# Compressive Strength Prediction Model of High Strength Concrete by Destructive and Non-destructive Technique

*Shobna* Singh[1], *Ali* K. Alhussainy[2], *Bharathi* Panduri[3], *B* Rajalakshmi[4*], *Manish* Gupta[5], *Harjeet* Singh[6], *G Chandramohan* Reddy[7]

[1]Department of Civil Engineering, IES College of Technology, Bhopal, Madhya Pradesh, India.
[2]Hilla University College, Babylon, Iraq.
[3]Department of Information Technology, GRIET, Bachupally, Hyderabad, Telangana, India.
[4]Department of Computer Science, New Horizon College of Engineering, Bangalore.
[5]Lovely Professional University, Phagwara, India.
[6]Lloyd Institute of Engineering & Technology, Knowledge Park II, Greater Noida, Uttar Pradesh, India.
[7]Department of Mechanical Engineering, MLR Institute of Technology, Hyderabad, Telangana, India-500065

**Abstract.** Concrete's compressive strength can be tested in a laboratory before construction begins. Since concrete is a natural material and cannot be destroyed, it is not possible to determine its compressive strength through destructive testing. Rebound hammers are typically used in the field to evaluate the structural elements' ability to withstand hardened concrete. As part of the current study, a comparison was made between concrete's compressive strength measured by destructive testing and its surface hardness measured by rebound hammering. Tests were conducted on laboratory-made concrete cubes in this study to determine destructive and non-destructive behavior. Minitab software was used for regression analysis. Schmidt rebound hammer tests, a type of nondestructive testing (NDT), were shown to have very strong relationships with concrete destructive compression tests. Schmidt rebound hammers are commonly used to measure the surface hardness of concrete, since the hammer rebound number and concrete strength are theoretically correlated. Utilising a Schmidt hammer, it was applied. Standard concrete cubes with crushing strengths between 20 and 30 MPa were created using various mix proportions. Using regression analysis, destructive and non-destructive values are correlated. The linear regression equation is well suited for obtaining the compressive strength using rebound value by using linear regression equation.

**Keyword-:** Concrete compressive strength, destructive testing, rebound hammer, non-destructive testing (NDT) regression analysis, concrete strength correlation.

* Corresponding Author: inprint@yahoo.com

## 1 Introduction

The most used building material for constructions is concrete. Since its use, the determination of compressive strength has emerged as the primary area of interest for researchers, and it is widely accepted as the primary criterion for evaluating the quality of concrete [1-2]. Since it is simple to use, portable, inexpensive, and non-destructive, this index test is frequently used to assess concrete strength equipment. One tool used to assess the rebound is a hammer [3-4]. It is a hardness test since its foundation is the notion that the surface hardness of an elastic mass determines how well it can rebound back [5-8]. The purpose of these tests is to regulate the amount of concrete produced and to quickly detect building deteriorations caused by under-service loads [9]. However, the damaging techniques are costly and require a lot of time [10-12]. Furthermore, in situ concrete is not represented by cube and cylinder concrete examples made in a lab. Moreover, the load-bearing capacity of building elements is decreased when core specimens are obtained from structural elements [13-16]. Non-destructive testing can, in fact, be used on both newly constructed and pre-existing structures. For new construction, quality control is the primary application, whereas non-destructive testing is utilised to assess the structural integrity of existing structures [17-21]. Common concrete cubes are subjected to non-destructive testing with a Schmidt hammer and destructive testing with a compression testing machine in this experimental inquiry [22]. Typical concrete cubes were made with a range of mix proportions, resulting in crushing strengths of 20 to 30 MPa. Non-destructive tests like the Schmidt Hammer test are common today due to technological advances [23]. This index test is commonly used to test equipment to find the strength of concrete since it is easy to use, portable, affordable, and non-destructive. A hammer is used to evaluate the rebound. The test is referred to as a hardness test since it is predicated on the notion that an elastic mass's ability to rebound back depends on the surface hardness [24]. Concrete's strength is correlated with the amount of energy it absorbs. The rebound hammer test appears straightforward, but it actually entails intricate impact issues and the related stress-wave propagation [25-28]. In advance of testing, the concrete surface needs to be properly selected and prepped. The hammer then needs to be pressed against the test surface with a certain amount of energy applied [29-32]. The plunger must be allowed to strike perpendicular to the surface since the hammer's inclination angle influences the outcomes. After impact, each tested area should have at least ten readings taken in order to record the rebound number [33]. Although the hardness and strength of concrete do not uniquely correlate, given specimens can be used to derive experimental data associations [34]. The components that affect the concrete surface, such as temperature, carbonation, surface preparation, and kind of surface finish, determine this relationship. The type of hammer, inclination, mix ratios, and aggregate form all affect the final result [35]. It is necessary to stay away from areas with high porosity, rough texture, scaling, or honeycombing. Rebound number is affected by carbonation and aggregate type affects rebound number and, in turn, projected strength. Previous study on the connection between NDT and concrete strengths was primarily limited to laboratory-made specimens.

