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Research Article

Comparison of Compressive Strength of M30 Grade Concrete with Destructive and Nondestructive Procedures Using Digital Image Processing as a Technique

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Destructive, semidestructive, and nondestructive methods are used to assess the compressive strength of concrete and its substantial mechanical property. In the destructive method, samples of concrete are crushed and treated under compression to determine its compressive strength. As such, the impact is seen on test results like the method of casting and compaction. The tests on concrete become limited in the destructive method and are confined to predict compressive strength, flexural strength, etc. To overcome its limitations and to study concrete matrix, semidestructive and nondestructive test methods came into limelight. Among nondestructive methods, strength prediction can be carried out using Schmidt's rebound hammer test, ultrasonic pulse velocity test, image analysis techniques, radioactive tests, etc. Consequently, an advanced technique to predict the strength of the structural element using digital image processing technique has been introduced, and one can have a glimpse of the enlarged image, which quantifies and is used to assess the strength. The various characteristic features associated with the image help to calculate the strength of the structural element. A high-pixel camera is used to take images of concrete cube samples, and they are analyzed with digital image processing techniques and a tool in MATLab or directly by making use of ImageJ software. In addition, digital image processing techniques are being implemented in various fields such as medical, industrial, remote sensing, and engineering. The present paper proposes to cast $150 \times 150 \times 150$ mm-sized M30 grade concrete cube samples and to study their strength after a period of 7 days and subsequently after 28 days. Destructive and nondestructive methods are used, and the samples are analyzed with digital image processing techniques using ImageJ software. The observed findings are discussed in the paper.

1. Introduction

Concrete is an incredibly vital construction material known for its durability and possesses several attributes that make it the best option for use in buildings and structures. The concrete is widely available, is inexpensive, and enjoys quite significant properties. Destructive, semidestructive, and nondestructive tests are available today to assess the properties of concrete [1]. Certain mechanical properties of concrete can be measured with conventional nondestructive methods such as rebound hammer test and ultrasonic pulse velocity test. In the case of rebound hammer test, after analyzing the data for more than 65 years, it has been concluded that the estimated compressive strength determined with the rebound hammer is higher than that of the destructive procedures [2]. Factors such as compaction, curing environment of concrete, temperature variations, and water-cement ratio influence the rebound index, which ultimately impacts the compressive strength of concrete. Therefore, it is imperative to modify or limit or develop the nondestructive test standards [2]. However, in the case of ultrasonic pulse velocity test, a few factors like its dry state or saturated condition and the type of cement used influence the results to a certain extent [3]. In recent times, structural health monitoring (SHM) became the buzzword in the field of structural engineering, which includes the study of both concrete and steel. Various NDT techniques such as sweep frequency approach, infrared techniques, camera-based techniques, and sensor techniques are available to monitor the quality of structures of both concrete and steel. Among all, use of sensors is the best approach, which gives caution in case of any invisible damages like cracks and corrosion of bars and further monitors the strength of the structures [4, 5].

Different types of NDT techniques can be performed on various elements of construction, but all methods will not arrive at accurate results. For instance, the ultrasonic pulse velocity test and acoustic test are more suitable and accurate for historical stone masonry; radar methods and penetrating radiation methods may be used in case of brick material; and the ultrasonic pulse velocity test may be used for concrete [6]. Assessment of strength is influenced by hardness, resistance against penetration, rebound capacity, and ability to transmit ultrasonic pulses and X-rays. At present, ANN (artificial neural network) and IP (image processing) are in use to solve engineering problems, and as noticed here, there exists high correlation between ANN, IP, and actual test results, where the variance is between 97.18 and 99.87%. It is therefore proved that combination of the above techniques will always lead to satisfactory outcomes [7]. The difference between the test results offered by destructive and nondestructive tests declined within 28 days. In the ultrasonic pulse velocity test, results declined with respect to the increase in W/C ratio because it increases porosity in the concrete samples and the dynamic modulus of elasticity decreased with an increase in W/C ratio [8]. NDT techniques like rebound hammer and ultrasonic pulse velocity tests were conducted in nuclear power plants where High Strength Concrete whose Compressive Strength was more than 40 MPa, and the results were acceptable with the strength correction factor [9]. In recent times, rebound hammer results have become accurate by applying artificial neural networks in predicting compressive strength of in situ concrete [10].

Digital image processing is one of the important areas of electronics and computer science engineering as the two significant tech brothers revolutionized all the fields, and with digitalization, many developments are being noticed. Growth of digital image processing has led to numerous innovations in the area of digital imaging. In reality, many engineering fields are predominantly using analog techniques and slowly paving way to advanced digital imaging. Civil engineering is one of the oldest engineering sectors, and entwined with digital technology, it has been producing unpredictable results. Recently, many inventions were proposed in civil engineering with digital image processing techniques [11]. The compressive strength of concrete, especially concrete made up of cement replacement materials (CRMs), i.e., fly ash and silica fumes, is predicted with image processing and artificial neural networks (ANNs) modeling. The predicted compressive strength is found to be very accurate up to 98.65% in destructive tests [12]. The image processing algorithms were proposed and applied to assess the strength, and the error rate was about a mere 1-2% [13]. Digital image processing can be used to detect the construction progress by adopting a suitable algorithm, which can detect the structural elements and their defaults at site [14]. In building materials, digital image processing techniques were applied to determine the quality of the marble stone in industry. In marble industry, quality, texture, and basic composition of stone can be verified and classified through image processing techniques [15]. Image analysis techniques are used to decide the strength and durability of the age-old historic constructions. Historic stones were captured on the digital camera, and the images were analyzed on the system using digital image processing techniques. The results were compared using the direct compression test. The two test results were similar, with an error margin of + -2% [16]. In GIS and remote sensing, images of a certain large area are captured using satellites and digital image techniques are applied to the images to generate digital thematic maps [17].

