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Research Article

IoT-Based Intelligent System for Internal Crack Detection in Building Blocks

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Cracks that are detected in concrete structures represent significant damage, and they can lead to a detrimental effect on the structure's durability. Their identification in a timely manner can help ensure structural safety and guide in-depth maintenance operation. Automatic detection of such cracks has been proposed using internal crack detection utilizing ultrasonic sensors in concrete. Cracks within the concrete can be detected using ultrasonic sensors. In this investigation, we introduced an intelligent method that is aimed at developing a crack detection scheme using ultrasonic sensors. These ultrasonic sensors are used for the detection of cracks in buildings which cannot be seen with our naked eyes; they are capable of alerting authorities via SMS message and providing the cracks' location via GSM and GPS modules. To monitor internal cracks in the concrete cubes and cylinders, the ultrasonic sensors can be fixed at the centre of the cube which will be used for interval crack monitoring based on crack detection technology. The grade of concrete used for testing is M_{25}, and it is well mixed with the ingredients of cement, fine aggregate, coarse aggregate, and water. The concrete is placed in the cube moulds having the dimensions 150 mm × 150 mm × 150 mm. The cylinders used in the case of the experimental analysis are of the dimensions of 150 mm diameter and 300 mm height. These specimens are cast and kept in the curing tank for 28 days to attain the maximum strength. After completion of the curing period, the specimens were taken out from the tank and weighed. After this weighing process, the cubes and cylinders are about 8.884 kg and 13.399 kg, respectively. The information about the cracks can be displayed on the LCD, and also, the transmitted short message about the cracks can be exchanged between the devices using IoT.

1. Introduction

Concrete is the most often utilized material in the world for numerous civil infrastructure projects such as bridges and buildings. They are safely constructed by superimposing the various loads to the foundation, but their structural integrity is compromised by a variety of operating environmental factors. As a result, their strength is critical in nature, maintaining a high level of safety structures and durability, and their efficiency factors are critical because civil infrastructure accounts for a significant portion of the national economy. The adopted ultrasonic sensor system can be classified into two major modules, namely, the hardware module and the software module. An ultrasonic sensor has two main parts, (a) the transmitter and (b) the receiver; the transmitter sends out a signal after it has been reflected off the surface or cracks [1, 2]. The principle of the ultrasonic sensor emits short bursts of high-frequency sound at regular intervals. Background interference is effectively suppressed by using ultrasonic sensors. Almost all materials which reflect the sound can be detected regardless of hue. Microultrasonic sensors are ideal for target distances ranging from 20 mm to 10 m, and they will record the time, pinpoint precision, etc. Some of the sensors can even resolve the signal to 0.025 precision [3, 4].

In this, the ultrasonic sensors play a major role in spotting the crack inside the concrete cube. Through ultrasonic ways, the cracks in the surface can be detected and the depth can be displayed. The GSM (Global System for Mobile Communication), GPS (Global Positioning System), and microcontroller-based broken bridge track detection are, when implemented, an efficient method for the detection of cracks which are present in the tracks. If a stretch is detected, then this sensor will send a signal to the Arduino UNO board which will activate the GPS receiver to exchange the information using IoT [5, 6].

In this paper, we proposed a low-cost, low-power IoT-based embedded technology to help and improve the safety standards for cylindrical concrete by preventing the cracks and impediments in the buildings. The testing crack prototype can identify fractures and impediments on buildings and cracks quickly. The findings indicate that this proposed technology will improve the dependability of safety systems [7–9]. By incorporating these characteristics into real-time applications, it can reduce the accidents by up to 70%. The major objectives of the paper are given below.

(1) The proposed IoT-based GPS and GSM for the internal crack detection system is an assisting unit that uses ultrasonic sensors to identify the cracks in cylindrical concrete available in buildings and bridges, etc.

