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Application of Artificial Using Structural Health Monitoring Tools & Technique: A Review

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Abstract: Structural health monitoring is putting a damage detection and characterization strategy into practice for engineering structures. Monitoring changes to the material and geometric qualities of engineering structures entails observation and analysis of the system using samples of response data. Operational assessment, data collecting, normalization, cleaning, feature extraction, data condensation, and statistical modal creation are all part of structural health monitoring. Important structures must be frequently inspected and shielded from serious damage if their lifespan is to be extended. This study's goal is to investigate various techniques and approaches for monitoring structural health and how they are used in an Indian context. This study reviews the literature regarding several structural health monitoring techniques and their applications.

Keywords: Structural Health Monitoring, Damage, Inspection, Artificial Intelligence, Model Development, Sensor

I. INTRODUCTION

Structural health is achieved via a variety of methods. Sensor-based structural health monitoring has advanced over the past many years. SHM systems can provide real-time data that can be used to make critical decisions about the safety and reliability of structures in operation. The technology is in place to identify structural problems and to alert engineers before any dangerous incidents occur. This technique is frequently used to keep an eye on significant buildings like bridges, dams, power plants, etc., and to guard against serious harm. An important technique for assuring the integrity and safety of a structure is structural health monitoring, which tracks the progression of damage and predicts performance decline. Non-destructive testing, image processing, physical inspection, real-time sensor monitoring, and other methods are some of the approaches used to monitor the structural health of buildings. The approach of using sensors to monitor structures is the most popular of these. The success of SHM systems relies on the quality and accuracy of the collected data, which requires careful planning and selection of appropriate sensors and data processing techniques. Different types of sensors are used to track various structural features. Strains, structural displacement, vibration frequencies, and other variables are measured using fiber optic sensors. AI and ML are being increasingly used in SHM to automate data processing and analysis. This helps in improving the accuracy of SHM systems and reducing the time required for data interpretation. Artificial intelligence (AI) may be used to improve structural health monitoring with sensors. Processing data from sensors may be made easier by using artificial intelligence in the structural health monitoring of significant structures. To do this, it is essential to understand how artificial intelligence may be combined with sensor technologies. As a result, these papers are an overview of previous research on the use of various SHM and AI techniques.

II. LITERATURE REVIEW

Shevtsov D, et al[37] (2022) "Progress in Sensors for Monitoring Reinforcement Corrosion in Reinforced Concrete Structures" The authors provide a detailed overview of various techniques used for corrosion monitoring, including electrical resistance, electrochemical impedance, linear polarization resistance, and acoustic emission. They also discuss emerging technologies, such as fiber optic sensors and wireless sensor networks, which have the potential to enhance corrosion monitoring. The paper highlights the importance of corrosion monitoring in reinforced concrete structures, which is crucial for ensuring their longevity and safety. The authors emphasize that corrosion is one of the main causes of deterioration in reinforced concrete structures and can result in significant structural damage if left unchecked. Hence, early detection and monitoring of corrosion are essential for effective maintenance and repair of these structures. The systems are based on physical inspection techniques like thermography and electromagnetism, as well as electrochemical techniques like potentiometry and polarization. The evaluation focuses on the current sensors and their findings, as well as the benefits and drawbacks of their configurations and other tools employed. We discuss both conventional methods and existing commercial goods in addition to experimental novel sensors.

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Kujawinska M[24] (2019) "Remote Online Monitoring and Measuring System for Civil Engineering Structures" this paper presents an intelligent distributed system for preserving data and monitoring civil engineering structures remotely and online. A controlling server is connected to a group of optical, full-field displacement sensors that make up the system. The server conducts measurements in accordance with predetermined tasks, and it then stores initial data or outcomes in a distant, central database. The operator also instructs the server to do checks, which might produce an alert or require a certain response. The structure of the system, potential application areas, and security measures for data transit are all covered in this article. The findings from the database, which are used for online monitoring of a threshold value of strain for an illustrative region of interest in the engineering structure, are presented and discussed in the article.

Anay R[6] (2018) "Design of Beam-Columns Using Artificial Neural Networks" this article discusses the process of designing steel beam-columns using the American Society of Steel Construction's manual method. The study aimed to explore the potential of artificial neural networks in this process. To achieve this, a dataset was generated using the Staad.Pro software package utilized for the training and testing of the neural network. The findings revealed that the artificial neural network was able to accurately identify appropriate sections for the design of steel beam-columns learning.

Flah, et al[14] (2021) "Machine Learning Algorithms in Civil-structural Health Monitoring" This study offers a thorough overview of the state-of-the-art in machine learning algorithms and their applications for monitoring the health of civil structures. The authors discuss the advantages and limitations of machine learning algorithms and provide examples of their use in practice. The paper highlights the importance of civil-structural health monitoring in ensuring the safety and longevity of infrastructure systems. The authors emphasize that traditional methods of monitoring, such as visual inspection and manual data collection, are time-consuming and may not provide accurate and reliable data. On the other hand, machine learning algorithms have the capacity to analyze massive volumes of data and spot patterns and anomalies that conventional approaches might miss. The study examines several machine learning techniques, such as random forests, decision trees, support vector machines, and artificial neural networks. The authors discuss the advantages and limitations of each algorithm and provide examples of their applications in civil-structural health monitoring.

