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Structural Audit and Rehabilitation of Old Building in BDCE Campus

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ABSTRACT

Structural Audit of a building means everything connected to the conduct of a building, which includes strength of the columns, beams, pillars, iron bars, plasters, sewage discharge systems, water pipeline systems, etc. The need of structural audit is for maintenance and repairs of existing structures timely which leads to prolonged life of the building and safety of the occupants to avoid any mishaps and save valuable human life. The periodical structural auditing of existing buildings is thus of utmost importance in finding the present serviceability and structural viability of structure.

Keywords- Structural Audit, Rehabilitation, Old Buildings, Non-Destructive Testing, Retrofitting Techniques

1. INTRODUCTION

In the ever-evolving landscape of educational institutions, the preservation and rejuvenation of aging infrastructure stand as integral components for ensuring the longevity, safety, and cultural continuity of campus environments. This review article embarks on an exploration of the nuanced and multifaceted domain of Structural Audit and Rehabilitation, with a specific focus on the venerable buildings nestled within the campus of BDCE Campus. These structures, bearing the imprints of history and architectural legacy, require a meticulous approach to address the challenges associated with the passage of time. As educational edifices age, the imperative to assess their structural integrity becomes paramount. The process of Structural Audit serves as a diagnostic tool, unraveling the complexities of these aged buildings and paving the way for informed decisions regarding their preservation and enhancement. The BDCE campus, with its architectural gems, serves as an evocative backdrop for an in-depth examination of the methodologies employed in these structural audits. The initial segment of this review article embarks on a journey into the methodologies underpinning structural audits. From cutting-edge non-destructive testing techniques to sophisticated structural health monitoring, these methods provide a comprehensive understanding of the structural conditions of old buildings, laying the foundation for a strategic approach to their rehabilitation. However, the challenges encountered in the preservation of historical structures within the BDCE campus are as unique as the architectural features they embody. The second section of this review navigates through these challenges, emphasizing the need for interdisciplinary collaboration among engineers, architects, and preservationists. Compliance with modern building codes, material deterioration, and the delicate balance between preservation and functionality are all integral components of this complex narrative. Transitioning from the theoretical to the practical, the subsequent section delves into the rehabilitation phase. It unpacks a spectrum of strategies, from the integration of innovative materials to the application of retrofitting techniques, all tailored to breathe new life into the aging structures. Supported by enlightening case studies within the BDCE campus, this section paints a vivid picture of successful applications and lessons learned from the intersection of theory and practice. Moreover, the review article contemplates the economic and environmental dimensions of structural rehabilitation, weighing the merits of breathing new life into existing structures against the allure of new constructions. The discourse extends to considerations of adaptive reuse and the preservation of cultural heritage, spotlighting the role of educational campuses in fostering sustainable practices.

A.Aim:

To suggest suitable rehabilitation for increasing

B. Objective:

1) Performing preliminary inspection of the building.
2) Preparation of architectural, structural plan of building.
3) Visual Inspection to highlight critical area.
4) Performance of NDT test.
5) Finding the actual strength of the building.
6) Suggesting remedial measures.
7) To prepare a structural audit report

2. LITERATURE REVIEW

2.1."STRUCTURAL AUDIT OF BRIDGES" by Ms. P. S. Jadhav, Ms. R.S.Chavan, Mr. G. K. Mohite R. D.Gosavi, Prof.P.S.Shinde (September2017)

The purpose of this paper is to create awareness among the civil engineers about the health examination of the bridges. It is very necessary to do regular examination of old bridges. Thus, this paper gives some knowledge on the tests of strength and the major factors affecting the life span of the bridge. The life span of the bridges is too long. This means there is a great chance of reduction in the strength, increase in challenges like deterioration, natural hazards, etc. there may also be no. of accidents taking place over the bridge. The structural audit ensures that the structure is safe and has no risk.it is conducted by a professional