(2) These sensors will check for the presence of a crack and displays the message on the LCD display if it exists. If the crack is detected, the data can be communicated using IoT

(3) As a result, the proposed method reduces automobile accidents and saves lives and also reduces the economic losses. This method is highly effective in reducing the need of human assistance in detecting cracks

2. Existing Method and Review of Literature

Crack detection is a telltale sign that a building is deteriorating. Crack detection is frequently required during the maintenance stage of a civil structure. In addition, inspection of the structural integrity based on crack analysis becomes substantial for the service life perdition of the structure. The process of determining the cracks using manual processes for large-scale structures is tedious and time-consuming, and many researchers are proposing their models based on image-processing concepts, which allows for a more rapid and efficient measurement of cracks in concrete [8, 9]. The general framework of these models is shown in Figure 1.

Figure 1 depicts an image-processing methodology based on an automated methodology for concrete detection. This model numerically expresses the crack defects, and this method can also be used to detect the internal cracks [10–12].

Figure 1 depicts an image-processing methodology based on an automated methodology for concrete detection. This model numerically expresses the crack defects, and this method can also be used to detect the internal cracks [11, 13].

For identifying and analyzing concrete surface cracks, Hsieh et al. [8] developed an automated technique-based image-processing system. Crack detection is performed based on the crack analysis which is performed on a picture of a concrete surface, and the crack width, length, and area are calculated. A numerical model for crack flaws was created by Bao et al. [3], and the suggested technique is used to identify and quantify the cracks. Mak and Picken suggested an image-based automated crack identification model for postdisaster building evaluation; the authors show that the suggested method may provide considerable benefits in postdisaster building element analysis based on numerical tests [14].

Chidambaram and colleagues [15] offer a hybrid detection method that incorporates both digital picture correlation and acoustic emission. The Otsu method and Sobel's filtering in Talan et al.'s work made use of image-processing techniques to identify cracking flaws in digital pictures. A multifractal analysis of crack patterns was carried out by Gonzalez et al. [16] with applications in reinforced concrete shear walls. In [17], Otsu suggested the identification of surface cracks in tunnel linings based on infrared pictures, and it is an effective crack identification method. Low contrast, uneven light, and severe noise pollution are all prevalent problems in tunnel lining photos, and the proposed solution is capable of addressing them.

Furthermore, one of the most important tasks of pavement surveys is to detect cracks that occur on the pavement surface. It is because if cracks are found early and properly repaired, the cost of road reconstruction can be reduced by up to 80% [18]. As a result, numerous image-processing methods for detecting asphalt pavement cracks where fissures have been formed. Image thresholding algorithm-based road crack identification models by Subramanian et al. [19], Alam et al. [20], and Kogilavani et al. [21] have all provided solutions.

Furthermore, many scholars [22–24] have established models based on edge detection algorithms. Nonetheless, the above-mentioned crack detection models' performance is frequently hampered by the complex texture of asphalt pavement and the shading conditions of digital images [25]. As a result, more sophisticated methods such as to

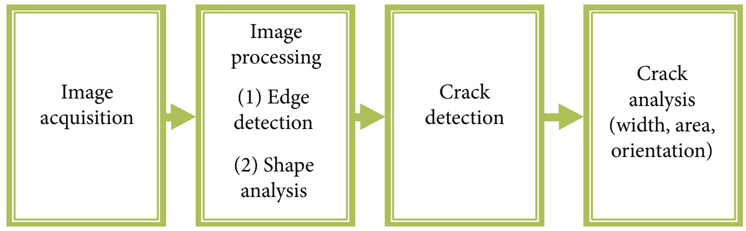


Figure 1: Image-processing-based crack detection model.

boost fracture detection performance, beam let transform [21], and shadow reductions [22] have been applied. According to a survey of the literature, applying intelligent image-processing models for automatic crack identification and analysis is becoming more popular.

