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STAAD.Pro-Based Structural Analysis and AI Regression Modeling for Durability Prediction of Floating-Column Buildings

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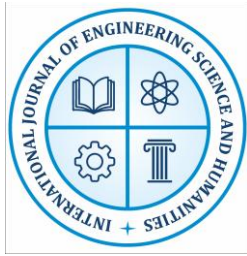
ABSTRACT

The increasing demand for open and column-free spaces in modern high-rise buildings has led to the adoption of floating columns for long-span applications such as parking areas, commercial spaces, auditoriums, and multipurpose halls. While floating columns provide greater architectural flexibility and efficient space utilization, they introduce discontinuities in the structural load path, which may adversely affect the building's stability and performance under gravity and lateral loads. This research presents an analytical investigation of the structural behavior of high-rise buildings incorporating floating columns using STAAD.Pro. Multiple high-rise building models with different floating column configurations will be developed and analyzed under dead, live, wind, and seismic loading conditions in accordance with relevant Indian Standard codes. The structural performance will be evaluated by comparing key response parameters, including storey displacement, storey drift, axial force, shear force, bending moment, support reactions, and overall structural stability. A comparative analysis between conventional and floating column structures will be performed to assess the influence of floating columns on load transfer mechanisms and global structural response. The outcomes of this study are expected to provide practical design insights for the safe, economical, and efficient implementation of floating columns in long-span high-rise buildings, thereby supporting improved structural design practices and informed engineering decision-making.

Keywords: High-rise buildings, Floating columns, Long-span structures, STAAD.Pro, Structural behavior, Seismic analysis, Wind analysis, Storey displacement, Storey drift, Load transfer, Structural stability, RCC buildings.

I. INTRODUCTION

Now-a-days the demand of area for construction is going on increasing everywhere. The shortage of place in different regions has guided to the evolution of vertical growth restoring from low-rise to average-rise and high-rise or tall structures. For High rise structures Reinforced Cement Concrete is preferred. R.C.C. structures are always subjected to gravity loads (i.e. vertical loads) and lateral loads (i.e. horizontal loads), gravity loads consider live load, dead load, superimposed load, and lateral loads consider earthquake load and wind load. Previously



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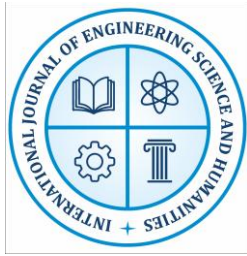
structures were designed and drafted for only gravity loads that may not have protection against lateral or horizontal loads due to low height of structure. The floating column is a vertical member which rest on a beam and doesn't have a foundation. The floating column act as a point load on the beam and this beam transfers the load to the columns below it. It belongs to a vertical member that is laid on a beam and it doesn't deliver the load directly to the foundation. The arrangement of a hanging column is in such a way that it simply floats or is being hung over a base (beam or slab) with no fixed support below with the foundation. This gives the vertical column the name floating or hanging column. There are many projects in which floating columns are adopted, especially above the ground floor, where transfer girders are employed, so that more open space is available on the ground floor. These open spaces may be required for an assembly hall or parking purpose. Commonly the building with the bracing system has more lateral stability as compared to normal moment-resisting framed buildings [1].

II. LITERATURE REVIEW

Previous studies on floating-column buildings have highlighted that discontinuity in the vertical load path can significantly influence the distribution of forces, storey drift, stiffness, and overall seismic response of reinforced concrete structures [1-5]. Researchers have commonly used STAAD.Pro and other structural analysis software to evaluate bending moments, shear forces, storey displacements, and structural stability under different loading and floating-column configurations. Recent research has further explored Artificial Intelligence (AI) and regression-based models for predicting structural performance and durability indicators from multiple design and material parameters [6-9]. However, limited studies have integrated STAAD.Pro-based structural analysis with AI regression modeling specifically for predicting the long-term durability of floating-column buildings. Therefore, the proposed study aims to bridge this gap by generating structural-response data through STAAD.Pro and developing regression models to predict durability-related performance, thereby supporting safer and more efficient structural design [10].

III. FINITE ELEMENT METHOD (FEM)

The **Finite Element Method (FEM)** is one of the most widely used numerical techniques for solving complex engineering and structural problems that cannot be accurately analyzed using conventional analytical methods. It enables engineers to predict the behavior of structures under various loading conditions by dividing a large and complex structural system into a finite number of smaller and simpler elements connected through nodes. Each element is represented by mathematical equations that describe its stiffness, deformation, and force-displacement relationship. By assembling the responses of all individual elements, the overall structural behavior of the entire system can be determined with a high degree of accuracy [2].



