Wind Engineering Joint Usage/Research Center
FY2025 Research Result Report

Research Field: Wind Hazard Mitigation/Wind Resistant design
Research Year: FY2025
Research Number: 25252002
Research Theme: Predicting Tornado vortex induced pressure coefficients and wind profile on structural projections in low rise buildings using convolutional neural networks

Representative Researcher: Dr Nakul Gupta

Budget [FY2025]: 1,77,000 Yen

1. Research Aim:

- To evaluate the damage in low rise structure and attached canopies due to aerodynamic loads and wind caused by tornadoes like flow due to varying roughness of surface.
- Developing a Deep Learning model to predict coefficient of pressure (Cp) and wind profile using x, y location coordinates, roughness, and angle of the canopy as input parameters.

2. Research Method

It is proposed in the present project to conduct the extensive study on low rise buildings with attached canopies for different parameters under the influence of different location of Tornadoes induced vortexes and angle of the canopy as input parameters. The building models can be tested for different parameters of surface roughness also. So, it is planned to carry out the study on models with different roughness of the surface. The researchers had already studied the effects on varying length of attached canopy through awarded collaborative research projects from JURC, in past. In the present study, provided architecture outlines a systematic pipeline for developing a Deep Learning model to predict coefficient of pressure (Cp) and wind profile. View of the different roughness bend on the simulator are shown in Figure-1.

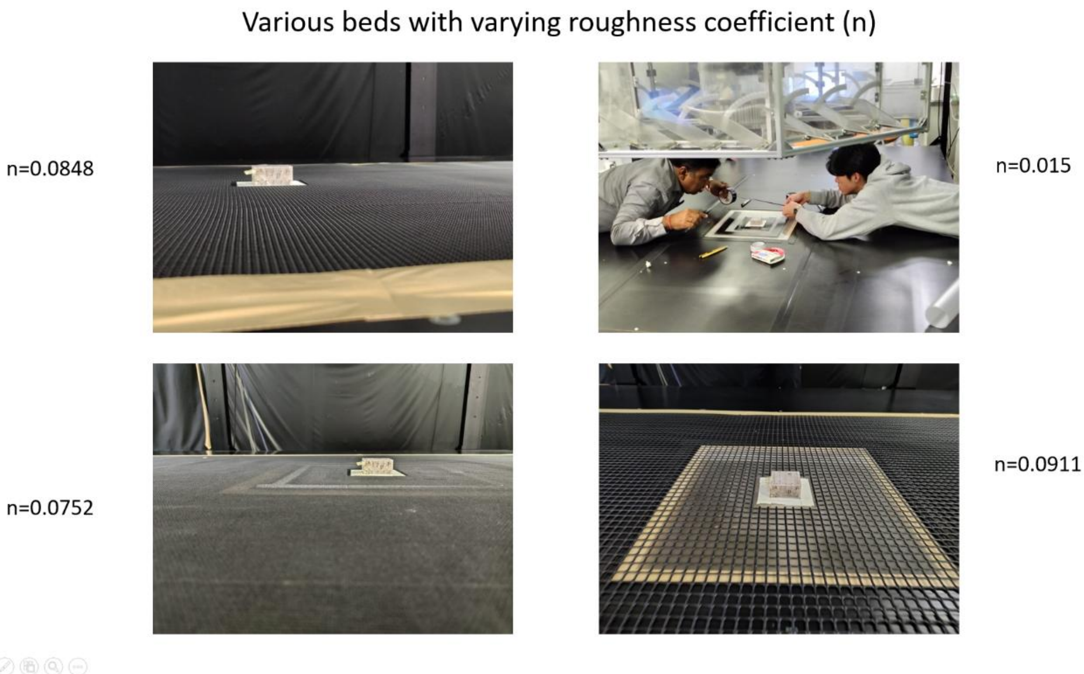


Fig-1: - Different roughness bed with manning's coefficient used during the experiment

