STRUCTURAL HEALTH MONITORING OF AN EXISTING BUILDING BY NON-DESTRUCTIVE EVALUATION USING ULTRASONIC PULSE VELOCITY TESTER

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ABSTRACT: Structures are assemblies of load carrying members capable of safelytransferring the superimposed loads to the foundations. Their main and most looked afterproperty is the strength of the material that they are made of. Concrete, as we all know, is anintegral material used for construction purposes. Thus, strength of concrete used, is required tobe known before starting with any kind of analysis. In the recent past, various methods andtechniques, called as Non-Destructive Evaluation (NDE) techniques, are being used forStructural Health Monitoring (SHM).The objective of work is to carryout Structural Health Monitoring of building based on Non Destructive testing using Ultrasonic Pulse Velocity Tester. For our work we have considered a 5-storey educational building which is nothing but the R-Block of Usha Rama College of Engineering & Technology. There is a need for regular monitoring and maintenance of the structure for achieving increased life and service of the structure. In total there are 725 columns in R-Block. Each floor of the 5-floored structure consists of 145 columns. These are divided in to two parts, one as Part-A: 620mm x 260mm (112 no's)and Part-B: 290mm x 290mm (33 no's).CONTROLS Model 58-E4800 Ultrasonic pulse velocity testerNon-Destructive equipment is used in the present work. The range of concrete quality grading values measured on small columns vary from 3.1 to 4.7 km/sec where as the range of concrete quality gradingvalues measured on large columns vary from 3.0 to 4.7 km/sec.
KEYWORDS: Structural Health Monitoring, Non Destructive Testing, Concrete, Columns, CONTROLS Model 58-E4800 Ultrasonic pulse velocity tester, Concrete Quality Grading.

I. INTRODUCTION

1.1 GENERAL

The field of NDT is a very broad, interdisciplinary field that plays a critical role in inspecting that structural component and systems perform their function in a reliable fashion. Certain standards has been also implemented to assure the reliability of the NDT tests and prevent certain errors due to either the fault in the equipment used, the miss-application of the methods or the skill and the knowledge of the inspectors. To keep a high level of structural safety, durability and performance of the infrastructure in each country, an efficient system for early and regular structural assessment is urgently required. The quality assurance during and after the construction of new structures and after reconstruction processes and the characterization of material properties and damage as a function of time and environmental influences is more and more becoming a serious concern.Non-destructive testing (NDT) methods have a large potential to be part of such a system. NDT methods in general are widely used in several industry branches.

1.2 STRUCTURAL HEALTH MONITORING

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 wave's 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.

1.3 NON DESTRUCTIVE TESTING OF CONCRETE

It is often necessary to test concrete structures after the concrete has hardened to determine whether the structure is suitable for its designed use. 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 nondestructive 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. The present work focuses on the NDT methods relevant for the inspection and evaluation of concrete materials.

1.4 OBJECTIVE OF WORK

The main objectives of the present project work are listed below. Due to certain limitations like time, availability of equipment, etc., the experimental work has been limited to the use of Ultra sonic pulse velocity tester for evaluation of columns only.

1. To evaluate the concrete quality grading of all columns of 5 floors of R-Block existing in the campus of Usha Rama College of Engineering & Technology.
2. To provide critical assessment report on the structural health of the structure.
3. To point out various in-situ problems and to suggest various measures to improve the structure's long life.

II. CASE STUDY

2.1 GENERAL

For our work of Structural Health Monitoring based on Non Destructive Testing we have considered a 5-storey educational building which is nothing but the R-Block of Usha Rama College of Engineering & Technology. There is a need for regular monitoring and maintenance of the structure for achieving increased life and service of the structure. Several interfering agents from different sources mostly of environmental, geological, earth quake, manmade may cause deterioration. Hence to check the present condition of the structure, the Non Destructive Evaluation was performed using Ultrasonic Pulse Velocity Tester.The building area was surveyed with tape and measurements were taken. The dimensions of columns were also measured. A total of 725 columns were identified. AutoCAD plan of R-block 5 floorswas shown in the following Figure 2.1.Plan map for R-Block in STAAD.Pro is shown in Figure 2.2.3D view of the R-Block Building in shown in figure 2.33D Rendering of R-Block in Staad.Pro is shown in figure 2.4.Taking the values of velocity of waves passing through the concrete column using Ultrasonic Pulse Velocity Tester is shown in the figure 2.5.

