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Performance Assessment of Minor Bridge by NDT Testing Machine at Sant Narahari Maharaja Bridge near Amrut Garden Chowk Satpur, Nashik

Prof. Puneet Jain
[1]*Assistant Professor,*
Department of Civil Engineering,
Sandip Institute of Engineering and Management, Nashik –422010, Maharashtra,India.
[2] Suraj Vijay Pagare,[2] Shubham Kishor Shinde [3] Karansingh Pramod Patil[4],
Sandip Institute of Engineering and Management, Nashik –422010, Maharashtra,India.
Corresponding Author: Prof. Puneet Jain.

ABSTRACT
This project investigates the performance assessment of a minor bridge using a non-destructive testing (NDT) technique: the rebound hammer. Destructive testing is not always necessary or desirable when evaluating a structure's health. NDT methods offer a valuable alternative, allowing for targeted assessments without compromising the bridge's integrity. This project aims to explore the effectiveness of the rebound hammer in identifying potential deterioration within the concrete of a minor bridge.The research will focus on utilizing the rebound hammer to assess the in-situ strength and uniformity of the bridge's concrete. By analyzing the rebound values at various locations, the project will create a profile of the concrete's condition. This information will be crucial in determining the bridge's overall performance and identifying any areas that may require further investigation or repair.The focus on the rebound hammer acknowledges the technique's simplicity and widespread application. While this project employs a single NDT method, it emphasizes the potential of NDT for bridge assessments. The findings aim to contribute to the development of cost-effective and sustainable strategies for minor bridge maintenance.
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KEYWORDS: *Non-Destructive Testing (NDT), Rebound Hammer, Concrete, Bridge Performance Assessment, Minor Bridge.*

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I. INTRODUCTION

Many older bridges today experience traffic loads exceeding their original design capacity. This is primarily due to the significant increase in both traffic volume and vehicle weight. Bridges are designed for longevity, requiring engineers to anticipate future traffic demands. However, accurately predicting future traffic patterns is challenging, and often, the actual volume surpasses initial estimates.

As a result, reassessing the reliability of older, minor bridges for modern traffic loads is a crucial area of research. Non-destructive testing (NDT) offers a valuable tool for determining bridge condition, ultimately aiding decisions on repair or replacement. This project focuses on utilizing a specific NDT technique - the rebound hammer - for assessing the performance of minor bridges.

The rebound hammer offers a simple, portable method for evaluating the in-situ strength and uniformity of concrete within a bridge structure. By analyzing the rebound values at various locations, this project aims to create a profile of the concrete's condition. This information will be critical in determining the overall performance of the minor bridge and identifying any areas that may require further investigation or repair.

While this project employs a single NDT method, it emphasizes the potential of rebound hammers for cost-effective assessments of minor bridges. The findings aim to contribute to a better understanding of how NDT results can be interpreted and utilized for informed decision-making regarding bridge maintenance and repair strategies.

By focusing on these objectives, the project aims to demonstrate the applicability of the rebound hammer for cost-effective assessments of minor bridges in India. The findings will contribute to a better understanding of how NDT results, specifically those obtained using a rebound hammer, can be interpreted and utilized for informed decision-making regarding bridge maintenance and repair strategies.

some specific objectives of NDT testing on minor bridges in India:

Identify defects: NDT helps detect hidden flaws and defects in the bridge materials like concrete, steel, or wood. These defects can be cracks, delamination (separation of layers), corrosion, or voids (air pockets). Early detection of these defects allows for timely repairs and prevents bridge failures.

Evaluate strength and integrity: NDT techniques can be used to assess the strength and integrity of the bridge components. This information is vital for determining the load-carrying capacity of the bridge and ensuring it can handle the intended traffic.

Monitor deterioration: NDT testing can be used as a periodic health check for the bridge. By comparing NDT results over time, engineers can monitor the rate of deterioration of the bridge and plan for future maintenance or rehabilitation work.

Cost-effective maintenance: NDT is a relatively inexpensive way to assess bridge health compared to destructive testing methods. This allows for targeted repairs and maintenance, saving costs in the long run.

Following Indian Standards like IS: 1700 [Indian Standard 1700 - Code of Practice for Indian Standard Specifications for Grouting (Second Revision)] and IRC: SP 54 [IRC: Special Publication 54 - Guidelines for Non-Destructive Testing of Bridges] can help ensure proper procedures are followed during NDT testing of minor bridges in India.

