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# **Robot Structural Engineering using Artificial Intelligence Methods for Building Analysis**

**S.Sowdeshwari<sup>1</sup>, J M Venkatesan<sup>2</sup>, Saranya K<sup>3</sup>, Dr.M.Gunasekaran<sup>4</sup>,**

Assistant Professor, Department of Civil Engineering, Paavai Engineering College, Namakkal, Tamil Nadu, India

Assistant Professor, Department of Civil Engineering, Ganesh College of Engineering, Salem, Tamil Nadu, India

Assistant Professor, Department of Civil Engineering, Dhanalakshmi Srinivasan college of Engineering,  
Coimbatore,Tamil Nadu, India

Associate Professor, Department of civil Engineering, K.S.R College of Engineering, Tiruchengode, Tamilnadu, India

**ABSTRACT:** AI in structural engineering holds immense promise for the industry. With its ability to automate analysis and design processes, improve accuracy, and enable real-time monitoring, AI is driving efficiency and propelling the field of structural engineering into a new era. Planning, analysis and design building was done. All the structural components were designed manually and detailed using AutoCAD. The dimensions of structural members are specified and the loads such as dead load, live load, floor load and earthquake load are applied. Deflection and shear tests are checked for beams, columns and slabs. The tests proved to be safe. Theoretical work has been done. Hence, I conclude that we can gain more knowledge in practical work when compared to theoretical work. ANN's ability to derive enormous historical data can be coupled with the large data handling capability of the modern computers. ANN can model any functional relationship with reasonable accuracy. Machine Learning algorithms and their application in the field of Civil and Structural engineering are worth exploring. Material model based on ANN helps in explaining and deriving complex, unknown and non-linear functional relationships. This helps to simplify decision making, saves time and helps to reasonably obtain results with accuracy. The paper demonstrates that the software are just tools to come up with a good result, high efficiency and proper construction with lesser difficulties and mistakes, because BIM is not limited in some tools. Indian Standard IS 456-2000 had used for design purposes, and checking the design results of the software.

**KEYWORDS:** Artificial Intelligence, Structural Engineering, Beam, Column, Applications, ROBOT Structural Analysis

## **I. INTRODUCTION**

In an increasingly complex and data-rich world, technologies such as ML and DL have emerged as powerful tools to analyze data and process complex algorithms and models. AI is defined as a larger concept of creating systems through algorithms that can perform based on the predicting relationships or models by ML. Furthermore, ML and DL allow computers to learn from data and improve the performance of predicting outputs, which simplifies the processing of the optimized material design and further monitors the behavior. Especially for the field of biomedical material design, the ML and DL models such as convolutional neural networks (CNN) perform well in capturing the different hierarchical levels of material [1]. For example, the applications to the civilization field could be inspired because the materials are optimized for maximum strength with minimum resources. SDD techniques can be conducted by ANN by extracting the shape of bending structures and GAN is able to be applied to generate the architectural drawings. However, the difficulties of using ML and DL are not negligible, such as data source limitations and non-observable processing. This paper delves into the primary ML and DL frameworks, including GAN and ANN, and evaluates their influence on material design, structural damage detection (SDD), and architectural design. The potential difficulties of using ML and DL methods in structural and material engineering are stated such as limited data resources and ethical issue, and some future suggestions are given to address the corresponding challenges

Construction Material Design Construction material design is critically important, as it directly impacts safety, efficiency, and sustainability. Concrete, as a commonly used construction material, can be predicted compressive strength, tensile strength, and other properties by ML or DL. For instance, the challenges of construction material

optimization can possibly be constrained by an objective [2]. The method of using ML and DL models can be extremely convenient while using optimization algorithms, such as nonlinear or linear regression programming. The neural networks are suitable for property predictions and material screening by using the capabilities of non-linear [4]. Concrete design could be a problem with predicting the specific strength, especially the compressive strength, roughness, and crack propagation. ML can be helpful in structural health monitoring (SHM), particularly the concrete structures [5]. For instance, using Extreme Gradient Boosting (XGBoost) and BPNN can identify the compressive strength of multiple types of concrete with given input values of w/c ratio, mortar, and ratio of fine and coarse aggregates [4,6]. XGBoost is a tree-based ML algorithm used for both classification and regression tasks and this model indicates an 85% accurate result to the experimental.