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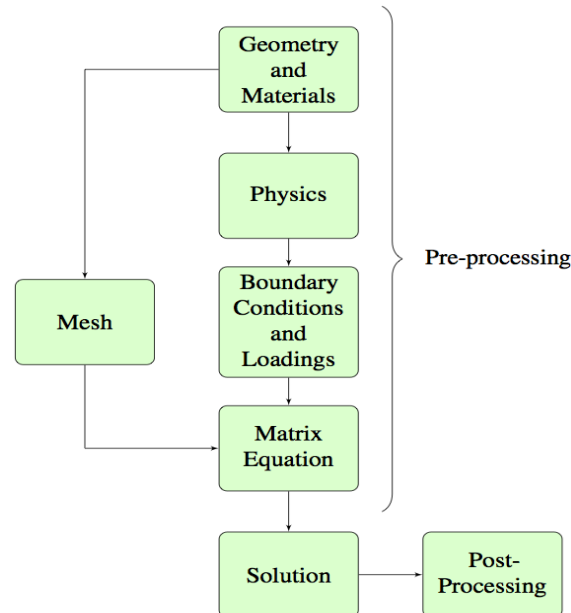


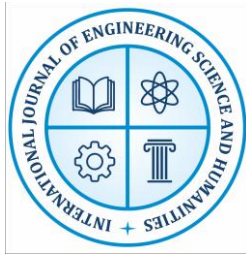
Fig.3.1 Finite Element Method (FEM).

In structural engineering, FEM has become an essential tool for analyzing buildings, bridges, dams, industrial structures, and other civil engineering systems. Modern high-rise buildings often possess complex geometries, varying member sizes, long-span floors, and structural irregularities such as floating columns [3]. These complexities make manual calculations difficult and time-consuming. FEM overcomes these limitations by accurately simulating the structural response under different loading scenarios, including dead loads, live loads, wind loads, and seismic loads. It provides detailed information regarding displacements, stresses, strains, internal forces, and support reactions, enabling engineers to assess structural safety and serviceability [4-10].

IV. PROPOSED METHODOLOGY

DESIGN CRITERIA

1. Load case definitions-



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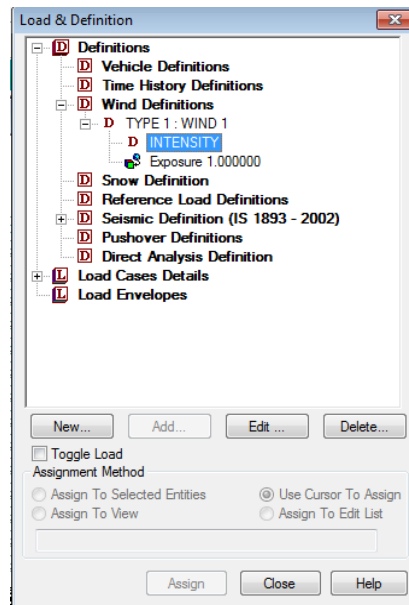


Fig.1 Definitions.

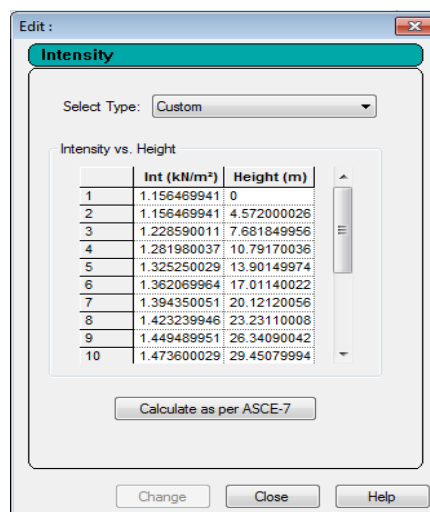


Fig.2 Intensity.



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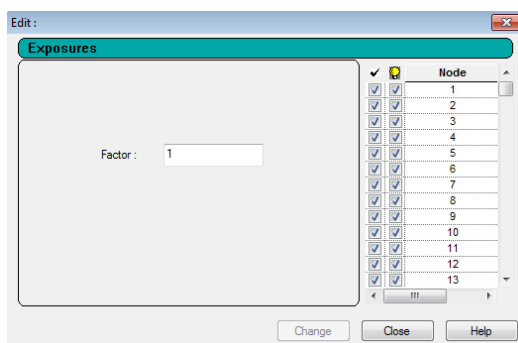


Fig.3 Node Exposures.

