International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 15 Issue 07 , July - 2026

Smart Bridge Monitoring System

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Abstract: This paper is based on a smart bridge monitoring system using Internet of Things (IoT) technology with image processing for continuous monitoring of the bridge's structural health. In this project, we use an ESP32-CAM module connected to a TTL converter to capture surface images of the bridge and identify cracks using an adapted AI model based on the Edge Impulse platform. Along with this crack detection, an ESP32-SIM800L microcontroller is also used to collect sensor data, like a soil-moisture sensor for water-level detection, a DHT11 sensor for tracking temperature and humidity, and an MPU6050 sensor for measuring vibrations and seismic activity. The collected data is sent to the Blynk cloud platform, where we can monitor the real-time data and receive alerts whenever any parameter exceeds the safety limit. The system helps in early detection of cracks on bridges, water level alerts, seismic alerts, and high temperature.

Keywords: ESP32-CAM, ESP32-SIM800L, Soil Moisture Sensor, DHT11 Sensor, MPU6050 Sensor, crack detection.

I. INTRODUCTION

Bridges are really one of the important things in transportation infrastructure, which helps the people to cross the geographical obstacles like river and mountains, making transportation easier. During their working lifetime as we know bridges are exposed to multiple stress factors, like heavy traffic loads, temperature variations, high humidity, and vibrations. If it is continuously exposed to these conditions, slowly the bridge loses its structural strength, which might lead to severe degradation or even terrible failure if not detected in a timely manner. There are several bridge collapses that have happened in the past, which highlighted the urgent need for ongoing and accurate monitoring systems that ensure safety and prevent major accidents.[1-2]

The present bridge inspection method depends on manual survey and visual evaluation. Which is effective to some extent, but these methods are labour-intensive and costly and do not provide real-time information about the bridge condition. These limitations have motivated us to research smart and automated monitoring solutions that utilize sensors and communication technology to monitor and deliver continuous condition updates. [3]

The aim of our project, which we have proposed, is to implement a smart bridge monitoring system by combining IoT and image processing. Here we use an ESP32-CAM module integrated with a TTL converter to capture real-time images of the bridge surface and an edge impulse platform, which processes these images to identify the cracks on the bridge surface. [4] Along with that, we are also using multiple sensors to monitor another structural parameter. Parameters like a soil moisture sensor to track surrounding water levels, a DHT11 sensor to measure temperature and humidity, and an MPU6050 sensor to detect vibration and seismic activity. [5] The ESP32-SIM800L module collects and transmits all sensor data to the Blynk cloud platform, allowing easy real-time monitoring, and also generates alerts automatically whenever a measured value exceeds its threshold. The crack detection results are also displayed on the Blynk dashboard. [6-7]

The project that we have done provides a cost-efficient, reliable, and fully automated approach for the early detection of defects such as cracks, corrosion, and unusual vibrations like earthquakes. The work helps to maintain bridge safety, supports predictive maintenance, and contributes to the long-term sustainability of bridge infrastructure. [8]

II. METHODOLOGY

In this project we have adopted IoT-based technology with image processing to develop a real-time bridge health monitoring system, which will be capable of detecting any abnormalities in the bridge structure and ensuring safe operation. The construction that we have planned in our project helps to continuously gather and analyze the parameters collected by the sensors along with detecting the crack on the bridge surface through the image processing concept. The complete project setup that we have did have two main subsystems: one is the sensing module and communication module, and the other one is the crack detection module. Where the two modules operate synchronously in coordination with each other to give complete values of the bridge model. [9-10]

The sensors are connected to the ESP32-SIM800L microcontroller. This microcontroller collects data from the sensors. Processes it. The DHT11 sensor records temperature and humidity, which helps us indicates the possibility of corrosion on the bridge, when the humidity is high it increases the oxidation of components., which increases the chances of corrosion. The soil moisture sensor is used to determine the water level around the bridge, which helps in early warnings of flooding or leakage that could weaken structural stability. The MPU6050 sensors measure vibration and also acceleration data by capturing unusual movement of the bridge or seismic effects that helps to indicate or to detect factors like earthquake. [11-12]

