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Conditional Assessment of Building using Non-Destructive Tests

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Abstract: ***The concrete assessment is important for the proper diagnosis of successful rehabilitation work. The paper exhibit contextual analysis in cooperating the utilization of different Non-Destructive Test (NDT), to evaluate the concrete quality of building age over 8 years. NDT used such as Rebound Hammer Test, Ultrasonic pulse velocity, carbonation depth, rebar locator and cover meter. At first, the structure deteriorates because of, physical causes, cyclic temperature variations and chemical attack due to nature. Later on, if not gave careful consideration, these weaken quickly and fail to meet the useful prerequisite for its designed service life. The building structure can be examined by utilizing a visual perception, non-destructive evaluation technique (NDE), lab and field test performing scientific analysis, planning and documentation is more useful for classification and category of distress. The research paper likewise focusses around standard testing procedure of NDT and succession of task for acquiring precision and in addition the issues made amid the testing and the confinements of the tests are considered.***
Keywords: ***Rebound Hammer, Ultra-sonic Pulse velocity, Carbonation Test, Ferro Scanning***

I. INTRODUCTION

The issue of upgrading the existing engineering structures has been one of the greatest challenges for over a decade. Public Building Infrastructure consists of abroad category of the building, owned by both Government and private firms, these provide the basic amenities, services, and installation, which are necessary for the efficient functioning of a society. Therefore, infrastructure development becomes the basis of development of all other section economically such as transportation, communication system, water services, school, hospitals, malls etc. Managing this infrastructure, however, is highly challenging because of the large size of facilities, complex nature of the infrastructure and the people using it and the high cost involved. Periodical surveys and assessment of infrastructure are very important to assess the existing condition. They must be carried on a regular basis after an appropriate time. It has been observed that with the passage of time all the structures whether framed or load bearing, deteriorate due to climate (wind, sunlight, rain etc.). The deterioration in the form of spalling of concrete, cracks, corrosion of reinforcement etc. If no retrofitting measures are taken, the structure becomes unfit to use.

Schools and Colleges are important buildings, as they are the future of every country and if they will deteriorate rapidly, it will become a problem for the society and the country. So, it is necessary to study the causes of deterioration by considering the factors responsible for deterioration and identify suitable means to stop this deterioration.

There is an urgent need to identify government schools and colleges and housing colonies that have been constructed in past, which are deteriorating and would involve a huge amount for maintenance, should be diagnosed as early as possible. So, there exists a need for the condition survey of these buildings to develop a systematic plan for maintenance of these buildings.

This study is performed in view of the above reference. The complete investigation of few educational buildings, Cable Car building and Residential colonies of Chandigarh Punjab Haryana and Jammu and Kashmir has been carried out to determine the causes of deterioration and suggest their possible remedies.

II. LITERATURE REVIEW

Condition assessment is defined as measuring and evaluating the current state of a constructed facility in terms of indices such as flexibility/stiffness, damping, toughness against fatigue, resistance to deterioration mechanisms and aging, and, the available strength, deformability, and energy dissipation capacities under the probable failure modes. Condition assessment includes identifying any design, construction or maintenance errors as well as any local defects, deterioration, and damage such that the global state of health, i.e. the structural reliability of the facility may be established for rational management decisions

The conditional survey conducted by a licensed engineer is beneficial in the decision making the process of the condition of building for the purpose of purchase, sale, refinancing, avoiding potential claims, renovation and /or maintenance of a property and building.

A conditional survey provides an assessment of physical property conditions. The extent of a condition Survey can vary depending on the client's need for information.

Condition assessment based on modal testing and structural identification is discussed. This technique was successfully applied to seven highway bridges. Modal flexibility obtained by post-processing the frequencies and mass normalized modal vectors was used as a structural condition index. The reliability of modal flexibility was verified by comparing bridge deflections obtained from modal flexibility to those measured during static truck-load tests.