2.2 METHODOLOGY

This section presents the actual method of operation of the available ultrasonic pulse velocity tester in the field. IS code provides detailed information regarding NDT by ultrasonic pulse velocity tester in IS-13311(Part 1):1992

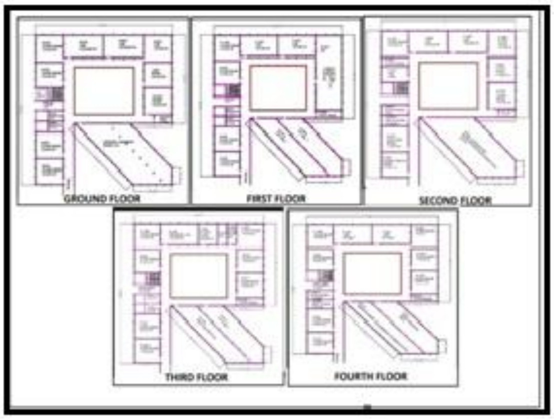

Figure 2.1 AutoCAD plans of R-block 5 floors

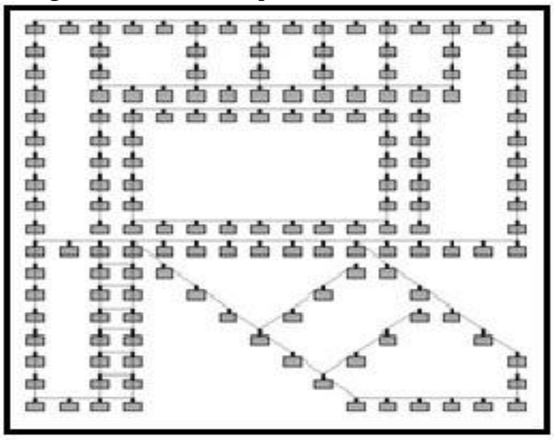

Figure 2.2 Plan map for R-Block in STAAD.Pro

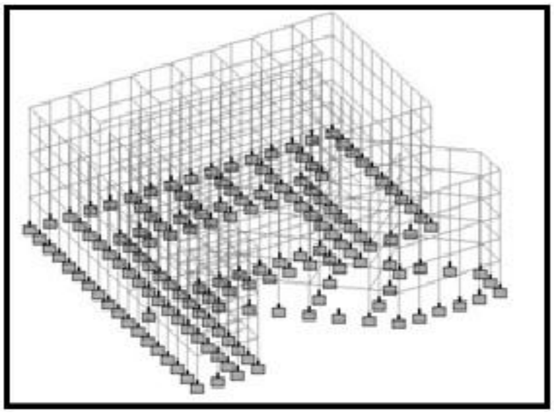

Figure 2.3 3D view of the R-Block Building

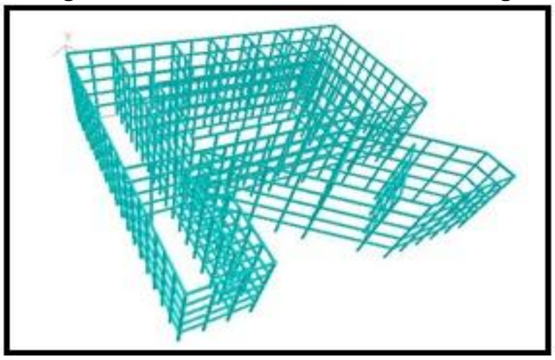

Figure 2.4 3D Rendering of R-Block in Staad.Pro

Figure 2.5Taking values of columns in Ultrasonic pulse velocity tester

2.3ULTRASONIC PULSE VELOCITY TESTER

The equipment should be calibrated before starting the observation and at the end of test toensure accuracy of the measurement and performance of the equipment. It is done by measuringtransit time on a standard calibration rod supplied along with the equipment.The velocity isCalculated as:V=L/T, Where V=pulse velocity, L=travel length in meters and T=effective time in seconds

Testing of Specimen

3 readings of Ultrasonic Pulse Velocity (USPV) were obtained for each cube. The cubes were then given a load of 7 N/mm2 (as specified by the IS CODE 13311) in the Compression Testing Machine and the USPV were obtained. The cubes were then loaded up to their ultimate stress and the Breaking Load was obtained.

