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STRUCTURAL HEALTH MONITORING OF STRUCTURES BY USING NON-DESTRUCTIVE TESTING

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Abstract :
This study has been undertaken to investigate the structural health monitoring of structures, which involves inspection, monitoring, and maintenance. We studied the damage detection and its repairs, rehabilitation techniques in RCC structures using NDT. The ultrasonic pulse velocity tester is applied to monitor basic initial cracking of concrete structures and hence to introduce a threshold limit for failure of the structures. The strength of the concrete is detected using rebound hammer test and location of discontinuity or cracks, voids in concrete by using ultrasonic of existing building. The effectiveness and usefulness of the NDT method in structural health monitoring of structures is presented.

Index Terms **- structural health monitoring, NDT, rebound hammer, ultrasonic pulse velocity.**

I. INTRODUCTION

Buildings constructed with concrete showed that it can be sensitive to the deterioration, so the assessment and rehabilitation of old concrete buildings is an important issue. Assessment is needed for the recognition of potential damage to structures. The purpose of this study is based on non-destructive testing (NDT) to access and the structural health monitoring for concrete structures. The NDT investigation avoids damage of structure. The ultrasonic pulse velocity and Schmidt rebound hammer were being used for this investigation. These methods are used quite a long time for damage analysis, cracks, voids and other deterioration of concrete structures. Now days innovative NDT methods can be used for the assessment of existing structures are still not established for regular inspections. Therefore, the objective of this project is to study the performance, complexity and restrictions of NDT. The purpose of establishing standard procedures for nondestructive testing of structures is to qualify and quantify the material properties of in-situ concrete.

II. METHODOLOGY AND OBJECTIVE OF THE CASE STUDY

2.1 Methodology

In this study methodology consists of examination of old structure and assessment of structure using NDT method. The preliminary investigation is carried out with aim to evaluate the structure. The preliminary inspection is the first and most important effort in the evaluation of a structure. This inspection provides the initial analytical data that are used to assess the structural adequacy of an existing structure. The typical preliminary inspection involves the following phases: a) Gathering the Information about structure and b) Identifying problems. The preliminary inspection report shall contain the objectives of recording the nature and extent of the observed problems, identify the affected members or areas, estimate or define the causes of the problems, state the requirement for a detailed investigation. The inspection consists of visual inspection and detailed inspection.

In visual inspection, evaluation of the structure to study the, presence of cracks & presence of rust mark on the surface has been done. By adopting this one can determines whether or not to proceed with detailed inspection. In detailed inspection, structure involves the testing method as NDT. Reasons for detailed inspection considered enumerated as follows

a) The preliminary inspection indicates a need for closer examination.
b) The potentially serious deterioration in the structure.
c) The significantly increase the loads on a structure.
d) The condition of the structure has changed significantly since the last inspection

2.2 Objective of the case study

The main objectives of study are to evaluate the existing RCC building with following points as follows:

- To discuss the principles, testing procedures, and data analysis of the NDT methods.
- To study the strength of the concrete structure elements by using rebound hammer test.
- To study the detection of discontinuity or cracks voids in concrete by using ultrasonic test.
- To study the location of reinforcement and diameter of rebar by using profoscope test.

- To study the detection of damages and quality of concrete in;

III. Structural Health Monitoring of the Building

In this study the RCC building under consideration is as follows**:**

Basic Information:

Name of building: Old Quarters Building.
Type of building: RCC Building of G + 2 Floors
Address: Warananagar, Kolhapur, MS, India.

Description of Building:

Year of construction – 1981
Age - 45 years
Weather Effect - Yes

Fig.1. Existing Building: Case Study

Visual Inspection:

Visual inspection is a quick scan of the structure to assess its state of general health. This work as forms the basis for detailing out the diagnosis of problems and to quantify the extent of distress. Simple tools and Instruments like camera with flash, magnifying glass, binoculars, gauge for crack width measurement, chisel and hammer used to carry out the visual inspection.

