ARUP

Cox Architecture

Lot 106 Newcastle Airport

Wind shear and turbulence report

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Executive Summary

Arup have been commissioned to provide an experienced-based impact assessment of the proposed Astro Aerolab building on Lot 106 at Newcastle Airport. The development will be located to the south-west of Runway 30. This report follows on from a review of the latest drawings, combined with our experience in wind shear and turbulence studies at airports around the world.

It is important to appreciate the difference between wind shear and mechanical turbulence, and some general discussion is included in Appendix 1. This assessment has used the Australian National Airports Safeguarding Framework (NASF, 2018) Guideline B for building generated wind shear and mechanical turbulence.

The proposed development is located just outside the NASF (2018) Guideline B assessment zone for Runway 30 and therefore does not require any additional analysis. If the Runway 30 threshold were to change move to the north-west, the development would breach the 1:35 slope height assessment zone requiring further additional analysis. The building-wake deficit calculation for the 6 kt cross-flight wind-shear criterion would not be exceeded in accordance with NASF (2018) for any incident wind speed.

The turbulence criterion cannot be assessed with the desktop procedures in the NASF (2018) guideline, and more detailed numerical or physical modelling would be required. The building is well located at over 900 m to the south-west of the runway. The critical operational wind directions would be from the west-south-west, which are infrequent at Williamtown. For winds more to the north-west, aircraft approaching Runway 30 would be above the wake region, and for winds more to the south-west would land on Runway 12. The proposed building would not be expected to increase the risk of turbulence issues compared with the existing natural turbulence.

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Disclaimer

This assessment of the site environmental wind conditions is presented based on engineering judgement. In addition, experience from more detailed simulations have been used to refine recommendations. No detailed simulation, physical or computational study has been made to develop the recommendations presented in this report.

1. Introduction

The primary aim of this section of the report is to determine the influence of the proposed development on the wind characteristics for landing aircraft at Williamtown RAAF airport. This report assesses the structure in accordance with the Australian Guidelines as defined in NASF (2018). Landing aircraft are decelerating and moving slower than departing aircraft, and are more susceptible to changes in the relative wind speed between the aircraft and the wind. Departing aircraft are generally accelerating, and ascend more rapidly than landing aircraft descend, further reducing their susceptance to changes in wind conditions. The point of most interest for aircraft operations is therefore on the immediate approach to the touchdown point and subsequent deceleration along the runway.

The relative location of the proposed development building to relevant runways is shown in Figure 1 including anemometer locations.

Figure 1: Aerial view showing NASF Guideline B and Dutch assessment zones (Google Earth 2021)

There are two mechanisms of concern for aircraft operations: wind shear and turbulence. Wind shear is the difference in mean wind speed between two locations along the flight path, whereas turbulence is a measure of the temporal fluctuations in the wind at the same location. Typically, turbulence is generally significantly worse than wind shear on aircraft operations. A longer discussion is presented in Appendix A.1. Generally, the greatest wind shear generated by a structure is during a cross-wind when the wind is coming directly over the structure perpendicular to the nominated runway. For turbulence, the impact of the structure is greatest directly downwind of the structure.

2. Assessment

The Australian National Airports Safeguarding Advisory Group (NASAG) has released Guideline B for the effect of buildings on wind shear and turbulence for aircraft, NASF (2018). This is based on an extensive study completed by the Dutch combining field studies, wind-tunnel testing, and flight simulator experiments on a range of plane sizes from a Fokker 100 to a Boeing 747 and described in Nieuwpoort (2010). These criteria have been adopted by various airports around the world.

The wind-shear criteria in NASF (2018) are that over a distance of 100 m along the flight path the change in mean wind-speed should be less than 7 knots (3.6 m/s) in the component of wind speed in the along-flight direction, and 6 knots (3.1 m/s) in the cross-flight direction, Figure 2. The turbulence criterion states that the standard deviation of building induced wind speed should be less than 4 knots (2.1 m/s). These criteria do not give an indication of the size of, or energy level associated with the gusts as aircraft would comfortably land in natural turbulence levels in excess of 4 knots (2.1 m/s). A spectral analysis would be required to extract the frequency structure of the gusts from which a measure of the size could be inferred. This is beyond the scope of the current discussion and current research.