Mounting of Transducers

The direction in which the maximum energy is propagated is normally at right angles to the face of the transmitting transducer, it is also possible to detect pulses which have traveled through the concrete in some other direction. The receiving transducer detects the arrival of component of the pulse which arrives earliest. This is generally the leading edge of the longitudinal vibration. It is possible, therefore, to make measurements of pulse velocity by placing the two transducers in the following manners (Figure 2.6)

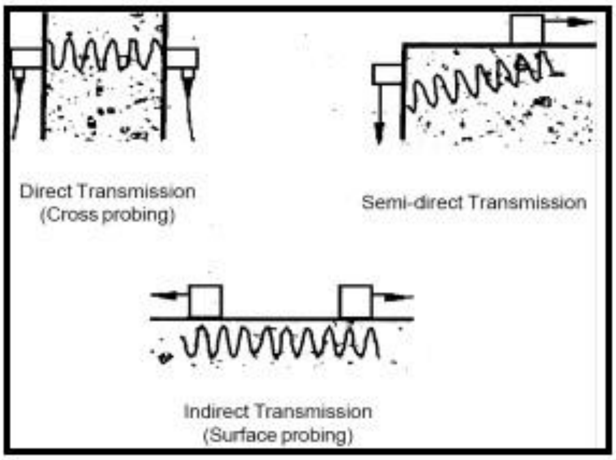

Figure2.6 Various Methods of UPV Testing

Figure 2.7Ultrasonic Pulse Velocity Tester

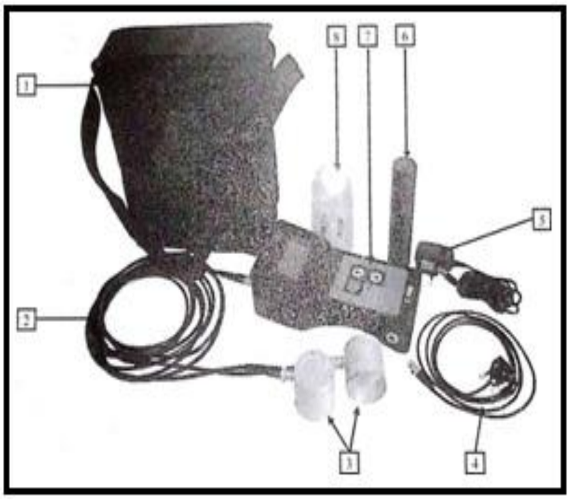

Figure 2.8 Parts of Ultrasonic Pulse Velocity Tester

Table 2.1 Description of parts of Ultrasonic Pulse Velocity Tester

Reference	Description
1	Bag with strap
2	Cable with BNC connectors
3	54 KHz probes
4	RS232 cable for PC connection
5	Battery charger
6	Sample bar
7	ultrasonic pulse velocity tester, including 2 2400 mAh rechargeable batteries
8	coupling agent

III. EXPERIMENTAL INVESTIGATION & TEST RESULTS

The experimental work was conducted on R-Block with CONTROLS Model 58-E4800 Ultrasonic pulse velocity tester and readings were taken for all the columns of each floor. The reading for each column was taken at nearly the half height of the column. Like this all the columns in the five floors were tested with Ultrasonic pulse velocity testerand the results were tabulated. Total numbers of columns tested are 725. Some of the results obtained for columns of Part-A and Part-B are given in the following Tables 3.1& 3.2:

Table 3.1 Few Column UPVTest Values for Ground Floor (Part- A)

COLUMN NO	COLUMN DIMENSIONS	UPV (µs)	Pulse Velocity (km/sec) V=D/T
1	620mm X 260mm	55.2	4.7
2	620mm X 260mm	57.9	4.5
3	620mm X 260mm	55.4	4.7
4	620mm X 260mm	59.1	4.4
5	620mm X 260mm	59.2	4.4
6	620mm X 260mm	60.4	4.3
7	620mm X 260mm	62.3	4.2
8	620mm X 260mm	66.2	3.9
9	620mm X 260mm	55.3	4.7
10	620mm X 260mm	56.9	4.6

Table 3.2Few Column UPVTest Values for Ground Floor (Part- B)

COLUMN NO	COLUMN DIMENSIONS	UPV (µs)	Pulse Velocity (km/sec) V=D/T
1	290mm X 290mm	91.4	3.2
2	290mm X 290mm	71.2	4.1
3	290mm X 290mm	94.4	3.1
4	290mm X 290mm	95.4	3.0
5	290mm X 290mm	62.4	4.6