## 2 Methodology

The purpose of this study was to develop basic correlations that on-site engineers utilised. The materials used to make the samples were regular Portland cement, crushed hard limestone, and aggregate from nearby natural sources. The Schmidt hammer rebound strength was measured in the laboratory using 15 x 15 x 15-cm standard cube specimens made of different concrete compositions. We prepared 30 concrete cubes with crushing strengths ranging from 20 to 30 MPa for testing. After the 28-day casting period, ten hammer strikes were evenly dispersed on each specimen's two opposing sides—that is, the sides that

had been lying sideways during the concreting process—in compliance with IS. Based on the average of the ten Schmidt hammer rebound readings, a Schmidt hammer rebound number was calculated. The Schmidt Hammer test was first performed with the cubes positioned horizontally to test the opposing cube surfaces positioned vertically, and then with the cubes positioned horizontally to test the opposite cube surfaces positioned horizontally. Lastly, with a typical compression machine, the identical cubes underwent destructive testing to determine their crushing strengths. The cube specimen is inside the testing apparatus.
Organizations all over the world utilize Minitab, a statistical and procedure enhancement programming tool, for analysing information in order to lower costs and enhance quality. Quality engineers, researchers in statistics, and Six Sigma practitioners use the Minitab program tools to assist address real-world problems. Minitab is an effective tool for visualizing, analysing, and using data to solve difficult problems. It provides trustworthy statistical techniques for pattern recognition, trend identification, and relationship discovery. Minitab, which is accessible on conventional-computers and cloud platforms, boosts efficiency and teamwork by giving users access to statistics and analysis of information from any location, opening up countless possibilities.
Engineers can use regression evaluation to estimate compressive strength on distinctive types of concrete grades, which enables them to plan structures that can help expected loads and make properly-knowledgeable judgements. Using regression analysis, it is easy to predict or estimate the dependent variable's value for those who know what the explanatory factors are. Regression analysis offers a quantitative method for making decisions based on empirical data. By depending on statistical models and evidence, it helps in lowering subjective judgement and biases. This data-driven strategy encourages well-informed decision making and improves the quality and dependability of engineering assessments.

## 3 Procedure of Regression Analysis

Regression models of various kinds were employed in this work to ascertain the association between destructive and non-destructive variables. The complete process flow chart is displayed in Fig. 1. The first data for the learning process is gathered and stored in the data storage or ingestion section. Generally speaking, the data may be in both structured and unstructured formats. These records can be gathered from streaming APIs and distributed cloud-stored web logs of companies.

