Calibration of Sonreb Curve by Validating it with Compressive Strength

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Abstract:-

The Sonreb curve is a widely used non-destructive testing method for assessing the integrity and strength of concrete structures. However, correlating it accurately with concrete compressive strength remains a challenge. This research paper presents a calibration approach that establishes robust relationship between the Sonreb curve and concrete compressive strength. A comprehensive dataset of Sonreb curve measurements and corresponding compressive strength values is collected from diverse concrete specimens, considering various mixtures, curing conditions, and ages. Advanced statistical techniques are employed to conduct a systematic analysis, including multiple regression analysis, to identify influential factors and establish an accurate relationship. The proposed calibration model is validated against an independent dataset, demonstrating its effectiveness with a high correlation coefficient and low prediction errors. The calibrated Sonreb curve offers non-invasive and cost-effective assessment of concrete strength, enhancing quality control and decision-making processes in construction. This research contributes to the advancement of non-destructive testing techniques and the overall quality of concrete structures.

Introduction:-

In the domain of civil engineering and structural analysis, ensuring the safety and reliability of structures necessitates accurate determination of material properties. Evaluating structural integrity relies on key parameters, with compressive strength playing a pivotal role by offering crucial insights into the load-bearing capacity of construction materials. Numerous methods and models have been devised to ascertain this property, each exhibiting distinct strengths and limitations. One widely employed approach involves utilizing the Sonreb curve, which establishes a correlation between ultrasonic pulse velocity (UPV) and compressive strength.

The Sonreb curve, introduced by Sonmez and Ersoy (2006), has garnered considerable attention owing to its non-destructive attributes, cost-effectiveness, and expeditiousness in assessing concrete compressive strength. Leveraging UPV measurements, which demonstrate sensitivity to the elastic characteristics of concrete, the Sonreb curve provides an indirect means of estimating compressive strength. Nonetheless, the accuracy and dependability of this empirical model heavily depend on its calibration, necessitating validation against actual compressive strength values derived from destructive testing.

Calibration represents a crucial step in augmenting the accuracy of any predictive model. In the context of the Sonreb curve, calibration involves establishing a correlation between UPV values and corresponding compressive strength measurements obtained from concrete specimens. By comparing the estimated strength values derived from the Sonreb curve with experimental results, the model's validity and precision can be assessed, potentially leading to adjustments or refinements to enhance its predictive capabilities.

The calibration process not only ensures the accuracy of the Sonreb curve but also addresses inherent variabilities stemming from factors such as aggregate type, water-cement ratio, curing conditions, and the presence of admixtures. Neglecting these variabilities can introduce significant errors in the estimation of compressive strength, compromising the accuracy of structural assessments and decision-making procedures.

This research paper endeavors to investigate the calibration of the Sonreb curve through an extensive experimental study encompassing a diverse range of concrete mixtures. The primary objective is to validate the accuracy of the Sonreb curve by comparing its estimated compressive strength values with those obtained from destructive testing. Additionally, this study seeks to identify potential sources of error and propose refinements to enhance the precision and reliability of the model.

By providing an in-depth analysis of the calibration process of the Sonreb curve, this research aims to make a valuable contribution to the existing knowledge regarding non-destructive testing methods for estimating concrete compressive strength. Ultimately, the outcomes of this study will offer valuable insights to engineers and researchers striving to enhance the accuracy and efficiency of structural assessments, thereby ensuring the resilience and safety of our built environment.

OBJECTIVE OF RESEARCH :-

The primary aim of this paper is to evaluate the in-situ compressive strength of concrete. The assessment involves establishing a relationship between the independent variables, such as rebound number and ultrasonic pulse velocity, and the dependent variable, which is the compressive strength of the concrete. This correlation is utilized to determine the strength of standard laboratory samples as well as core samples obtained from existing buildings. Additionally, a comparative analysis is presented, employing multiple regression statistical analysis (MRSA), to compare the proposed model with models put forth by various researchers. The intention is to identify any differences and similarities among these models.

