Structural Health Monitoring of Bridge using Non-Destructive Technique

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ABSTRACT-

Structures are a combination of various load carrying members which transfer the loads to the foundation from the superstructure safely. At the design stage, the loading of the structure is defined and appropriate material choices are made based on their properties. However, the structure deteriorated over the passage of time because of some factors like material aging due to environmental conditions and service loads and due to unpredictable external loads i.e. earthquakes, wind and impact etc. which cannot be avoided.

Consequently, structural failure includes loss of life and economic damage. In recent years, the collapse and failures of various structure increases the concern about structure integrity, durability and reliability. For example, over one half of 690,000 bridges on the federal highway system in US are more than 50 years old and over one third are structurally and functionally obsolete and about 5 billion is spent annually on bridge rehabilitation.

It was observed that the result given by one method did not confirm the result given by other method. Hence, it is difficult to decide the correct value of strength of material. In the present study an attempt has been made to correlate the strength obtained by rebound hammer, penetration resistance and ultrasonic pulse velocity method.

Keyword: ANN, NDT, Bridge, Rebound Hammer, Regression, Penetration.

I. Introduction

A structure should meet the requirement of safety, durability, serviceability and sustainability for a long-term operation. The performance of a structure deteriorated with the passage of time for its whole life. This deterioration is mainly because of damages due to material aging, environmental conditions and change in nature of service load. This causes catastrophic structural failures which include loss of life and economic disruption. The structural health monitoring technology provides a way to evaluate the safety and durability of a structure during its service life, to ensure its serviceability and sustainability. With increasing number of collapses in major infrastructures, structural health monitoring (SHM) becomes significantly important. To keep a high level of structural safety, durability and performance of the infrastructure in each country, an efficient system for early and regular structural assessment is urgently required. The various important structures like bridges, nuclear plants need regular inspection and testing with reliable technologies. Nondestructive testing (NDT) methods have a large potential to be part of such a technology. A variety of advanced NDT methods have been developed and are available for investigating and evaluating the different parameters related to strength, durability and overall quality of concrete. Each method has its own merits and demerits. Therefore, more than one method generally used in combination so that the strength of one compensates the weakness of other.

II. Objective

In view of the relative limitations, of any one of the methods for predicting the strength and quality of concrete, use of more than one i.e. Ultrasonic pulse velocity (UPV), rebound hammer and Windsor’s probe penetration methods was made in combination to compensate the errors arising out of influence of materials, concrete mix and environmental parameters on the respective measurements. Better accuracy of the estimation of concrete strength is achieved by use of such combined methods. Combination of UPV and rebound hammer methods can be used for the assessment of the quality and likely compressive strength of in-situ concrete. Similarly, other combination can also be used for predicting strength and quality of concrete. In the present study, the correlation between the predicted strength and strength obtained from various Non-Destructive Test equipment’s has been established, so that a more accurate value of predicted strength could be obtained.
III. Experimental work

Materials:

Concrete: As per the batch on construction site.

Compressive Strength Test:

Compressive strength was calculated through proper procedure with cube size 150*150*150 mm and is cured for 7 and 28 days before testing.

Non-Destructive Test: Test like Ultrasonic Velocity, Rebound Hammer, Windsor probe Penetration.

IV. Results & Discussion

NDT:

<table>
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<tr>
<th>Cube No.</th>
<th>Rebound No.</th>
<th>Penetration Depth (mm)</th>
<th>Pulse Velocity (Km/s)</th>
<th>Compressive Strength using CTM</th>
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<tbody>
<tr>
<td>1</td>
<td>26</td>
<td>4.02</td>
<td>4.918</td>
<td>32.31</td>
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<td>2</td>
<td>38.25</td>
<td>2.49</td>
<td>4.688</td>
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V. Analytical study

Relationship between Rebound and Actual Compressive Strength using CTM
Relationship between Probe Penetration Depth and Actual Compressive Strength using CTM

![Graph showing the relationship between probe penetration depth and actual compressive strength using CTM.](image)

Relationship between Pulse Velocity and Actual Compressive Strength using CTM

![Graph showing the relationship between pulse velocity and actual compressive strength using CTM.](image)

Comparison between predicted compressive strength by regression and actual compressive strength using CTM based on Rebound Number

![Graph comparing predicted compressive strength by rebound hammer using regression with actual compressive strength using CTM.](image)
Comparison between predicted compressive strength by ANN and actual compressive strength using CTM based on Rebound Number

Comparison between predicted compressive strength by regression and actual compressive strength using CTM based on probe penetration depth

Comparison between predicted compressive strength by regression and actual strength based on pulse velocity
Comparison between predicted strength by ANN and actual strength using CTM based on pulse velocity

![Graph 1: Predicted vs Actual Strength](image1)

Predicted Comparison by regression and actual strength using CTM based on pulse velocity

![Graph 2: Predicted vs Actual Strength](image2)

ANN Predicted compressive strength by combined model of rebound number and penetration depth

![Graph 3: Predicted vs Actual Strength](image3)
VI. Conclusion

In the present study, Correlation has been developed for single and multiple NDT parameters with actual compressive strength by regression and ANN model. The following conclusions have been made:

- In case of single NDT technique, it was found that the prediction of strength using rebound hammer was more suitable which makes engineering judgment quite easy. The use of the rebound hammer methods yields more reliable and closer results to the actual strength with high coefficient of determination and %age root mean square error for regression and ANN was found 15.861 and 16.720 respectively.

- An acceptable level of accuracy was achieved for strength estimation of concrete using Windsor’ probe penetration method but it is not recommended to be used alone to predict strength of concrete.

- It has been observed that Ultra sonic pulse velocity method can’t be used as alone for prediction of strength, which shows worst relationship between predicted strength and actual strength. This could be explained of the fact that the pulse velocity is most affected by concrete composition in comparison to other NDT 114 method. However, in the present study, the strength has been predicted by ANN. The formula used for the prediction of strength represents a good correlation between pulse velocity and compressive strength and could be used to predict the strength. The percentage root mean square error is 14.349 and 12.758 by regression and ANN model respectively.

- A combined model developed in ANN by using inputs from rebound hammer as well as penetration predicts more accurately in comparison to prediction made by model having input from single NDT techniques. The %age root mean square error was found 3.240 and 3.144 by regression and ANN model respectively.

- The developed equations in the present study for different NDT techniques could be used to predict more accurate results.

References


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