The microcontroller collects all these sensor data, processes the readings of what it got, and transmits them to the Blynk cloud. The Blynk cloud helps to display each parameter, which is continuously displayed in real time; we have given predefined threshold values for parameters like temperature, humidity, water level, and vibration. If any parameter crosses the safe limit, the alert will be triggered on the Blynk dashboard, where the maintenance department can get to know and take some corrective measures. [13-14]

Along with the sensor module, the crack detection module also operated in parallel, which inspects the bridge surface using an image processing method. [15-16] This crack detection module uses an ESP32-CAM along with a TTL converter to ensure stable data transfer between components. The camera helps to capture images of the bridge surface after few intervals of what we have set, and these images are processed by the AI model in the Edge Impulse tool/platform. The model that we have trained identifies cracks based on the captured patterns. Based on the analysis of the results, an appropriate message is displayed on the Blynk dashboard. If cracks are found, then it is displayed as “Crack Detected,” and if not, then it is displayed as “No Crack Detected.” This automatic detection method helps to reduces the need for manual inspection and improves the consistency of crack detection.

Both the modules operate in parallel to access real-time data collection, analyze it, and visualize it. The results from both modules are transmitted to the Blynk cloud, where the user can view the real-time condition or status of the bridge and also their historical data. These stored data can be later analyzed to identify any continuous variation in vibrations, humidity, or crack formations, which supports the maintenance of the bridge structure and its life cycle management. By using advanced technology, the project we have done achieves accurate, continuous, and automatic monitoring of bridge structure with less human interference. [17-18]

In summary, we can say that the method that we have used is a practical, low-cost, and dependable solution for the bridge monitoring. By integrating these sensors, the system enables early detection of faults, which helps in timely response and improves the overall safety and durability of bridge structures.

