# Macquarie Place, Parramatta
# Ventilation and Daylighting analysis

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Client

## Crown International

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|---|---|---|
| | Project Leader | Date |

# EXECUTIVE SUMMARY

Studies were conducted to assess the ventilation and lighting potential of the slots a typical tower level floor in a new residential apartment complex - Macquarie Place, Parramatta. This was to address concerns raised by the design review panel in Report 1.

## Ventilation Study

To study the ventilation potential, Computational Fluid Dynamics (CFD) was used. An initial wind analysis was conducted to determine the most common wind directs, and the velocity that was exceeded 80% of the time and 50% of the time.

These two velocities were used to determine the ventilation potential of the corridors and of the apartments. Apartments with access to the slots, and hence cross ventilation, were compared to apartments that did not have access to the slots.

It was found that under both wind conditions, there was air movement along the length of both the corridors, and that additional mechanical ventilation may not be necessary. It was also found that the apartments with access to the slots had better ventilation compared to the apartments that did not have access to the slots, though the direction and velocity of wind are likely to affect which apartments are well ventilated and when.

Further, for the purposes of ventilation it was also recommended that:

- Windows to the slots are placed near the back of the apartments to increase the range of natural ventilation

- Positioning windows directly facing each other is avoided, as this may lead to flow of air from one apartment into another.

- If bathrooms or kitchens are to be located at the slots, that they have windows to allow for their own ventilation, and to assist in ventilating the entire apartment.

- Narrowing of the apartments without access to the slots is avoided to prevent the deepest part of the apartment suffering from poor ventilation

## Daylight Study

To investigate the potential of the slots to increase daylight availability in the building, two daylight models were built:

- One with no windows to the slots
- One with windows in the slots to both the corridors and the apartments

By comparing the results of the two models it is possible to see the impact the slots have in increasing daylight availability to the building.

The results of the daylight modelling showed that significant light is available in the corridors when windows to the slots are included. This will reduce reliance on artificial lighting provided good controls on lighting are included in the electrical design.

Daylight in the apartments was also modelled, and it was found that in a completely open plan apartment the additional light from the slots is not significant. However, if internal walls obstruct light penetration to rooms in the apartment (such as bathrooms to the rear of the apartment), then the addition of a window to the slot in that room may provide a significant improvement in daylight

Based on these findings, it was recommended that the slots were retained in the design to improve ventilation in the apartments with access to the slots and the corridors, as well as increase daylighting of the corridors and enclosed spaces in the apartments.

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| Issue/Status | Revision | Date Issued | Author | Checked | Approved | Comment |
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| FINAL | | 27/11/09 | MFL | KWP | KWP | |
| Draft | | 23/11/09 | MFL | KWP | KWP | |

# 1 Introduction

Floor plans provided by Joshua International Architects have been analysed to address concerns raised by the Design Review Panel in Report one (Part B), 5. Ensuring Residential Amenity.

> "*The panel is concerned that appropriate residential amenity is provided in the proposed development. The proponent should ensure that the proposals amenity is described with reference to the Residential Flat Building Design Code (RFDC) and that the Control Checklist and the Rules of Thumb therein are used as a base for appropriate housing amenity. Where this basis is departed from the proponent should provide credible argument that appropriate amenity is provided.*
>
> ***In particular, the light, acoustic and ventilation characteristics provided by the "slots" require justification. The panel agrees that the "slots" should be a minimum of three metres wide and this depth may not be sufficient and requires further justification.*** *Some of the internal apartment plans do not appear to take enough advantage of the slots. The panel believes that the RFDC building depth and natural ventilation paths are not strictly complied with and is therefore not convinced that natural ventilation amenity is provided. The additional building depth may also effect the availability of natural light. In addition, where bathrooms and kitchens are adjacent to the slots they should be provided with windows. Where bedrooms have their only window into the slot it should be designed to enable easy view out of the slot by the occupant. All windows into the slots, including the common area windows should be openable to provide natural ventilation. This may require fire engineering advice and this should be incorporated prior to the submission of the proposal for approval.*"

The ventilation "slots" have been analysed using Computational Fluid Dynamics (CFD) to determine how these effect the ventilation through the corridors and facilitate movement of air into the apartments. Effective ventilation is essential to maintain indoor environment quality, and keep contaminants, such as odours or fumes, at concentrations below levels which have adverse effects on occupants.

Radiance, a radiosity software for prediction of natural light, was used to analyse the effectiveness of the slots in providing daylight into the interior of the apartments and the internal corridors.

## 1.1 Limitations

The analysis has been completed on preliminary apartment layouts of the primary wind direction at two wind speeds. Different ventilation characteristics will be experienced under different wind conditions of speed and direction.

These results present the air movement at only given conditions, and do not represent the ventilation for all time.

## 1.2 Sources of information

- Floor Plans Supplied by Bates Smart dated 22/10/09
- Phoenics – Computational Fluid Dynamics software v.2008
- SEPP 65 - Design quality of residential flat development
- Design Review Panel  Report One (Part B)
- Australian Standard AS 1668

# 2 Approach

## 2.1 Wind Analysis

A wind analysis was conducted to determine the climatic wind conditions of the site.

Weather data from a Meteonorm file was used to determine the frequency of wind speeds and directions. METEONORM is a global climatological database. It uses recorded weather data from over 7,400 weather stations across the world (including 667 across Australia) to interpolate data for any point on earth. As the data in these weather files have not been scrutinized by the ASHRAE approved procedure, more than one file has been used to provide a more robust result.

This was then compared with weather data available at the Bureau of Meteorology and found to correlate well.

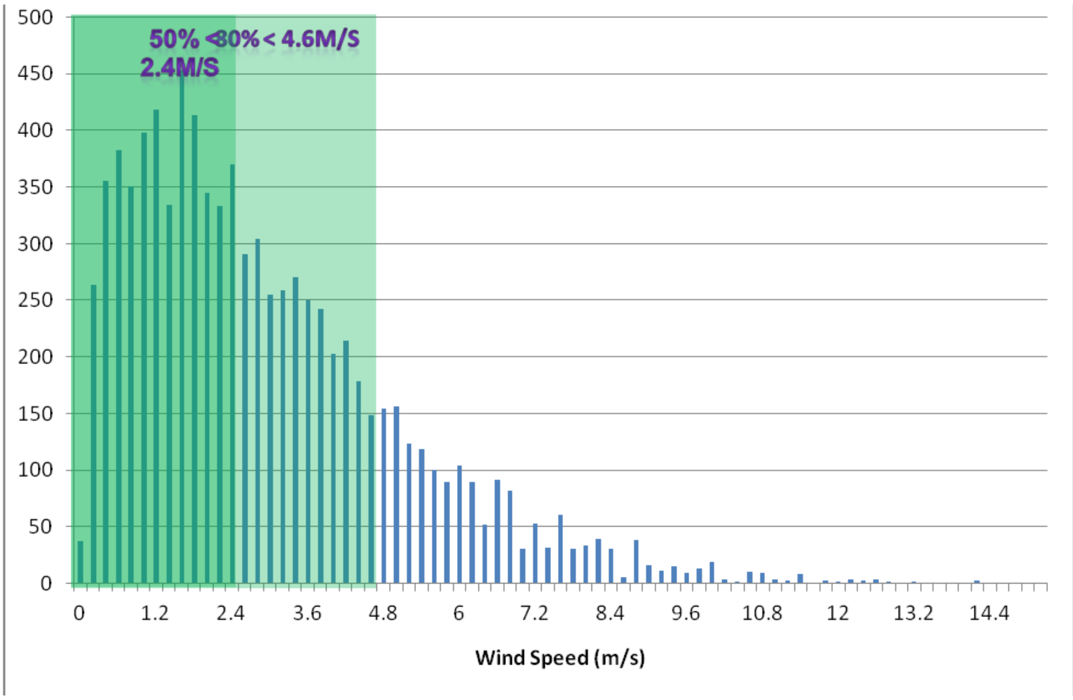


Figure 1: Wind speed distribution

The results of the anaysis determined that:

- Average wind speed is 2.9m/s.
- for 50% of the time wind speed is <2.4m/s
- for 80% of the time, wind speed is <4.6m/s.
- For 20% of the time, wind speed is <1.0m/s

As natural ventilation is facilitated by wind speed, in addition to temperature difference, 1.0m/s, 2.4m/s and 4.6m/s were uses as benchmark velocities to demonstrate ventilation that would be achieved at a range of wind velocities.

The slowest wind speed is indicative of the worst case scenario where ventilation will be poorest, though wind speed is exceeded 80% of the time.

2.4m/s is indicative of the median case where 50% of the time wind speed exceeds this velocity and 50% of the time the wind is slower than this velocity.

4.6m/s represents the upper range of the velocity distribution - 80% of the time, the wind velocity is less than this.