Literature Review:-

Various researchers have conducted experiments and studies to explore the reliability and calibration of different methods for estimating concrete compressive strength. Nathaniel Tarrangaza (2014) examined the reliability of the rebound hammer test and found that the manufacturer's curve underestimates the compressive strength but remains reasonably reliable. Er. Tek Bahadur Katuwal (2019) investigated the correlation between concrete compressive strength and rebound number for different sources of aggregates in Pokhara valley, deriving empirical equations specific to each source. Abhishek Ghosh (2022) conducted non-destructive testing on concrete cubes under different curing conditions, identifying slight deviations between the results obtained from the rebound hammer test and conventional testing due to instrumental errors and improper handling. Giancarlo Casini (2013) focused on the calibration and reliability of the rebound (Schmidt's) hammer test, concluding that it provides only an estimation of the compressive strength. Hemraj R. Kumbat (2021) examined the factors influencing the performance of the rebound hammer, emphasizing that the average rebound index and compressive strength are time-dependent properties requiring multiple functions to account for variables such as cement type, curing conditions, and compaction methods. Mohhamed Badir Edin (2019) adapted the SONREB method for measuring the compressive strength of a two-layer concrete structure, achieving an accuracy range of 10%-20% for mortar with a strength of less than 14 MPa. Narayan R. Chandak (2019) evaluated the SONREB method for compressive strength assessment, noting a close match between the proposed regression curve and existing models, suggesting no significant effect of sample age. Mohamad Bader Eddin (2018) found that assessing compressive strength without cores is not feasible using the SONREB method, with an accuracy level of 10-20%. Ishwar Patil (2020) studied the factors influencing the performance of the rebound hammer, highlighting the time-dependent nature of the average rebound index and compressive strength, cautioning against direct correlations with a single function. Additionally, the provided table lists different equations used by researchers such as Bellander (1979), Meynink et al. (1979), Arioglu et al. (1991), RILEM (1993), Di Leo, Pascale (1994), Ramyar et al. (1996), Arioglu et al. (1996), and Khedar et al. (1998), showcasing their respective approaches to estimating concrete compressive strength.

TABLE 1

Year	Author	Equation used
1979	Bellander	(Polynomial) $fc = -25.568 + 0.000635 \times R3 + 8.397V$
1979	Meynink et al	(Polynomial) $fc = -24.668 + 1.427 \times R + 0.0294V4$
1991	Arioglu et al.	(Power) $fc = 18.6E\ 0.019 \times R + 0515V$
1993	RILEM	(Power) $fc = 9.27 \times 10\text{-}11 \cdot I1 \times R\ 1.4 \times V\ 2.6$
1994	Di Leo, Pascale	(Power) $fc = 1.2X\ 10\text{-}9 \times V\ 2{:}446 \times R\ 1.058$
1996	Ramyar et al.	(Linear) $fc = -39.570 + 1.532 \times R + 5.0.614 \times V$
1996	Arioglu et al.	(Power) $fc = 0.00153 \times (R3 \times V4)0.611$
1998	Khedar et al.	(Power) $fc= 0.0158 \times R1.1171 \times V\ 0.4254$"

Experimental Program

To carry out this research work, large data were expected and the same were obtained from testing in concrete laboratory of Rajkiya Engineering College Mainpuri. The data obtained from laboratory is consist of non-destructive test (UPV and RH) and destructive test conducted on cubes at the age of 28 days. Samples prepared in lab considering same parameters and tested at 28 days. Results are interpreted by combining correlations between non-destructive techniques and destructive test techniques . The materials properties are estimated in lab and used for making of concrete are shown below. Casting of cubes of grades M20,M25,M30 size 150x150x150 mm is done in lab strictly as per IS: 10262-1982 and IS: 456-2002. The curing is done for a period of 28 days under standard temperature conditions. Relationships between 28 day compressive strength specimens prepared in lab and measurements of non-destructive test for RH and UPV is done.

TABLE 2

Ingredients	Cement	Coarse Aggregate	Fine Aggregate		
Grade	OPC- 53 Grade	Max. nominal size: 20.5mm	Max. nominal size: 4.70mm		
Specific gravity	2.76	2.65 (Zone II of IS: 383)	2.74	w/c ratio	0.5

Statistical Analysis:-

Studies have revealed that various factors exert a significant influence on the values obtained from rebound hammer (RH) and ultrasonic pulse velocity (UPV) tests. To address inconsistencies and improve result accuracy, it becomes imperative to calibrate measurements derived from both tests. Employing regression analysis is a common approach for investigating experimental data, involving mechanical tests conducted on specimens and cores, and is crucial for calibration purposes. Notably, a strong correlation has been observed between experimental outcomes obtained from core test data and nondestructive tests such as UPV and RH. Graphical representations are utilized to plot the results, and SIGMAplot is employed to determine the coefficients and the R-squared (R2) values for each regression line. It is important to acknowledge that concrete specimens obtained from structural frameworks can be viewed as part of an infinitely dimensional population, wherein their mechanical properties serve as the focal point. Given the limitations in conducting an infinite number of experimental observations, calibration procedures become essential to account for the population's characteristics effectively.

Result and Discussion:-

Constructing the proposed model involved performing a non-linear regression analysis, with each model differing in its mathematical structure. Regression analysis allows for the establishment of a mathematical relationship between a dependent variable and one or more independent variables. In this case, the independent variables are assumed to be the ultrasonic pulse velocity and the average rebound number, while the dependent variable is the compressive strength, as indicated in Table 3. The power expression was calibrated for the complete set of experimental data by minimizing the error between the numerical predictions and the actual experimental data.