Due to a lack of objective and reliable condition assessment techniques for constructed facilities, it is not possible to implement cost-effective management techniques for infrastructure preservation. For example, presently in the INDIA, a major portion of the highway bridge stock is deemed in need of repair and/or replacement, and the corresponding financing need is estimated at $20 Billion. Since in INDIA building conditions are typically determined by visual inspection and expressed in terms of a subjective "condition index", the estimated financing need may not be accurate. If a certain portion of the financing need could be provided, it is questionable whether it would be possible to rationally prioritize these funds for the maintenance, retrofit, upgrade and replacement of building which are deemed structurally deficient. Since our knowledge on fundamentals of buildings behaviour (i.e. the actual critical limit states, capacities and failure modes of different types of buildings) is incomplete, we may be investing scarce resources into buildings that have adequate reserve capacities while we may be delaying replacement of those buildings that may be susceptible to sudden collapse. Therefore, we should provide condition assessment technique which is based on modal testing and structural identification that should help improve the current practice.

Condition assessment also enables operators and owners to understand the health of their assets and manage remaining life. Effective management is critical to ensuring safe and reliable operation up to and beyond design life.

A preliminary Conditional Survey involves inspection of site and building system photographs and videos are taken to illustrate the deficiencies that may be found. After documentation of the existing conditions, the collected data is analysed and findings and recommendations are summarized in a brief report. If required a tentative construction cost estimate may also be included in the report.

After a preliminary Condition Survey is completed, the detailed Conditional Survey was done to gather and document additional details that are necessary to prepare renovation drawing, upgrade operation system, and /or negotiate a property purchase or sale

In addition to the obvious benefit of knowing the current condition and potential renovations and/or upgrade costs for a specific building, it defines property conditions at a specific point in time.

In response to these infrastructural challenges, several condition assessment systems have evolved. Their main function includes an asset manager of the current condition, a prediction of future deterioration, the selection of maintenance and repair strategies, the improvement of structure condition after the repair and the prioritization based on the building components should be repaired given the bridge constraints.

A Conditional Assessment system, therefore, involves strategic decisions about the repair, replacement or upgrading of a specific component of the system within the building. Thus, for such component system regarding the physical condition of the building we have to make a wise decision. Thus, it is the original condition assessment of the building, that governs all subsequent repair and rehabilitation.

National Disaster Management Division Ministry of Home Affairs, Government of India New Delhi June 2007 [1] have briefly described how to carry out the condition assessment of buildings before taking up repair and upgrading work. This will determine whether or not a distressed building should be demolished to build back better or whether it will be cost-effective to either repair or retrofit it, in the context of overall safety

Straub 2003[2] Defined conditional assessment as "A tool for assessing the technical performance of the properties to underpin long-term maintenance expectations"

Telcholz 1995[3] Defined conditional assessment as "A service provided by design professionals which included the performance of building audits, primarily for reports of building deficiencies, to raise the building's performance to its original "new" potential"

Sadek et al 2003[4] Defined conditional assessment as "A system inventory and inspection to evaluate the current conditional of the system based on established measures of the condition"

Strong 2004[5] Defined conditional assessment as "A vehicle for producing a complete inventory of deficiencies in a facility by thoroughly assessing the existing physical conditions and functional performance of buildings, equipment, utilities, and grounds".

Rugless 1993[6] Defined conditional assessment as "A process of systematically evaluating an organization's capital assets in order to project repair, renewal, or replacement needs that will preserve their ability to support the mission or activities they were assigned to serve"

DFES2003[7] Defined conditional assessment as "A tool to provide a systematic, uniform and objective basis for getting information on the state of premises".
Fagan and Kirkwood 1997[8] Defined conditional assessment as "An information system customized for the input, storage, manipulate, and reporting of facility related information".
Kaiser 1993[9] Defined conditional assessment as "A process for inspecting and reporting the physical condition and function performance of the building and infrastructural systems and components".
Chouinard et al 1996[10] Defined conditional assessment as "The evaluation of the condition of the functional system that meets the desired objectives".
NCES 2003[11] Defined conditional assessment as "A data collection process with the goal of conducting a comprehensive inventory that meets the needs of the entire district management efforts in a coordinated manner and thereby avoids the need for redundant collection efforts".
JCEF 2004[12] Defined conditional assessment as "A state of repair of building infrastructure that takes into consideration all the building system from roof and windows to electrical and mechanical system".
Lewis and Payant 2000[13] Defined conditional assessment as "A process whereby the organization's facility systems, components, and subcomponents are evaluated according to their conditions".

