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Use of Artificial Neural Network based Prediction of Optimum Case of Multistory Buildings by using Structural Response

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Abstract: This research presents a hybrid civil engineering and computer science approach for the efficient structural analysis of multistory buildings subjected to seismic forces. A total of ten distinct building models labeled NS and BD1 to BD9 were developed using structural analysis software, incorporating Response Spectrum Analysis and varying concrete grades (M25 and M30). A grade change scenario was introduced in slab components at different floor levels, with resulting horizontal displacements extracted as key response parameters. These outputs served as critical input for two Python based Artificial Neural Network (ANN) models: one using a Feed Forward algorithm and the other using Back Propagation, both integrated with Artificial Intelligence (AI) and Machine Learning (ML). Preprocessing tasks such as data normalization, cleaning and missing value treatment were performed using Pandas and NumPy. Model training and validation were conducted using TensorFlow and scikit learn, employing 200 epoches for optimal learning. Performance evaluation using Mean Squared Error (MSE) and R^2 score revealed exceptional accuracy, from this the ANN model achieving an MSE of 0 and R^2 of 1. Among the building cases analyzed, the ANN approach successfully identified the most structurally efficient configuration with minimum displacements in both UX and UY directions. This methodology not only enhances computational speed and accuracy compared to conventional practices but also promotes data driven decision making for cost effective and optimized structural design. The research underscores the applicability of ANN embedded with AI &ML techniques in building engineering and opens pathways for broader multidisciplinary implementations.
Keywords: Artificial Intelligence, Machine Learning, Artificial Neural Network, Structural Analysis, Seismic Performance, Multistory Buildings, Displacement Prediction

I. ROLE AND IMPORTANCE OF NEURAL NETWORKS IN BUILDING ENGINEERING

In the field of building engineering, neural networks play a transformative role by enabling intelligent analysis and decisionmaking. These braininspired computational models are designed to mimic how the human brain processes information through interconnected nodes called neurons. Their ability to learn from data makes them ideal for handling complex, nonlinear problems common in structural design and performance assessment. Artificial Neural Networks (ANNs) can predict structural behaviour and optimize material usage with high accuracy. ANN learning capacity improves as more data becomes available, making them valuable particularly useful in areas like seismic risk analysis, energy efficiency modelling, smart building &automation. They also assist in identifying patterns in construction data, which enhances planning and safety. Compared to traditional methods, neural networks offer greater flexibility and predictive power. As a result, they are becoming essential tools for sustainable and intelligent infrastructure development in modern building engineering.

II. GAP IN RESEARCH

This project focuses on addressing these gaps by developing a Python based AI model that:
1) Integrates machine learning algorithms using ANN with structural engineering analysis.Uses real or simulated response data for training and prediction.
2) Consider variable design inputs, different grade change approach within the building.
3) Provides an optimized solution for multistory building configurations.Validates results in comparison with conventional IS code based approaches.

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III. RESEARCH OBJECTIVES

On keeping in mind the problem statement, the outline for new research work has proposed in the form of objectives given below :

1) To create the different building cases with seismic analysis using building analysis software.
2) To make a concept of grade change effect within the variable cases and to analyse the building structure and obtain the maximum displacement output parameter for both horizontal lateral directions.
3) To create AI and ML based code on python language with pre processing steps such as data normalization with missing value treatment and data cleaning.
4) To select the technique for validation of selected datasets.
5) To make a relationship of data from input values.
6) To evaluate the model performance using Mean Square Error (MSE) and RSquare (R^2) score.
7) To evaluate, analyze and compare the efficient building case characterized by the minimum response values of displacement parameter using Artificial Neural Network embedded with AI and ML based predictive model framework.

The main and foremost objective is to create and use the Feed Forward and Back Propagation type Artificial Neural Network embedded with AI and ML based coding that will be used for faster prediction & faster building analysis. From this dissertation, it has essential to combine the multidisciplinary approach that combine civil engineering and computer science that provides recommendation of economic case among different grade change scenario and in the parallel field.

IV. PROCEDURE AND 3D MODELING OF THE STRUCTURE

The study considered a total of ten commercial building cases, labeled NC and BD1 through BD9, all situated on medium soil in seismic zone III with a zone factor (Z) of 0.16. The buildings were assumed to have an Ordinary Shear Wall combined with a Special Moment Resisting Frame (SMRF), resulting in a response reduction factor of 4. The damping ratio was taken as 5%, and the importance factor for these commercial buildings was considered to be 1.5. Below is the list of buildings framed for analysis.