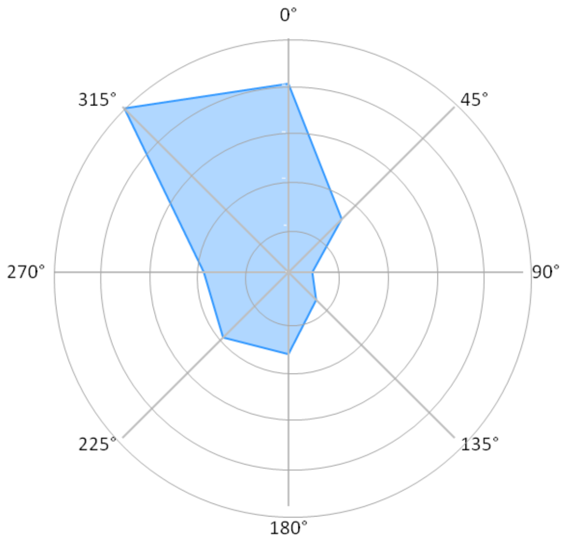

Figure 2: Wind direction distribution

The results of the analysis determined that the predominant wind direction was North Westerly, occurring 28% of the time. This was closely followed by Northerly with 20%.

Note that wind speed data is generally measured at a height at 10 meters above ground.

## 2.2 Computational Fluid Dynamics

Phoenics software was used to model the effect of the slots on the ventilation of a tower floor. The floor that was investigated is approximately 60m above the ground level, and approximately ¾ of the height of the building.

The simplified scale model was used to determine the pressure differentials on the openings into the floor at the height, taking into account the effects of the local buildings. The two adjacent buildings shown in Bates Smart Architectural Drawing EA6.00 have also been built into the model. These have a height of approximately 30 and 45m. In addition to this, a roughness height appropriate for modeling wind profiles in suburbs with regular large obstacles was also used. This incorporates turbulence and other effects generated by obstacles such as buildings and street plantings.

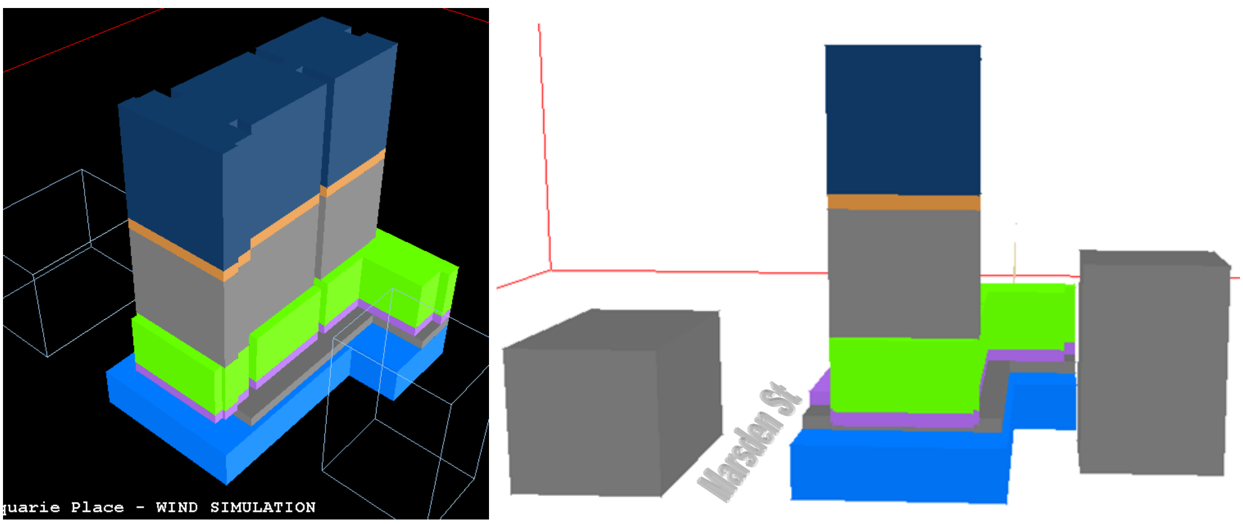

Figure 3: CFD model of the whole building showing surrounding buildings.

Investigated floor is orange.

The pressure readings were taken off this model and applied to a model of the floor with the internal layouts.

The typical floor modelled is shown in Figure 4, based on drawing EA2.09 by Bates Smart. Purple blocks represent lifts and bathrooms.


Figure 4: Floor plan of the analysed floor to show the internal walls

The wind speeds and directions determined from the wind analysis were used within the CFD model to determine results for 2 cases. These cases were:

- North, North West: 1.0 m/s
- North, North  West: 2.4 m/s

## 2.3 Daylight analysis

In addition to their potential to provide improved cross ventilation to the apartments, the slots have also been included for the benefit they provide to daylight penetration.

It is hoped that rooms with a window to the slots will have increased daylight penetration compared to those with not adjacent to the slots. The common corridors will also benefit from additional daylight penetration, reducing the need for artificial lighting.

In order to undertake this technical assessment, detailed computer modelling was conducted. Radiance, a radiosity software for prediction of natural light, was used to model the daylight performance. It was developed by Lawrence Berkeley Laboratories in the USA and radiance has been independently validated as the most accurate computation method that is capable of photo-realistic rendering for accurate assessment of visual comfort and glare issues.

## 2.4 Daylight modelling parameters

The model included a number of design inputs, focusing mainly on building geometry, building materials, and a light model of the Sydney 9am sky.  The 9am sky was chosen as this is an hour when direct light will penetrate the slots on one side of the building, but not on the other, demonstrating the benefit provided by the slots from both direct and indirect light.

A three dimensional computer model provided by the architect was used for modelling the daylight. An image of this model is provided below. The model was manipulated to separate different materials before being exported to Radiance to measure the daylight availability. Materials properties were assigned as shown in Figure 6.

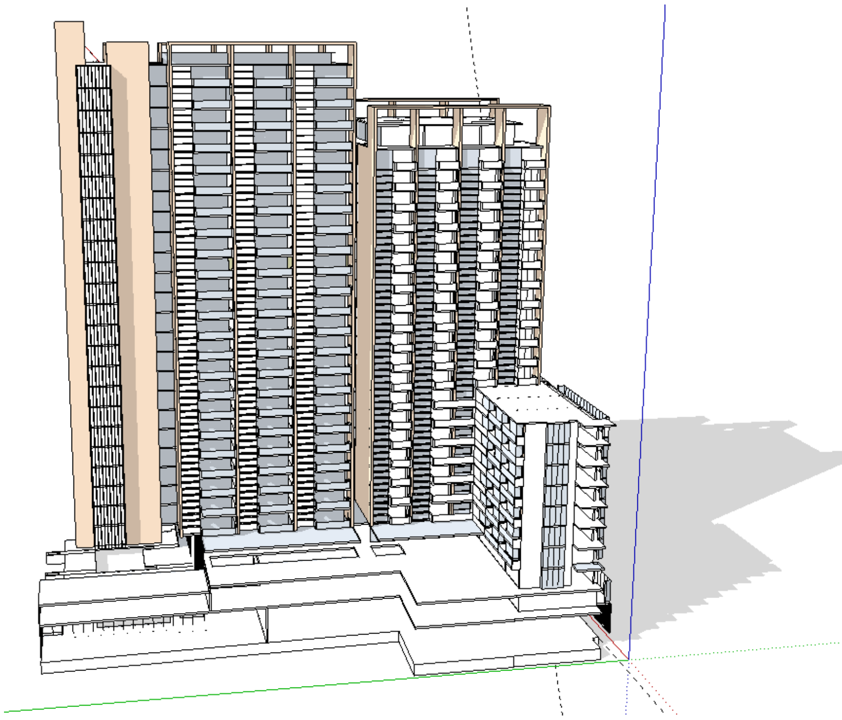

Figure 5: 3D architectural model

| Glazing | Visual Light Transmittance |
|---|---|
| Balustrades | 81% |
| Windows and glazed doors to apartments | 81% |
| Windows to corridors | 81% |
| **Surface** | **Reflectance** |
| Floor | 0.45 |
| Internal wall | 0.8 |
| Ceilings | 0.8 |
| External Building | 0.5 |

Figure 6 Glazing and materials properties

In order to measure the impact on daylight from the slots, windows were added into the 3D model which allowed light to penetrate into the corridors and the back of the apartments next to the slots. The location of the windows which were included in the model are shown in the section image of the 3D model below.

The daylight images for both models were compared to each other below to demonstrate the daylight benefit provided by the slots.

