Numerical investigation the influence of solid and porous parapets on wind loads on low-rise buildings

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Abstract. Several studies have shown that parapets mitigate the damage and economic losses due to wind action on buildings. Therefore, in this work, a computational analysis of the influence of different parapet geometries and heights on the wind flow on the roofs of low-rise buildings has been developed using the *Ansys Workbench* software. Solid and porous parapets were considered, and a decrease in the external pressure coefficient with increasing parapet height was observed, as well as a greater efficiency of porous parapets than solid ones.

Keywords: wind action, parapets, *Ansys*.

1 Introduction

The parapets can provide relief to roof systems by resisting wind uplift. However, there is no consensus on their effectiveness because the reduction in the magnitude of wind pressure is directly related to factors such as the height of the parapet, the angle of wind direction, and the shape of the building.

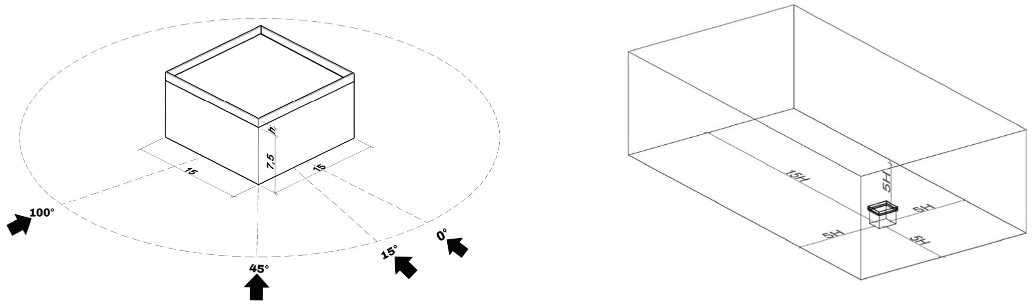
Among the recent studies involving numerical simulation, it is worth highlighting a procedure to optimize the porosity of parapets to improve the aerodynamic behavior of low-rise buildings presented in [1]. Also, *Aly et al.* [2] experimentally investigated the change in flow around a low-rise building with a considerable width-to-height ratio caused by perimeter solid parapets. The authors concluded that the best performance in reducing the average and peak pressures across the roof surface occurred for 14% of the eave's height. The contribution of this work was to simulate the action of wind on roofs with the *Ansys Workbench* software using different ratios between the height of the parapet and the eaves and different parapet geometries.

2 Methodology

In this work, were used for geometries and simulations, the *Autodesk AutoCAD*, and *Ansys Workbench* software, respectively.

The dimensions of the building were 15 m x 15 m x 7.5 m for length (L), width (W), and height (H_e), respectively (Fig. 1a). Furthermore, three different parapet heights (h_p): h_p=0.75 m (h_p/H_e =0.1), h_p=1.00 m (h_p/H_e =0.13), and h_p=1.25 m (h_p/H_e =0.17), all with a width of 0.15 m. Also, four geometries were considered for the parapets: continuous solid, around the entire perimeter of the roof; discontinuous solid, with gaps at the edges of length proportional to h_p; continuous porous, around the perimeter and with holes of 0.5 m in diameter; and discontinuous porous, located in the corners, also with holes 0.5 m in diameter and with a length equal to 10% of the littlest horizontal direction of the building, here being 1.5 m.

The control volume has defined the dimensions according to [3], dependent on the maximum height (H) of the model: 5H for the front and side distance, 6H for the height, and 15H for the distance behind the building to guarantee the development of flow (Fig. 1b). Thus, here we use three values to H: H=8.25 m when h_p/H_e=0.1; H=8.5 m when h_p/H_e=0.13, and finally, H=8.75 m for h_p/H_e=0.17. Table 1 presents the boundary conditions and parameters used in the simulations.



(a) (b)

Figure 1. (a) Geometry and (b) control volume.

Table 1. Boundary conditions and non-dimensional parameters.

