	F-H&7-6	30	30	32	31
11	B	1ST.FL	150	F-H&6-5	32	28	30	29
12	B	1ST.FL	150	E-F&5-4	28	28	30	29
13	B	2ND.FL	150	F-H&8-7	30	32	32	31
14	B	2ND.FL	150	F-H&7-6	30	30	32	31
15	B	2ND.FL	150	F-H&6-5	32	32	30	32
16	B	2ND.FL	150	E-F&5-4	28	30	28	29
17	C	1ST.FL	150	A’-A&7-6	32	32	30	32
18	C	1ST.FL	150	A’-A&6-5	28	28	30	29
19	C	1ST.FL	150	A-B&7-6	30	32	32	31

S.NO	BLOCK	FLOOR	Thickness (mm)	GRID WISE LOCATION OF BEAM	RM Reading			Avg. RM READING
					Right	Middle	Left	
1	C	1st.FL	150	A-B&6-5	28	28	30	29
2	C	2ND.FL	150	A'-A&7-6	30	30	30	30
3	C	2ND.FL	150	A'-A&6-5	28	28	38	28
4	C	2ND.FL	150	A-B&7-6	30	32	28	30
5	C	2ND.FL	150	A-B&6-5	28	26	28	27
6	D	1ST.FL	150	B-C&4-3	32	32	30	32
7	D	1ST.FL	150	C-D&4-3	28	28	30	29
8	D	1ST.FL	150	F-H&4-3	28	28	30	29
9	D	1ST.FL	150	C-D&3-2	30	30	30	30
10	D	1ST.FL	150	D-F&3-3	28	26	32	29
11	D	1ST.FL	150	C-D&2-1	32	32	30	32
12	D	1ST.FL	150	D-E&2-1	28	28	30	29
13	D	1ST.FL	150	F-G&2-1	28	26	32	29
14	D	2ST.FL	150	B-C&4-3	30	30	32	31
15	D	2ND.FL	150	C-D&4-3	32	32	30	32
16	D	2ND.FL	150	F-H&4-3	28	28	30	29
17	D	2ND.FL	150	C-D&3-2	30	32	32	31
18	D	2ND.FL	150	D-F&3-3	32	32	30	32
19	D	2ND.FL	150	C-D&2-1	28	28	30	29
20	D	2ND.FL	150	D-E&2-1	28	26	32	29
21	D	2ND.FL	150	F-G&2-1	30	30	32	31

Some of the picture while taking Rebound Hammer readings on slabs is shown below:

Picture 17: RH Reading on slab of Block A

4.2 Ultrasonic Pulse Velocity Tester Readings

To ascertain the quality of concrete Ultra Pulse Velocity test has been carried out. Ultra Pulse Velocity test has been carried out to check the quality of concrete. The UPVT readings obtained are tabulated below for beams & Slabs.