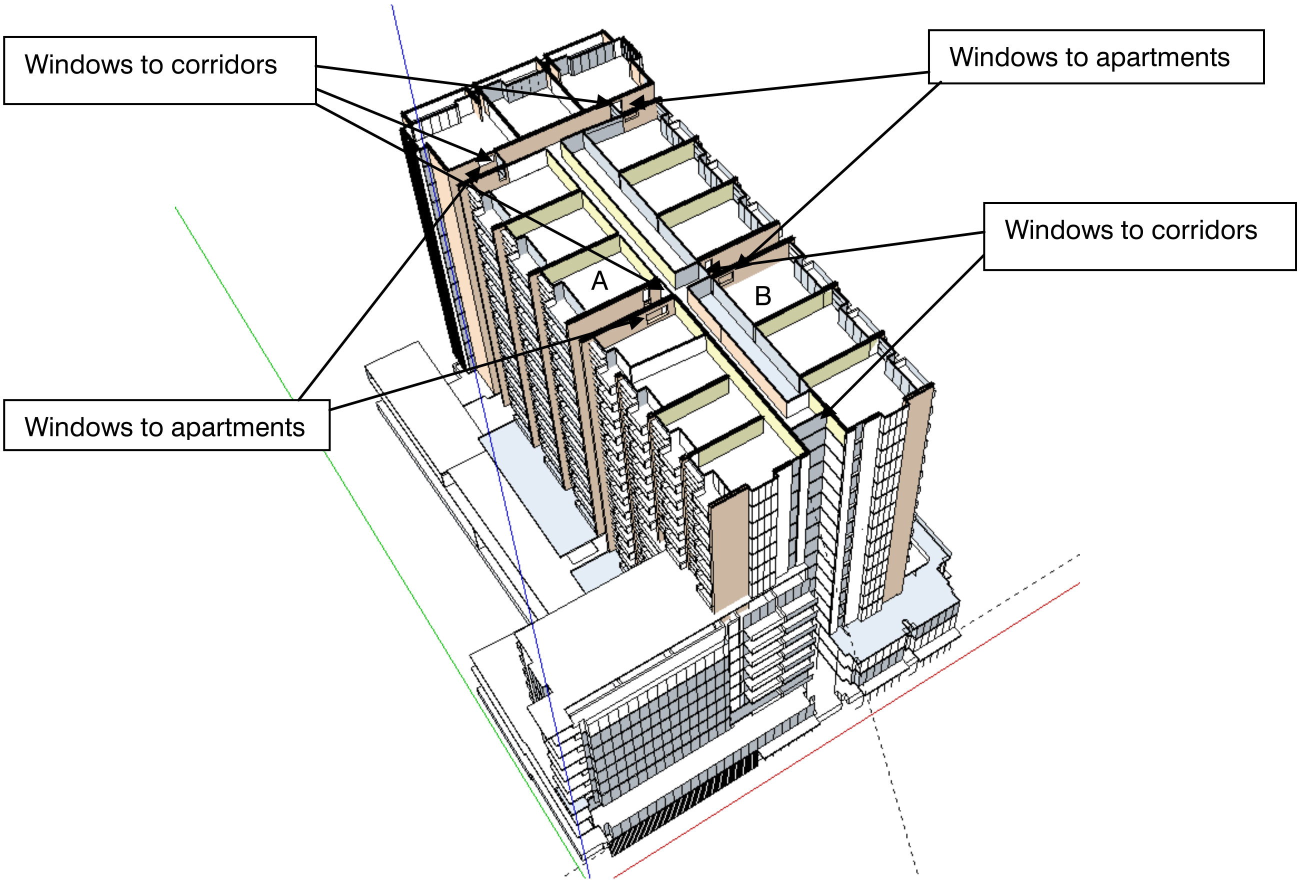


Figure 7: Windows added in to the 3D building model

# 3 Ventilation Results

The following images present the results from the analysis of the internal and external analysis of flow with wind speeds of 1.0 m/s and 2.4 m/s, coming from a north, north westerly direction in accordance with the speeds and direction determined in section 2.1.

## 3.1 1.0 m/s

The results below represent conditions which will be exceeded for at least 80% of the time. The external pressure and velocity conditions experienced at this speed are shown in the figures below.

### 3.1.1 External pressures and velocities

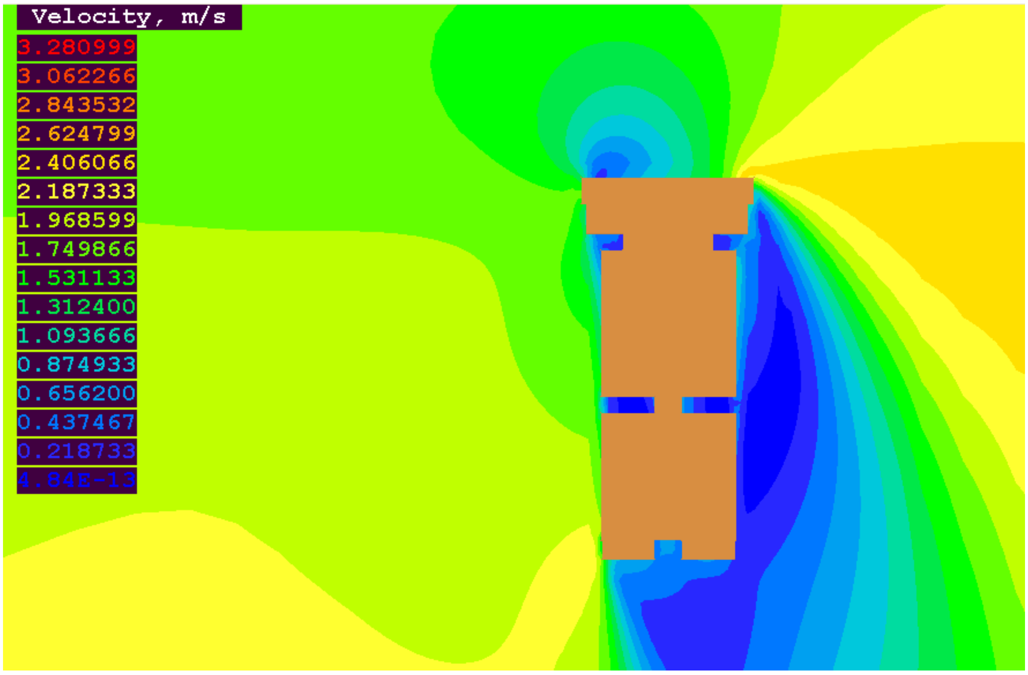


Figure 8: Velocity approaching the building – 1 m/s


Figure 9: Pressure approaching the building – 1 m/s

A wind shadow is visible in the first diagram. At the elevation investigated, the approaching wind speed was faster than the input 1.0m/s value at 10m above ground level. Approaching at approximately 2m/s, the wind speed decreases as it approaches the building and is slower in the wind shadow. These correspond with the higher pressures located in the same areas.

### 3.1.2 Internal – Corridors

The figures below show the results of the air movement within the building at the wind speeds modelled above. Figure 11 shows a close up of the air movement in proximity to one of the slots, demonstrating increased air movement in that area.

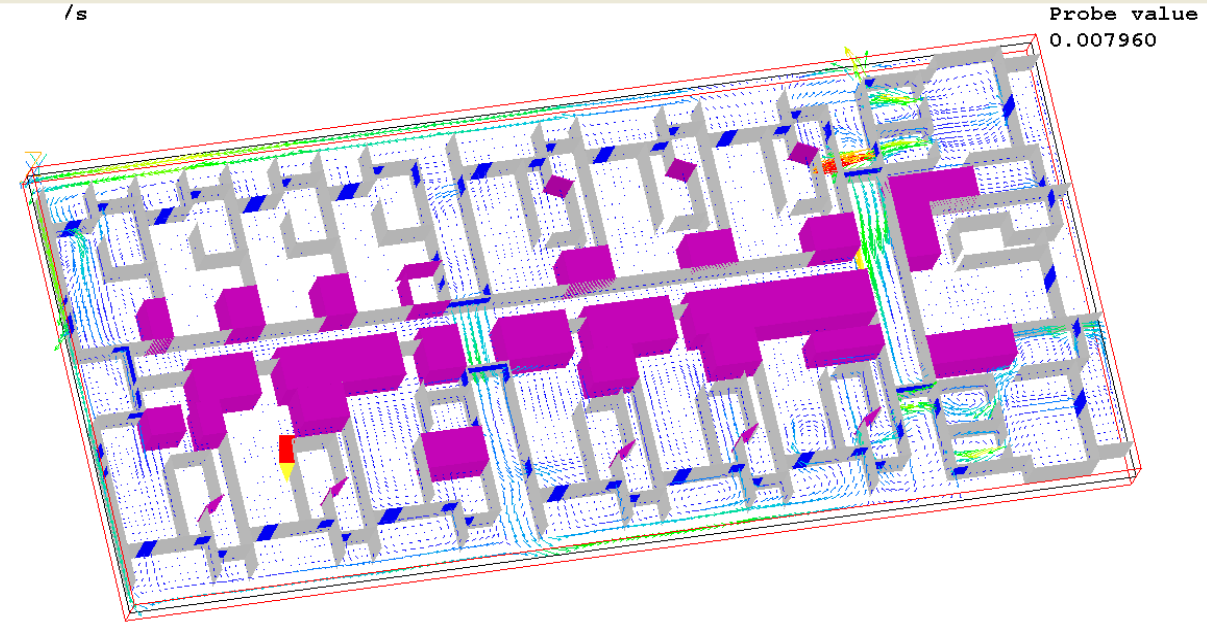


Figure 10: Air movement within the building – 1 m/s

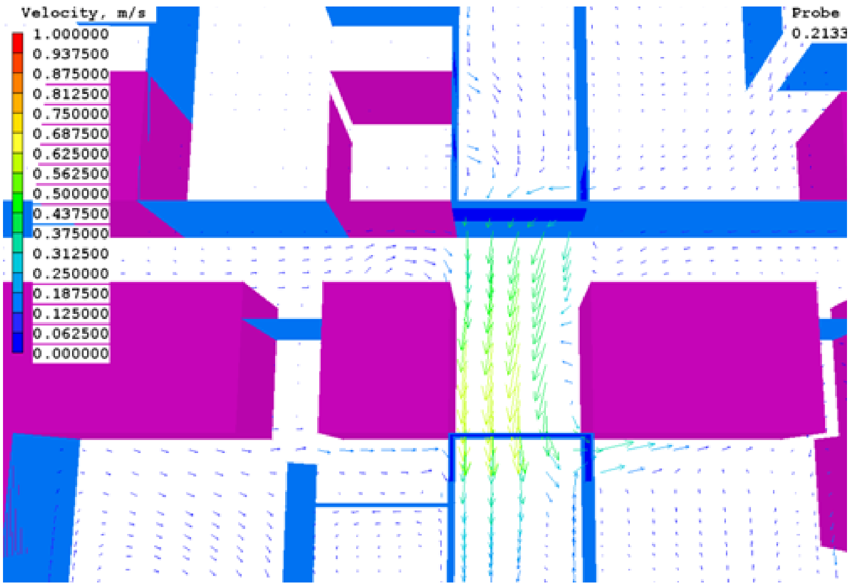


Figure 11: Air movement within the long corridor – 1 m/s

Both of the corridors show movement of air through due to the slots. A lot of this movement is from in one slot to out a directly opposite facing slot. However, there is movement from the interior of the long corridor towards the centre slot exit. This flow indicates that additional mechanical ventilation of the corridors may not be necessary – a significant energy saving. The area of these openings has been modeled as 1 m high and the full width of the available corridor wall. Australian Standard AS1668 requires an opening area of at least 5% of the floor area for adequate ventilation of a space. This area exceeds this requirement.