II. LITERATURE REVIEW

India's extensive network of minor bridges plays a vital role in connecting communities and facilitating transportation. However, many of these bridges are aging and may not meet current safety standards due to factors like increased traffic loads or environmental wear. Destructive testing methods, while providing detailed information, can be expensive, time-consuming, and disrupt traffic flow. (Holický et al., 2013)

The field of civil engineering are not as innovative as other engineering and science fields. Despite this, we now live in a world where innovation is more important than ever considering the incoming future. The maintenance and improvement of existing infrastructure lacks investment and around the world you find failing infrastructure that are a risk to the society in many ways. With the increased population and the climate changes a lot of necessary changes needs to be done in the future and the governments are struggling a lot to fund and mandate the future. (Autodesk, n.d.)

Non-destructive testing (NDT) emerges as a valuable alternative for assessing the performance of minor bridges in India.

NDT techniques allow engineers to evaluate the condition of concrete within the bridge structure without causing any damage. This minimizes disruption to traffic and keeps project costs lower compared to destructive testing methods.

Here's how NDT aligns with current trends in bridge assessment:

Cost-Effectiveness: NDT offers a cost-efficient approach to bridge assessment, particularly for minor bridges where extensive testing may not be feasible.

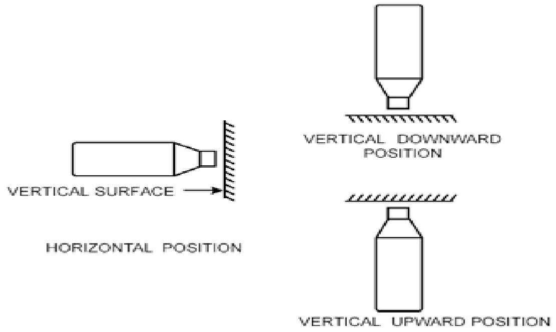
Sustainability: By extending the lifespan of existing bridges through informed repairs based on NDT results, we contribute to a more sustainable infrastructure system in India.

Minimal Disruption: NDT methods are generally quick and can be performed with minimal traffic flow interruption. This minimizes inconvenience for commuters and reduces overall project duration.

This project specifically focuses on the rebound hammer as an NDT technique for minor bridge assessments in India. The rebound hammer is a simple, portable tool that can be used to evaluate the in-situ strength and uniformity of concrete. The following sections will explore the rebound hammer in more detail and discuss other NDT methods that can be used in conjunction with it for a more comprehensive bridge assessment.

III. METHODOLOGY

Experimental methodology is on priority basis to testing the bridge strength, rebound hammer should be calibrated using a calibration test anvil supplied by the manufacturer for that purpose. The testing anvil should be of steel having Brinell hardness number of about 5000. For taking a measurement, the hammer should be held at right angles to the surface of the structure. The test thus can be conducted horizontally on vertical surface and vertically upwards or downwards on horizontal suraces.



(Source- Ayaz Mahmood, "Structural Health Monitoring Using Non Destructive Testing Of Concrete", 2008)

If the situation demands, the hammer can be held at intermediate angles also. The average of about 10 to 20 impacts would give an approximate indication as to the compressive strength of concrete at that location. The device is sensitive to a number of factors such as the surface finish, striking aggregate or mortar, the age, the moisture content and hardness, and these factors can influence the predicted strength concrete. Correlations of rebound number should be developed where possible with the compressive strength of concrete. The most satisfactory way of establishing a correlation between compressive strength of concrete and its rebound number is to measure both the properties simultaneously on concrete cubes. The concrete cubes specimens are held in a compression testing machine under a fixed load, measurements of rebound number taken and then the compressive strength determined as per IS 516: 1959. The fixed load required is of the order of 7 N/ mm2 when the impact energy of the hammer is about 2.2 Nm. The load should be increased for calibrating rebound hammers of greater impact energy and decreased for calibrating rebound hammers of lesser impact energy. Only the vertical faces of the cubes as cast should be tested. At least nine readings should be taken on each of the two vertical faces

accessible in the compression testing machine when using the rebound hammers. D. Interpretation of results: After obtaining the correlation between compressive strength and rebound number, the strength of structure can be assessed. In general, the rebound number increases as the strength increases and is also affected by a number of parameters i.e. type of cement, type of aggregate, surface condition and moisture content of the concrete, curing and age of concrete, carbonation of concrete surface etc. Moreover the rebound index is indicative of compressive strength of concrete up to a limited depth from the surface. The internal cracks, flaws etc. or heterogeneity across the cross section will not be indicated by rebound numbers. As such the estimation of strength of concrete by rebound hammer method cannot be held to be very accurate and probable accuracy of prediction of concrete strength in a structure is ± 25 percent.

