Asian Journal of Science, Engineering and Technology (AJSET)
eISSN: 3006-6980 (online)
https://ideapublishers.org/index.php/ajset
Vol. 5, No. 1 (January-December), 2026, pp. 49-57
https://doi.org/10.47264/idea.ajset/5.1.5
Original Research Article

Destructive and non-destructive testing of locally sourced concrete in Pakistan

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Article History

Received:
02-Oct-2025

Revised:
23-Dec-2025

Re-revised:
11-Mar-2026

Accepted:
12-Mar-2026

Published:
31-Mar-2026

Abstract:

Assessing concrete's compressive strength is crucial in all phases of construction for structural safety, especially when using local materials that may vary in quality and composition. This study aims to experimentally demonstrate the destructive (DT) and nondestructive testing (NDT) methods for evaluating the strength of locally sourced M15-grade concrete in Pakistan. Concrete cubes (n=50, 1:2:4 mix, w/c = 0.6) were tested for strength after 28 days of curing. The NDT involved using the Schmidt Rebound Hammer in vertical and horizontal orientations, while DT was performed using a cube compression testing machine. Regression analysis revealed a positive correlation between rebound numbers and compressive strength, with cubic models providing the highest predictive accuracy for both the vertical and horizontal orientations. Such models provide the base for practical field-level strength estimation using NDT. Further, paired t-test analysis showed no statistically significant difference ($P<0.05$) between predicted and measured strengths, supporting the reliability of the developed calibration equations. Overall, these calibration equations will offer a rapid and practical NDT approach for estimating in-situ concrete strength, enabling field engineers and quality-control teams to make quicker and more reliable decisions in local construction projects.

Keywords: Schmidt rebound hammer, Non-destructive testing, In-situ strength assessment, Compressive strength, Quality control in concrete.

How to Cite: Munir, M. M., Rehman, H. S. U., Hanan, A., Rehman, M. U., Munawar, A. A. (2026). Destructive and non-destructive testing of locally sourced concrete in Pakistan. *Asian Journal of Science, Engineering and Technology (AJSET), 5*(1), 49-57. https://doi.org/10.47264/idea.ajset/5.1.5

1. Introduction

Concrete is an essential building material in modern infrastructure and plays a pivotal role in ensuring the durability and structural integrity of constructions worldwide. In developing countries like Pakistan, the demand for economical yet resilient construction solutions are always high; therefore, optimization of concrete strength is a significant aspect (Sultan *et al.,* 2023). Concrete's strength is not only a critical determinant of load-bearing capacity but also a primary indicator of its quality and longevity. However, due to different environmental and climatic conditions across Pakistan, the factors influencing concrete strength can vary, necessitating a localized approach to its assessment and optimization (Kim *et al.,* 2015; Sultan *et al.,* 2023).

The compressive strength of concrete is traditionally tested using destructive tests (DT) on cubes with specific dimensions and made on site on the day of laying the concrete mix according to EN 12390-2 (Ivanchev, 2022). The DT involves subjecting samples to stress until failure; therefore, they provide precise and direct measurements of the maximum load-bearing capacity of the material. However, they are expensive, labor-intensive, and less practical for *in-situ* assessments due to the permanent damage inflicted on samples, which is particularly unsuitable for existing structures where preservation is required (Raj and Pedram, 2015; Ivanchev, 2022).

On the other hand, nondestructive testing (NDT) methods, such as the ultrasonic pulse velocity test and Schmidt Rebound Hammer test (SRHT), estimate concrete strength without compromising its structural integrity (Alharthy, 2021; Ivanchev, 2022). They are known to be simpler, faster, more economical, and easily adaptable to the field (Munir et al., 2018); consequently, they are often used for quality control, on-site assessments, and periodic evaluations of aging infrastructure. Various studies from Pakistan have reported the use of NDT for testing the strength and quality of concrete and brick structures (Munir et al., 2018; Shah et al., 2023; Azam et al., 2022).

Concrete is a non-homogeneous material; therefore, a unique assessment model for all concrete types does not exist. This challenge is evident in the complex construction landscape of Pakistan, where the concrete strength assessment needs to be adapted to locally sourced materials and region-specific construction practices (Munir *et al.,* 2018; Azam *et al.,* 2022). As the accuracy of compressive strength testing methods can be affected by material composition, aggregate type, and local environmental factors, it often requires calibration of NDT with DT results for reliable application (Vasanelli *et al.,* 2017; Raj and Pedram, 2015; Akram *et al.,* 2017). For these combined methods, the published calibration curves are derived from controlled industrial mixes rather than field-grade concrete commonly used in Pakistan. Therefore, this investigation aims to examine the correlation between DT and NDT methods for locally sourced concrete. By calibrating NDT outcomes with traditional DT results, this research seeks to develop a robust framework for assessing concrete quality, ensuring more accurate, efficient, and adaptable quality control procedures in Pakistan's construction industry.

