

# The Neighbor Effect Factor: Quantifying the Influence of Adjacent Buildings on Drag Force

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## Abstract.

Urban areas have been increasingly expanding their built environment. Initially, buildings may be constructed in isolation; however, over time, new structures are inevitably erected nearby, potentially altering wind action in a non-negligible manner—conditions often not accounted for in the original design. This study evaluates the Neighborhood Factor (NF)—defined as the ratio between the drag force on a building in the presence of an adjacent structure and the drag force on the same building in isolation—based on experimental wind tunnel tests. The neighboring building, with the same dimensions as the main building, was positioned in four different locations, all aligned with the studied building. Three wind directions were considered: 0°, 45°, and 90°. For each configuration, mean NF values were computed from time series of drag force measurements obtained experimentally. Results indicate that the presence of neighboring buildings can significantly increase drag force, reaching values above 18% compared to the isolated case, depending on their relative position and distance. These findings highlight the importance of accounting for the aerodynamic influence of surrounding structures in wind load assessments for buildings.

**Keywords:** Wind Load Effects, Surrounding Buildings, Urban Wind Effects

## 1 Introduction

Population growth, the significant appreciation of land in central urban areas, the increasing occupation of these regions, and the natural expansion of metropolitan zones have driven the construction of large-scale buildings in locations previously underutilized or predominantly occupied by low-rise structures. In such scenarios, the initial design assumptions for these early developments often account for the unobstructed action of wind on all façades. However, over time, it is common for new buildings of comparable height and scale to be erected nearby.

According to Blessmann [1], the presence of surrounding obstacles modifies the wind flow pattern, leading to changes in the pressure distribution over a building's façades. This aerodynamic interference directly affects the drag force acting on the structure. Depending on the relative positioning and geometry of the neighboring buildings, such interactions may either reduce or amplify the wind-induced forces and moments. In some cases, this may result in values exceeding the limits prescribed by design codes, as reported by Vieira [2], [3], [4], and other researchers.

In this context, the present study aims to assess the influence of an adjacent building of equivalent size on the drag force, expressed through the neighborhood factor. Experimental data obtained by Vieira [2] from wind tunnel tests were used for this purpose. Based on these measurements, a comparative analysis was conducted considering the drag force acting on a standalone building and on the same building when placed in proximity to another of identical dimensions. interference between structures.

## 2 Theoretical review

The drag force is one of the primary parameters to be considered when assessing wind effects on a building. As stated in ABNT-NBR6123:2023 [6], it represents the component of the wind load aligned with the flow direction and is determined using eq. (1). Its computation involves the dynamic pressure ( $q$ ), the drag coefficient ( $C_a$ ), the effective frontal area ( $A_f$ ), and the shelter factor—also referred to as the neighboring interference factor ( $f_v$ ).

$$F_a = q C_a A_e f_v. \quad (1)$$

An alternative approach to obtaining more accurate drag force values, rather than relying exclusively on the formulas provided by design standards, is to perform experimental testing capable of yielding more representative data on wind effects. In these tests, the geometry of the model determines the placement of multiple pressure tap points, which serve as the primary data acquisition locations. Throughout the measurement campaign, numerous readings are recorded, and depending on the study objectives, these data can be processed and analyzed using different methodologies.

Certain statistical analyses are particularly useful when processing data from wind tunnel experiments, such as the time-averaged mean, variance and standard deviation.

In wind tunnel experiments, it is often impractical to perform multiple tests to obtain key results. In this study, the experiment is treated as a discrete-time stochastic process, and the temporal average of the measured drag forces is used to represent their mean behavior. The discrete-time average is given by:

$$\bar{x} = \frac{1}{n} \sum_{i=1}^n x_i. \quad (2)$$

where  $x_i$  represents each individual measurement and  $n$  is the total number of readings.