The mode input is the original image captured by the digital camera. The suggested enhanced Otsu technique is then used to apply the image-thresholding procedure on the original picture. The M2GLD algorithms, as well as the classic Otsu algorithm, were discussed in the previous section, which make up the suggested improved Otsu technique. Following the picture penalization procedure, the picture concentrated effort procedure is used to remove noisy pixels and the noncrack objects mentioned in Figure 2. The research work is considered an image-based automatic crack identification model for postdisaster building evolution; the authors show that the suggested method can provide significant benefits in postdisaster building element analysis based on a numerical experiment [26, 27]. Furthermore, one of the most important tasks of concrete surveys is to detect cracks that occur on the pavement surface. If the cracks are found at early stages and they can be properly repaired, the cost of road reconstruction can be reduced by as much as 80%. As a result, numerous image-processing methods for detecting asphalt pavement cracks have been developed. The image-processing procedure is divided into two steps: firstly, the area with less than a particular number of pixels (Np) are removed, and then, an axis is added to the image length of an object, where

$$\mathrm{ARI} = \frac{L_M}{L_N}. \tag{1}$$

The major axis and minor axis lengths are measured using an object-circumscribed ellipse [11–15]. The major axis and minor axis lengths are L_M and L_N, respectively.

The limitations of the existing methods are as follows. This is the research gap identified in existing methods. The limitations are as follows:

(1) The existing method does not have an IoT-based GPS and GSM for internal crack detection system which is an assisting unit that uses ultrasonic sensors to identify the cracks in cylindrical concrete available in buildings and bridges, etc.

(2) The sensors used in the existing method are unable to detect the presence of a crack

(3) Due to these limitations, the existing method cannot reduce the automobile accidents and cannot reduce the economic losses. That is why the existing methods are not effective in reducing the need of human assistance in detecting cracks

3. Materials and Method

3.1. Proposed Method. The "GPS and GSM for internal crack detection" is an assisting unit that uses ultrasonic sensors to identify cracks in cylindrical concrete. The sensors are used to detect the presence of cracks and display the message on an LCD display if the cracks are detected [16–18]. As a result, this proposed method reduces the automobile accidents and saves lives and also reduces the economic losses [19]. The block diagram of the proposed method is shown in Figure 3. The objectives of the proposed method are given below.

(1) The proposed IoT-based GPS and GSM for internal crack detection is an assisting unit that uses ultrasonic sensors to identify the cracks in cylindrical concrete available in buildings and bridges, etc.

(2) Detect impediments trying to access the concrete structures (e.g., buildings, bridges, and dams)

(3) The sensors will check for the presence of a crack and displays the message on the LCD display if it exists. If the crack is detected, the data can be communicated using an IoT device

(4) As a result, the proposed method reduces automobile accidents and saves lives and also reduces the economic losses. This method is highly effective in reducing the need of human assistance in detecting cracks

3.2. Block Diagram for Proposed Method

3.2.1. Arduino UNO. Arduino is a user-friendly hardware and software platform which is freely available, and it is an open source software. The Arduino board can detect input like light from a sensor, a button like in Figure 3, or a twitter tweet and convert them to outputs such as turning a motor, lighting and LED, or turning on a computer. Anything may be posted on the internet. The Arduino IDE (Integrated Development Environment) is a piece of software developed by Arduino that is used to write, compile, and upload code to Arduino devices. This is an open source programme, which is simple to install and use to start compiling code