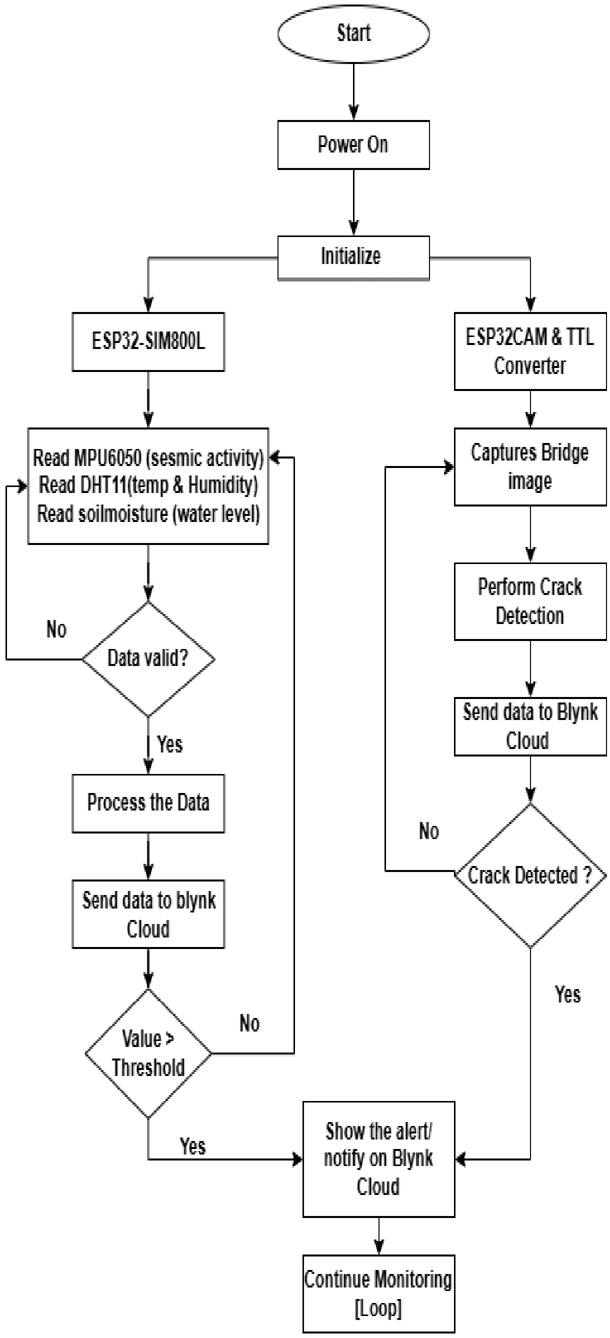


Figure 1: Flowchart of operational work flow

III. IMPLEMENTATION

To verify how effectively the proposed system works, we have built a prototype bridge model with all necessary sensors and modules to simulate the real operating conditions. The experimental setup what we made was used to check how well the system detects cracks, monitors

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 15 Issue 07 , July - 2026

environmental and mechanical conditions, and sends data for remote monitoring. [19-20]

We put the sensors in the places based on what they do. The MPU6050 sensor was attached on the bridge pillars to measure vibrations and detect the movements i.e. seismic activity of the bridge. To monitor temperature and humidity we have installed DHT11 sensor on top of the bridge. [21-22] The soil-moisture sensor was placed at the base of the bridge to monitor water levels and detect if there are possibilities of flooding. All the sensor we used were connected to the ESP32-SIM800L microcontroller, where the data was collected, and then processed and sent to the Blynk cloud. The Blynk cloud dashboard displayed the real time readings and triggered the alert when any sensor value has exceeded its defined threshold. [23-25]

For surface inspection method, the ESP32-CAM module along with a TTL converter was placed facing the bridge surface. It captured images at some fixed intervals, and then it is analysed by the Edge Impulse model for crack detection. When a crack was identified, it displayed “Crack Detected” and that was also uploaded or updated to the Blynk cloud. [26-27]

The model we build successfully demonstrated smooth integration of IoT sensors and AI-based image analysis for real-time bridge monitoring. The system has the capacity to efficiently handle continuous data collection, and gave alerts automatically, so we can verify that the system is compact, cost-efficient, and one of the scalable solutions for bridge health monitoring. [28-30]

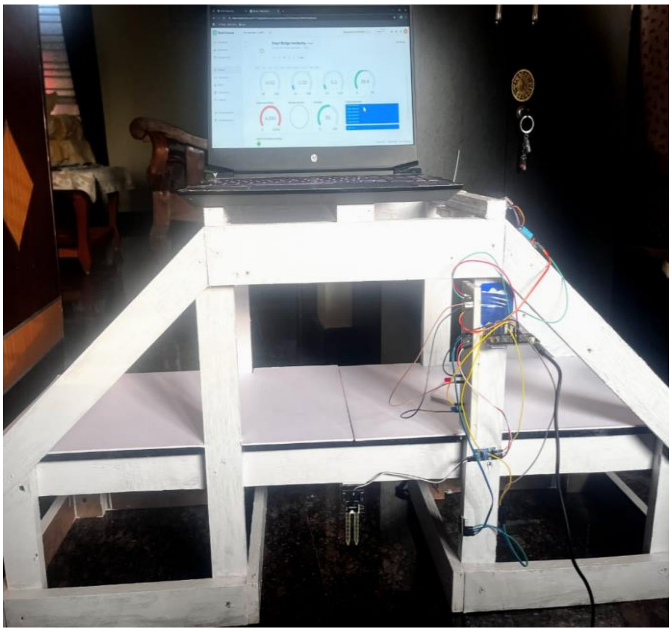


Figure 2: Experimental Setup

The figure 3 shows the actual implementation of the proposed idea on the bridge model using block representation. The sensors and ESP32 microcontroller were placed at the suitable location for continuous monitoring of bridge’s structural parameter, along with environmental and surface conditions. The system sends the real time data monitored to the Bynk platform.