Field Testing

The field testing phase will involve applying the rebound hammer on a selected minor bridge in India.

Bridge Selection: A minor bridge representative of typical bridge construction in India will be chosen for field testing. Factors like bridge age, material type, and traffic volume will be considered during selection.

Visual Inspection: A thorough visual inspection of the bridge will be conducted to identify any visible signs of deterioration such as cracks, spalling, or delamination. This information will be documented and used for comparison with the rebound hammer results.

Rebound Hammer Testing: The rebound hammer test will be performed on various pre-defined locations across the bridge deck surface. The locations will be chosen to ensure a representative coverage of the entire bridge area.

Data Collection: Rebound hammer readings, along with details like the test location and any observations about the concrete surface condition, will be meticulously recorded.

Data Analysis and Interpretation:

The collected field data on rebound hammer readings will be analyzed in conjunction with the established calibration curve (developed in phase 1) to estimate the in-situ compressive strength of the concrete at various test locations on the bridge.

The estimated compressive strength values will be evaluated to assess the overall health and uniformity of the concrete within the bridge deck.

The results from the visual inspection will be compared with the NDT findings to create a comprehensive picture of the bridge's condition.

IV. EXPERIMENTAL STUDY

4.1 Introduction

Equipment

The rebound hammer

(such as the Schmidt Hammer) is a simple, handy tool which is used to measure the hardness and predict the strength of the concrete. This is a spring-loaded impacting device that incorporates a scale to measure the energy of the rebound following the impact. The extent of rebound gives an indication of the strength of the concrete at the surface position tested.

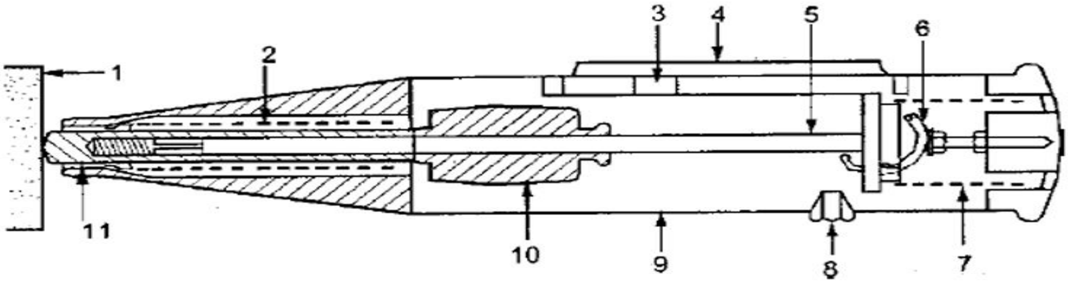


Fig. 4.1 CROSS SECTION OF REBOUND HAMMER TEST

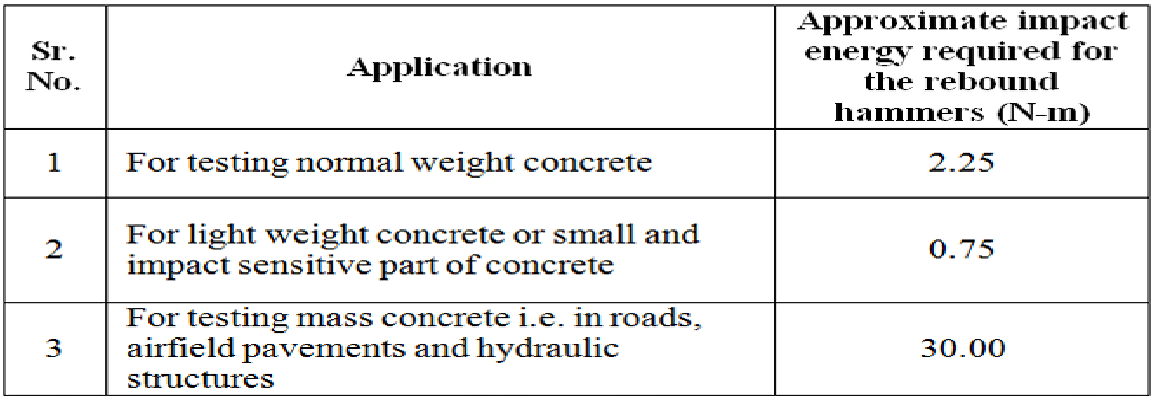
1. Concrete surface;
2. Impact spring;
3. Rider on guide rod;
4. Window and scale;
5. Hammer guide;
6. Release catch;
7. Compressive spring
8. Locking button;
9. Housing;
10. Hammer mass;
11. Plunger