Condition	*Parameters*
Method of mesh	Tetrahedron
Reference pressure	101325 [Pa]
Air temperature	25 [°C]
Flow regime	Subsonic
Inlet	$U/U_{\mathrm{ref}}=(z/z_{\mathrm{ref}})^{\alpha}$
U_{ref}	8 [m/s] (*Application 1*) 35 [m/s] (*Applications 2, 3, 4 and 5*)
z_{ref}	10 [m]
α	0.16 (*Application 1*) 0.32 (*Applications 2, 3, 4 and 5*)
Relative pressure of outlet	0 [Pa]
Turbulence Model	RNG k-*Epsilon*
Roughness	0.01 [m]

3 Numerical applications

3.1 Application 1: Validation

The validation of the methodology aims to verify the physical consistency of the obtained data by comparing them with the literature. For this purpose, it was considered a geometry with dimensions like those of [4] with 3.97m in length, 3.22 m in width, and 3.1 m in height. Also, a parapet of 0.5 m in height and the roof were higher than the base, with 4.45 m in length and 3.7 m in width, with the control volume being the same as Fig. 1b, with H=3.6m. Table 2 shows the *Cpe* values of the central area inside the windward parapet for wind incidence angles of 0°, 15°, 45° and 100°, where *Cpe* is the external pressure coefficient. Then, the *F-test* and *Student's t-test* statistical tests determined whether the results obtained had significant differences: the first compared the variances, and since these were supposedly equal, a second test determined whether the differences were insignificant. Considering the *null hypothesis*, *one-tailed distribution*, and using *Microsoft Excel* software obtained a *p-value* = 0.08 and a *critical t-value* = 1.94, and, as 0.08 < 1.94, the difference between the means in the *Cpe* values was insignificant.

Table 2. *Cpe* in the internal central area of the parapet considering wind at 0°, 15°, 45° and 100°.

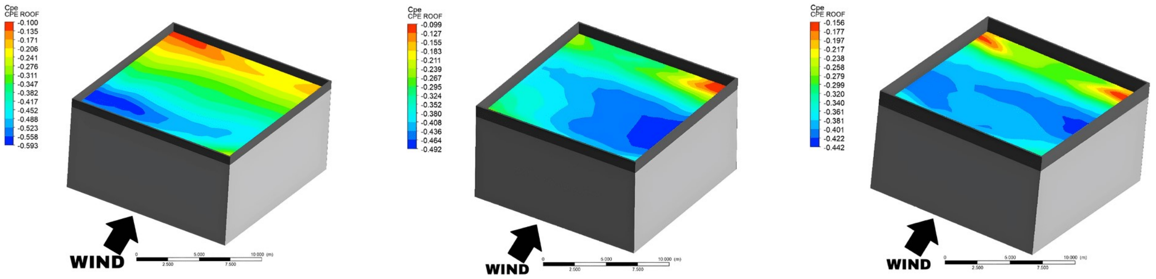
Wind incidence	0°	15°	45°	100°
Bedair and Stathopoulos [4]	-0.59	-0.68	-0.59	-0.41
Present work	-0.48	-0.51	-0.50	-0.20

3.2 Application 2: Solid Continuous Parapet

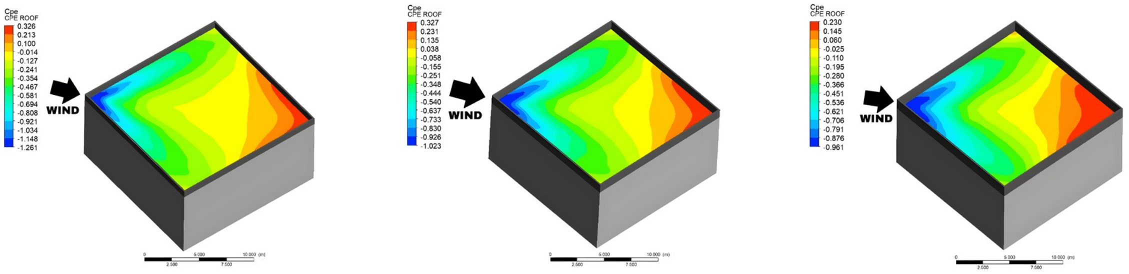
Case 1 (wind at 0°): In the three situations analyzed with the wind at 0°, suction peaks appeared on the windward side of the roof. Considering h_p/H_e=0.1 (Fig. 2a), a decrease of approximately 17% in the suction peak was noted for h_p/H_e=0.13 (Fig. 2b), and of 25% for h_p/H_e=0.17 (Fig. 2c). In general, it was noted that as the h_p/H_e ratio increased, suction peaks decreased due to the change in the height of the parapet.