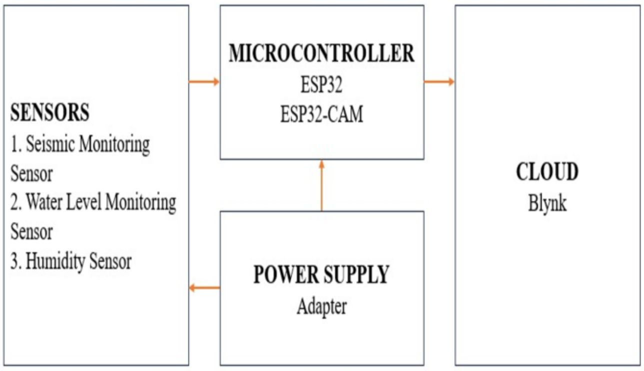


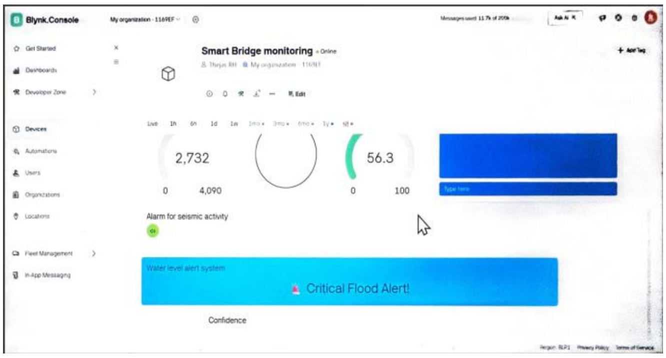
Figure 3: Block Represtation of proposed Model

IV. RESULTS AND DISCUSSION

The Smart Bridge monitoring system what we planned was successfully developed and tested, where each module we used gave good performance during the testing. The results what we got was displayed on the Blynk dashboard, allowing real-time monitoring of the bridge conditions.

The soil-moisture sensor helped us to properly detect the water level under the bridge. When there was normal water level or safe condition *“Normal Water Level”* was displayed in the Blynk dashboard (Figure. 4), and when the level crossed the threshold what we defined for safe condition, it indicated *“Critical Flood Alert”* (Figure. 5).

Figure 4: Normal water level Display



International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 15 Issue 07 , July - 2026

Figure 5: Critical alert Display

The MPU6050 sensor, using its gyroscope, detected angular velocity variations along the X, Y, and Z axes(Figure 6). When the bridge was stable, we observed that the reading was almost constant(Figure. 7). Then to verify its working properly we introduced the vibration manually, where the system detected variations and automatically triggering a red alert on the dashboard along with the audible alarm. These results helped us to verify that the system could accurately sense and give response to seismic or vibration changes in the structure.