III.PROBLEM FORMATION AND METHODOLOGY

It has been observed that with the passage of time all the structures whether framed or load bearing, deteriorate due to climate (wind, sunlight, rain etc.). The deterioration in the form of spalling of concrete, cracks, corrosion of reinforcement etc. If no retrofitting measures are taken, the structure becomes unfit to use.
Schools and Colleges are important buildings, as they are the future of every country and if they will deteriorate rapidly, it will become a problem for the society and the country. So, it is necessary to study the causes of deterioration by considering the factors responsible for deterioration and identify suitable means to stop this deterioration.
There is an urgent need to identify government schools and colleges and housing colonies that have been constructed in past, which are deteriorating and would involve a huge amount for maintenance, should be diagnosed as early as possible. So, there exists a need for the condition survey of these buildings to develop a systematic plan for maintenance of these buildings.
This study is performed in view of the above reference. The complete investigation of few educational buildings, Cable Car building and Residential colonies of Chandigarh Punjab Haryana and Jammu and Kashmir has been carried out to determine the causes of deterioration and suggest their possible remedies.
In a detailed Conditional Survey, on-site interviews (through the questionnaire given in Appendix-1), maintenance history review, Conditional Assessment done on the following buildings in Chandigarh, Haryana, and Punjab. Data collected in this survey shall be used to get the appropriate idea about the condition of the buildings. The list of the buildings are as follows:
Site 1: IVL Dhunseri Petrochem Industries Private Limited
Site 2: Indus Tower Karnal
This research concentrates on providing the non-destructive test results with the aim of contributing towards the development of building inspection rating systems to assess the building defects. The system gathers two sets of data i.e. the condition of the building and the criticality of a building's defects which can be analysed to provide a rating of the buildings overall condition.

A. The survey is based on the

1) Visual Inspection (Photographic Inspection).
2) Conditional Survey.
3) Non-Destructive Testing.

B. Visual Inspection

Visual examination is the starting point of inspection. Cracks, rust staining, and spalling are the most obvious defects which can be identified. Often the location of these can give a good indication of the cause of the problem, but an open mind must be kept at this stage until further investigation is undertaken to confirm the root cause. If visual inspection of a structure suggests that a problem may be present, an in-depth examination should be carried out.
The purpose of the site inspection is to identify the type and age of construction, gravity and lateral load resisting systems, and to make a preliminary assessment of the existing condition of the structure. Visual defects may be related to poor workmanship or

material deterioration. These show up as excessive deflection and flexural cracking, while foundation movements may cause diagonal cracks. Material deterioration is normally indicated by cracking and spalling. It is particularly important to differentiate between the various types of cracks found. Examination of crack patterns often suggests the most probable cause of the problem.
Access facilities are usually minimal, so the extent of examination is limited. Hammer- tapping (to locate hollowness or delamination), and the use of the Schmidt Hammer, cover meter or crack width gauge is often helpful. Potential problems associated with cracking, excessive deflections, water permeability, and evidence of corrosion should be specially noted. By observing the site and examining pertinent drawings and records, the probable causes of damage are deduced, and the areas of serious concern are located. It is often possible to judge whether the damage is corrosion related and this is useful in planning subsequently in the detailed survey.

Table 1 classification of structural damage

S.NO.	Intensity	Visual damage
1.	Light	Final crack (<1mm) light spalling at isolated spots
2.	Moderate	Medium cracks (1-2mm) light spalling
3.	Severe	Wide cracks (<2mm) at different locations
4.	Very severe	Wide Cracks

C. Condition Survey

The purpose of the survey is to collect sufficient data to pinpoint the cause and source of the problem and to determine the extent of the damage. Depending on the probable cause of the damage, the site work involves a combination of the following processes:

1) Detailed visual inspection;
2) Survey of cracks, spalls, steel pitting and other defects;
3) Potential mapping with half-cell potentiometer, or similar instrument, that identifies zones of high corrosion risk;
4) Drilling holes or mini-cores for carbonation test and chloride content analysis;
5) Coring of concrete for determination of strength and petrography examination;
6) Measurement of concrete cover and reinforcing bar spacing with a cover meter;
7) Schmidt hammer test for Delamination or compressive strength (comparison only);
8) Ultrasonic test for honeycombing depth of cracks, or compressive strength (comparison only);
9) Assessment of depth of discoloration (in the damage) with hammer and chisel.