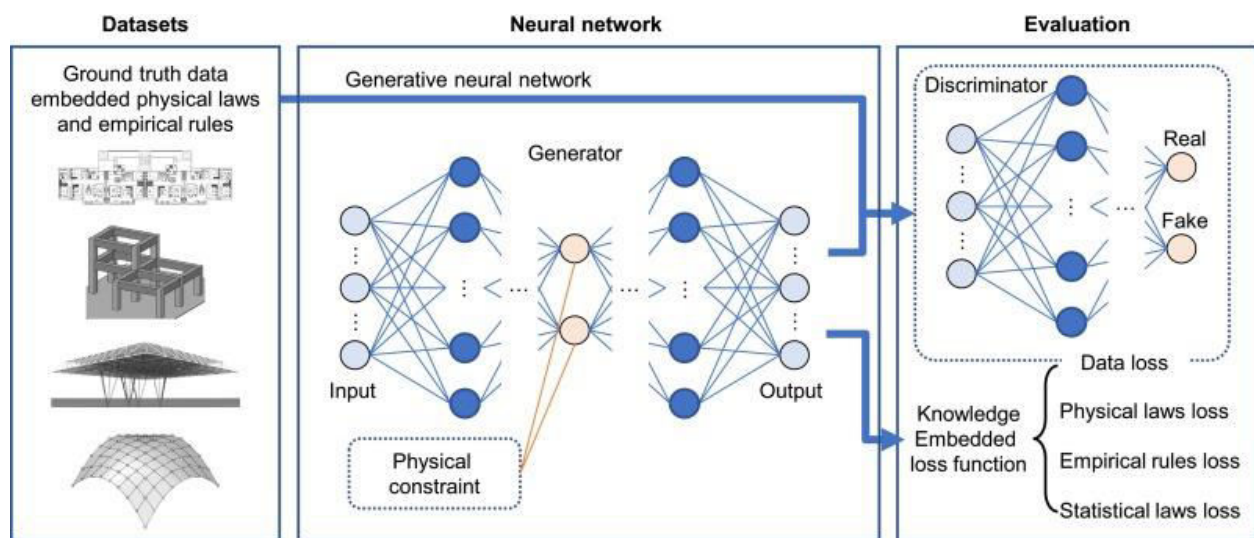


Fig 1: Generative AI design for building structures

Structure Damage Detection (SDD) and Maintenance A structural system is a critical aspect of civil and mechanical engineering that involves creating the framework, support systems, and overall configuration of a structure to ensure it can withstand the loads and environmental conditions it may be subjected to. As mentioned, the success of predicting the material properties proves the SDD and predictive maintenance feasibility. ML-driven parametric SDD techniques are introduced, wherein the feature extraction step involves the identification of specific modal parameters from the structural systems using either input-output or output-only modal identification methods. For example, a proficient ML classifier, after being skillfully trained, is employed to analyze the modal parameters to evaluate the structural soundness [8]. An ANN model is trained based on the shapes of the bending structure and Fourier coefficients are as a damage index to identify the positioning. Moreover, an advanced study states six hidden neurons of an ANN structure contribute to the accurate rate of SDD conducted by Bayesian Algorithms [8].

## II. LITERATURE REVIEW

Concluded term Artificial Intelligence is becoming more and more popular nowadays is due to its ability to process things and learn things in the same as the human brain does and at the same time rectify and learn from its mistakes. Artificial Intelligence gives more benefits like decreasing the chances of error, giving more efficient solutions to problems which humans cannot solve manually as, it can make tasks easier and less time consuming. In field of engineering specially in structural engineering AI can give more accurate design parameters when testing is not possible, will provide more accurate computational and statistical efficiency[2]. The main purpose of this review article is to study different applications of AI in structural or civil engineering, steps involved in the development of these systems, different types of AI methods, AI in structural engineering, and finally their shortcomings and solutions to overcome are discussed[3].