In case of tests on coarse aggregate, the shape of coarse aggregate can be determined with digital images. The coarse aggregate is spread over an area, and digital images are taken; furthermore, the images are analyzed to determine the particle size of the coarse aggregate. The flakiness of coarse aggregate can also be determined by the same process [18, 19]. The cement content in concrete, which plays a key role in attaining good compressive strength, can be predicted by image analysis using ImageJ software, which helps in estimating the chlorine content in cement [20]. The compressive strength of concrete can also be predicted by using digital image processing techniques; the outer surface of the concrete is captured on a high-resolution digital camera, images are converted to greyscale, and the histogram of the image is generated. By analyzing this picture using the MatLab technique, the compressive strength of the concrete is predicted and compared with that of the conventional method [21]. Besides concrete, digital image processing techniques are used even in other specializations of civil engineering, like environmental engineering, in predicting pH value and settling velocity of water [22, 23].

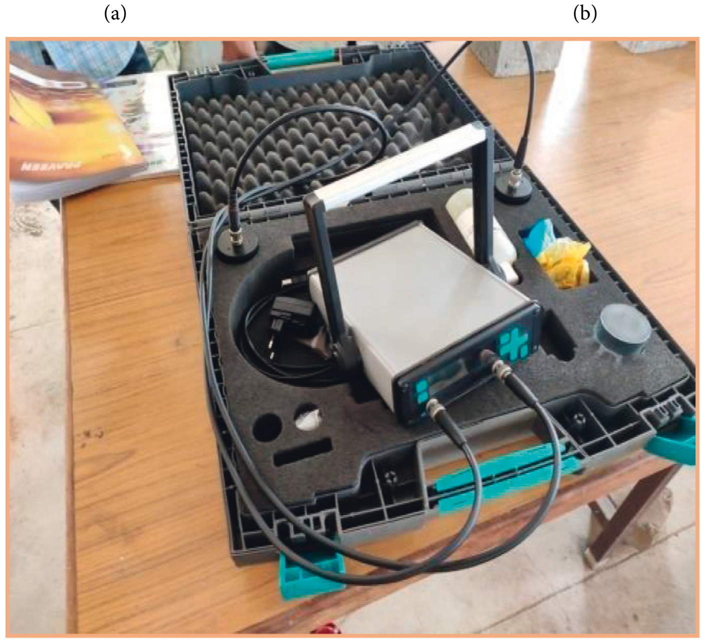
Accordingly, the above case studies helped the authors to progress toward digital image processing techniques to be used in predicting the compressive strength of concrete along with conventional destructive and nondestructive procedures. This paper aims to study compressive strength property of M30 grade concrete with nondestructive tests such as rebound hammer test, SonReb method (combination of rebound number and ultrasonic pulse velocity), and a new approach digital image processing as one of the techniques, and the results are compared with the destructive procedure. Pros and cons of the nondestructive tests and the suitability of using digital image processing techniques in predicting the compressive strength of concrete have been discussed. The test procedures are as follows.

2. Materials

For the experimentation procedures, ordinary Portland cement of grade 53 is used. Preliminary experiments on cement were conducted, and the initial and final settings of

(a)

(b)



(c)

Figure 1: (a) Compression testing machine. (b) Schmidt's rebound hammer test apparatus with a digital display. (c) Pundit's ultrasonic pulse velocity test.

cement were 60 and 480 min, respectively. Standard consistency of the cement sample is 32% with a fineness of 3.5%. All the properties of cement are satisfactory as per Indian Standard Code 12269-1987 [24]. Locally available sand has been procured for experimentation, and it is confirmed to Zone-II according to Table 4 of Indian Standard Code 383-1970 [25]. The specific gravity test is conducted on the fine aggregate, and the result is found to be 2.63. Locally available crushed granite is used as the coarse aggregate in the experimentation, and its specific gravity is 2.62. Potable water from the local sources, which is suitable for mixing and curing of concrete, has been used for experimentation.

3. Analyzing Digital Images

In recent era, drastic changes have been taking place in the digital world. Even in the civil engineering field, analysis of digital images has replaced the regular conventional method of assessment with interdisciplinary studies. Conventional images or photos have to be captured during the casting and testing, but these cannot be analyzed properly. Digital images can be captured during the casting and testing of concrete samples, analyzed, and used for various purposes like prediction of strength, study of bonding, study of ITZ (interfacial transition zone), and finding permeability of concrete. Every system has a basic component from which the whole system is made up of, and just like atom is the basic unit of matter, "pixel" is the basic component of the digital image. A digital image is a combination of number of unit cells called "pixels." Usually, digital camera specifications are defined in "megapixels." For example, the digital camera has specifications of 1 megapixel which implies that the image, which is captured, consists of 1 mega (10^6) number of pixels, to say that the image has 1 million of pixels and each pixel has a pixel number. For a color image, there will be RGB colors. Each color has 8 bytes (red = 2^8, green = 2^8, and blue = 2^8). The pixel number varies from 1 to $2^8 \times 2^8 \times 2^8$, i.e., from "0" to "16777215" (numbering starts from "0" onwards), but analyzing such a large number of data may be tedious and conclusions cannot be drawn in profound form. So, the color image must be transformed to greyscale, and after this conversion, the pixel number varies from 1 to 2^8. The pixel number can vary from 0 to 255. As a rule, "0" value indicates black and "255" indicates white. Grey tones with different shades are formed among these values.

Steps for analyzing the image using ImageJ software:

(i) Opening ImageJ software
(ii) Adding or uploading the digital image to the software
(iii) Cropping the image by cutting down the unnecessary edges of the image
(iv) Converting the RGB color image into greyscale image
(v) Analyzing the image and extracting the histogram of the image

Table 1: Classification of concrete by the ultrasonic pulse velocity test [28].