6	290mm X 290mm	61.4	4.7
7	290mm X 290mm	80.9	3.6
8	290mm X 290mm	81.2	3.6
9	290mm X 290mm	62.4	4.6
10	290mm X 290mm	67.5	4.3

The UPV test values obtained from the experimental work are used to estimate the concrete quality grading. The resulting concrete quality grading values for all the 725 columns are studied for analysis. It was observed that concrete quality gradingvalues measured on large columns are bigger than the concrete quality gradingvalues measured on small columns. This peculiar difference may be due to the less importance given to the columns at the construction time. The range of concrete quality gradingvalues measured on small columns vary from 3.1 to 4.7 km/secwhere as the range of concrete quality grading values measured on large columns vary from 3.0 to 4.7 km/sec.Based on the test results obtained from the experimental procedures the data can be classified in to three classes. Hence the concrete quality grading values obtained for large columns and small columns are suitably divided in to three classes for analysis as given in table 3.3

Table 3.3 USPV Criterion for Concrete Quality Grading (As per IS 13311(Part 1): 1992)

S.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

IV. RESULTS AND DISCUSSION

The minimum, maximum and average values of pulse velocity values of columns of each floor of the building are given in the Table 4.1 below.

Table4.1 Minimum, Maximum and Average values of Pulse Velocity by Cross Probing

FLOOR	COLUMN DIMENSION	Pulse Velocity By Cross Probing (Km/sec)		
		MIN	MAX	AVG
GROUND FLOOR	620mm X 260mm	3.1	4.7	4.02
	290mm X 290mm	3.1	4.7	4.03
FIRST FLOOR	620mm X 260mm	3.1	4.7	4
	290mm X 290mm	3.0	4.7	3.97
SECOND FLOOR	620mm X 260mm	3.1	4.7	3.97
	290mm X 290mm	3.1	4.7	3.96
THIRD FLOOR	620mm X 260mm	3.1	4.7	4.02
	290mm X 290mm	3.0	4.7	4.06
FOURTH FLOOR	620mm X 260mm	3.1	4.7	3.90
	290mm X 290mm	3.1	4.7	4.10

The concrete quality grading of columns for five floors are shown in the form of pie charts from Figure 4.1 to Figure4.10 for better understanding.

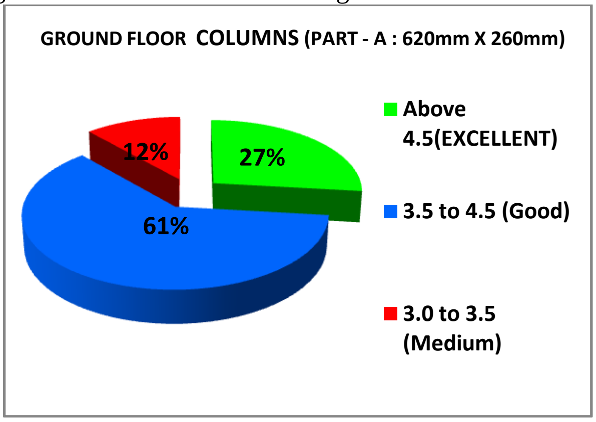

Figure 4.1 Test Results of Ground Floor (PART A)

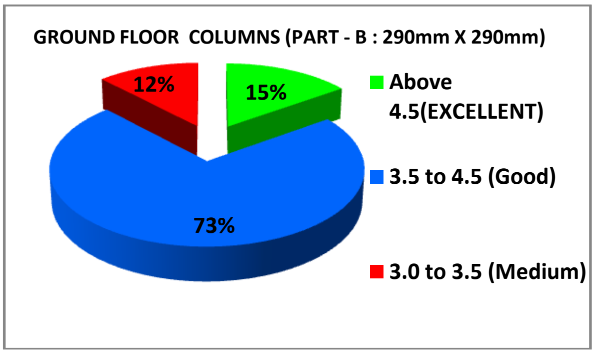

Figure 4.2 Test Results of Ground Floor (PART B)