A more directly interpretable measure of variability is the standard deviation, which expresses the spread of the data in the same units as the measured values. It is calculated as the square root of the variance, as shown in eq. (3). In this study, the standard deviation provides insight into the fluctuations of the drag force over time, complementing the temporal mean and allowing for a clearer understanding of the stochastic behavior observed in the wind tunnel experiments.

$$\sigma = \sqrt{\frac{1}{n-1} \sum_{i=1}^n (x_i - \bar{x})^2}. \quad (3)$$

According to the provisions of ABNT-NBR6123:2023 [6], the effects induced by the presence of a neighboring building in the vicinity of another can be accounted for through the inclusion of the neighboring interference factor ( $f_v$ ). The NF is calculated according to eq. (4) and should be applied in the standard expressions by multiplying the aerodynamic coefficient under consideration. In the case of the drag coefficient, its value can increase by up to 30%.

$$NB = \frac{C_{\text{building with neighborhood}}}{C_{\text{isolated building}}}. \quad (4)$$

The specific value to be adopted depends on the distance between the buildings and is determined according to the criteria established by ABNT-NBR6123:2023 [6], as shown in eq. (5):

$$f_v = \begin{cases} 1.3, & \text{se } s/d^* \leq 1.0 \\ 1.0, & \text{se } s/d^* \geq 3.0 \end{cases} \quad (5)$$

where:

- $s$ : the separation between the planes of the facing façades of two adjacent tall buildings, with  $a \times b$  being the building plan dimensions (ranging from  $1 \times 1$  to  $1 \times 4$ ), and  $d^*$ .
- $d^*$ : the smaller of the following dimensions:
  - shorter side  $b$ ;
  - semi-diagonal  $1/2\sqrt{a^2 + b^2}$ .

The dimensions presented follow those shown in Figure 1.

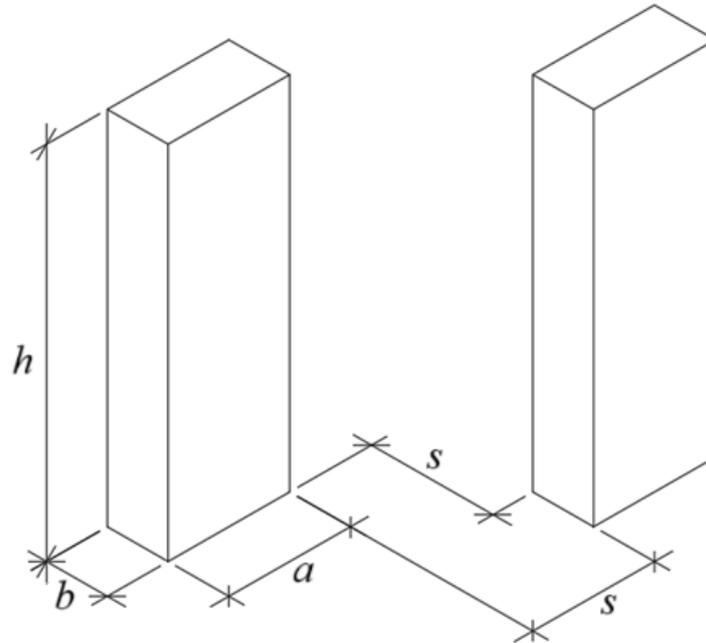


Figure 1. Measures used in determining the NF

### 3 Methodology

#### 3.1 Experimental Study

This study used the standardized building model developed by the Commonwealth Advisory Aeronautical Research Council (CAARC) as its reference. Consequently, it is commonly referred to as the “CAARC building,” a convention maintained throughout this work. Employing this model enables experimental procedures consistent with those used in laboratories worldwide and facilitates the comparison of aerodynamic data and results from different studies. The CAARC model (Figure 2) consists of a prismatic structure with a rectangular cross-section, representing a building with dimensions of 30.48 m  $\times$  45.72 m  $\times$  182.88 m. The models used to simulate surrounding structures were also scaled according to the CAARC building dimensions.

For the building under study, pressure measurements were conducted on all four façades at ten vertical levels. Using these measurements, forces were calculated over the influence areas corresponding to each pressure tap. From these forces, the drag force acting on the building was determined according to the wind direction. Beyond analyzing the building in isolation, the study also evaluated the effect of a neighboring building of identical height, placed in front of the main building in four different configurations, as illustrated in Figure 3, where ‘H’ denotes the height of the building under investigation.

Using the collected experimental data, the resultant drag forces on the building façades were determined for wind directions of  $0^\circ$ ,  $45^\circ$ , and  $90^\circ$ , in accordance with the Brazilian standard and commonly adopted practices in international wind load codes. For each configuration, the resultant drag force was computed from point pressure measurements following standardized calculation procedures.

