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Design and Analysis of Multistory Building and Prediction of its Deflection Using Artificial Intelligence Method

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Abstract- On demand of growing population construction of high –rise building is being made compulsory for avoiding land scarcity in future. So these high-rise are difficult to be analyzed manually. So many computerized commercial software are available for analyzing a structure digitally. It uses limit state method in RCC for designing by considering all the standard code books and gives the design. Structural planning and design is an art and science of designing with economy elegance and durable structure. The entire process of structural planning and designing is not only requires imagination and thinking but also sound knowledge of structural engineering besides knowledge of practical aspects such as relevant design codes and by-law backed up by experiences. The purpose of standards is to ensure and enhance the safety, keeping careful balance between economy and safety. The design involves load calculations manually and analyzing the whole structure by STAAD pro and STAAD etc. Complicated and high-rise building need and very time taking and cumbersome calculations using conventional manual methods. STAAD pro provides us a fast, efficient, easy to use accurate platform for analyzing an multi-storey building. Finally we make an attempt to define the economical structure by STAAD.Pro.

Keywords- Seismic Analysis, Wind Analysis, Multistorey building, Staad.Pro.

I. INTRODUCTION

Human life is affected due to nature's forces like floods, hurricanes, tornadoes, earthquakes etc. The structural design for a building must ensure that the building is able to stand safely, to function without excessive deflections or movements which may cause fatigue of structural elements, cracking or failure of fixtures, fittings or partitions, or discomfort for occupants.

It must account for movements and forces due to temperature, creep, cracking and imposed loads. It must also ensure that the design is practically buildable within acceptable manufacturing tolerances of the materials. It must allow the architecture to work, and the building services to fit within the building such that it is functionable (air conditioning, ventilation, lighting etc.).

Now a days due to the over population in the urban cities and high cost of the land, there is a need to accommodate in multi-storey building.

The determination of general shape, specific dimension and size is known as structure analysis, so that it will perform the function for it create and will safely withstand the influences which will act on throughout its useful life. The entire process of structural planning and designing requires not only imaginations and calculations, but also science knowledge of structural engineering decide knowledge of particle aspect, such byelaws and design codes, backed by sample experience and judgment.

Building construction is the engineering deals with the construction of building such as residential houses. In a simple building can be define as an enclose space by walls with roof, food, cloth and the basic needs of human beings. In the early ancient times humans lived in caves, over trees or under trees, to protect themselves from wild animals, rain, sun, etc. as the times passed as humans being started living in huts made of timber branches.

The shelters of those old have been developed nowadays into beautiful houses. Rich people live in sophisticated condition houses. Buildings are the important indicator of social progress of the county. Every human has desire to own comfortable homes on an average generally one spends his two-third life times in the houses. The security of civic sense is the responsibility. These are the few reasons which are responsible that the person do utmost effort and spend hard earned saving in owning houses. Nowadays the house building is major work of the social progress of the county. Daily new techniques are being developed for the construction of houses economically, quickly and fulfilling the requirements of the community engineers and architects do the design work, planning and layout, etc, of the buildings. Draughtsman is responsible for doing the drawing works of building as for the direction of engineers and architects.

1. Building Durability Prediction Using AI

Building durability prediction using AI refers to the use of artificial intelligence techniques to estimate and forecast the longevity and performance of a building's components and overall structure over time. This involves analyzing various factors that affect building durability, such as environmental conditions, material properties, construction quality, maintenance practices, and historical performance data.

Key aspects of building durability prediction using AI include:

Data Collection and Integration
Gathering data from multiple sources, including sensor data, historical maintenance records, weather data, and material specifications.

Machine Learning Algorithms
Employing machine learning models such as regression analysis, neural networks, and decision trees to identify patterns and correlations in the data that impact building durability.

Predictive Modeling
Developing models that can predict the future condition of building components based on current and historical data. These models help in estimating the remaining useful life of different elements of the building.

Anomaly Detection
Using AI to detect anomalies or deviations from normal performance, which may indicate potential issues or failures that need attention.

Risk Assessment
Assessing the likelihood of different types of degradation or failure and their potential impact on the building's structural integrity and functionality.

Maintenance Optimization
Providing recommendations for preventive and corrective maintenance actions to enhance building durability and reduce lifecycle costs.

Simulation and Scenario Analysis
Running simulations to understand how different scenarios (e.g., changes in environmental conditions or usage patterns) might affect building durability.

Integration with Building Information Modeling (BIM)
Integrating AI-driven predictions with BIM systems to provide a comprehensive view of the building’s current and future state.

Continuous Learning
Continuously updating and refining the AI models with new data to improve accuracy and reliability over time.