2.2."STRUCTURAL AUDIT OF OLD STRUCTURES" by Swapnil U Biraris, Aishwarya G Gujrathi, Abhishek D Pakhare, Anjali N Satbhai, Pournima K Vispute (January 2017)

The above paper gives the information regarding the importance of structural audit and steps involved in conducting it that should be strictly carried out for an old structure. The structures whose life span has been more than 25 years an overall heath and performance check-up of structure should be conducted. It emphasizes on different repairs and retro fitting measure to be used for buildings after structural audit. It also mentions that as humans are mainly accommodated in such structures so it is of prime importance to conduct the audit so that it can help to save life, property and reduces risk factor. We under stood the purpose behind conducting audit where firstly to save human life and property, to understand condition of building, finding critical areas and repair them immediately.

2.3."STRUCTURAL AUDIT OF RCC BUILDING" by Sanket Sanjay Suryawanshi, Vaibhav Vishnu Vishe, Deepak Premchand Sah, Reetika Sharan (2018)-

The paper states the faulty mechanism in the structure and different measures to overcome them. It states that the structure can be residential, commercial or historical monument. The ancient structures had huge impact on life because of its long-life span. But nowadays the structures become less efficient and lose their strength before the design period. So, to prevent any further damage, regular check-ups and health examination of the building is carried.

2.4."STRUCTURAL AUDIT" by B.H Chafekar, O.S Kadam, K.B Kale, S.R Mohite, P.A Shinde, V.P Koyle (2013)-

The paper covers he structural audit of the overall structures. According to the author(s), the frame is the heart of the building. It is designed by the structural engineer with the help of bye-laws provided for the structure. Various techniques are used to assess the old frames. The structure is a system of interconnected element to transfer the loads safely to the soil. It is similar to a 'table'. The engineer will call the legs of table as columns, battens as beams and sheet ply as slab. When a no. of tables is connected horizontally and vertically, they we get a building structure. The structural audit is like checking a patient by a doctor. It is important to know the real status of the old buildings.

2.5 "Structural Audit of a Residential Building" by Bhairavi Pawar, Dhiraj Phapale , Akash Suryavanshi , Vikas Shinde, Swati Bhangale (2022)-

Civil Engineering Industry is one of the oldest diligences which gives an introductory structure to all mortal beings. Every structure has its own service life and it should stand forcefully on its position during its complete service life. Over a period of time, as these structures come aged, we find in them certain declination or deterioration with attendant torture manifested in the form of cracking, disjoining, delaminating, corrosion etc. Similar deteriorated structures can be rehabilitated and retrofitted by using varied types of compounds & modernistic repair accouterments. The paper brings out the current state of concrete structures & the considerable areas where enhancement is demanded during its service life stage for sustainable expansion & so the approach of carrying out Repair, Rehabilitation & Retrofitting.

2.6 "Structural Audit of RCC Building in Kolhapur City" by Mahesh A. Lokhande (2021)-

A structural audit is required for framed structures in order to propose suitable corrective actions for all sorts of structural flaws and damages. So that it can continue to meet the requirements for strength and serviceability. A structural audit should be performed at least once every five years for any structure. A structural audit should be performed every three years for structures older than 15 years. Corrosion and ageing appear to be the most common causes of structural member deterioration. Dampness and leakage from slabs, fractures in walls, and other factors cause corrosion in structural elements. As a result, the building's strength and serviceability can be improved by performing the following steps: slabs for water proofing.