### 3.1.3 Internal – apartments

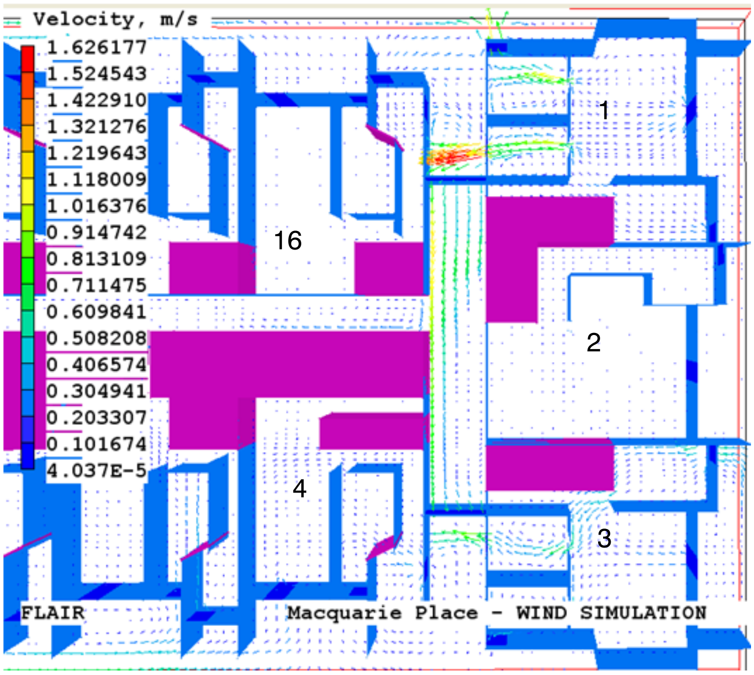


Figure 12: Apartments 1-4 and 16

Apartments 1 and 3 show good movement of air through the space as air is able to move from one side of the apartment, though the open plan area and out the bedrooms into the slots. Apartment 2, without access to cross ventilation, has much poorer movement of air.

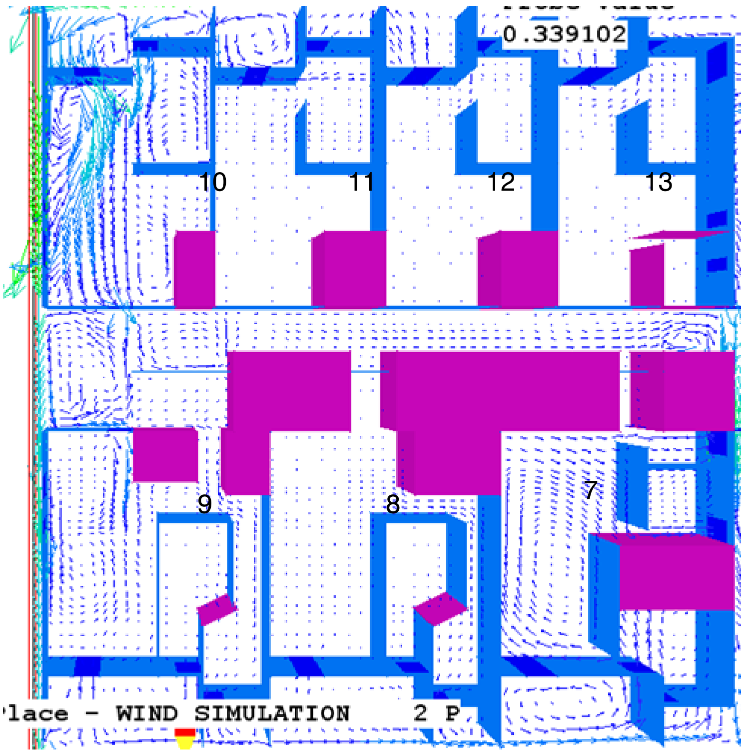


Figure 13: Apartments 9 and 10

Apartments 9 and 10 show good ventilation, due to the ability for cross ventilation. Air is able to enter though openings on one side and exit from another side, moving through the entire open plan area of the apartment without impediment.

Apartments 6 and 7 also show good cross ventilation due to access to the slots. The windows at these apartments are located at the full depth of the slot, allowing for air to move effectively through the entire space.

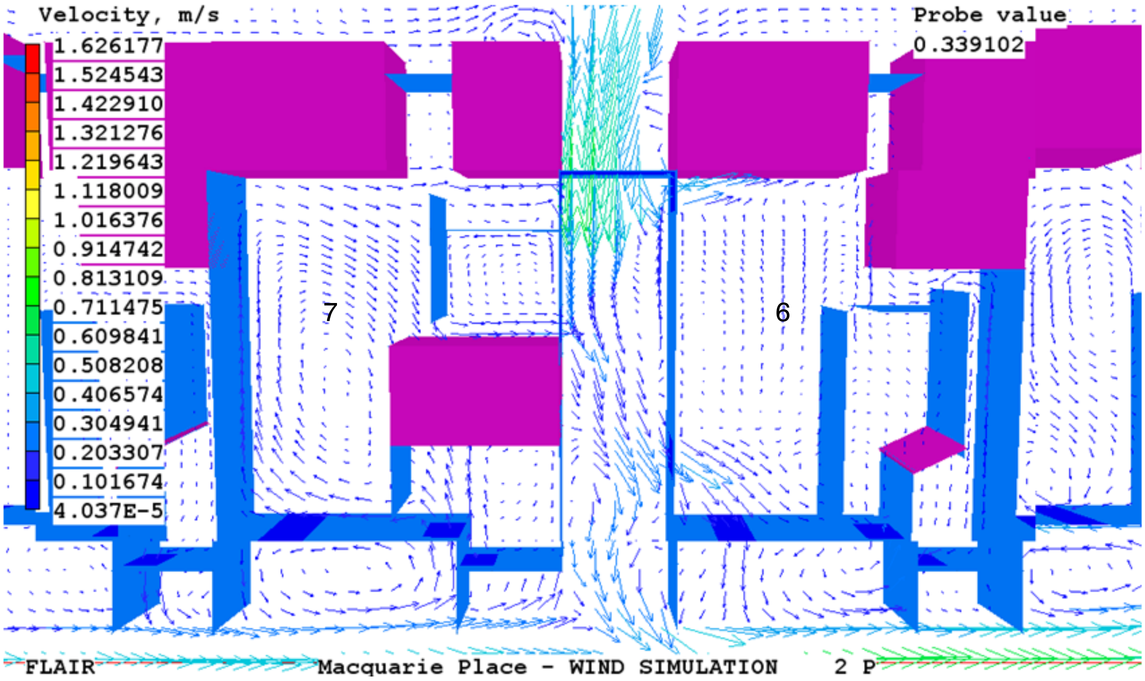

Figure 14: Apartment 6 and 7

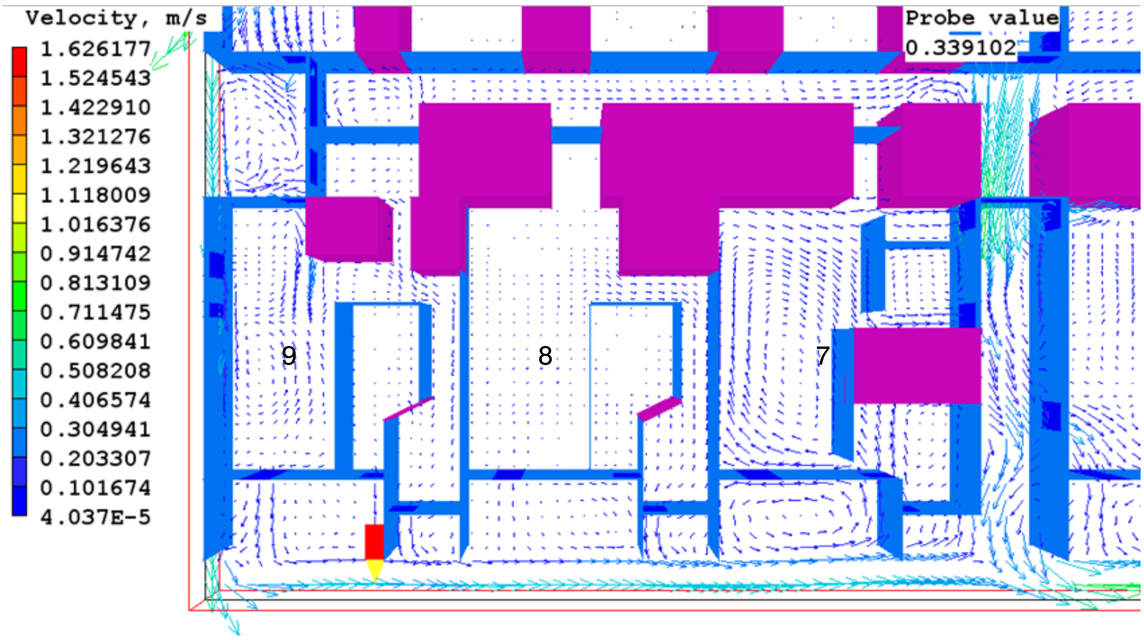

Figure 15: Apartments 7, 8 and 9

In comparison to apartments 7 and 9, apartment 8 with no access to the slots shows the poorest ventilation. Without cross ventilation it is difficult for air to reach the full depth of the apartment, particularly if there is insufficient pressure gradient on the openings.

