# Numerical simulation in the wind action analyses in logistic sheds with a bridge vent

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*Abstract:* Using *Ansys Fluid Flow* software, a numerical investigation was to study the wind distribution around logistic sheds with a bridge vent. Then, were considered several wind directions - direct approaching, oblique, oblique opposing, lateral, and opposing - and neighborhood conditions. The *Shear Stress Transport* turbulence model and rectangular mesh were employed. The application validation of the CFD technique occurred in the logistic shed without a bridge vent, and the results showed good concordance with the literature. Results analyzed areas characterized by suction and overpressure, as well as the attachment points and the recirculation zones in the flow visualization.

*Key-Words:* Wind action, *Ansys*, logistic shed, bridge vent, pressure coefficients.

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## 1 Introduction

The ridge vent is a metal structure installed on the ridge of the roof widely used in various buildings such as warehouses, factories, stadiums, exhibition halls, and greenhouses [1]. Usually is employed for thermal comfort and natural lighting, besides being a sustainable and economically viable option.

Due to the wind action, the ridge vents cause the *stack* and *Venturi effects*. In the first case, the higher internal pressure in the upper opening directs the airflow to the outside. Like this, the lower internal pressure in the lower aperture facilitates the entry of outside air, replacing the hot air remaining, originating the so-called stack effect [2].

The *Venturi effect* is the result of the combination of a small inlet with a large outlet, producing a concentrated air movement and higher speed, limited to a small section of the environment [3].

In addition to natural lighting and thermal comfort, several authors indicate the ridge vents in the building as safety openings [4]. In general, only its benefits are available in constructive element commercialization. However, because it is an increase in the shape of the upper part of the structure, some harmful aggravating factors may occur. One is a considerable increase of suctions in extensive roof areas, of the external overpressure load, depending on the proportion, the type of lantern, and, likewise, the wind incidence [5]. In the literature, ridge vent use is an element to favor natural ventilation [1] or specific cases, such as vegetation houses [6]; [7]; [8]. Thus, given the scarcity, the pressures on the external surface of the roof with the presence of ridge vents are necessary [5].

In this paper, the objective is to investigate the influence of the ridge vents associated with the neighborhood and the different wind incidence directions in the numerical calculation of the pressure coefficients due to the wind action on the buildings with gable roofs located in industrial and logistics condominiums.

## 2 Methodology

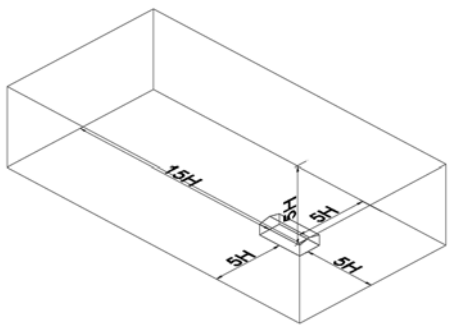
In this work were done meshes and post-processing with the *Ansys Workbench* software. For geometry modeling, *Autodesk AutoCAD* software.

According to [9] was used a control volume composed of the structure to be analyzed, surrounded by the control volume, whose dimensions depend on the height H of the building, with a distance of 5H and 15H between the entrance and the exit and the building, respectively; and 6H between the height of the volume (Fig. 1a).

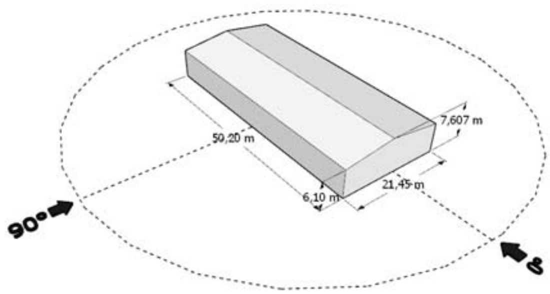
For the CFD technique validation, according to [10], the model adopted is shown in Fig. 1b. In particular, the ridge vent dimensions are a width of 1 m and a height of 0.634 m, while its inclination is 8º.

For the other applications, considering diverse neighborhood conditions, namely the number and geometric configuration of buildings on the ground, in conjunction with the different angles of wind incidence, the geometrical characteristics of the industrial shed are summarized in Fig. 1 (c-f). To study the effects of building configurations and incident wind angles on airflow patterns around the building were considered the effects of direct approaching (0º), wind oblique (45º), oblique opposing (135º), lateral (90º), and opposing (180º) wind directions.

The *Ansys Fluid Flow* software, and the *Shear Stress Transport* turbulence model, were adopted for simulations. Table 1 depicts the boundary condition and non-dimensional parameter details.




(a)

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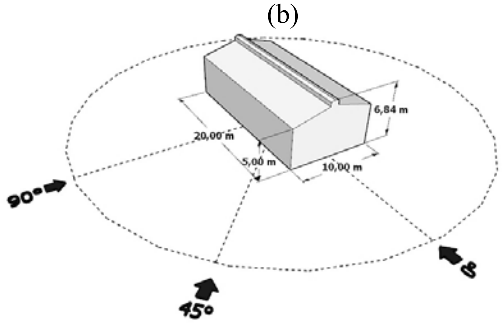
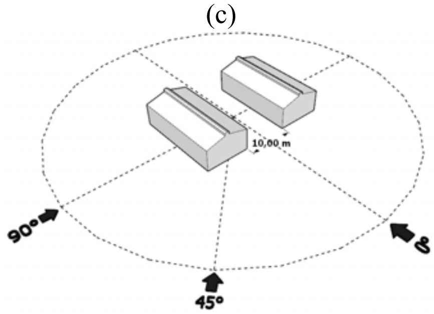



(c)

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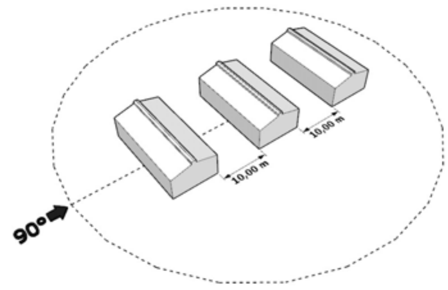


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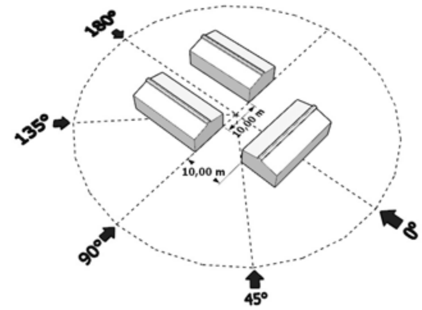



(f)

Fig. 1 (a) Control volume and (b-f) geometry and different angles of incidence of the wind.