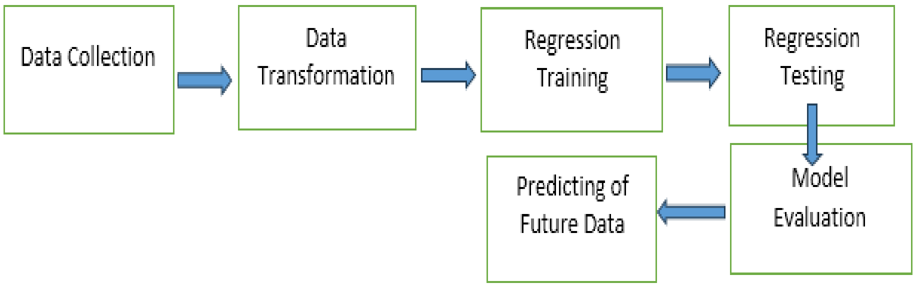


**Fig. 1:** Flowchart of the Regression Process

The two fundamental forms of regression are simple linear regression and multiple linear regression, which are used for more complex data and analyses. Compared to simple linear regression, multiple linear regression uses more than one independent variable in order to explain or predict the dependent variable's outcome (while keeping all others constant). An analysis is conducted after collecting relevant data from several sources and analyzing the information. Data transformation, on the other hand, is the process of cleaning and formatting the data, which includes tasks such as the handling of missing values, normalizing the data, and possibly creating new features of the data. Using the prepared data, a regression model is trained using Regression Training. In order to assess the accuracy and reliability of the model, it undergoes Regression Testing and Model Evaluation. Predicting Future Data involves applying the model to new, similar datasets in order to make predictions.

## 4 Results and Discussion

The goal of this study for on-site engineers was to find basic relationships. The samples were created using Portland cement, crushed limestone, and aggregate from nearby natural sources. The Schmidt hammer rebound strength was measured in the lab using sample cubes (15 x 15 x 15 cm) construct with different concrete compositions. Thirty concrete cubes with crushing strengths between twenty and thirty MPa were ready for testing. a connection between rebound number and compression strength. A 28-day-old concrete cube that underwent DT and NDT is displayed. Therefore, the compressive strength value increases with the rebound number. These are the results for the different mixtures M20, M-25, and M-30 after 28 days in terms of linear, quadratic, and cubic relationships for compressive strength and rebound number. The results are shown below.

**Table 1:** Results 0f relation between DT and NDT Test of M20 Grade Concrete for 28 Days

| Type | Compression Machine Test (D. T | NDT Schmidt Hammer Test (N.D.T) | Correlated Values DT = 20.77 +0.016 NDT |
|---|---|---|---|
| 20 | 20.78 | 19.7846 | 21.01828339 |
| 20 | 22.7822222 | 21.2543 | 21.3285897 |
| 20 | 22.2488889 | 20.7644 | 21.22515426 |
| 20 | 21.6222222 | 19.6213 | 20.98380491 |
| 20 | 21.3377778 | 23.7038 | 21.84576688 |
| 20 | 20.6355556 | 26.8065 | 22.50085797 |
| 20 | 20.8755556 | 17.1718 | 20.46662774 |
| 20 | 19.9333333 | 20.2745 | 21.12171883 |
| 20 | 20.8755556 | 17.1718 | 20.46662774 |
| 20 | 19.9333333 | 20.2745 | 21.12171883 |
| Average | 21.09 | 20.67 | 21.20 |

Table 1 displays the correlation between two test types' findings for M20 grade concrete samples at 28 days. The Compression Machine Test and the Non-Destructive Test (NDT) with a Schmidt Hammer (D.T.) A Compression Machine Test measures the concrete strength directly, whereas a Schmidt Hammer Test measures concrete strength indirectly based on rebound values. As you can see in the table, each row represents a set of concrete samples that were tested using both testing methods. This table shows each test type's values, as well as the correlated values obtained using the equation "DT = 20.77 + 0.016 NDT", which establishes a relationship between the two tests. According to the table, the average values for each test type are 21.09 for the Compression Machine Test and 20.67 for the Schmidt Hammer Test. 21.20 is the average of the correlated values.

**Table 2:** Results 0f relation among DT and NDT test of M25 Grade Concrete for 28 Days

| Type | Compression Machine Test (D.T) | NDT Schmidt Hammer Test (N.D.T) | Correlated Values DT = 22.42 + 0.170 NDT |
|---|---|---|---|
| 25 | 27.56 | 26.8065 | 26.9771 |
| 25 | 27.2711111 | 27.0927 | 27.0257 |
| 25 | 26.3688889 | 22.6 | 26.2623 |
| 25 | 27.1688889 | 25.5203 | 26.7584 |
| 25 | 24.8133333 | 25.2139 | 26.7063 |
| 25 | 28.6133333 | 24.99 | 26.6683 |
| 25 | 27.6755556 | 26.99 | 27.0083 |
| 25 | 24.68 | 26.2 | 26.874 |
| 25 | 26.7022222 | 25.6634 | 26.78277 |
| 25 | 27.1244444 | 26.1533 | 26.8660 |
| Average | 26.797 | 25.721 | 26.91 |

Research of the relationship between two types of tests performed on M25 grade concrete samples at the 28-day. In the Table 2 below, it is shown how the compression machine test (D.T.) and non-destructive test (NDT) with a Schmidt Hammer performed. Compression device checks measure the concrete's compressive strength directly, whereas Schmidt Hammer tests measure its rebound strength not directly. Every row of the table represents a set of concrete samples tested with both techniques. We offer the values for each type of test, along with the correlations among the outcomes of the 2 tests within the form of the equation "DT = 22.42 + 0.172 NDT", which establishes a courting among the 2 test results.