Fig 1: Components of a Rebound Hammer (Source- Guidelines on Non-Destructive Testing of Bridges, August, 2009, Government of India)

A. Objective: The rebound hammer method could be used for – (a) Assessing the likely compressive strength of concrete with the help of suitable co-relations between rebound index and compressive strength. (b) Assessing the uniformity of concrete. (c) Assessing the quality of concrete in relation to standard requirements. (d) Assessing the quality of one element of concrete in relation to another.

B. Principle: The method is based on the principle that the rebound of an elastic mass depends on the hardness of the surface against which mass strikes. When the plunger of rebound hammer is pressed against the surface of the concrete, the spring controlled mass rebounds and the extent of such rebound depends upon the surface hardness of concrete. The surface hardness and therefore the rebound are taken to be related to the compressive strength of the concrete. The rebound value is read off along a graduated scale and is designated as the rebound number or rebound index. The compressive strength can be read directly from the graph provided on the body of the hammer. TABLE I: The impact energy required for rebound hammer for different applications (Source-Guidelines on Non-Destructive Testing of Bridges, August, 2009, Government of India)

TABLE 4.1 PARAMETERS OF IMPACT ENERGY BY HAMMER



Sr. No.	Application	Approximate impact energy required for the rebound hammers (N-m)
1	For testing normal weight concrete	2.25
2	For light weight concrete or small and impact sensitive part of concrete	0.75
3	For testing mass concrete i.e. in roads, airfield pavements and hydraulic structures	30.00

3.3. Influencing Factors of Rebound Hammer Test
The various factors influencing Rebound Hammer Test include the following:
Type of Aggregate
Type of Cement
Surface and moisture condition of the concrete
Curing and Age of concrete
Carbonation of concrete surface

1. **Type of Aggregate:**
The correlation between concrete compressive strength and the rebound number varies with different aggregates, with normal correlations established for common aggregates like gravels and crushed aggregates. Testing lightweight aggregates requires special calibration.

2. **Type of Cement:**
Concrete made with high alumina cement is expected to exhibit higher compressive strength than Ordinary Portland Cement (OPC). However, the use of supersulphated cement decreases compressive strength by 50% compared to OPC.

3. **Type of Surface and Moisture Condition:**
The rebound hammer test is more effective for close-textured concrete than for open-textured concrete. High honeycomb or no-fines concrete is unsuitable for testing. Strength is overestimated on floated or trowelled surfaces compared to moulded surfaces. Testing wet concrete surfaces results in lower strength values, potentially underestimating strength by up to 20% compared to dry concrete.

4. **Type of Curing and Age of Concrete:**
The relationship between concrete strength and hardness changes over time. Curing conditions and moisture exposure affect this relationship, with concrete aged between 3 days to 90 days exempted from age-related effects. Special calibrated curves are necessary for older concrete.