Table 1. Boundary conditions and parameters.

| Condition | Parameters |
|---|---|
| Method of mesh | Tetrahedron (*Application 1*) |
| | Rectangular (*Applications 2,3 and 4*) |
| Reference pressure | 101325 [Pa] |
| Air temperature | 25º [C] |
| Specific mass | 1.185 kg/m³ |
| Inlet | 35 [m/s] |
| Relative pressure of outlet | 0 [Pa] |
| Roughness | 0,0025 [m] |
| Turbulence model | *Shear Stress Transport* |

## 3 Numerical applications

**Application 1 (*Validation*):** Here, for two wind directions (0° and 90°), the *Cpe* results on the buildings with gable roofs were calculated and compared with [10]. Figure 2 shows the positions of the external pressure coefficients in the structure, and Table 2 presents the values obtained for the external pressure coefficients.

Then, the *T-test* was used to determine significant differences between the present work results and [10], considering a null hypothesis that the means are not different. Thus, for wind at 0°, because of a one-tailed distribution, $p$-value=0.50 was obtained for a critical $t$=1.78. As 0.50<1.78, it was possible to conclude that the difference between the mean values of *Cpe* is insignificant. Likewise, for wind at 90°, $p$-value=0.45 was obtained for a critical $t$=1.78. As 0.45<1.78, also the difference is despicable.

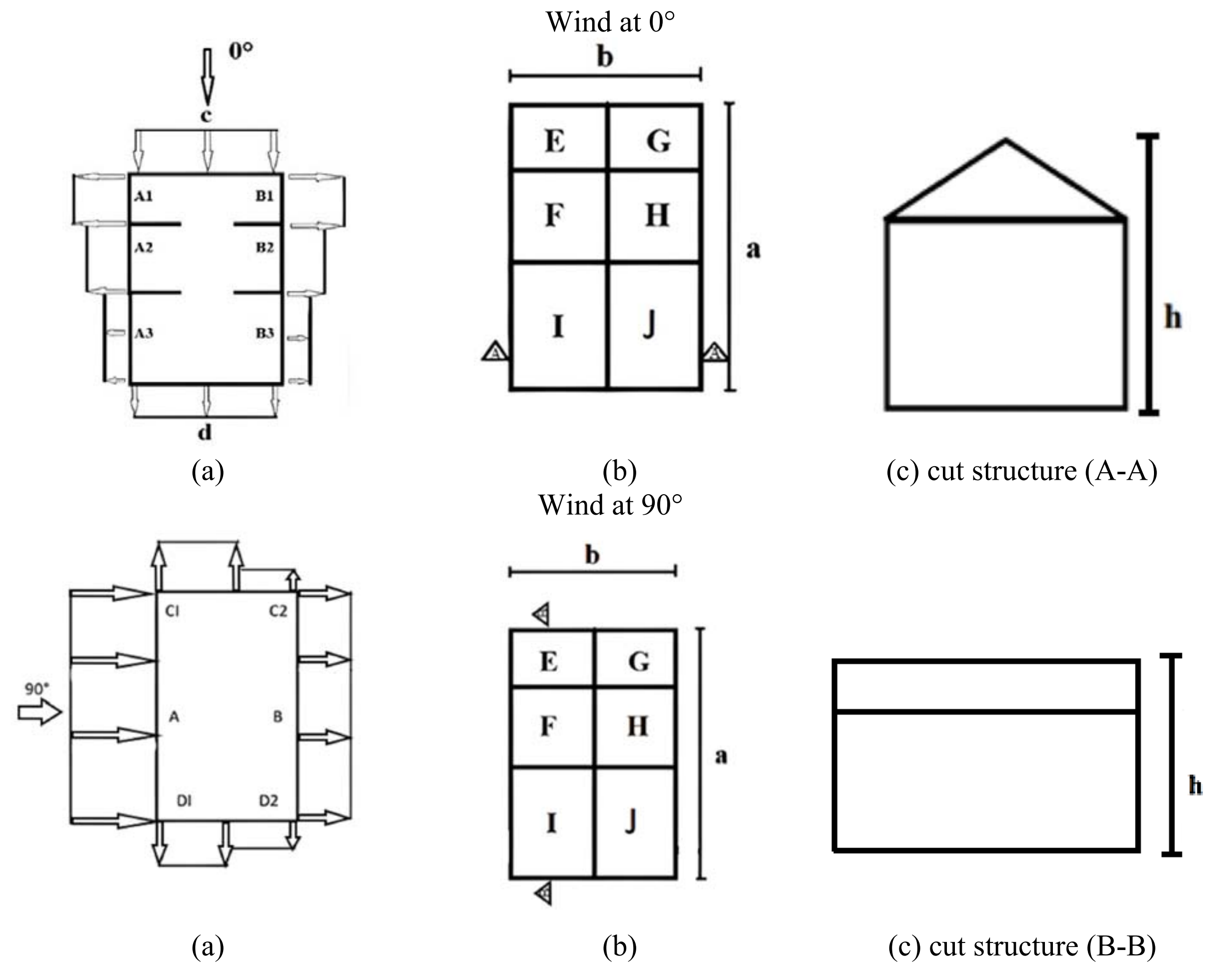



Fig. 2 Positioning the *Cpe* and dimensions of edification with gable roof for the wind at 0° and 90°: (a) location of the walls coefficients; (b) of the roof, and (c) cut structure.

