

Non-statutory: For Guidance Only

DESIGN GUIDE FOR WIND – TABLE OF CONTENTS

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1.0 Introduction

The City of Wellington is well-known for its windy environment. This is largely due to the influence of Cook Strait which produces high winds which are more frequent than in any other lowland location in New Zealand. Gusts over 18 metres/second are experienced in Wellington on average about 150-170 days a year, compared with 90 days in Invercargill, 70 in Paraparaumu, 60 in Christchurch or 50 in Auckland.

The effects of Cook Strait and also the hills around Wellington produce prevailing winds in the City which are either northerly or southerly. The northerlies are more frequent than the southerlies, but both can produce equally severe winds. The southerlies are colder and hence more discomforting.

Some areas of the City are particularly affected by northerlies, others by southerlies. In the past, the poor design of some buildings has made this already bad situation intolerable. These buildings have created street environments where walking can be not just uncomfortable but actually dangerous.

The occasional publicity given to pedestrians being blown over, or ropes being placed along pavements for pedestrian safety, gives an indication of the seriousness but belies the extent of the problem. It is generally accepted internationally that wind gusts exceeding 15 metres/second have a very serious effect on pedestrians, and those above 23 metres/second make conditions totally unsuitable for walking. Wind gusts of 21, 22 and 23 metres/second have been recorded in the central city area.

To avoid or mitigate the adverse effects of wind, specific rules apply as conditions on permitted building development. This design guide may be read in conjunction with the rules and has the following aims:

- to help designers, developers and decision-makers to become aware of what adverse effects proposed buildings, large or small, are likely to have on wind conditions in the central area
- to give a general indication of how adverse wind effects can be reduced.

The Guide is not intended to dictate how buildings should be designed. Rather, it outlines in non-scientific terms the basics of wind effects caused by buildings and shows how particular relationships can cause or alleviate problems.

Building form and detailing can greatly affect wind-flow patterns and speeds. With an appreciation of how winds flow around buildings, designers can avoid creating high wind speeds at ground level. This is an especially important consideration for buildings proposed for exposed sites, and near significant sites such as parks.

The removal of a building from, or its introduction to, the central area may have no effect upon the wind environment, or it may reduce or increase wind conditions. A crucial factor is the building's relationship to adjacent buildings. In a complex situation such as the central city area, adequate wind reports prepared by an independent consultant are invaluable, whilst wind tunnel tests are frequently essential prerequisites to satisfactory developments.

2.0 Analysis

Safety and Comfort Aspects

Tall buildings induce changes in local ground winds. The size of these changes varies from site to site. When these wind changes happen at pedestrian level, it can make activities such as sitting, strolling, shopping, or going into a building difficult and even dangerous. In various countries it has been reported that strong pedestrian-level winds have sometimes affected the financial and operational success of new buildings. Remedial treatment for adverse winds may be necessary, and could involve substantial cost.

Safety

No matter how windy the City may be, ultimately pedestrian safety must be a major determinant of building design. The criteria for judging the acceptability of proposed development schemes should be the likelihood of danger to pedestrians - conditions at street level should not be worsened by a new building. It may be that a different building form could provide a higher degree of comfort.

Developers, designers and Council share a corporate responsibility to work towards a more sheltered urban environment. It is not sufficient merely to ensure that the streets are sheltered from winds that could knock people to the ground or blow them into the path of vehicles. The aim should be to create sheltering environments wherever possible to allow people to make the best possible use of their city, outdoors as well as indoors.

Comfort

Comfort may be considered from two aspects, wind speeds and discomfort levels.

Wind Speed

It is not the mean wind speed, but rather the peak gust wind speeds and associated changes in speed which people feel most. For some time, the concept of using peak annual three-second gusts to classify the wind environment of a site with regard to people's comfort has been used.