4.2.1 UPVT Readings for Beams

UPVT Tests were done on Beams & the test locations are shown in the fig.11

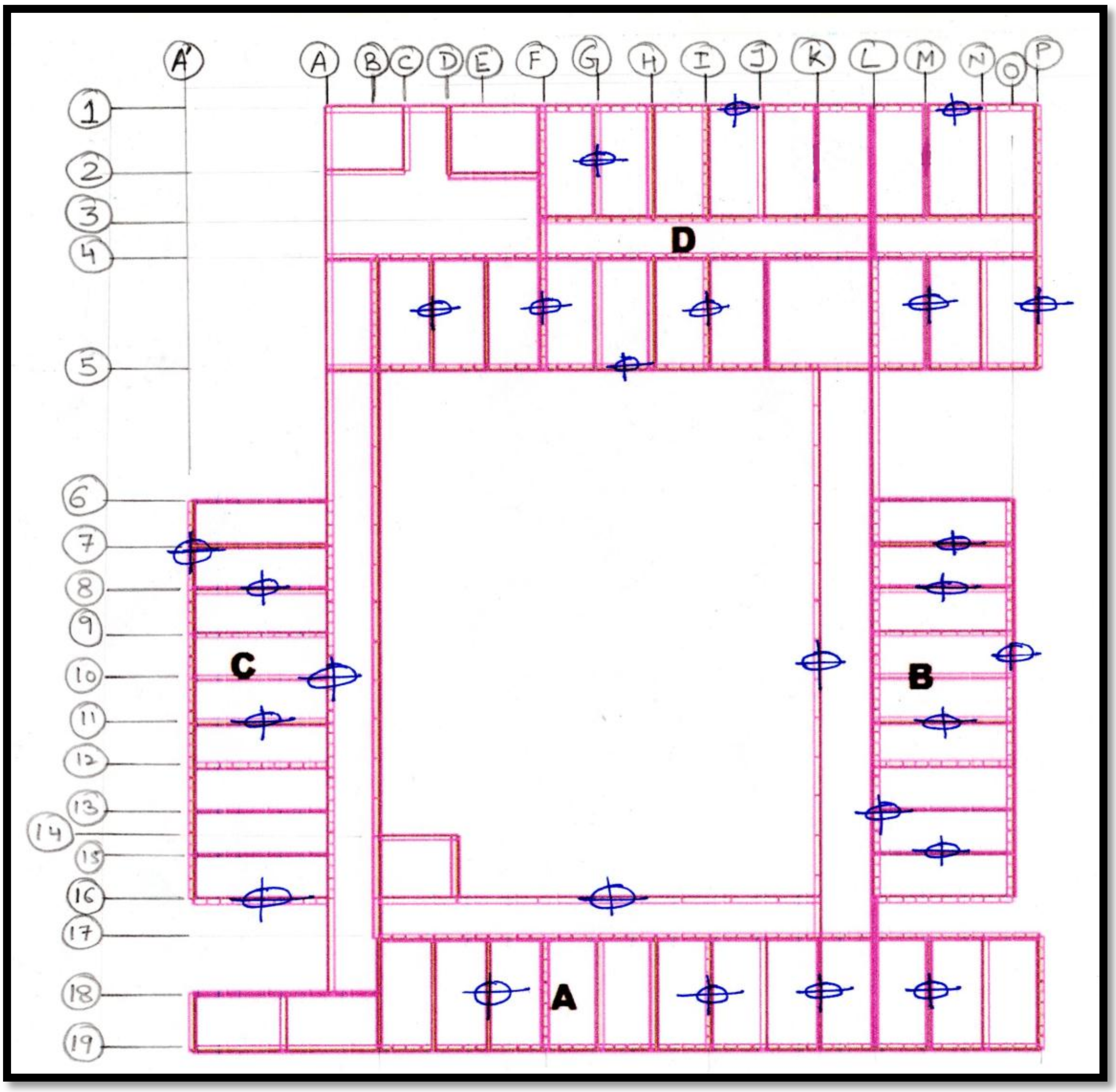
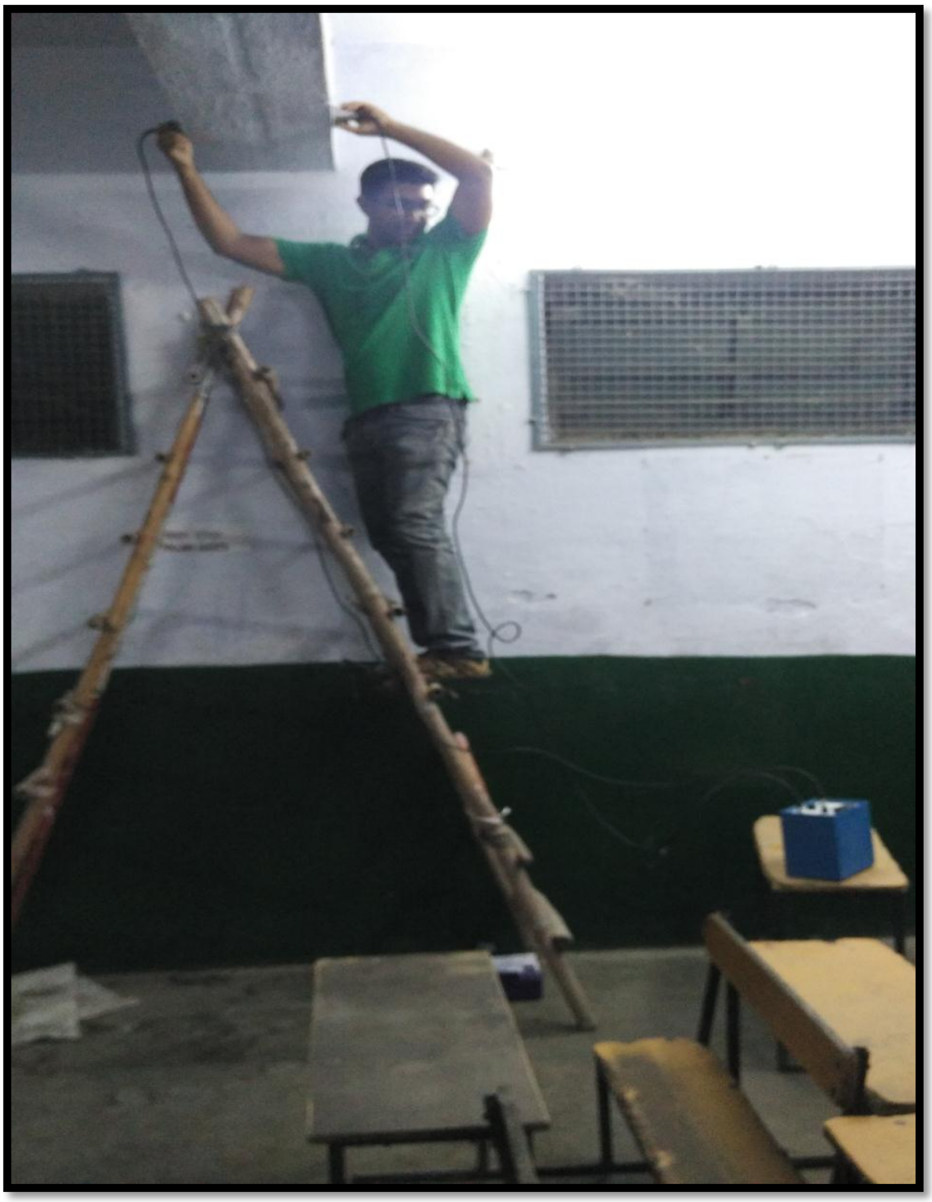