Table 1: List of buildings framed with assigned abbreviation

Case No.	Abbreviated cases	Description of cases
1.	NS	Structure having same grade of concrete in slab members – M25 and no change in grade at any floor level.
2.	BD1	Structure having M25 grade of concrete in slab members and change in grade to M35 at level – Roof.
3.	BD2	Structure having M25 grade of concrete in slab members and change in grade to M35 at level – 7th floor.
4.	BD3	Structure having M25 grade of concrete in slab members and change in grade to M35 at level – 6th floor.
5.	BD4	Structure having M25 grade of concrete in slab members and change in grade to M35 at level – 5th floor.
6.	BD5	Structure having M25 grade of concrete in slab members and change in grade to M35 at level – 4th floor.
7.	BD6	Structure having M25 grade of concrete in slab members and change in grade to M35 at level – 3rd floor.
8.	BD7	Structure having M25 grade of concrete in slab members and change in grade to M35 at level – 2nd floor.
9.	BD8	Structure having M25 grade of concrete in slab members and change in grade to M35 at level – 1st floor.
10.	BD9	Structure having M25 grade of concrete in slab members and change in grade to M35 at level – GF/Plinth floor.

As per the above mentioned input constraints, the other input required as The fundamental time period of the buildings was 0.616 seconds in both the X and Z directions. Each structure had a total height of 35.3 meters. The beam sizes varied, with dimensions of 0.45 m × 0.30 m and 0.50 m × 0.35 m, while the columns measured 0.60 m × 0.50 m.

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The thickness of the shear walls was 130 mm, and the slab thickness was 125 mm. The materials used for construction included M25 and M35 grade concrete along with Fe 500 grade steel.

For analysis and interpretation, Python was used as the programming language, and all computations were carried out using the Google Collaboratory platform.