Based on the calculated drag force values for each reading, the NF was determined by comparing the drag force measured in the presence of the neighboring building with the mean drag force obtained for the isolated building. Using the NF values, measures of central tendency, such as the mean, and measures of dispersion, such

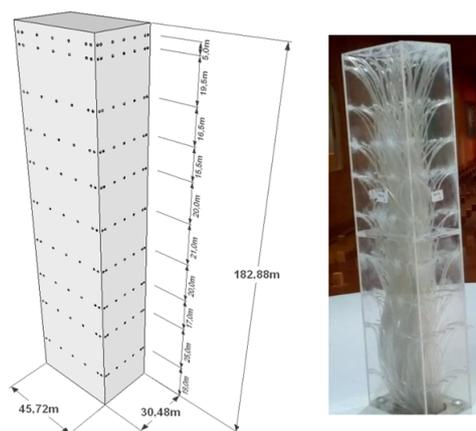


Figure 2. CAARC Building Model

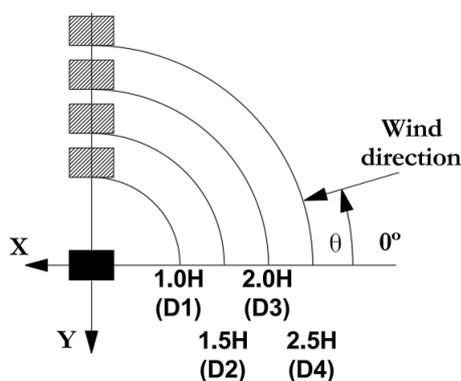


Figure 3. Positioning of neighboring buildings

as the standard deviation, were computed for each neighbor position, enabling a quantitative assessment of the aerodynamic influence of the adjacent structure. Key descriptive statistics of the drag forces, including mean, variance, and standard deviation, were derived according to the methodology proposed by Villoslada et al. [5]. Additionally, NF values were plotted across the readings for each neighbor configuration, allowing visualization of the variability in responses and the effect of the separation between buildings. Mean values and percentage increases or decreases in drag force were also reported to facilitate the interpretation of the neighborhood's impact on the studied building.

## 4 Results and analysis

After processing the data, the results presented in Table 1 were obtained. As shown in Figure 4, for wind at  $0^\circ$  incidence, all cases involving neighboring buildings exhibited average values of the Neighborhood Factor (NF) greater than 1.0, indicating an increase in drag force. Case V1D1 showed the greatest impact, with an average NF of 1.187 and a standard deviation of 0.134, suggesting a significant influence of the neighboring building positioned at a distance of 1.0 H. Cases V1D3 and V1D4 displayed similar values, close to 1.15, whereas V1D2 presented a more moderate increase, with an average NF of 1.055.

For wind at  $45^\circ$  incidence, the behavior was more heterogeneous, as illustrated in Figure 5. Case V1D1 presented an average NF below 1.0 (0.845), indicating a reduction in drag force, possibly due to aerodynamic shielding effects. In contrast, V1D2, V1D3, and V1D4 exhibited values close to 1.0, with small positive or negative variations. Standard deviations remained around 0.09, suggesting relative stability of the results for this wind direction.

Finally, for wind at  $90^\circ$  incidence, all average NF values were significantly below 1.0, as shown in Figure

Table 1. Mean and Standard Deviation of Neighbor Factor

Neighboring	0°		45°		90°	
	Mean NF	$\sigma$	Mean NF	$\sigma$	Mean NF	$\sigma$
V1D1	1.187	0.134	0.845	0.084	0.099	0.108
V1D2	1.055	0.143	0.998	0.090	0.169	0.122
V1D3	1.151	0.142	0.983	0.097	0.430	0.132
V1D4	1.150	0.132	0.999	0.089	0.431	0.114