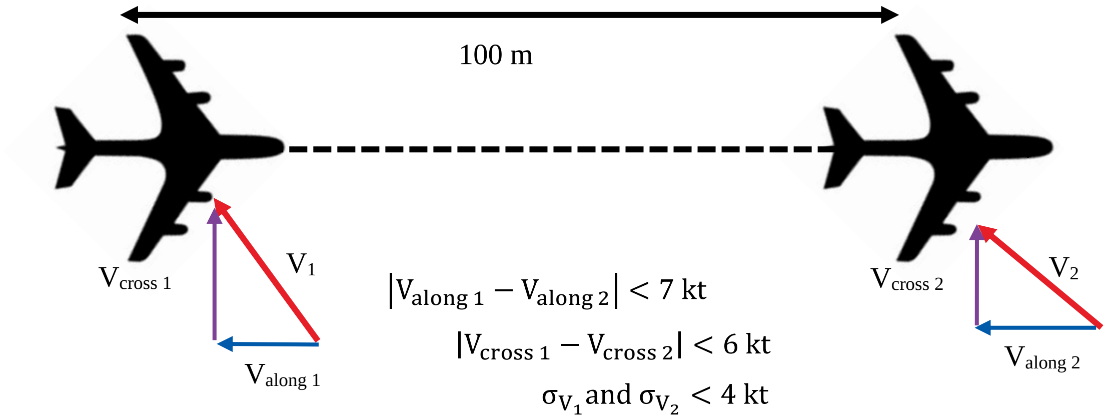

Figure 2: Interpretative sketch of NLR criteria

The National Airports Safeguarding Framework (NASF) Guideline B (NASF 2018) provides guidance on managing the risks posed by building-generated wind shear and turbulence at airports. The NASF assessment methodology is reproduced in Figure 3 where CASA is the Civil Aviation Safety Authority, the government aviation approval body in Australia.

Step 1

Buildings require assessment if they are within the grey assessment zones indicated in Figure 4 relative to the runway threshold. These zones are illustrated in Figure 1, indicating that the proposed development is inside the assessment zone for Runway 12, but outside for Runways 21 and 30.