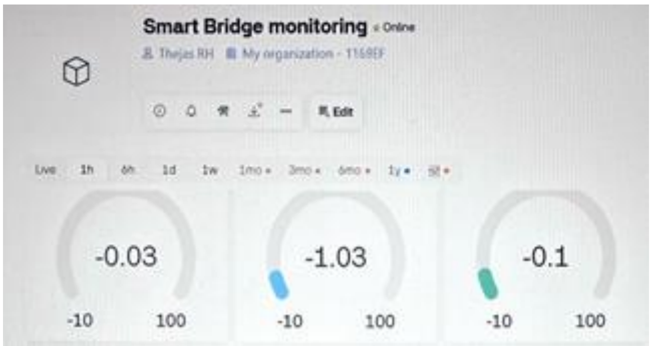


Figure 6: Axes variation

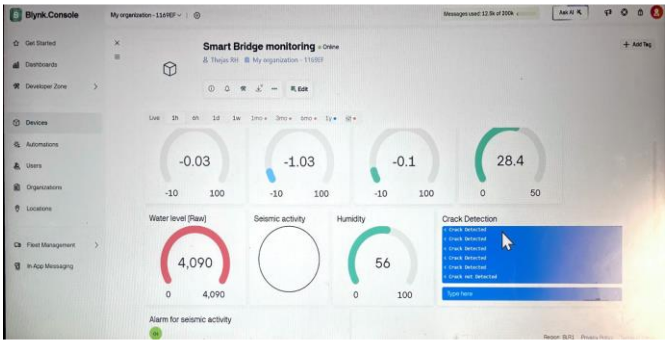


Figure 7: Sesmic Activity Alert

The ESP32-CAM helped to capture images of the bridge surface and sent them to the AI model developed on Edge Impulse. The Edge Impulse crack detection model what we trained achieved an accuracy of 91.7% during training and testing process. The model what we prototyped successfully identified surface cracks and displayed either *"Crack Detected"* or *"Crack Not Detected"* messages on the Blynk dashboard (Figure. 8). This confirmed the accuracy and reliability of the image-processing system for early crack detection in our system.

Figure 8: Crack detection

We need to monitor humidity and sensor because it helps us in assessing how environmental changes may affect the bridge structure over time. we used DHT11 which was useful to continuously measure temperature and humidity(Figure 9), and the readings were displayed live on the Blynk dashboard.

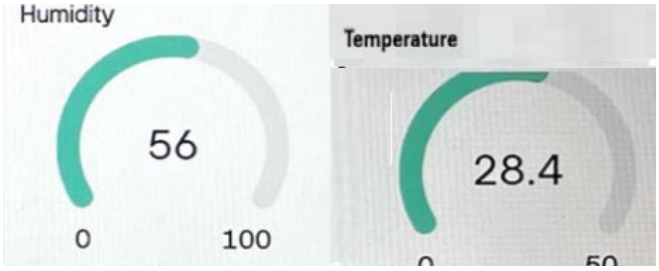


Figure 9: Humidity and temperature display

Overall, the prototype we build worked properly and monitored readings with timely visual alerts. The results what we discussed or got verifies that the integration of IOT and Image processing gave and effective and low maintenance solution for continuous bridge health monitoring and preventive maintenance.

TABLE I: Observation of Experimental Results

SL. NO	PARAMETER	RESULTS OBSERVED	INFERENCE
1	ESP32 controller unit	Sensor data successfully acquired and transmitted to Blynk cloud.	Reliable data communication established.
2	Soil moisture sensor (Normal Condition)	Normal water level displayed on Blynk Cloud	Safe water level detected
3	Soil moisture sensor (Critical Condition)	Threshold exceeds triggered flood alert	Critical flood condition identified
4	DHT11 Sensor	Real-time	Environment

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 15 Issue 07 , July - 2026

		temperature and humidity values displayed	monitoring achieved
5	MPU6050 Sensor (stable State)	Minimal variation in X,Y and Z axes	Normal structural condition
6	MPU6050 Sensor (Abnormal Vibration)	Significant fluctuation detected	Seismic/vibration alert generated
7	ESP32-CAM Module	Clear surface image captured	Effective surface inspection
8	AI Crack detection model	Achieved 91.7% accuracy during testing	High Crack detection reliability
9	Crack detection output	"Crack detected/Crack not detected " displayed	Visual confirmation provided
10	Blynk IOT Dashboard	Real Time Visualization and alert notification	Remote monitoring enabled

TABLE II: System Testing Results

Sl. no	**T (°C)**	**SA (g)**	**CD**	**WL (Raw)**	**Bridge health status**
1	26 (N)	1.2 (N)	No Crack (0.45)	4200 (N)	Excellent
2	30 (A)	1.8 (N)	Crack (0.82)	3800 (HA)	Safe
3	32 (A)	2.0 (N)	Crack (0.87)	3300 (C)	Critical
4	35 (A)	2.4 (S)	Crack (0.92)	2900 (Flood)	Collapse

Abbreviations:

T- Temperature; **SA** - Seismic Activity; **CD-** Crack Detection; **WL-** Water Level; **N**- Normal; **A**-Alert; **H**-High; **HA**- High Alert; **C**- Critical; **S**- Severe.

