Design Features to Change and/or Ameliorate Pedestrian Wind Conditions

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Introduction

Figure 1: Downwash circulates over the podium pool deck of a 1:300 wind-tunnel model of a beachside condominium. This circulation requires ameliorative measures like an open trellis and substantial foliage.

A windy environment around the base of a building, particularly near a main entrance or plaza area, will detract from the appeal of the site and perhaps discourage clients and shoppers from visiting the area. Many examples exist of unsuccessful outdoor restaurants and cafes in a windy environment at the base of tall buildings (Cochran, 1979). Similarly, an outdoor pedestrian space, such as a recreational pool area (Figure 1) of a residential condominium, should be protected from strong, mean winds. Thus, there is a direct financial motivation to ameliorate the wind environment if it is going to adversely influence the appeal of a building to the owners and customers of that building. In the extreme case a site may be dangerous, particularly to the infirm. Penwarden and Wise (1975) discuss the case of two elderly women who were killed when a gust of wind at the base of a tall building blew them over. Whilst this is not a common event, potential litigation is a design parameter that should be considered.

Figure 2: Topographic influence on pedestrian wind conditions.

Many factors will have an impact on the wind conditions around a building. Some of these parameters include: the ambient wind statistics, local topography (Figure 2), building massing, nearby foliage and the proximity of similarly tall structures. These all may influence the resulting winds around the base of a new building and at elevated levels on balconies and terraces. It is for this reason that many new-building designers evaluate their project in a boundary-layer wind tunnel with the subject building both installed and removed from the turntable. In this way, the project's impact on the local environment may also be assessed. The experience gained from studies like these will form the basis of this paper, where once the flow physics are established, the alteration of architectural massing or landscaping modifications may be used to create a pleasant pedestrian area from one that was unacceptable previously. This paper will also discuss architectural geometries that should be avoided, such as the 1960s architectural trend of having tall buildings on ground-floor columns with an open plaza underneath or having the main ground-floor entrance on a corner rather than recessed at the center of a face.

Building Massing and Orientation

It is well known that the design of a building will influence the quality of the ambient wind environment at its base. A shear curtainwall to ground level with a rectilinear floor plan (circular shapes typically do not cause flows of this type) is often a design which may aggravate street-level winds by allowing the high-elevation, faster winds to flow down the face of the structure. The mechanism is called downwash (see Figures 1 and 3). Once the wind reaches the ground it is then accelerated around the ground-level corners (see Figure 4). A large canopy may interrupt the flow as it moves down the windward face of the building. This will protect the entrances and sidewalk area by deflecting the downwash at the second storey level (Figure 5). However, this approach *may* have the effect of transferring the breezy conditions to the other side of the street. Large canopies are a common feature near the main entrances of major office buildings. The architect may elect to use an extensive podium for the same purpose if there is sufficient land and it complies with the design mandate (Figure 6). This is a common architectural feature for many major projects in recent years, but it may be counterproductive if the architect wishes to use the podium roof for long-term pedestrian activities, such as a pool or tennis court.

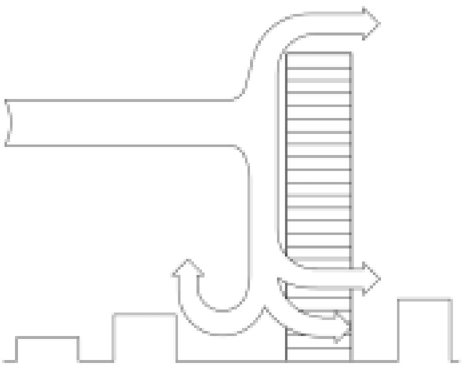

Figure 3: Downwash to street level may generate windy conditions for pedestrians. This is particularly true for buildings much taller than the surrounding buildings.