Although there is an obviously subjective element to a person's "comfort", and there are slight divergences of opinion amongst researchers, there is a remarkably close agreement on the general effects of winds upon people. These may be summarised as:

| | |
|------------------|--|
| 10 metres/second | generally the limit for comfort when standing or sitting for lengthy periods in open space |
| 15 metres/second | generally the limit of acceptability for comfort whilst walking |
| 18 metres/second | threshold of danger level |
| 23 metres/second | completely unsuitable for walking |

Comparative Discomfort

Whether people are comfortable on windy days depends upon several factors, including:

- wind speed - notably peak wind gusts
- the climate and the season
- the temperature, precipitation sunlight, shade and humidity
- what people are doing
- what people are wearing
- the age and psychological state of the individual.

To address all these aspects comprehensively is beyond the scope of this Design Guide. The Guide instead compares a person's comfort in the vicinity of a site with no buildings, to the same person's comfort in the same area with a building in place. From this comparison a percentage increase in wind speed around the building can be derived. Throughout this guide the percentage increase in wind speed is referred to as a percentage increase in discomfort.

Two particular phenomena are not directly included in the measures of discomfort:

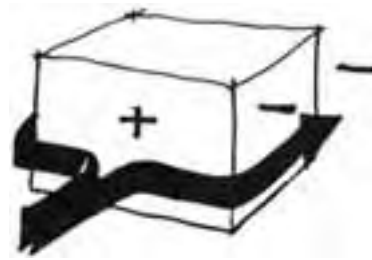
- the direction of the flow relative to pedestrians which has an especially critical effect when the flow is ascending (the "reversed umbrella" effect!)
- rapid changes in wind speed which have a showy effect on pedestrian discomfort, especially if the pedestrian is moving.

The purpose of the guide is to demonstrate clearly the degree to which a building can adversely affect the wind conditions at ground level.



The Basics of Interaction Between Buildings and Wind

Buildings form obstacles to wind flows, causing a positive pressure zone to be formed on the windward face. At the same time, a negative pressure (which forms a suction) zone is created at the sides of the building. An increase in wind velocity occurs where the two zones meet, and the wind flows from the positive to the negative.



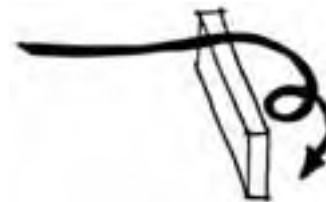
Pedestrian-level winds result from a complex reaction between the wind and the building(s), involving the building's shape, size and relationship with other buildings. Different-shaped buildings generate different wind effects.



The best approach to the problem of unpleasant pedestrian wind conditions lies in the placement and design of buildings. Buildings should not be allowed to be erected regardless of their surroundings, and tall buildings should not be built in isolation. Attention should be given to the immediate forecourt area of buildings.



One building placed to windward of another can act as a wind shield, protecting the second building. A tower block rising out of a podium, a building with substantial verandahs around it just above pedestrian height, a building which has vents through it in non-pedestrian areas to channel wind, or a building which is circular or octagonal in shape present fewer undesirable wind effects. However, even with such designs as these, it can't be assumed that further wind analysis is unnecessary, since variations of building design or the immediate environment may combine to worsen wind conditions.



It is very difficult to predict accurately the interaction between the complex and turbulent natural wind flow and a sharp-edged three-dimensional object like a building. The only currently available way to accurately predict a building's wind environment is by way of a detailed wind tunnel study. Since these are costly, the developer is often in a dilemma, undecided whether to:

- undertake a full wind tunnel test before preparing working drawings, and risk having the wind tunnel report invalidated by subsequent design changes; or
- undertake the full wind tunnel test after the preparation of working drawings, and risk the report necessitating major changes to the working drawings.

Guidance at the initial design stage can avoid the need for time-consuming and expensive major revisions. The following paragraphs summarise the likely effects of isolated buildings of simple basic form on the ground-level wind environment in their vicinity. The diagrams, and particularly the discomfort levels which are theoretical case studies undertaken overseas, are accurate only for isolated buildings. In complicated situations, such as central Wellington, it becomes much more difficult to predict the wind effects of a new building. This makes expert advice essential.