Table 2. *Cpe* for the wind at 0° and 90° in the building.

| | | A1-B1 | A2-B2 | A3-B3 | C | D | EG | FH | IJ |
|---|---|---|---|---|---|---|---|---|---|
| Wind at 0° | Present work | -0,7 | -0,2 | -0,2 | 0,7 | -0,2 | -0,7 | -0,2 | -0,2 |
| | [10] | -0,7 | -0,3 | -0,2 | 0,7 | -0,2 | -0,7 | -0,2 | -0,1 |
| | | C1-D1 | C2-D2 | A | B | EG | FH | IJ | |
| Wind at 90° | Present work | -0,7 | -0,3 | 0,7 | -0,1 | -0,5 | -0,7 | -0,5 | |
| | [10] | -0,7 | -0,3 | 0,7 | -0,2 | -0,5 | -0,6 | -0,5 | |

**Application 2** ***(isolated logistic shed with and without ridge vent)***

**Case 1 (wind at 0°):** With the wind blowing perpendicularly to the smaller façade, the external pressure coefficient values for the sheds with and without a ridge vent showed similarity. A decrease in overpressure occurred in the shed with ridge vent (0.012 Pa, approximately), and, on the other hand, an increase concerning the negative pressure of 0.004 Pa. Also, in the shed with the ridge vent, there was an increase in the flow velocity of 1.374 m/s (Fig. 3a-b).

**Case 2 (wind at 45°):** The oblique incidence of wind on the roof caused intense suction peaks. In general, these suction tips reach the highest values in models with a rectangular plan in windward water with θ = 10° and in leeward water with θ = 15° [5]. The pressure coefficients were distributed uniformly in the logistic shed without a ridge vent. Furthermore, these pressures were less intense when compared to the logistic shed with a ridge vent. In the logistic shed with a ridge vent, generally, there was a significant decrease in the suction tips in windward water (Fig. 3a-b).

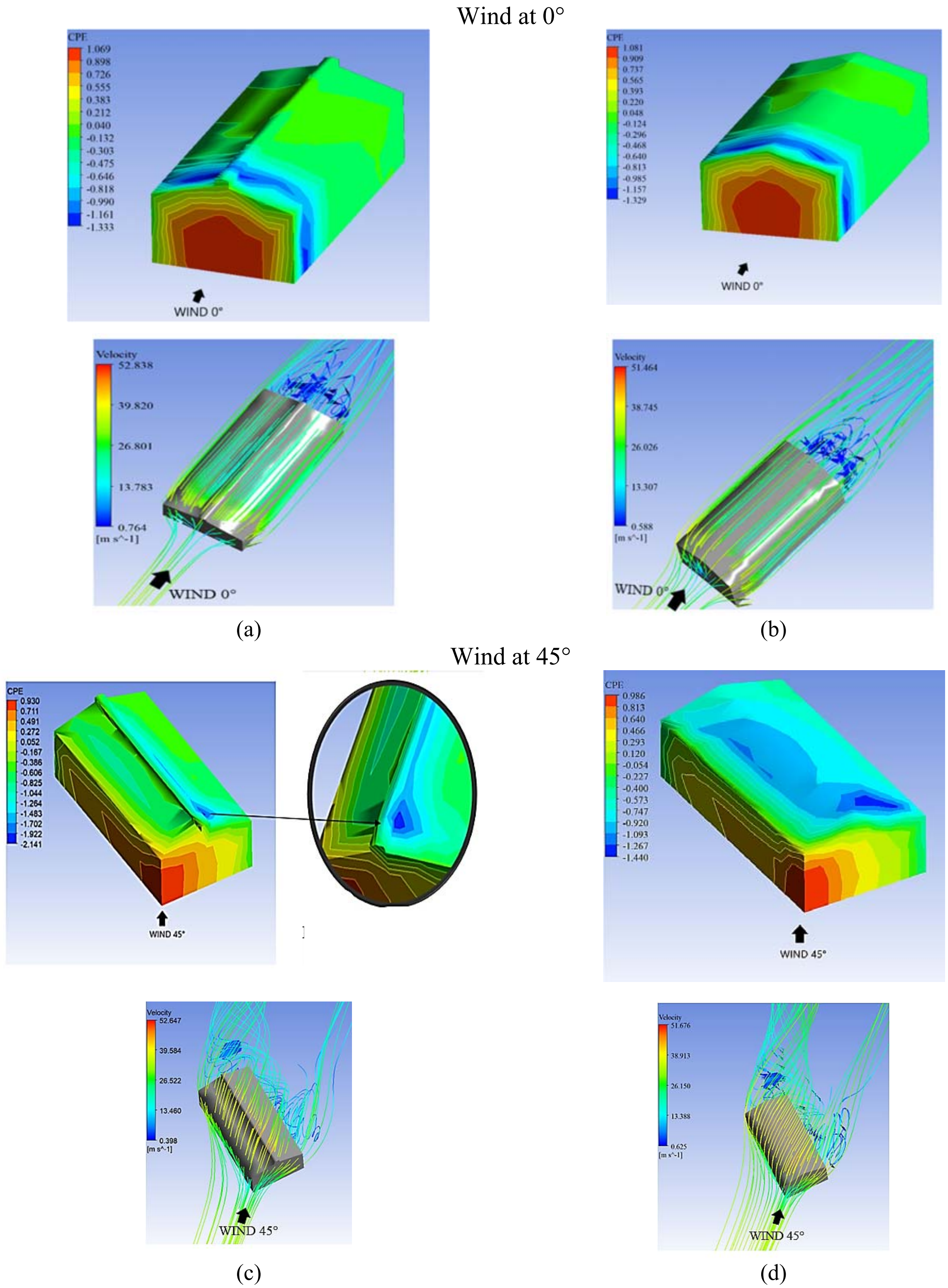



Fig. 3 Top view for the *Cpe* contour and streamlines for isolated logistic sheds (a), (c) with and (b), (d) without ridge vents with wind at 0° and 45º, respectively.

**Case 3 (wind at 90°):** In this case, was observed a reduction in negative $Cpe_{max}$ in the building with a ridge vent. In addition, the values of the windward roof suction tips were significantly lower, showing a difference, in modulus, of 6.16 Pa. This fact is in line with [5]: the suction tips on the main cover decrease with a ridge vent (Fig. 4a-b).