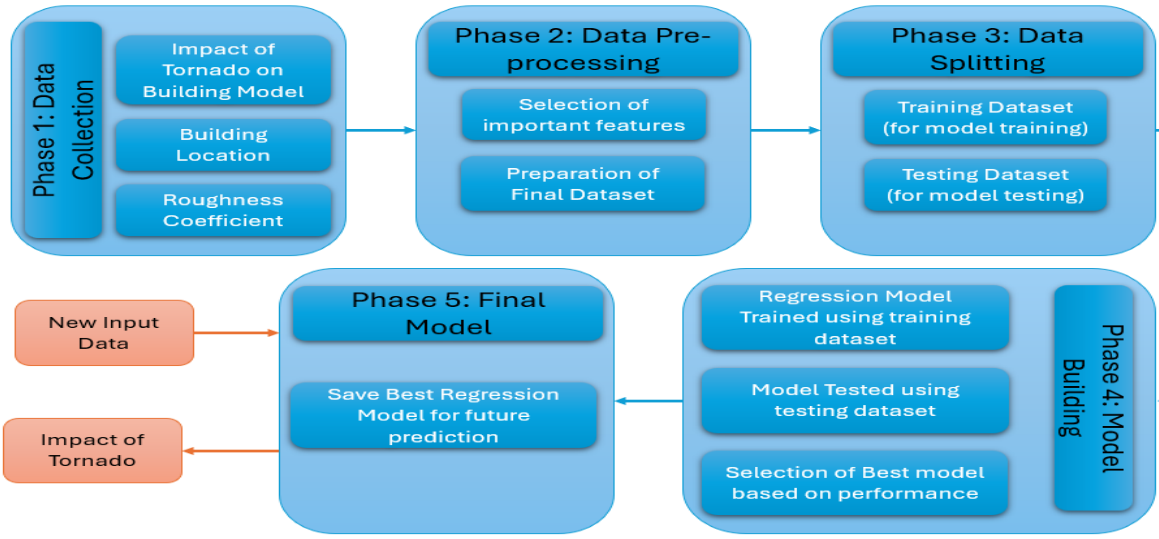
Fig-2:- Roughness coefficient testing done in open channel flume

3. Research Result

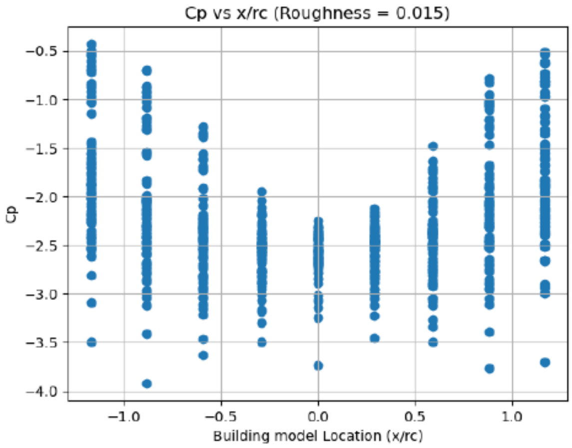
A series of experiments were conducted using a tornado-like flow simulator at Tokyo Polytechnic University to measure the temporal variations of wind pressure coefficients on low-rise building models with attached canopies of 29.8 mm length, fixed at 3/4th height of the building at a 10-degree angle. The experiments were carried out for different distances between the centers of tornado-like flows and the building, and different surface roughness beds surrounding the building models, with distances normalized by the radius of maximum wind of the swirling flows. Time series data were collected on the building model surface, canopy surface, and surroundings as the tornado approached and left the building in both x and y directions, and the mean components of the pressure coefficients are presented as follows:

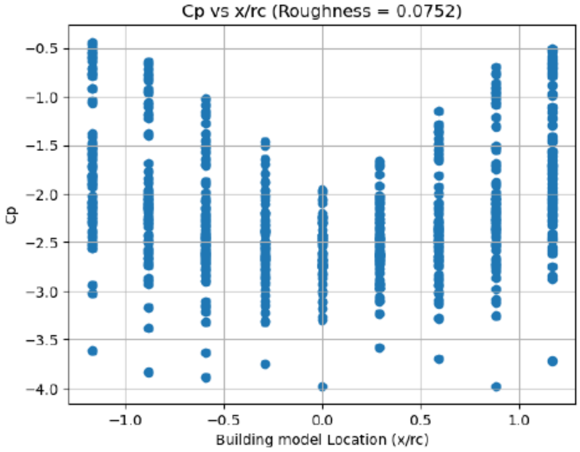
1. Among the regression models tested (Linear Regression, SVR, and Random Forest), Random Forest was selected as the best-performing model based on evaluation metrics (r^2, MSE, and RMSE).
2. The Random Forest model achieved a high degree of accuracy with an r^2 value of 0.96, demonstrating its effectiveness in predicting complex tornado-induced pressure coefficients.
3. While Random Forest and SVR showed strong performance, Linear Regression was found to be the least effective, failing to capture the non-linear nature of the wind pressure data.
4. Given the high performance of current regression models the next logical progression is the implementation of Convolutional Neural Networks (CNN). By incorporating the wind velocity profile as an additional input layer alongside spatial pressure data, the model will further refine the prediction of tornado-vortex induced loads on low-rise geometries, enabling a more comprehensive understanding of the correlation between incident wind shear and structural pressure distribution.