Rectangular Towers and Slab Blocks

Because the natural wind speed increases with height, the top of a tower is exposed to wind speeds and pressures that are higher than at its base. The higher pressures at the top of a rectangular building force the air to flow down its windward face, so increasing wind speeds at pedestrian level.

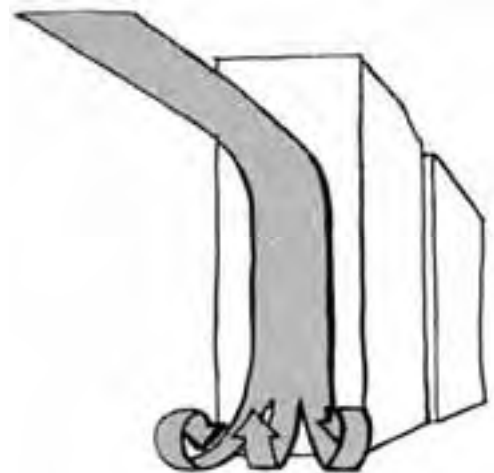
Downwash

The taller the building, the greater the pressure difference driving the wind. This phenomenon is known as downwash.

A simple rectangular building will have a zone of increased wind speed at the base of its windward face, due to downwash.

Wind flows are induced downward to street level. The effects vary with the building height, typically

- a 5-storey building will cause a 20 percent increase in discomfort level
- a 16-storey building, a 50 percent increase
- a 35-storey building, a 120 percent increase.

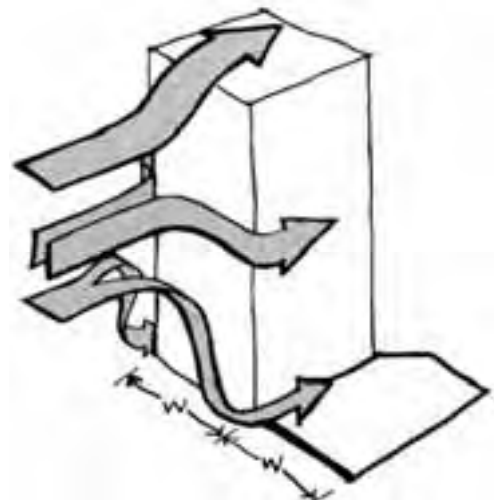


Corner Effect

The air concentrated at the base of the windward face of a building naturally flows rapidly from there around the windward corners of the building towards its relatively more sheltered sides and rear. The transition zone between high- and low-speed wind flows at these corners is small. Pedestrians crossing this zone encounter, unexpectedly and hence in a potentially dangerous way, sudden changes in wind speed. The greatest wind speeds are generated within a distance equal to the width of the building face.

The increase in discomfort levels due to the corner effect can be similar to the range experienced from the downwash effect.

One way of decreasing the corner effect is to extend the building by adjacent structures of decreasing height, achieving a "pyramid" effect. This allows most of the wind to clear the "corner" well above pedestrian level.

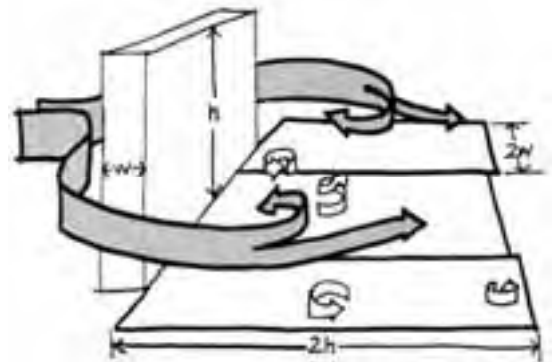
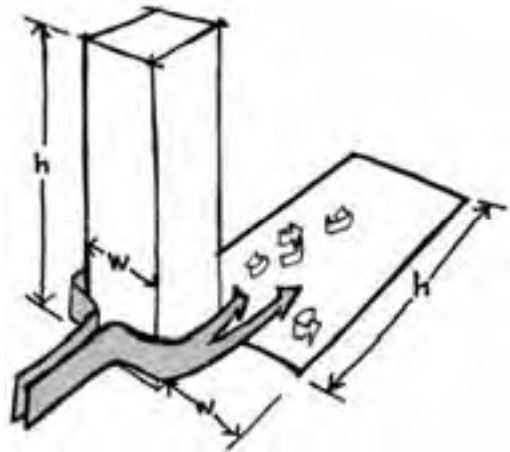