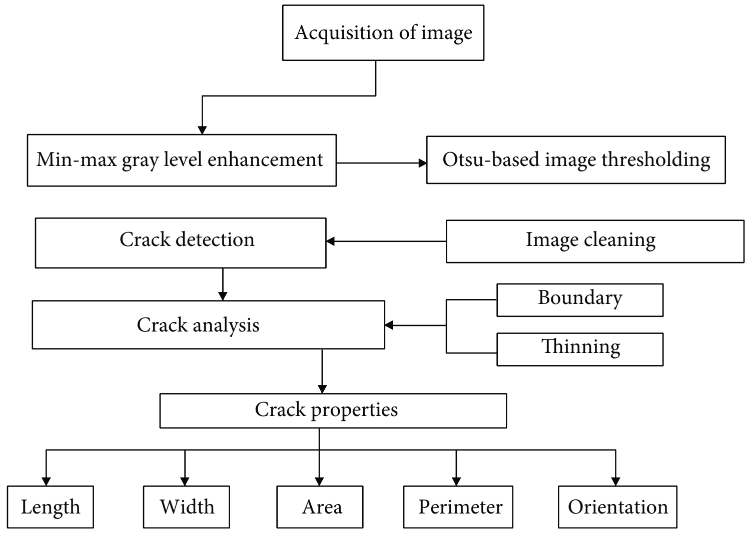


Figure 2: Image enhancements with the proposed method.

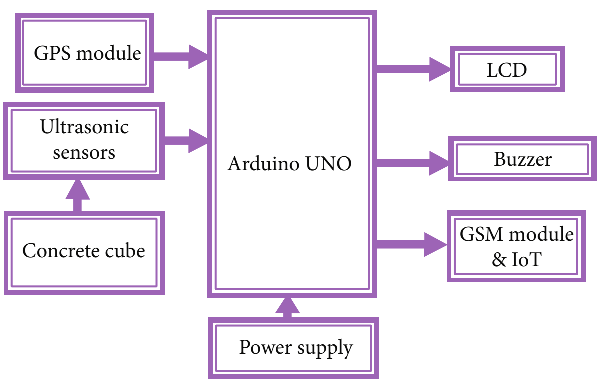


Figure 3: Block diagram of the proposed method.

on the fly, and is compatible with almost all Arduino modules. The Arduino IDE is an open source software that is used to write and build code for the Arduino module. It is easily accessible for operating systems such as Mac, Windows, and Linux, and it is based on the Java Platform. This environment includes built-in methods and instructions for debugging, modifying, and compiling code.

3.2.2. GSM Module. A GSM modem is also known as a GSM module, and it is a hardware device which uses GSM technology used to connect remote networks. From the standpoint of the mobile phone network, they are substantially identical to a regular phone, including the requirement for a SIM card to identify themselves to the network.

3.2.3. Ultrasonic Sensor. Ultrasonic waves travel at a faster rate than normal sound waves (i.e., the sound that humans can hear). Ultrasonic sensors send ultrasonic pulses into the air and detect reflected waves from objects. Ultrasonic sensors contain a wide range of features such as intrusion alarm systems, automated door openers, and backup sensors for vehicles.

New application industries such as industrial automation equipment and automotive electronic industries are growing and will continue to rise in parallel with the rapid expansion of information processing technology. The research work [14] developed a unique piezoelectric ceramics manufacturing method to create several types of ultrasonic sensors which are small and have very high performance. The below-mentioned catalog's information will assist in making the best use of ultrasonic sensors.

Figure 4: Ultrasonic wave travel in air.