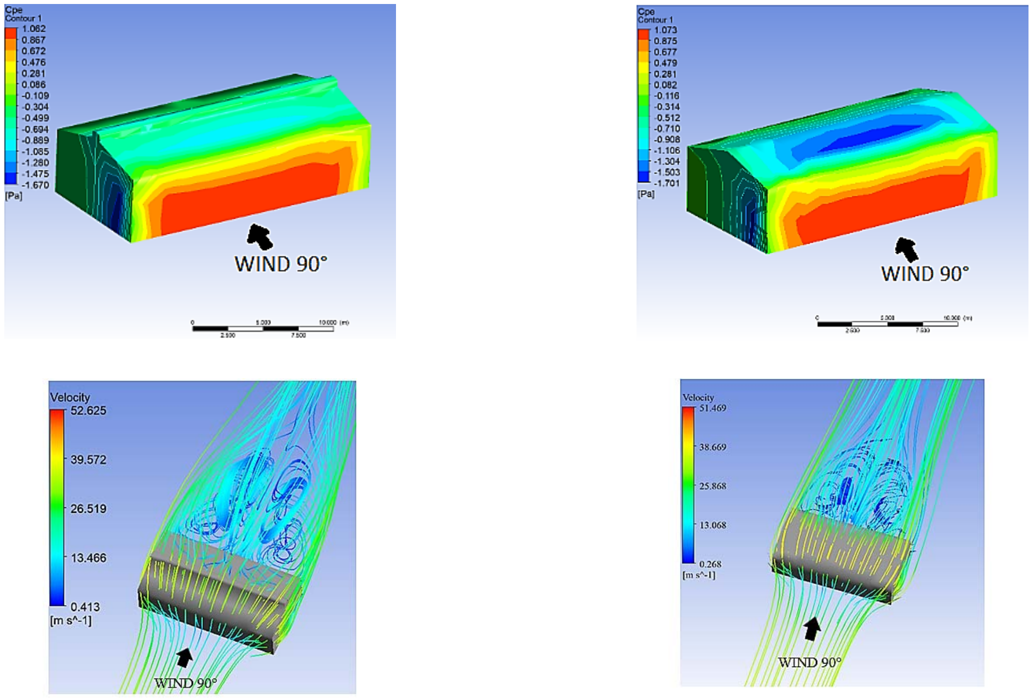



Fig. 4 Top view for the *Cpe* contour and streamlines for isolated logistic sheds (a) with and (b) without ridge vents with wind at 90°.

**Application 3** ***(Side-by-side logistics shed with and without ridge vent)***

**Case 1 (wind at 0°):** In side-by-side buildings causes interference of flow in favour of upstream obstacles or due to the proximity of both. The side-by-side analysis of the sheds with the wind at 0° resulted in values similar to the external pressure coefficients obtained separately. Thus, the flow interference in favour of side-by-side buildings is of small magnitude, as shown in the pressure coefficients (Fig. 5).

**Case 2 (wind at 45°):** Under the oblique incidence of wind, violent local actions can occur with the formation of vortices causing high suction values. These operate in small areas close to edges, corners of walls, and roofs [5]. In both situations analyzed, there was the formation of top vortices at the corners of the building (Fig. 5). In addition, the neighborhood effect decreased the *Cpe* values of the more rear sheds. The suction zones extended along the entire length of the roof of the logistics shed without a ridge vent. The closed ridge vent significantly influenced the mean pressure distribution in the coverage. However, a considerable increase in suctions on the ridge vent cover can be noticed [5] (Fig. 5).

**Case 3 (wind at 90°):** Due to the shielding effects of surrounding buildings, wind loads on enclosed buildings present different flows from isolated structures [11]. In the wind analysis at 90°, both buildings - with and without ridge vents - showed interference from the flow in the wake. In this way, there was a decrease in peak wind loads of lesser intensity than those in the isolated structure without surrounding buildings. In both cases, the more windward sheds minimized the violent actions of the wind, reducing the pressure coefficients of the more leeward building (Fig. 5). However, for the building with a ridge vent, the formation of spiral vortices occurred in the leeward of the building, boosting the small suction zones in this region (Fig. 6).

To clarify the shielding effect on leeward buildings, in the following case, a third building was considered side by side and with the wind at 90º.

**Case 4 (there edifications with the wind at 90°):** The flow incident laterally in the logistic shed with a ridge vent causes a reduction of suction in the principal and ridge vent coverages [5]. In the roof of the logistic shed with a ridge vent was possible to notice a reduction of the negative *Cpe* (Fig. 6). However, in the logistic shed without a ridge vent, the negative values of *Cpe* were more intense, and in the main roof, a larger suction region was noted (Fig. 7).