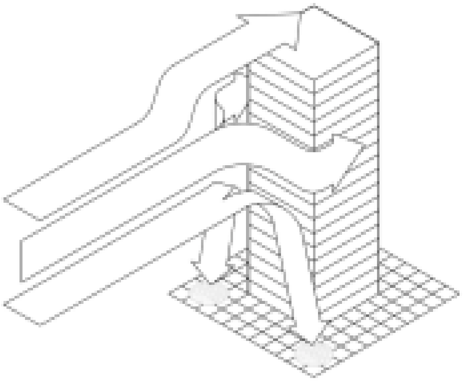

Figure 4: High wind areas may be expected at the ground-level corners where downwash accelerates into a horizontal direction along the street.

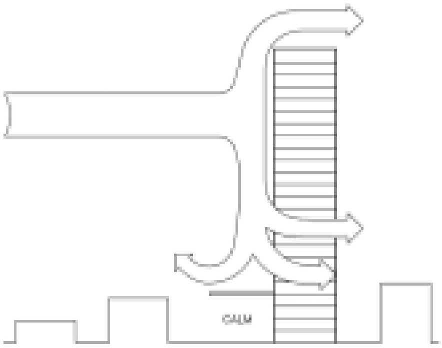

Figure 5: A large canopy is a common solution to this pedestrian-wind problem at street level.

Another massing issue, which may be a cause of strong ground-level winds, is an arcade or thoroughfare opening from one side of the building to the other. This effectively connects a positive-pressure region on the windward side with a negative-pressure region on the lee side. A strong flow through the opening often results as illustrated in Figure 7. A similar phenomenon occurs with a high-rise building raised up on columns, a design popular in the 1960s (Penwarden and Wise, 1975). The uninvitingly windy nature of these open areas is a contributing reason behind the rarity of this type of architectural form in modern high-rise buildings. One exception is in calm, tropical climates where the extra breeze creates a desirable feature. For example, the Hitachi Building in Singapore has used this approach to provide shaded, cooler areas at the ground-level entrances with great success. However, the same design in a windy city with cold winters, like Chicago, would be an unfortunate design choice.

An entrance alcove behind the building line will generally produce a calmer entrance area (Figure 8) at a mid-building location. In some cases a canopy may not be necessary with this scenario, depending on the local geometry and directional wind characteristics. The same undercut design at a building corner is usually quite unsuccessful (Figure 9). This is due to the accelerated flow mechanism described in Figure 4 and the ambient directional wind statistics - often described graphically using a wind rose. If there is a strong directional wind preference at the city in question, and the corner door is shielded from those common stronger winds, then the corner entrance may work. However, it is more common for a corner entrance to be adversely impacted by this local building geometry and the strong winds that more commonly occur in that city, both influencing the exposed corner entrance. The result can range from simply unpleasant conditions to a frequent inability to open the doors (Figure 9).

The way in which a building's vertical line is broken up may also have an impact. For example, if the

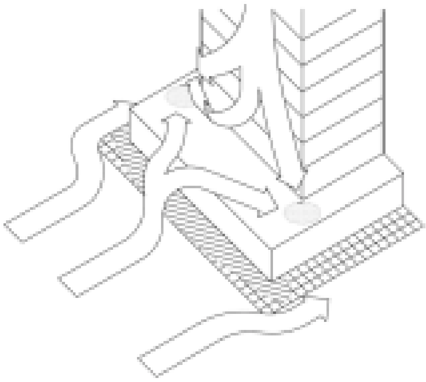

Figure 6: The tower-on-podium massing often results in reasonable conditions at ground level, but the podium may not be useable.

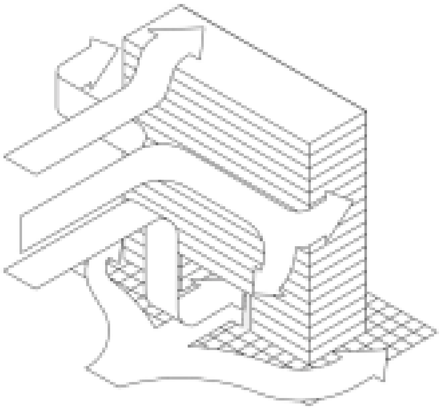

Figure 7: An arcade or open column plaza under a building frequently generates strong pedestrian wind conditions.