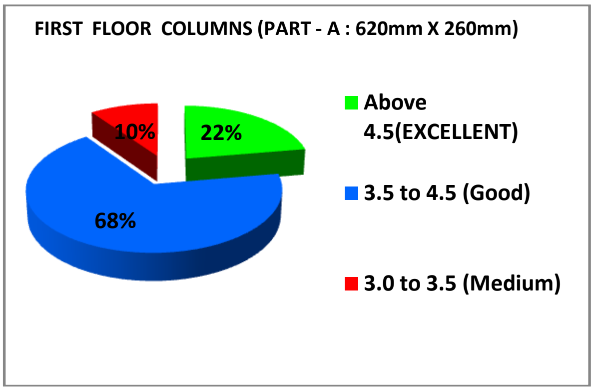

Figure 4.3 Test Results of First Floor (PART A)

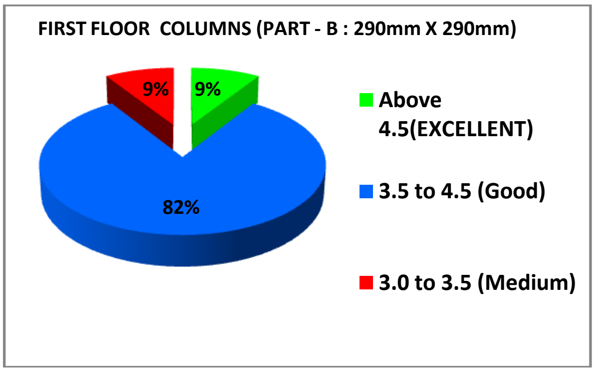

Figure 4.4 Test Results of First Floor (PART B)

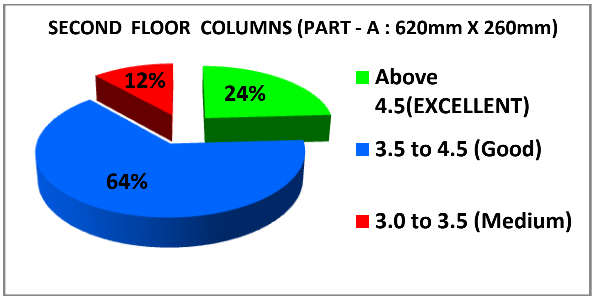

Figure 4.5 Test Results of Second Floor (PART A)

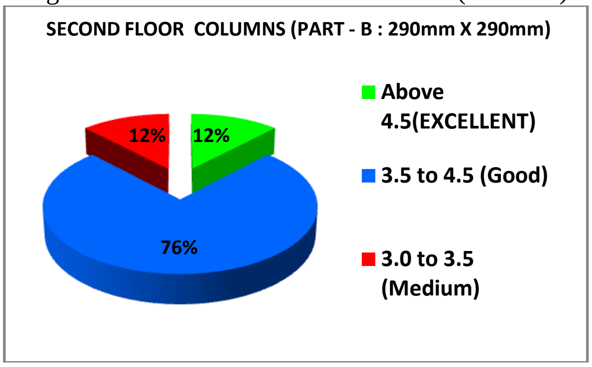

Figure 4.6 Test Results of Second Floor (PART B)

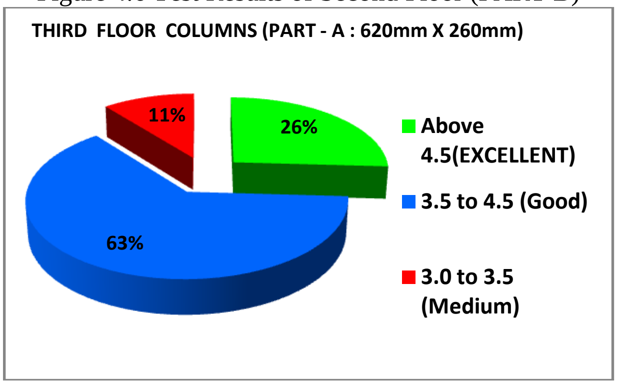

Figure 4.7 Test Results of Third Floor (PART A)

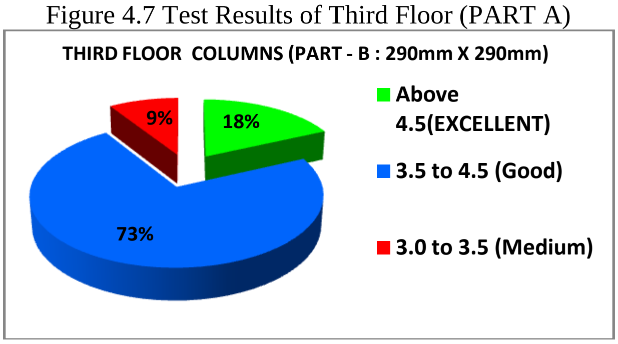

Figure 4.8 Test Results of Third Floor (PART B)

