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INFRASTRUCTURE HEALTH MONITORING IN NASHIK REGION

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***Abstract**: The structural audit is an overall health and performance check-up of structures. It is important to the structures to check their safety and they have no risk. The need for structural audit is for maintenance and repairs of existing structures whose life exceeds the age of 30 years to avoid any accidents and to save valuable life. This study designates the inspirations for the various practices of civil infrastructure and provides case studies on special types of structure. In this project, we are going to do the health monitoring of the Infrastructures like buildings, bridges and water tanks which are located in Nasik Region using non-destructive techniques. The Nasik Municipal Corporation has already given the notices to the owners of the buildings which are structurally damaged, for submitting the structural audit report and also making it structurally strong. So we are also taking care of that given notices are followed or not. Similarly, we are also working under smart city project of Nasik Municipal Corporation in which the Victoria Bridge is taken under consideration for flood controlling and renovation determination. The bridge is constructed before 100 years on the river and connects the central part of Nasik. And the structural behavior of old water tank is also studied and replacements are done. This paper deals with the study of the different parameters of structural inspection including visual inspection, non-destructive testing and repairing of damaged constructions. Unawareness to maintenance causes severe distress and damages to infrastructure over period of time. Most of the building constructed in last 23 to 30 years is in severe structural distress, hence these infrastructures needs a periodical survey from structural point of view to asses from structural health.*

Keywords: Infrastructure, structural audit, performance, building, bridge, water tank, retrofitting, health monitoring, diagnosis of existing structures, maintenance and repair.

1. INTRODUCTION

In today's world most commonly used construction material is concrete. After 1970 and 1980, all major countries made a consensus of new preventions and suitable durability practices of concrete (IS Code – 456:2000). In the current scenario of building research, repair and rehabilitation play a vital role as it serves important in building applications. The major defects reported, discussed and suitable, economical solutions for particular defects are identified. A civil infrastructure offer the means for a society to function and includes buildings, pedestrian and vehicular bridges, tunnels, factories, conventional and nuclear power plants, offshore petroleum installations, heritage structures, port facilities and geotechnical structures, such as foundations and excavations. Cracks are the universal problem of concrete structures, this is affecting the art of structure and they are also destroying the walls of integrity, affecting the safety of the building, and also reducing the durability of the structure.

Bye-Laws: As per clause No. 75 of revised Bye-Laws of Cooperative Housing Societies:

The Society shall cause the 'Structural Audit' of the building as follows:
- For building aging between 15 to 30 years once in 5 years
- For building aging above 30 years once in 3 years

1.1 Structural Audit?

The structural audit is an overall health and performance check-up of a building like a doctor examines a patient. It guarantees that the building and its premises are safe and have no risk. It analyses and suggests appropriate repairs and retrofitting measures required for the buildings to perform better in their service life. The structural audit must be done by an experienced and licensed structural consultant.

1.2 Stages in Carrying Out Structural Audit.

Study of architectural and structural drawings, design criteria's, design calculations, structural stability certificate of existing structures. If architectural and structural drawings are not available, as-built drawings can be prepared by an engineer.

1.2.1 Need for visual inspection.

-To recognize the types of structural defects
-To identify any signs of material deterioration
-To identify any signs of structural distress and deformation
-To identify any alteration and addition in the structure,

1.2.2 General information of the infrastructures

-Name and address of the building
-Number of stories in each block of building
-Description of the main usage of building viz. residential,Commercial, Institutional.

1.2.3 Structural System of the building

-Substructure: Settlement of columns or foundations,
-Settlement of walls and floors,
-Superstructure: Materials used and framing system of structure, identification of the critical structural members like floating columns, transfer beams, slender members, rusting of exposed steel and its extent.

1.2.4 Addition or Alterations in the building

-Identification of change of occupancy
-Alteration or addition of partition walls
-Alteration or addition of a balcony.

1.2.5 Dampness and leakages

-Detect the dampness in walls.
-Identify the leakages in Terrace, toilets, plumbing lines, drainage lines.