Fig.2. Leakages

Fig.3. Cracks

Fig.4. Vegetation Growth

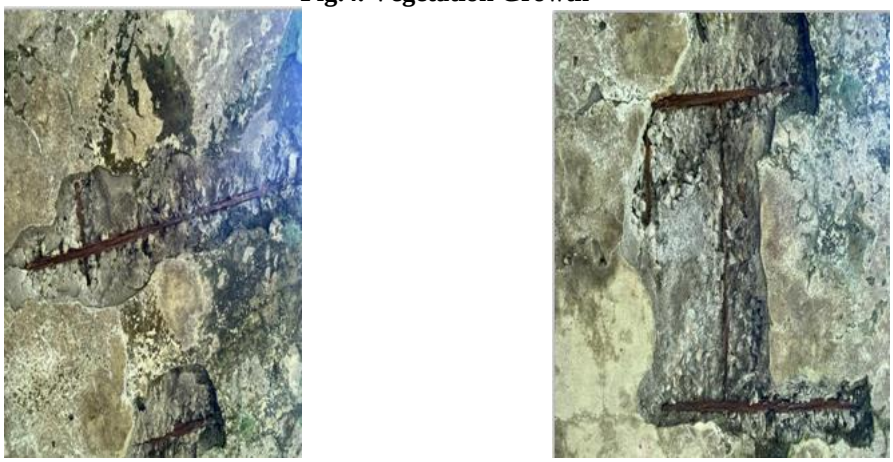

Fig.5. Spalled cover concrete and exposed reinforcement

Fig.6. Exposed Plaster

Tapping Observation:

The column and beam were subjected to tapping by Hammer. For some of the beams & columns hollow sound was recorded. This hollow sound was due to loss of integrity between reinforced steel and surrounding concrete.Fig.7 represent the tapping observation of the building.

Fig.7. Tapping by hammer

Fig.8. Rebound hammer testing

DETAIL INSPECTION:

Detail inspection involves field testing methods which are taken by:
Rebound hammer, UPVT, Profoscope

FIELD TESTING:

REBOUND HAMMER TEST:

Table No 1 Rebound Hammer Test on column

Name of Column	Avg of Rebound No.	Compressive Strength N/mm2	Quality of Concrete
C1	29	22	Fair
C2	24.33	15	Poor
C3	26.16	18	Poor
C4	26.67	17	Poor
C5	24.33	16	Poor
C6	25.66	17	Poor
C7	28.66	21	Fair
C8	27.83	20	Fair
C9	26.83	15	Poor
C10	28.83	21	Fair
C11	23.50	12	Poor
C12	25.16	17	Poor
C13	22.66	13	Poor
C14	27.5	19	Poor
C15	22.23	14	Poor
C16	26.16	18	Poor
C17	31.50	26	Fair
C18	25.33	16	Poor
C19	28.66	21	Fair
C20	28.66	21	Fair
C21	26.66	18	Poor
C22	26.16	18	Poor

C23	25.33	16	Poor
C24	31.33	26	Poor
C25	24.66	16	Poor
C26	27.33	19	Poor

Table No 2 Rebound Hammer Test on Beam

Name of Beam	Avg of Rebound No.	Compressive Strength N/mm2	Quality of Concrete
B1	27.50	19	Poor
B2	27	18	Poor
B3	25.33	16	Poor
B4	29.5	22	Fair
B5	29.83	24	Fair
B6	27.83	20	Fair
B7	24.33	16	Poor
B13	28	21	Fair
B9	29.83	24	Fair
B10	28.16	20	Fair
B14	25.66	16	Poor
B15	29.33	22	Fair
B17	27.83	24	Fair
B18	23.50	12	Poor

Table No 3 Rebound Hammer Test on Slab

Name of Slab	Avg. of Rebound No.	Compressive Strength N/mm2	Quality of Concrete
S1	26.33	18	Poor
S2	23.5	12	Poor
S3	21.83	11	Poor
S5	28	21	Fair
S7,S8	25.33	16	Poor
Stair	25.33	16	Poor

ULTRASONIC PULSE VELOCITY:

The ultrasonic pulse velocity obtained was found out to be below 3.0 km/s i.e. 2.21 km/s at all of the concrete sections which indicates medium & doubtful quality of concrete. The ultrasonic pulse velocity obtained was found out to be below 3.0 km/s i.e. 2.50 km/s at all of the concrete sections which indicates medium & doubtful quality of concrete. The ultrasonic pulse velocity obtained was found out to be below 3.0 km/s i.e. 2.54 km/s at all of the concrete sections which indicates medium & doubtful quality of concrete.