Case 2 (wind at 45°): Now, for h_p/H_e=0.13 (Fig. 2e), the suction peak values reduced by approximately 18%

compared to h_p/H_e=0.1 (Fig. 2d). As for the ratio h_p/H_e=0.17 (Fig. 2f), the values decreased by approximately 24%. Also, the suction peaks at the windward corners of the roof developed due to the top vortices. It is also possible to observe the lower *Cpe* values at the corners and edges (Fig. 2f) and, consequently, a more uniform pressure distribution.



(a) h_p/H_e= 0.1, wind at 0° (b) h_p/H_e= 0.13, wind at 0° (c) h_p/H_e= 0.17, wind at 0°.



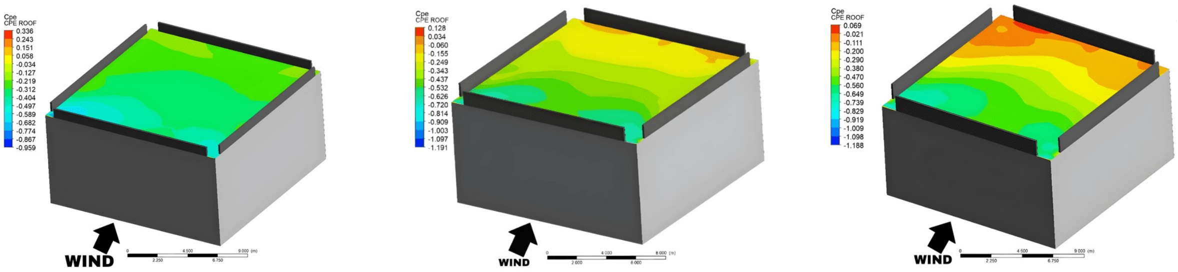
(d) h_p/H_e= 0.1, wind at 45° (e) h_p/H_e= 0.13, wind at 45° (f) h_p/H_e= 0.17, wind at 45°.

Figure 2. *Cpe* on the roof with solid continuous parapet.

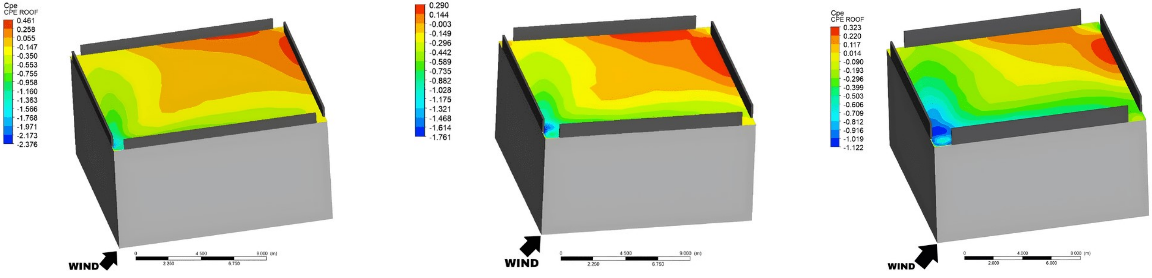
3.3 Application 3: Solid Discontinuous Parapet

Case 1 (wind at 0°): In comparison to *Application 2*, was noted an increase in the suction peak values (Fig. 3). A positive pressure zone was recorded on the leeward side, whereas in a similar case in *Application 2*, only negative values for *Cpe*. Contrary to *Application 2*, as the h_p/H_e ratio increased, the values of the suction peaks did not decrease.

Case 2 (wind at 45°): In this case, were observed intense suction peaks at the corners of one of the parapets near the windward edge of the building (Fig 5). These suction peaks presented higher values compared to those of *Application 2,* of approximately 88% for h_p/H_e=0.1 (Fig. 3d), 72% for h_p/H_e=0.13 (Fig. 3e) and 16% for h_p/H_e=0.17 (Fig. 3f).



(a) h_p/H_e= 0.1, wind at 0° (b) h_p/H_e= 0.13, wind at 0° (c) h_p/H_e= 0.17, wind at 0°.