1.3 Destructive testing And Non-destructive tests

1.3.1 Destructive testing

In destructive testing, tests are carried out to the specimen's failure, to understand a specimen's structural performance or material behavior under different loads. These tests are generally much easier to carry out, yield more information, and are easier to interpret than non-destructive testing. Destructive testing is most suitable, and economical, for objects which will be mass-produced, as the cost of destroying a small number of specimens is negligible. It is usually not economic to do destructive testing where only one or very few items are to be produced (for example, in the case of a building). Some types of destructive testing are as follows,

- **Stress Testing**: It is a form of testing that is used to determine the stability of a given system or entity. It involves testing beyond normal operational capacity, often to a breaking point, to observe the results. Stress testing may have a more specific meaning in certain industries, such as fatigue testing for materials.

- Crash Testing: It is a form of destructive testing usually performed to ensure safe design standards in crashworthiness and crash compatibility for automobiles or related components. Some of the examples are Frontal-Impact Tests, Offset Tests.

- Side-Impact Tests: Rollover Tests, Roadside hardware crash tests, etc. The tests are not discussed here as it is beyond the scope of this presentation.

- Hardness Testing: Hardness refers to various properties of matter in the solid phase that gives it high resistance to various kinds of shape change when force is applied. 5Macroscopic hardness is generally characterized by strong intermolecular bonds. However, the behavior of solid materials under force is complex, resulting in several different scientific definitions of what might be called "hardness" in everyday usage.

1.3.2 Non Destructive Testing

Non-destructive testing (NDT) is a wide group of analysis techniques used in the science and technology industry to evaluate the properties of a material, component, or system without causing damage. The terms Non-destructive examination, Non-destructive inspection, and Non- destructive evaluation are also commonly used to describe this technology Because NDT does not permanently alter the component being inspected, it is a highly valuable technique that can save both money and time in product evaluation, troubleshooting, and research.

- **Non-destructive Tests:**

1. **Rebound Hammer Test**
2. **Pulse-Echo Method**
3. **Impact Echo Method**
4. **Ultra Sonic Pulse Velocity Method.**
5. **Probe Penetration Test**
6. **Ground Penetration Radar Method**
7. **Carbonation Test, etc.**

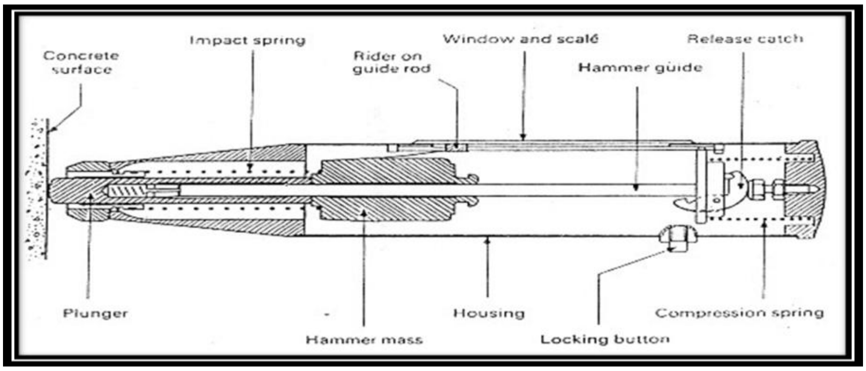


Fig 1 - Components of Rebound hammer test: Method of testing

Rebound Hammer: For determination of the compressive strength of the concrete

Application of rebound hammer test:

1. For determination of the compressive strength of the concrete
2. Determine uniformity of the concrete.
3. Determine quality of the concrete

The structural diagnosis is a vast, important, and highly responsible job that is connected with the lives of human beings. It is mandatory and advisable to carry out the periodical structural audit of the infrastructures by professional experts and act immediately through recommendations provided in the audit report. The effective implementation of auditing enhances the life span of structure, prevents deterioration of building leading to sustainability. Based on the damage, we are going to give the best solution to overcome that defect and to strengthening the structure. It will increase the life span of structure and helps economically.

2. LITURATURE REVIEW

This chapter presents a critical study of the previous work published in literatures and study of research papers. Some papers are examined for assessment of structural health of RC Buildings & other infra-structures like bridge, water tank accordingly objectives were framed and observations are carried out. Various research papers and articles were reviewed and summarized in the subsequent heads.

Ngoc Tan Nguyen, Zoubir-Mehdi Sbartaï, et al. (2013) [1] In this study, the methodology consists of performing statistical analysis for assessing the spatial variability and estimating the required minimal number of NDT measurements. The spatial correlation of NDT measurements is studied with variographic analysis. Some correlation lengths were identifying ranging 40–60 cm for the laboratory slab and the investigated bridge pier. Kriging method was used as a robust geo-statistical tool, which allows the representation of the spatial variability of concrete structures. Spatial variability of concrete is an important characteristic, which equalizes the non-homogeneity of mechanical and physical properties on structural components. Assessing it can be of great interest for either locating potential damaged areas in an existing structure, or reliability analysis. A two-stage experimental program was carried out using NDT on laboratory concrete slabs in out- door environment and on an existing bridge.