V. CONCLUSION

The project we developed successfully integrated IoT and AI-based image processing which helps us in continuous structural health monitoring. The ESP32-SIM800L microcontroller efficiently collected and transmitted data from all the sensors which it was connected with, while the ESP32-CAM, linked through a TTL converter, captured surface images for real-time crack detection using a trained Edge Impulse model. When we combine together, these modules continuously track vibration, humidity, temperature, and water levels, and instantly send alerts to the Blynk cloud, also abnormalities or cracks are detected.

The system helps in real time monitoring and early fault detection which is affordable for the proper bridge maintenance. For the future work we can make it advanced by using high resolution cameras, implementing solar-powered systems for remote deployment, and incorporating advanced AI models for more precise crack classification and predictive maintenance. Also, we can link the system with GIS-based monitoring platforms which helps to expand its application to large-scale infrastructure management.

DECLARATION STATEMENT

Funding	The authors received no financial support for this project
Conflicts of Interest	The authors declare no conflict of interest
Ethical approval and consent to participate	This Study does not involve human or animal subjects and therefore does not require ethical approval or consent.
Availability of Data and materials	Yes, few data were available
Authors Contribution	All authors contributed equally to the project

REFERENCES

[1]. Zhihang Deng, Minshui Huang, Neng Wan, and Jianwei Zhang, "The Current Development of Structural Health Monitoring for Bridges: A Review," *Buildings*, vol. 13, no. 1360, pp. 1–34, May 2023

[2]. Bikramjit Singh, Amar Shivkar, Atish Bankar, and Sagar D. Dhawale, "A Review Paper on Bridge Monitoring System," *International Research Journal of Engineering and Technology (IRJET)*, vol. 7, issue 12, pp. 1589–1592, Dec. 2020

[3]. S. A. Putra, B. R. Trilaksono, and D. S. Laila, "Multiagent Architecture for Bridge Capacity Measurement System Using Wireless Sensor Network," *IEEE Transactions on Instrumentation and Measurement*, vol. 70, 2021.

[4]. Ashish Jirapure, Sneha Atram, Yashshree Sulbhewar, Ritik Lokhande, and Ritesh Bhagat, "IoT-Based Health Monitoring System for Building and Bridges," *International Journal of Creative Research Thoughts (IJCRT)*, vol. 11, issue 4, pp. 596–599, Apr. 2023

[5]. Sharmikha Sree R., Meera S., Deepika R., Divya S., and Priyadarshini V. S., "Automatic Bridge Monitoring System Using IoT," in *Smart Intelligent Computing and Communication Technology*, IOS Press, 2021

[6]. P. Karthik, M. Kumar, and S. Rao, "Bridge Safety Monitoring Using NodeMCU," IJISRT, vol. 5, issue 3, 2019.

[7]. H. Narayana et al., "Smart Bridge Failure Prevention System Using IoT," IJERT, vol. 5, issue 8, 2018.

[8]. G. Abhinav, P. Sai Kumar, and K. Praveen, "IoT Based Bridge Structural Health Monitoring System," IJRECE, vol. 8, issue 3, 2020.

[9]. Shital N. Vitekar and Viddulata A. Patil, "Automatic Bridge Monitoring System Using Wireless Sensor Network," *IOSR Journal of Electronics and Communication Engineering (IOSR-JECE)*, vol. 12, issue 6, pp. 29–33, Nov.–Dec. 2017

[10]. M. Sreesanthi and M. Jyothi, "IoT Based Smart Monitoring System for Bridges," IJERT, vol. 8, issue 6, 2019.