D. Non -Destructive Tests

These tests are based on indirect measurement of concrete strength through measurement of surface hardness and dynamic modulus of elasticity. Calibration curves relating these properties to the strength of concrete are available. For surface hardness rebound of an impact from the concrete surface is measured.
The most commonly adopted NDT methods for assessment of the strength of concrete and their principles are given in the following:

TABLE 2 NDT Methods and Principles

Rebound Hammer	Spring-driven mass strikes the surface of concrete and rebound distance is given in R-values. Surface hardness is measured and strength estimated from calibration curves, keeping in mind the limitations.
Ultrasonic Pulse Velocity	It operates on the principle that stress wave propagation velocity is affected by the quality of concrete. Pulse waves are induced in materials and the time of arrival measured at the receiving surface

	with a receiver. Ultrasonic pulse velocity is influenced by elastic modulus and strength of concrete.
Core testing	The drilled cylindrical core is removed from the structure, tests may be performed on the core to determine compressive and tensile strength, torsional properties, static modulus of elasticity, etc.
Carbonation test	Carbonation occurs when CO_2 from air finds its way into the body of concrete through its pores in presence of moisture & water forms carbonic acid which neutralizes the Ca $(OH)_2$ formed due to the reaction during setting of concrete thus reducing the alkalinity of concrete
Reinforcement Scanning Test	The test for reinforcement scanning is done with help of HILTI PS 200 Ferro scan a portable system for detecting rebar in concrete structures. The tools help in obtaining the real image of the reinforcement and evaluate the reinforcement mesh

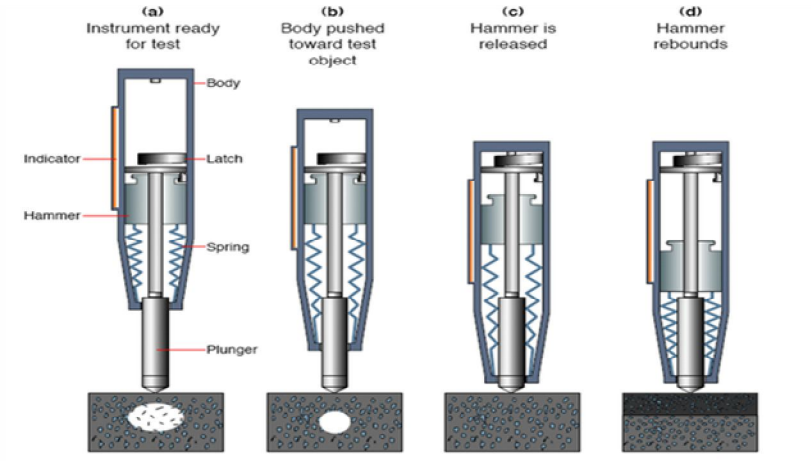

FIGURE 1 SCHMIDT HAMMER

Table 3: Rebound Hammer Comparison Table

INSTRUMENT	AVERAGE REBOUND NUMBER	QUALITY OF CONCRETE
Schmidt Hammer N-TYPE	Greater than 40	Very good hard layer
	30 to 40	Good layer
	20 to 30	Fair
	Less than 20	Poor concrete
	0	Delaminated
Schmidt Hammer P-TYPE	Above 75	Excellent
	55 to 75	Very Good
	40 to 55	Good
	30 to 40	Reasonable
	20 to 30	Average
	Below 20	Poor

Table 4: Upv Comparison Table

S. No.	Ultrasonic Pulse Velocity (km/sec)	Concrete quality Grading
1.	V greater than 4.0	Very good
2.	V between 3.5 and 4.0	Good, but maybe porous
3.	V between 3.0 and 3.5	Poor
4.	V between 2.5 and 3.0	Very poor
5.	V between 2.0 and 2.5	Very poor and low integrity
6.	V Less than 2.0 and reading fluctuating	No integrity, large voids suspected

Figure 2 Ultra-Sonic Pulse Velocity

IV. RESULT AND DISCUSSION

A. Report On Fire Damaged Portion Of Ivl Dhunseri Petrochem Industries Private Limited

1) *Background:* To check the structural integrity of fire hazardous building of IVL Dhunseri Petrochem Industries Private Limited survey was carried out to assess integrity fire affected portions of the building. The concrete strength and quality were found out by using Rebound hammer and Ultrasonic technique Methods. The carbonation test is also conducted to check the pH of concrete.