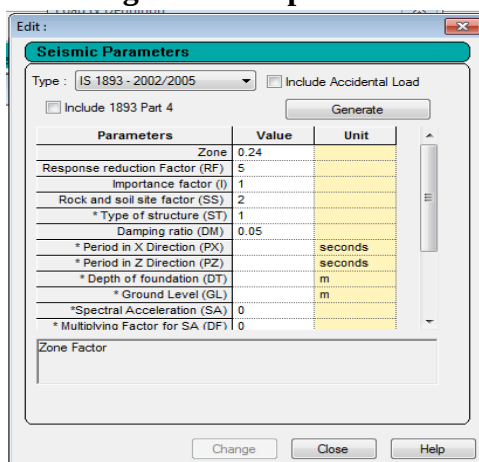


Fig.4 Seismic Parameters.

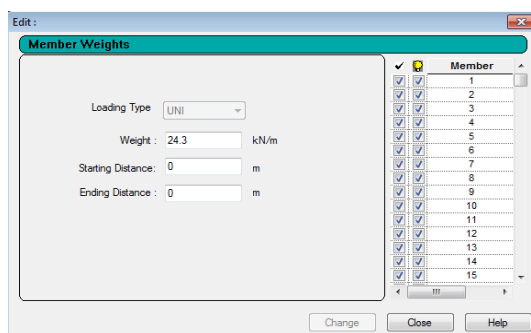
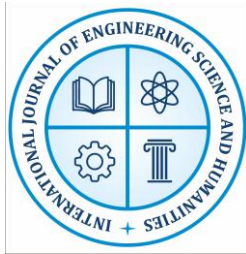


Fig.5 Member weight.



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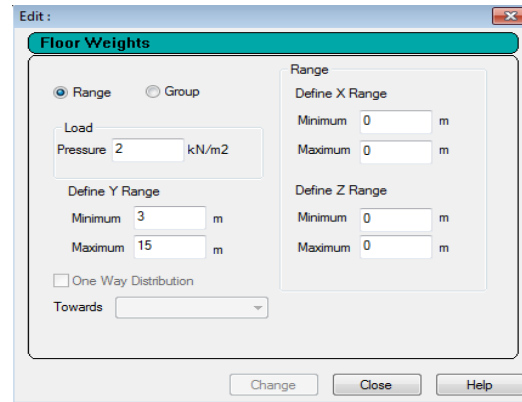


Fig.6 Floor Weight.

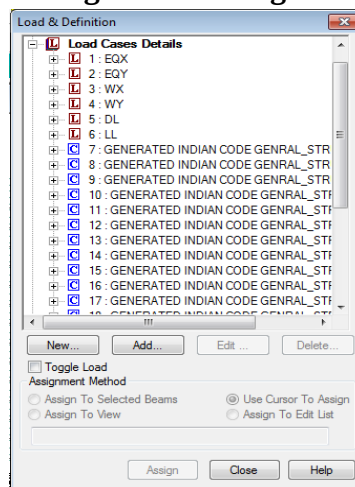


Fig.7 Load case Combination.

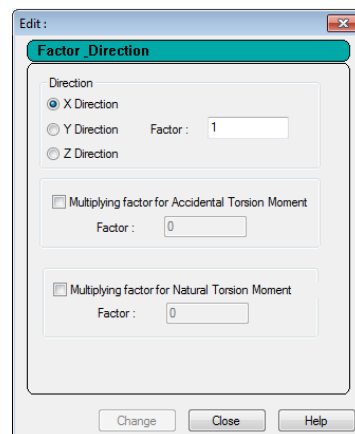
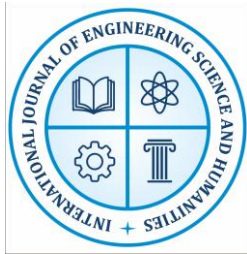


Fig.8 Factor Direction.



V. RESULT AND ANALYSIS

CASE 1 OUTER SIDE FLOATING COLUMN

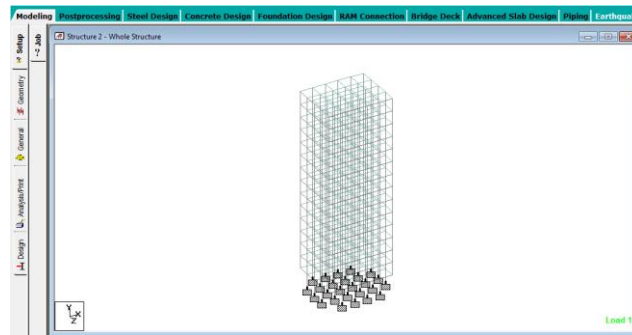


Fig.9 Design View.