3. PROPOSED METHODOLOGY

3.1 Proposed Methodology:

1. **Literature Review:** Conduct an extensive literature review to explore existing research, case studies, and methodologies related to structural audit, rehabilitation, and preservation of historical buildings in educational campuses. This phase provides a comprehensive understanding of the current state of knowledge in the field.
2. **Case Study Selection:** Identify and select specific old buildings within the BDCE campus for in-depth case studies. Consider buildings with diverse architectural characteristics, historical significance, and varying degrees of structural issues. This step ensures a well-rounded analysis and application of methodologies to different contexts.
3. **Structural Audit Methodologies:** Examine and analyze the methodologies employed in structural audits, focusing on their relevance to historical structures. This includes non-destructive testing techniques, structural health monitoring, visual inspections, and advanced computer-aided 205odelling. Evaluate the strengths and limitations of each method in the context of the BDCE campus.
4. **Interdisciplinary Collaboration:** Investigate the role of interdisciplinary collaboration in the structural audit and rehabilitation process. Explore how architects, structural engineers, preservationists, and other stakeholders collaborate to address the unique challenges posed by old buildings. Highlight successful examples of teamwork and integration of expertise.
5. **Challenges Faced in BDCE Campus:** Systematically analyze the challenges encountered during the structural audit and rehabilitation initiatives within the BDCE campus. This includes architectural complexities, compliance with building codes, material deterioration, and the delicate balance between preservation and modern functionality.
6. **Rehabilitation Strategies:** Explore and categorize the rehabilitation strategies implemented within the BDCE campus based on the findings of the structural audits. Investigate the use of innovative materials, retrofitting techniques, and sustainable practices. Illustrate

these strategies with specific examples from the case studies.

7. **Economic and Environmental Considerations:** Evaluate the economic implications and environmental considerations associated with the decision to rehabilitate old buildings rather than opting for new construction. Consider factors such as cost-effectiveness, energy efficiency, and the potential for adaptive reuse. Draw comparisons between rehabilitation and new construction projects within the campus.
8. **Integration of Case Studies:** Integrate the findings from the selected case studies into the broader discussion, emphasizing the practical application of methodologies and their impact on the preservation and enhancement of old buildings. Discuss lessons learned, successes, and areas for improvement based on the real-world experiences within the BDCE campus.
9. **Conclusion and Future Directions:** Summarize the key insights derived from the review, highlighting the significance of structural audits and rehabilitation in the context of educational campuses. Propose future directions for research and practice, emphasizing areas that warrant further exploration and innovation.
10. **References:** Compile a comprehensive list of references, citing relevant literature, research papers, and sources that contribute to the theoretical framework and practical understanding of structural audit and rehabilitation in the context of historical buildings within educational campuses.

3.2 Testing of Hardened Concrete

Destructive tests (DT) and **Non-destructive tests** (DT) are the tests done on hardened concrete. Concrete is the oldest and most important construction material in the world. Testing of the concrete plays an important role to know the strength, durability and condition of the structure. Destructive tests and Non-Destructive tests are done to determine the important properties of concrete like compressive strength, flexural strength, tensile strength etc.

1. Concrete Destructive Test: The quality of concrete is important for construction. Hardened concrete attains strength as it matures. The destructive test of concrete helps to understand the behaviour and quality by breaking the test specimen at certain loads. The primary step of the destructive test is to cast test specimens from freshly made concrete. The destructive testing method is suitable and economically beneficial for the concrete specimens that are produced at a large scale. The main intention of destructive tests is to investigate the service life and detect the weakness of design that might not show under normal working conditions. It includes methods where the concrete specimen is broken so as to determine mechanical properties i.e. hardness and strength. This type of testing is very easy to carry out, easier to interpret, and yields more information.

Types of Destructive tests: The main intention of destructive tests is to investigate the service life and detect the weakness of design that might not show under normal working conditions. These tests determine the compressive, flexural and tensile strength of concrete. There are different types of tests available to examine the hardened concrete.

1. Compressive strength test of concrete: Compressive strength of concrete is the ability of the concrete to withstand loads without cracking or deformation. The concrete specimen to conduct this test should be either cylindrical or cubic. The apparatus for performing this test is a Compression testing machine. The relevant IS code for this test is IS 516-1959. The load at which the specimen fails measures its strength. **Compressive strength of the concrete = Load at which the concrete breaks / Cross-sectional area of the specimen** The unit of compressive strength of concrete is N/mm^2. The test should be done at 7, 14 & 28 days.