Fig 11: Plan showing test points of Beams

S.NO	BLOCK	FLOOR LVL	GRID WISE LOCATION of Beam	Distance b/w T & r (mm)	UPVT Reading (Micro sec)			Avg. UPVT Reading (Micro sec)	Velocity of wave (Km/sec)
					Right	Middle	Left		
1	A	1ST F	E&19-17	300	115	111	120	115	2.6
2	A	1ST F	I&19-17	300	107	103	106	105	2.8
3	A	1ST F	K&19-17	300	98	101	102	100	3
4	A	1ST F	M&19-17	300	103	109	111	108	2.8
5	A	2ST F	E&19-17	300	106	113	110	110	2.7
6	A	2ST F	I&19-17	300	113	107	110	110	2.8
7	A	2ST F	K&19-17	300	107	104	99	103	2.9
8	A	2ND F	M&19-17	300	108	116	102	109	2.8
9	B	1ND F	L-O&15	300	89	98	95	94	3.1
10	B	1ND F	L-O&11	300	87	93	90	90	3.3
11	B	1ND F	L-O&8	300	95	91	100	95	3.1
12	B	1ND F	L-O&6	300	98	91	84	91	3.2
13	B	2ND F	L-O&15	300	103	99	109	104	2.9
14	B	2ND F	L-O&11	300	81	90	86	86	3.4
15	B	2ND F	L-O&8	300	97	82	89	89	3.3
16	B	2ND F	L-O&6	300	83	79	88	83	3.6

S.NO	BLOCK	FLOOR LVL	GRID WISE LOCATION of BEAM	Distance b/w T & r (mm)	UPVT Reading (Micro sec)			Avg. UPVT Reading (Micro sec)	Velocity of wave (Km/sec)
					Right	Middle	Left		
17	C	1ST F	A'-A&16	300	103	99	109	104	2.9
18	C	1ST F	A'-A&11	300	97	82	89	89	3.3
19	C	1ST F	A'-A&10	300	98	101	102	100	3
20	C	1ST F	A'-A&8	300	103	109	111	108	2.8
21	C	2ST F	A'-A&16	300	106	113	110	110	2.7
22	C	2ST F	A'-A&11	300	98	91	84	91	3.2
23	C	2ST F	A'-A&10	300	107	104	99	103	2.9
24	C	2ND F	A'-A&8	300	108	116	102	109	2.8
25	D	1ND F	K&3-1	300	89	98	95	94	3.1
26	D	1ND F	F&5-4	300	87	93	90	90	3.3
27	D	1ND F	I&5-4	300	95	91	100	95	3.1
28	D	1ND F	P&5-4	300	98	91	84	91	3.2
29	D	1ND F	G&3-1	300	103	99	109	104	2.9
30	D	2ND F	K&3-1	300	81	90	86	86	3.4
31	D	2ND F	F&5-4	300	97	82	89	89	3.3
32	D	2ND F	I&5-4	300	98	101	102	100	3
33	D	2ND F	P&5-4	300	97	82	89	89	3.3
34	D	2ND F	G&3-1	300	108	116	102	109	2.8

Some of the picture while taking UPVT Reading on beams is shown below:



Picture 18: Taking UPVT Reading of beam in block B

4.2.2 UPVT Reading for Slab

UPVT Tests were done on Beams & the test locations are shown in the fig.