Berrocal, et.al[7] (2020) "Crack Monitoring in Reinforced Concrete Beams by Distributed Optical Fiber Sensors" the paper provides a comprehensive overview of the current state of the art in distributed optical fiber sensing technology and its applications in crack monitoring. The authors highlight the importance of crack monitoring in reinforced concrete structures, as cracks can indicate potential structural damage or failure. They emphasize that traditional crack monitoring methods, such as visual inspection and manual measurement, can be time-consuming and may not provide accurate and reliable data. Distributed optical fiber sensors, on the other hand, can provide real-time, continuous monitoring of cracks and can detect even small cracks that may not be visible to the naked eye. The paper reviews various types of distributed optical fiber sensors, including fiber Bragg gratings (FBGs) and Brillouin optical time-domain analysis (BOTDA). The authors discuss the advantages and limitations of each type of sensor and provide examples of their use in practice.

Alzughaibi, et.al[5] (2020) "Feasibility of Utilizing Smart-Phone Cameras for Seismic Structural Damage Detection" this study, the author utilized the already installed sensors for monitoring the state of buildings after an event. It is now feasible to use the visual data recorded by these cameras to alert concerned employees and authorities about the status of the building thanks to smartphones, which are available and equipped with active vibration sensors and cameras. This method is unaffected by the weather and doesn't need offshore points. Shake table tests were conducted to verify the accuracy of this technique, which was found to achieve sub-millimeter precision. Feature extraction, feature tracking, and scaling factor are image processing techniques used in this method, which utilizes smartphone cameras to track upper story movement and convert it into inter-story drift ratio (IDR) for structural health monitoring.

Salehi, et.al[34] (2018) "Emerging artificial intelligence methods in structural engineering" this study focuses on Artificial intelligence (AI) has emerged as a powerful alternative to traditional modeling techniques, offering the ability to handle uncertain and complex problems efficiently. AI is the process of developing intelligent tools that mimic the intellect of humans. When testing is not an option, AI-based solutions may be utilised to establish the engineering design parameters, saving a lot of time and effort. Furthermore, AI can enhance the speed and accuracy of decision-making and improve computational efficiency. Deep learning (DL), machine learning (ML), and pattern recognition (PR) are some of the most often employed AI approaches in structural engineering. The goal of this review article is to give a broad overview of current advances in AI approaches and how they have been used in structural engineering during the last ten years. It discusses the advantages of using ML, PR, and DL to address the limitations of conventional models and identifies potential research avenues and emerging trends in this field. Lastly, the paper also discusses the limitations of these techniques.

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Yang, et.al[43] (2021) "Structure Monitoring and Deformation Analysis of Tunnel Structure" this study focuses on an important topic of research in the domains of structure and transportation engineering structural health monitoring. Intelligent perception techniques that incorporate visual input from several sources must be developed for tunnel structure monitoring. This study investigates the segmentation of tunnel structure deformation, fractures, and water seepage with an emphasis on composite tunnel structure monitoring utilizing visual perception technologies. A proposed approach for deformation monitoring using laser-based technology improves the precision of structural health monitoring. The results show that while photogrammetric technology can precisely detect and quantify the dimensions of illnesses, deformation analysis based on TLS can efficiently verify the location of water seepage and fractures.

Singh P, et.al[38] (2020) "Structural Health Monitoring and Damage Detection Through Machine Learning Approaches" in this, recent advancements in sensors, high-speed Internet, and cloud computing have led to a surge in the popularity of data-driven approaches for structural health monitoring (SHM). Machine learning (ML) has been introduced in civil engineering for SHM and has gained significant research attention. The major goal of SHM is to create diverse data processing approaches and provide data that relates to processes at various levels of damage recognition. With data gathered from a system in various structural states, SHM uses methods for damage detection and classification, including a guided wave, hierarchical nonlinear PCA, and machine learning-based piezoelectric sensor network. With an emphasis on creating ML-based methodologies, this paper's major goal is to assess recent work on SHM and provide readers with an overview of various SHM applications. The study highlights current advancements in SHM as well as vibration-based and vision-based monitoring approaches.

Hoang, et.al[20] (2018) "An Artificial Intelligence Method for Asphalt Pavement Pothole Detection Using Least Squares Support Vector Machine and Neural Network with Steerable Filter-Based Feature Extraction" this research proposes a pothole detection approach using artificial intelligence (AI) for asphalt pavement. The authors utilize a dataset of 200 image samples to train and evaluate the performance of machine learning techniques. The experimental findings show that both LS-SVM and ANN are efficient methods for detecting potholes, with precise categorization rates surpassing 85%, and are based on 20 iterations of sub-sampling runs. With an area under the curve of 0.96 and a classification accuracy rate of about 89%, the LS-SVM produces the best results. As a result, the suggested AI technique, particularly when combined with LS-SVM, may prove to be a useful tool for aiding transportation authorities and road inspectors in spotting pavement potholes.