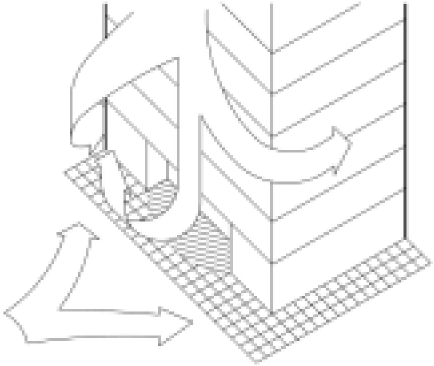

Figure 8: A mid-building alcove entrance usually results in an inviting and calm location.

floor plans have a decreasing area with height the flow down the "stepped" windward face may be greatly diminished. To a lesser extent the presence of many balconies can have a similar impact on ground-level winds, although this is far less certain and more geometry dependent. Condominium designs with many elevated balconies and terrace areas near building ends or corners often attract a windy environment to those locations (Figure 10). Mid-building balconies, on the broad face, are usually a lot calmer. Corner balconies are generally a lot windier and so the owner is likely to be selective about when the balcony is used or endeavours to find a protected portion of the balcony that allows more frequent use, even when the wind is blowing.

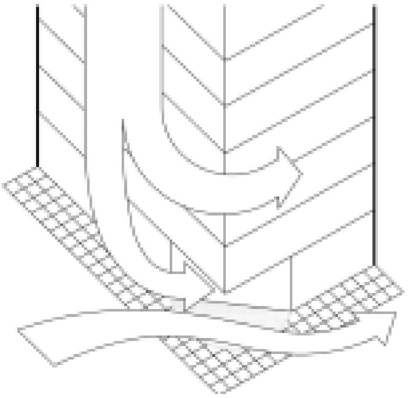

Figure 9: Accelerated corner flow from downwash often yields an unpleasant entrance area.

The Influence of Terrain

The presence of topography around a site will impact the ambient pedestrian conditions in much the same way as major neighbouring buildings do in the vicinity of proposed new development. Figure 2 shows the complex terrain of Victoria Peak on the island of Hong Kong. Being in the shadow of substantial topography such as this is renowned for impacting pedestrian-wind conditions and must be physically modeled in the wind tunnel to make a reliable assessment of the higher-speed winds (pedestrian comfort) and lower-speed winds (removal of pollution or viruses such as SARS) around the anthropogenic environment being assessed. In some circumstances the new building is an integral part of the complex terrain (Figure 11) and so flow over the terrain passes over the balconies of the condominium in much the same manner as the escarpment itself. Thus, the terrain at a new building site may reduce the wind speeds by shielding the new development, or it may speed up the local winds due to the presence of a hill or escarpment. In fact, both phenomena may occur on the same project, depending on the wind direction being studied.

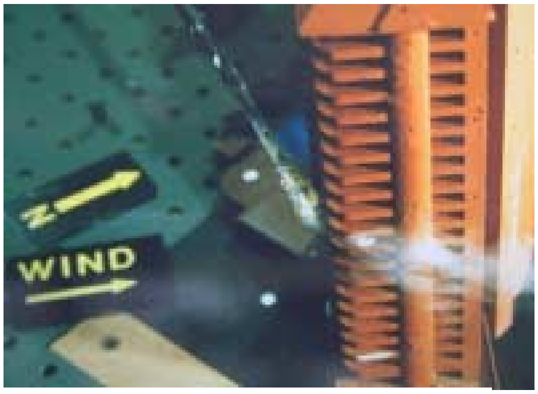

Figure 10: Strong flow through elevated corner and end balconies may diminish their usefulness.

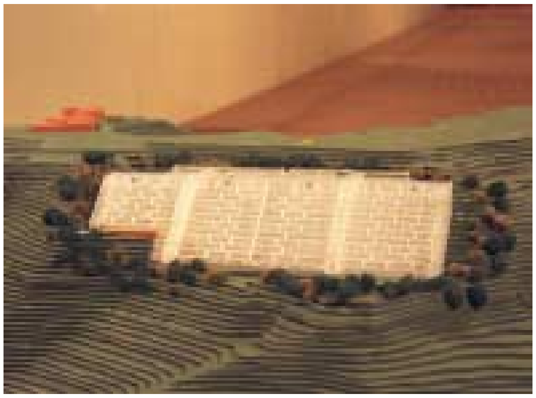

Figure 11: Filipino condominium at Lake Taal within the complex terrain of a major escarpment.