Range of ultrasonic pulse velocity results (km/s)	Classification of concrete
>4.5	Excellent
3.5–4.5	Good
3.0–3.5	Medium
<3.0	Doubtful

4. Methodology to Determine the Compressive Strength of Concrete

4.1. Destructive Tests. The destructive test procedure is one of the oldest and conventional methods to determine the various strengths and study the quality of concrete after destruction. Mechanical properties of concrete can be determined by destructive tests such as compressive strength test, splitting tensile strength test, and flexural strength test, which are regular type of destructive tests on concrete. Among all these tests, compressive strength test is frequently performed on concrete cubes and cylinders. The analog testing procedure consists of casting cubes or cylinders of different grades of concrete samples and curing them in a water tank. The sample is tested using the compression test machine (CTM) shown in Figure 1(a), and the uniform rate of loading is applied until the specimen crushes.

4.2. Nondestructive Tests. The nondestructive test implies the prediction of properties of concrete without any damage or destroying the specimen sample or structure, and there are different types of tests based on the principles. Some of the NDT techniques are Schmidt's rebound hammer test, Pundit's ultrasonic pulse velocity test, combined ultrasonic-rebound hammer test, and digital image processing method. The advantages of the NDT techniques are as follows:

(i) Man force required for NDT techniques is very less compared to destructive tests
(ii) Preparatory works in destructive testing require more labor than in NDT
(iii) No portion or very small portion of the structure is damaged in NDT compared to destructive testing
(iv) Probability of structural damage is very low, which may cause the need for reinforcement
(v) In special cases like thin walls and dense reinforced concrete structures, sample extraction in destructive test has no scope, whereas NDT can overcome such hurdles in reality
(vi) Handy tools and less-expensive equipment may be used for nondestructive tests compared to destructive tests

However, the advantages are valuable only if those results lead to accuracy in reality [26].

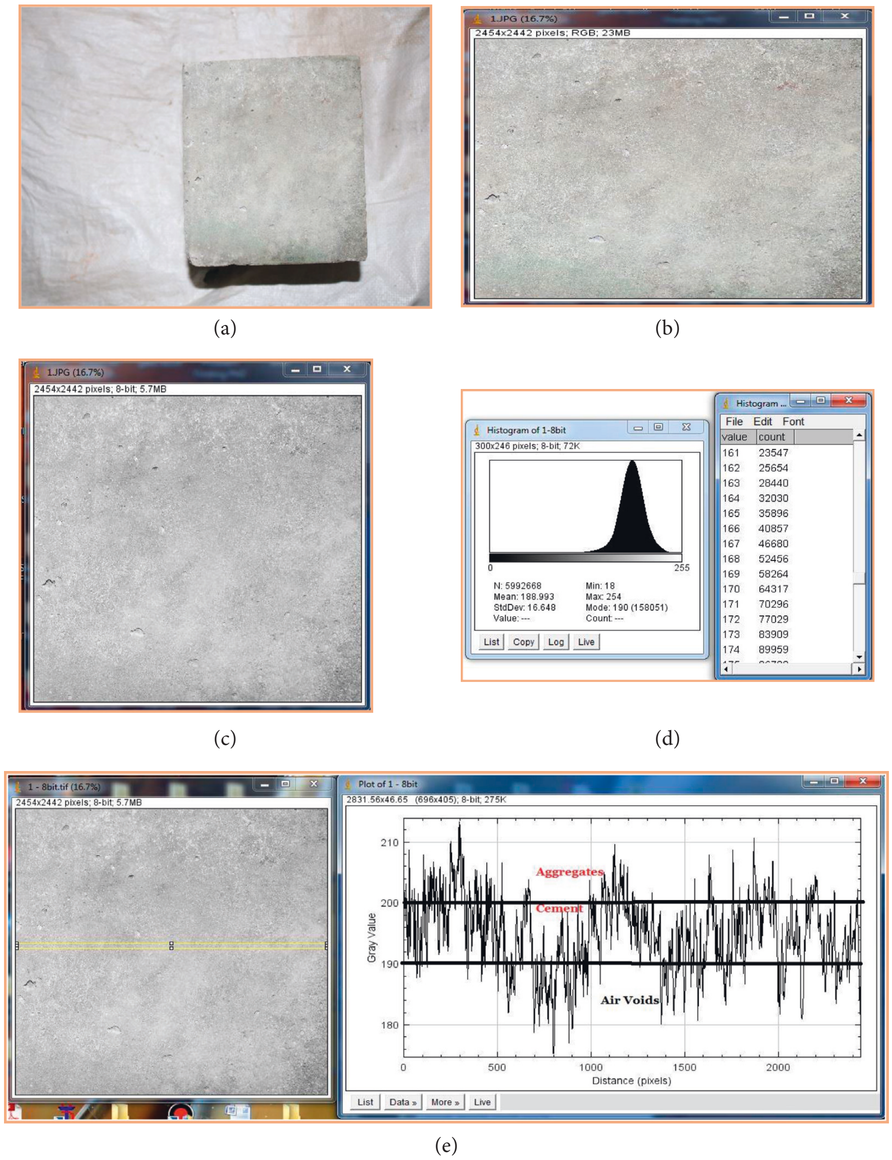


Figure 2: Digital image of (a) a concrete cube, (b) the concrete cube after cropping in RGB color, (c) the concrete cube after converting into greyscale, (d) the histogram, and (e) the profile of the rectangular section of the cube surface.