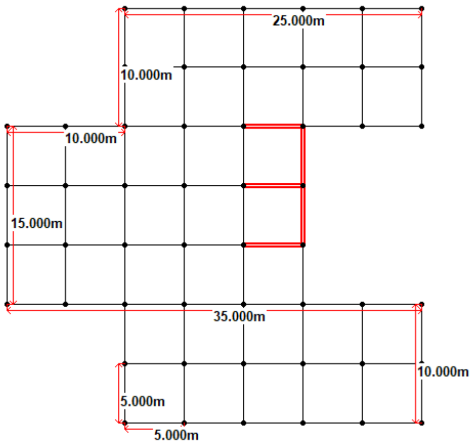

Fig. 1: Plan of all cases

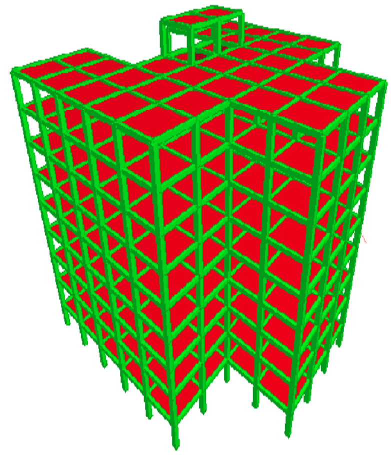

Fig. 2: 3 D view of all structural cases

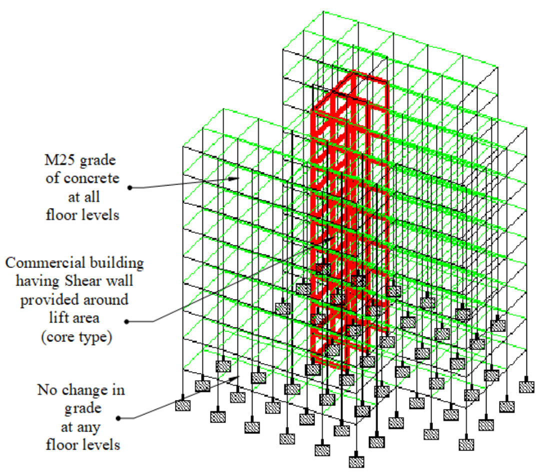

Fig. 3: Case NS

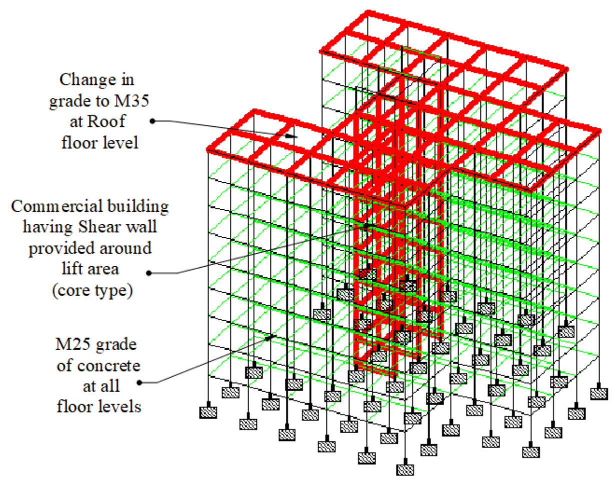

Fig. 4: Case BD1

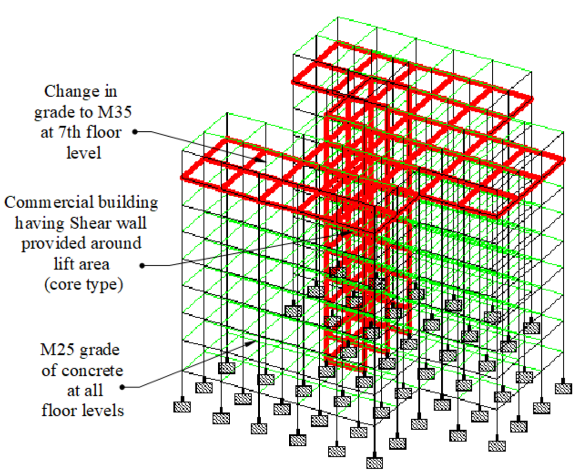

Fig. 5: Case BD2

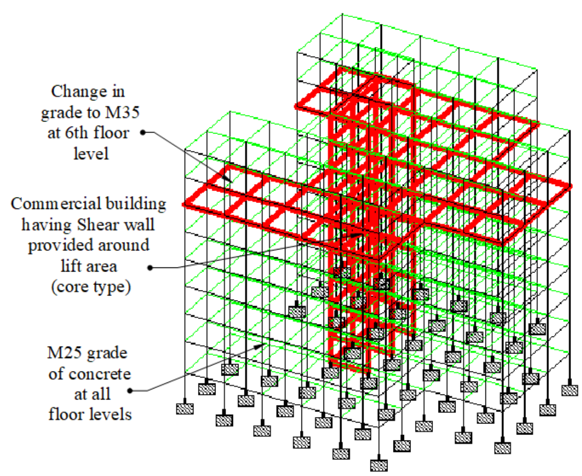

Fig. 6: Case BD3

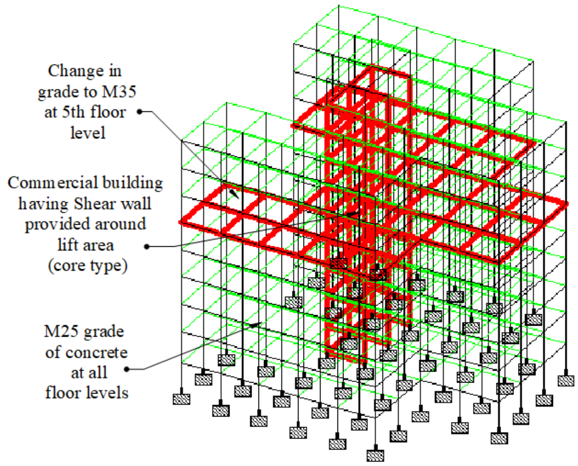

Fig. 7: Case BD4

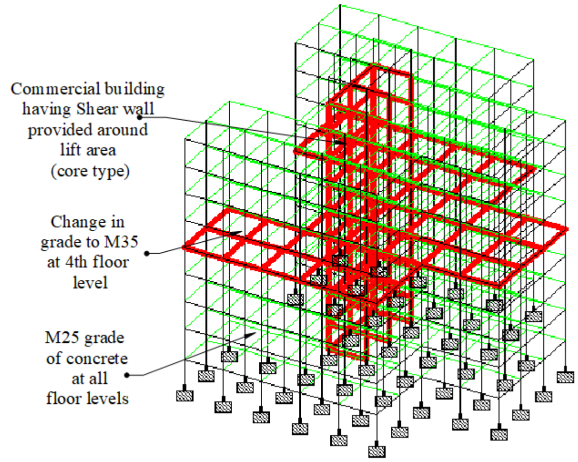

Fig. 8: Case BD5

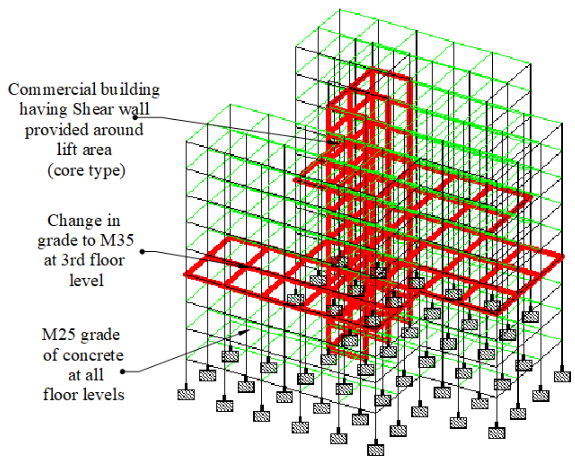

Fig. 9: Case BD6

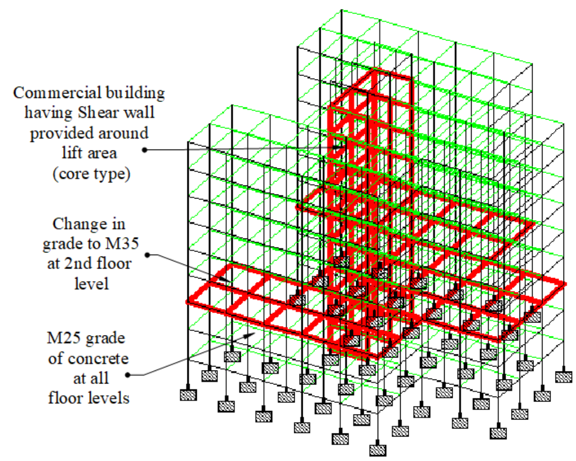

Fig. 10: Case BD7

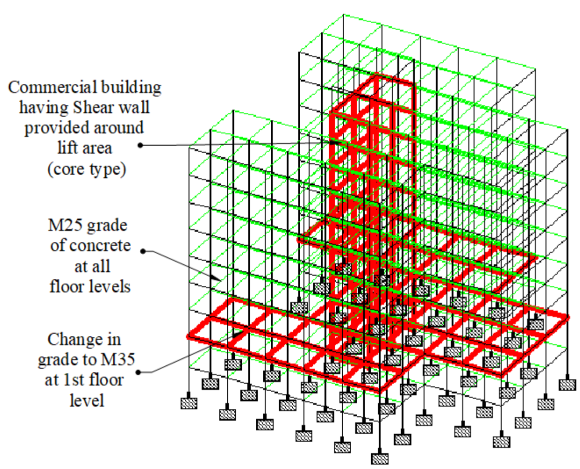

Fig. 11: Case BD8

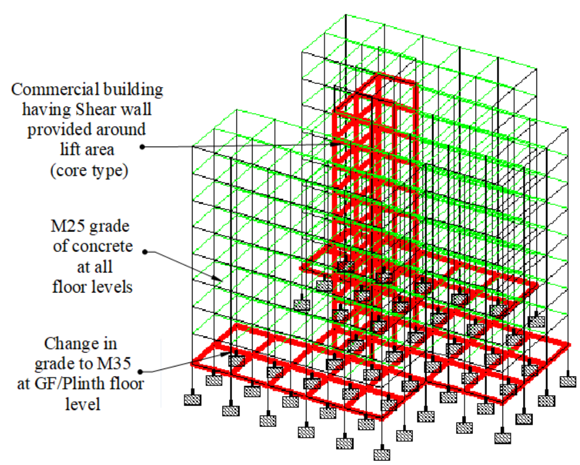

Fig. 12: Case BD9

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V. RESULTS AND DISCUSSION

Results are shown in tabular and in graphical form are as follows:

Table 2:Input data of maximum displacement in both horizontal directions required for all building analysis cases using ANN

Case	Description of case	Displacement Ux	Displacement Uy
NS	All floors with same grade	118.397	159.374
BD1	Grade change at Roof level	118.285	159.293
BD2	Grade change at 7th floor level	118.126	159.129
BD3	Grade change at 6th floor level	117.901	158.712
BD4	Grade change at 5th floor level	117.839	158.503
BD5	Grade change at 4th floor level	117.923	158.617
BD6	Grade change at 3rd floor level	117.946	158.616
BD7	Grade change at 2nd floor level	117.99	158.641
BD8	Grade change at 1st floor level	118.053	158.701
BD9	Grade change at GF/Plinth floor level	118.209	158.982

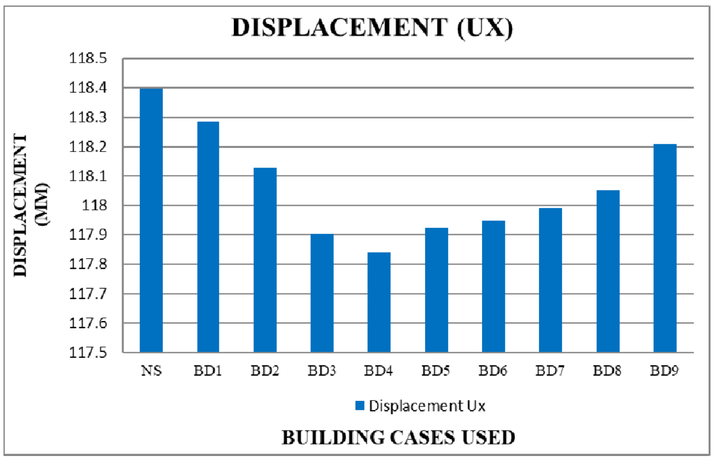

Fig. 13: Graphical representation of maximum displacement in horizontal direction Ux required for all building analysis cases arranged using general intelligence