[11]. Prajwal C., Goutham C., Kiran N., Shiva Prasad D. R., and Dr. K. V. Padmaja, "IoT Based Bridge Health Monitoring System," *International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering (IJAREEIE)*, vol. 9, issue 6, pp. 1586–1592, 2020

[12]. K. Abhishek, R. Kumar, and P. Singh, "Wireless Sensor Based Smart Bridge Monitoring System," IJESC, vol. 10, issue 3, 2020.
[13]. S. Gupta and R. Patil, "Safety and Monitoring of Bridges Using IoT," IJIES, vol. 7, issue 2, 2019.
[14]. Prasad and M. Reddy, "IoT Based Real-Time Water Level Monitoring for Bridges," IJERT, vol. 8, issue 9, 2019.
[15]. T. Sree Latha et al., "Bridge Damage Detection Using Accelerometer," IJRTER, vol. 4, issue 3, 2018.
[16]. P. Harini and S. Varsha, "IoT Based Bridge Level Detection and Alert System," JETIR, vol. 6, issue 4, 2019
[17]. Shilpa Kumari, Tanya Meghani, Utkarsh Awasthi, Vaidik Tiwari, Dr. Shravan Sable, and Prof. Shraddha Shrivastava, "Smart Bridge System," *Journal of Emerging Technologies and Innovative Research (JETIR)*, vol. 11, issue 5, pp. 86–92, May 2024
[18]. Andrea Maroni, Enrico Tubaldi, Hazel McDonald, and Daniele Zonta, "Monitoring-Based Adaptive Water Level Thresholds for Bridge Scour Risk Management," *Reliability Engineering & System Safety*, vol. 238, p. 109473, June 2023
[19]. N. Kumar, K. Reddy, and S. Verma, "Smart Bridge Monitoring Using Sensors and IoT System," IJRTE, vol. 8, issue 2, 2019.
[20]. M. Mohan et al., "Smart Bridge Monitoring System Using GSM and Sensors," IJERT, vol. 6, 2020.
[21]. C. Ramesh and D. Prakash, "Vibration-Based Bridge Monitoring Using Arduino," IJERT, vol. 9, issue 4, 2020.
[22]. Kumar and V. Yadav, "Microcontroller Based Bridge Vibration Alert System," IRJET, vol. 6, issue 5, 2019.
[23]. S. M. Jagtap and P. P. Mhatre, "Smart Bridge Monitoring and Alert System Based on IoT," IJIRSET, vol. 7, issue 9, 2018.
[24]. S. Patidar and M. Tiwari, "Arduino-Based Bridge Condition Monitoring System," IJARSET, vol. 7, issue 5, 2020.
[25]. S. Ravi and M. Devi, "IoT Based Flood and Bridge Level Monitoring System," IJERT, vol. 8, issue 8, 2020.
[26]. R. Thakur and A. Deshmukh, "IoT Based Structural Crack Detection for Bridge Monitoring," IJERT, vol. 6, issue 9, 2019.
[27]. P. Sharma et al., "Intelligent Bridge Monitoring Using Wireless Sensors," IJETT, vol. 67, issue 5, 2019.
[28]. R. Al-Ali, S. Beheiry, A. Alnabulsi, S. Obaid, N. Mansoor, N. Odeh, and A. Mostafa, "An IoT-Based Road Bridge Health Monitoring and Warning System," *Sensors*, vol. 24, no. 469, pp. 1–22, Jan. 2024.
[29]. R. Sridhar and P. Divya, "Real-Time Bridge Condition Monitoring Using IoT," IJERT, vol. 7, issue 5, 2018.
[30]. D. Roy et al., "Smart Structural Health Monitoring Using Simple Sensors," IJIRSET, vol. 6, issue 11, 2019.

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