Wake Effect

Increases in wind velocities and turbulence add to the discomfort felt downwind from buildings. Much of the discomfort occurs as a result of the corner effect but it persists for a long way behind the building and can spread out, as indicated in the diagrams. Discomfort levels are worsened by increases in building height.

For example, an isolated 16-storey tower block building causes about a 40 percent increase in the level of discomfort, whereas a 30-storey building causes a 120 percent increase.

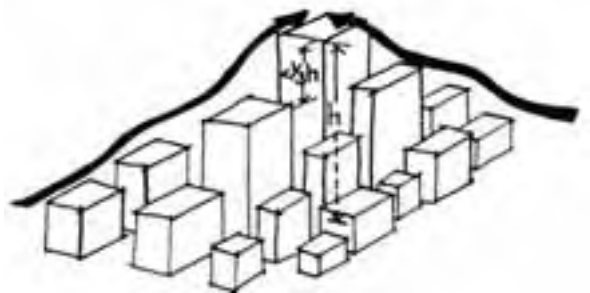
Each slab block is different in terms of the discomfort it creates and the area of ground it affects. A 16-storey slab block may increase the discomfort level by 60 percent.



Cumulative Effect

Each of the above effects is a different aspect of the same phenomenon: the interaction of a single building with the wind. When groups of buildings are being assessed, the wind effects can be cumulative.

This cumulative increase in wind speed may be substantially reduced if existing or subsequent constructions nearby are of sufficient height to give a localised stepping-down effect. This may occur where the difference in height between the obtruding building and windward adjacent buildings is less than one-third the height of the dominant building.

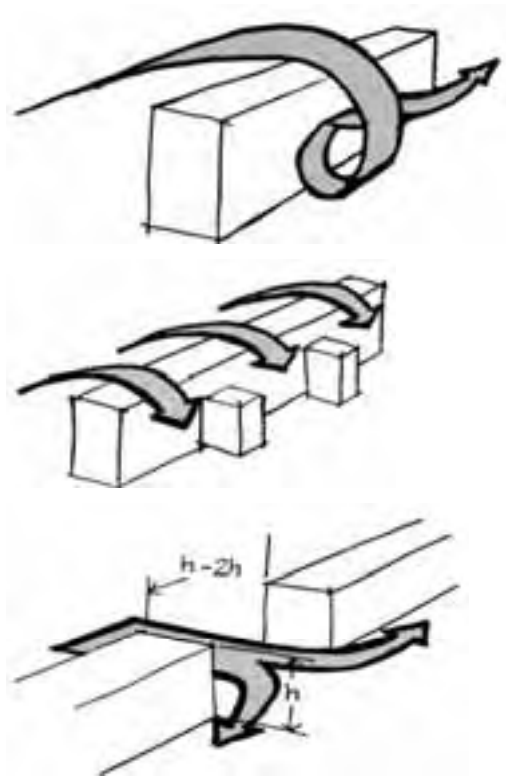


Low Bar Buildings ("Row" Effect)

Low, "bar"-shaped buildings which present wide unshielded faces exposed to any prevailing winds cause the wind to literally trip over these bars. When a building or group of buildings is narrow, less than 10 storeys high, and its length is approximately eight or more times its height, this causes a 40 percent increase in discomfort.