R. Pucinotti (2013) [2] In this paper a series of destructive laboratory tests on 359 cores, extracted from specimens realized ad hoc at the Laboratory for Materials and Structures of the Mediterranean University of Reggio Calabria and from nine existing structures (buildings, viaducts, bridges and tunnels) were performed with the purpose to estimating the characteristic strength of in situ concrete. Moreover, an analytical expression was pro- posed in order to estimate the in situ characteristic concrete compressive strength. The results of these applications were compared with those obtained by other equations available in technical literature showing that the proposed formulation is capable of provided a good estimate of the in situ characteristic concrete compressive strength.

Zoubir-Mehdi Sbartaï a, Denys Breysse a, et al. (2012) [3] This paper presents the strategy employed and the first results obtained from a comprehensive experimental database of NDT techniques. It also emphasizes how the variability of measurements can be taken into account and how statistical analyses can be used to evaluate the relevance of the available NDT techniques. Developing a strategy for the management and maintenance of the built heritage is a key challenge for research. In this context, a large experimental program was implemented to develop a methodology for NDT of concrete structures based on the determination of: (a) the sensitivity of the NDT techniques, (b) the uncertainty of the NDT measurements, and (c) the optimal combination of NDT techniques to enhance the evaluation of concrete properties

Dimitrios G. Aggelis, (2013) [4] Coming to the special issue, it includes extended and updated versions of the papers presented in the aforementioned special session after another round of poor review. The subject of SHM of civil infrastructure goes hand in hand with the new developments in the field of NDT and evaluation. Information on the structural condition is essential in order to plan the necessary maintenance action in structures that have long ago stopped being considered maintenance-free. If the useful life span of a structure can be safely extended for years or decades this immediately has a positive consequence in the always limited available budget for repair and new construction. Fast, reliable, cost-efficient and easy to implement methodologies are certainly sought for in order to be adopted in the life cycle of the structure. The special issue represents the new developments in several monitoring techniques including acoustic emission, elastic wave and vibration methods, radar, thermographs, while case studies with high practical interest are presented. Examples of monitoring of cultural heritage structures are also included as well as theoretical approaches to damage visualization. Hopefully the papers of this issue will give a good insight of new developments in the field of testing of infrastructure and materials both concerning scientific outbreaks which offer better characterization potential as well as applications.

Nikolaos Zoidis a, Efthymios Tatsis b, et al. (2013) [5] The objective of the present study is the evaluation of the condition of the concrete floor that suffers from extensive cracking on its surface, through systematic tests using NDT methods. The study contained a thorough visual inspection and recording of cracks, estimation of the crack depth uses ultrasonic pulse velocity measurements, and investigation for voids between the concrete floor and the underlying aggregate layer using the Impulse-Response method, concrete floor thickness estimation using the Impact-Echo method and concrete quality estimation using cores cutting. The purpose of the study was to investigate the causes that led to extensive cracking on the floor surface in order to plan the repair strategy. The repair method that was chosen was based on grout injections in order to fill the voids located between the concrete and the underlying aggregate layer. The injections were executed in a triangular grid and were monitored using the Impulse-Response method. The area, where the injections took place, was inspected using the method before and after the injections and a secondary grid was designed taken into account the results. After injecting in the secondary grid, the area was inspected again using the Impulse- Response method in order to confirm the successful fillings of the voids.

R. Latif Al-Mufti, A.N. Fried, (2012) [6] The increasing demand for concrete in construction places pressure on its constituent materials including aggregate. Attention has previously been turned to alternative aggregates, such as recycled concrete aggregate (RCA), to reduce the impact of quarrying. It is the aim here to investigate the very early age behaviour and properties of RCA concrete in relation to normal concrete using non-destructive testing. Ultrasonic pulse velocity (UPV) and surface hardness tests have been carried out on concretes made with different mix proportions. A system was set up which enabled the continuous measurement of UPV throughout the fresh and hardening stages. RCA concrete produced lower strength and UPV values than normal concrete. However, higher surface hardness was obtained for RCA concrete. Relationships have been established between strength and UPV, covering the period from immediately after mixing and up to 1 day or 28 days. This would enable more accurate assessments of important early age concrete strengths from UPV measurements. It has also been established that UPV measurements can be used to determine concrete setting.