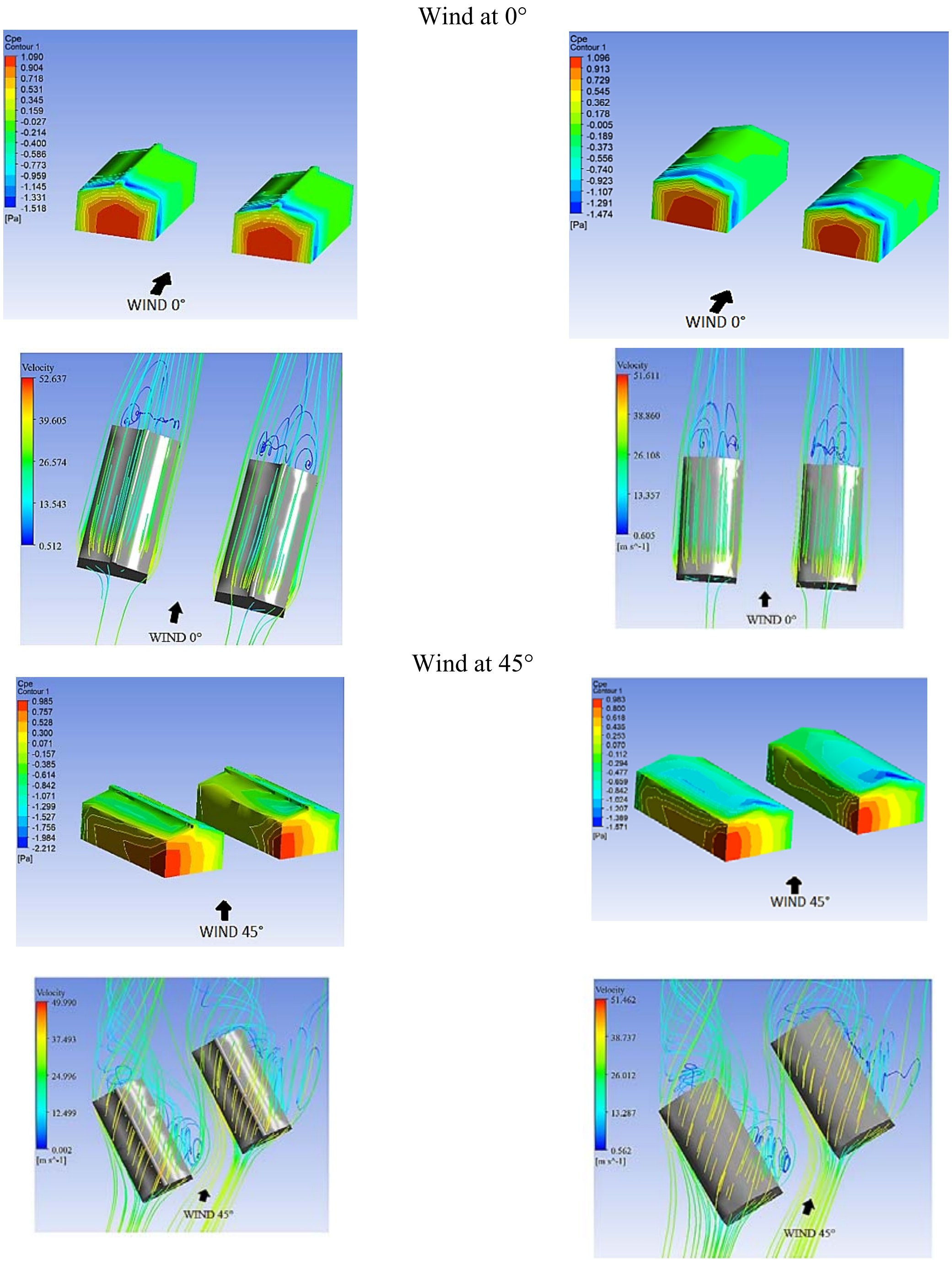


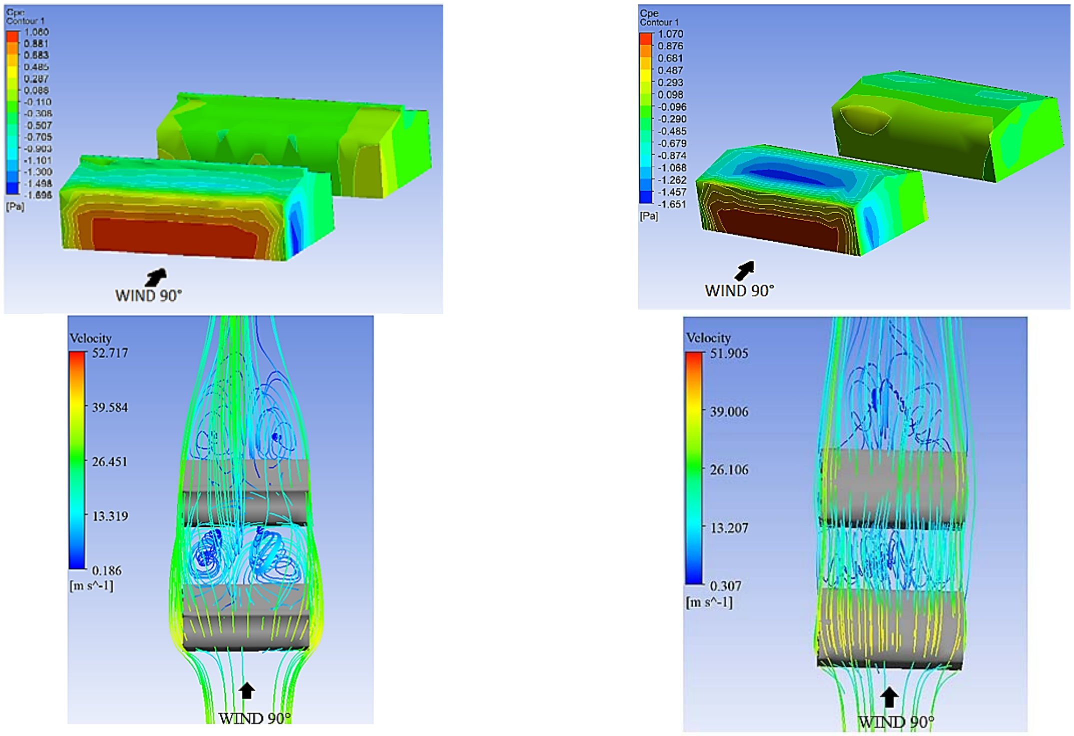

Fig. 5 Top view for the *Cpe* contour for side-by-side logistics shed (a) with and (b) without ridge vents.

Between the logistic shed with a ridge vent formed conical vortices and suction tips. In addition, this geometric arrangement generated an increase of 4,583 in the flow velocity in the logistic shed with a ridge vent compared to the logistic shed without a ridge vent. Consequently, the logistic shed with a ridge vent endangered the neighboring buildings, causing the compromise of the metallic structure between the buildings. On the other hand, the logistic shed without a ridge vent plus a leeward had a lower performance in the principal roof protection (Fig. 7).