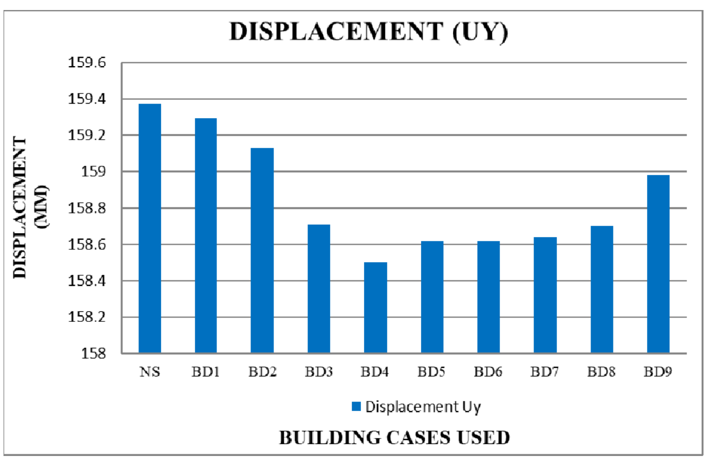

Fig. 14: Graphical representation of maximum displacement in horizontal direction Uy required for all building analysis cases arranged using general intelligence

Most favourable case determination by Feed Forward ANN embedded with artificial intelligence and machine learning

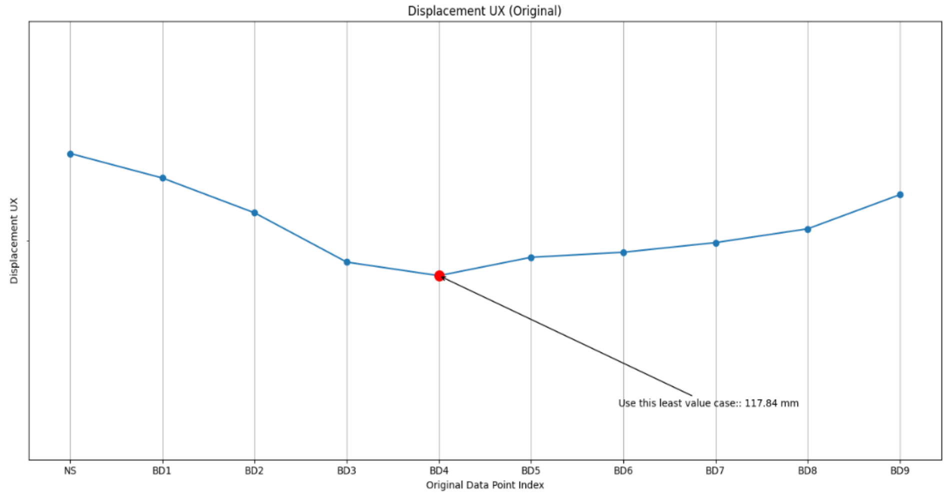

Fig. 15:General graphical plot of Displacement Ux using matplotlib.pyplot and marking least value with matplotlib.ticker

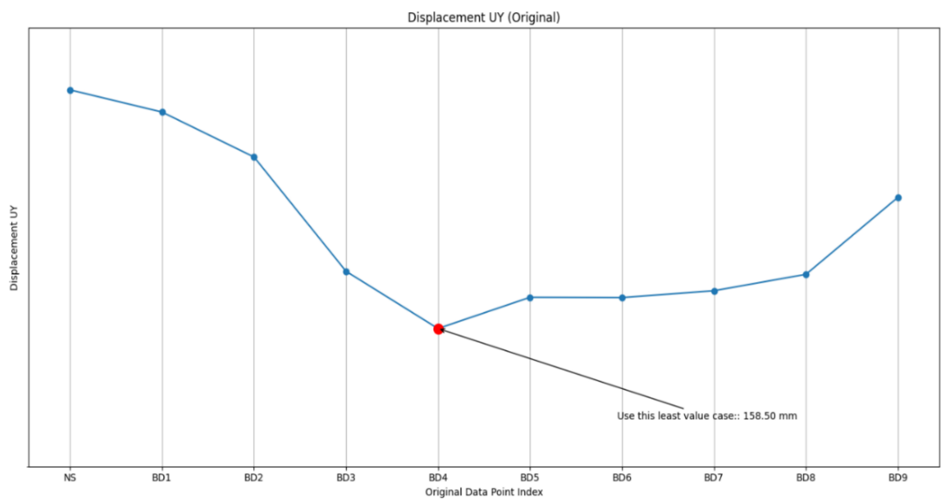

Fig. 16: General graphical plot of Displacement Uy using matplotlib.pyplot and marking least value with matplotlib.ticker

```
Efficient Value (Least Ux from input data):
----------------------------------------
Case Name       : BD4
Description     : Grade change at 5th floor level
Displacement Ux: 117.839

Efficient Value (Least Uy from input data):
----------------------------------------
Case Name       : BD4
Description     : Grade change at 5th floor level
Displacement Uy: 158.503

Recommended case with least value of both case:
----------------------------------------
Case Name       : BD4
Description     : Grade change at 5th floor level
Efficiency      : For both Ux and Uy displacement direction
```