**Table 3:** This study analyzed the correlation between DT and NDT checks performed on concrete of M30 grade over a 28-day period

| Type | Compression Machine Test (D. T) in N/mm² | NDT Schmidt Hammer Test (N.D.T) | Correlated Values DT = 24.13 + 0.217 NDT |
|---|---|---|---|
| 30 | 30.7688889 | 31.7055 | 31.0100 |
| 30 | 30.3244444 | 29.4193 | 30.5139 |
| 30 | 31.3466667 | 28.4395 | 30.2993 |
| 30 | 29.88 | 27.99 | 30.2038 |
| 30 | 29.8933333 | 28.2 | 30.249 |
| 30 | 32.0577778 | 32.522 | 31.18727 |
| 30 | 33.6355556 | 30.2358 | 30.6911 |
| 30 | 34.0133333 | 29.4193 | 30.5139 |
| 30 | 30.8133333 | 33.5018 | 31.3998 |
| 30 | 31.0355556 | 30.8469 | 27.8237 |
| Average | 31.373 | 30.22 | 31.98 |

Table 3 presents the findings of a study analyzing the relationship between two types of tests performed on M30 grade concrete samples at the 28-day mark. The Non-destructive test (NDT) with a Schmidt Hammer and the Compression machine test (D.T). Whilst the Schmidt Hammer test offers an indirect measurement based on rebound readings, the Compression machine test determines the concrete's compressive strength directly. Every row in the table represents a set of concrete samples tested the use of each technique. The values recorded for every test type, alongside the correlated values received using the equation "DT = 24.13 + 0.217 NDT," which establishes a relationship between the two check results, are provided.

 https://doi.org/10.1051/e3sconf/202455201111

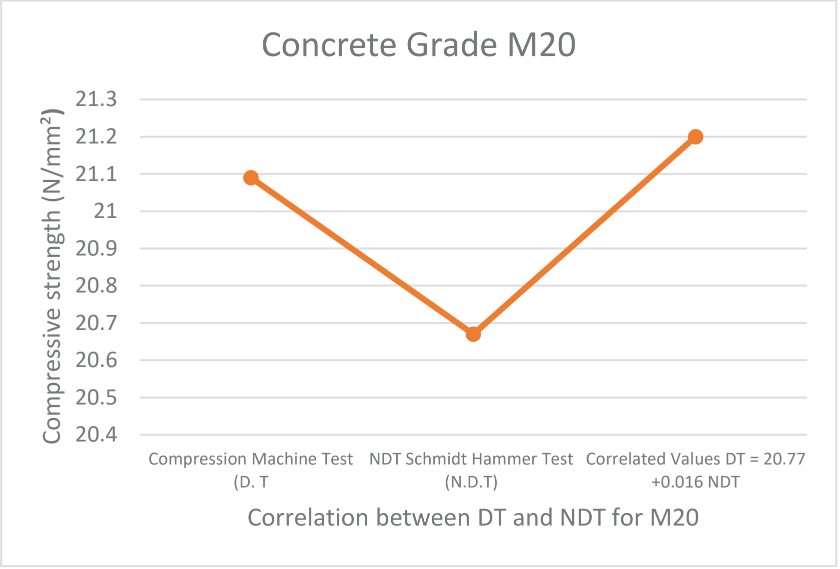


**Fig. 2:** Correlation between Destructive and Non – Destructive methods for concrete grade M20

Fig. 2 shows the average values of each test type, with the Compression Machine Test averaging 21.09 and the Schmidt Hammer Test averaging 20.67. Correlation values average 21.20. In context of the similarity of correlated values for the Compression Machine Test and Schmidt Hammer Test, these findings suggest a correlation. Using Schmidt Hammer rebound values as an estimate of compressive strength, the equation provides further support for this correlation. A method such as this provides engineers and construction professionals with an alternative method for assessing concrete strength when direct testing is not possible.