2. Materials and methods

Cement (Maple leaf; Ordinary Portland Cement), sand (Lawarancepur Sand), and coarse aggregate (Margalla crush 0.5 inch down) were obtained from local suppliers. The concrete of grade M15 was prepared by mixing the ingredients into a 1:2:4 ratio (ACI 211.1 specification for normal weight concrete). A uniform mix of constituents was obtained using a mixing machine.

Slump test was performed on fresh concrete according to BS EN 12350-4 Part-4. Briefly, the concrete was filled in the slump cone in three layers and compacted by 25 strokes using a tamping rod. After lifting the cone, the 2.5-inch slump indicated the good workability of concrete without excessive flow or collapse.

Concrete was poured into molds in ~5 cm layers, and compacted immediately after mixing to avoid segregation and laitance. At first, in hand compaction, each layer received 35 strokes (15 cm^3) or 25 strokes (10 cm^3) with a tamping bar, ensuring penetration into previous layers and tapping mold sides to close voids. Then each layer was compacted using an electric or pneumatic vibrator until fully compacted.

A total of fifty concrete cubes (15 cm^3) were produced from freshly prepared concrete according to relevant British Standards (BS-1881-Part 116). The specimen was de-moulded after 24 hours and immersed in a curing tank filled with water and cured for 28 days, with water change every 7 days. Before testing, specimens were thoroughly dried and weighed to ensure a minimum weight of 8.1 kg.

2.1. Nondestructive testing

The SRHT measures compressive strength considering the magnitude of the rebound (surface hardness) from the test material. This relationship of surface and rebound values is influenced by material mix ratios, aggregate properties, conditions of curing, and hammer orientation. Ignoring these factors may result in 70% deviation in strength estimates. Therefore, a smooth, clean, and dry surface was selected for testing, avoiding rough or incompletely compacted areas. Loose surface material was removed as needed. The rebound hammer was held perpendicular to the concrete surface, with impact points at least 2 cm from the edges.

For each test, the hammer's plunger was pressed against the concrete, allowing a spring-loaded mass to strike and rebound, with the rebound distance indicating surface hardness. The test was repeated 10 times per specimen, and the average rebound number was recorded (BSI 1881 Part-201).

2.2. Destructive testing (CT)

The specimen was then carefully positioned between the bearing plates of the testing machine, ensuring that both plates and specimen surfaces were free from any loose material. The cubes were aligned centrally on the bearing plate, and load was applied axially at a steady rate of 140 kg cm^{-2} $minute^{-1}$ without shock until failure occurred, with initial cracking and final breakdown points observed, following the British Standard EN 12390-3. The compressive strength of the concrete cube (MPa) was calculated according to EN 12390-4, using Equation 1.

$$f_c = K\frac{P}{A} \quad \text{……………………………………Equation 1.}$$

Where, f_c is compressive strength of concrete cube (MPa), P represents the maximum applied load at failure (kN), A is the loaded area of the specimen (mm^2), and K is a correction factor for the influence of the shape and size of the test specimen (Ivanchev, 2022).

3. Theoretical framework and statistical analysis

Calibration of NDT against compressive DT is required for reliable use. Regression-based calibration models provide the theoretical basis for linking rebound indices to actual strength, with nonlinear functions often offering better accuracy due to the heterogeneous nature of concrete (Ivanchev, 2022). In regions like Pakistan, where locally sourced materials vary in composition, localized calibration equations are essential for improving the reliability of nondestructive strength assessment.

Test Kolmogorov–Smirnov method was used to test the normality of the data. Linear and non-linear regression analysis were conducted using MATLAB R2020a software to study the correlation between the rebound index and crushing strength of concrete cubes for both positions under consideration. The analysis assumed normally distributed residuals, homoscedasticity, and independence of observations, and these assumptions were checked using residual plots and goodness-of-fit indicators. Additionally, the paired t-test was used to compare the experimental and predicted strength of cubes. To capture the heterogeneous behavior of concrete, non-linear polynomial models were included. However, such models may be sensitive to data spread and can introduce overfitting when applied beyond the tested range. Variability in local materials and manual compaction may also influence model accuracy, and these factors should be considered when applying the calibration equations to other mix designs.

