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Analysis of Structural Integrity in High-Rise Buildings Under Dynamic Load Conditions Using AI: A Computational Perspective

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Abstract--- The structural integrity of high-rise buildings under dynamic load conditions, such as earthquakes, wind, and other environmental factors, is critical to ensuring safety and resilience. Traditional methods for assessing these conditions often rely on static or generalized models, lacking the precision needed for real-time and complex scenarios. To address these limitations, this study proposes a Dynamic Load Conditions using Artificial Intelligence (DLC-AI) framework, which integrates advanced AI algorithms to model, predict, and analyze dynamic stress and strain in high-rise structures. The framework leverages real-time data, machine learning models, and computational simulations to improve predictive accuracy and adaptive responses to varying load conditions. Application of DLC-AI demonstrates enhanced accuracy in predicting structural weaknesses and mitigating potential risks. Findings reveal that the proposed method significantly improves structural resilience, reduces response times during emergencies, and provides architects and engineers with actionable insights for sustainable urban development.

Keywords--- Buildings, Dynamic Load, AI, Environmental Factors.

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I. Introduction

Tall buildings' structural integrity becomes significantly more important under dynamic loads like environmental stresses, wind speed, and earthquakes (Roshani, 2023). Conventional methods used in structural analysis can rely on static or simplistic models incapable of managing the complexity of complex real-time events (Liang et al., 2023). For such constraints, this work introduces a Dynamic Load Conditions with Artificial Intelligence architecture (He et al., 2023). The platform models, predicts, and assesses dynamic stresses and structural responses based on real-time information, computer-based modeling, and strong machine learning techniques (Zhao et al., 2023). Useful information generated by the DLC-AI framework raises resilience as well as accuracy in forecasting urban development (Xiong et al., 2023).

II. Related Works

In this paper, modern methods to strengthen the safety and resilience of tall buildings against earthquakes and wind are investigated. Finite-element modeling, nonlinear time history analysis, and anti-deformation trusses exhibit higher structural performance; they direct the building techniques and ensure stability in the current prefabricated systems.

Finite-Element Modeling (FEM)

A new separable system with separate gravity and lateral load-resisting parts that improves the efficiency of prefabricated high-rise buildings. Seismic fragility and dynamic responses were evaluated using parametric analysis and Finite-Element Modeling (FEM) (Peng et al., 2023). Studies about modern systems compared to older ones showed better seismic performance led some experts to suggest a cautious limit of 1/1000 for storey drift ratios in common earthquakes.

Nonlinear Time History Analysis (NTHA)

Because of self-induced anomalies within their seismic design, mass distribution, and structural engineering, seismic analysis for tall structures is of utmost concern (Intekhab et al., 2023). Since such buildings cannot be adequately accounted for by conventional design codes, advanced methods like Nonlinear Time History Analysis (NTHA) are sensitive to varying ground vibrations and hence require high accuracy, which makes them costlier than traditional techniques but more effective in predicting earthquake damage.

Anti-Deformation Trusses (ADT)

With wind load considerations at its core, the paper discusses the lifting of the steel structure corridor of Haiyue Center, Quanzhou. The web rods and Anti-Deformation Trusses (ADT) can guarantee that something does not sway, while safety facilities can prevent accidents from happening (Ruan et al., 2023). Asynchronous lifting will allow for regulated stress, which leads to maximum displacement of 25 mm and load fluctuation of 20%. This provides direction for construction for lifting projects affected by wind.

III. Proposed Method

The suggested DLC-AI framework that utilises the complexity of advanced AI algorithms can be used to study dynamic stress and strain in high-rise buildings under different load situations. It therefore enhances the predictability, resiliency of structures, and attenuation of risks for safer urban development by incorporating real-time data with machine learning techniques.