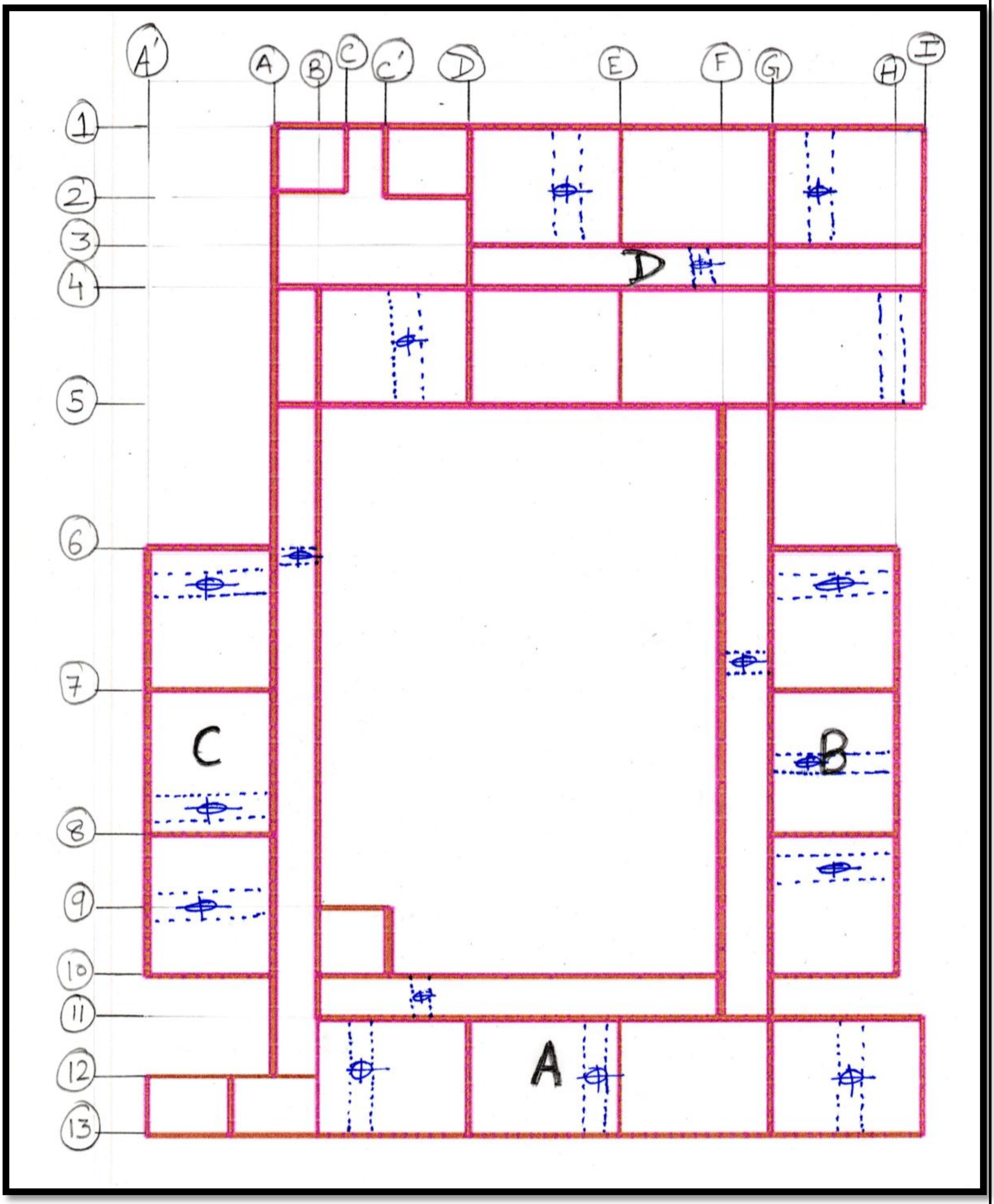


Fig 12: Plan showing test points of slabs

S.NO	BLOCK	FLOOR LVL	GRID WISE LOCATION of Slab Panel	Distance b/w T & r (mm)	UPVT Reading (Micro sec)			Avg. UPVT Reading (Micro sec)	Velocity of wave (Km/sec)
					Right	Middle	Left		
1	A	1ST F	A-D&13-11	450	138	134	142	138	3.2
2	A	1ST F	A-D&11-10	450	154	149	146	156	3.0
3	A	1ST F	D-E&13-11	450	140	132	137	136	3.3
4	A	1ST F	G-I&13-11	450	162	168	157	162	2.7
5	A	2ND F	A-D&13-11	450	155	167	159	160	2.8
6	A	2ND F	A-D&11-10	450	143	151	146	147	3.0
7	A	2ND F	D-E&13-11	450	154	163	169	162	2.8
8	A	2ND F	G-I&13-11	450	148	136	140	141	3.1
9	B	1ST F	G-I&10-8	450	139	149	155	148	3
10	B	1ST F	G-I&8-7	450	126	135	130	130	3.4
11	B	1ST F	G-I&7-6	450	129	125	136	130	3.4
12	B	1ST F	F-G&7-6	450	140	132	137	136	3.3
13	B	2ND F	G-I&10-8	450	162	168	157	162	2.7
14	B	2ND F	G-I&8-7	450	154	163	169	162	2.8
15	B	2ND F	G-I&7-6	450	166	160	171	166	2.7
16	B	2ND F	F-G&7-6	450	154	149	146	156	3.0

S.NO	BLOCK	FLOOR LVL	Grid wise location of slab Panel	Distance b/w T & r (mm)	UPVT Reading (Micro sec)			Avg. UPVT Reading (Micro sec)	Velocity of wave (Km/sec)
					Right	Middle	Left		
17	C	1ST F	A'-A&10-8	450	162	168	157	162	2.7
18	C	1ST F	A'-A&8-7	450	154	149	146	156	3.0
19	C	1ST F	A'-A&7-6	450	148	136	140	141	3.1
20	C	1ST F	A-B&7-6	450	162	168	157	162	2.7
21	C	2ND F	A'-A&10-8	450	155	167	159	160	2.8
22	C	2ND F	A'-A&8-7	450	143	151	146	147	3.0
23	C	2ND F	A'-A&7-6	450	154	163	169	162	2.8
24	C	2ND F	A-B&7-6	450	148	136	140	141	3.1
25	D	1ST F	B-D&5-6	450	140	132	137	136	3.3
26	D	1ST F	D-E&3-1	450	126	135	130	130	3.4
27	D	1ST F	E-G&4-3	450	129	125	136	130	3.4
28	D	1ST F	G-I&3-1	450	140	132	137	136	3.3
29	D	1ST F	G-I&5-4	450	126	135	130	130	3.4
30	D	2ND F	B-D&5-6	450	148	153	157	153	2.9
31	D	2ND F	D-E&3-1	450	154	163	169	162	2.8
32	D	2ND F	E-G&4-3	450	148	136	140	141	3.1
33	D	2ND F	G-I&3-1	450	154	149	146	156	3.0
34	D	2ND F	G-I&5-4	450	154	163	169	162	2.8

Some of the picture while taking UPVT Reading on beams is shown below:

Picture 19: UPVT on slab of block D

4.3 Results Obtained From Staad

A 3D Model of the building is prepared and is analyzed keeping all the parameters of the building as they are in actual. The staad model is mainly prepared to determine the magnitude of compressive stress in the load bearing wall. The model is analyzed for all the load combination as per IS 456, IS 1893 & IS 875, the building is also analyzed for earthquake load combination also and the results are displayed below.