Demonstrate that branch of computer science that develops machines and software with humanlike intelligence. Artificial Intelligence proves to be the most promising path to more efficient practices in civil engineering. AI can be successfully implemented as a vital game changer in the field of Structural engineering to determine engineering design parameters when testing is not possible. Even with the vast range of adaptability that AI possesses, it is never, at least in the near future that AI is to be considered to perpetually replace human involvement as it can never account for the rationality that is purely human in possession[10]. On the contrary, the essence of it is to be touchwood to assist and help in the field of structural engineering to expand their workflow. The complex and deeplearning algorithms possessed by modern AI systems provide clear cut platforms to the engineers and is something to be put resources into engineering[6].

Computed the widespread use of artificial intelligence (AI) in civil engineering has provided civil engineers with various benefits and opportunities, including a rich data collection, sustainable assessment, and productivity. The trend of construction is diverted toward sustainability with the aid of digital technologies. In this regard, this paper presents a systematic literature review (SLR) in order to explore the influence of AI in civil engineering toward sustainable development. In addition, SLR was carried out by using academic publications from Scopus (i.e., 3478 publications)[9].

The prominence gained by Artificial Intelligence (AI) over all aspects of human activity today cannot be overstated. This technology is no newcomer to structural engineering, with logic-based AI systems used to carry out design explorations as early as the 1980s. Nevertheless, the advent of low-cost data collection and processing capabilities have granted new impetus and a degree of ubiquity to AI-based engineering solutions. This review paper ends by posing the question of how long will the human engineer be needed in structural design. However, the paper does not aim to answer this question, not least because all such predictions have a history of going wrong. Instead, the paper assumes throughout as valid the claim that the need for human engineers in conventional design practice has its days numbered. In order to build the case towards the final question, the paper starts with a general description of the currently available AI frameworks and their Machine Learning (ML) sub-classes. The paper then proceeds to review a selected number of studies on the application of AI in structural engineering design. A discussion of specific challenges and future needs is presented with emphasis on the much exalted roles of “engineering intuition” and “creativity”. Finally, the conclusion section of the paper compiles the findings and outlines the challenges and future research directions[5].

Adoption of digital information tools in the construction sector provides fertile ground for the birth and growth of companies that specialize in applications of technologies to design and construction. While some of the technologies are new, many implement ideas proposed in construction research decades ago that were impractical without a sound digital building information foundation. Building Information Modelling (BIM) itself can be traced to a landmark paper from 1975; ideas for artificially intelligent design and code checking tools date from the mid-1980s; and construction robots have laboured in research labs for decades. Yet only within the past five years has venture capital actively sought startup companies in the ‘Construction Tech’ sector. Following a set of digital construction innovations through their known past and their uncertain present, we review their increasingly optimistic future, all through the lens of their dependence on digital information. The review identifies new challenges, yielding a set of research topics with the potential to unlock a range of future applications that apply artificial intelligence[4].

### **III. METHODS**

Structural engineering involves the application of scientific and engineering principles to design, analyze, and construct various types of structures, including buildings, bridges, dams and towers. Structural engineers leverage their expertise in mechanics, materials science, and mathematics to address complex challenges and deliver more innovative designs and solutions that meet the needs of society. Structural engineering is nowadays essential in engineering disciplines such as civil engineering. It encompasses an array of activities ensuring infrastructure stability, safety, and functionality. Structural engineers shape the built environment through all the phases of planning, analysis, and execution.