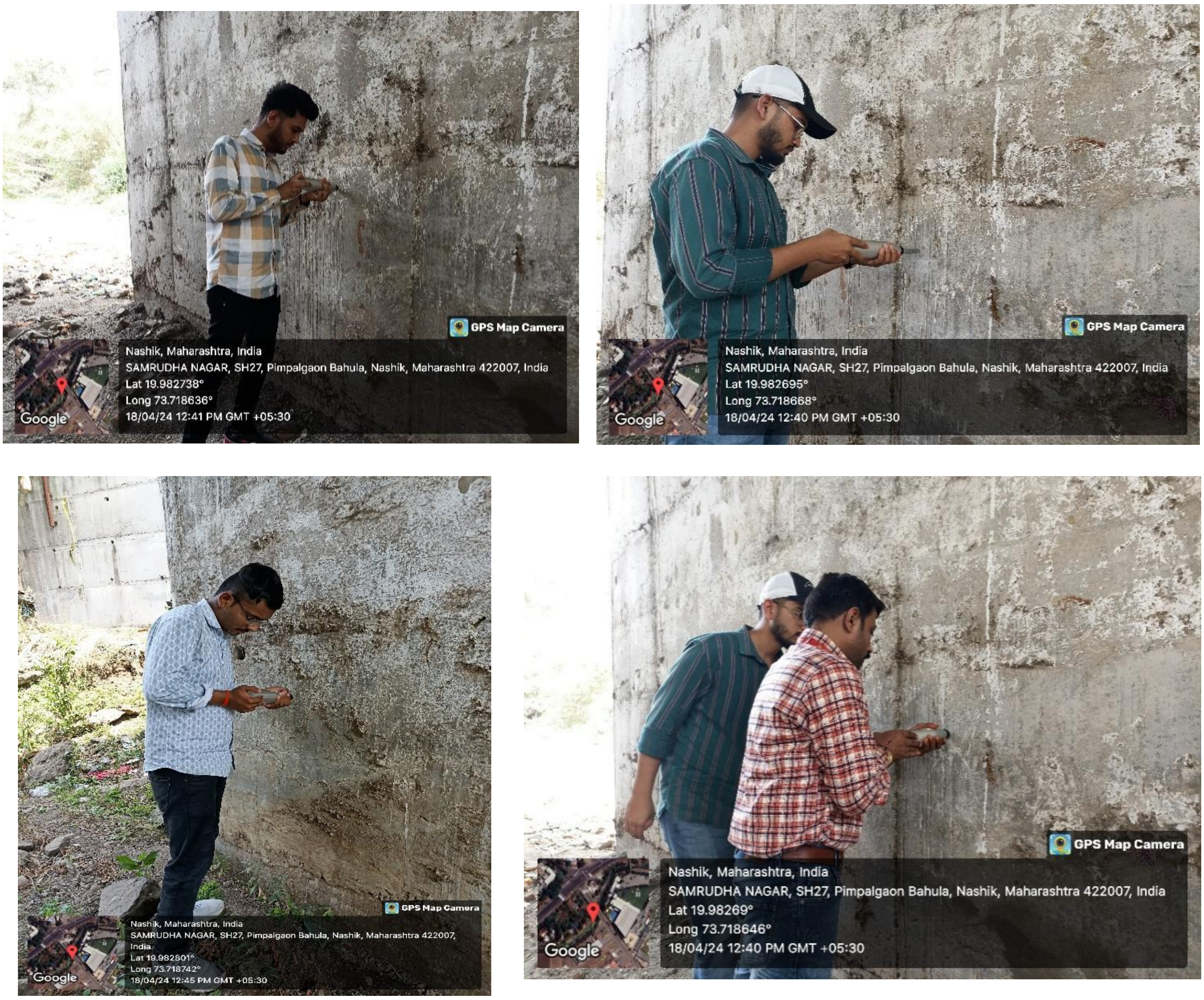
5. **Carbonation on Concrete Surface:**
Rebound hammer tests on carbonated concrete surfaces estimate higher strength (approximately 50%). Testing should be conducted on the non-carbonated layer after removing the carbonated layer to obtain accurate results.

V. RESULT AND DISCUSSION

Rebound Hammer Test:

The procedure for the rebound hammer test on a concrete structure commences with the calibration of the rebound hammer. Once calibrated, the rebound hammer is positioned perpendicular to the surface of the concrete structure to capture readings. The test can be performed horizontally on a vertical surface or vertically upwards or downwards on horizontal surfaces.

Holding the rebound hammer at an intermediate angle will yield different rebound numbers for the same concrete. **Fig 5.1 shows Testing Location of Rebound Hammer Site with GPS Coordinates.**



3.5. Some Important Considerations in Rebound Hammer Test

The important points to note while performing the Rebuild hammer Test are:
Ensure the concrete surface is smooth, clean, and dry.
Use a grinding wheel or stone to remove any loose particles from the concrete surface before conducting the rebound hammer test.
Avoid testing on rough surfaces due to incomplete compaction, loss of grout, or spalled and tooled concrete surfaces.
Maintain a minimum distance of 20 mm between the point of impact of the rebound hammer and any edges or shape discontinuities on the concrete surface.
Take six readings of the rebound number at each testing point and calculate the average value as the rebound index for the corresponding observation point on the concrete surface.