3. METHODOLOGY

3.1 HEALTH MONITORING OF RCC BUILDING.

In order to carry out structural audit old RCC building is selected of age around 50 years,

3.1.1 STEPS FOR STRUCTURAL HEALTH MONITORING OF BUILDING

Structural audit is carried out is as follows:

Step 1: Preparation of architectural and structural plan of the building. Architectural and structural plans are helpful in structural calculation, identifying or highlighting critical areas in the building;

Step 2: Making assumption of load based on the intendeduse of the building i.e whether it is commercial, residential. Finding which code requirement has been met.

Step 3: Preliminary inspection of the building:

1. Visual inspection, 2. Tapping observation.

Visual inspection: In this building is thoroughly inspected from flat to flat noting cracks, spells, crazing, seepage etc. Highlighting critical area of investigation and repair same is marked on the plan of the building.

Tapping observation: During this observation some of the structural member's area subjected to hammer tapping and tapping sound is noted i.e whether it is hollow or dence.

Step 4: Test recommendation**:** After highlighting critical area in the building next step is to recommend the appropriate test to evaluate the structure which may include Non-destructive tests like

Step 5: E-Tab modeling: This step involves preparation of E-Tab model of the building order to find response of the structure to gravity and earth quake loading. This step will give demand of the building to the loading.

Step 6: Finding actual capacity of the members and finding Demand to capacity ratio for structural members.

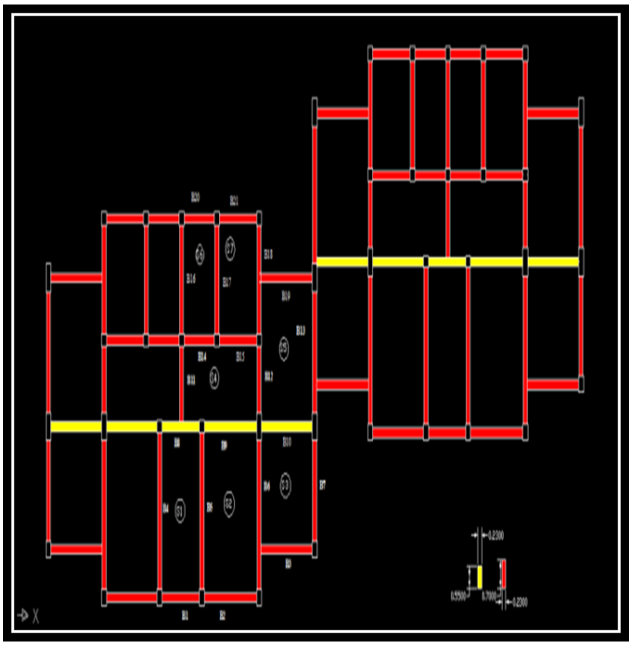
Step 7: Recommendation of remedial or retrofitting methods for the suitable structural Members.

Step 8: Preparation of structural audit report.

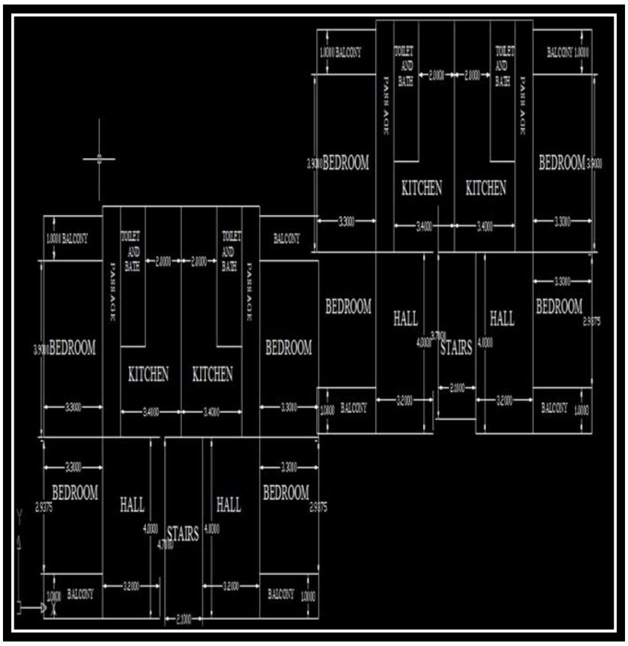
3.1.2 PRELIMINARY DETAILS OF BUILDING.