4.2.1. Schmidt's Rebound Hammer Test. Among all the nondestructive tests on concrete, Schmidt's rebound hammer test is the most commonly used test carried out on concrete, as shown in Figure 1(b). The rebound hammer test directly relates to the compressive strength of concrete, and the test results can be obtained instantly. The basic principle behind this test is the rebound nature of an elastic mass (concrete in the present scenario), which depends on the hardness of the surface against which the mass impinges. The energy which is absorbed by the concrete is directly related to its compressive strength property. Even though the test procedure is simple, the test involves complex problems of impact and is associated with stress-wave propagation [26].

4.2.2. Pundit's Ultrasonic Pulse Velocity Test. The ultrasonic pulse velocity method, as shown in Figure 1(c), is one of the NDTs (nondestructive tests) conducted on concrete specimens to determine the mechanical properties of concrete without any destruction. In this method, the time taken by ultrasonic pulse to pass through the concrete is recorded, which ultimately gives the velocity of the ultrasonic pulse in that particular concrete specimen. This method is a litmus test for any concrete specimen, by which one can determine whether the concrete has good properties or not in terms of density, homogeneity, uniformity, etc. In this method, ultrasonic waves are passed through the concrete cube specimen and ultrasonic waves or sound waves, which travel through a medium having frequency more than 20000 Hz, cannot be detected by human ear. Humans can hear sounds with frequency ranging from 20 Hz to 20,000 Hz. The ultrasonic pulse velocity test is more significant as it studies the internal structure of the concrete specimen. The results of

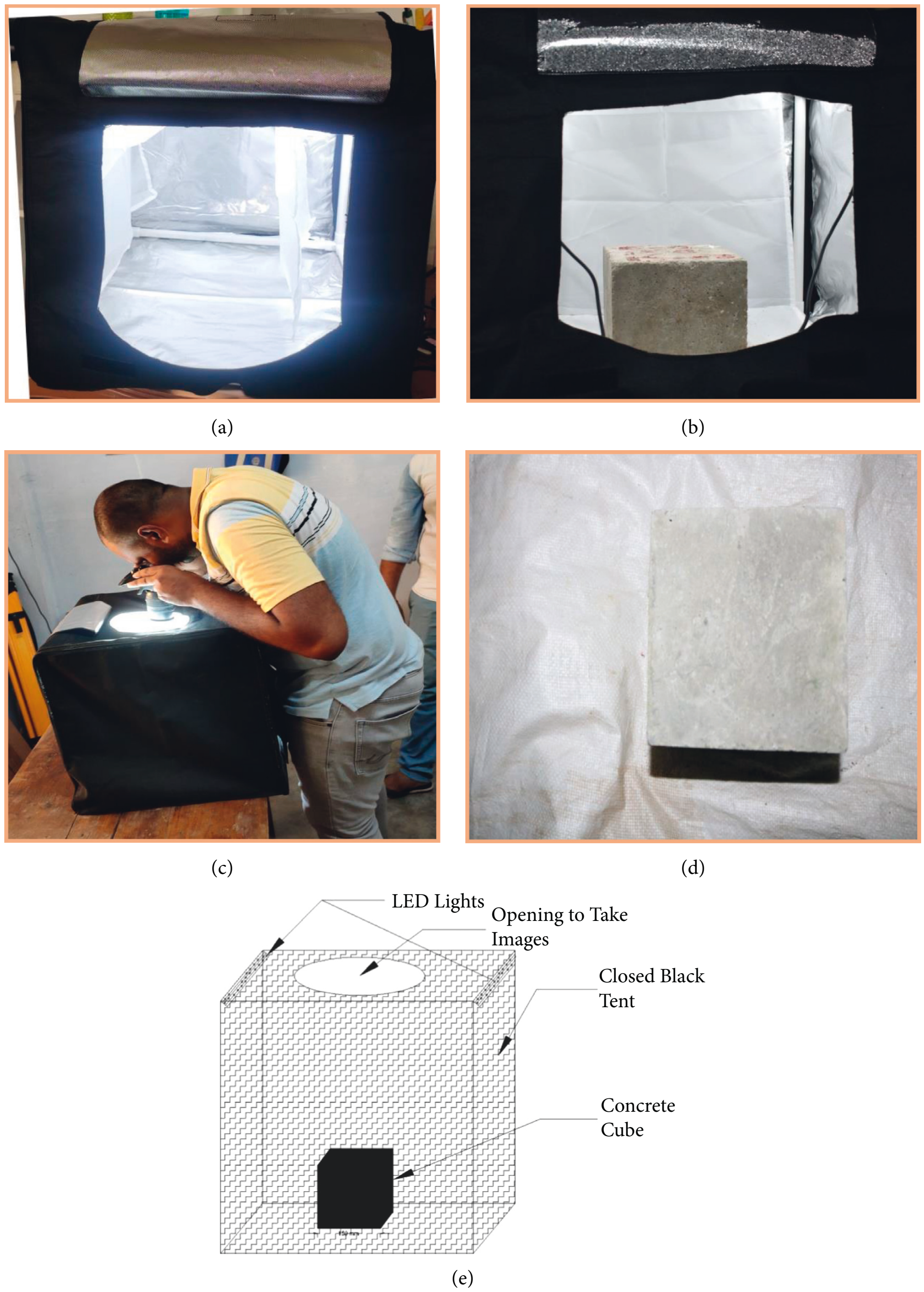


Figure 3: (a) Test setup to take digital images: (b) concrete cube after placing in the setup; (c) capturing images of concrete cube surfaces from the top; (d) the digital image captured; (e) block diagram of the test setup for capturing digital images.

ultrasonic pulse velocity test reflect whether the compaction of concrete is done properly or not at the time of casting. Poor results imply that a honeycomb type of structure is formed in the concrete.

(1) *Analysis of Ultrasonic Pulse Velocity Test Results.* According to the Indian Standard Code 13311 (Part 1) 1992 [27], based on the range of results to justify its quality, the concrete can be classified as excellent, good, medium, and doubtful based on ultrasonic pulse velocity result as shown in Table 1 [28].