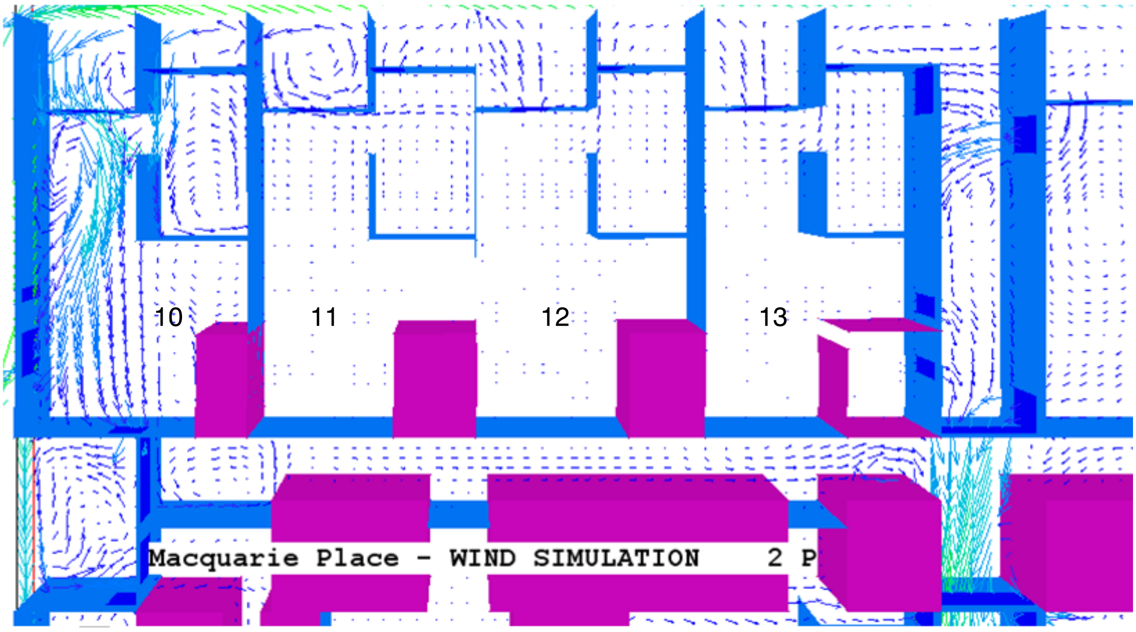

Figure 16: Apartments 10-13

The narrower apartments 11 and 12 show worse air movement. The depth of these apartments makes it difficult for air to move all the way through. Apartment 10 demonstrates good ventilation through the entire space as cross ventilation is possible, and is not adversely affected by narrowing of apartment.

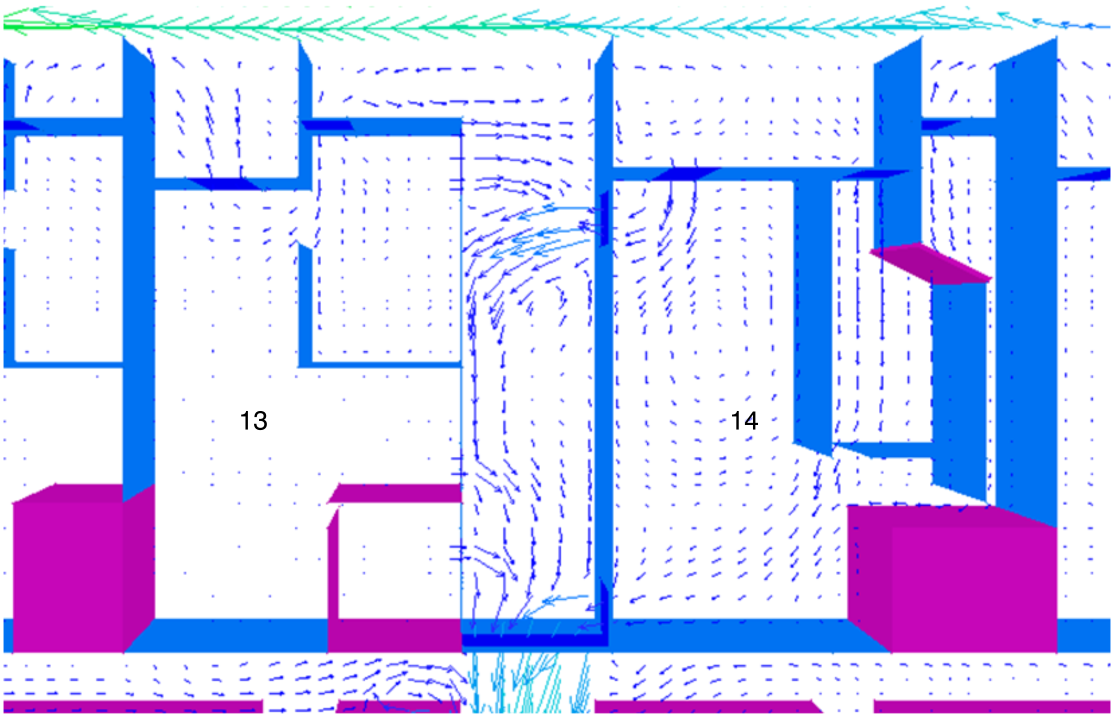

Figure 17: Apartments 13 and 14

Though apartment 13 does have access to a slot, it is not as well ventilated as other apartments with slot access. This may be due to the depth of the apartment, the location of the windows or the direction of the wind. Apartment 14 which is wider and has a window to the open plan area right at the full depth of the apartment has greater movement of air than apartment 13.

Bathrooms located at a slot should have openable windows to maximise ventilation through the entire apartment. Again, window placement is important to ensure privacy and prevent air going from one apartment to another.

### 3.2 2.4 m/s

At faster wind speeds, similar results are experienced within the apartments and within the corridors. The external pressure and velocity conditions experienced at this speed are shown in the figures below.

#### 3.2.1 External pressures and velocities

Greater velocities approaching the building and a larger pressure gradient is observed with 2.4m/s winds. Whilst the pressure gradient with 1m/s was 8 Pa, the pressure gradient with 2.4 m/s has almost doubled to 19 Pa.