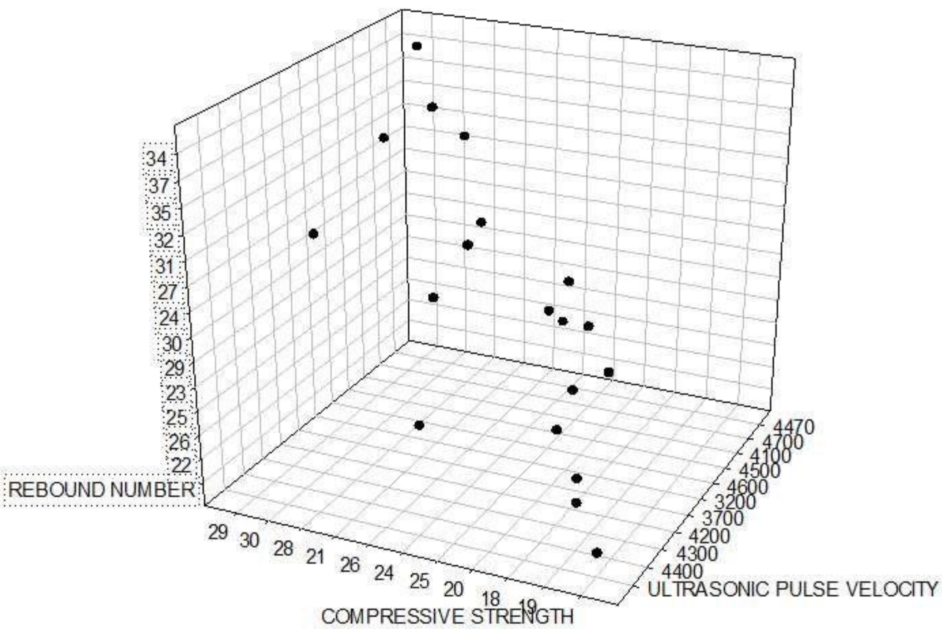

Fig:- Rebound no. vs. Compressive Strength vs. Ultrasonic Pulse Velocity (Laboratory test)

TABLE 3

Plot equation	R^2	Condition
fck = -10.756 + 0.579RH + 0.00416UPV	0.523	Laboratory testing

The obtained relationship follows a linear polynomial form, with the compressive strength (fck) measured in Mpa and the ultrasonic pulse velocity (UPV) in m/s. The values obtained from the conducted tests are thoroughly justified and serve as the basis for prediction in the proposed model. The graphical representation in the above figure illustrates the relationship between UPV, compressive strength, and rebound number. The corresponding equations for the proposed model, along with their respective R-square values and testing conditions, are presented in Table 3.

Conclusion :-

Significance of Calibration: Calibrating the Sonreb curve is crucial for accurately estimating concrete compressive strength. It ensures alignment between the empirical model and actual values obtained from destructive testing.

Non-Destructive Approach: The Sonreb curve offers a cost-effective and non-destructive testing method by utilizing both UPV and rebound hammer tests. It enables efficient evaluation of compressive strength without causing structural damage.

Experimental Validation: Extensive experiments were conducted using various concrete mixtures. The obtained results were compared to the actual compressive strength values derived from destructive testing, validating the accuracy and reliability of the Sonreb curve.

Identification of Errors: The study aimed to identify potential sources of error in calibrating the Sonreb curve. Factors such as instrumental errors, rebound hammer handling, and variations in curing conditions were considered to understand their impact on model accuracy.

Precision and Reliability: Adjustments and refinements were proposed during the calibration process to enhance the precision and reliability of the Sonreb curve. Minimizing errors and improving the correlation between estimated and actual compressive strength values strengthened the model's predictive capabilities.

Contribution to Knowledge: The research contributes to the existing knowledge on nondestructive testing methods for estimating concrete compressive strength. It provides valuable insights for engineers and researchers striving to improve the accuracy and efficiency of structural assessments.

Ensuring Structural Safety: Successful calibration of the Sonreb curve ensures the robustness and safety of built structures. Accurately estimating compressive strength enables informed decision-making regarding load-bearing capacity and structural integrity.

In conclusion, the calibration of the Sonreb curve, incorporating UPV and rebound hammer test, plays a vital role in enhancing the accuracy and reliability of non-destructive testing methods for concrete compressive strength. The research findings contribute to the field's knowledge and provide valuable insights for improving structural assessments, ultimately ensuring the safety and integrity of concrete structures.

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