4.2.3. SonReb Method. The SonReb method is one of the important methods used to predict the compressive strength of concrete. The name itself implies that the method is a combination of both ultra“Son”ic pulse velocity and “Re-b”ound hammer tests. The principle involved in the SonReb method is rebound number (RN) and the ultrasonic pulse velocity as input and the compressive strength as output. The SonReb method is significant as it is a combination of both the rebound hammer test and ultrasonic pulse velocity test. The rebound hammer test gives the strength of the concrete specimen near the surface, whereas the ultrasonic pulse velocity test reflects the interior properties of concrete. So, by considering various correction factors, the SonReb method achieves accuracy.

Many authors contributed different empirical formulas to correlate the compressive strength of concrete with rebound number (RN) and ultrasonic pulse velocity. There are numerous types of relationships, such as linear, polynomial, power, exponential, and logarithmic, based on which empirical formulas are developed [29–31]. The following are some of the most reliable equations among all methods [32]:

$$f_{ck} = 7.695 \times 10^{-11} \times (RN)^{1.4} \times (V)^{2.6}, \quad (1)$$

$$f_{ck} = 1.2 \times 10^{-9} \times (RN)^{1.058} \times (V)^{2.446}, \quad (2)$$

$$f_{ck} = 0.0286 \times (RN)^{1.246} \times (V)^{1.85}. \quad (3)$$

f_{ck} = compressive strength of concrete (N/mm^2), RN = rebound number, and V = ultrasonic pulse velocity (in m/s).

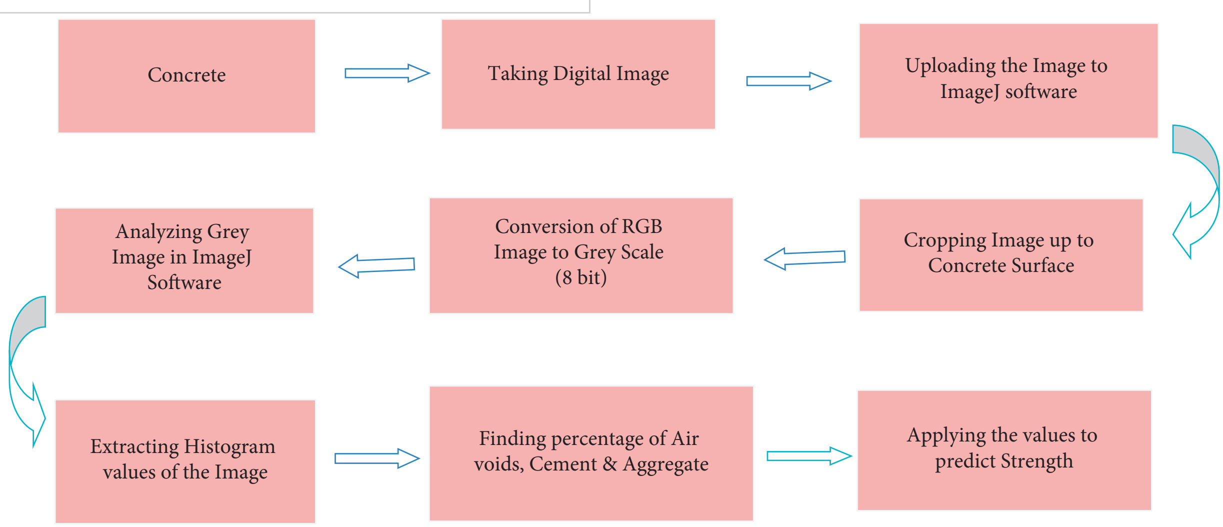
Based on the given three formulations, another formulation is proposed based on Technical Standards of Tuscany region, which is the mean value calculated by the three formulations and the mean value is considered as SonReb results in this paper.