-Year of construction-1968 Age- 49 years.
-Name: HEDE Apartment
-Location: Satana (Nashik).
-Storey: G+2
-Type: Residential
-No. of flats: four 2bhk flats on each floor
-Storey Height: 3 .4m

-Side view of totally damaged building at Malhar Road Satana, Nashik.



- Beam layout



- Architectural plan

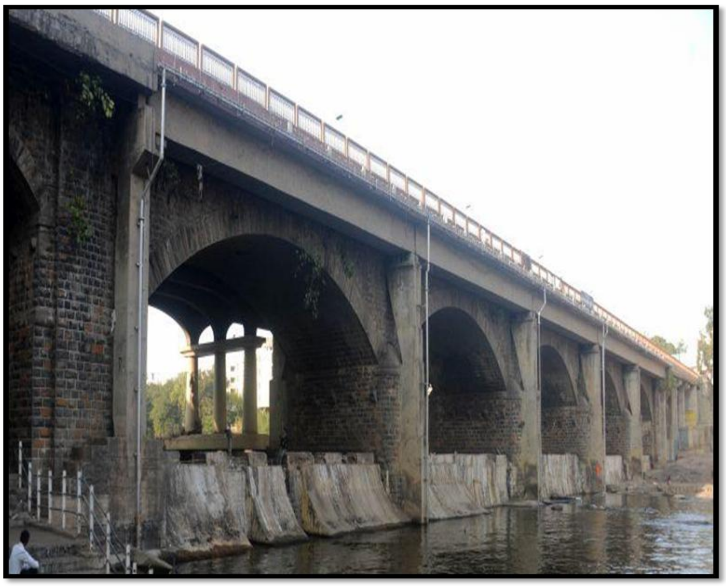
3.2 HEALTH MONITORING OF BRIDGE

A bridge is a structure built to span physical obstacles without closing the way underneath such as a body of water, valley, or road, for the purpose of providing passage over the obstacle. Designs of bridge vary depending on the function of the bridge, the nature of the terrain where the bridge is constructed and anchored, the material used to make it, and the funds available to build it.

3.2.1 Details of the bridge:

-No. of spans – 103
-Total length of bridge – 201.27m
-Width – 19m
-Height of top slab from water level – 14.5m (approx.)
-District- Nashik, Maharashtra.

-Parapet – 1m stone parapet
-Electric poles – 10m c/c
-Footpath – 2m both side
-Carriage way – 11m



Victoria Bridge Nasik.

3.2.2 Steps for assessment of bridge.
-General information of the bridge.
-Structural System of the bridge
-Assessment of defects
-Distress mapping

3.3 HEALTH MONITORING OF WATER TANK

To assess the consumption status in the RCC ESRs, the examination on the evaluation of erosion influenced structure of solid water tanks is completed. The examination includes visual investigation, non-ruinous test utilizing half-cell estimation, and resistivity estimation. The synthetic investigation is done to decide chloride content in the gathered solid powder test. The initial step of examination is visual assessment in visual assessment saw that splits, rust, decolouring are distinguished at different area.

3.3.1 Steps to be followed in Structural Auditing

Step 1: It is imperative that we must have Architectural and Structural plans of the water tank. It will be helpful if we have detailed structural calculationsincluding assumptions for the structural design.
Step 2: If the Architectural plans and Structural plans are not available, the same can be prepared by any Engineer.
Step 3: Inspection of the water tank - A detailed inspection of the building can reveal the Following:
-Any settlements in the foundations.
-Cracks in columns, beams and slabs.
-Concrete disintegration and exposed steel reinforcements Images can be helpful.
-Slight tapping using hammer can reveal deterioration in concrete.
-Corrosion in reinforcement.
-Status of sagging, deflection cracks.
-Status of Architectural features viz. Chhajjas.
-Cracks and swelling in R.C.C. members or deflection or corrosion.
-Leakages from terrace
-Leakages & dampness.
-Status of repairs & last repaired.
-What was repaired?
-Who was the Agency?