One way to reduce, or even cancel, the row effect is to add one or several wings to the main block, thus localising the pedestrian wind level disturbances.

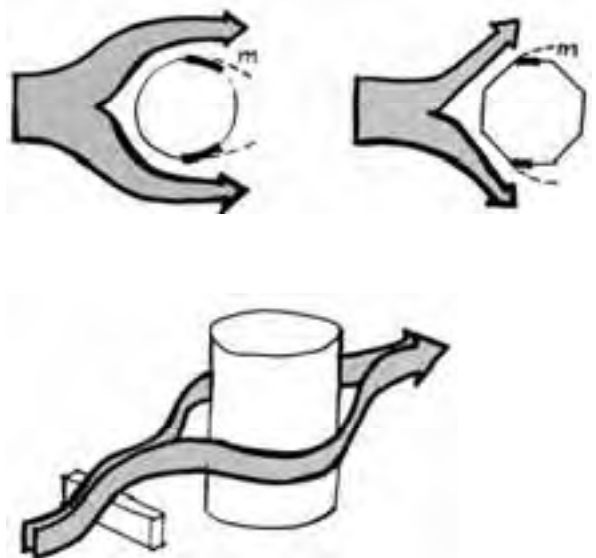
Where there are openings in the rows and the predominant wind is angled at the row, an up to 30 percent increase in discomfort level may be experienced when the width of the opening is one to two times the height of the row.



Circular Towers and Multi-sided Towers

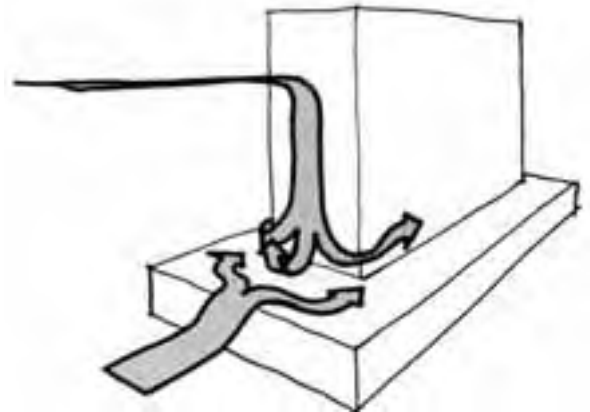
Buildings which are circular or near-circular in plan encourage the wind to flow laterally, inducing relatively little downwards flow. Circular buildings do still induce high wind speeds at the maximum width at right angles to the wind direction (m).

These wind speeds will be reduced even more if there are relatively low buildings upwind. This is in marked contrast to the earlier examples where the dominant building is rectangular, rather than circular.



Tower Podium

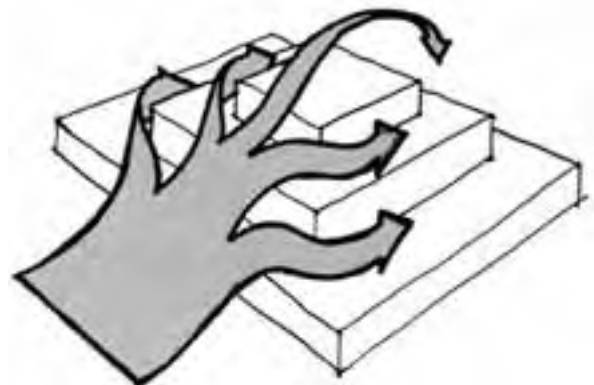
Podium bases to towers, if properly designed, can be used effectively in areas where wind problems are anticipated. In this case, the podium base deflects some of the downward wind flow before it reaches ground level. Obviously the open-air podium area should not be used for general public access.