**Application 4 *(Three logistics sheds with and without ridge vent)***

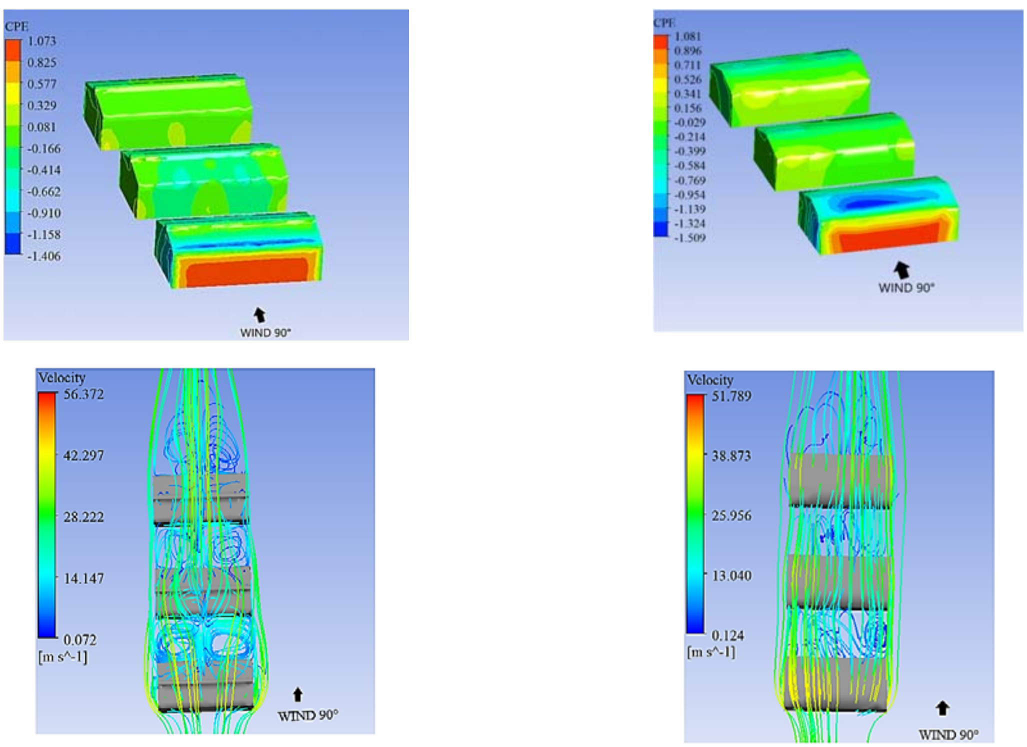
**Case 1 (wind at 0°):** The shielding effect, in this case, occurred on the most windward building. Between the buildings, there was an increase in the flow velocity due to the Venturi effect (Fig. 8).

Wind at 90°




(a) (b)

Fig. 6 Top view for the *Cpe* contour for side-by-side logistics shed (a) with and (b) without ridge vents.




(a) (b)

Fig. 7 Top view for the *Cpe* contour for three edifications side-by-side logistics shed (a) with and (b) without ridge vents with wind at 90°.

Also, the decrease in wind speed in the logistics shed without a ridge vent, while the logistics shed with ridge vents showed higher speed peaks (Fig. 8).

**Case 2 (wind at 45°):** Near the upwind edges of flat rooftops occurs extremely suctions for oblique wind directions (~ = 45°). This phenomenon results from conical vortices that spring from the edges of the rooftops under these conditions (Fig. 9), and they are relevant to wind damage to the roofing system or roof cladding [12]; [13].

Essentially, this phenomenon is similar to providing some 50% of the lift force to delta-wing aircraft. Therefore, conical vortices are also known as *delta-wing* vortices.

Also, due to the disposition of the building more to the windward side, the lines of air current formed dynamic effects generating a region of turbulence in its wake to the leeward side. In the coverage of the logistics shed with a ridge vent, the negative pressure coefficient was higher in the leeward extension of the ridge vent. However, the suction *Cpe* was more significant across the total length of coverage in the logistics shed without a ridge vent. Also, vortices were more intense in the logistics shed without a ridge vent (Fig. 9). The closed ridge vent may have contributed to the wind force reduction on the main roof of the building [5].

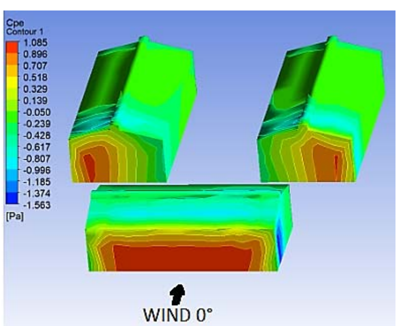
**Case 3 (wind at 90°):** Here (Fig. 8), the logistics shed with and without ridge vent side by side showed behavior similar to Case 3 of Application 3 (Fig. 7). In the lateral shed logistics, with and without a ridge vent, which did not suffer the shielding effect, the velocity reached identical magnitudes of Case 3 of Application 2 (Fig. 6).

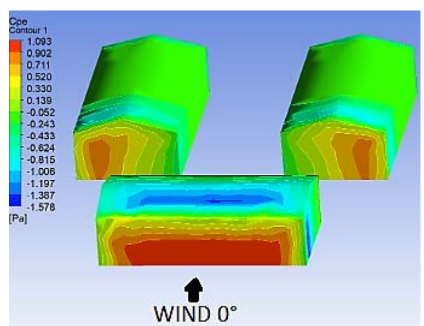
**Case 4 (wind at 135°):** In this case, the geometric configuration (Fig. 8) favored that the flow, when encountering an obstacle, could move laterally along the contour. It was also possible to notice the shielding effect caused by the logistic shed further windward. Hence, in the leeward of this building, there was a funneling of the flow.

Although these effects occurred in both houses, the suction regions occurred in different areas: along the leeward side of the logistic shed with a ridge vent and on the main roof of the other logistic shed.

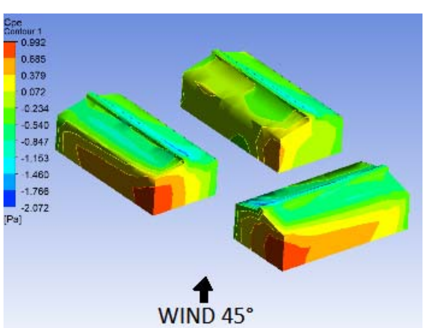
**Case 5 (wind at 180°):** Here, there was an increase in wind speed on the facing walls of the buildings with the flow funneling. Building area density, relative height, and arrangement patterns of surrounding buildings are relevant factors in shielding. When the density of the building area increases, the absolute values of the mean negative wind pressure coefficients gradually decrease. In this way, the density of buildings is favorable in reducing negative *Cpe* and variations in wind loads. The two buildings added to windward (Fig 8) shielded a portion of the runoff. As a result, there was a decrease in the overpressure *Cpe* on the face perpendicular to the wind incidence and the smoothing of the suction tips on the main roof.