By leveraging AI for building durability prediction, stakeholders can make more informed decisions regarding construction materials, design choices, and maintenance strategies, ultimately leading to more sustainable and cost-effective building management.

II. ARTIFICIAL INTELLIGENCE (AI)

Artificial Intelligence (AI) is a branch of computer science focused on creating systems capable of performing tasks that typically require human intelligence.

These tasks include, but are not limited to, learning, reasoning, problem-solving, perception, and language understanding. AI systems are designed to mimic cognitive functions such as recognizing patterns, making decisions, and adapting to new information.

Key components and concepts of AI include
1. Machine Learning (ML)
A subset of AI that involves the development of algorithms that allow computers to learn from and make predictions or decisions based on data. ML algorithms can be supervised, unsupervised, or reinforcement-based.

2. Neural Networks
Computational models inspired by the human brain's structure, consisting of interconnected nodes (neurons) that process information in layers. Deep learning, a subset of ML, uses large neural networks to handle complex tasks such as image and speech recognition.

3. Natural Language Processing (NLP)
A field of AI focused on enabling machines to understand, interpret, and generate human language. NLP is used in applications like chatbots, language translation, and sentiment analysis.

4. Computer Vision
The ability of AI systems to interpret and understand visual information from the world, such as images and videos. This includes tasks like object detection, image classification, and facial recognition.

5. Expert Systems
AI programs that mimic the decision-making abilities of a human expert in a specific domain. They use a knowledge base and inference rules to provide solutions or recommendations.

6. Autonomous Systems
AI-powered systems that can operate independently without human intervention, such as self-driving cars and drones.

7. Reinforcement Learning
A type of ML where agents learn to make decisions by taking actions in an environment to maximize cumulative reward. It is used in applications like game playing and robotics.

8. Data Mining
The process of discovering patterns and knowledge from large datasets using AI techniques.

AI has broad applications across various industries, including healthcare (diagnosis, personalized medicine), finance (fraud detection, algorithmic trading), retail (recommendation systems, inventory management), and many more. The goal of AI is to create intelligent agents that can perceive their environment, understand context, and perform tasks that achieve specific objectives efficiently and effectively.

III. PROPOSED METHOD - FINITE ELEMENT METHOD (FEM)

The finite element method (FEM) is a numerical technique used in engineering and physics to approximate and solve complex differential equations that govern physical phenomena. It's widely applied in structural analysis, heat transfer, fluid dynamics, electromagnetics, and other areas. Here's a breakdown of how it works:

1. Discretization
FEM divides a complex physical system or domain into smaller, simpler subdomains called finite elements. These elements can be triangles, quadrilaterals, tetrahedra, hexahedra, etc., depending on the nature of the problem and the geometry of the domain.

2. Node Connectivity
Nodes are points within each finite element where physical quantities such as displacements, temperatures, velocities, or electric potentials are calculated. The connectivity between nodes defines the shape functions used to interpolate these quantities within the element.

3. Element Properties
Each finite element has properties such as material properties (like Young's modulus, thermal conductivity, etc.), geometric properties (dimensions, angles), and boundary conditions (loads, constraints).

4. Assembly of Global System
The finite elements are assembled into a global system of equations based on the governing differential equations of the problem. This system represents the overall behavior of the entire domain.

5. Solution of Equations
Using numerical methods like matrix algebra, FEM solves the system of equations derived from the assembly process. The solution yields the values of the physical quantities of interest (e.g., displacements, stresses, temperatures) throughout the domain.

6. Post-Processing
After obtaining the numerical solution, engineers perform post-processing to extract and analyze specific results. This may include visualizing stress distributions, calculating reaction forces, assessing thermal gradients, or evaluating fluid flow patterns.

7. Accuracy and Convergence
FEM allows for refinement of the mesh (i.e., increasing the number of finite elements and nodes) to improve accuracy. Convergence studies ensure that the numerical solution approaches the exact solution as the mesh is refined.

FEM is highly versatile and applicable to a wide range of engineering problems, offering insights into the behavior of structures and systems that may be difficult or impossible to analyze analytically. It's a cornerstone of modern engineering analysis and design processes.

Deflection Prediction Model Using Neural Network (NN)
Building a deflection prediction model using neural network (NN) methods involves several steps. Here's a general guide to help you get started:

Data Collection and Preprocessing
- Gather a dataset containing information about structures (e.g., beams, bridges) along with their corresponding deflections under various loads.
- Preprocess the data by cleaning it (handling missing values, outliers), normalizing features (scaling to a standard range), and splitting it into training, validation, and test sets.

Feature Selection
- Identify relevant input features that can influence deflection predictions. These may include material properties (e.g., Young's modulus, cross-sectional area), geometry (e.g., length, width), applied loads, support conditions, etc.