2. Splitting tensile strength test: The splitting tensile strength test is one of the tests on hardened concrete for determining its tensile strength. Concrete is a durable construction material. Under tension, concrete is brittle in nature. Therefore, it causes cracks and deteriorates. The splitting tensile strength test measures the concrete tensile strength. For this test, we use cylindrical specimens with 150 mm diameter and 300 mm height. The tensile strength of concrete is **Splitting**

tensile strength of concrete, T= 2P/ Ω LD. The unit of tensile strength is N/mm. The IS 5816: 1999, ASTM C496 gives the standard aspects for this test.

3. Flexural strength test: The flexural strength test and splitting tensile strength test are almost the same. Because both the tests measure the tensile strength of concrete. The flexural strength test of concrete measures the tensile strength of concrete through an indirect method. The relevant codes for this test are ASTM C293 & ASTM C78. This test measures the ability of concrete to resist failure in bending. The modulus of rupture is the measure of tensile strength. Its unit is MPa or psi. **Modulus of rupture, MR = 3PL/ 2bd^2**

Where, P is the Ultimate applied load, L is the span length, b & d is the average width and depth of specimen at fracture.

2. Non-destructive Testing of Concrete: This test provides immediate results, strength, and real properties of the concrete structure. Non-destructive testing of concrete is a method to obtain the compressive strength and other properties of concrete from existing structures. The standard method of assessing the quality of concrete in buildings or structures is to test cast samples simultaneously for compressive, flexural, and tensile strength. In the non-destructive method of testing, without loading the specimen to failure (i.e. without destructing the concrete) we can measure strength of concrete. Now days this method has become a part of quality control process. This method of testing also helps us to investigate crack depth, micro cracks and deterioration of concrete. Non-destructive testing of concrete is a very simple method of testing but it requires skilled and experienced persons having some special knowledge to interpret and analyze test results. These non-destructive methods may be categorized as penetration tests, rebound tests, pull-out techniques, dynamic tests, radioactive tests, maturity concept.

Methods of Non-Destructive Testing of Concrete:

1. Rebound Hammer Method: Rebound hammer is an instrument or a device, which is used to assess the relative compressive strength of concrete based on the hardness at or near its exposed surface. Rebound hammer is also known as Schmidt's Hammer or Swiss Hammer as it is invented by Ernst Schmidt, a Swiss engineer. The non-destructive tests are the group of useful methods to evaluate the strength of construction materials without causing damage. It is not always possible to do destructive tests for the materials of construction like concrete, block and clay bricks, etc. particularly when they are already laid. They are independent tests sufficient to make the structural engineering decisions after establishing figurative substantiation through its application. Rebound hammer test procedure is used to examine the hardness of concrete particularly when you want to carry out repairs of RCC structure.

The table below shows the quality of concrete based on the average rebound number or rebound index:

Average Rebound Number		Quality of Concrete
1.	> 40	Very Good
2.	30 -40	Good
3.	20-30	Fair
4.	< 20	Poor and/or delaminated
5.	0	Very Poor and/or delaminated

2. Ultrasonic pulse velocity method: Ultrasonic Testing is one of the non-destructive test methods based on the transmission of the ultrasonic pulse in the component or materials like concrete, steel, etc. Ultrasonic testing is known as **UT** or **Ultrasonic Pulse Velocity Test** or **UPV Test**. The ultrasonic testing method is based on the use of equipment composed of transducers which produce and receive the ultrasonic wave of 0.01 to 60 MHz. The pulse (wave) depends on the density and the elastic properties of the materials of RCC structure. This test is done to assess the quality of concrete by ultrasonic pulse velocity method as per IS: 13311 (Part 1) – 1992. The underlying principle of this test is – The method consists of measuring the time of travel of an ultrasonic pulse passing through the concrete being tested. Comparatively higher velocity is obtained when concrete quality is good in terms of density, uniformity, homogeneity etc.