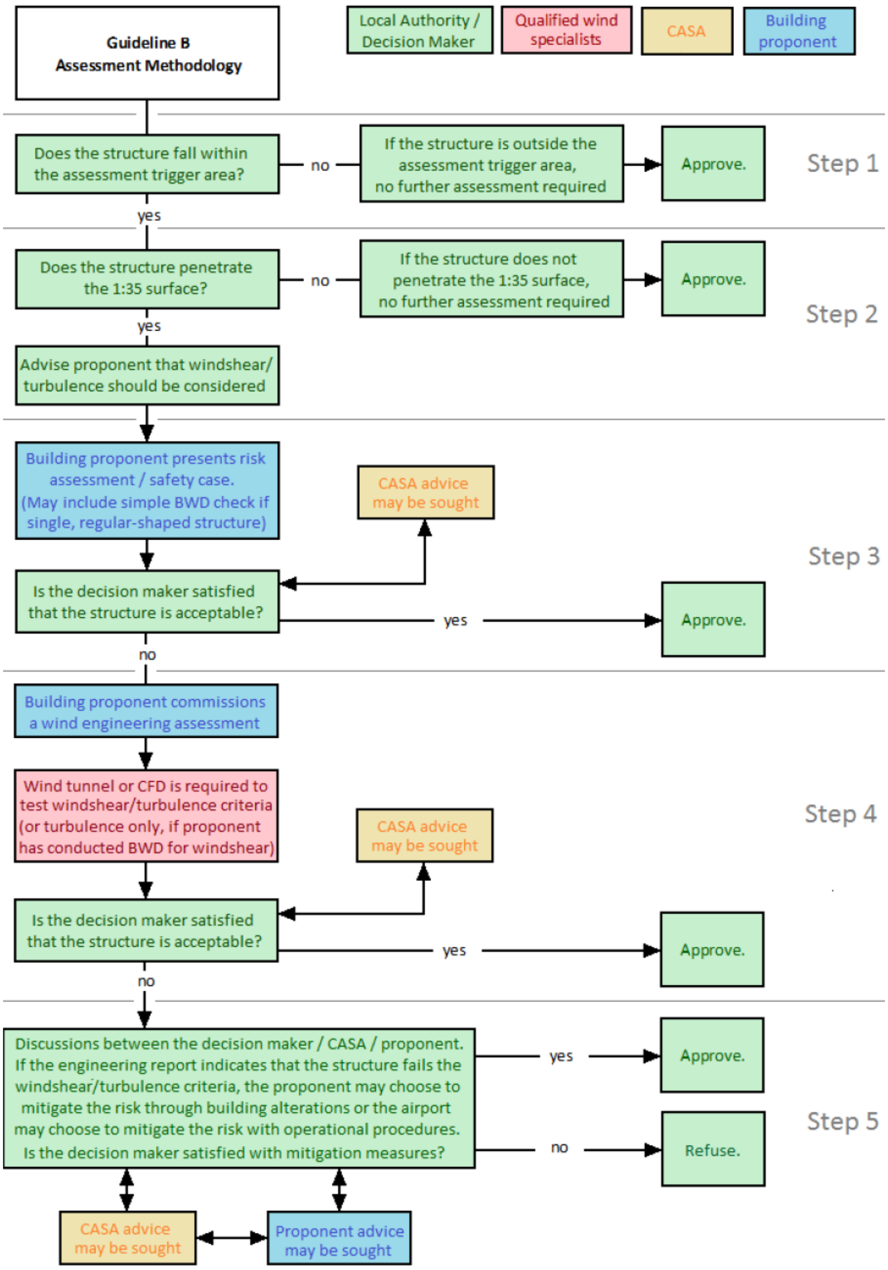

Figure 3: NASF (2018) assessment methodology

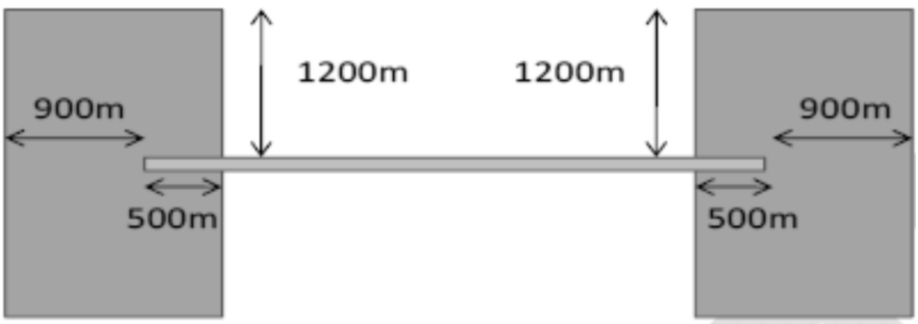

Figure 4: Runway assessment envelope (NASF, 2018)

Step 2

Step 2 in NASF (2018) is to assess the height of the structure relative to a height plane rising at a slope of 1:35 from the centreline of the Runway extension. Drawings of the proposed development are presented in Figure 5. The highest section of the proposed building is at 30.75 m above the Runway 30 threshold at a distance of about 970 m from the runway centreline, hence protrudes above the 1:35 height limit plane, Figure 5.

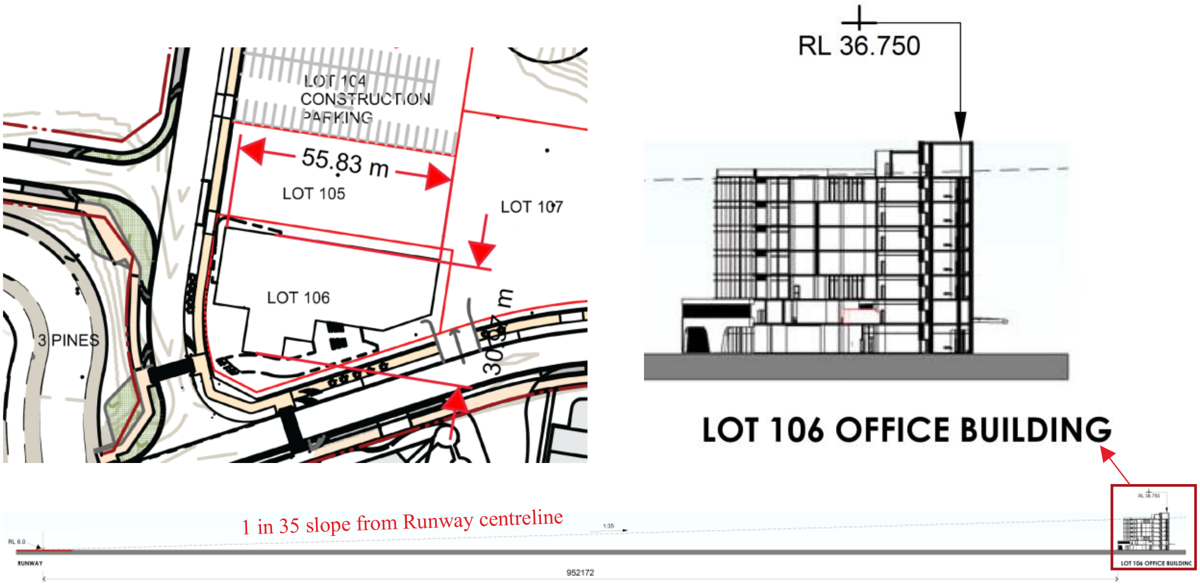

Figure 5: Ground floor plan (T), section looking west (C), and relative position to Runway 12 (B)