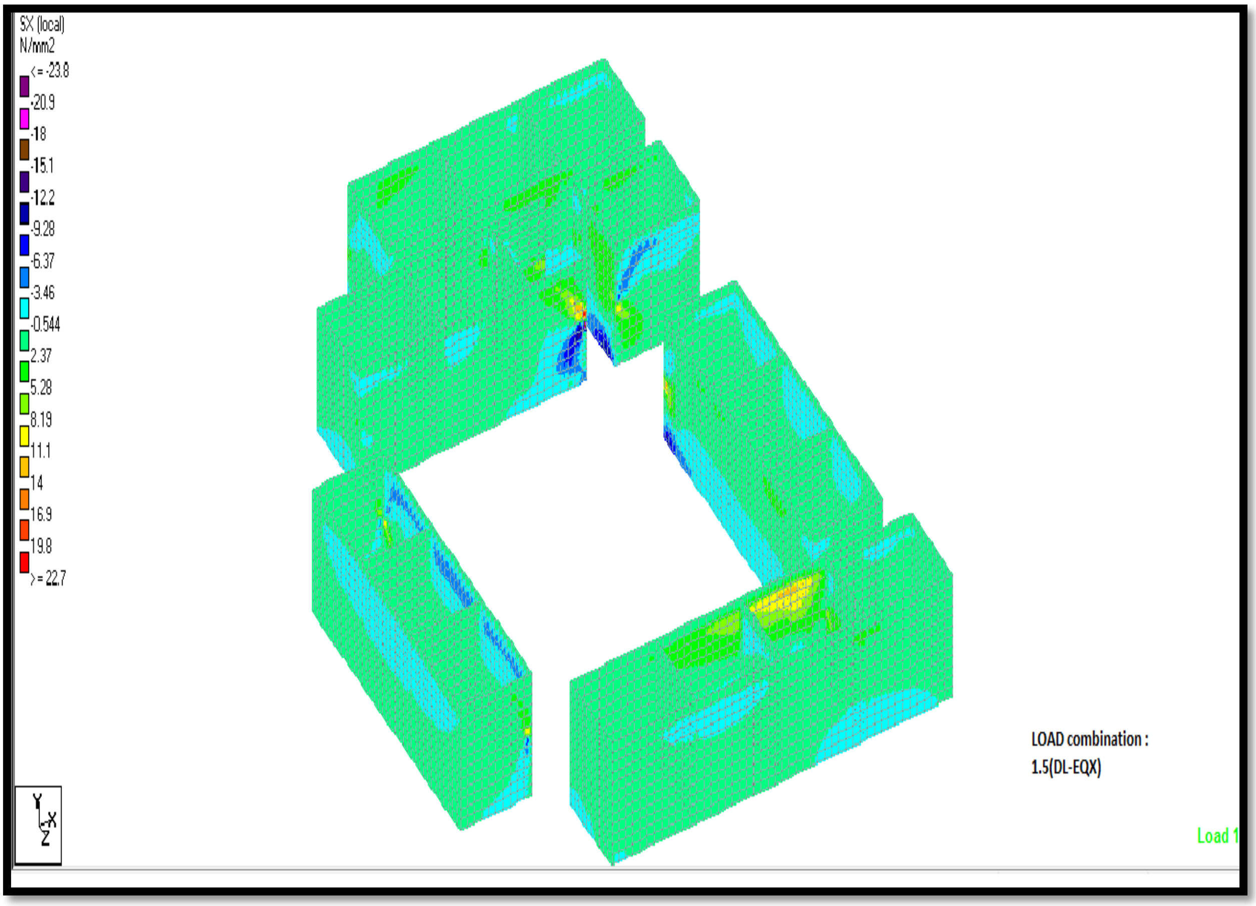


Fig 13: STRESSES INDUCED IN WALLS FOR LOAD COMBINATION 1.5(DL-EQX)