3.3. HC-SR04 Sensor Features

(i) The operating voltage is +5 V

(ii) 2 cm to 450 cm theoretical measuring distance

(iii) 2 cm to 80 cm practical measuring distance

(iv) 3 mm precision

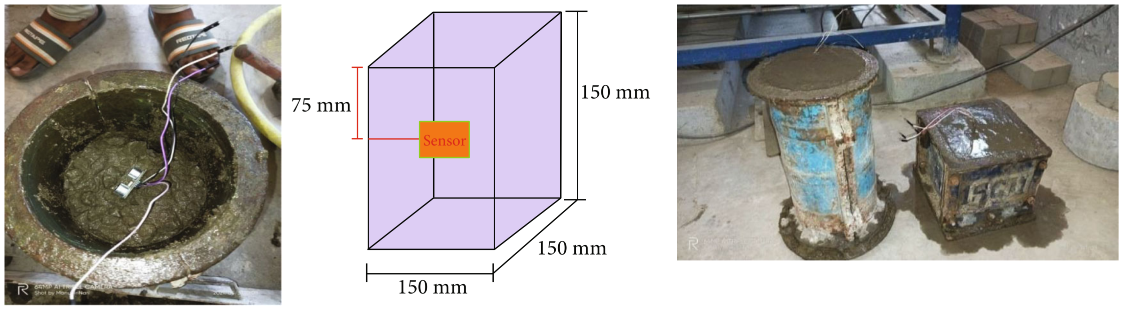
(v) Covered measuring angle: 15°

(vi) 15 mA is the operating current

(vii) 40 Hz is the operating frequency

3.4. HC-SR04 Ultrasonic Sensor: Working. This sensor is frequently used in a variety of applications including distance measurement or object detection. The ultrasonic transmitter and receiver are housed in two eye-like projections on the module's front. The sensor is based on the elementary concept

$$\text{Distance} = \text{Speed} \times \text{Time}. \quad (2)$$



(a) (b)

Figure 5: (a) Ultrasonic sensors are placed inside the concrete cube and its depth. (b) Wired connections after placing ultrasonic sensors in the concrete cube and cylinder.

The ultrasonic transmitter emits an ultrasonic wave that passes through the air and is reflected back toward the sensor if it comes into contact with any substance. The ultrasonic receiver module detects the reflected wave as depicted in Figure 4.

3.4.1. LCD Display (16 ∗ 2). A liquid crystal display (LCD) screen is a type of electronic display that can be used for a variety of purposes. A 16 ∗ 2 LCD display module is a low-cost module that can be found in a wide range of devices and circuits. A 16 ∗ 2 LCD has two lines and can display 16 characters per line.

3.4.2. Buzzer. A buzzer is also known as a beeper, and it is an auditory signaling device which is mechanical, electromechanical, or piezoelectric. Buzzer and beepers are commonly used in alarm clocks and timers and to validate human input such a mouse click or keyboard keystroke.

Figure 6: Specimens kept under curing for 28 days.

Figure 7: Displayed message on LCD, when no crack is detected.

4. Result and Discussions

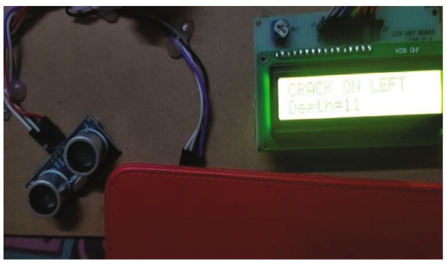
The ultrasonic sensors are placed in a concrete cube as shown in Figure 4, and after 24 hours, these cube specimens are taken out from the moulds and kept in a water tank for curing as shown in Figures 5(a) and 5(b). After 28 days, the curing process can be done, and the specimens are tested for compression under a compressive testing machine (CTM) as per IS 516:1959. If the cracks are not found in the specimen, then it shows no crack detected on the LCD as shown in Figure 6.

If the cracks are found in the concrete cube, the sensors detect the location and width of the crack present, and if the crack is not detected, this means that it does not send any message to the mobiles as shown in Figure 5. If the crack is detected, this means it sends via SMS to the mobile as shown in Figures 7–9. After detecting the crack, the message is displayed on the LCD. For reference, the sensors were named as left and right, where the depth is 11 for one concrete cube, and the data is communicated to the mobile along with the latitude and longitude. Figures 8(a) and 8(b) represent the depth of the cracks available in the right and left sides of the cube. The sensors are placed at the right and left sides of the cube. If the crack is detected by the sensors, then the message is displayed on the LCD connected to the system.

The left sensor is housed within a rectangular cube. As the pressure increases, fractures emerge inside the concrete, which are detected by the sensor and sent through SMS to a smart phone as shown in Figure 10. By not receiving the track's echo, the ultrasonic sensors can detect cracks in buildings and bridges. If the track's echo is received, then that gives the information that no crack is detected in the track. The output of the ultrasonic sensor is rounded and sent to a microcontroller that is linked to GPS and GSM.