Fig. 17:Output recommendation of efficient value case using Feed forward ANN

Most favourable case determination by Back Propagation ANN embedded with artificial intelligence and machine learning

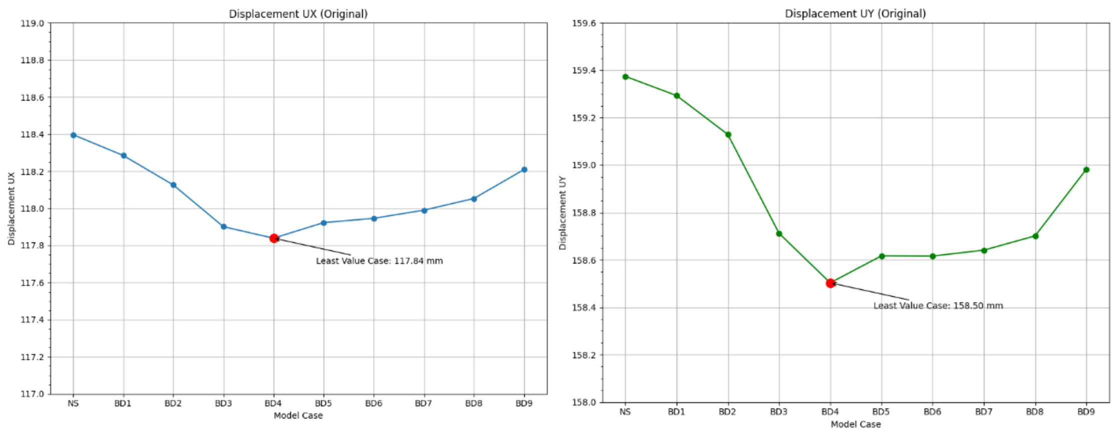

Fig. 18: General graphical plot of Displacement Ux and Uy using matplotlib.pyplot and marking least value with matplotlib.ticker when running ANN with feed forward approach

```
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 82ms/step
Mean Squared Error for Linear Regression for UX: 0.00
R-squared for Linear Regression for UX: 1.00
----------------------------------------
Mean Squared Error for Linear Regression for UY: 0.00
R-squared for Linear Regression for UY: 1.00
```

Fig. 19: Calculation check of Mean Square Error (MSE) and R Square Score for both UX and UY

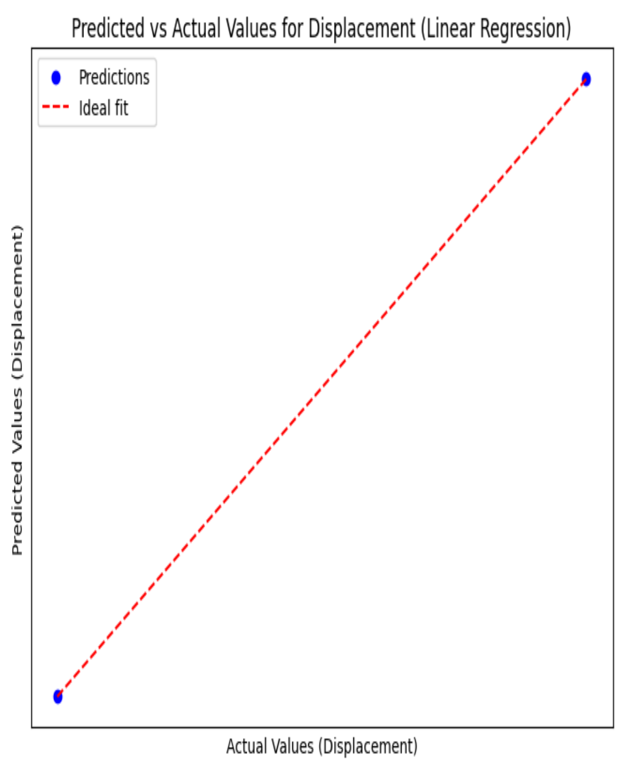

Fig. 20: Graphical plot of Predicted V/s Actual Values for displacement when performing linear regression