Jeong, et.al[22] (2020) "Development of a Structural Monitoring System for Cable Bridges by Using Seismic Accelerometers" the author of this study developed a structural health monitoring system for cable-stayed bridges. The system uses seismic accelerometers to record data and perform condition assessments of the structure. To monitor the safety and serviceability of the structure, response indices are derived from the recorded acceleration data. The raw data is processed through several stages including noise filtering, baseline correction, numerical integration, and relative difference calculation, to obtain final data. The monitoring system consists of four major processes: raw data format conversion, noise filtering, response index generation, and condition evaluation. The system was tested on a cable-stayed concrete bridge with multiple accelerometers installed. During testing, seismic data were recorded when a magnitude 5.0 earthquake occurred 225 km away from the bridge. Despite the epicenter being far away, the system was able to detect slight ground movement and carry out the four-step assessment process to obtain results.

Alwis, et.al[4] (2021) "Fiber Optic Sensors Embedded in Textile-Reinforced Concrete for Smart Structural Health Monitoring" the author of this study conducted a review of research related to sensors technology, specifically focusing on the use of fiber optic sensors in textile reinforced concrete. The aim was to bridge the gap between civil engineering and sensors technology fields by exploring the advancements made in both areas. The study discusses the potential benefits of using fiber optic sensors for the effective monitoring of structures during the construction stage and highlights the advantages over conventional methods of structural health monitoring. The study also suggests that incorporating Artificial Intelligence (AI) with fiber optic sensor technology could further enhance the efficiency and intelligence of the monitoring system.

Zymelka, et.al[45] (2021) "Practical Evaluation of Printed Strain Sensors Based on Long-Term Static Strain Measurements" the author of this study focused on the creation of printed strain sensors, which have a variety of uses, including monitoring the status of civil infrastructure, is made possible by advances in printable electronics. In the realm of monitoring structural health, printable strain sensors offer a technique for large-area, low-cost production. While earlier research has shown that printed strain sensors are suitable for measuring dynamic strain, more study is needed to determine how long such sensors will remain stable when measuring static strain. Since printed strain sensor arrays have the potential to be used for static strain analysis in large civil structures, this study aims to assess both their long-term stability and that potential. The results demonstrated low signal drift and good strain sensitivity, making printed strain

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sensors suitable for static strain analysis of engineering structures, as demonstrated by tracking static strain changes in a small crack in the dam structure.

Golnaragh, et.al[18] (2019) "Application of Artificial Neural Network in Predicting Formwork Labour Productivity" the author of this study investigated productivity in construction as a measure of the resources utilized and output produced, usually expressed as man-hours required versus planned man-hours. As a labour-intensive industry, construction productivity is critical to project success and failure, as it impacts the economy's gross domestic product. The variety of controllable and uncontrollable elements impacting productivity makes modeling construction workforce productivity difficult. In order to account for and anticipate productivity, Artificial Neural Network (ANN) techniques that use supervised learning algorithms have proven to be superior to statistical regression methods. This study sought to forecast projected productivity by taking into account operational and environmental factors. In order to compare the outcomes of several ANN approaches, including GRNN, BNN, RBFNN, and ANFIS, the optimal approach for calculating projected productivity was chosen. The study's conclusions show that BNN performs better in modeling construction workforce productivity than other methodologies.

III. MAJOR INFERENCES

- The majority of the research on smart sensors and SHM has concentrated on their fundamental sensing abilities.
- Recent developments in structural health monitoring, such as smart sensors, have enormous potential.
- Although several types of sensors are employed in SHM, there is a gap in combining sensors with AI technology.
- Use of AI techniques with a monitoring system will give us ease in work as constant monitoring can be eliminated and precise outcomes will increase work efficiency.

CONCLUSION

Monitoring of structure is a very important parameter as nowadays critical issues are developing after construction or during construction. Structural health monitoring is a way to avoid minor errors and provide precise results like strain monitoring, the temperature of concrete, load variation, etc. Different methods of SHM will become helpful like visual inspection, non-destructive testing, sensor-based inspection, etc. With many benefits and potential applications in structural health monitoring, sensor technology is advancing. Applying sensors to massive infrastructures makes it easier to monitor the health of structures. Even after deploying sensors to monitor the health of structures, it is challenging to analyze the data that is sent to the sensor every time. The efforts can be minimized by using artificial intelligence (AI). The data processing process will be facilitated by the use of artificial intelligence in SHM, and the kind of damage and its location may be directly determined. The process of structural health monitoring is examined in this study, and information on how the structural health monitoring system operates is acquired.

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