To monitor internal cracks in the concrete cubes and cylinders, the ultrasonic sensors were fixed at the centre of the cube which will be used for interval crack monitoring based on crack detection technology. The grade of concrete used is M_{25} and well mixed with the ingredients of cement,

(a)



(b)

FIGURE 8: (a) Detection of internal cracks through LCD display (right). (b) Detection of internal cracks through LCD display (left).

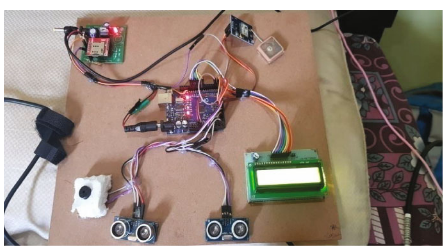


FIGURE 9: Experimental sensors in the cube setup before placing the cylinder.

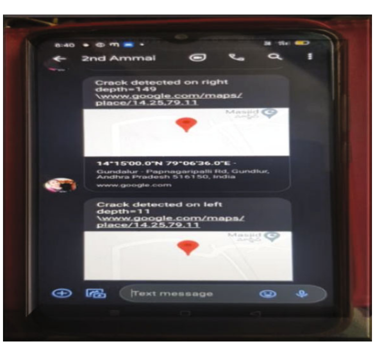


FIGURE 10: Received message in mobile, when crack is detected.

fine aggregate, coarse aggregate, and water. The concrete is placed in the cube moulds having the dimensions 150 mm × 150 mm × 150 mm and the cylinders of dimensions of 150 mm in diameter and 300 mm in height. These specimens were casted and kept in a curing tank for 28 days to attain the maximum strength. After completion of the curing period, the specimens were taken out from the tank and weighed. Cubes and cylinders are about 8.884 kg and 13.399 kg, respectively. Now, the specimens were kept under a compressive testing machine, and connections were given as shown in Figures 2, 3, and 4. The load is applied gradually with an intensity of 1.4 kN/s. And the results were taken for every 50 N which are shown in Table. 1. The cube and cylinder calculations mentioned in Tables 1 and 2 are given below.

TABLE 1: Cube strength for 7 days and detected crack sizes.

S. no.	Load in *N*	7-day cube compressive strength in N/mm^2	Cracks in mm
1.	50	2.22	0.00
2.	75	3.33	0.00
3.	100	4.44	0.15
4.	125	5.56	0.20
5.	150	6.67	0.30
6.	175	7.78	0.30
7.	200	8.89	0.75
8.	250	11.11	0.75
9.	275	12.22	1.00
10.	300	13.33	1.00
11.	325	14.44	1.75
12.	358	15.91	2.50

TABLE 2: Cube strength for 14 days and detected crack sizes.

S. no.	Load in *N*	14-day cube compressive strength in N/mm^2	Cracks in mm
1.	50	2.22	0
2.	100	4.44	0.20
3.	150	6.67	0.50
4.	200	8.89	0.50
5.	250	11.11	0.70
6.	300	13.33	0.70
7.	350	15.56	0.90
8.	400	17.78	1.26
9.	450	20.00	1.55
10.	515	22.88	1.95

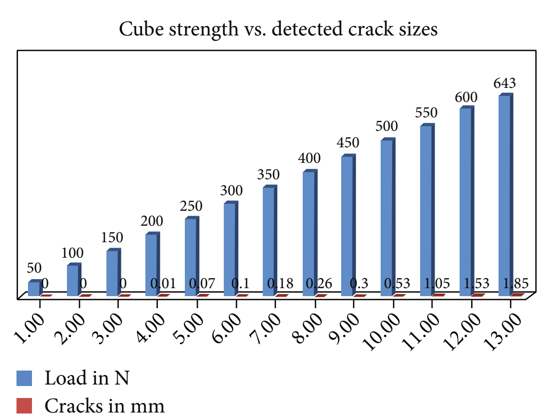


FIGURE 11: Cube strength vs. detected crack sizes.