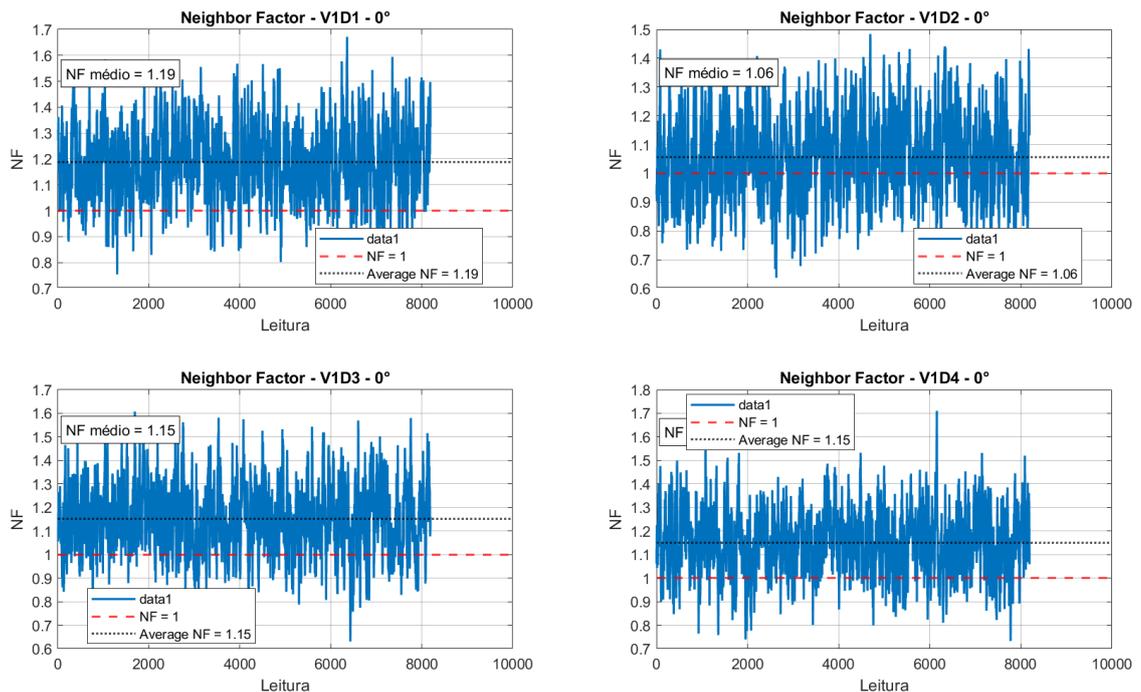


Figure 4. Mean and Standard Deviation of Neighbor Factor - 0°

6, indicating a substantial reduction in drag force. Case V1D1 recorded the greatest reduction, with an average NF of 0.099 and a standard deviation of 0.108, evidencing a strong aerodynamic blockage effect. Cases V1D3 and V1D4 showed similar values (0.430 and 0.431), whereas V1D2 presented an even more pronounced reduction (0.169), confirming that lateral proximity of neighboring buildings can drastically decrease aerodynamic loads for this wind orientation.

## 5 Conclusions

For the wind direction of 0°, all configurations with neighboring buildings exhibited Neighborhood Factor (NF) values greater than 1.0, indicating an increase in drag force. The V1D1 case showed the highest impact, with an average NF of 1.187 and a standard deviation of 0.134, suggesting a strong aerodynamic influence from the neighboring building positioned at a distance of 1.0 H. The V1D3 and V1D4 configurations presented similar results, around 1.15, while V1D2 showed a more moderate increase with an average NF of 1.055. In contrast, for the 45° wind direction, the results were more heterogeneous: V1D1 had an NF below 1.0 (0.845), indicating a drag reduction likely due to aerodynamic shielding effects, whereas V1D2, V1D3, and V1D4 exhibited values close to 1.0, with small positive or negative deviations. The standard deviations for this direction remained around 0.09,