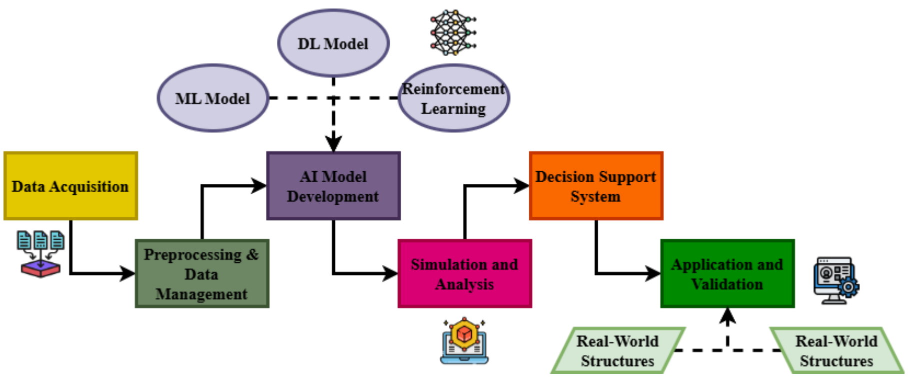

Figure 1: Framework of the Proposed DLC-AI Method

Figure 1 illustrates the DLC-AI framework for structural integrity analysis in high-rise buildings. It comprises six stages: data acquisition, preprocessing and data management, AI model development (using ML, DL, and reinforcement learning), simulation and analysis, decision support system, and application with validation on real-world structures. This framework ensures adaptive and accurate structural resilience under dynamic load conditions.

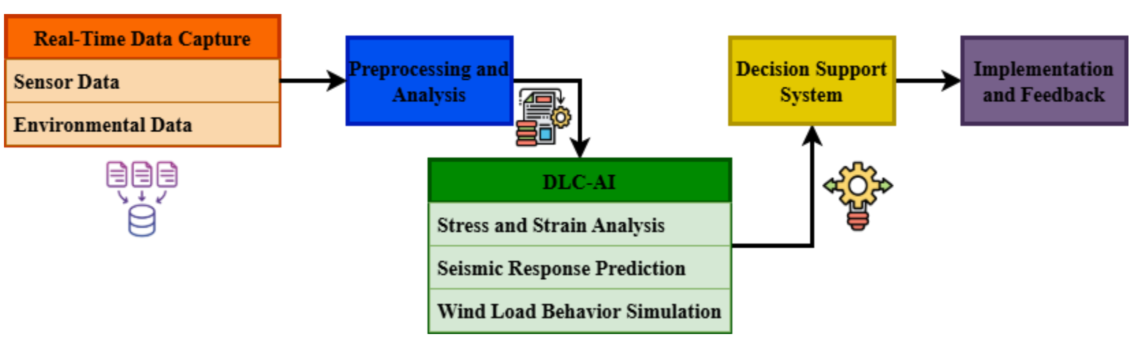

Figure 2: Workflow of DLC-AI Framework for Structural Analysis

The use of DLC-AI to evaluate the stability of a skyscraper under changing loads is shown in Figure 2. Core DLC-AI is integrated into the system to simulate wind loads, seismic reactions, and stress and strain. Other components include sensors, environmental data, real-time data collecting, preprocessing, and analysis. Insights may also facilitate decision-making and execution via iterative adjustments informed by feedback.

IV. Result and Discussion

Results show that FEM, NTHA, ADT, and DLC-AI all perform comparably in terms of structural robustness and reaction times. Figures 3 and 4 show that DLC-AI is better than other methods when it comes to responding to changing stresses, forecasting the reliability of structures, and improving decision-making in real-time when faced with seismic and wind loads.