Model Architecture
- Choose a suitable neural network architecture for regression tasks. Common architectures include feedforward neural networks (FFNN) with multiple hidden layers, convolutional neural networks (CNN) for structured data, or recurrent neural networks (RNN) for sequential data (if applicable).
- Decide on the number of neurons in each layer, activation functions (e.g., ReLU, sigmoid, tanh), and regularization techniques (e.g., dropout, L2 regularization) to prevent overfitting.

Training the Neural Network

- Initialize the neural network with random weights and biases.
- Define a loss function (e.g., mean squared error, mean absolute error) to measure the difference between predicted deflections and actual deflections.
- Choose an optimizer (e.g., Adam, SGD) to minimize the loss function during training.
- Train the neural network using the training dataset, adjusting the weights and biases iteratively through backpropagation.
- Monitor the model's performance on the validation set to prevent overfitting. Adjust hyperparameters if necessary.

Evaluation and Testing

- Evaluate the trained model using the test dataset to assess its performance in predicting deflections for unseen data.
- Calculate evaluation metrics such as root mean squared error (RMSE), mean absolute error (MAE), coefficient of determination (R-squared), etc., to quantify the model's accuracy.

Model Fine-Tuning (if needed)

- If the model performance is not satisfactory, consider fine-tuning by adjusting hyperparameters (e.g., learning rate, batch size, number of epochs), experimenting with different architectures, or augmenting the dataset with additional features or examples.

Deployment

- Once satisfied with the model's performance, deploy it for deflection prediction tasks in real-world scenarios. Ensure that input data is appropriately processed and scaled before feeding it into the deployed model.

By following these steps, you can build a neural network-based deflection prediction model capable of accurately estimating deflections in structural elements under various loading conditions.

Machine Learning (ML)

Machine learning (ML) is a branch of artificial intelligence (AI) focused on building systems that learn from data to improve their performance over time without being explicitly programmed for every task. The key aspects of machine learning include:

Algorithms and Models

Machine learning involves various algorithms that create models capable of making predictions or decisions based on data. These algorithms can be categorized into supervised learning, unsupervised learning, semi-supervised learning, and reinforcement learning.

Supervised Learning

In supervised learning, the model is trained on labeled data, meaning each training example is paired with an output label. The model learns to map inputs to the correct output based on this training data. Examples include classification (e.g., spam detection) and regression (e.g., predicting house prices).

Deflection

Deflection in structural engineering refers to the degree to which a structural element is displaced under a load. It is a critical parameter in the design and analysis of structures, as excessive deflection can compromise structural integrity, aesthetics, and functionality. Here’s a detailed explanation of deflection:

Definition

Deflection: The vertical or horizontal displacement of a structural element due to applied loads.

Importance

Structural Integrity: Excessive deflection can lead to structural damage, such as cracking in concrete, bending of beams, and failure of connections.

Serviceability

It affects the usability of structures, causing issues like uneven floors, misaligned doors/windows, and discomfort for occupants.

Aesthetics

Visible deflection can impact the visual appearance of a structure, making it appear unstable or poorly constructed.

Types of Deflection

Vertical Deflection: Common in beams, floors, and slabs, measured as the displacement in the vertical direction.

IV. RESULT AND SIMULATION OVERVIEW OF SIMULATION SOFTWARE

The full form of STAAD is STRUCTURAL AIDED ANALYSIS AND DESIGN. It was developed by Research Engineers International in Yorba Linda, CA later it was sold to Bentley systems in late 2005. STAAD. Pro is an analysis & design software package for structural engineering used in performing the analysis & design of wide variety of types of structures. It allows structural engineers to analyze& design virtually any type of structure through its flexible Modeling environment, advanced features & fluent data collaboration. STAAD.Pro may be utilized for analyzing and designing practically all types of structures – buildings, bridges, towers, transportation, industrial and utility structures. STAAD-PRO was born giant. It is the most popular software used now a days. Basically it is performing design works. There are four steps using STAAD-PRO to reach the goal.

- Prepare the input file.
- Analyze the input file.
- Watch the results and verify them.
- Send the analysis result to steel design or concrete design engines for designing purpose.

STAAD or (STAAD.Pro) is a structural analysis and design software application originally developed by Research Engineers International in 1997. In late 2005, Research Engineers International was bought by Bentley Systems.[1][2]

STAAD.Pro is one of the most widely used structural analysis and design software products worldwide. It supports over 90 international steel, concrete, timber & aluminium design codes.

It can make use of various forms of analysis from the traditional static analysis to more recent analysis methods like p-delta analysis, geometric non-linear analysis, Pushover analysis (Static-Non Linear Analysis) or a buckling analysis. It can also make use of various forms of dynamic analysis methods from time history analysis to response spectrum analysis. The response spectrum analysis feature is supported for both user defined spectra as well as a number of international code specified spectra.