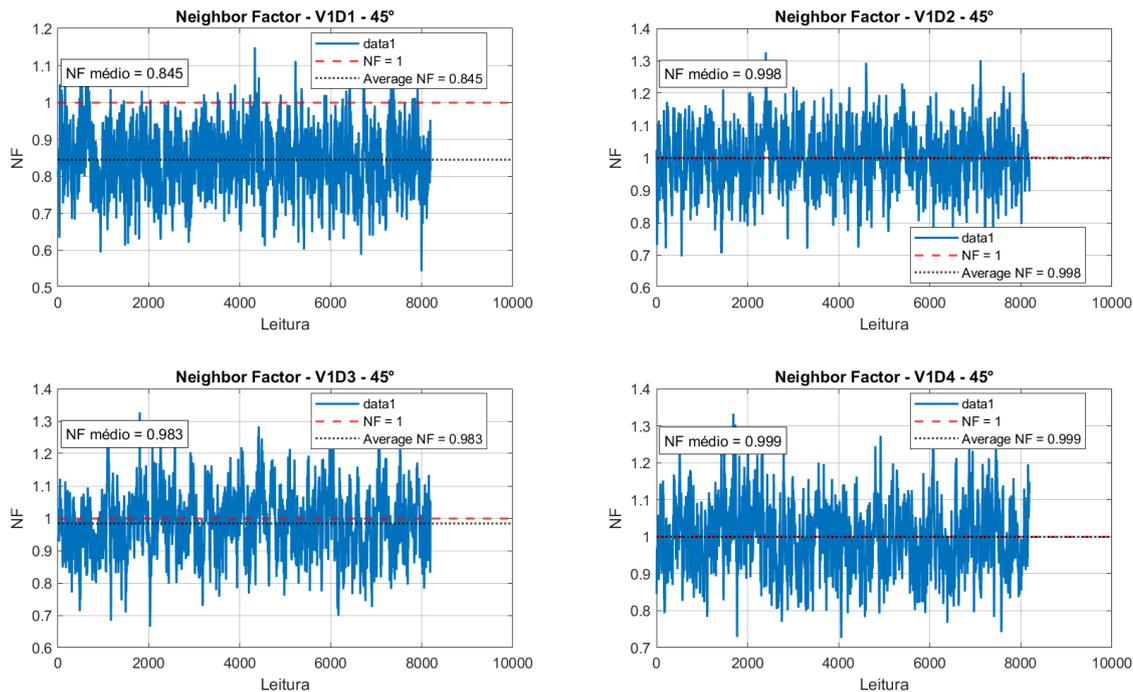


Figure 5. Mean and Standard Deviation of Neighbor Factor - 45°

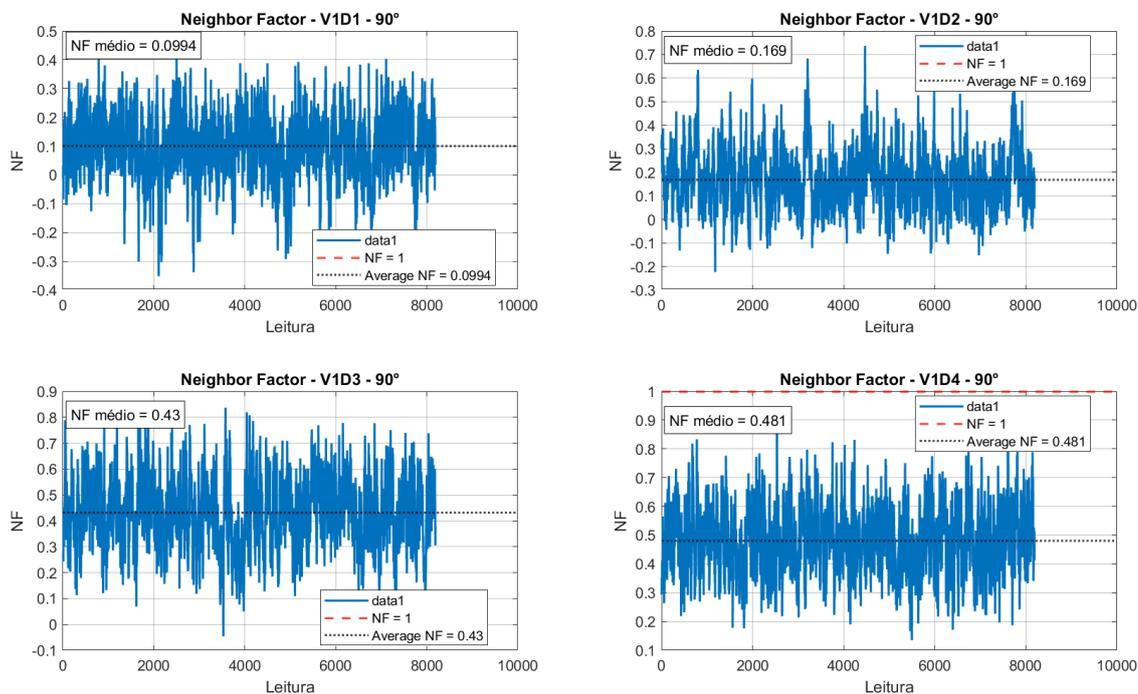


Figure 6. Mean and Standard Deviation of Neighbor Factor - 90°

indicating relatively stable responses.

For the 90° wind direction, all NF averages were significantly below 1.0, evidencing substantial drag force reduction. VID1 registered the most pronounced decrease, with an average NF of 0.099 and a standard deviation of 0.108, highlighting a strong aerodynamic blocking effect. VID3 and VID4 presented similar values (0.430 and 0.431), while VID2 showed an even greater reduction (0.169). Overall, the results confirm that the aerodynamic influence of neighboring buildings can either amplify or significantly mitigate wind loads, depending on their position relative to the studied building and the wind direction.

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