Interpretation of Results: The quality of concrete in terms of uniformity, incidence or absence of internal flaws, cracks and segregation, etc,indicative of the level of workmanship employed, can thus be assessed using the guidelines given below, which have been evolved for characterizing the quality of concrete in structures in terms of the ultrasonic pulse velocity.

1. PREPARING FOR USE:

The transducers should be connected to the sockets marked "TRAN" and "REC" before switching on the V meter and the V meter either be operated with;

1. The internal battery
2. An external battery
3. The A.C line

2. SET REFERENCE:

To check the instrument zero, a reference bar is provided and on it, the pulse time for the bar is engraved. Before placing it on the opposite ends of the bar apply a smear of grease to the transducer faces.

Until the reference bar transit time is obtained on the instrument read-out adjust the 'SET REF' control.

3. RANGE SELECTION:

It is recommended that the 0.1-microsecond range should be selected for path length up to 400mm for maximum accuracy.

4. PULSE VELOCITY:

Make careful measurement of the path length 'L' and to the surfaces of the transducers apply couplant and onto the surface of the material press it hard.

While reading is being taken do not move the transducers because in measurements this can generate noise signals and errors. Until a consistent reading appears on the display which is the time in microsecond for the ultrasonic pulse to travel the distance 'L', continue holding the transducers onto the surface of the material.

When the unit digit hunts between two values the mean value of the display readings should be taken.

5. Separation of Transducer Leads:

To prevent the two transducer leads from coming into close contact with each other when the transit time measurements are being taken it is suitable.

If this is not done the receiver lead might pick-up unwanted signals from the transmitter lead and an incorrect display of the transit time occurs.

4. RESULTS AND DISCUSSION

4.1 RESULTS AND DISCUSSION

[1] General Information Building

Table 4.1: General Information Building

Basic Information	
Name of Building	BDCE Campus
Name of Lab	Hydraulics Lab
Address	Sewagram Road 442001
Building Survey	
Name	Hydraulics Lab
Mode of Use	Commercial
Type of Structure	RCC Frame Structural
Previous Structural Audit	This is first structural audit
Date of Plan	30-01-1998
Description	
Floor Height	3m
Area of Hydraulics Lab	12.10m X 23.50 m
External Walls	Brick
Internal Walls	Brick
Survey	
Mode of Survey	Visual inspection using scale & tape

[1] Ultrasonic Pulse Velocity Test

Results-

Calculation of UPV Testing

1) C1-

Path Length (L)-0.300

Time Travel (T)-0.00009 sec

Pulse Velocity=L/T

Pulse Velocity=$\frac{0.300}{0.00009}$

Velocity of Ultrasonic wave (V)=3.33 Km/sec (As per IS Code - 13311 (Part 1) – 1992)

Medium

2) **C2-**

Path Length(L)-0.275m

Time Travel (T)-0.000075 sec

Pulse Velocity= $\frac{0.275}{0.000075}$

Velocity of Ultrasonic Wave (V)=3.66 Km/sec (As per IS Code - 13311 (Part 1) – 1992)

Good

3) **C3-**

Path Length(L)-0.265m

Time Travel (T)-0.000072 sec

Pulse Velocity= $\frac{0.265}{0.000072}$

Velocity of Ultrasonic Wave (V)=3.68Km/sec (As per IS Code - 13311 (Part 1) – 1992)

Good

4) **C4-**

Path Length (L)-0.270m

Time Travel (T)-0.000073sec

Pulse Velocity= $\frac{0.270}{0.000073}$

Velocity of Ultrasonic Wave (V)=3.69Km/sec (As per IS Code - 13311 (Part 1) – 1992)