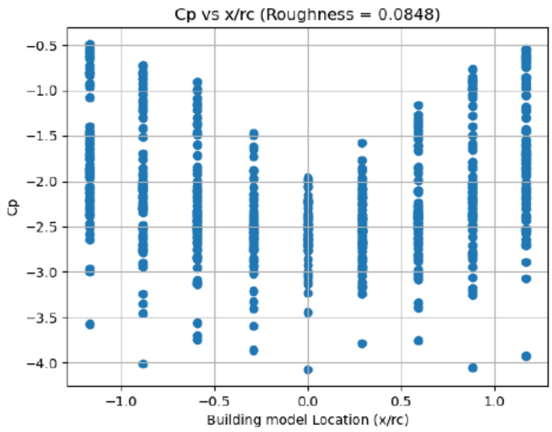
<u>Proposed Model</u>

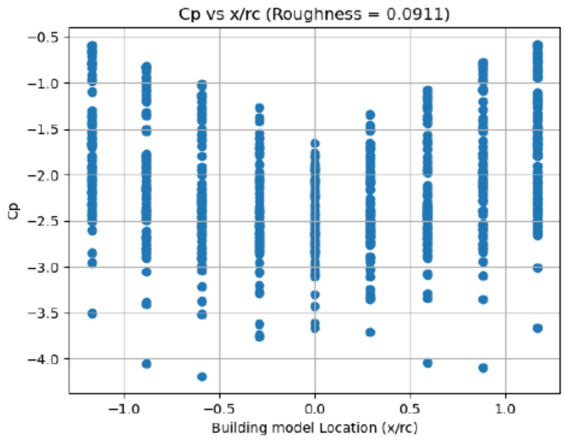


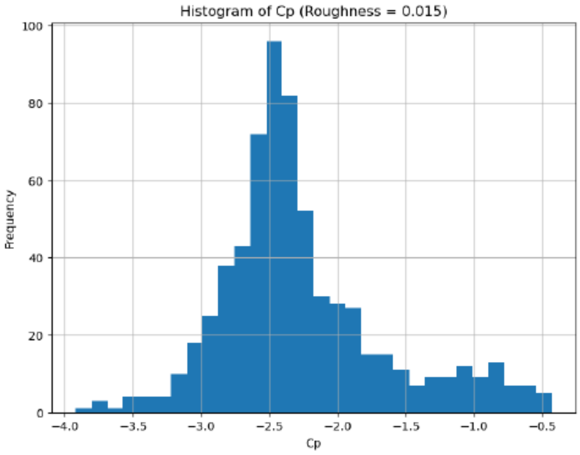
Exploratory Data Analysis (EDA)