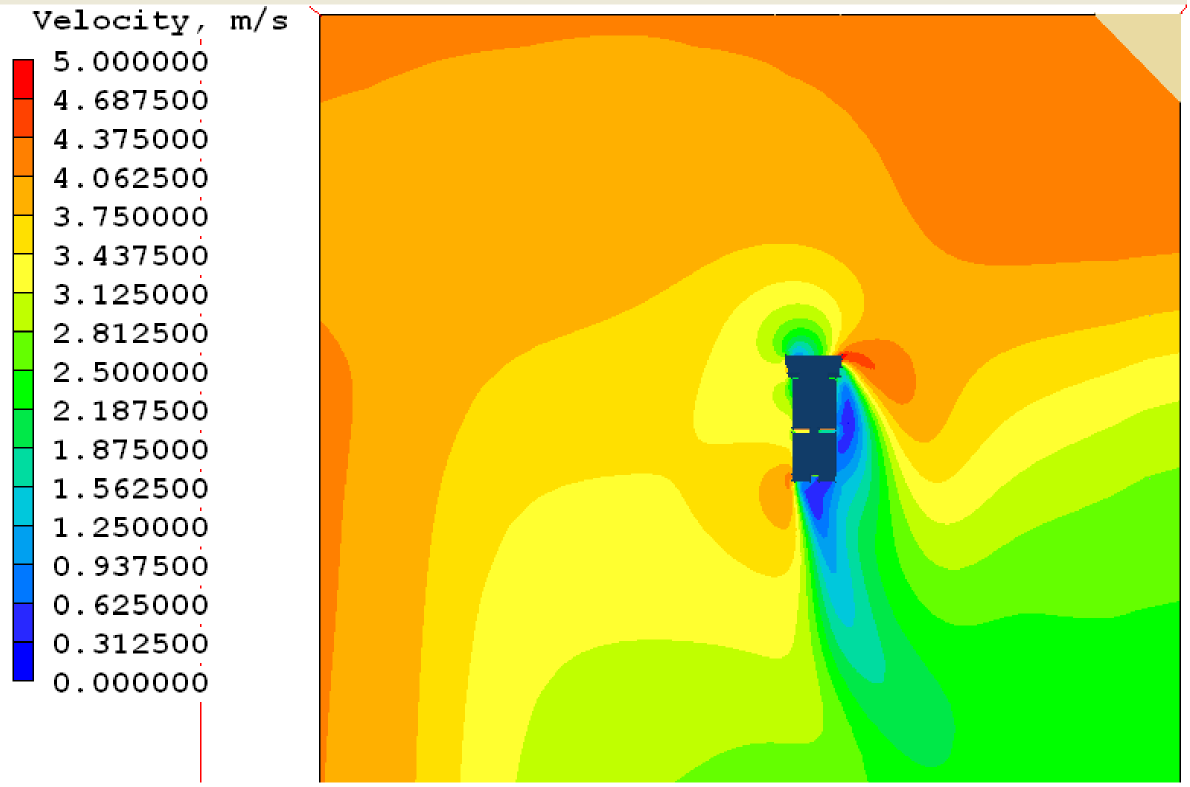


Figure 18: Velocity approaching the building – 2.4 m/s

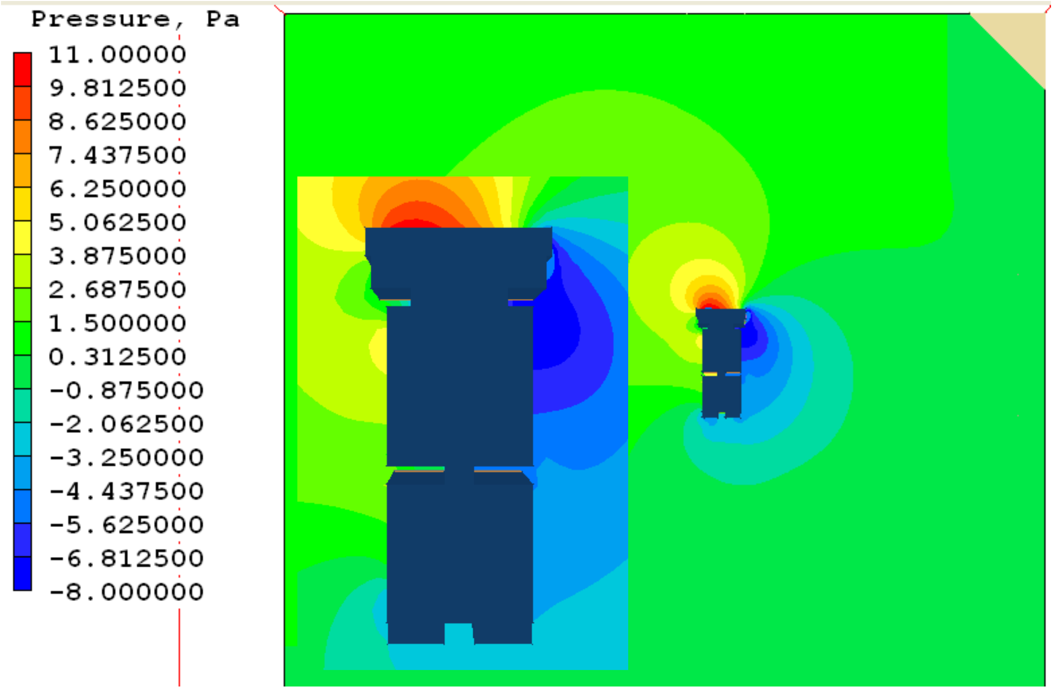


Figure 19: Pressure approaching the building – 2.4 m/s

### 3.2.2 Internal – Corridors

At these higher wind speeds it is shown that air movement through all apartments and corridors is improved, suggesting the slots may have a more critical role in providing ventilation at slower wind speeds. However, apartments next to the slots still show an improved air movement compared to those without access to a slot.

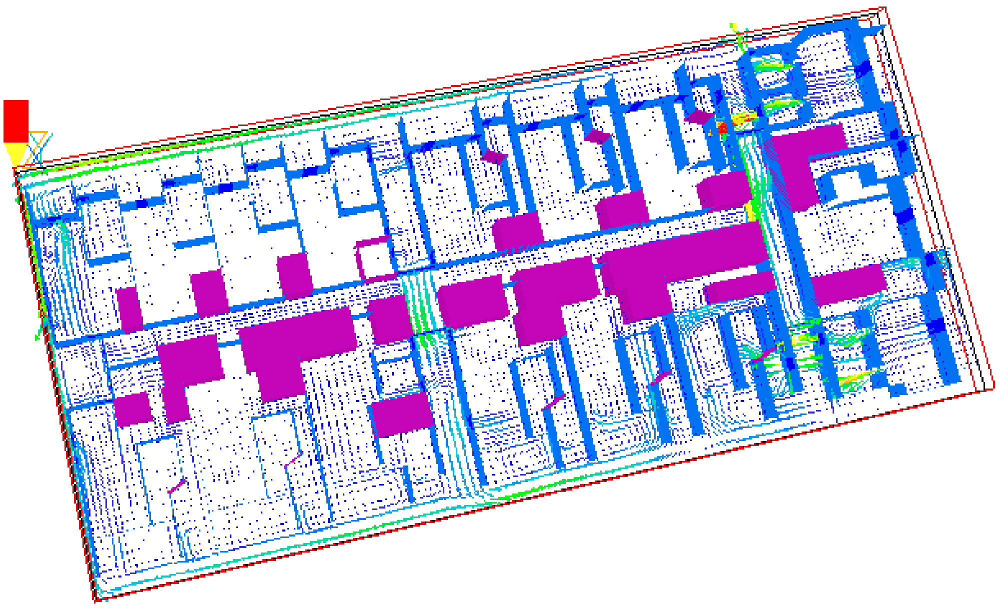

Figure 20: Air movement within the building – 2.4 m/s

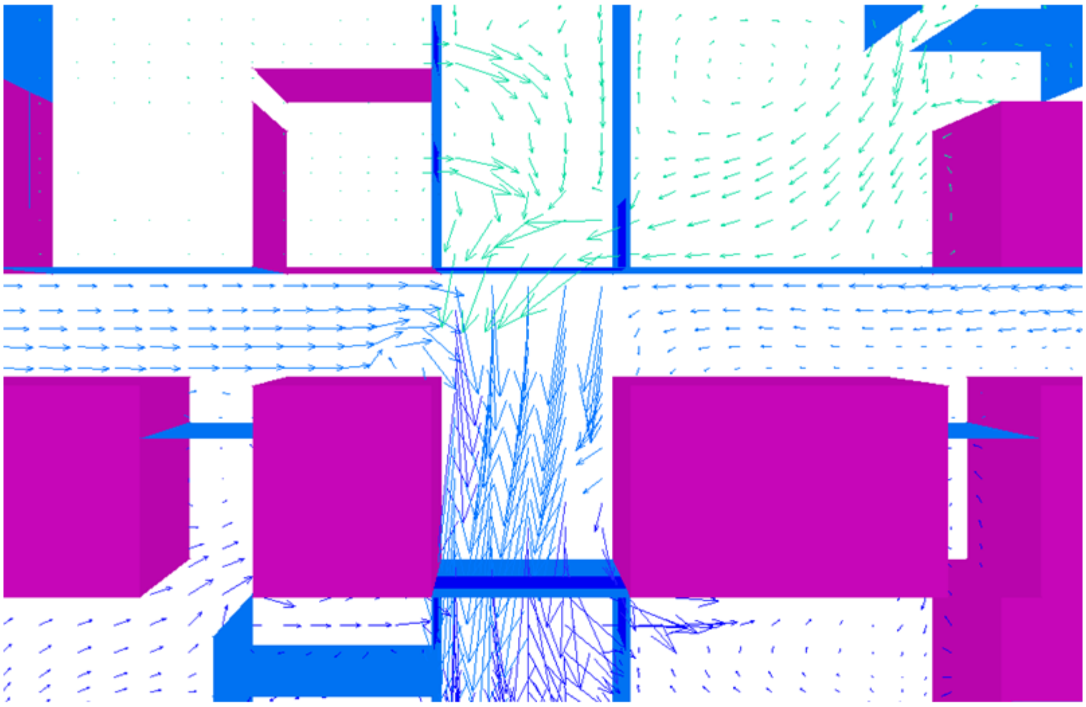

Figure 21: Air movement within the corridor – 2.4 m/s

Similar to what was observed at 1.0 m/s, air moves from within the long corridor to out the central slot. The air is moving more quickly than previously observed. The movement of air through the whole corridor again indicates that additional mechanical ventilation of the corridors is unlikely to be necessary.

### 3.2.3 Internal - Apartments

Apartments 11 and 12 are again the worst ventilated to do insufficient pressure gradient and depth of the apartment. The ventilation of apartment 8 is better relative than with lower velocities and also relative to apartments 11 and 12. This is due to better ventilation penetration with increased velocities.