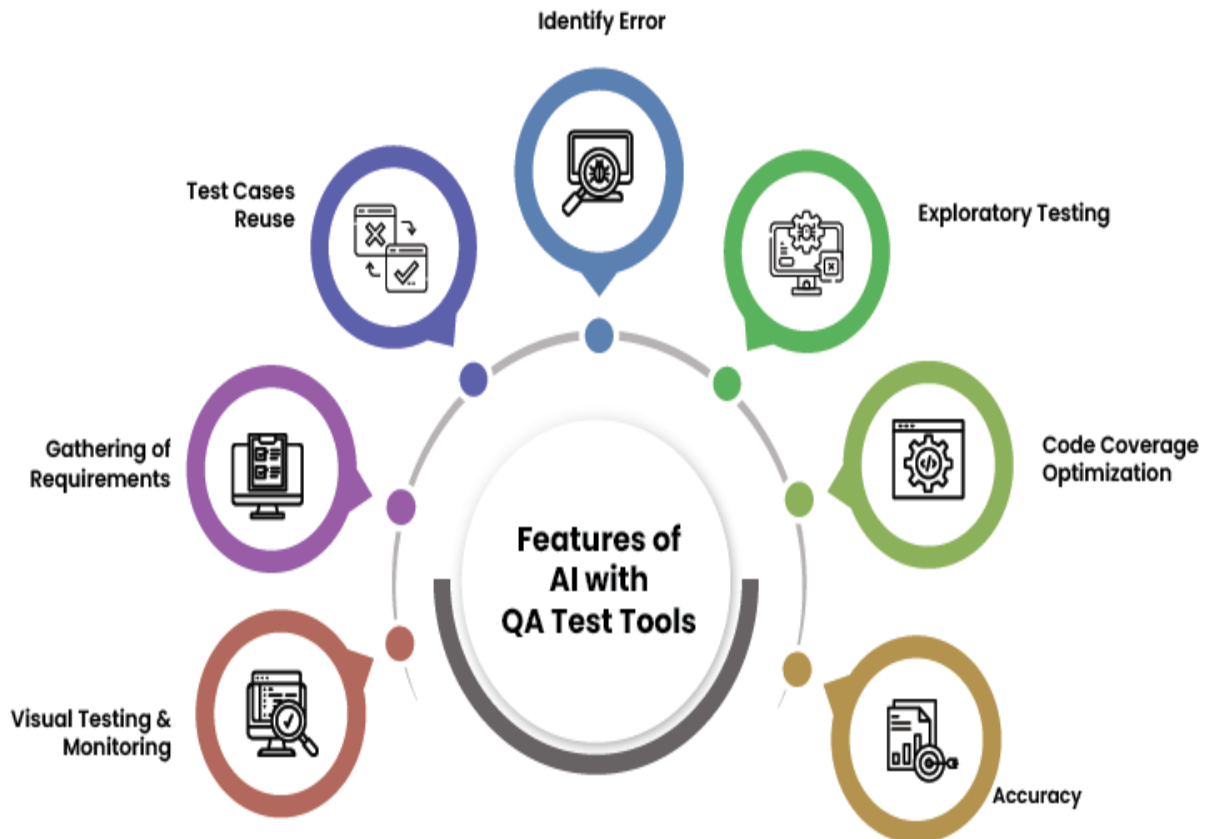


Fig 2: AI Transforms Quality Assurance Methods

The art and science of structural engineering have played a pivotal role in shaping the built environment throughout human history. Building structures' design and construction processes have evolved significantly during the last millennia, driven by advancements in materials, technology, and engineering principles. This article continues with a very short historical review, exploring the fundamental principles of why buildings stand up and why they fall, with strategies employed in structural design. The stability of a building structure is determined by its ability to withstand various forces and loads without collapsing. Structural engineers employ mechanics, physics, and materials science principles to analyze and design structures that balance these forces, ensuring stability, safety, and longevity. Key factors influencing structural stability include the distribution of loads, the selection of appropriate materials, and the structural configuration.