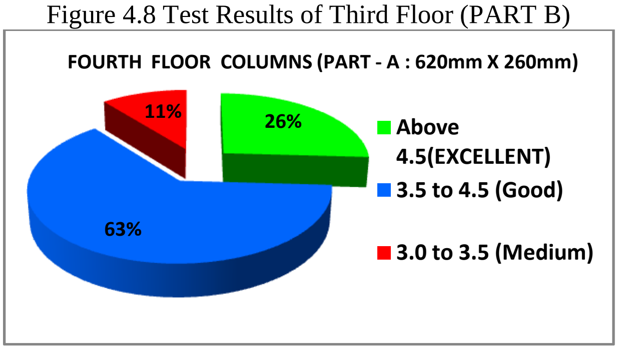

Figure 4.9 Test Results of Fourth Floor (PART A)

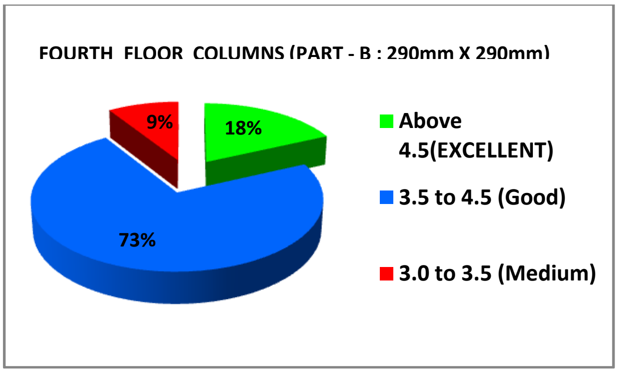

Figure 4.10 Test Results of Fourth Floor (PART B)

V. CONCLUSIONS

This section summarizes the conclusions derived from the project work carried out with the objective of Non Destructive Evaluation of a 5 storey RCC building using Ultrasonic pulse velocity tester.R-Block of Usha Rama College of Engineering & Technology was considered as case study. The building has an age of 8 years and in good condition. The objective of the present study is to identify any signs of deterioration in the structure which affect the serviceability of the structure, so that precautionary measures can be properly planned and adopted.

The following are the conclusions summarized:

1. The building consists of columns of two different sizes viz., 620mm X 260mm(large/ Part-A) and 290mm X 290mm(small/Part-B)
2. CONTROLS Model 58-E4800 Ultrasonic pulse velocity tester is used in the present work.
3. The instrument was first calibrated with cubes testing and found reasonable.
4. Each floor column concrete quality grading values are divided into three classes as per the data ranged availability.
5. Concrete quality grading in the range above 3.0 to 3.5 km/secclassifiedas Medium quality, 3.5 to 4.5 km/sec classifiedas good quality and Above 4.5 km/sec classifiedas Excellent quality. This classification is purely based on the data ranges available.
6. Average Concrete quality grading in Ground floor for large columns and small columns are 4.02 km/sec, 4.03 km/sec respectively. Average Concrete quality grading in First floor for large columns and small columns are 4 km/sec, 3.97 km/sec respectively. Average Concrete quality grading in Second floor for large columns and small columns are 3.97 km/sec, 3.96 km/sec respectively. Average Concrete quality grading in Third floor for large columns and small columns are 4.02 km/sec, 4.06 km/sec respectively. Average Concrete quality grading in Fourth floor for large columns and small columns are 3.90 km/sec, 4.10 km/sec respectively.
7. Over all the structure has adequate Concrete quality grading in all the columns of five floors.
8. There are certain exterior columns of large columns category have Concrete quality grading in the range of good.
9. Most of the exterior columns of small columns category

have Concrete quality grading in the range of good.

10. The main reason identified for the low range of Concrete quality grading of exterior columns is that there are cracks present in the columns. Certain columns have lost the plastering due to rain water falling. It is observed that rain water falls from the top floor of terrace on to the sunshade of each floor due to improper drainage facilities.
11. The outcome of the project can be the basis for repair and maintenance works to be carried out.

5.1 RECOMMENDATIONS

The important recommendation from the study of the building with NDT by Ultrasonic pulse velocity tester is that the columns especially exterior columns should be repaired for loss of plastering. The rain water should be properly drained and should not erode the columns.
This may lead to corrosion of reinforcement.

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