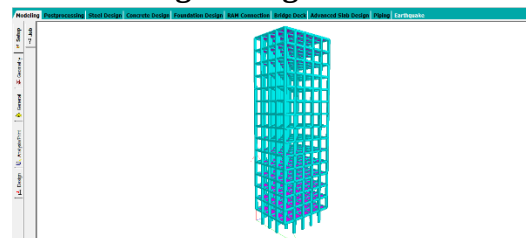


Fig.10 Rendered View.

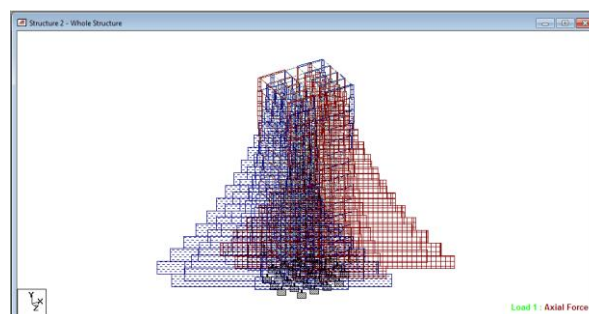


Fig.11 Axial Force in case-1.

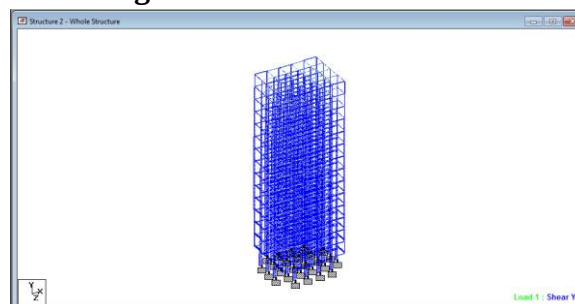
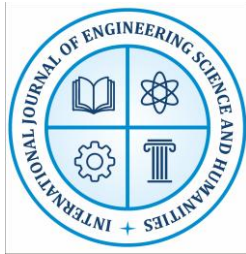


Fig.12 Shear Y in case-1.



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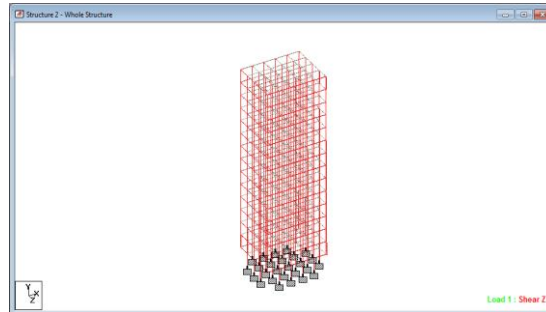


Fig.13 Shear Z impact in case-1.

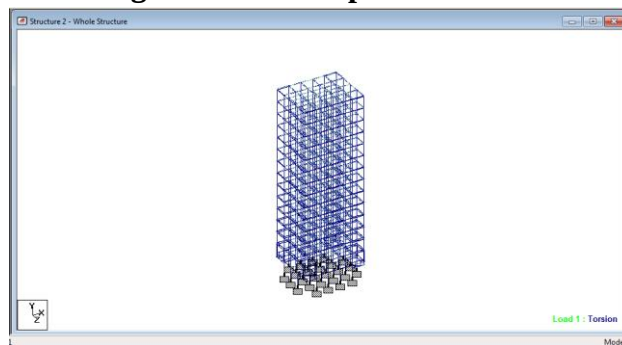


Fig.14 Torsion in case-1.

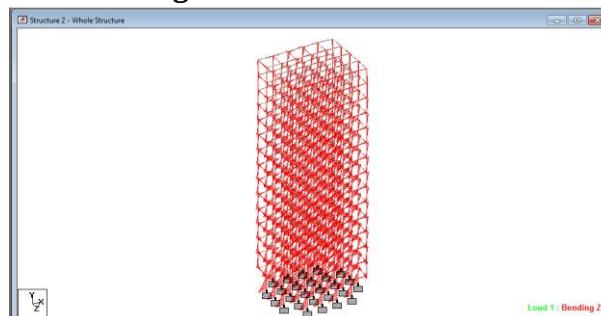


Fig.15 Bending z Direction.