#### IV. RESULT ANALYSIS

Delving into the terrain of AI and ML reveals a multitude of complex challenges confronting this evolving technology. The interpretability of AI models is a significant challenge, as understanding how AI algorithms arrive at specific conclusions is crucial for ensuring the safety and reliability of Civil Engineering structures. Data quality and quantity pose challenges, as AI models require large amounts of high-quality data to effectively learn and make accurate

predictions about structural behavior [16]. The hurdles involve in implementing ML in practice are data availability, model explainability, and overfitting. The challenge of overfitting is crucial in machine learning models, emphasizing that it is not only associated with model training but also with model selection. It suggests that a combination of data-driven procedures and domain knowledge can help mitigate overfitting issues in building structural design and performance assessments.

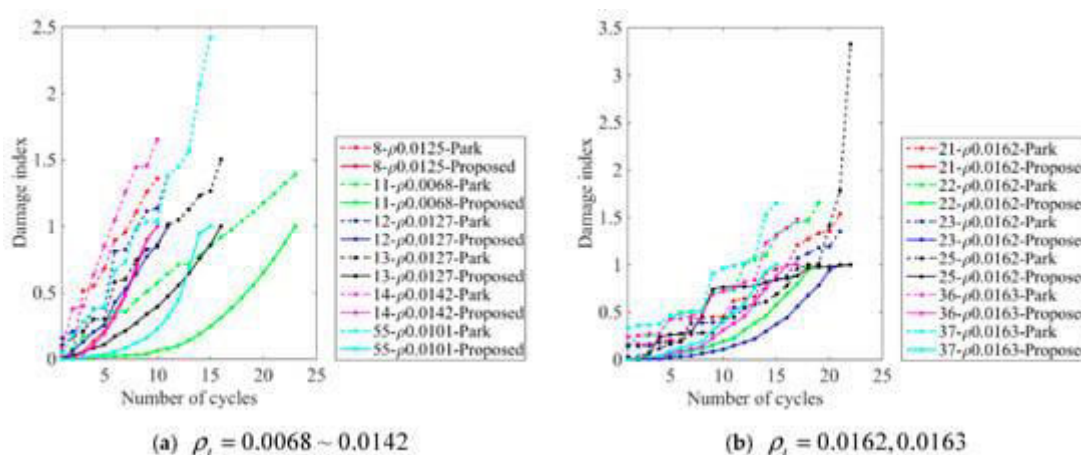


Fig3: Application of Machine Learning in Structural Engineering in Construction

The application of domain knowledge is crucial in addressing challenges in building structural design and performance assessment. Combining domain expertise with data-driven approaches can be a powerful strategy to overcome challenges in this field. The data taken for the training of AI Neural Networks was obtained with the use of the software suite for finite elements analysis 'ABAQUS'. The developed model was able to predict solutions for beam structures in significantly less time compared to traditional methods, indicating the efficiency and potential for further evolution with more training data. The methodologies employed in the papers vary but generally involve the results of how AI and ML can significantly enhance the developments in civil/structural engineering. These methodologies contribute to advancing our understanding of AI and ML applications in Structural Engineering and provide insights into their potential benefits and challenges.

## V. CONCLUSION

The integration of AI, ML, and DL technologies has ushered in a transformative across various domains, including material science, structural engineering, construction material design, and architecture design. These technologies offer unprecedented capabilities to analyze complex data, predict outcomes, optimize designs, and enhance the efficiency and sustainability of construction processes. Data collection and preprocessing are foundational to successful ML and DL applications. In material science and structural engineering, ML and DL models predict material properties, enabling precise material selection, and XG boost and BPNN are suitable models for concrete design with parameter-based analysis. SDD techniques are successfully conducted by ANN and the optimized ANN structure is investigated through Bayesian Algorithms. In architecture design, DL models such as CNNs and GANs enable the recognition of architectural styles and the generation of floor plans. The marriage of CNNs and GANs in models such as ArchiGAN demonstrates how AI transforms indoor scene synthesis, opening new vistas for innovative design. In essence, the fusion of ML, and DL holds enormous promise for the construction industry, propelling it toward data-driven decisionmaking, optimized designs, and sustainable practices.

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