4. Results and discussion

Rebound value and crushing strength datasets were recorded for the same set of cubes (Figure 1). The values for crushing strengths were 25.97 ± 3.49 (19.53–34.86). Meanwhile, the SHR values were recorded as 40.47 ± 4.67 MPa (Min 33.00 to Max 50.60) for vertical and 37.54 ± 4.51 (30.00–47.00) for horizontal position. The Pearson correlation analysis showed a significant correlation between NDT (both conditions) and DT methods for the locally sourced materials (Figure 1). The observed correlations align with previous findings documenting that NDT methods can reliably estimate strength within a certain range (Kallu *et al.,* 2015; Vasanelli *et al.,* 2017).

The effect of hammer orientation was evident; horizontal testing ($r = 0.71$, $R^2 = 0.50$, $p < 0.001$) consistently gave slightly better correlations than vertical testing ($r = 0.68$, $R^2 = 0.46$, $p < 0.001$). A paired-samples comparison of these two datasets also showed a statistically significant difference between these two conditions ($p < 0.001$). This difference could be attributed to gravitational effects on the hammer mass and surface impact mechanics (Hajjeh, 2012; Hamidian *et al.,* 2012). This finding implies that orientation-specific calibration curves could improve prediction accuracy. Meanwhile, the slightly lower R^2 values compared to other reports might be attributed to manual compaction methods and variability in local material properties used in this research (Akram et al., 2017).

The model performance was assessed using the coefficient of determination (R^2), root-mean-square error (RMSE), mean absolute error (MAE), and mean absolute percentage error

(MAPE) between predicted and measured crushing strength (Table 1; Figure 2). The cubic regression models consistently achieved higher coefficients of determination (R^2) compared to linear and quadratic models, for both orientations (Figures 1 and 2). These findings indicated that a non-linear function better represents the relationship between rebound index and compressive strength. Moreover, it also reflects a more complex nature of the tested material's behavior. Previous studies have also reported that a non-linear regression improved the predictive accuracy compared to simple linear fits (Vasanelli et al. 2017; Alharthy, 2021; Kallu & Roghanchi, 2015). Further, paired t-test results showed no statistically significant difference between measured and predicted strengths (all $p > 0.75$). On average, none of the three equations exhibits systematic bias (over- or under-estimation) relative to the destructive test results.

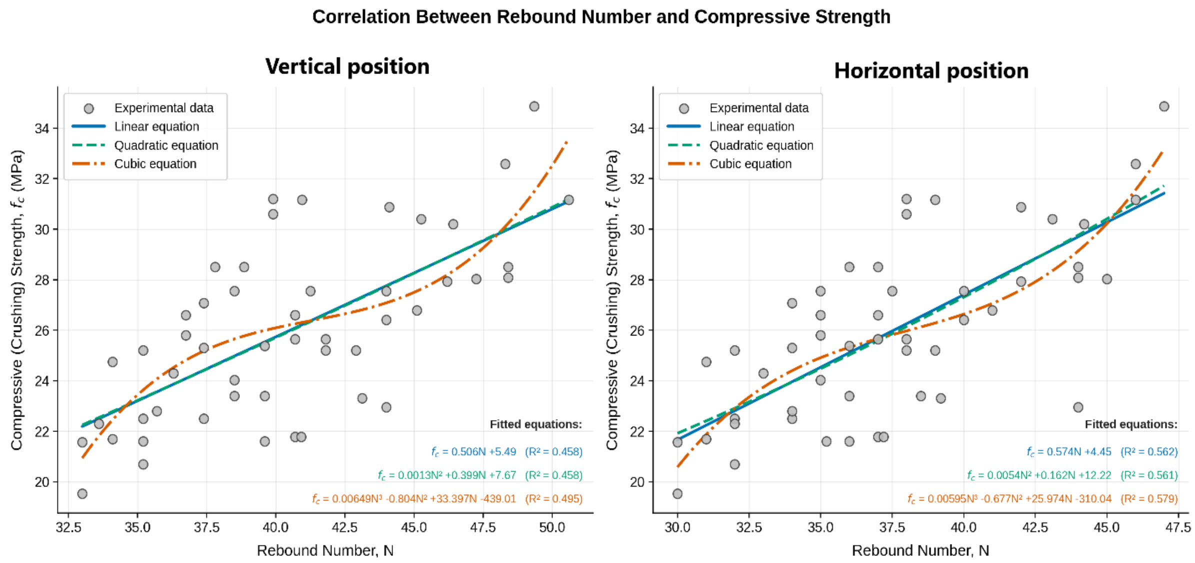

Figure 1: Correlation between rebound strength (x-axis) versus crushing concrete strength (y-axis). The fitted linear, quadratic, and cubic equations are overlaid.