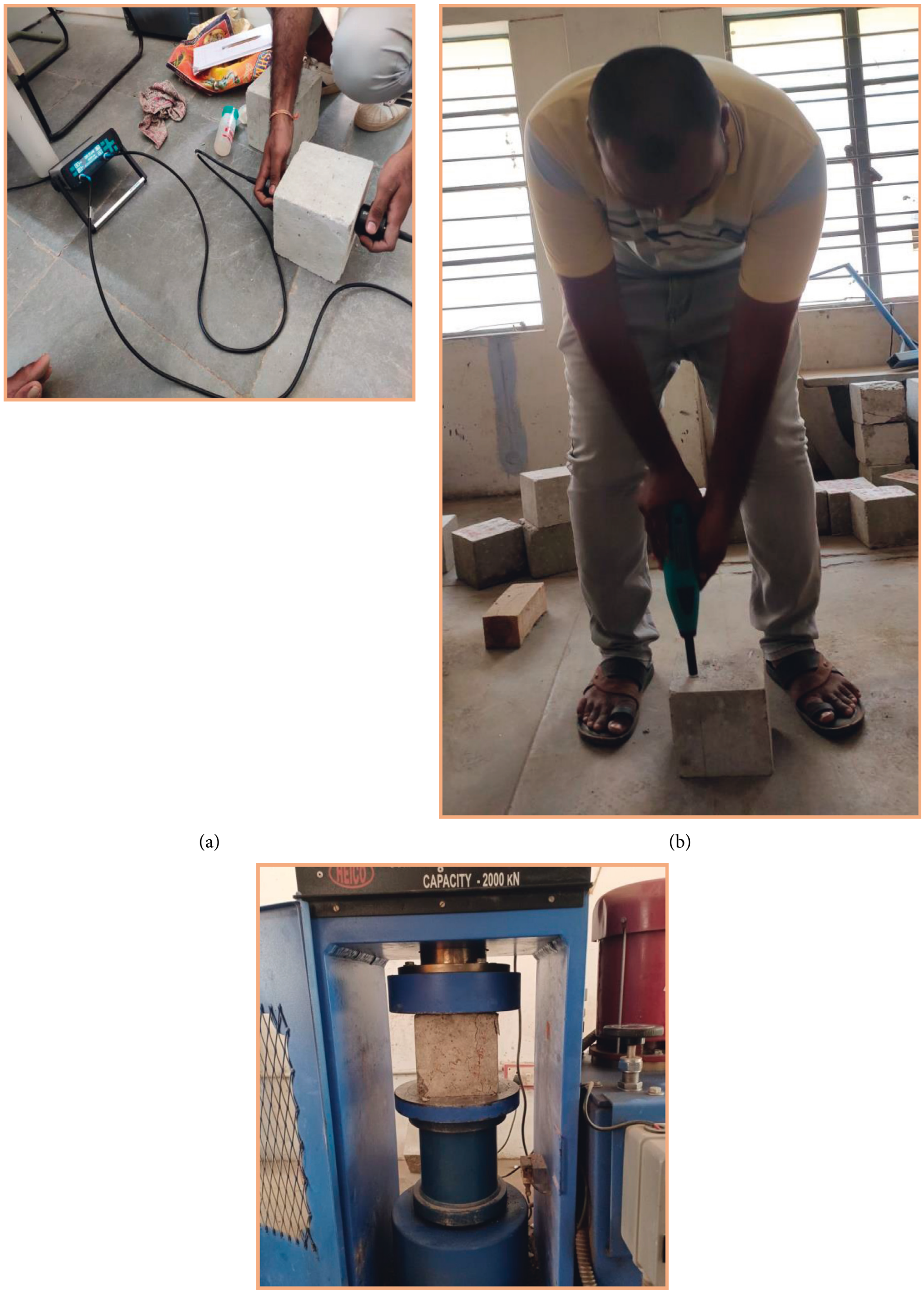
4.2.4. Digital Image Processing Method. The digital image processing test is one of the latest techniques to determine the compressive strength of the concrete without any destruction. There several relationships between the compressive strength and all the other mechanical properties of concrete. In this technique, the concrete surface is captured with in a closed setup to avoid errors of light reflection by using a high-resolution digital camera as shown in Figure 2(a). A digital image, which has been captured, is analyzed with MATLab, SCILab, ImageJ etc., for digital image analysis processing. The image is to be cropped up to the clear surface cutting down the unrelated things in the background as shown in Figure 2(b). As explained above, a digital image is a grouping of very small units called pixels. Each pixel has a pixel value depending upon light intensity while light rays strike the object. As specified in the earlier description, a color image has a very large variation of data and in order to have feasibility to analyze data, the image should be converted into greyscale as shown in Figure 2(c) [16]. After conversion into grey scale, the image is analyzed using the appropriate software and histograms as shown in Figure 2(d). A histogram is the graphical representation of the number of pixels in the whole image representing the same pixel value. By histogram data, 0 = 0 pixels, 1 = 2 pixels, 2 = 5 pixels. . . 255 = 3254 pixels are extracted. Then, the threshold pixel number is to be determined for air voids, cement, and aggregates. For this purpose, the grey value of a small section is to be obtained across the concrete cube surface image as shown in Figure 2(e). So, the concrete composition of air voids, cement, and aggregates in percentages is obtained. By these values, compressive strength of concrete is determined by the application of empirical formulas, which were obtained by previous researchers by conducting numerous experiments [21, 33].

$$f_{ck} = \frac{(\text{aggregate})^{0.021}}{(\text{cement})^{-1.004}} - (\text{air voids})^{-1.251}. \quad (4)$$

f_{ck} = compressive strength of concrete in N/mm^2.

(1) Flowchart for 'Prediction of Compressive Strength of Concrete by Digital Image Processing Technique





(a) (b)

(c)

Figure 4: Testing of concrete cube samples: (a) ultrasonic pulse velocity, (b) rebound hammer test, and (c) crushing under CTM.

5. Experimental Program

5.1. Design Mix. According to the Indian Standard Code 10262–2009 [34], a mixed design is prepared for M30 grade concrete with proportion 0.45 : 1 : 1.46 : 2.26 (water: cement: fine aggregate: coarse aggregate) by weight. To obtain better workability at the time of mixing of concrete, graded aggregates are used in two fractions as 60% of 20 mm and 40% of 12.5 mm of coarse aggregate in concrete composition.

5.2. Sample Preparation and Curing. Weigh batching is followed as per the mixed design proportion of M30 grade concrete, and twelve cube samples of size 150 × 150 × 150 mm are cast. As per the Indian Standard Code 456-2000 [35], six

Table 2: Comparison of compressive strength obtained by destructive and nondestructive tests.

Sample no.	No. of days of curing	Compressive strength by CTM (in N/mm^2)	Rebound hammer		Ultrasonic pulse velocity test	Compressive strength as per the SonReb method	Image analysis
		f_{ck} in N/mm^2	RN	f_{ck} in N/mm^2	Velocity (m/s)	f_{ck} in N/mm^2	f_{ck} in N/mm^2
1	7 days	20.444	21	14.5	4545.5	21.72	22.95
2	7 days	17.778	20	14.0	4622.5	21.27	16.90
3	7 days	19.555	20	14.0	4713.5	22.25	19.49514
4	7 days	19.111	21.5	16.5	4651.5	23.56	18.82616
5	7 days	18.889	23.5	18.5	4587	25.41	17.96898
6	7 days	19.555	24	19.5	4492	24.84	25.56
	Average	**19.222**		**16.166**		**23.175**	**20.28**
7	28 days	32.444	30.5	29.00	4833.5	39.36	27.26081
8	28 days	36.889	30.0	28.00	4792	37.81	32.54504
9	28 days	28.444	25.50	22.50	4870	32.20	26.6878
10	28 days	37.7778	24.00	19.50	4818	29.19	33.91921
11	28 days	39.111	27.00	24.00	4757	32.70	34.9321
12	28 days	31.111	27.50	25.00	4788	33.95	31.1603
	Average	**34.298**		**24.40**		**34.20**	**31.08**

*f_{ck} = compressive strength of concrete in N/mm^2.