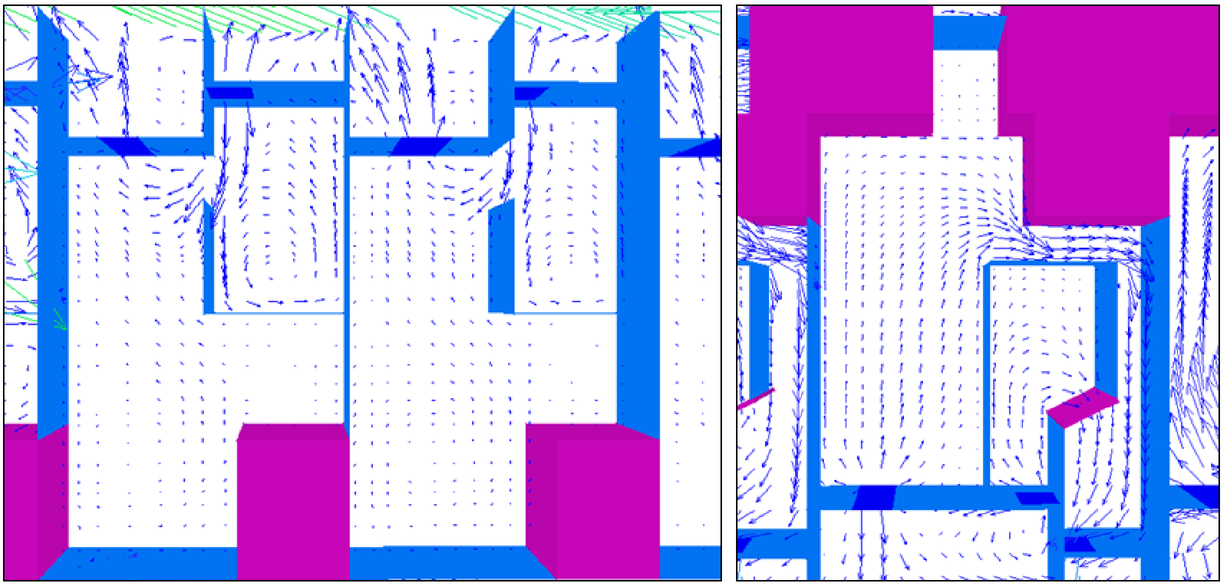

Figure 22: Apartments 11 and 12 (left), Apartment 8 (right)

A close up of apartments 13 and 14 again show that despite both apartments having access to the slot, the wider apartment with the window at the full depth of the apartment has better ventilation. More ventilation is observed to occur through the bathroom and study windows.

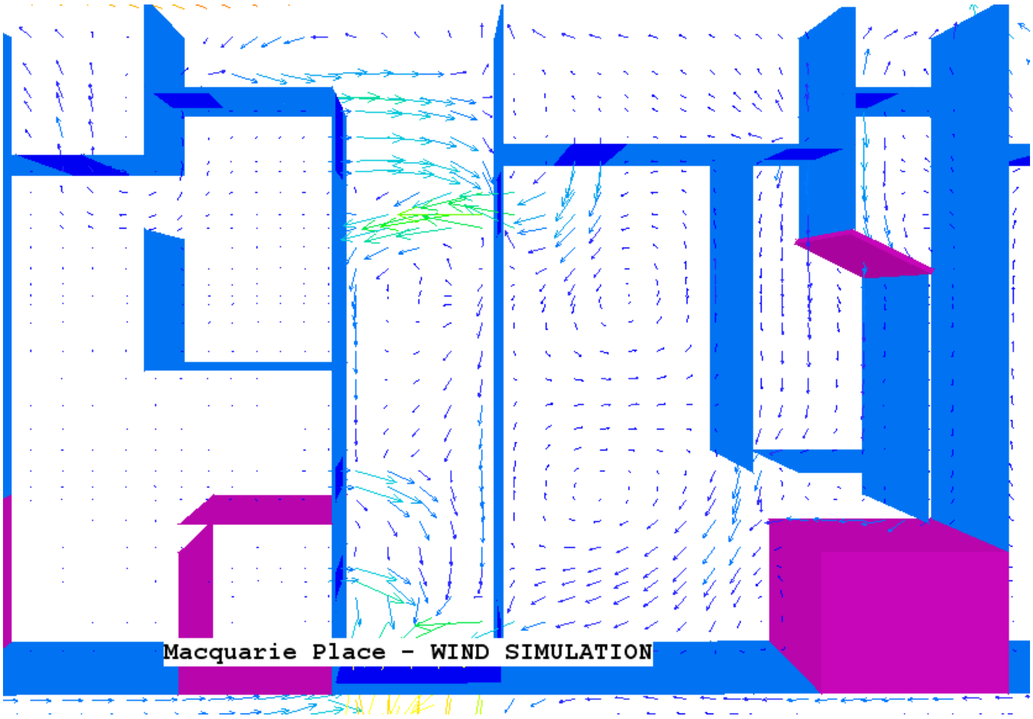


Figure 23: Apartments 13 and 14

### 3.3 Analysis

Apartments 11 and 12 are likely to be the poorest ventilated due to the depth of the apartments and lack of a significant pressure differential across window openings to facilitate ventilation. The ventilation in Apartment 8 improves at higher velocities.

The slots do facilitate ventilation with ventilation, as they allow for cross ventilation. Openings at the full depth of the space will lead to better ventilation throughout the apartment.

In general, ventilation improves with increasing velocity as the air is able to move through the space faster.

The two cases studied indicated that it may not be necessary to mechanically ventilate the corridors. Naturally ventilating the corridors will result in significant energy savings. There is also potential for a huge saving from not having to install the ventilation plant if natural ventilation is sufficient to meet ventilation needs.

The ventilation within apartments that are downwind or upstream that are otherwise identical is not the same; this is an indication that different apartments will experience benefits under different wind conditions. Only the north, north westerly direction was modelled; other wind conditions may show apartments which weren't well ventilated performing better.

However, under these particular wind conditions, the apartments with access to the slots were demonstrably better ventilated than those without access.

### 3.4 Recommendations

- Install slots to allow for cross ventilation of apartments and for the natural ventilation of the corridors
- Place windows to the slots near the back of the apartments to increase the range of natural ventilation
- Avoid placing windows directly facing each other as this may lead to flow of air from one apartment into another.
- If bathrooms are to be located at the slots, ensure they have windows to allow for their own ventilation, and to assist in ventilating the entire apartment.
- Avoid narrowing of the apartments without access to the slots to avoid the deepest part of the apartment suffering from poor ventilation

# 4 Daylight results

In order to demonstrate the daylight availability without slots in the building, the building was first modelled with no windows.

The building was then modelled with windows into the slots to show the impact on daylight availability in the corridors and the apartments. The results from this daylight modelling are shown below.

## 4.1 Corridors

The images shown below are a view down the central corridor with windows into the slots. It is already known that there will be very little daylight in the corridors without the slots, as the only source of light is from the window located in the south of the longer corridor.

The images of the corridors with the slots show the dramatic impact on light availability in the corridors provided by the slots. Energy consumption from corridor lighting will be dramatically reduced through the introduction of slots into the design.

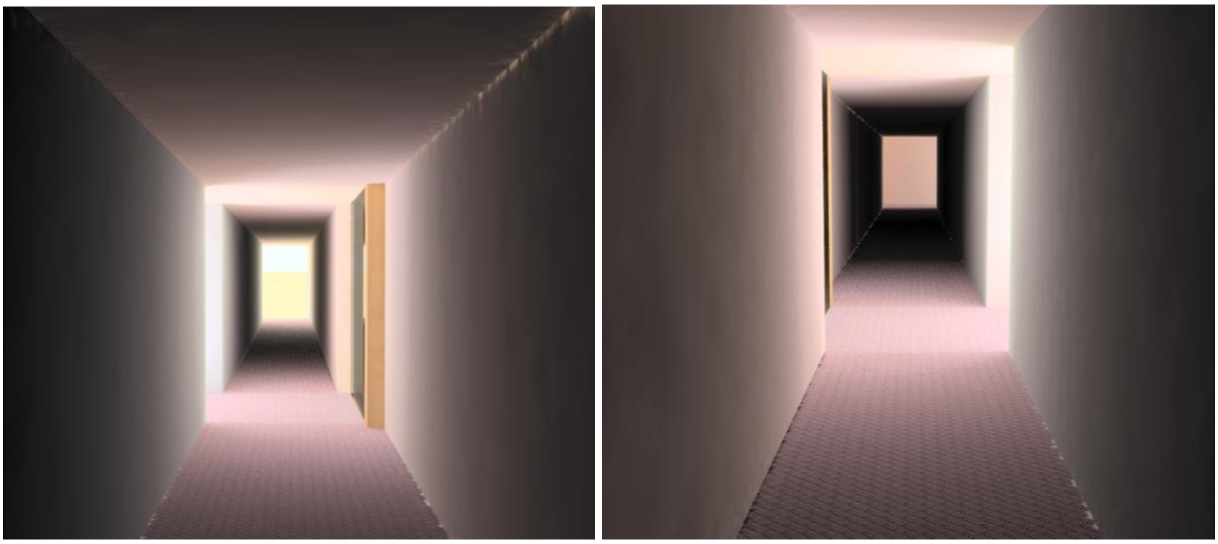

Figure 24: Daylight availability in the corridors facing north (left) and south (right)

The images above demonstrate that significant daylight penetrates the corridors when windows are provided to the slots. However, there is a significant light contrast near the daylit areas because of the large stretches of corridor without a window. In order to provide visual comfort, supplementary lighting may be required in areas of the corridor further from the slots. To reduce lighting energy consumption, lights should be separately wired so that only necessary lighting is used during daylight hours. Lighting control strategies are recommended in 14.3 below.