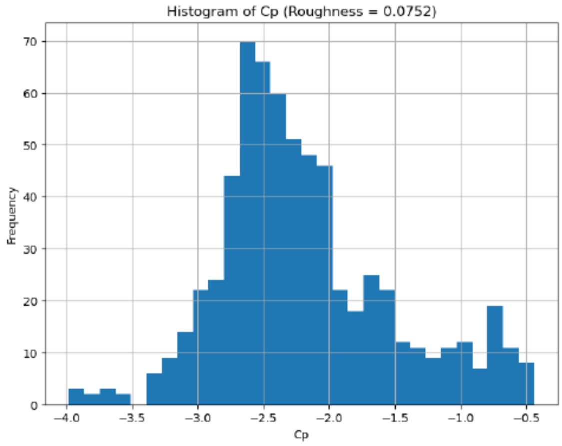


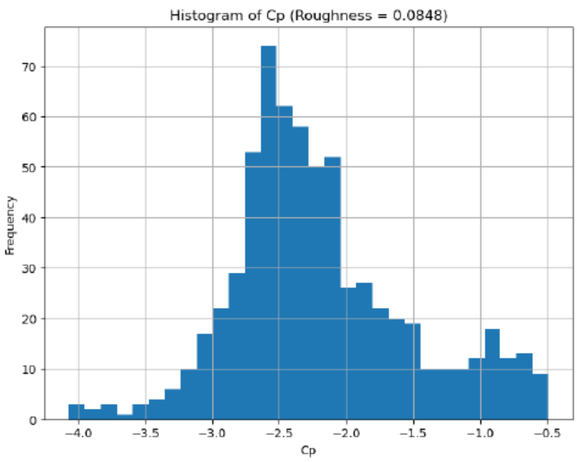


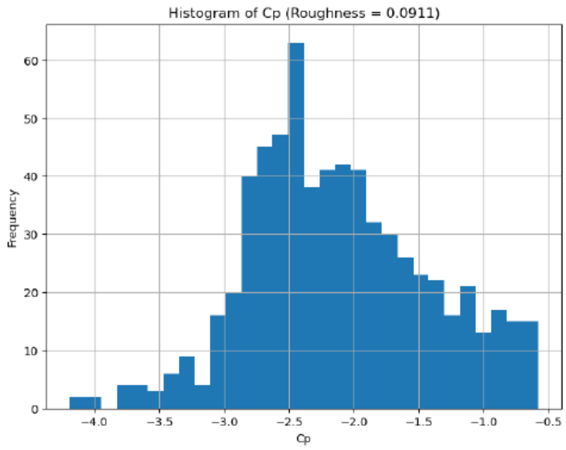


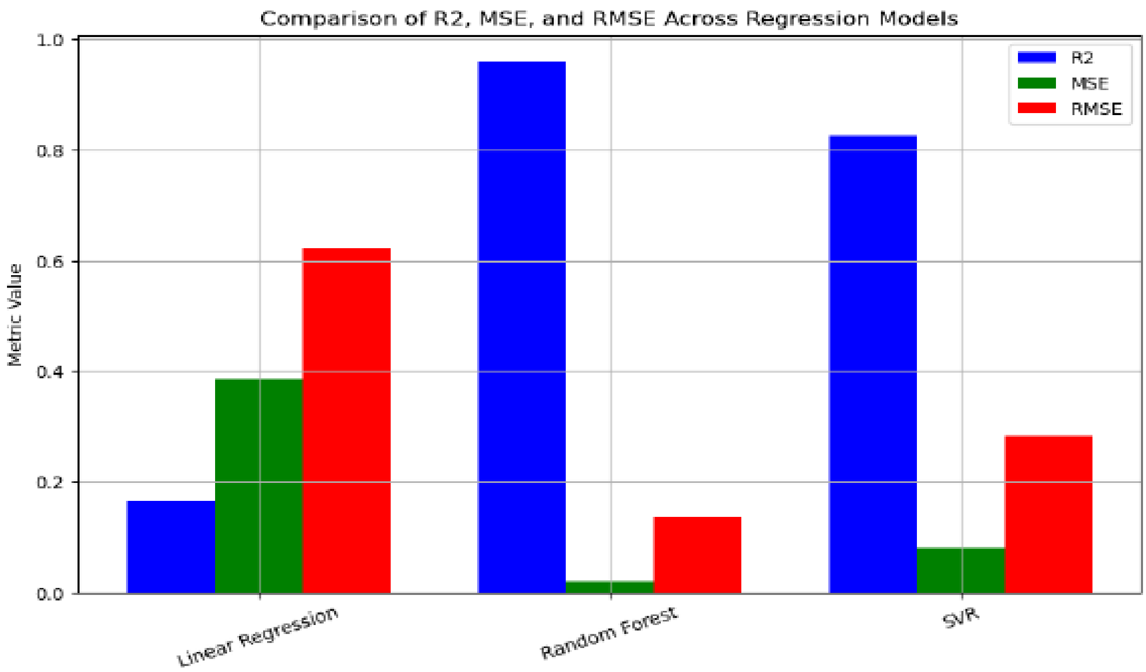












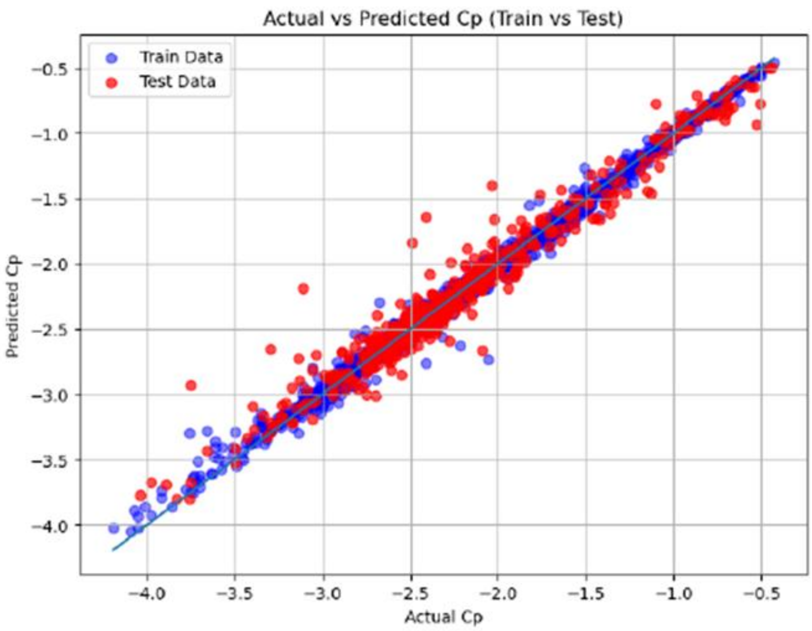


Fig 3: Random Forest

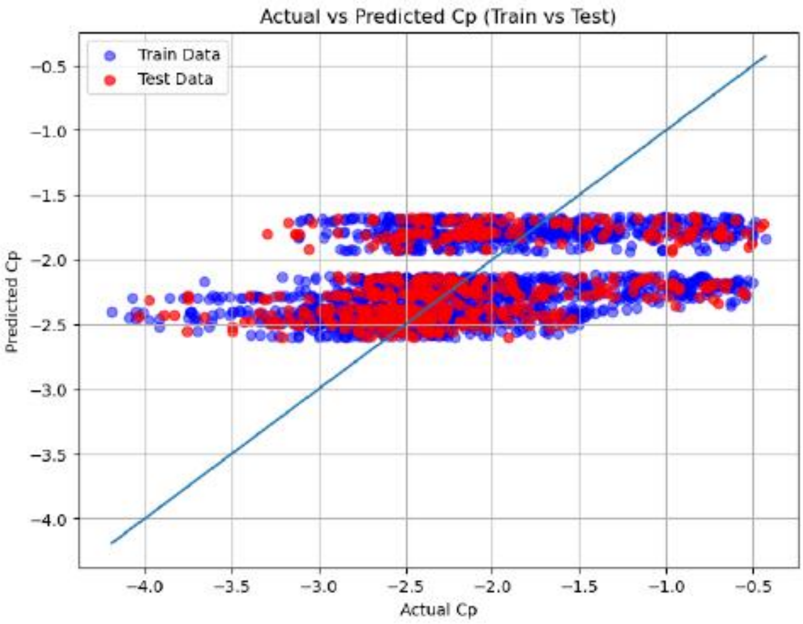


Fig 4: Linear Regression

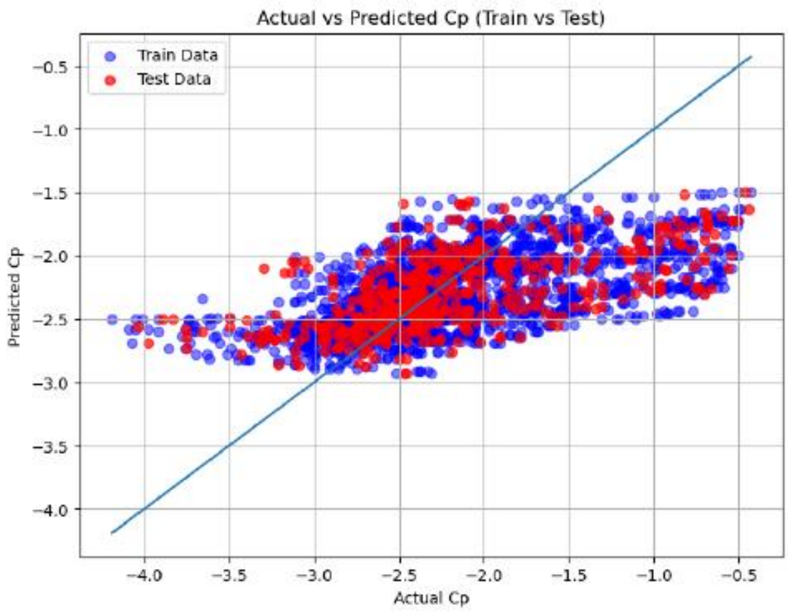
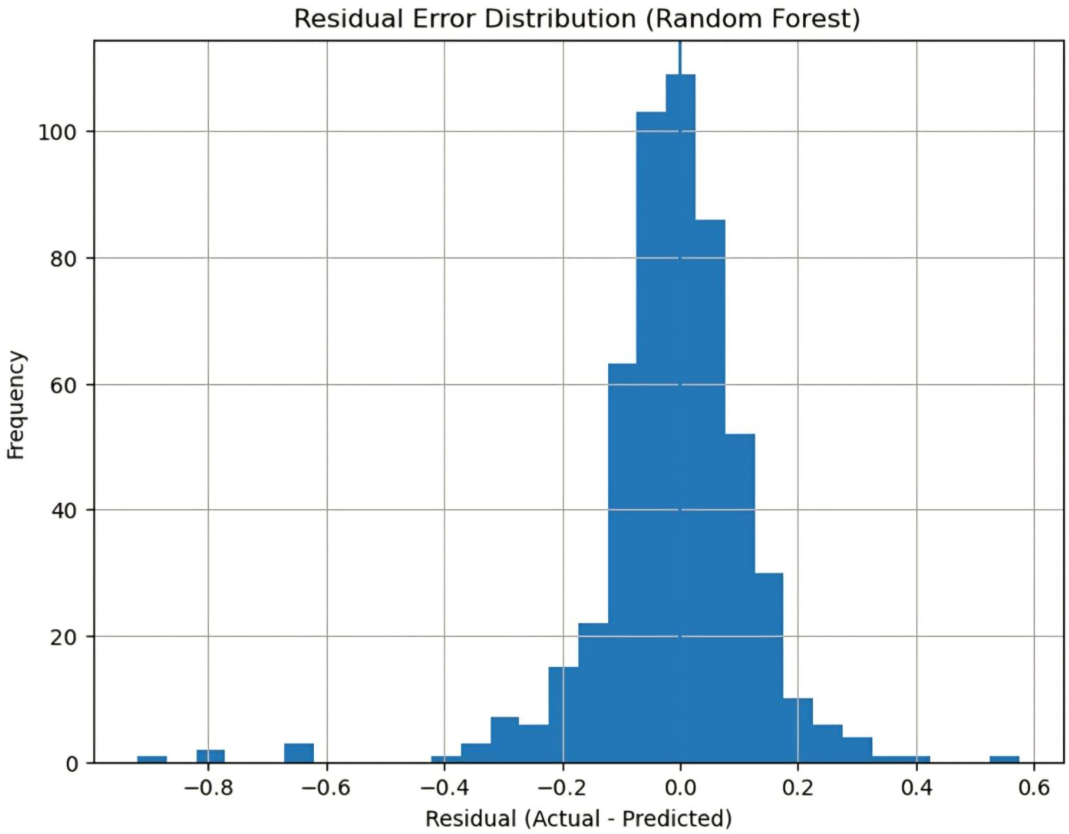


Fig 5: Support Vector Regressor



4. Published Paper etc.
Under Process

[Presentations at academic societies]
Under Process

[Published books] 1.
1.
[Other]
Intellectual property rights, Homepage etc.

4. Research Group
1. Representative Researcher
Nakul Gupta, Associate Professor, NICMAR Institute of Construction Management and Research, Delhi-NCR, Bahadurgarh, India