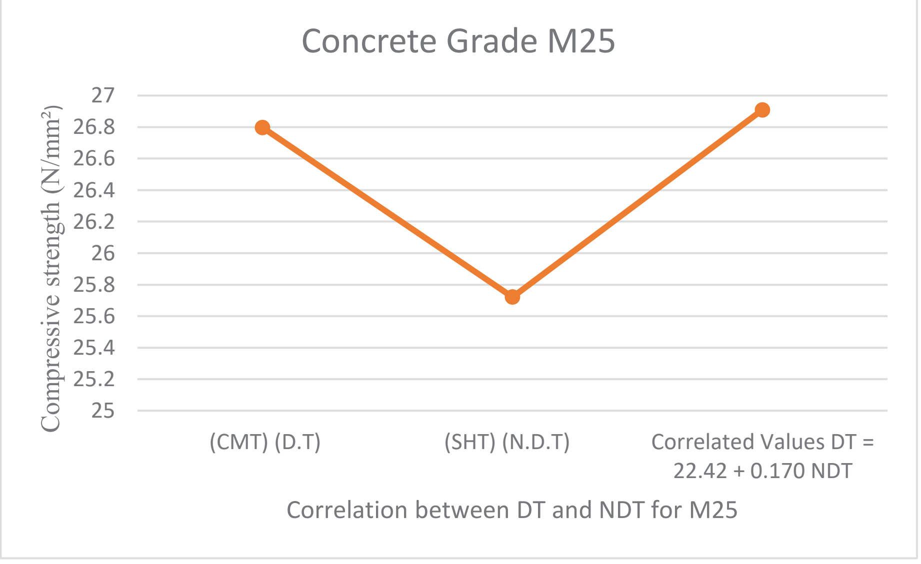


**Fig. 3:** Concrete grade M25 destructive and non-destructive testing comparison

Fig. 3 compares the results obtained from two different methods of testing M25 grade concrete samples at the 28-day mark, a Compression Machine Test (D.T) and a Non-

Destructive Test (NDT) using a Schmidt Hammer. In terms of the average value, the Compression Machine Test averaged 26.797 and the Schmidt Hammer Test averaged 25.721, which was the average value for each test type. There is an average correlation of 26.91. Results from the Compression Machine Test tend to be higher than those from the NDT Schmidt Hammer Test. It is notable, however, that the correlated values are closely aligned with both test methods.

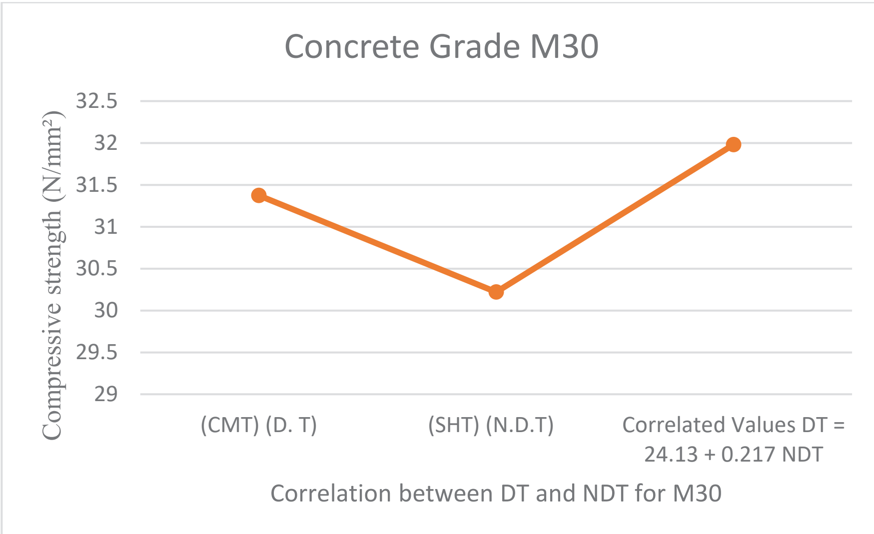


**Fig. 4:** Non-destructive and destructive methods for analyzing concrete grade M30

Fig. 4 given above compares two types of tests, namely, destructive testing and non-destructive testing. During 28 days of curing, the strength of concrete samples of grade M30 was determined by compressive strength tests for the samples. The results of the Compression Machine Test and NDT Schmidt Hammer Test are shown in the figure, connected by correlated values dating from the formula DT = 24.13 + 0.217 NDT. As can be seen here, assuming the correlation between the Schmidt Hammer Test and Compression Machine Test was followed, then the NDT Schmidt Hammer Test and Compression Machine Test are good for reliable results of compressive strength.