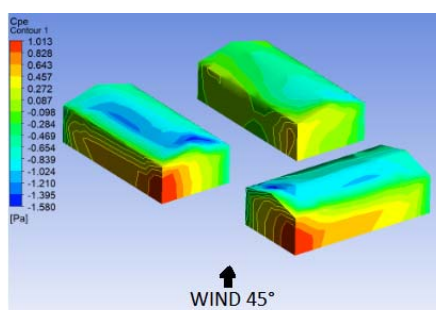
Wind at 0°




Wind at 45°




Wind at 90°

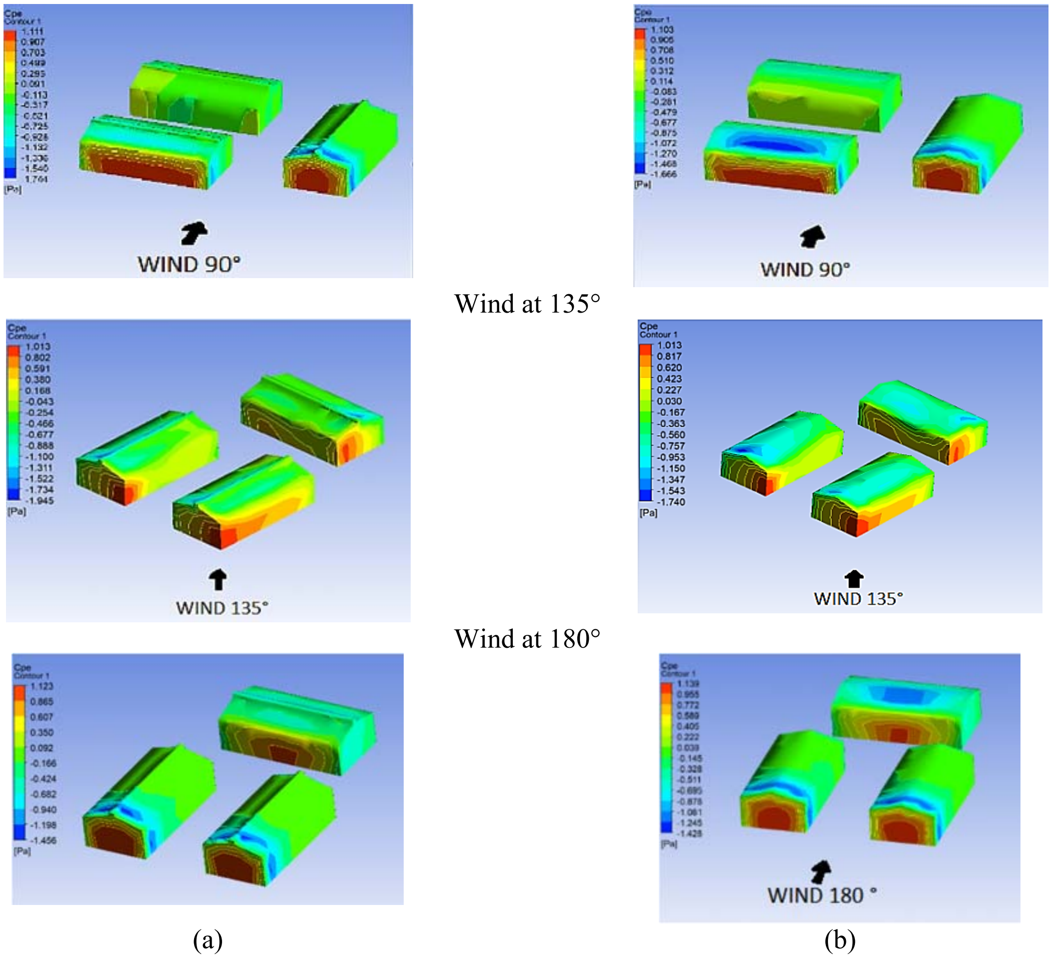



Fig. 8 Top view for the *Cpe* contour for three side-by-side logistic sheds (a) with and (b) without a ridge vents.

## 4 Conclusions

This paper used computational studies in the wind action analyses in logistic sheds with a bridge vent. The numerical simulations were carried out on significant regions of the roof using *Ansys Workbench* software.

For validation methodology, according to [10], it was considered a structure without a ridge vent and two wind directions (0° and 90°). The T-test was used to determine significant differences between *Cpe* of the present work results and [10] showed the difference was despicable.

The *Cpe* values for the isolated logistic shed with and without a ridge wind were similar to the wind blowing at 0° on the smaller facade. In this situation, there was a smaller decrease in overpressure in the logistics shed with a ridge vent and an increase concerning suction. With the wind at 45°, there was a significant decrease in the windward suction tips in the logistics shed with a ridge vent, whereas, in the leeward direction without a ridge vent, there was an increase in suction. Finally, with the wind at 90°, in the logistic shed with a ridge vent, there was a significant decrease in the suction tips of the main roof. With the wind at 45°, the corners of the building formed top vortices, and for the sheds further back, the neighborhood effect decreased the *Cpe* values.

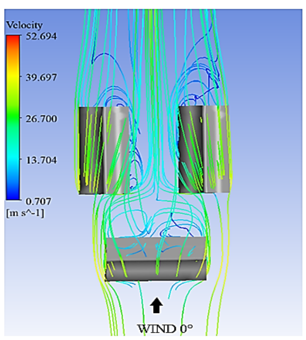
In the side-by-side logistic shed with a closed ridge vent, there was a significant influence on the distribution of average pressures on the roof cover, in addition to the largest suctions on the ridge vent cover. With the wind falling at 90°, both buildings suffered interference from the flow in the wake, resulting in a decrease in peak wind loads. A third building was considered side by side and with the wind at 90º to clarify the shielding effect. Conical vortices formation and suction occurred between the logistic shed with a ridge vent. Also, this geometric arrangement generated an increase of 4,583 in the flow velocity in the logistic shed with a ridge vent compared to the logistic shed without a ridge vent.