Pyramid Effect

Buildings which step up in a pyramid-like manner do not offer a great resistance to the wind. The building's irregularities (the stepped effect of the storeys and balconies) appear to dissipate a maximum of wind energy. Problems do arise in some zones such as at windward corners (where, for example, a 13-storey pyramid produces a 60 percent increase in discomfort) and on some windward balconies.

At ground level, however, it is quite sheltered. This method of construction is especially recommended, as attention can readily be given locally to the two exposure problems of windward corners and balconies.



Interaction Between Groups of Buildings and Wind

As indicated, it is not possible to predict what the effect of a proposed building or open space will be on adjacent developments. Unexpected wind patterns can and do occur.

Low and High Buildings

When wind flows over rows of buildings of a similar height, as in older parts of a town, pedestrian areas are generally sheltered; usually considerably better than if there were no buildings at all.

However, where a low building is upstream of a high building and the high building exceeds five storeys, there are likely to be major problems/increases in discomfort at ground level.

For example, downwash from a 20-storey high building with a wide windward face will cause a 50 percent increase in discomfort at its base when the building is on its own. There would be an 80 percent increase if there were a low (eg, five-storey) building on the windward side of (and located at a distance approximately equal to the low building's height from) the tall building. And there would be a 100 percent increase in discomfort in the wake of the high building.

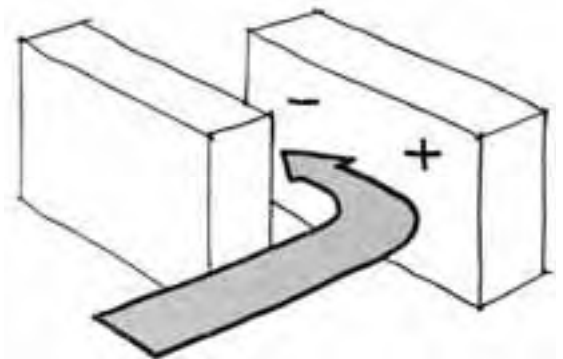
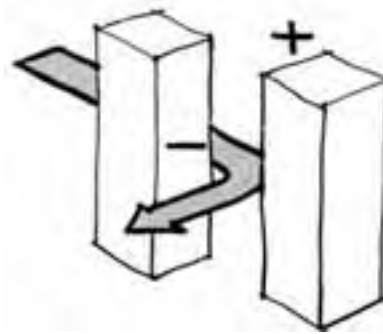


Staggered Buildings

Adjacent buildings may protect each other from high winds, or may make their wind environment worse. The buildings in the diagram opposite show an increased wind pressure on the unsheltered area (+) and a decreased pressure at the sheltered areas (-). Consequently wind rushes from the high pressure point to the low. This effect is especially important because of:

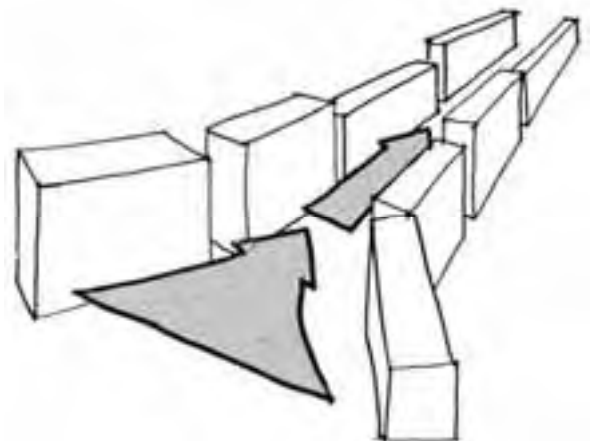
- the large area at ground level which is affected (it is related directly to the height of the buildings)
- the ways that the massing/scale of the buildings and relationship to other buildings can exacerbate the adverse wind effects. Discomfort levels are very wide-ranging, depending upon the scale and interrelationship of the staggered buildings and their neighbours.

The staggered buildings effect, especially associated with other phenomena, leads to the unexpected changes of wind direction encountered in city streets. In terms of discomfort experienced, this is a particularly bad situation.