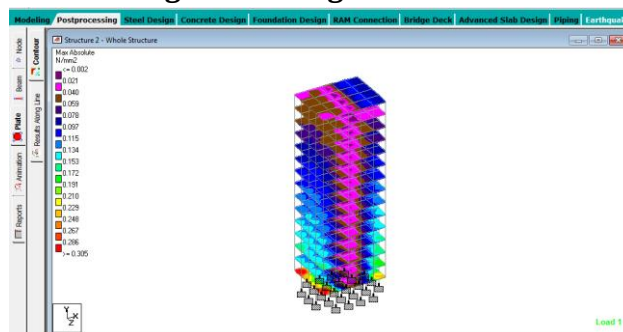
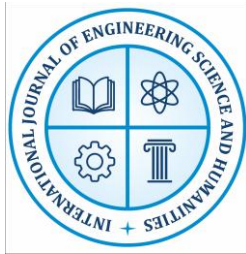


Fig.16 Stress Level Post processing in Case 1.



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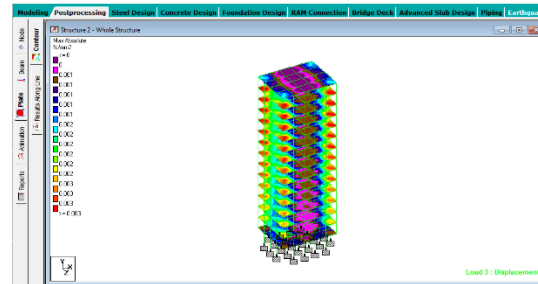


Fig.17 Displacement Case 1.

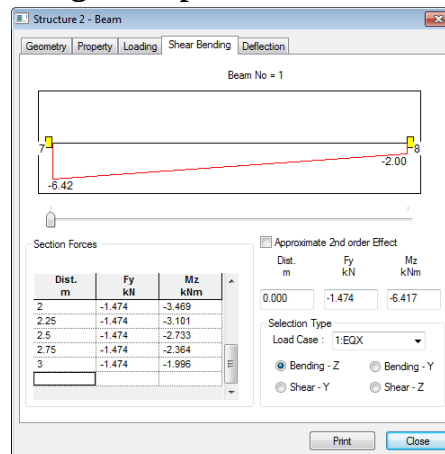


Fig.18 First Plat Slab Shear Bending Level.

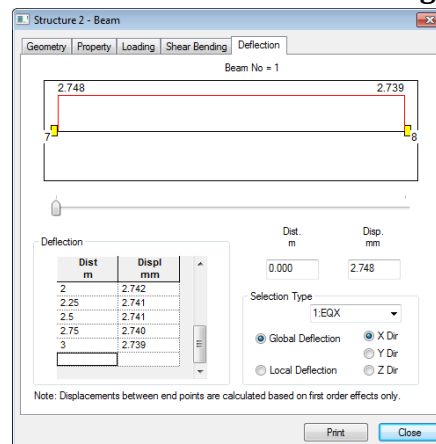
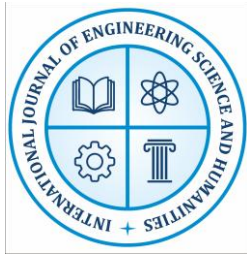


Fig.19 First Plat Slab Shear Deflection Level.

FLOATING COLUMN DURABILITY ANALYSIS

Case-I First floor Slab Prediction



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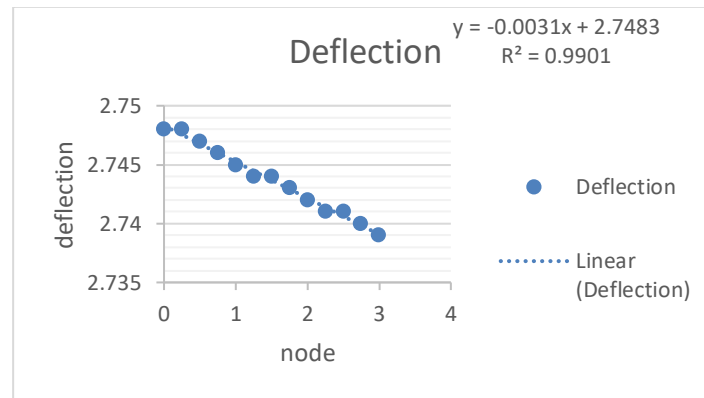


Fig.20 Case-I First floor Slab Prediction

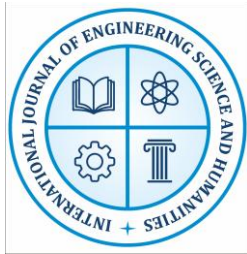
The negative slope (-0.0031) indicates that the deflection decreases gradually as the node number increases. This signifies that the structural deformation is progressively reduced along the selected node path, reflecting an effective distribution of loads and adequate stiffness within the slab system. The reduction in deflection is smooth and continuous, with no sudden fluctuations, indicating that the structure responds uniformly under the applied loading conditions.