Overall, these findings showed that the NDT should not replace DT for structural acceptance. However, it can still be very much appreciated as a screening tool for rapid, on-site assessment, especially when destructive sampling is not feasible. Moreover, the regression equations developed in our study will serve as predictive tools for estimating the in situ compressive strength of similar local concrete mixes in the Pakistani context.

Table 1: Goodness-of-fit and error statistics of the linear, quadratic, and cubic predictive equations

Orientation	Model	R^2	RMSE (MPa)	MAE (MPa)	MAPE (%)
Vertical	Linear	0.458	2.544	2.093	8.10
Vertical	Quadratic	0.458	2.543	2.094	8.10
Vertical	Cubic	0.495	2.457	2.041	7.91
Horizontal	Linear	0.562	2.288	1.868	7.28
Horizontal	Quadratic	0.561	2.289	1.871	7.30
Horizontal	Cubic	0.579	2.242	1.796	7.00

R^2 = Coefficient of determination, RMSE = root-mean-square error, MAE = mean absolute error, MAPE = mean absolute percentage error

Future research is needed to evaluate diverse mix designs, multiple curing durations, and aggregate types to develop more comprehensive calibration charts for Pakistan's complex construction environments. Further, incorporating other NDT methods such as Ultrasonic Pulse Velocity (UPV) would further improve prediction accuracy. Meanwhile, field-based validation of these combined methods on existing structures would also help translate laboratory findings into practical industry guidelines. Overall, continuing this research by developing region-specific calibration curves through multi-site testing would significantly enhance the applicability of NDT tools for the local construction sector.

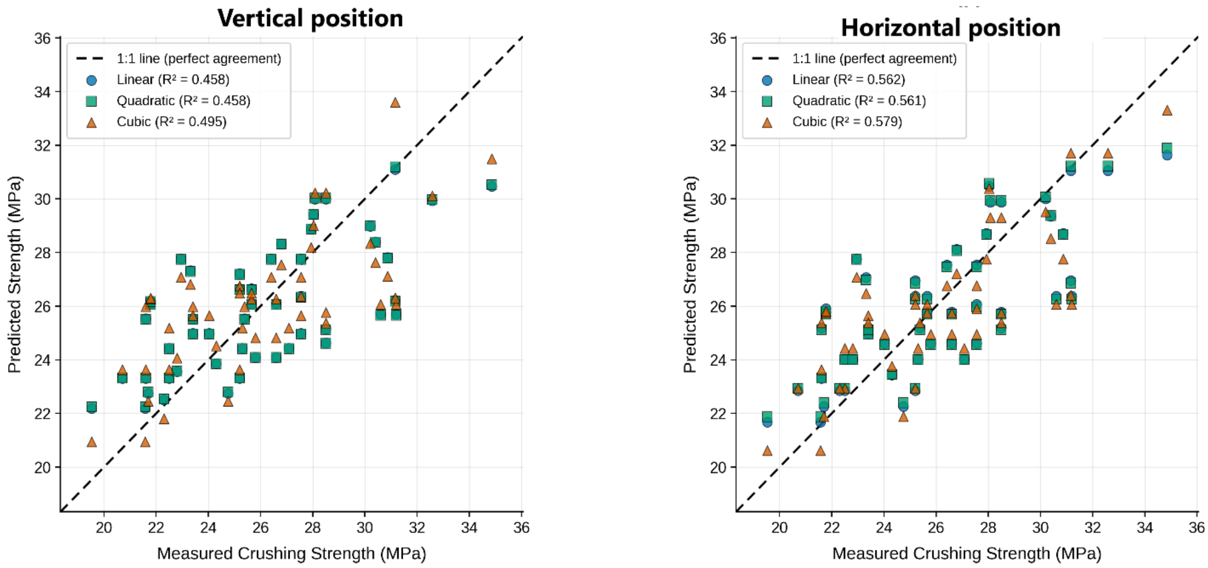

Figure 2: Correlation between experimental crushing strength (x-axis) and predictive strength (y-axis) of concrete for vertical (left) and horizontal (right) predictive measurements. Marker shape and color distinguish the linear (circle, blue), quadratic (square, green), and cubic (triangle, vermillion) equations. The black dashed line represents perfect agreement (1:1 line).