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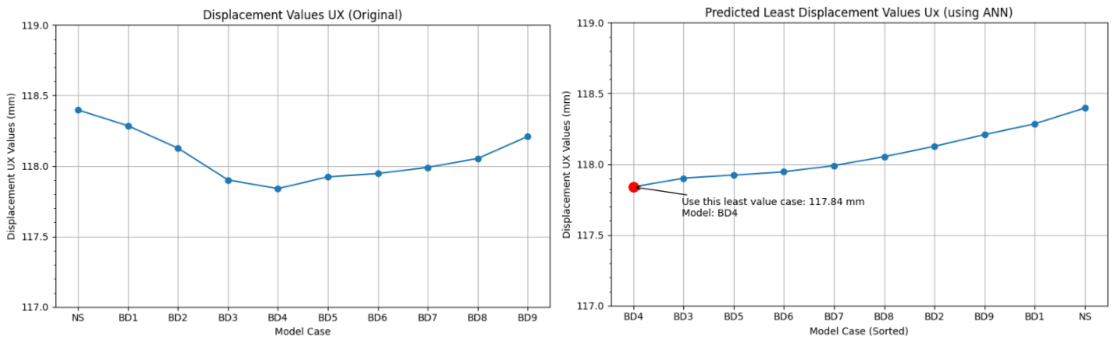

Fig. 21: Graphical plot of original displacement values Ux and predicted least displacement values Ux using ANN

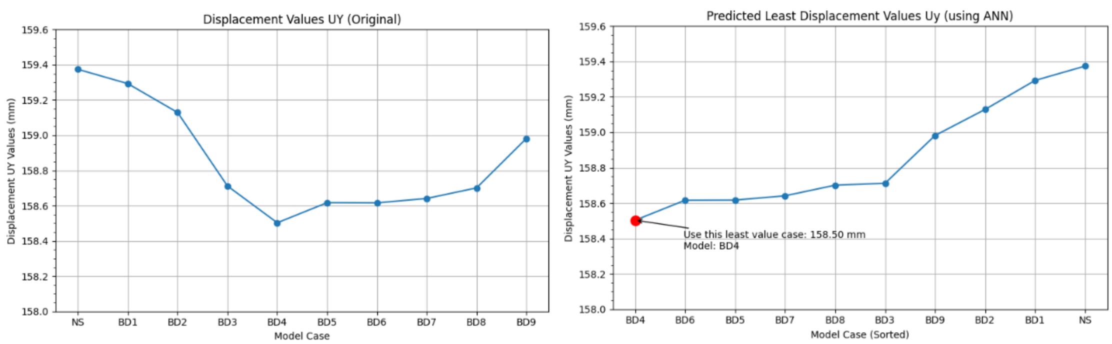

Fig. 22:Graphical plot of original displacement values Uy and predicted least displacement values Uy using ANN

```
Efficient Value (Least Ux from input data):
----------------------------------------
Case Name       : BD4
Description     : Grade change at 5th floor level
Displacement Ux: 117.839

Efficient Value (Least Uy from input data):
----------------------------------------
Case Name       : BD4
Description     : Grade change at 5th floor level
Displacement Uy: 158.503

Recommended case with least value of both case:
----------------------------------------
Case Name       : BD4
Description     : Grade change at 5th floor level
Efficiency      : For both Ux and Uy displacement direction
```

Fig. 23: Output recommendation of efficient value case using Back propagation ANN

VI. CONCLUSION

The conclusion can be pointed out are as follows:

1) Multiple structural models were successfully created using building analysis software, incorporating with the Response Spectrum Analysis. Total 10 separate building cases created abbreviated as NS, BD1 to BD9 respectively using M25 and M30 concrete grade.
2) The grade change scenario has conducted in structural analysis software with grade change in slab component at different levels keeping the other floor levels at same grade. After analysis, the analysis tool yields horizontal displacement values as key output parameters. The results obtained will be required as critical input data for AIML ANN model programming.
3) Two different Python based machine learning ANN model has developed, the former one has a feed forward ANN ability and the later one has back propagation with AI based learning ability to predict the best possible case that incorporates essential pre processing steps such as data normalization with missing value treatment and data cleaning to ensure high quality and reliable input data. This has achieved using Pandas and NumPy.

4) Suitable validation techniques such as TensorFlow &sklearnhas used that train test split data and conduction of cross validation to ensure robust evaluation of model performance. An epoch 200 has followed that specifies the number of times the entire training dataset (X and Y) will be passed through the neural network. In current case, it will be done 200 times, it means more epochs can lead to better learning with risk overfitting. train test split was applied to the dataset, and the models were trained and validated using TensorFlow version &sklearn version correspondingly.
5) The AIML based Feed Forward Artificial Neural Network and Back Propagation Artificial Neural Network model established using meaningful relationships between the input result parameters and output responses (displacement), demonstrating strong predictive capability with exact linear regression.
6) Model performance was assessed using Mean Squared Error (MSE) and R^2 score. The results indicate that ANN trained over 200 epochs, produced an MSE of 0 and an R^2 of 1, thus indicating enhanced predictive performance and robustness.
7) By evaluating various building case with grade change in slab members, the ANN model accurately pinpointed the most efficient configuration with the lowest displacement for both UX and UY directions. This outcome underscores the practical applicability of ANN techniques in enhancing structural design through data driven analysis and structural variables.