Use of Canopies, Trellises and High Canopy Foliage

Once the flow mechanism at a problem location has been established for the critical wind directions the remedial solutions may be explored for effectiveness in a boundary-layer wind tunnel. At model scales ranging from about 1:200 to 1:500, locations of interest may be investigated using a variety of techniques. One of the most common is the hot-film or hot-wire anemometer shown in Figure 12. This fine wire is uniquely suited to measuring both the mean and peak gust wind speeds at the pedestrian locations of interest due to its low thermal inertia. The hot film (more robust than a hot wire) may be fixed at the desired location for data collection, or be installed on a computer-controlled traverse for movement to sequential sites on the model (Law Flay and Barthel, 2003). As noted earlier, downwash off a tower may be deflected away from ground-level pedestrian areas by large canopies or podium blocks. The downwash then effectively impacts the canopy or podium roof rather than the public areas at the base of the tower (see Figures 5 and 6). Provided that the podium roof area is not intended for long-term recreational use (e.g. swimming pool, tennis court or putting green), this massing method is typically quite successful. However, some large recreational areas may need the wind to be deflected away without blocking the sun (e.g. the pool deck in Figure 1), and so a large canopy is not an option. Downwash deflected over expansive decks like these may often be improved by installing elevated trellis structures (Figure 14) or a dense network of trees to create a high, bushy canopy (Figure 13) over the long-term recreational areas. Various architecturally acceptable ideas may be explored in the wind tunnel prior to any major financial commitment on the project site.

Figure 12: The hot-film anemometer uses variations in electrical resistance, induced by cooling due to airflow, to measure mean and peak wind speeds in the boundary-layer wind tunnel.

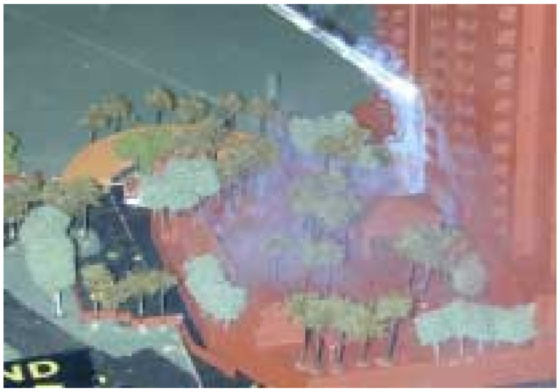

Figure 13: A porte cochere, some high-canopy foliage and a porous trellis all act to deflect the downwash off the tower.

Figure 14: A large-area porous trellis used to diminish the downwash-induced winds over a podium pool deck at a coastal Florida condominium.

Use of Landscaping Foliage and Porous or Solid Screens

Horizontally accelerated flows between two tall towers (Figure 15) may cause an unpleasant, windy, ground-level pedestrian environment, which could also be locally aggravated by ground topography. By inspection of the available wind data, the designer may find a dominant wind direction that can be used to align the buildings on the site so as to minimize these accelerated flows in highly trafficked pedestrian areas. In major entrance areas it is rarely an option to use extensive planting or porous screens to reduce the speed of the flow through the gap (Figure 16). However, these landscaping techniques are the preferred methodology to ameliorate winds that are principally horizontal (i.e. not the vertical downwash flow discussed previously). Extensive planting was used to improve conditions on the pool decks in Figures 17 and 19. The accelerated flow around the corner of the tower in Figure 17 was retarded using foliage and tall porous parapet screens on the podium perimeter. In Figure 19 massive planting and the use of porous screens calmed this hotel recreational area on the beach in Aruba from the very dominant easterly breezes.