2) *Objective:* The objective of the investigation is to test the structural integrity of the building by assessing the deterioration with respect to quality and strength of concrete, permeability, corrosion, cracks and other defects causing distress.

3) *Test Results*

Building Details

1.	Building	Framed structure
2.	Location	Munak, Asandh-Kohand Road, Karnal, Haryana
3.	Name	Micro Polyplet Pvt. Ltd
4.	Year of Completion	2003

Figure 3 Fire hazardous fluid heating room at 1st Floor

Figure 4 damaged beam and slab portion.

Table 5 Ultrasonic Test & Carbonation Test

Sr. No.	Location	UPV	R.H.	Compressive Strength N/mm^2
FIRST FLOOR				
1	Col-2 (near bottom level)	1970	35.5,41.5,31,33,40.5,40.5,35,34 = 36.4,	21
2	Col-2 (upper side)		17.5,14,21,12.5,12 = 16.2	Less than 10
3	Col-3 (bottom level)	2130	42.5,49.5,33.5,42,37.5,32.5,27,41.5 = 38.3,	21
4	Col-3 (upper side)		30.5,32,30.5,35.5,37,42.5,23.5,31.5 = 32.9,	16
5	Col-4 (bottom level)	2250	35,35,36,36,37,37=36	20
6	Col-4(top side)		35,38.5,33,30.5,33.5,36.5,37.5 = 37.1,	21
7	Col- 1 (bottom level)	1850	30,40,17.5,43.5,41,26,30 = 32.6	16
8	Slab from front side		31,16.5,14.5,17.5,24,22.5 = 21.5	10
9	Beam front side	1870	18,17.5,11,14,10,18,19 = 15.4	Less than 10
GROUND FLOOR				
10	Ground Floor Col-2 Surface velocity	3260 5650	40,41,42,44,39,42=41.33	26
11	Ground Floor Col-3	3170	43.5,54,43.5,44.5,46.5,45 = 46.2	35
12	Ground Floor Col-4	4200	36,33,32,39,36,37 = 35.5	20
13	Ground Floor Col-1	4120	45.5,40,42,44.5,45.5 = 43.5	30

4) Results And Recommendations

a) The concrete strength of the members of all the locations varies from 15- 20 N/mm^2.

b) The front portion of the room is majorly affected by the fire and heat. Because of high temperature, the concrete cover is spalling out of the main members

c) On tamping, hollow sound was observed, which indicates the detachment of concrete cover from its parent member.

d) The UPV value shows that the concrete quality has been impacted due to fire (high temperature) and at other locations on the ground floor the concrete quality is in excellent condition.

e) The Core was also extracted from one of the front columns up to 250mm depth, which shows the concrete is affected up to the cover level only.

f) The pH of concrete is decreased to 9 at 1st floor.

g) The loose material should be removed and jacketing of columns can be done with micro concrete.

B. REPORT ON Indus Towers Ltd

1) Introduction: There is a communication tower erected over a Dharmshala building in Sector-4 Karnal. The tower is erected on the rooftop of the building using three main beams and one tie beam. Thus, non-destructive testing of the concrete element along with condition survey to assess the strength & quality of concrete by using Rebound Hammer Test and Ultra Sonic Pulse velocity test and to determine cover & details of reinforcement was obtained by using Ferro scanner. So, the inspection was arranged and the structure was inspected and tested for its existing strength and Quality on dated 25th of February 2018

2) Objective: The study involves a determination of in-situ strength and quality of concrete and reinforcement details of structural members under investigation. The specific objectives of the study are to know: NDT tests to assess the quality of concrete structures.