The primary objective of this dissertation has achieved with developed and implemented Feed Forward and Back Propagationbased Artificial Neural Network (ANN) integrated with AI and Machine Learning (ML) technique that enable rapid prediction and efficient structural analysis of buildings. This approach facilitates high speed evaluation of structural performance under various scenarios, significantly improving computational efficiency compared to conventional methods. Furthermore, this research adopts a multidisciplinary methodology that bridges civil engineering and computer science, leveraging the strengths of both fields. By applying intelligent predictive modeling, the research work has capable of recommending the most economical structural configuration across various grade change scenarios. The study also demonstrates the model's applicability in parallel domains, promoting a data driven &decision making framework for cost effective and optimized structural design.

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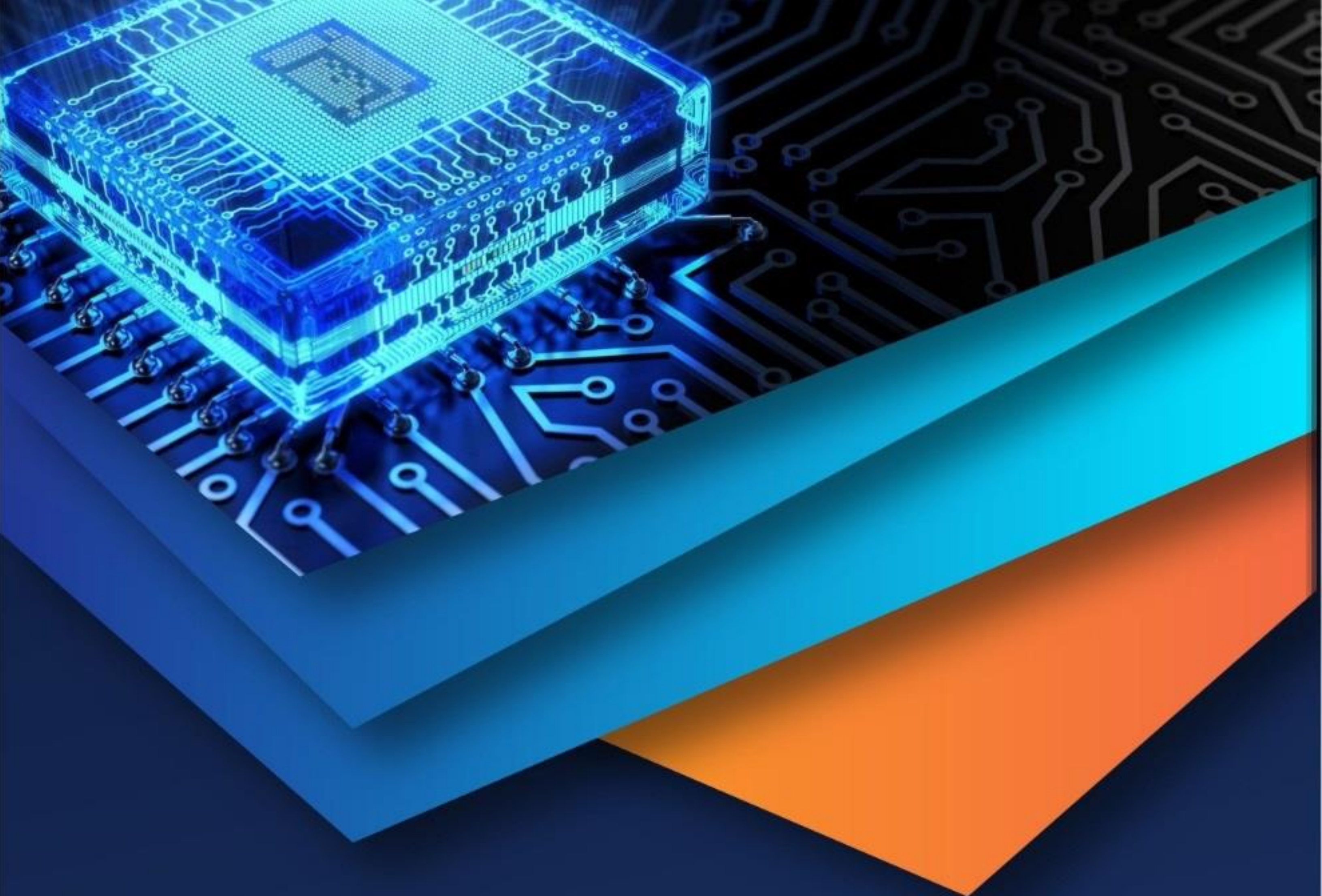

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