Step: 4 Preparation of Audit Report: On the basis of inspection of water tank an Audit Report is prepared.
Step 5: Tests Recommended: It is important that various tests are carried out in the old water tank. This will give an idea about the extent of corrosion, distress and loss of strength in concrete & steel.
Step 6: Highlight the critical areas and how to go for repairs.

4. RESULT AND DISCUSSION

4.1 Health Assessment of Building

4.1.1 Rapid Inspection and Tapping Observation

In our domain first, we had done a visual inspection and investigate the condition of building with respect to Preliminary inspection, Planning, Survey. After that, we had collected data related to building such as its architectural drawings, structural plans, date of construction, time required for construction etc.
-Structure exposure condition.
-Data of structural modification.
-Record when first time deterioration occurred.
-Past performed all repairing details.
-Inspection of past reports.
To click the photo of distressed of all different parts of structure then we had collected Images of the building and classified those Images by different distress such as dampness, cracks, corrosion, flooring settlement and Poor/improper maintenance etc.

-Vertical crack (Wide crack) Due to Thermal stress

-Termite

Discussion with owner

Horizontal orientation of hammer during a measurement

4.1.2 Result of building.

A. Results of rebound hammer number test for SLAB

SR.NO	SLAB LABLE	HAMMER POSITION	REBOUND NO	COMP STRENGTH
1	S1	VERTICALLY UP	29	16
2	S2	VERTICALLY DOWN	20	16
3	S3	VERTICALLY DOWN	22	16
4	S4	VERTICALLY DOWN	26	17
5	S5	VERTICALLY DOWN	24	18
6	S6	VERTICALLY DOWN	20	16
7	S7	VERTICALLY DOWN	26	17

Table No. 1: Rebound hammer number test for SLAB

B. Result of rebound hammer number test for BEAM

BEAM NO	BEAM SIZE	POSITION	REBOUND NO	AVG	HAMMER POSITION	C.S
B1	230*700	START	30	30.67	VERTICALLY UP	15

		MID	30			
		END	32			
B2	230*700	START	32	21.33	VERTICALLY UP	10
		MID	20			
		END	12			
B3	230*700	START	26	21.67	VERTICALLY UP	10
		MID	20			
		END	19			
B4	230*700	START	31	30.67	VERTICALLY UP	15
		MID	29			
		END	32			
B5	230*700	START	30	31.67	VERTICALLY UP	15
		MID	31			
		END	34			

Table No. 2: Rebound hammer number test for Beam

C. Determination of beam reinforcement:

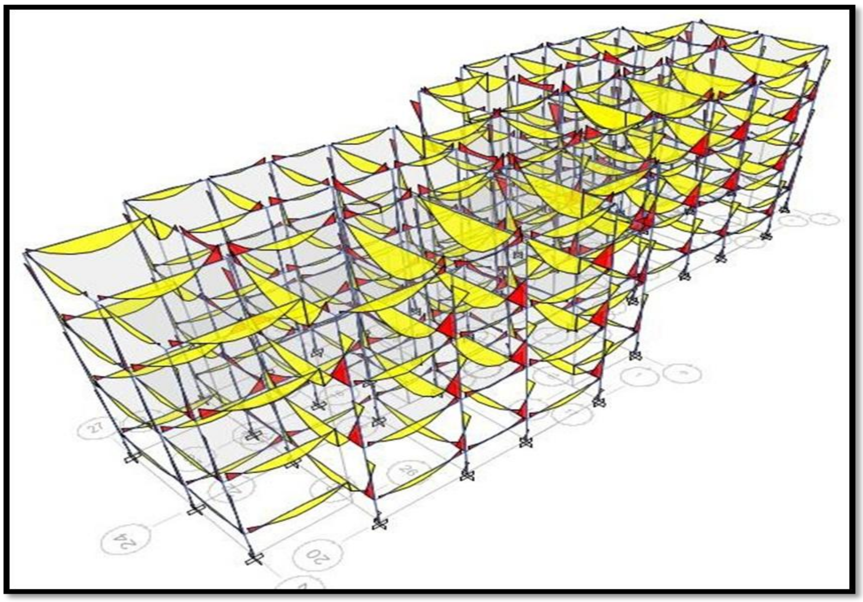
SR.NO	BEAM NO	BEAM SIZE(MM)	REINFORCEMENT
1	B1	230X700	2#12
2	B2	230X700	2#12,1#10
3	B3	230X700	2#12,1#10
4	B4	230X700	2#16,2#12
5	B5	230X700	2#16,2#12

Table No. 3: beam reinforcement.