Good

Below Table calculation same these procedure

Table 4.2: Results of Ultrasonic Pulse Velocity Test

SN	Path Length (L) m	Time of travel (T) Sec	Velocity of ultrasonic wave (v) Km/sec	Quality of Concrete	Range of strength of concrete Km/sec
C1	0.300	0.00009	3.33	Medium	3.0-3.5
C2	0.275	0.000075	3.66	Good	3.5-4.5
C3	0.265	0.000072	3.68	Good	3.5-4.5
C4	0.270	0.000073	3.69	Good	3.5-4.5
C5	0.260	0.000069	3.76	Good	3.5-4.5
C6	0.275	0.000076	3.61	Good	3.5-4.5
C7	0.255	0.000071	3.59	Good	3.5-4.5
C8	0.265	0.000074	3.58	Good	3.5-4.5
C9	0.272	0.000073	3.72	Good	3.5-4.5
C10	0.285	0.000078	3.65	Good	3.5-4.5

Observations:

1. **Quality Assessment:**

- The quality of the concrete is assessed based on the pulse velocity as per IS Code 13311 (Part 1) – 1992.
- **Medium Quality:** Velocity between 3.0 Km/sec to 3.5 Km/sec.
- **Good Quality:** Velocity between 3.5 Km/sec to 4.5 Km/sec.

2. **Observations for Individual Samples:**

- **C1:** Velocity of 3.33 Km/sec indicates medium quality concrete.
- **C2 to C10:** Velocities range from 3.58 Km/sec to 3.76 Km/sec, indicating good quality concrete.

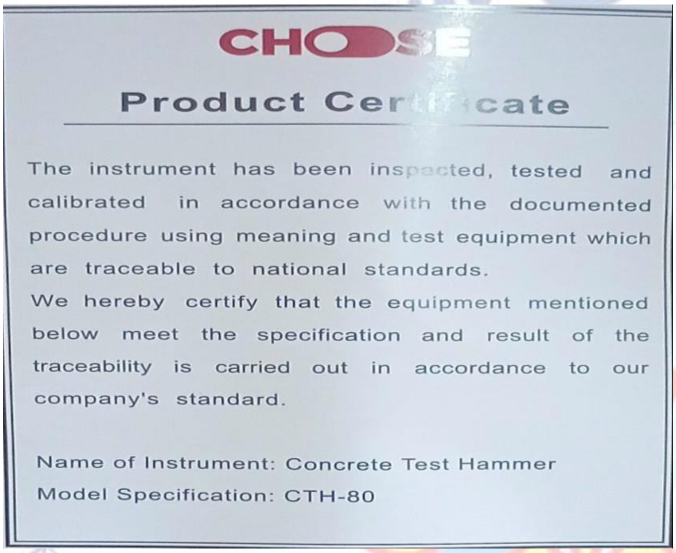
3. **Trends and Insights:**

- The majority of the concrete samples (C2 to C10) exhibit velocities within the range of 3.58 Km/sec to 3.76 Km/sec, classifying them as good quality concrete.
- Only sample C1 has a lower velocity of 3.33 Km/sec, which falls into the medium quality category.
- The consistent higher velocities (above 3.5 Km/sec) in samples C2 to C10 suggest uniformity in the concrete quality for these samples.

The UPV test results indicate that the concrete quality for the majority of the samples tested (C2 to C10) is good, with pulse velocities ranging between 3.58 Km/sec to

3.76 Km/sec. Only one sample (C1) falls into the medium quality category with a pulse velocity of 3.33 Km/sec. These observations suggest that the overall quality of the concrete is satisfactory, with most samples exhibiting good structural integrity. This assessment can help in determining the necessary rehabilitation measures and ensuring the long-term durability and safety of the concrete structures in the BDCE campus.

[2] Rebound Hammer Test


CHOSE

Product Certificate

The instrument has been inspected, tested and calibrated in accordance with the documented procedure using meaning and test equipment which are traceable to national standards.