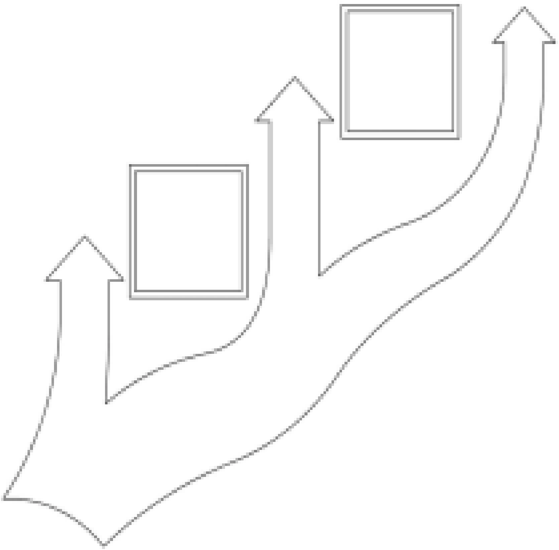

Figure 15: Wind may be accelerated horizontally between buildings with an adverse impact on pedestrians.

Figure 16: Horizontally accelerated flow between two tall towers may be minimized by judicious orientation away from dominant winds.

Horizontally accelerated flows that create a windy environment are best dealt with by using porous screens or substantial landscaping. Large hedges, bushes or other porous media serve to retard the flow and absorb the energy produced by the wind. A solidity ratio (i.e. proportion of solid area to total area) of about 60-70% has been shown to be most effective in reducing the flow's momentum (Rouse, 1950). These physical changes to the pedestrian areas are most easily evaluated by a model study in a boundary-layer wind tunnel. Figure 18 shows a tennis court that was part of a Taiwanese condominium development. By using trees to protect from key wind directions and a 3-m high porous perimeter fence, the conditions on the court were substantially improved. A comparative study showing the impact on the site with and without the ameliorative additions is a useful method of defining their effectiveness, and it also allows the architect to define the extent and usefulness of the pedestrian space. When these studies are done as part of the design process, the architect can be more assured of the success of open space, pool areas, balconies, terraces and entrances around a new project.

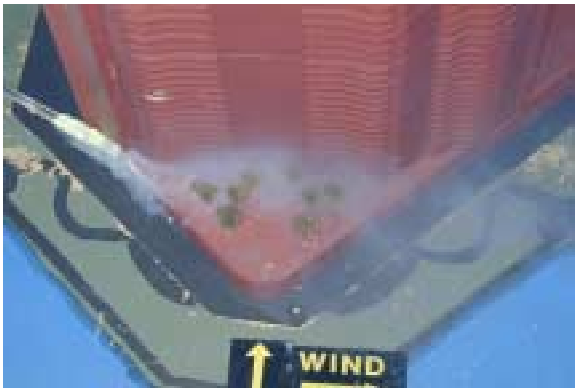

Figure 17: Accelerated flow around a tower corner washes over a pool deck.

Conclusions

In summary, there are two principal types of flow that adversely effect the pedestrian environment: (i) downwash flows bringing higher energy wind to lower elevations (usually best diminished by a podium or large canopy), and (ii) horizontally accelerated flows (often ameliorated by porous screens or plantings).

Figure 18: Foliage and porous fence were used to substantially reduce the wind speeds on this tennis court.

The wind comfort and safety of pedestrian areas around a new development may be assessed by a properly conducted wind-tunnel study, combined with direct interaction with the architect. Physical modeling of the wind flow used in conjunction with the statistical description of the ambient site winds, yields a powerful predictor of how a new project will be judged by the public, from the perspective of wind comfort, before construction commences. The knowledge gained from previous studies provides useful massing guidance to the architect in the design phase. The general massing guidelines are clearly illustrated by the line drawings, contained herein, and originally developed by Professor Jack Cermak of Colorado State University in 1980.

Figure 19: A detailed multi-phase study of a beachside hotel complex (pools, putting green, restaurant/bar etc.) with porous screens and extensive foliage.

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Figure 20: Used with artist permission, Mr. Bill E. Green, The Melbourne Age (1990).