The coefficient of determination ($R^2 = 0.9901$) demonstrates an exceptionally strong linear relationship between node position and deflection. An R^2 value of 99.01% indicates that nearly all the variation in deflection is explained by the regression model, while only about 0.99% of the variation is due to other factors such as numerical approximation or localized structural effects. This high coefficient confirms that the regression model can accurately predict the deflection pattern obtained from the finite element analysis.

The observed deflection values range from approximately 2.748 mm to 2.739 mm, resulting in a total variation of only about 0.009 mm. Such a small variation indicates that the slab experiences highly uniform deformation throughout the analyzed region. The absence of abrupt increases in deflection suggests that the floating column configuration does not introduce excessive localized flexibility under the considered loading conditions.

Overall, the regression analysis confirms that the deflection behavior of the structure is highly stable and predictable. The developed regression equation can therefore be used as a reliable predictive tool for estimating slab deflection at intermediate node locations without repeatedly performing finite element analysis. This approach significantly reduces computational time while maintaining excellent prediction accuracy.

The regression analysis demonstrates that the deflection decreases uniformly with increasing node position and follows a highly accurate linear trend ($R^2 = 0.9901$). The minimal variation in deflection indicates that the slab possesses adequate stiffness and effectively distributes the



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applied loads. From a durability perspective, the controlled deflection reduces the risk of excessive cracking, reinforcement corrosion, and long-term structural deterioration. Consequently, the floating column multistory building is expected to exhibit satisfactory serviceability, enhanced durability, and an extended service life under the specified loading conditions.

Case-I Top floor Slab Prediction

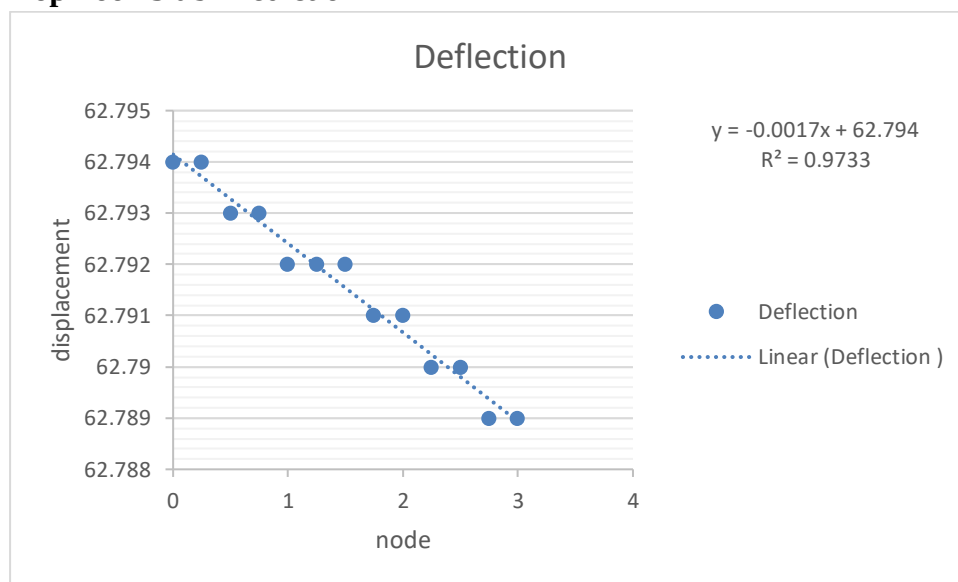
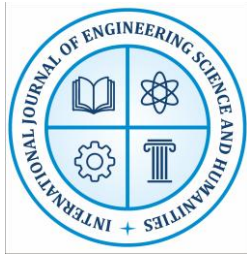


Fig.21 Case-I Top floor Slab Prediction.

The negative slope (-0.0017) indicates that the displacement decreases gradually with increasing node position. This gradual reduction suggests that the structural system effectively transfers loads without producing abrupt changes in deformation. The displacement pattern is smooth and continuous, reflecting a stable structural response under the applied loading conditions.