We hereby certify that the equipment mentioned below meet the specification and result of the traceability is carried out in accordance to our company's standard.

Name of Instrument: Concrete Test Hammer

Model Specification: CTH-80

Calibration Certificate

Calculation of Rebound Hammer Testing:

1]C1-22+22+20+19+14+33+22+14+14+21=201

Average of Rebound Hammer=201/10

=20.1 N/mm^2

2]C2=39+34+42+44+40+48+32+40+46+42=407

Average of Rebound Hammer=407/10

=40.7 N/mm^2

3]C3=

28+20+22+20+28+23+26+20+24+20=231

Average of Rebound Hammer=231/10

=23.1 N/mm^2

3]C4=

40+32+36+38+46+38+36+39+33+40=378

Average of Rebound Hammer=378/10

=37.8N/mm^2

Below Table calculation same these procedure

Table 4.3: Results of Rebound Hammer Test

SN	Column Name	Direction of Hammer	Average Rebound No.	Quality of Concrete
1	C1	90	21.3	Good
2	C2	90	40.7	Very Good
3	C3	90	23.1	Fair
4	C4	90	37.8	Good
5	C5	90	41	Very Good
6	C6	90	35	Good

7	C7	90	26	Fair
8	C8	90	22	Fair
9	C9	90	22.9	Good
10	C10	90	31	Good

Observations:

1. **Quality Assessment:**

- The quality of the concrete is classified based on the average rebound number:
- **Very Good:** > 40
- **Good:** 30 - 40
- **Fair:** 20 - 30
- **Poor:** < 20

2. **Individual Column Analysis:**

- **C1:** The average rebound number is 20.1, indicating good quality concrete.
- **C2:** The average rebound number is 40.7, indicating very good quality concrete.
- **C3:** The average rebound number is 23.1, indicating fair quality concrete.
- **C4:** The average rebound number is 37.8, indicating good quality concrete.
- **C5:** The average rebound number is 41.0, indicating very good quality concrete.
- **C6:** The average rebound number is 35.0, indicating good quality concrete.
- **C7:** The average rebound number is 26.0, indicating fair quality concrete.
- **C8:** The average rebound number is 22.0, indicating fair quality concrete.
- **C9:** The average rebound number is 22.9, indicating good quality concrete.
- **C10:** The average rebound number is 31.0, indicating good quality concrete.

3. **Overall Quality:**

- The majority of the columns (C1, C2, C4, C5, C6, C9, and C10) show good to very good quality concrete.
- Columns C3, C7, and C8 indicate fair quality concrete, which may require further investigation or remediation.

The Rebound Hammer Test results indicate that the concrete quality in most columns ranges from good to very good. A few columns show fair quality, which suggests variability in the concrete quality across the structure. These observations can help in identifying areas that may require additional attention or rehabilitation to ensure the overall structural integrity and longevity of the building in the BDCE campus.

4.2 SUGGESTED REMEDIAL MEASURES FOR CONCRETE QUALITY IMPROVEMENT

Based on the observations from the Ultrasonic Pulse Velocity (UPV) Test and Rebound Hammer Test, the following remedial measures are recommended to address the variability in concrete quality and enhance the overall structural integrity of the building in the BDCE campus.

1. **Strengthening and Repair of Concrete**

a. Crack Repair:

Epoxy Injection: For structural cracks, inject epoxy resin to restore the concrete's tensile strength.

Routing and Sealing: For non-structural cracks, route out the crack and seal it with a suitable sealant.

b. Spalling Repair:

Patch Repair: Remove loose or damaged concrete, clean the exposed reinforcement, and apply a suitable repair mortar or concrete patching compound.

c. Corrosion Protection:

Corrosion Inhibitors: Apply corrosion inhibitors to the surface to prevent further corrosion of the reinforcement.

Cathodic Protection: Install cathodic protection systems where corrosion is extensive.