## 4.2 Apartments

The 3D model provided did not include internal layouts in the apartments. Therefore the images provided below are internal shots of the entire floor plate of a single apartment without internal walls for bedrooms, bathrooms, etc. The images show the change in light levels experienced by the inclusion of a window into the slot.

The Figure 25 shows the two apartments labelled A and B, which have been modelled to show the impact of the slot windows.

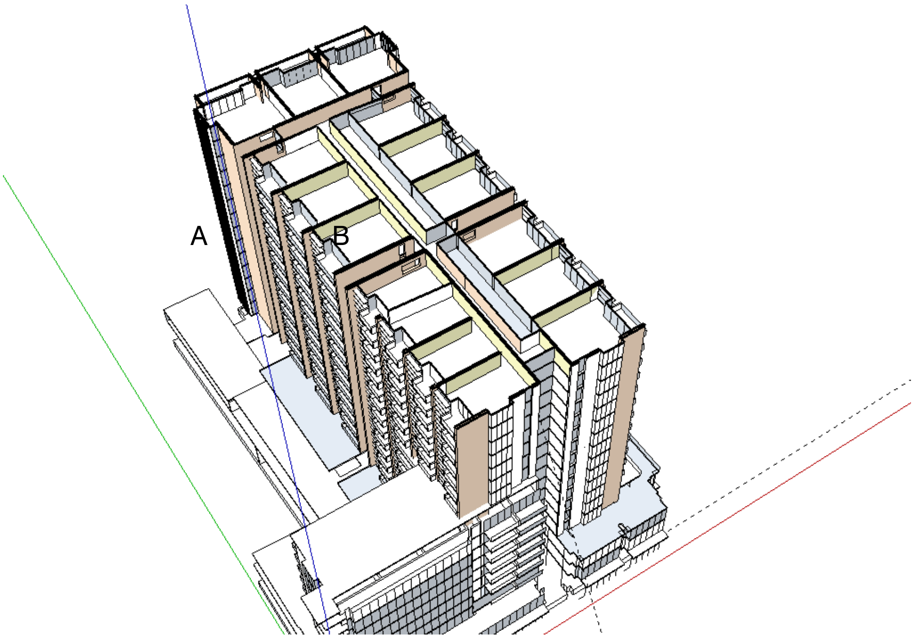


Figure 25: Floor plan of the building

Figure 26: Daylight availability in apartment A

Figure 27: Daylight availability in apartment B

Whilst the results do not demonstrate a drastic increase in daylight with the additional windows, it should be noted that if internal walls obstruct daylight availability from the main facade windows and glazed doors, then the daylight benefit provided by the slots will be greatly increased. For example, a bathroom adjacent to the slots will have restricted access to daylight from the facade of the building, therefore providing a window to the slot in such a room will improve daylight availability to that space, reducing artificial lighting requirements. The areas that will benefit from the slot windows illustrated in Figure 28.

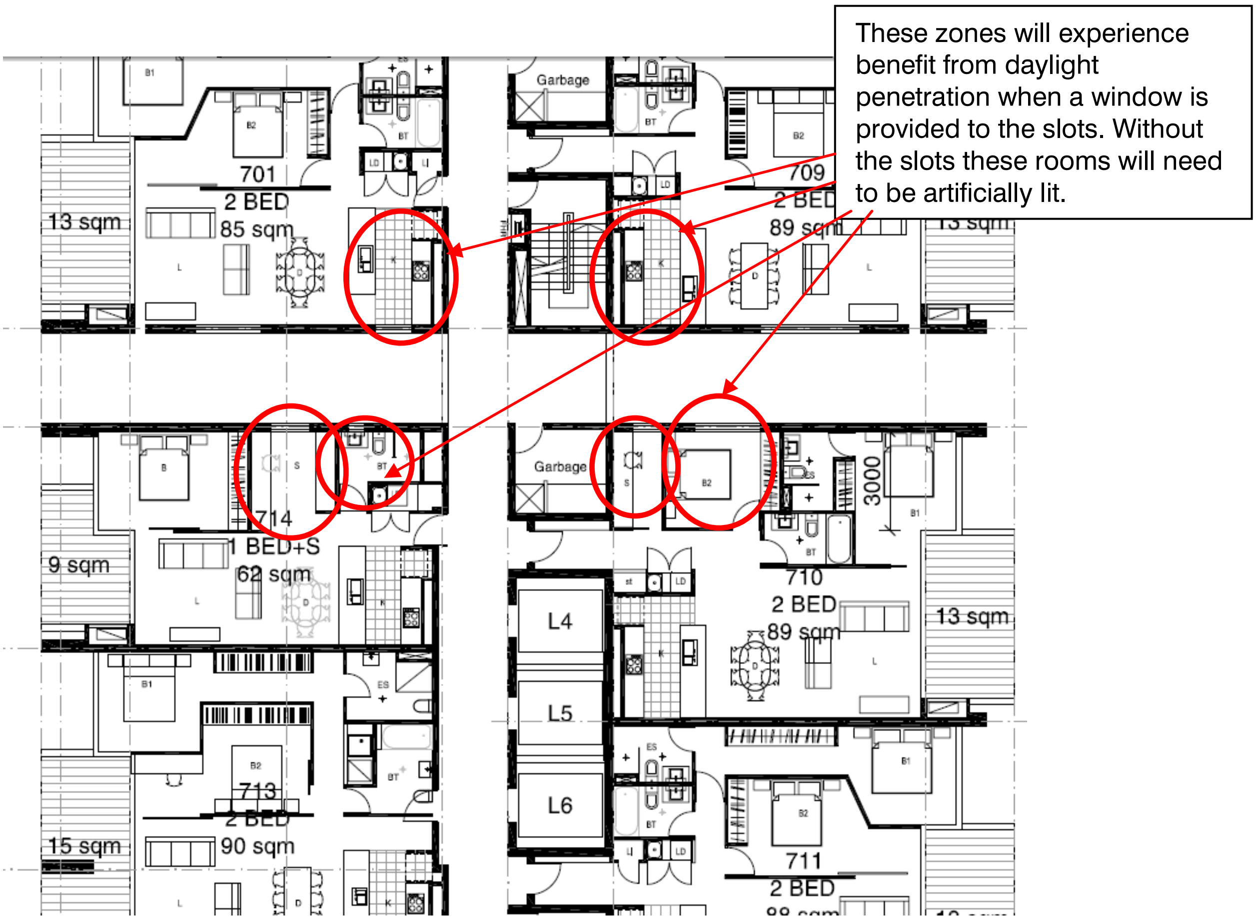


Figure 28: Rooms which will particularly benefit from windows to the slots

## 4.3 Recommendations

It is recommended windows are included in the common corridors to allow daylight to penetrate into this space. This will reduce the reliance on artificial lighting. Lighting controls should be included to ensure artificial lighting is not used when sufficient daylight is available. These controls can include:

- Daylight sensors to switch off unnecessary lighting when sufficient daylight is available; or
- Timer switches to switch off superfluous lights during daylight hours; and
- Separate lighting wiring so that lights that are required during daylight hours can be left on while superfluous lighting is switched off.

It is recommended that windows are provided to all rooms adjacent to the slots to improve daylight availability in the apartments. Where internal walls obstruct daylight penetration from the main facade it is particularly important to include windows in order to reduce reliance on artificial lighting. This provides both energy and environmental benefits.

# 5 Conclusion

Studies were conducted to assess the ventilation and lighting potential of the slots a typical tower level floor in a new residential apartment complex - Macquarie Place, Parramatta.

Computational Fluid Dynamics (CFD) was used for the ventilation study, and it was found that under both wind conditions, there was air movement along the length of both the corridors, and that additional mechanical ventilation may not be necessary. It was also found that the apartments with access to the slots had better ventilation compared to the apartments that did not have access to the slots, though the direction and velocity of wind are likely to affect which apartments are well ventilated and when.

To investigate the potential of the slots to increase daylight availability in the building, daylighting models were built. The results showed that significant light is available in the corridors when windows to the slots are included. This will reduce reliance on artificial lighting provided good controls on lighting are included in the electrical design.

Daylight in the apartments was also modelled, and it was found that in a completely open plan apartment the additional light from the slots is not significant. However, if internal walls obstruct light penetration to rooms in the apartment (such as bathrooms to the rear of the apartment), then the addition of a window to the slot in that room will provide a significant improvement in daylight

Based on these findings, it was recommended that the slots were retained in the design to improve ventilation in the apartments with access to the slots and the corridors, as well as increase daylighting of the corridors and enclosed spaces in the apartments.

Further, for the purposes of ventilation it was also recommended that:

- Windows to the slots are placed near the back of the apartments to increase the range of natural ventilation and daylight;
- Positioning windows directly facing each other is avoided, as this may lead to flow of air from one apartment into another;
- If bathrooms or kitchens are to be located at the slots, that they have windows to allow for their own ventilation, and to assist in ventilating the entire apartment;
- Narrowing of the apartments without access to the slots is avoided to prevent the deepest part of the apartment suffering from poor ventilation;
- Daylight sensors are installed to switch off unnecessary lighting when sufficient daylight is available;
- Timer switches are installed to switch off superfluous lights during daylight hours; and
- Separate lighting wiring is installed so that lights that are required during daylight hours can be left on while superfluous lighting is switched off.