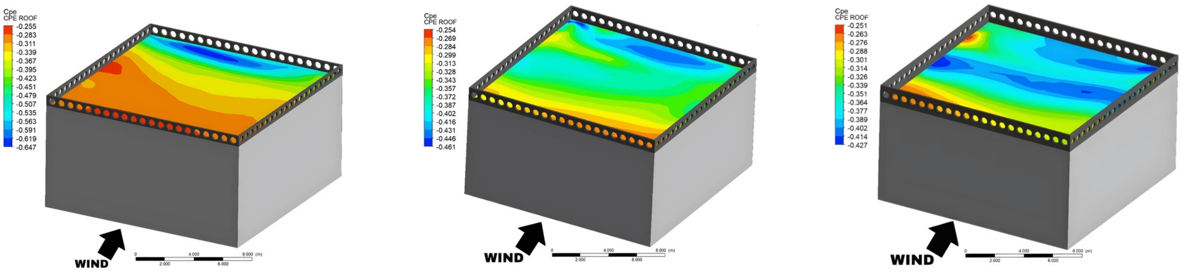
(d) h_p/H_e= 0.1, wind at 45° (e) h_p/H_e= 0.13, wind at 45° (f) h_p/H_e= 0.17, wind at 45°.

Figure 3. *Cpe* on the roof with solid discontinuous parapet.

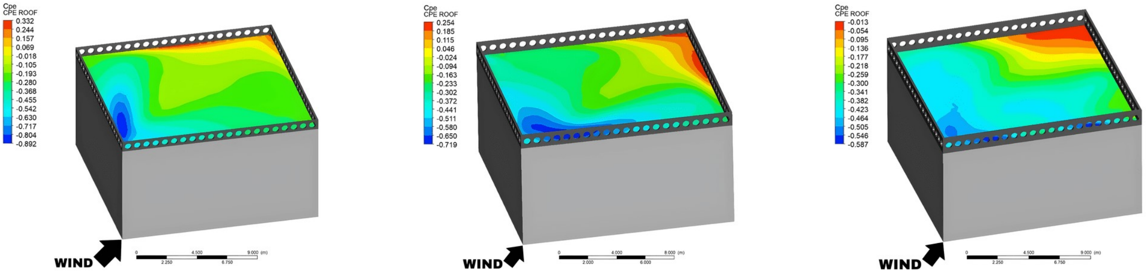
3.4 Application 4: Porous Continuous Parapet

Case 1 (wind at 0°): Here, as in *Application 1*, only negative *Cpe* was recorded on the roof of the building (Fig. 4). The suction peaks concentrated on the most distant face, as in the central region (Fig. 4c).

Case 2 (wind at 45°): In this case, was formed a suction zone in the region of the corners of the buildings. Concerning *Case 2* of *Application 1* were reduced the suction peaks by 29% for h_p/H_e=0.1 (Fig. 4d), 30% for h_p/H_e=0.13 (Fig. 4e), and 39% for h_p/H_e=0.17 (Fig. 4f).



(a) h_p/H_e= 0.1, wind at 0° (b) h_p/H_e= 0.13, wind at 0° (c) h_p/H_e= 0.17, wind at 0°.



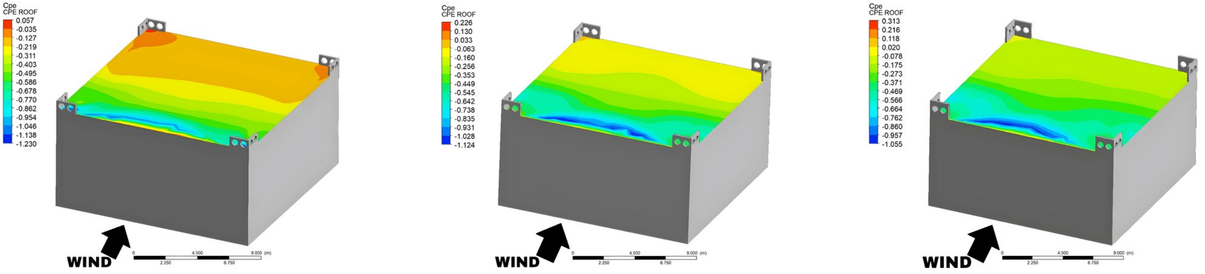
(d) h_p/H_e= 0.1, wind at 45° (e) h_p/H_e= 0.13, wind at 45° (f) h_p/H_e= 0.17, wind at 45°.

Figure 4. *Cpe* on the roof with porous continuous parapet.