## 5 Conclusion

A correlation was attempted between concrete compressive strength obtained by destructive test and concrete surface hardness obtained by rebound hammer each concrete cube used in this study was manufactured in a laboratory and subjected to both destructive and non-destructive tests. An analysis of regression was performed using the Minitab software. Destructive compression testing of concrete and non-destructive testing (NDT), or Schmidt rebound hammer, were shown to have a straightforward relationship. The compressive strength can be obtained using a correlation curve by measuring the bound number using a rebound hammer. It is important to remember, however, that the material qualities and testing circumstances could have an impact on the results found. For this purpose, formulas and local correlation curves have been created to produce compression strength values that are more reliable.

- Comparative Analysis of Compression Machine Test and Non-Destructive Test for M20, M25 and M30Grade Concrete.

- The average values for each test type, with the Compression Machine Test averaging at 21.09 and the Schmidt Hammer Test averaging at 20.67 and the correlated values average at 21.20 for M20.
- The average values, with the Compression Machine Test averaging at 26.797 and the Schmidt Hammer Test averaging at 25.721 and the correlated values average at 26.91 for M25.
- The Compression Machine Test averaging at 31.373 and the Schmidt Hammer Test averaging at 30.22 and the correlated values average at 31.98 for M30.
- Using Schmidt Hammer rebound values as a basis for estimating compressive strength, compression machine test results and NDT Schmidt Hammer test results can be correlated accurately.

## References

1. Hajjeh, Hassan R. "Correlation between destructive and non-destructive strengths of concrete cubes using regression analysis." Contemp. Eng. Sci 5, 10 (2012): 493-509.
2. Bhosale, Nilam, and P. A. Salunkhe. "To establish relation between destructive and non-destructive tests on concrete." Int. J. Eng. Res. Gen. Sci 4, 2 (2016): 634-644.
3. Samson, Duna, and O. T. Moses. "Correlation between non-destructive testing (NDT) and destructive testing (DT) of compressive strength of concrete." International Journal of Engineering Science Invention 3, 9 (2014): 12-17.
4. Karahan, Şebnem, Aydın Büyüksaraç, and Ercan Işık. "The relationship between concrete strengths obtained by destructive and non-destructive methods." Iranian Journal of Science and Technology, Transactions of Civil Engineering 44 (2020): 91-105.
5. Benyahia, K. A., M. Ghrici, S. Kenai, D. Breysse, and Z. M. Sbartai. "Analysis of the relationship between nondestructive and destructive testing of low concrete strength in new structures." Asian Journal of Civil Engineering 18, 2 (2017): 191-205.
6. Kheder, G. F. "A two stage procedure for assessment of in situ concrete strength using combined non-destructive testing." Materials and structures 32 (1999): 410-417.
7. Velay-Lizancos, Mirian, Isabel Martinez-Lage, Miguel Azenha, Jose Granja, and Pablo Vazquez-Burgo. "Concrete with fine and coarse recycled aggregates: E-modulus evolution, compressive strength and non-destructive testing at early ages." Construction and Building Materials 193 (2018): 323-331.
8. Wolfs, Rob JM, Freek P. Bos, and Theo AM Salet. "Correlation between destructive compression tests and non-destructive ultrasonic measurements on early age 3D printed concrete." Construction and Building Materials 181 (2018): 447-454.
9. Amini, Kamran, Mehdi Jalalpour, and Norbert Delatte. "Advancing concrete strength prediction using non-destructive testing: Development and verification of a generalizable model." Construction and Building Materials 102 (2016): 762-768.
10. Saha, Ashish Kumer, Subhra Majhi, Prabir Kumar Sarker, Abhijit Mukherjee, Ayesha Siddika, Farhad Aslani, and Yan Zhuge. "Non-destructive prediction of strength of concrete made by lightweight recycled aggregates and nickel slag." Journal of Building Engineering 33 (2021): 101614.
11. Aydin, Ferhat, and Mehmet Saribiyik. "Correlation between Schmidt Hammer and destructive compressions testing for concretes in existing buildings." Scientific Research and Essays 5, 13 (2010): 1644-1648.
12. Qurashi, Muhammad Ahmed, Syyed Adnan Raheel Shah, Muhammad Farhan, Muhammad Taufiq, Waleed Khalid, Hunain Arshad, Muhammad Tayyab, Gullnaz Shahzadi, and Muhammad Waseem. "Sustainable design and engineering: A relationship analysis between digital destructive and non-destructive testing process for lightweight concrete." Processes 7, no. 11 (2019): 791.