3.6. Impact Energy for Rebound Hammers for Different Applications (IS: 13311(2)-1992)
The impact energy for Rebound Hammer for variegated applications is mentioned in the table below:

Sl.No	**Applications**	**Approximate Impact Energy for Rebound Hammer in Nm**
1	**For Normal Weight Concrete**	**2.25**
2	**For light weight concrete / For small and impact resistive concrete parts**	**0.75**
3	**For mass concrete testing Eg: In roads, hydraulic structures and pavements**	**30.00**

3.7. Quality of Concrete Corresponding to different Rebound Number

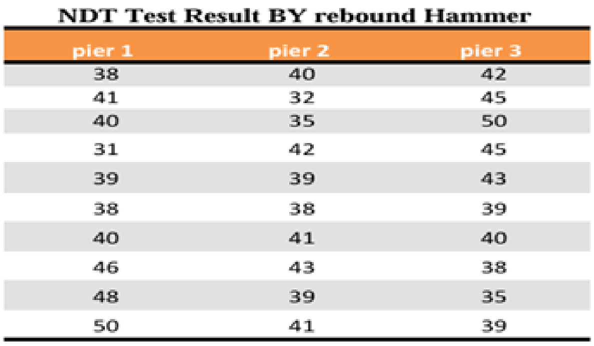
Average Rebound Number	**Quality of Concrete**
>40	**Very good hard layer**
30 - 40	**Good layer**
20 - 30	**Fair**
<20	**Poor**
0	**Delaminated**

Results:

Comparing Two Sample Variations' Rebound NumbersIt is reported that three findings were significant following an 80–114 day exposure of certain samples to brackish water:The following three things happened: a) the concrete surface became somewhat rough, which greatly reduced the smooth finish that came from using Formicaboard; b) the presence of salts and silt-like particles in the brackish water caused the change in surface smoothness; and c) despite the surface being air-dried for 24 hours before the rebound hammer test, the samples were still partially saturated with brackish water in their interior.

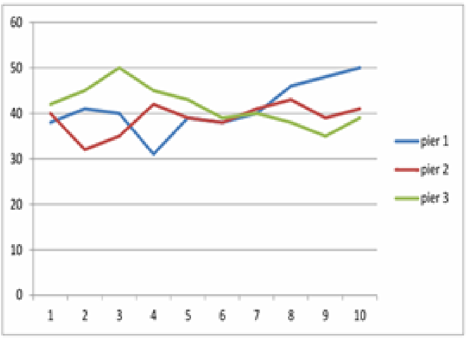
These findings are significant because surface roughness and sample moisture content have been shown to influence surface hardness and, in turn, the rebound number produced by the rebound hammer.The average rebound numbers (RN) for each pair of sample variations are compared in Table 1. The statistical t-test for two independent observations was used to do the comparison. The comparison was done to see if the type of environment the samples were exposed to had an impact on the rebound reading. The alternative hypothesis is that there is a substantial difference between the two groups' average relative neutron (RN) values. This is the null hypothesis. The degree of significance and p-value were evaluated in order to determine which hypothesis was most likely to be true given the available data.

When concrete cubes are exposed to brackish water, their rebound values are much lower than when samples are kept in a typical environment with a relative humidity of 75%. However, there is no discernible difference in the average rebound readings between the samples submerged in brackish water and those subjected to cycles of alternating drying and soaking in the brackish water. It is reasonable to assume that neither the experimental setup nor the duration of exposure to brackish water were adequate to significantly alter the bound reading. The study did not take into account real maritime circumstances, such as the existence of waves and dramatic temperature swings for concrete in the tidal zone.



NDT Test Result BY rebound Hammer

pier 1	pier 2	pier 3
38	40	42
41	32	45
40	35	50
31	42	45
39	39	43
38	38	39
40	41	40
46	43	38
48	39	35
50	41	39



VI. Discussion and Recommendation:

When the rebound number was plotted against the actual compressive strength of concrete, the data showed a high dispersion, which consistently supported earlier findings that the surface hardness of concrete is affected by several factors, including temperature, age, surface smoothness, moisture content, and carbonation. Therefore, measuring the real compressive strength of concrete cannot be done instead of using the Schmidt Hammer Test.The study also demonstrates that one element influencing concrete's compressive strength is the kind of environment it is exposed to. While it is not possible to obtain an exact measurement of the compressive strength of concrete using a Schmidt Hammer Test that utilises the rebound curve supplied by the apparatus manufacturer, it is dependable in determining a decrease or rise in changes the intensity caused by differences in the sample. The study also demonstrates that the rebound curve provided by the manufacturer typically underestimates the concrete's true compressive strength. Therefore, judgements on the safety and continued use of in-situ concrete based on the rebound curve provided by the manufacturer are cautious and generally trustworthy.

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