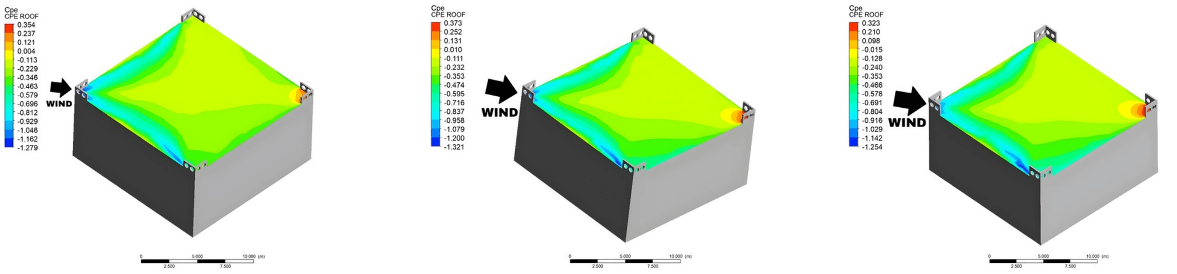
3.5 Application 5: Porous Discontinuous Parapet

Case 1 (wind at 0°): Now, were concentrated the suction peaks on the windward edge of the roof, and similarly to *Case 1* of *Application 3*, it was noted positive pressures. Compared to *Case 1* of *Application 2*, there was an increase in peaks of approximately 107% for h_p/H_e=0.1 (Fig. 5a), 128% for h_p/H_e=0.13 (Fig. 5b) and 138% for h_p/H_e=0.17 (Fig. 5c). As in the previous cases, the increase in the h_p/H_e ratio decreases the suction peaks.

Case 2 (wind at 45°): For 45° wind, as in *Case 2* of *Application 4*, were noted suction peaks beyond the windward corners of the building. Compared with *Case 1* of *Application 2*, there was an increase of approximately 1.4% for h_p/H_e=0.1 (Fig. 5d), 29% for h_p/H_e=0.13 (Fig. 5e), and 30% for h_p/H_e=0.17 (Fig. 5f). Like to *Case 1* of *Application 3*, the increase in the h_p/H_e ratio did not cause a reduction in the peak values.



(a) h_p/H_e= 0.1, wind at 0° (b) h_p/H_e= 0.13, wind at 0° (c) h_p/H_e= 0.17, wind at 0°.



(d) h_p/H_e= 0.1, wind at 45° (e) h_p/H_e= 0.13, wind at 45° (f) h_p/H_e= 0.17, wind at 45°.

Figure 5. *Cpe* on the roof with porous discontinuous parapet.

4 Conclusions

An analysis of the attenuation effect of different parapet geometries and heights on the wind action on the roof of low-rise buildings was developed using *Ansys Workbench* software.

The geometry of [4] was used and *Cpe* values were obtained at an intermediate central point of the parapet considering the wind at 0°, 15°, 45° and 100° to validate the methodology, and the *F* and *T Student* statistical tests were performed and differences between variances were considered insignificant. Thus, considering a continuous solid parapet with the wind at 0°, windward suction peaks occurred for h_p/H_e=0.1, h_p/H_e=0.13, and h_p/H_e=0.17. As the h_p/H_e ratio increased, the suctions decreased by about 17% and 25% for h_p/H_e=0.13 and h_p/H_e=0.17, respectively, compared to h_p/H_e=0.1. Suction peaks were observed at the windward corner due to the top vortices for the 45° wind. With the wind at 0°, the discontinuous solid parapets showed areas of positive pressure, unlike the continuous solid parapets. Therefore, the suction peaks did not decrease with varying h_p/H_e ratio. Continuous porous parapets produced the lowest suction among the situations analyzed. Thus, there was a reduction of about 29% for h_p/H_e=0.1, 30% for h_p/H_e=0.13, and 39% for h_p/H_e=0.17 compared to continuous solid parapets for the 45° wind. Finally, a discontinuous porous parapet was considered with the wind at 0°. Suction peaks were observed on the windward side. The suction peaks decreased as the h_p/H_e ratio increased. However, there was an increase of 107% for h_p/H_e=0.1, 128% for h_p/H_e=0.13 and 138% for h_p/H_e=0.17 compared to the continuous solid parapet. Suction peaks occurred in regions other than the windward corner for the 45° wind. Finally, the variation of h_p/H_e did not reduce the peaks.

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