Table 3: Comparative difference between destructive and nondestructive tests.

No. of curing days	Destructive test	Nondestructive tests: Rebound hammer		SonReb method		Image analysis	
			% diff		% diff		% diff
7 days	19.222	16.166	**−15.89%**	23.175	**+20.56%**	20.28	**+0.055%**
28 days	34.298	24.40	**−28.85%**	34.20	**−0.0028%**	31.08	**−9.382%**

*% diff indicates the percentage difference between average compressive strength of destructive and particular nondestructive tests.

samples were tested at the age of 7 days of curing and the other six samples were tested at the age of 28 days of curing.

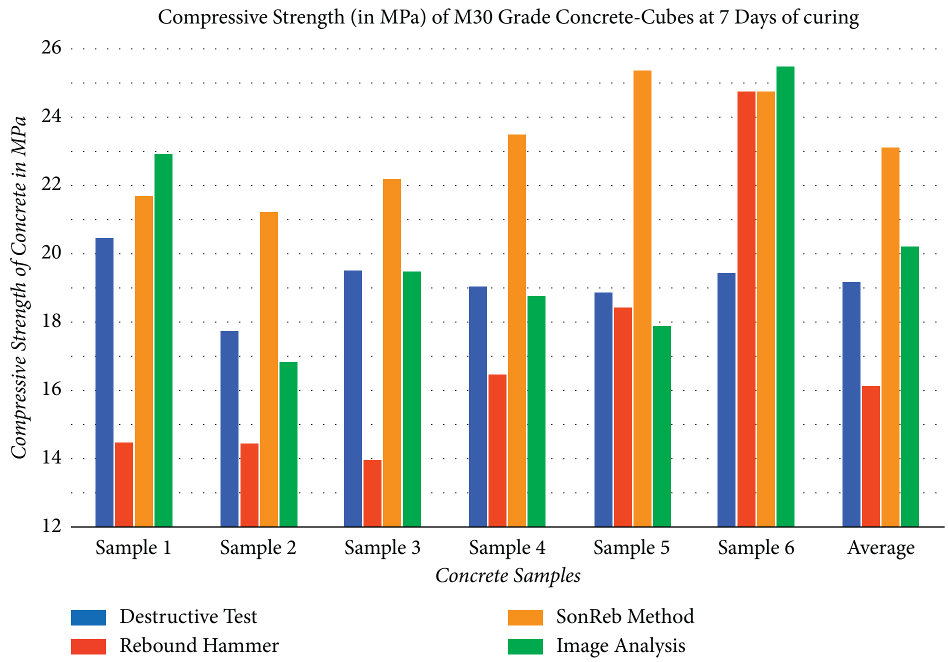
6. Testing Procedures

As mentioned in the methodology and as per Indian Standard Code 456-2000 [34], after the completion of the curing period, the samples were tested in CTM by the destructive nature and the results are tabulated in Table 2. Before destruction, NDT were completed and carried over to the destruction of concrete cube samples.

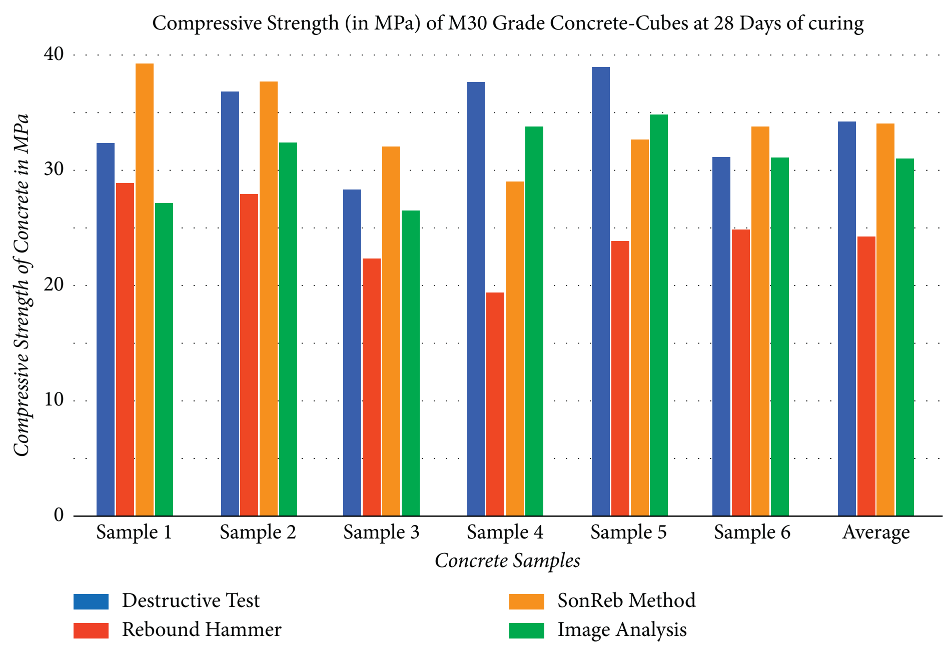
6.1. Nondestructive Test Procedures. The given steps were followed during the test procedure.