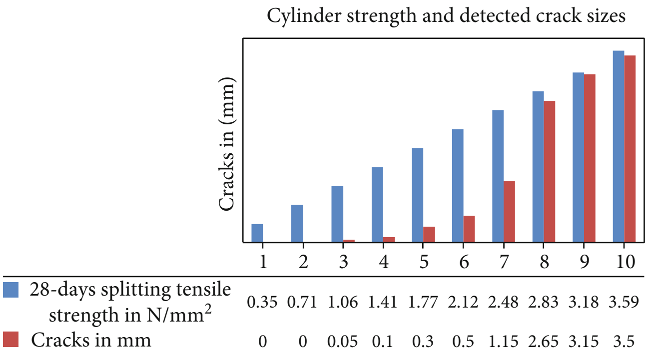


Figure 12: Cylinder strength and detected crack sizes.

Table 3: 28-day cube strength and detected crack sizes.

S. no.	Load in N	28-day cube compressive strength in N/mm^2	Cracks in mm
1.	50	2.22	0.00
2.	100	4.42	0.00
3.	150	6.67	0.05
4.	200	8.89	0.10
5.	250	11.11	0.10
6.	300	13.33	0.15
7.	350	15.56	0.18
8.	400	17.78	0.26
9.	450	20.00	0.30
10.	500	22.22	0.53
11.	550	24.44	1.05
12.	600	26.67	1.53
13.	643	28.58	1.85

Table 4: Cylinder strength for 7 days and detected crack sizes.

S. no.	Load in N	7-day splitting tensile strength in N/mm^2	Cracks in mm
1.	25	0.71	0.00
2.	50	1.06	0.10
3.	75	1.41	0.50
4.	100	1.77	1.30
5.	125	2.12	1.90
6.	179	2.53	2.50

From Figures 11 and 12 and Tables 1, 2, 3, 4, 5, and 6, it is found that the cracks that are detected by the sensors are good enough, and these can be used in monitoring the health of structures. These sensors can be utilized such that a structure which is in a seismic zone can detect and monitor the vibrations that are coming from the earth, and these will be displayed on the screen. The cracks and the vibration sensors can be used for the structures which are under construction and which are already constructed. The sensors are placed in concrete structures for the detection of vibration alerts and cracks, and the information can also be exchanged between the devices using IoT, so that this proposed method can save the lives of the people living in the buildings.

Table 5: Cylinder strength for 14 days and detected crack sizes.

S. no.	Load in N	14-day splitting tensile strength in N/mm^2	Cracks in mm
1.	25	0.35	0.00
2.	50	0.71	0.00
3.	75	1.06	0.05
4.	100	1.41	0.10
5.	125	1.77	0.30
6.	150	2.12	0.50
7.	175	2.48	1.15
8.	193	2.73	2.65

Table 6: Cylinder strength for 28 days and detected crack sizes.

S. no.	Load in N	28-day splitting tensile strength in N/mm^2	Cracks in mm
1.	25	0.35	0.00
2.	50	0.71	0.00
3.	75	1.06	0.05
4.	100	1.41	0.10
5.	125	1.77	0.30
6.	150	2.12	0.50
7.	175	2.48	1.15
8.	200	2.83	2.65
9.	225	3.18	3.15
10.	254	3.59	3.50

5. Conclusion

This paper describes the intelligent method for detecting the cracks and impediments in pillars of buildings. This method is cost effective, the reliability of safety measures in collapsing older structures can be improved as a result of this new creative technology, and also, this method is used to identify faults in tracks of the bridges. This helps to detect the cracks in buildings which are not visible to our necked eyes. It is capable of alerting authorities via SMS message and providing the cracks' locations via GSM and GPS modules. This method cannot cause any damage to nearby structures. The design is extremely efficient and user-friendly. The detection of fractures in a surface is very simple using this method. It is simple to use, and power consumption is also very low. Reduction of accidents can be effectively minimized by using this method. Therefore, it is concluded that this intelligent system is very effective and can minimize the accidents that can be caused during disasters by providing the information through mobiles and buzzer sounds.

Data Availability

The data used to support the findings of this study are included in the article.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this article.

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