Table No 4 Ultrasonic Pulse Velocity Test on Column

Column No.	Travel Path Length (mm)	Travel Time(µs)	Velocity (km/sec)	Probing Method	Quality Of Concrete
C1	9512	164	1.56	Surface Probing	Doubtful
C2	11438	146	1.67	Surface Probing	Doubtful
C3	14148	135	1.91	Cross Probing	Doubtful
C4	12869	230	2.96	Surface Probing	Doubtful
C5	7933	329	2.61	Surface Probing	Doubtful
C6	7911	298	2.36	Surface Probing	Doubtful
C7	7482	174	1.28	Surface Probing	Doubtful
C8	8638	139	1.20	Surface Probing	Doubtful
C9	24514	77.5	1.9	Cross Probing	Doubtful
C10	10130	152	1.54	Cross Probing	Doubtful
C11	11727	145	1.7	Surface Probing	Doubtful
C12	8693	138	1.2	Cross Probing	Doubtful
C13	1952	149	2.91	Surface Probing	Doubtful
C14	7966	157	1.25	Surface Probing	Doubtful

C15	13600	169	2.3	Surface Probing	Doubtful
C16	14281	154	2.2	Cross Probing	Doubtful
C17	15447	123	1.9	Surface Probing	Doubtful
C18	16406	128	2.1	Cross Probing	Doubtful
C19	29457	129	3.8	Cross Probing	Good
C20	15973	226	3.61	Surface Probing	Good
C21	6718	387	2.6	Surface Probing	Doubtful
C22	27642	123	3.4	Cross Probing	Medium
C23	8446	264	2.23	Surface Probing	Doubtful
C24	12485	169	2.11	Surface Probing	Doubtful
C25	7266	439	3.19	Cross Probing	Medium
C26	10044	227	2.28	Surface Probing	Doubtful

Table No 5 Ultrasonic Pulse Velocity Test on Beam

Beam No	**Travel Path (mm)**	**Travel Time(µs)**	**Velocity (km/sec)**	**Probing Method**	**Quality Of Concrete**
B1	11003	269	2.96	Surface Probing	Doubtful
B2	12064	325	2.98	Surface Probing	Doubtful
B3	7206	247	1.78	Surface Probing	Doubtful
B4	8412	359	3.02	Surface Probing	Medium
B5	4839	436	2.11	Surface Probing	Doubtful
B6	6964	224	1.56	Surface Probing	Doubtful
B7	9105	246	2.24	Surface Probing	Doubtful
B8	7879	382	3.01	Surface Probing	Medium
B9	8636	176	1.52	Surface Probing	Doubtful
B10	14751	181	2.67	Surface Probing	Doubtful
B11	12014	273	3.28	Surface Probing	Medium
B12	9034	352	3.18	Surface Probing	Medium
B13	9465	337	3.19	Surface Probing	Medium
B14	8251	143	1.18	SurfaceProbing	Doubtful
B15	10964	264	2.89	Surface Probing	Doubtful

Table No 6 Ultrasonic Pulse Velocity test on Slab

Slab No.	Travel Path (mm)	Travel Time (µs)	Velocity (km/sec)	Probing Method	Quality Of Concrete
S1	8486	326.4	2.77	Surface Probing	Doubtful
S2	19860	128.9	2.56	Surface Probing	Doubtful
S3	81646	135.2	1.21	Surface Probing	Doubtful
S5	10522	148.2	1.56	Surface Probing	Doubtful
S7,S8	10782	368.2	3.97	Surface Probing	Good
Stair	7198	445.9	3.21	Surface Probing	Medium

IV. CONCLUSION

Structural health monitoring is important point of view so that appropriate remedial measures can be recommended for all types of structural defects and damages. It continues to serve strength and serviceability requirement. For any structure, carry out structural health monitoring at least once in five years. For structures older than 15 years structural health monitoring should be carried out once in 3 years. The finding, our building is suffering from class C2-B category where it needs to repair building without eviction, but need structural repair. The condition of the building appears to be quite bad and major structural distress is observed in some of the columns and beams of the external walls.

With reference of observation, building need to be thoroughly repaired and painted in planned manner. Concrete structure face cracking problems during their life period, these cracks must be given serious and careful attention. So to prevent building from cracks we recommend Epoxy injection treatment. It is observed that main cause of damage of the structural members is due to seepage so the strength and serviceability of the building can be increased by taking necessary measures such as water proofing of slabs and walls to stop seepage of water into structural members to avoid further damage of the structure. Micro concrete is a dry ready mix cementetious based composition formulated for use in repairs of areas where the concrete is damaged so it is used to repair spalling of slab in kitchen, passage and staircase. To increase seismic capacity and to improve flexural strength of column and beam jacketing treatment considered.

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