6.1.1. Capture of Digital Images and Analysis. Digital images of test samples are to be captured in a separate environment having no other effects which may influence the histogram of the image. For this purpose, a special environment is created as shown in Figure 3(a). The special environment consists of a tent having opening on the side and top and two LED lights to have equal focus while taking images. The cured specimens are shifted into the tent and placed on a flat surface as shown in Figure 3(b). Digital images are taken on all six sides of the cube specimen in order to avoid and nullify errors, as shown in Figure 3(c). As explained in the methodology, the captured images are analyzed using ImageJ software. Figure 3(d) shows the digital image of the concrete cube sample after 28 days of curing.

6.1.2. Schmidt's Rebound Hammer Test. After capturing digital images of the specimens, samples are to be examined by Schmidt's rebound hammer test. It works on the principle of the surface hardness of the concrete sample. Hence, Schmidt's rebound hammer is to be handled carefully to extract the rebound number (RN) of the sample. In the test procedure, it is mandatory to select a better surface on the concrete for the testing operation. A fixed amount of energy is applied on the concrete surface by pushing the hammer against the concrete surface. The plunger through which the energy is applied on the concrete must be permitted to strike perpendicularly on the test surface. There should not be any inclination to the surface of the sample during the application of plunger as any slight angle of inclination may also influence results. After the application of energy, the rebound hammer is locked by pressing a button provided and the rebound number as generated on the rebound hammer is noted as shown in Figure 4(b). There is no direct relation between the hardness of the surface to the compressive strength of concrete, but an empirical relation is developed as determined by previous research, where the compressive strength is determined by establishing a relationship between the rebound number (RN) and the compressive strength of concrete. The test is repeated to avoid mistakes



(a)



(b)

Figure 5: Results of compressive strength (in MPa) of M30 grade concrete obtained by destructive method, rebound hammer test, SonReb method, and digital image processing. (a) 7 days of curing and (b) 28 days of curing.

and errors in the process of testing and to reach the accurate compressive strength of concrete [36].

6.1.3. Pundit's Ultrasonic Pulse Velocity Test. For the ultrasonic pulse velocity test, Pundit's ultrasonic pulse velocity testing machine is used, which consists of an electrical pulse generator and two transducers having one transmitting transducer and another receiving transducer. The amplifier, an electromagnetic timing device, is used to determine the velocity of wave propagation. Meanwhile, the concrete specimen cube is placed on the table surface. Two transducers are to be rubbed initially with grease or petroleum jelly or kaolin or liquid soap. The concrete surface is made smooth at the place of application of transducers, and ultrasonic waves are propagated through the concrete specimen from the transmitter transducer to the receiver transducer. The sound waves propagate through the concrete medium, and the time taken for travelling is noted down to be displayed on the electronic timing device attached to the apparatus. The length of the specimen and time are noted down from the device. The velocity of the propagating waves is calculated and recorded as shown in Figure 4(a). There is no direct relation between compressive strength of concrete and ultrasonic pulse velocity, but the SonReb method correlates rebound hammer results with ultrasonic pulse velocity results and is helpful in determining the compressive strength. Results of the SonReb method are calculated as per the formula specified in equations (1)–(3), and their average values are presented in Table 2.

6.2. Destructive Test Procedures. Destructive testing conducted on the compressive testing machine (CTM) is as per Indian Standard Code 516 [37]. Samples are to be tested by using CTM, and the compressive strength has been tabulated in Table 2. The crushed sample is shown in Figure 4(c).

7. Results and Discussion

After curing for 7 and 28 days, six samples of M30 grade concrete cube specimens have been casted and tested for the study. All types of tests as discussed above are conducted step by step, and the results are summarized and presented in Tables 2 and 3. Graphs comparing the compressive strength of concrete (f_{ck}) cubes in all the test procedures of 7 days and 28 days are shown in Figures 5(a) and 5(b).

8. Conclusions

Interlinking of different applications as discussed in the present study has proved to save time and money, and precise incremental results have been obtained. Civil engineering is one of the oldest branches of engineering, and application of other engineering branches into civil engineering has been shown as a new approach to solve many civil engineering problems. There are many conventional experiments in civil engineering, which can be interconnected technologically by using digital image processing techniques, a solution for numerous problems. In the present study, twelve M30 grade concrete samples are casted. Of the twelve, six samples are tested at the age of 7 days of curing and the rest of the samples are tested at the age of 28 days. Conclusions drawn based on the results of destructive and NDT procedures are as follows:

(1) The rebound hammer test, which works on the principle of surface hardness, is the most effective procedure for testing samples at 7 days compared to 28 days.

(2) Gradual increase in the results of ultrasonic pulse velocity can be seen from 7 days to 28 days samples. It may be because of the reaction occurring in the C-S-H gel from 7 to 28 days.

(3) The SonReb method is one of the finest methods interlinking both RBH and ultrasonic pulse velocity results with compressive strength and bestows accurate results when results are considered in average.

(4) Digital image processing techniques are helpful in the prediction of the compressive strength of concrete by analyzing the surface images.

(5) "ImageJ" software, one of the free software packages, is user-friendly and most flexible to extract histograms of digital images.

(6) A unique pattern is observed in all histograms when grouped as 7 days and 28 days.

(7) Relationship (4) used for predicting the compressive strength of concrete by digital image processing is satisfactory in obtaining results.

(8) Compressive strength results obtained by digital image processing techniques are almost similar to the results obtained by destructive procedures and SonReb method.

(9) The average compressive strength of concrete samples at 28 days is almost equal to the results of the SonReb method with a difference of −0.0028% and results of the image analysis method with −9.382% difference.

(10) The image analysis method fetches accurate results as it studies the concrete surfaces to the maximum extent using modern digital image processing techniques.

(11) Digital image processing techniques can be applied to higher grades of concrete cube samples in order to generalize the procedure towards emerging of a new nondestructive test of concrete.

Data Availability

Necessary data are included within the manuscript.

Conflicts of Interest

The authors declare that they have no conflicts of interest regarding the publication of this paper.

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