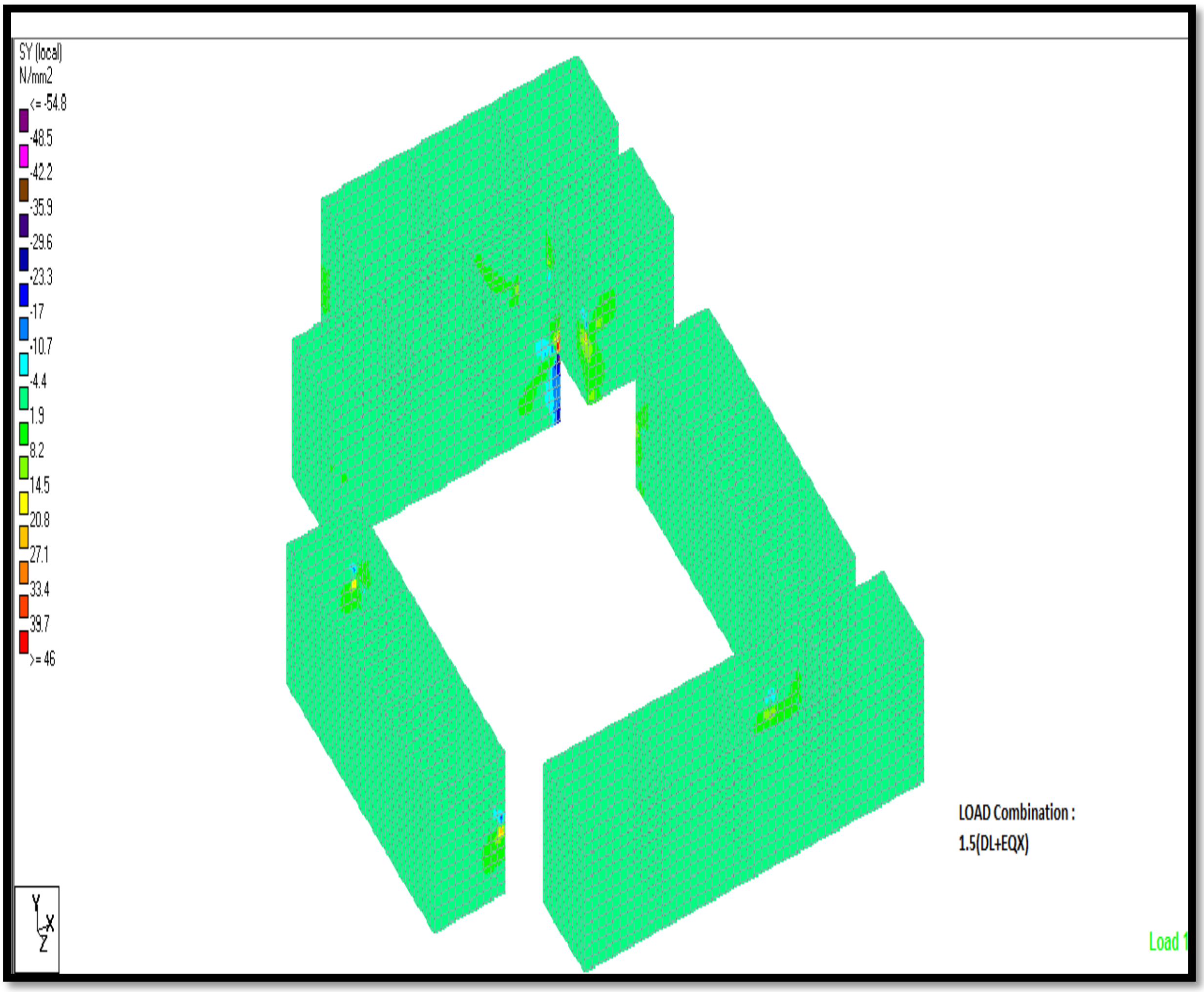


Fig14: STRESSES INDUCED IN WALLS FOR LOAD COMBINATION 1.5(DL+EQX)

4.4 RESULT SUMMARY

The results obtained as discussed in chapter-4 for beams, slabs & walls by Rebound hammer test & UPVT are compiled and summarized in this Chapter. The summery of these test results are discussed below:

4.4.1 REBOUND HAMMER

The result summary of walls are tabulated below

BLOCK	FLOOR	RANGE OF REBOUND HAMMER READING	RANGE COMPRESSIVE STRENGTH (N/mm^2)
BLOCK –A	Gr.F	26 -24	14-18
	1ST.F	23-26	14-18
BLOCK –B	Gr.F	23-26	14-18
	1ST.F	23-26	14-18
BLOCK-C	Gr.F	23-24	14-18
	1ST.F	23-24	14-18
BLOCK-D	Gr.F	23-26	14-18
	1ST.F	23-26	14-18

The result summary of beams are tabulated below

BLOCK	FLOOR	RANGE OF REBOUND HAMMER READING	RANGE COMPRESSIVE STRENGTH (N/mm^2)
BLOCK –A	1st.F	29 -31	15-18
	2ND.F	29-31	14-18
BLOCK –B	1st.F	28-31	14-18
	2ND.F	29-31	15-18
BLOCK-C	1st.F	28-31	14-18
	2ND.F	29-31	15-18
BLOCK-D	1st.F	29-32	15-20
	2ND.F	29-32	15-20

The result summary of slabs are tabulated below

BLOCK	FLOOR	RANGE OF REBOUND HAMMER READING	RANGE COMPRESSIVE STRENGTH (N/mm^2)
BLOCK –A	1st.F	29 -30	15-16
	2ND.F	29-32	15-20
BLOCK –B	1st.F	29-31	15-18
	2ND.F	29-31	15-18
BLOCK-C	1st.F	29-32	15-20
	2ND.F	27-30	12-16
BLOCK-D	1st.F	29-32	14-18
	2ND.F	29-31	15-18