Step 3

For buildings exceeding the height limit, Step 3 assesses the impact of the building for a cross-wind event producing wind shear through a building wake deficit (BWD) check. Buildings are further classified depending on the plan form shape and whether they are isolated or multiple (NASF 2012). An assessment using the Guideline B estimation procedure has been undertaken due to the relatively prismatic form of the building, including adoption of a "very conservative" safety margin due to the multiple sized building sections, Figure 6.

For the proposed development, a BWD assessment was made to evaluate the potential for wind-shear assuming an isolated building.

Case C	**Building Shape:** Complex Building Shape AND/ OR Multiple Buildings	In this instance, unless a very conservative safety margin is added to the mean velocity deficit data provided in **Table 1**, one of the following quantitative modelling techniques should be used: 1. Wind Tunnel using Hot-Wire Sensors, 2. Wind Tunnel using Particle Image Velocimetry (PIV), or 3. Computational Fluid Dynamics (CFD).

Figure 6: Extract from NASF (2012) Guideline B, Table 2

From the analysis it was found that the 6 knot cross-flight wind shear criterion at building height would not be exceeded for the proposed building located at such a distance from the Runway centreline.

3. Conclusions

The proposed development is located outside the NASF (2018) Guideline B assessment zone for Runway 30 so does not require any additional assessment.

Notwithstanding the above, the building breaches the 1:35 slope height assessment zone from the Runway 30 centreline so requires additional assessment. The more detailed building wake deficit assessment indicates that the 6 kt cross-flight wind shear criterion at building height would not be exceeded for a building of this size and massing.

The turbulence criterion can not be assessed with the desktop procedures in the NASF (2018) guidelines, and more detailed modelling would be required. However, for the strong prevailing wind directions that would be of concern at Williamtown RAAF, the relatively small size of the building at a significant distance from the runway, and the height of approaching aircraft to Runway 30 relative to the height of the proposed development, there would not be expected to be any increased risk compared with the existing turbulent conditions. Additional modelling would not be considered necessary.

References

ICAO (International Civil Aviation Authority), 2005, Manual on low-level wind shear.

NASF, 2012, Managing the risk of building generated windshear and turbulence at airports, Guideline B.

NASF, 2018, Managing the risk of building generated windshear and turbulence at airports, Guideline B.

Nieuwpoort, A.M.H., J.H.M. Gooden, & J.L. de Prins, 2010, Wind criteria due to obstacles at and around airports, National Aerospace Laboratory, NLR-TP-2010-312.

Peterka, J.A., R.N. Meroney, and K.M. Kothari, 1985, Wind Flow Patterns About Buildings, Journal of Wind Engineering and Industrial Aerodynamics, Vol. 21, pp.21-38.

A.1 Discussion on wind shear and mechanical turbulence

Paragraph 2.2.1 from ICAO (2005) states:

'In the explanation of wind shear given in Chapter 1, the changes in wind speed and/or direction concern changes in the mean (or prevailing) wind from one reference point in space to another. Short-term fluctuations of the wind about a mean direction and/or speed are normally referred to as "variations" from the prevailing wind. Such variations of the wind, individually at least, are temporary, like eddies; while eddies clearly involve wind shear; because they are on a much smaller scale than an aircraft, they tend to affect the aircraft as bumpiness or turbulence. The scale on which the wind shear operates, in relation to the overall size of the aircraft concerned, is therefore of fundamental importance.'

From the above, it can be appreciated that wind shear is based on a difference in mean wind speed between two locations, whereas turbulence is the variation in wind speed and direction at a location with respect to time.

The "variations" mentioned above are generally called turbulence in the wind engineering community and will be used in this document. Turbulence can be quantified with the standard deviation of wind speed at a location with time. This does not give an indication of the size of, or energy level associated with the gusts. A spectral analysis would be required to extract the frequency structure of the gusts from which a measure of the size could be inferred. This is beyond the scope of the current discussion, and would be impractical to monitor full-scale.