5. Conclusions and recommendations

This study confirmed a positive correlation between non-destructive and destructive testing of concrete produced with locally available materials in Pakistan. Cubic regression models provided the best fit ($R^2 = 0.495$ for vertical, $R^2 = 0.579$ for horizontal measurements), and statistical analysis showed no significant difference between experimentally measured and model-predicted strengths.

Integrating NDT into standard inspection procedures can support faster verification of concrete quality, particularly in projects where timely evaluations are critical. Therefore, industry stakeholders, including site engineers, contractors, and quality-control personnel, are encouraged to incorporate these calibration equations into routine field assessments to minimize unnecessary destructive sampling and enhance on-site decision-making.

Meanwhile, wider implementation of NDT in both public and private sector projects could significantly strengthen quality control practices for safer and more efficient infrastructure development. Consequently, the construction regulatory bodies may also consider adopting region-specific NDT calibration guidelines based on these findings to promote more consistent and reliable strength evaluation across Pakistan's diverse construction environments.

Declaration of conflict of interest

The author(s) declared no potential conflicts of interest(s) with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship and/or publication of this article.

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References

Akram, M. S., Farooq, S., Naeem, M., & Ghazi, S. (2017). Prediction of mechanical behaviour from mineralogical composition of Sakesar limestone, Central Salt Range, Pakistan. *Bulletin of Engineering Geology and the Environment, 76,* 601–615. https://doi.org/10.1007/s10064-016-1002-3

Alharthy, S. E. (2021). Destructive and non-destructive test characteristics of concrete produced with iron slag aggregate. *Water Science, 35*(1), 186–194. https://doi.org/10.1080/23570008.2021.1994243

Azam, R., Riaz, M. R., Haq, E. U., Shihata, A., & Zawam, M. (2022). Development of quality assessment criteria for burnt clay bricks of different ages based on ultrasonic pulse velocity test. *Buildings, 12*(8), 1069. https://doi.org/10.3390/buildings12081069

Hajjeh, H. R. (2012). Correlation between destructive and non-destructive strengths of concrete cubes using regression analysis. *Contemporary Engineering Sciences, 5*(10), 493–509. https://www.m-hikari.com/ces/ces2012/ces9-12-2012/hajjehCES9-12-2012.pdf

Hamidian, M., Shariati, A., Arabnejad Khanouki, M. M., Sinaei, H., Toghroli, A., & Nouri, K. (2012). Application of Schmidt rebound hammer and ultrasonic pulse velocity techniques for structural health monitoring. *Scientific Research and Essays, 7*(21), 1997–2001.

Kallu, R., & Roghanchi, P. (2015). Correlations between direct and indirect strength test methods. *International Journal of Mining Science and Technology, 25*(3), 355–360. https://doi.org/10.1016/j.ijmst.2015.03.005

Kazmi, S. M. S., Abbas, S., Munir, M. J., & Khitab, A. (2016). Exploratory study on the effect of waste rice husk and sugarcane bagasse ashes in burnt clay bricks. *Journal of Building Engineering, 7,* 372–378.

Kim, T.-K., Lee, J., Park, S., Choi, H., & Nguyen, P. (2015). Performance based evaluation of concrete strength under various curing conditions to investigate climate change effects. *Sustainability, 7*(8), 10052–10077. https://doi.org/10.3390/su70810052

Raj, K., & Pedram, R. (2015). Correlations between direct and indirect strength test methods. *International Journal of Mining Science and Technology*, *25*(3), 355-360. https://doi.org/10.1016/j.ijmst.2015.03.005

Munir, M. J., Abbas, S., Qazi, A. U., Nehdi, M. L., & Kazmi, S. M. S. (2018). Role of test method in detection of alkali–silica reactivity of concrete aggregates. *Proceedings of the Institution of Civil Engineers—Construction Materials, 171*(5), 203–221. http://dx.doi.org/10.1680/jcoma.16.00058

Sultan, M., Jawad, M., Iqbal, M. M., Ghafoor, I., Farooq, U., Ud Din, S., & Mushtaq, A. (2023). A comparative study: Effects of fineness of cement on consistency and compressive strength of different branded cement in Pakistan. *Journal of Applied Engineering Sciences, 13*(1), 9–16. https://doi.org/10.2478/jaes-2023-0002

Vasanelli, E., Colangiuli, D., Calia, A., & Luprano, V. A. (2017). Estimating in situ concrete strength combining direct and indirect measures via cross validation procedure. *Construction and Building Materials, 151*, 916–924. https://doi.org/10.1016/j.conbuildmat.2017.06.141