4.4.2 UPVT SUMMARY

The result summary of Beams are tabulated below

BLOCK	FLOOR	RANGE OF UPVT READING	Quality of concrete (N/mm^2)
BLOCK –A	1st.F	2.6-3	DOUBTFUL
	2ND.F	2.7-2.8	DOUBTFUL
BLOCK –B	1st.F	3.1-3.3	MEDIUM
	2ND.F	2.9-3.6	MEDIUM
BLOCK-C	1st.F	2.8-3.3	DOUBTFUL
	2ND.F	2.7-3.2	DOUBTFUL
BLOCK-D	1st.F	2.9-3.3	DOUBTFUL
	2ND.F	2.8-3.4	DOUBTFUL

The result summary of Slabs are tabulated below

BLOCK	FLOOR	RANGE OF UPVT READING	Quality of concrete (N/mm^2)
BLOCK –A	1st.F	2.7-3.3	DOUBTFUL
	2ND.F	2.8-3.1	DOUBTFUL
BLOCK –B	1st.F	3-3.4	MEDIUM
	2ND.F	2.7-3	DOUBTFUL
BLOCK-C	1st.F	2.7-3.1	DOUBTFUL
	2ND.F	2.8-3.1	DOUBTFUL
BLOCK-D	1st.F	3.3-3.4	MEDIUM
	2ND.F	2.9-3.1	DOUBTFUL

CHAPTER 5

CONCLUSIONS AND FUTURE WORK

5.1 CONCLUSION

NDT methods are very effective in health monitoring of buildings, by following the procedures as mentioned in IS 13311.1 reliable results can be obtained and there by the present strength of the building can be evaluated.

In this project NDT tests such as Rebound Hammer & UPVT were done on a school building which is more than 50 years old. The strength of beams, slabs & load bearing walls were tested using these NDT tests.

To get an idea about what are the magnitude of stresses in the structural component of the building a 3D model is prepared in Staad pro where the building is analyzed by applying all the loads that are acting on the building as per IS codes and the stresses obtained are the actual stresses induced in the building.

The following conclusion are obtained after conducting NDT tests :

A. The Rebound Hammer readings of walls lie in the range of 23 to 26 giving the compressive strength from 14 to 18 N/mm^2, for beams compressive strength lies in the range of 15 to 20 N/mm^2 & for slabs it lies b/w 13-16 N/mm^2.
B. UPVT readings indicate that for both beams & slabs most of the readings indicate that the quality of concrete is doubtful.
C. As we compare the results from staad the stresses obtained in the walls are in the range of 8 to 10 N/mm^2 which is less than the strength obtained from Rebound Hammer tests.
D. It was seen that various parts of the buildings like portion of beams, slabs the reinforcement is exposed & as a result rusting of reinforcement is occurring there by causing spalling of concrete.

5.2 RETROFITTING MEASURES

Retrofitting measures can be used to upgrade the strength of the building and can increase its service life .There are various retrofitting schemes are available which can be adopted. Now with the results which we have got from the NDT tests & through visual inspection the various retrofitting steps which can be followed are discussed as below:

1. At many location in the school building it is seen that the reinforcement is exposed & concrete has fallen off due to bulging and the reinforcement is rusting there by causing more spalling.

   Retrofitting measures: For such a problem the location is identified & where rusting of reinforcement has occurred the old reinforcement is removed and new reinforcement mesh is placed and there after concrete is placed over it with suitable admixtures at the joints as shown in the figure.

Picture 20: Retrofitting for slab

Picture 21: Retrofitting for slab

2. Since the quality of concrete from UPVT for most of the beams & slabs is doubtful and the strength from Rebound Hammer test lies b/w 15-20N/mm^2 & 13-16N/mm^2 for beams & slabs respectively.

   Retrofitting measures: As the quality of concrete is doubtful the jacketing of beams & slabs can be done to increase its strength as shown in the figure.