To emphasise the difference between wind shear and turbulence, a brief discussion on the driving mechanisms involved in generating turbulence, and low level wind shear in the form of a thunderstorm downburst is included. Low level in wind engineering terms is defined as below about 500 m.

The typical atmospheric boundary layer created by large synoptic wind events is created by friction at the ground surface, and therefore changes from the ground up. The boundary layer typically extends about 500 to 1000 m above ground level. Increasing friction caused by ground objects causes a decrease in the near ground mean wind speed and an increase in turbulence. During strong wind events, the ratio of mean wind speed at 500 m to that at 10 m is typically about 1.6 for winds over open terrain (scattered trees and uncut grass), and 2.1 times for winds over suburbia. The mean wind speed at 500 m over open terrain is about 10% higher than that over suburbia. During strong wind events, turbulence intensity ratios between 500 m and 10 m are typically about 0.4, with winds over suburbia having about 1.3 times the turbulence intensity of those created over open country terrain. Turbulence intensity is defined as the standard deviation normalised by the local mean wind speed. It should be noted that at lower wind speeds, less than 10 m/s, the standard deviation and hence turbulence intensity values can increase.

To develop ICAO (2005) defined moderate and strong wind shear in open country terrain from 40 m to 10 m above ground level, the mean wind speed at 10 m would have to be in excess of 18 m/s (36 kt), and 33 m/s (66 kt) respectively. However, paragraph 5.2.8 of ICAO (2005) indicates that an aircraft could withstand a wind shear of 1.67 m/s per s (3 kt/s); for an aircraft landing in open country terrain with a ground speed of 55 m/s on a 3° glide slope, this would relate to a mean wind speed at a height of 10 m of approximately 75 m/s (150 kt), which would evidently never occur.

Turbulence intensity is wind speed dependent and the lower the mean wind speed the higher the turbulence intensity. However, once the mean wind speed exceeds about 10 m/s, (20 kt) the turbulence statistics become relatively less sensitive to wind speed. At the lower wind speeds, turbulence intensity is not considered a significant issue to aircraft safety, as the change in relative air speed between the aircraft and the wind is negligible. Turbulence is also a function of the meteorological event; local pressure driven winds such as a summer onshore wind will contain much smoother flow than winds associated with a large frontal system, even if they come from the same direction. This report only deals with developed atmospheric boundary layer flows and does not deal with meteorological events such as frontal systems and thunderstorm events, which cannot be practically modelled.

It is evident from the above, and an appreciation of the different surrounding terrain roughness that the existing wind conditions at an Airport are diverse depending on wind speed and direction. Determining the cause of any wind related pilot complaints based on isolated meteorological data would be exceptionally difficult; especially if it could be proven there were a lack of complaints during similar wind event days. It would be considered necessary to investigate the number of similar meteorological events and determine whether similar complaints were received on those days. Discussions with pilots would also be considered important to determine the frequency and severity of turbulent events.

The most likely cause of low-level wind shear at the Airport is caused by a frontal system, thunderstorm downdraft, or some form of temperature inversion. A mechanism for generating low level wind shear in thunderstorms is created by a descending column of cold air reaching the ground, then being turned by the ground plane, Figure 7. These events are called thunderstorm downbursts and have a central diameter of between 400 m and 4 km. The dashed white line starting on the left of Figure 7 at an elevation 1 k ft (300 m) is a typical glide slope for a landing aircraft. The concern for aviation is that a landing aircraft initially experiences a significant headwind in excess of 20 m/s (40 kt), which changes into a tailwind after passing through the centre of the descending column of air where the wind is coming vertically downward. The headwind causes the aircraft to rise, whereby the pilot will lower the throttle causing the aircraft to descend back to the glide slope, but then tailwind causes a reduction in lift causing the aircraft to land short of the runway. Thunderstorm downburst events typically last for only a few minutes and therefore have the spatial and temporal size to create localised wind shear.