Figure 5 Beams nomenclature

Figure 6 Conducting Ferro scanning of Beam 4

Figure7 UPV test

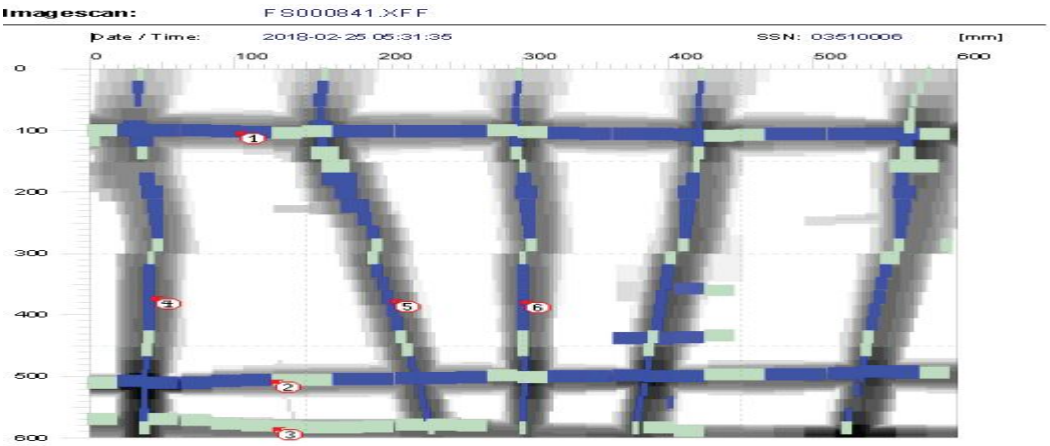

Figure 8 Ferro Scan Image Location Beam 1

This scan is of side face of the beam, on analysis, it shows that there are total 3 No of Rebars in this face of the beam. One top bar is of 20mm and two bottom bars of 20mm are provided. On scanning from the bottom, it shows 3 rebars of 20mm is provided.

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Marker:	x: [mm]	y: [mm]	Comment:
1	103	103	Diameter of rebar 20mm, cover 41mm, centre to centre distance between marker1 and marker 2 = 405mm
2	126	508	Diameter of rebar 20mm, cover 34mm,
3	129	588	Diameter of rebar 20mm, cover 33mm, centre to centre distance between marker 2 and marker 3 = 80mm
4	42	374	Diameter of rebar 8mm, cover 25mm, centre to centre distance between marker 4and marker 5 = 168mm
5	210	378	Diameter of rebar 8mm, cover 25mm, centre to centre distance between marker 5 and marker 6 = 98mm
6	300	379	Diameter of rebar 8mm, cover 25mm,

3) Results

TABLE-6 Ferro Scanning Result

Sr.no	Location	Reinforcement details
1	Beam 1 (towards the stairs)	3 bars on the face side and 3 bars on the bottom side of 20mm
2	Beam 2 (Central Tie beam)	2 bars on the face side and 3 bars on the bottom side of 20mm
3	Beam 3 (Side beam over the side wall of the building)	3 bars on the face side and 3 bars on the bottom side of 20mm
4	Beam 4 (near DG set)	3 bars on the face side (1 top bar is of 20mm & two bottom bars are of 16mm) 3 bars on the bottom side of 16mm

TABLE-7 Rebound hammer, UPV and Carbonation Test Result

Sr.no	Location	Avg RH value	UPV m/s	Compressive Strength N/mm^2
1.	Beam 1 (towards the stairs) Point-1	22,24,25.5,26,24,25=24.41	2244	16
2.	Beam 1 (towards the stairs) Point-2	25,25.5,24.5,23,21,22=23.5	2465	15
3.	Beam 2 (Tie beam) point-1	19,17.5,16,21,18,18=18.25	1230-ID	Less than 10
4.	Beam 2 (Tie beam) point-2	21,23,22,24,25,26=23.5	2156	15
5.	Beam 3 (Side beam towards the road) point-1	26,22,26,25,22.5,26=24.58	2474	16
6.	Beam 3 (Side beam towards the road) point-2	20,22,24,23,21,21.5=21.91	2125	13
7.	Beam 4 (near DG set) point-1	23,19,18,25,26,26=22.83	2163	14
8.	Beam 4 (near DG set) point-2	20,21,19,19,25,27=21.83	2223	13
9.	Column-1	21,18,19,20,21,21=20	1230-ID	10
10.	Column-2	22,21.5,21.5,22,21,22=21.61	1673-ID	13
11.	Column-3	21,19,19,25,24,24.5=22.03	1740-ID	13

4) Conclusions: Based on the investigation & study carried out by various members, the following conclusions are drawn:

a) The average relative strength of concrete varies from less than 10 to 16 N/mm^2 corresponding to the rebound hammer and ultra-sonic pulse velocity tests

b) The general quality of concrete is in the range of doubtful/Poor corresponding to the Ultrasonic Pulse Velocity test.

c) The output of Ferro scanning results is attached to the report.