4.1.3 E TAB RESULTS:

SR. N0	BEAM	MU KN
1	A6	644
2	A8	516
3	B9	370
4	C6	694
5	C8	872

SR. NO	COLUMN	PU KN
1	A6	644
2	A8	516
3	B9	370
4	C6	694
5	C8	872



ETABS Analysis results:

Due to combined effects of carbonation, corrosion & effect of continuous drying and wetting and harsh weather condition building structure is in really bad condition and should be subjected to the repair immediately.

4.2 Health Assessment of Bridge

4.2.1 Distress Mapping

Distress Mapping: - Any Indication of poor or unfavourable condition on the bridge or giving any signs of failure is distress mapping.

- Following are the type of distresses in HMA:

-Fatigue cracking.
-Block cracking.
-Transverse cracking.
-Longitudinal cracking.
-Reflection cracking at joints.
-Edge cracking.

Damaged Flooring on Pathway

Edge cracking

4.2.2 VISUAL INSPECTION OF THE STRUCTURE

-Identification of visible structural damage, such as concrete cracking or spalling, and observations on quality of construction
-Identification of potential non-structural falling hazards, including ceilings, partitions, curtain Walls, parapets, fixtures, and other non-structural building elements.
-Observations on the condition of soil and the foundation

4.2.3 RECOMMENDED CORRECTIVE MEASURES FOR BRIDGE

-Removal of vegetation, since during flood, every year, branches of trees are stuck up in the steel structure at the end, these have to be cleaned every year.
-The concrete posts of parapet wall are cracked and damaged; it is advisable to replace these by same section of the present parapet wall with 75 x75 x 6, four angle frame with cross bracing.
-Flooring on footpaths is damaged and to be repaired.
-Cracks in the pier cap supporting steel trusses to be repaired; it is advisable to provide a 12mm steel plate around this portion to the RCC sides.
-Railings of steel pipes at the side of the footpath needs to be repaired wherever damaged.
-Repair of footpath and Slab by grouting.

4.3 Health Assessment of Water Tank

4.3.1 Visual observations

This method involves both direct and indirect visual inspection techniques, direct inspection is where the material is inspected directly by the human eye with no additional visual aids, indirect inspection may involve the use of magnifying glass, mirror etc. Flowing some observations are listed below.

Blackish patches on dome periphery

Corrosion damage on Ring Beam inner side

4.3.2 Recommended Corrective Measures: Water Tank.

A. <u>Repair Scheme for Column</u>

-Propping the beams on all the sides of the columns for full vertical height. The props shall be able to take the total load coming on to the column.
-Chipping open the cover concrete until all the corroded steel rods are and cleaning of rods with brush
-Chipping the spelled surface of concrete to remove all loose materials. Then brushing it with steel wire brush to remove all loose particles. Washing the surface with potable water.

B. <u>Repair Scheme for Beams</u>

-Encasement is done using micro concrete of SIKA/ FOSROC or equivalent approved material with 25% aggregate (washed/cleaned) by weight of size 6.4 mm and down size. The curing has to be done immediately after stripping the formwork.

C. <u>Repair Scheme for Slabs</u>

-Propping the slab at intervals of sayabout1.5 m.
-Additional bars introduced are anchored to the beam.
-Additional steel shall be tied to the existing steel or anchored using anchors drilled into the slab.

CONCLUSION

1. The structural diagnosis is vast, important and highly responsible job which is connected with lives of human beings. It is mandatory and advisable to carry out the periodical structural audit of the buildings by professional experts and act immediately through recommendations provided in audit report.
2. The selection of Infrastructures depending on importance, ownership, use, risk and hazard, such structures needs inspection, monitoring and maintenance programmes that may improves their lifespan.
3. As the structural audit is done on visual basis, hence the recommended repair measures should be followed as soon as possible before any major mishap takes place.
4. If the structure affected by cracking, corrosion then a proper treatment is needed for restoring the strength. There are different non-destructive techniques, from which a suitable method should be selected and solution is done as per need of the infrastructure.
5. The effective implementation of auditing enhances the life span of structure, prevents deterioration of building leading to sustainability. Audit will enhance the life of the infrastructures by getting the information about its fault immediately.
6. This project is for the safety of Infrastructures which has directly correlation with human lives.

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