13. Saremi, Setare Ghahri, and Dimitrios Goulias. "Concrete strength gain monitoring with non-destructive methods for potential adoption in quality assurance." Construction and Building Materials 260 (2020): 120464.
14. Bhosale, Nilam, and P. A. Salunkhe. "To establish relation between destructive and non-destructive tests on concrete." Int. J. Eng. Res. Gen. Sci 4, 2 (2016): 634-644.
15. Malek, Jedidi, and Machta Kaouther. "Destructive and non-destructive testing of concrete structures." Jordan journal of civil engineering 8, no. 4 (2014): 432-441.
16. Suji Prasad, S. J., M. Thangatamilan, M. Suresh, Hitesh Panchal, Christober Asir Rajan, C. Sagana, B. Gunapriya, Aditi Sharma, Tusharkumar Panchal, and Kishor Kumar Sadasivuni. "An efficient LoRa-based smart agriculture management and monitoring system using wireless sensor networks." International Journal of Ambient Energy 43, 1 (2022): 5447-5450.
17. Joseph, Sudha, Kavitha Joseph, Trevor C. Lindley, and David Dye. "The role of dwell hold on the dislocation mechanisms of fatigue in a near alpha titanium alloy." International Journal of Plasticity 131 (2020): 102743.
18. Prasad, C. Durga, S. Kollur, M. Nusrathulla, G. Satheesh Babu, M. B. Hanamantraygouda, B. N. Prashanth, and N. Nagabhushana. "Characterisation and wear behaviour of SiC reinforced FeNiCrMo composite coating by HVOF process." Transactions of the IMF 102, 1 (2024): 22-28.
19. Meenal, R., D. Binu, K. C. Ramya, Prawin Angel Michael, K. Vinoth Kumar, E. Rajasekaran, and B. Sangeetha. "Weather forecasting for renewable energy system: a review." Archives of Computational Methods in Engineering 29, 5 (2022): 2875-2891.
20. Akshatha, S., S. Sreenivasa, L. Parashuram, Fahad A. Alharthi, and Tadimety Madhu Chakrapani Rao. "Microwave assisted green synthesis of p-type Co3O4@ Mesoporous carbon spheres for simultaneous degradation of dyes and photocatalytic hydrogen evolution reaction." Materials Science in Semiconductor Processing 121 (2021): 105432.
21. Akshatha, S., S. Sreenivasa, L. Parashuram, V. Udaya Kumar, S. C. Sharma, H. Nagabhushana, Sandeep Kumar, and T. Maiyalagan. "Synergistic effect of hybrid Ce3+/Ce4+ doped Bi2O3 nano-sphere photocatalyst for enhanced photocatalytic degradation of alizarin red S dye and its NUV excited photoluminescence studies." Journal of Environmental Chemical Engineering 7, 3 (2019): 103053.
22. Ramkumar, M., C. Ganesh Babu, K. Vinoth Kumar, D. Hepsiba, A. Manjunathan, and R. Sarath Kumar. "ECG cardiac arrhythmias classification using DWT, ICA and MLP neural networks." In Journal of Physics: Conference Series, vol. 1831, 1, p. 012015. IOP Publishing, 2021.
23. Kumar, CB Pradeep, B. S. Prathibha, K. N. N. Prasad, M. S. Raghu, M. K. Prashanth, B. K. Jayanna, Fahad A. Alharthi, S. Chandrasekhar, H. D. Revanasiddappa, and K. Yogesh Kumar. "Click synthesis of 1, 2, 3-triazole based imidazoles: Antitubercular evaluation, molecular docking and HSA binding studies." Bioorganic & Medicinal Chemistry Letters 36 (2021): 127810.
24. Rajesh, A., K. Gopal, B. Rajesh Kumar, A. P. Sathiyagnanam, and D. Damodharan. "Effect of anisole addition to waste cooking oil methyl ester on combustion, emission and performance characteristics of a DI diesel engine without any modifications." Fuel 278 (2020): 118315.
25. Naik, Ramachandra, S. C. Prashantha, H. Nagabhushana, S. C. Sharma, H. P. Nagaswarupa, and K. M. Girish. "Effect of fuel on auto ignition route, photoluminescence and photometric studies of tunable red emitting Mg2SiO4: Cr3+ nanophosphors for solid state lighting applications." Journal of Alloys and Compounds 682 (2016): 815-824.