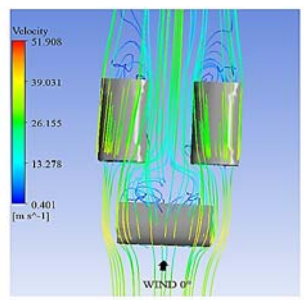
The wind perpendicular to the three sheds caused a shielding effect on the building further to the windward side and increased the speed between the buildings. While the logistic shed without a ridge vent decreased the wind speed, the highest peaks occurred in the one with a ridge vent. Obliquely, in the coverage of the logistic shed with a ridge vent, the suction was higher in the leeward extension of the ridge vent, and in the total length of coverage in the logistic shed without a ridge vent, the suction was more significant. Lateral on the winder façade, the windward logistic shed minimized the violent actions of the wind, generating a lower *Cpe* in the leeward sheds. However, this geometric arrangement favored the formation of conical vortices and suction spikes. In addition, the flow velocity increased between the buildings, with greater intensity in the one with a ridge vent. In this sense, the logistic sheds generated identical results with the wind at 135º, distinguished by the focus on suction pressures. However, the suction regions occurred in different areas: along the leeward side of the logistic shed with a ridge vent and on the main roof of the other logistic shed. The oblique flow opposite the sheds caused intense suction spikes. For the logistic shed without a ridge vent, the roof pressure coefficients were uniformly distributed and were less accentuated when compared to those with a ridge vent. With the wind opposite the building, the two buildings on the windward side shielded the flow of the logistic shed further down the airflow, causing a decrease in overpressure on the face perpendicular to the incidence of the wind, as well as the smoothing of the suction tips on the roof main.

These results provide information about directing structural reinforcements at the weakest points of the analyzed geometries. Moreover, the role of the closed ridge vents in the coverage of the building, in addition to joint analysis of neighborhood conditions and the wind incidence directions.

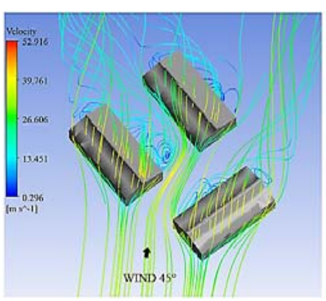
For future works, other approaches may be implemented using different geometric configurations, likewise more wind incidence directions, and the influence of the topographic conditions of the terrain. Additionally, also can be determined the internal pressure coefficients and the wind loads in the critical regions of the structure.

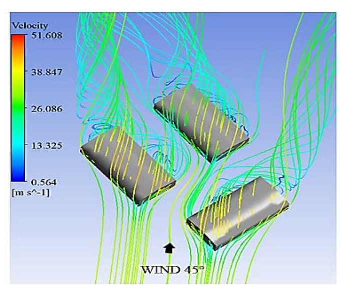
Wind at 0°



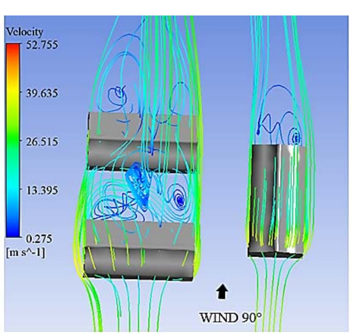



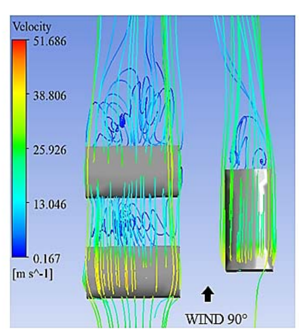

Wind at 45°




Wind at 90°



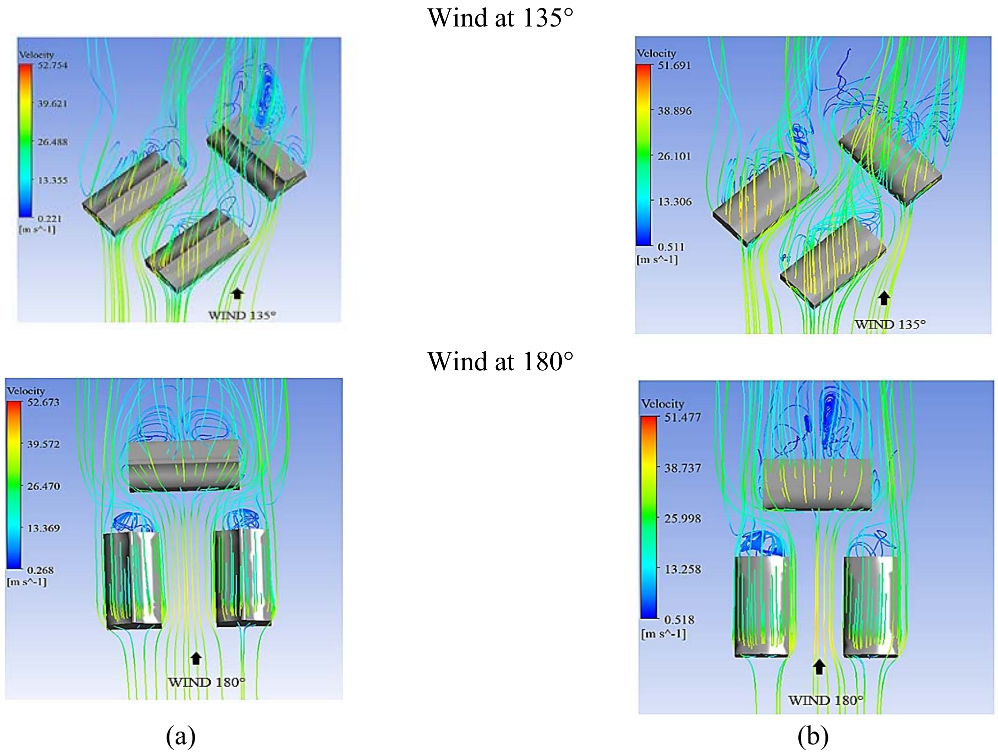



Fig. 9 Streamlines for the *Cpe* contour for three side-by-side logistic sheds (a) with and (b) without ridge vents.

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## Contribution of individual authors to the creation of a scientific article

Luan Mendes was responsible for the methodology and carried out the simulation and writing the results. Marco Campos carried out the conceptualisation; review and editing.

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**Conflict of Interest**

The authors have no conflicts of interest to declare that are relevant to the content of this article.