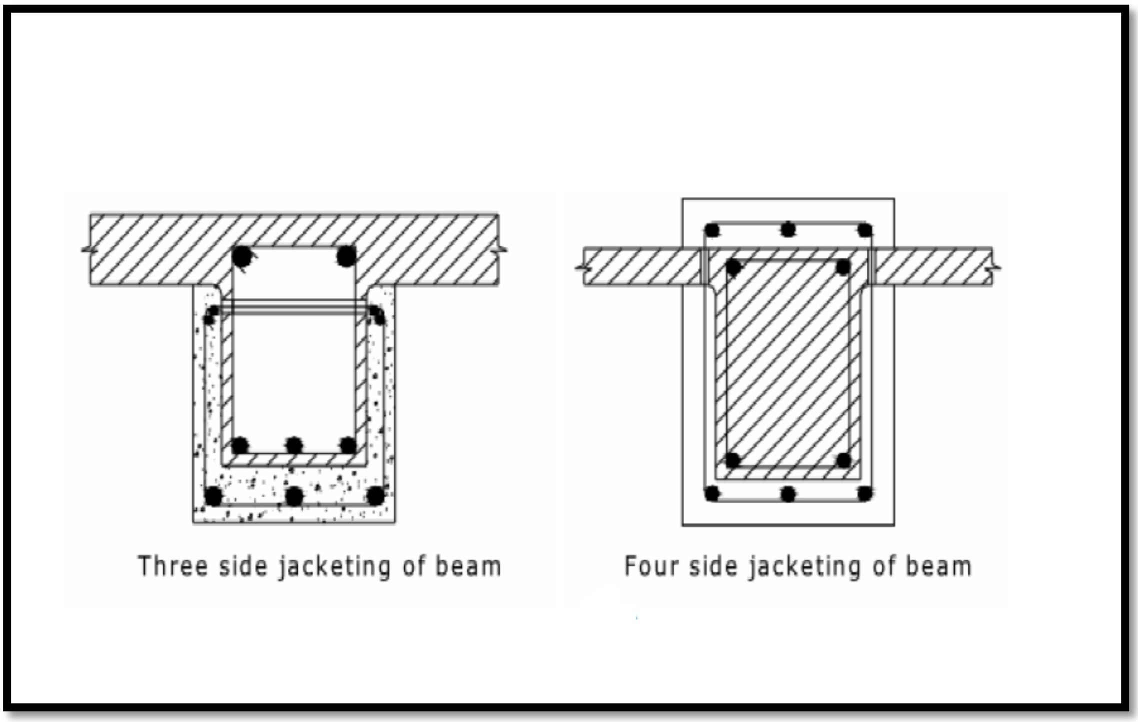
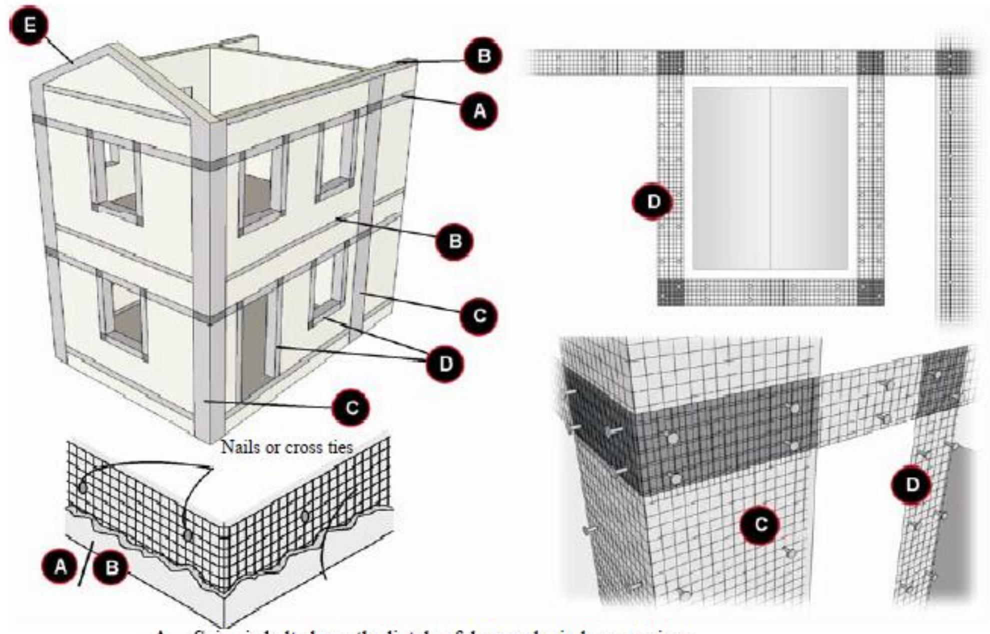


Fig 15: Jacketing of beams

3. The strength of load bearing walls are sufficient in case of compression , but in case of earthquake there may be tension in the wall panel which can cause severely to the building.

   Retrofitting measures: For this problem wire mesh can be applied at the corners & at opening which can provide sufficient strength to the building in case of earthquakes and can prevent sever damage to the building as shown in figure.



A Seismic belt above the lintels of door and window openings.
B Seismic belt just below the roof
C Vertical Seismic belt at wall junctions (L & T junctions)
D Seismic belt around doors & windows
E Seismic belt around the gable wall
Note:- Use of galavanised welded steel wire mesh as reinforcement every where

Overall arrangement of Seismic Belt

Fig 16: Retrofitting of Brick walls

5.3 RECOMMENDATION FOR FUTURE WORK

There is scope for future work in this project in this project work only Two NDT Techniques were used for evaluation of strength & quality of the structural elements. Since in this project the school Principal has asked me to restrain from conducting tests which require to make cuts or a patch is to be cut in the structural elements so some of the NDT tests were avoided.

Some of the tasks/work for future are discussed below:

- The structural members can be checked for their strength & quality by extracting cores from them with the help of core cutting machine.
- For exact analysis of the building complete detail about the reinforcement need to be found out with the help of Ferro meters which gives us the exact location its diameter its spacing , so that exact analysis of the building can be done.
- Carbonation test can be performed to determine the extant up to which carbonation of concrete has occurred.
- Preparation of a new 3D model incorporating all the retrofitting changes that are done in the building & checking the performance of the building.

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-------End of Report--------