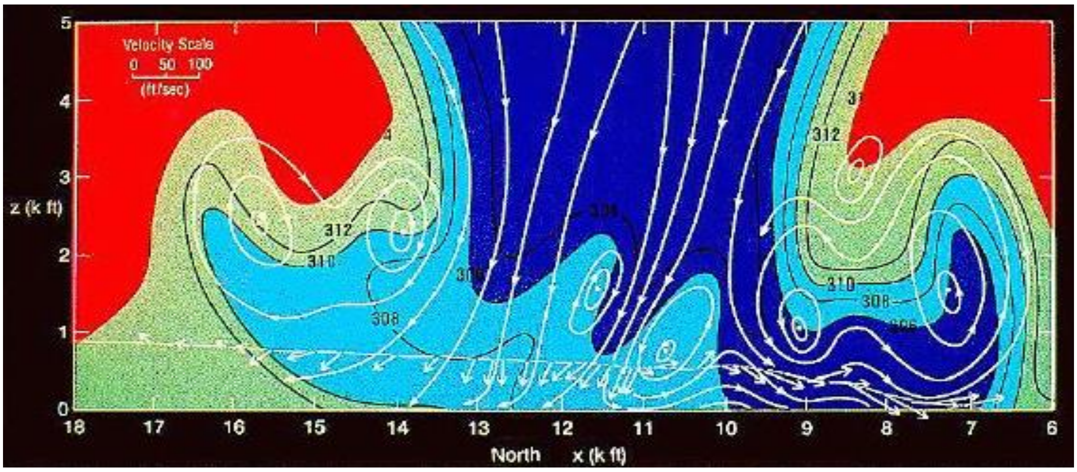

Figure 7: Radar image of a thunderstorm downburst

The wind flow patterns over a building Figure 8, are completely different in that there will be recirculation zones near the windward wall and roof edge, and in the immediate lee of the building. The typical extent of these recirculation zones relative to the height of the structure, h, is illustrated conservatively in Figure 8; for instance Peterka et al. (1985) describe the downstream recirculation zone extending 2 to 6 times the height of the structure. These regions are not fixed but fluctuate in time thereby increasing downstream turbulence, but wind shear would only be experienced in the recirculation zones. As the distance increases from the structure the flow pattern will resort to the undisturbed state. This distance is a function of the geometry of the building, and the roughness of the surrounding terrain, but the mean velocity and turbulence intensity at roof height would be expected to be within 10% of the free stream conditions at 10 times the height of the structure downwind from the building. The building will influence the wind pattern to a distance larger than this, but the magnitude of any change would be slight. The frequency of turbulence shed from the building would be expected to be fairly high and the spatial extend of a similar size to a large aircraft, therefore any effect would be expected to be of short duration.

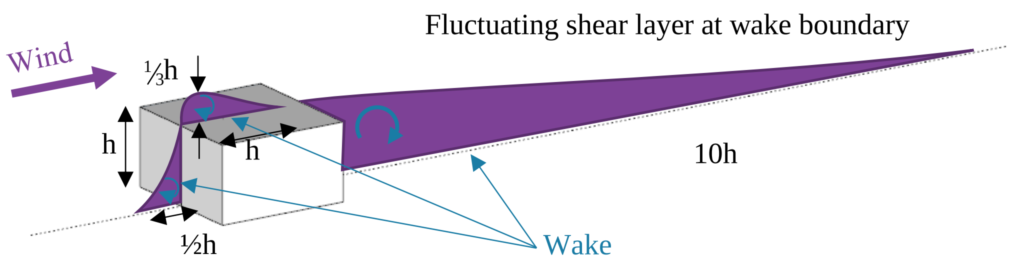

Figure 8: Sketch of the flow pattern over an isolated structure

It is evident from the above that the wind shear situation for flow over a structure is completely different to that for a thunderstorm. Unless the aircraft were to fly directly through one of the small wake regions, which are probably smaller in spatial extent than the aircraft itself, it would not experience any wind shear. The only concern would be if a large building were constructed right next to the runway and there were no provisions for using another runway during strong cross-wind events.

For oblique wind directions, flow around a large isolated regular structure has the potential to generate strong vortices that can extend for a significant distance downwind. These vortices have the potential to impact aircraft operations.

The wind flow pattern behind a group of buildings is significantly more complicated as the flow pattern is based on the compound shape. There is no method to analyse these complex flow pattern and physical or numerical modelling has to be adopted.

This discussion is in agreement with the ICAO Manual which in section 3.2.2 states:

'…This means that while the buildings are comparatively low, they present a wide and solid barrier to the prevailing surface wind flow. The wind flow is diverted around and over the buildings causing the surface wind to vary along the runway. Such horizontal wind shear, which is normally very localised, shallow and turbulent, is of particular concern to light aircraft operating into smaller aerodromes, but has also been known to affect larger aircraft.'