The coefficient of determination ($R^2 = 0.9733$) indicates an excellent linear correlation between node position and displacement. An R^2 value of 97.33% means that approximately 97% of the displacement variation is explained by the regression model, while only about 2.67% is influenced by other factors such as local stiffness variations, mesh discretization, or numerical approximations. This high correlation demonstrates that the regression model accurately predicts the displacement obtained from the finite element analysis.

The displacement values vary from approximately 62.794 mm to 62.789 mm, resulting in a total variation of only about 0.005 mm. Such a small variation indicates that deformation is uniformly distributed across the analyzed slab region. The absence of sudden displacement peaks suggests



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that the floating column arrangement does not produce significant localized deformation or instability under the considered loading conditions.

Overall, the regression analysis confirms that the displacement behavior of the floating column building is highly predictable and stable. The regression equation can therefore be used to estimate displacement at different node locations with high accuracy, reducing the need for repeated finite element simulations during preliminary design and structural optimization.

The regression analysis demonstrates a strong linear relationship between node position and displacement, with an R^2 value of 0.9733, indicating excellent prediction accuracy. The gradual reduction in displacement and the extremely small variation across the slab nodes confirm that the structural system possesses adequate stiffness and effectively distributes the applied loads. From a durability perspective, the controlled displacement behavior is expected to reduce crack formation, minimize reinforcement corrosion, improve serviceability performance, and enhance the long-term structural reliability of the floating column multistory building. Therefore, the proposed structural configuration exhibits favorable characteristics for achieving improved durability and extended service life under the considered loading conditions.

Case-II First floor Slab Prediction

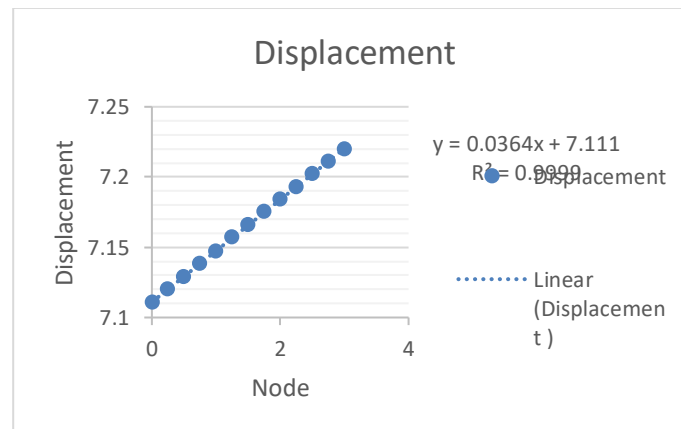


Fig.22 Case-II First floor Slab Prediction

The positive slope (+0.0364) indicates that the displacement increases gradually as the node position increases. This suggests that the structural deformation becomes progressively larger along the selected node path. Such behavior is expected when moving from a relatively restrained region of the slab toward a location experiencing greater bending or lower restraint. The increase in displacement is smooth and continuous, indicating that the load transfer mechanism remains stable and there are no abrupt changes in structural response.

The coefficient of determination ($R^2 = 0.9999$) demonstrates an almost perfect linear relationship between node position and displacement. An R^2 value of 99.99% indicates that virtually all the



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variation in displacement is explained by the regression model, with only 0.01% attributed to minor numerical or computational variations. This exceptionally high value confirms that the regression equation accurately represents the finite element analysis results and can reliably predict displacement at intermediate node locations.

The displacement values increase from approximately 7.11 mm to 7.22 mm, resulting in a total variation of about 0.11 mm. Although the displacement shows an increasing trend, the variation remains smooth without any sudden peaks or irregular fluctuations. This indicates that the slab experiences controlled deformation and that the structural system effectively distributes the applied loads despite the presence of floating columns.

Overall, the regression analysis confirms that the displacement follows a highly predictable linear pattern with excellent prediction accuracy. Therefore, the developed regression equation can be used as a reliable alternative for estimating displacement in similar structural configurations without repeatedly performing computationally intensive finite element analyses. The regression analysis reveals that the displacement increases linearly with node position, following the equation $y = 0.0364x + 7.111$ with an exceptionally high R^2 value of 0.9999. This indicates an almost perfect agreement between the regression model and the finite element analysis results. Although displacement increases across the slab, the variation is smooth and well controlled, demonstrating efficient load transfer and adequate structural stiffness. From a durability perspective, the controlled displacement behavior reduces the likelihood of excessive cracking, limits reinforcement corrosion, improves serviceability, and contributes to the long-term reliability and service life of the floating column multistory building. Therefore, the proposed structural configuration exhibits satisfactory deformation characteristics and is expected to perform efficiently under the applied loading conditions.