Additionally, STAAD. Pro is interoperable with applications such as RAM Connection, AutoPIPE, SACS and many more engineering design and analysis applications to further improve collaboration between the different disciplines involved in a project. STAAD can be used for analysis and design of all types of structural projects from plants, buildings, and bridges to towers, tunnels, metro stations, water/wastewater treatment plants and more.

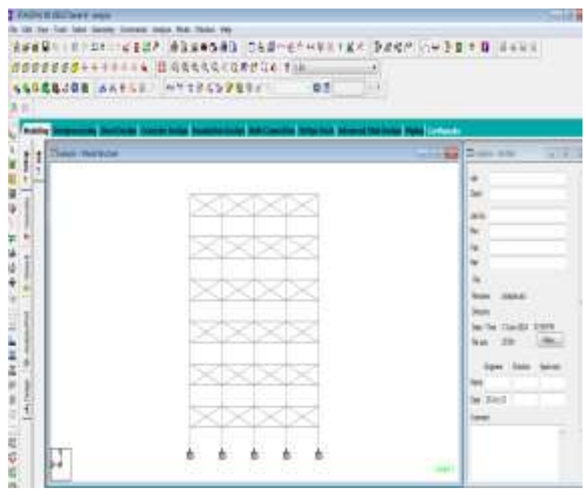

Fig 1: Structure.

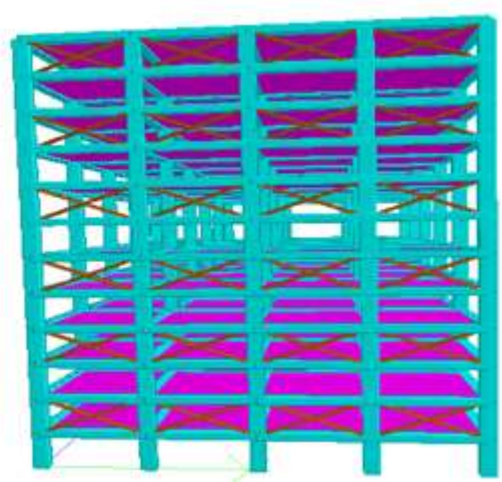

Fig 2: 3D view

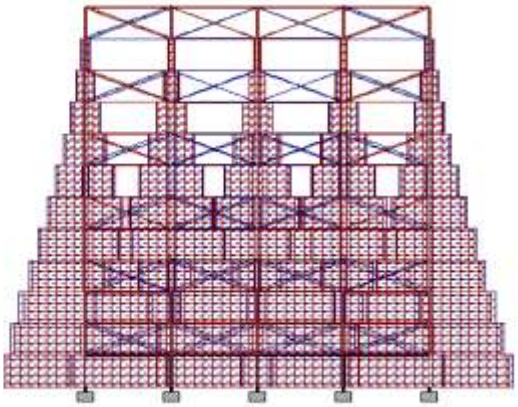

Fig 3: Axial Force y

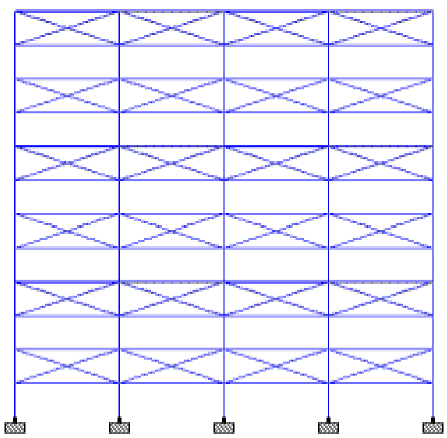

Fig 4: Axial shear Force y

V. CONCLUSION & FUTURE SCOPE

In the early design phase, designers and clients aspire to compare multiple structural designs, considering both different stability frameworks and variations in geometry. Unfortunately, the current process of evaluating multiple designs is time-consuming. To address this challenge, predictive models can be used to estimate performance in terms of structural and environmental costs based on the given geometry. These models rely on the established relationship between performance and input geometry where the established relationship is depending on the used predictive model. Traditional curve fitting methods, such as polynomial regression models, often fall short in accurately predicting a complex nonlinear relationship. Therefore, in this research the potential of artificial neural network was examined as an alternative. It was found that the artificial neural network is able to accurately predict structural and environmental based on the input geometry.

Planning and building a civil engineering structure is a serious and complex project, designing a safe architecture for the structure is of course an essential part to avoid risks. Nowadays, conventional methods to verify the safety of a complex and non linear structure can be very time expensive. Neural Network approaches can help to reduce this computational time. With this work we proved the potential of neural network models by predicting approximations of solutions for beam structures designs in less time than with a traditional method.

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