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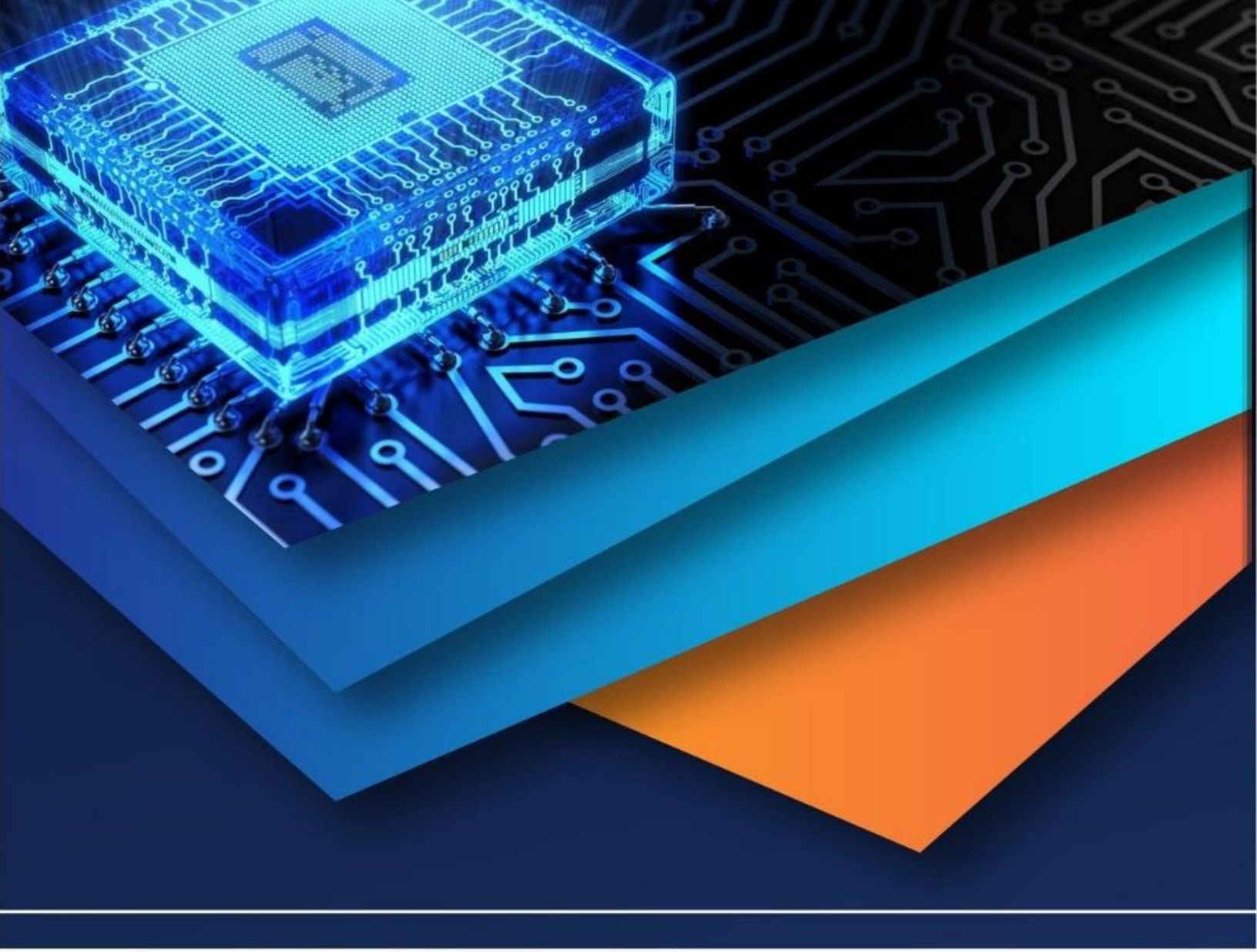

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