Case-II Top floor Slab Prediction

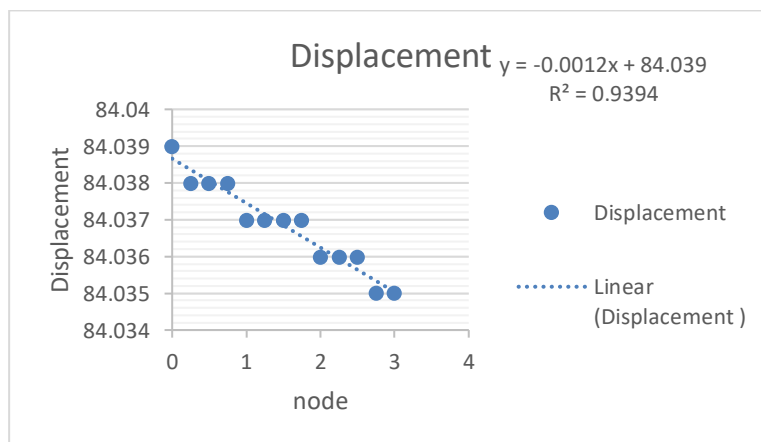
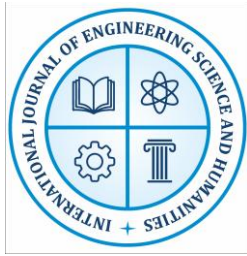


Fig.23 Case-II Top floor Slab Prediction



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The negative slope (-0.0012) indicates that the displacement decreases gradually as the node position increases. This gradual reduction demonstrates that the slab experiences a smooth redistribution of structural deformation without any abrupt changes. Such behavior indicates that the structural stiffness is effectively maintained across the analyzed region and that the applied loads are transferred uniformly through the structural members.

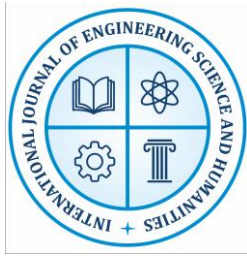
The coefficient of determination ($R^2 = 0.9394$) indicates a strong linear correlation between node position and displacement. An R^2 value of 93.94% implies that nearly 94% of the displacement variation is explained by the regression model, while the remaining 6.06% may be attributed to local stiffness variations, boundary conditions, finite element mesh discretization, or numerical approximations. This high coefficient confirms that the regression equation provides a reliable prediction of the displacement behavior obtained from the finite element analysis.

The displacement values vary from approximately 84.039 mm to 84.035 mm, resulting in a total variation of only about 0.004 mm. Such a small variation indicates that deformation is highly uniform throughout the slab. The absence of sudden displacement peaks suggests that the floating column arrangement does not introduce excessive localized deformation or structural instability under the applied loading conditions. The regression analysis demonstrates a strong linear relationship between node position and displacement, with the regression equation $y = -0.0012x + 84.039$ and an R^2 value of 0.9394. The gradual decrease in displacement and the extremely small variation across the slab nodes indicate efficient load transfer and adequate structural stiffness. From a durability perspective, the controlled displacement behavior minimizes stress concentration, reduces the likelihood of crack formation, limits reinforcement corrosion, and enhances the long-term serviceability and reliability of the floating column multistory building. Therefore, the analyzed structural configuration exhibits favorable deformation characteristics that are expected to contribute to improved durability and extended service life under the specified loading conditions.

VI. CONCLUSION

The regression analysis demonstrates a strong correlation between the finite element analysis (FEM) results and the predicted displacement values, with R^2 values ranging from 0.94 to 0.9999. The high coefficient of determination indicates that the displacement behavior of the floating column multistory building is highly predictable and consistent. The regression model accurately captures the displacement trend with minimal prediction error, confirming the reliability of the proposed prediction approach.

From a durability perspective, the regression results indicate that the displacement variation across the slab is smooth and well controlled. Such controlled structural deformation suggests that the applied loads are uniformly distributed throughout the structural system, thereby



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reducing the possibility of excessive stress concentration. Lower stress concentration minimizes the initiation and propagation of structural cracks, which are one of the primary causes of long-term deterioration in reinforced concrete buildings.

Furthermore, the uniform displacement pattern implies that the slab and supporting structural members experience balanced deformation without abrupt displacement changes. This behavior contributes to maintaining structural integrity and reduces the likelihood of excessive flexural cracking. Controlled crack development limits the ingress of moisture, chlorides, carbon dioxide, and other aggressive environmental agents, thereby reducing the risk of reinforcement corrosion and concrete degradation.

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