26. Naveen Kumar, Rangaswamy, J. Suresh Goud, Pudhari Srilatha, Pattasale T. Manjunatha, S. Prasanna Rani, Raman Kumar, and S. Suresha. "Cattaneo–Christov heat flux model for nanofluid flow over a curved stretching sheet: An application of Stefan blowing." Heat Transfer 51, 6 (2022): 4977-4991.
27. Vallabhuni, Rajeev Ratna, G. Yamini, T. Vinitha, and S. Sanath Reddy. "Performance analysis: D-Latch modules designed using 18nm FinFET Technology." In 2020 International Conference on Smart Electronics and Communication (ICOSEC), 1169-1174. IEEE, 2020.
28. Dhanalaxmi, B., and G. Apparao Naidu. "A survey on design and analysis of robust IoT architecture." In 2017 International Conference on Innovative Mechanisms for Industry Applications (ICIMIA), 375-378. IEEE, 2017.
29. Nikam, Pritam B., Jayendra Kumar, V. Sivanagaraju, and Achinta Baidya. "Dual-band reconfigurable EBG loaded circular patch MIMO antenna using defected ground structure (DGS) and PIN diode integrated branch-lines (BLs)." Measurement 195 (2022): 111127.
30. Vallabhuni, Rajeev Ratna, Jujavarapu Sravana, Chandra Shaker Pittala, Mikkili Divya, B. M. S. Rani, and Vallabhuni Vijay. "Universal shift register designed at low supply voltages in 20 nm FinFET using multiplexer." In Intelligent Sustainable Systems: Proceedings of ICISS 2021, 203-212. Singapore: Springer Singapore, 2021.
31. Kishore, Somasundaram Chandra, Raji Atchudan, Thomas Nesakumar Jebakumar Immanuel Edison, Suguna Perumal, Muthulakshmi Alagan, Rajangam Vinodh, Mani Shanmugam, and Yong Rok Lee. "Solid waste-derived carbon fibers-trapped nickel oxide composite electrode for energy storage application." Energy & Fuels 34, 11 (2020): 14958-14967.
32. Malagavelli, Venu, Srinivas Angadi, J. S. R. Prasad, and Subodh Joshi. "Influence of metakaolin in concrete as partial replacement of cement." Int J Civil Eng Technol 9, 7 (2018): 105-111.
33. Ashok Babu, Puralasetty, Javanna Latheef Mazher Iqbal, S. Siva Priyanka, Machana Jithender Reddy, Gaddam Sunil Kumar, and Rajaram Ayyasamy. "Power control and optimization for power loss reduction using deep learning in microgrid systems." Electric Power Components and Systems 52, 2 (2024): 219-232.
34. Saritha, M., M. Lavanya, G. Ajitha, Mulinti Narendra Reddy, P. Annapurna, M. Sreevani, S. Swathi, S. Sushma, and Vallabhuni Vijay. "A VLSI design of clock gated technique-based ADC lock-in amplifier." International Journal of System Assurance Engineering and Management 13, 5 (2022): 2743-2750.
35. Pittala, Chandra Shaker, Rajeev Ratna Vallabhuni, Vallabhuni Vijay, Usha Rani Anam, and Kancharapu Chaitanya. "Numerical analysis of various plasmonic MIM/MDM slot waveguide structures." International Journal of System Assurance Engineering and Management 13, 5 (2022): 2551-2558.