1. Collaborate Researchers
1. Rajesh Goyal, Professor, NICMAR Institute of Construction Management and Research, Delhi-NCR, Bahadurgarh, India
2. Pawan Kumar Verma, Symbiosis Institute of Technology, Nagpur Campus, Symbiosis International (Deemed University), Pune, Maharashtra, India
3. Masahiro Matsui, Professor, WERC, Tokyo Polytechnic University, Japan

5. Abstract (half page)

Research Theme Impact of Tornado vortex induced aerodynamic loads on structural projections in low rise buildings

Representative Researcher (Affiliation): Prof. Rajesh Goyal, NICMAR Institute of Construction Management and Research, Delhi-NCR India Summary

This research investigates tornado-vortex induced aerodynamic loads on low-rise buildings with attached canopies through experimental simulation and machine learning analysis. Conducted at the Tokyo Polytechnic University tornado-like flow simulator, the study measured temporal variations in wind pressure coefficients (Cp) across varying surface roughness beds and building locations. Evaluation of multiple regression techniques—including Linear Regression and Support Vector Regression (SVR)—identified Random Forest as the superior model, achieving an r^2 value of 0.96 in predicting complex tornado-induced pressure coefficients. While these results establish a high-performance baseline for structural load prediction, the study outlines a future implementation of Convolutional Neural Networks (CNN) to further refine predictions by incorporating wind velocity profiles as an additional input layer.