Analysis of Structural Resilience

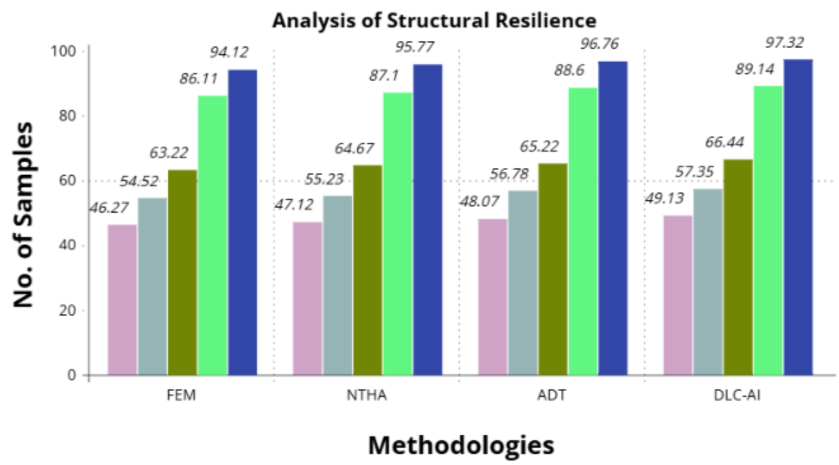

Figure 3: Analysis of Structural Resilience

Figure 3 plots the structural robustness of four different methods namely, FEM, NTHA, ADT, and DLC-AI. Considering the example count of 97.32, as against more conventional methods, the DLC-AI framework exhibits superior structural robustness under dynamic stresses. This effectively suggests that the DLC-AI methodology is efficient in predicting the safety and structural dependability of high-rise buildings by carrying out stress analyses and adapting to seismic and wind load circumstances.

Analysis of Response Times (low)

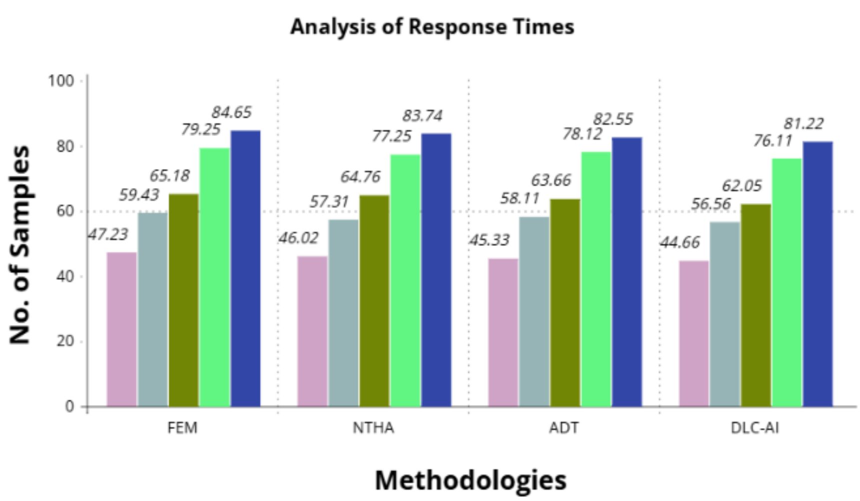

Figure 4: Analysis of Response Time

Figure 4 compares the methods used for reaction times under dynamic load. Here, with consistent gains across samples of data, DLC-AI progresses well beyond existing methods like FEM, NTHA, and ADT. This shows how it performs with regard to the changes in stress and strain and how precise the associated prediction is. The study thus indicates that DLC-AI can enhance the structural robustness of high-rise building scenarios and real-time decision-making.

V. Conclusion

This research suggested the DLC-AI architecture for making tall structures resilient against dynamic loads. The framework significantly improves both the prediction accuracy, robustness, and adaptive responses of the system because it integrates computer simulations, advanced AI models, and real-time data collecting. DLC-AI identifies structural flaws, reduces risks, and promotes sustainable urban development more effectively than more conventional approaches. The findings presented above provide evidence of the importance of this result for contemporary structural engineering and disaster preparation. Future research will focus on the optimization of AI models for a wide variety of structural systems and environmental situations as well as incorporation of sophisticated reinforcement methods.

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