2. **Surface Treatment and Protection**

a. Surface Coatings:

Waterproof Coatings: Apply waterproof coatings or membranes to prevent water ingress.

Anti-Carbonation Coatings: Use anti-carbonation coatings to protect the concrete from carbon dioxide penetration, which can lead to carbonation and corrosion of reinforcement.

b. Sealants:

Joint Sealants: Ensure all joints are properly sealed with flexible sealants to accommodate movement and prevent water ingress.

3. **Structural Strengthening**

a. Fiber Reinforced Polymer (FRP) Wrapping:

Wrap columns, beams, and other structural elements with FRP to enhance their strength and ductility.

b. Jacketing:

Concrete Jacketing: Increase the cross-sectional area of columns and beams by adding a layer of new concrete with additional reinforcement.

Steel Jacketing: Use steel plates or jackets to encase and strengthen structural elements.

c. External Post-Tensioning:

Apply external post-tensioning to beams and slabs to enhance their load-carrying capacity.

4. **Improving Concrete Quality**

a. Use of Admixtures:

Superplasticizers: To improve workability without increasing the water-cement ratio.

Silica Fume, Fly Ash, or GGBS: To enhance strength and durability.

b. Proper Curing:

Ensure adequate curing of concrete elements to achieve the desired strength and durability.

c. Mix Design Optimization:

Review and optimize the concrete mix design to achieve better consistency and strength.

5. **Monitoring and Maintenance**

a. Regular Inspections:

Conduct periodic structural audits and inspections to identify and address issues early.

b. Non-Destructive Testing:

Use UPV and Rebound Hammer tests periodically to monitor the condition of the concrete.

c. Maintenance Plan:

Establish a comprehensive maintenance plan, including cleaning, sealing, and protective coatings, to extend the lifespan of the structure.

6. **Seismic Retrofitting**

a. Addition of Shear Walls:

Add shear walls to increase the building's resistance to lateral forces.

b. Bracing:

Install steel braces in key locations to enhance the structure's stability during seismic events.

c. Base Isolation:

Consider the installation of base isolators to reduce seismic forces transmitted to the building.

Conclusion: Implementing these remedial measures will significantly enhance the quality, strength, and durability of the concrete structure in the BDCE campus. Addressing the identified deficiencies through targeted interventions will ensure the building's safety and functionality, extending its service life and maintaining its structural integrity. Regular monitoring and maintenance will further ensure that any emerging issues are promptly addressed, maintaining the building's performance over time.

5. CONCLUSION

In the intricate dance between preserving the past and embracing the future, the structural audit and rehabilitation of old buildings within the BDCE campus emerge as a compelling narrative of resilience, innovation, and interdisciplinary collaboration. This review article has traversed the realms of structural engineering, architectural preservation, and sustainable development to unravel the complexities inherent in the preservation of historical structures within educational institutions. The methodologies employed in structural audits, ranging from advanced non-destructive testing to structural health monitoring, have laid the groundwork for a nuanced understanding of the aging buildings within the BDCE campus. The integration of these methodologies has not only safeguarded the structural integrity of these historical edifices but has also contributed to the broader discourse on the application of technology in heritage conservation.

Interdisciplinary collaboration has proven to be a linchpin in addressing the unique challenges posed by old buildings. The synergy between architects, structural engineers, and preservationists has not only enriched the process but has also become a model for effective problem-solving in the preservation domain. Compliance with modern building codes, material deterioration, and the delicate balance between preservation and functionality have been met with ingenuity and adaptability. The rehabilitation phase has witnessed the transformation of theoretical insights into practical solutions. Innovative materials, retrofitting techniques, and sustainable practices have breathed new life into aging structures, demonstrating that the past and present can coexist harmoniously. Case studies within the BDCE campus have served as beacons of success, illustrating how strategic interventions can rejuvenate historical buildings while preserving their cultural significance.

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Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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