Channel Effect

A row of buildings running more or less parallel to each other forming a channel or corridor open to the sky is not in itself a cause of discomfort, but can cause discomfort when it receives some other adverse wind conditions and transmits them for the whole length of the corridor. Adverse effects are accentuated when the corridor is well-defined (such as there being few gaps and generally standard height) and is relatively narrow (when the width between rows is less than three times the buildings' height). These effects can be reduced by the introduction of sharp changes in direction.



Funnelling Effect

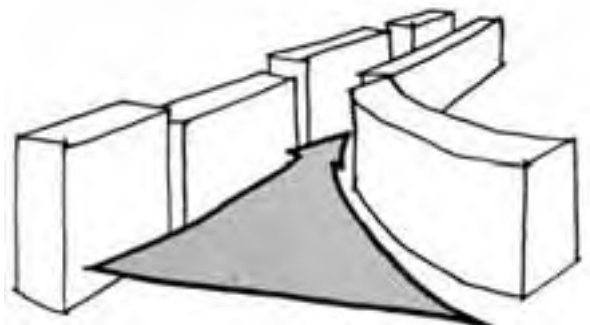
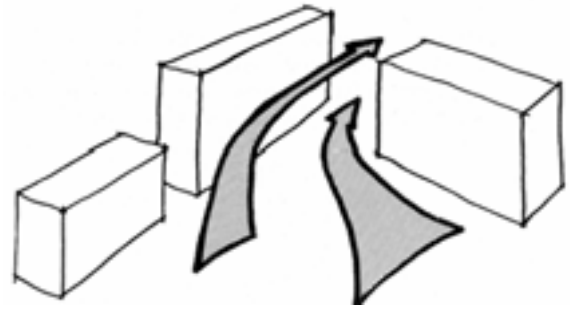
This collector, or "bottleneck", phenomenon is created by two structures with an opening between them. The axes of the two may make a right angle or an acute angle. The critical zone for comfort is at the neck.

Adverse funnelling effects occur when the relevant buildings are more than five storeys high, more than 100 metres long, and the upstream and downstream funnels are clear of obstructions.

Discomfort is worst when the width of the opening is two to three times the mean height. Buildings 8-10 storeys high cause a 30 percent increase in discomfort and buildings 18 storeys high cause a 60 percent increase.

There would be a greater adverse wind reaction where the Venturi effect applies. If, after the bottleneck, the rows of buildings diverge, then an aerodynamic nozzle is formed, the wind accelerating once past the bottleneck. In this situation, building heights of about five storeys could cause a 100 percent increase in discomfort level.

If one or more of the buildings forming the acute angle is also curved in plan, a more aerodynamic situation is created and the wind problem is increased.



Stepping Effect

Groups of buildings which present a windward face which increases continuously in height create varying pressure zones on the lee side. Differing low-pressure zones will occur behind the different buildings. An additional wind current, often at an acute angle to the prevailing wind, will be set up between these varying low-pressure areas.



Courtyard Effect

When buildings are linked together to form an open courtyard, the wind will either jump over the courtyard, or blow down into it. Four factors determine which of the two will happen:

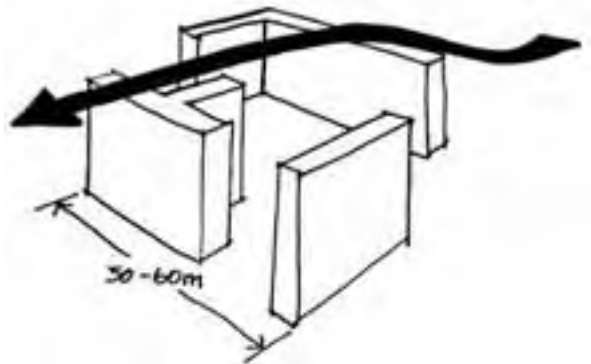
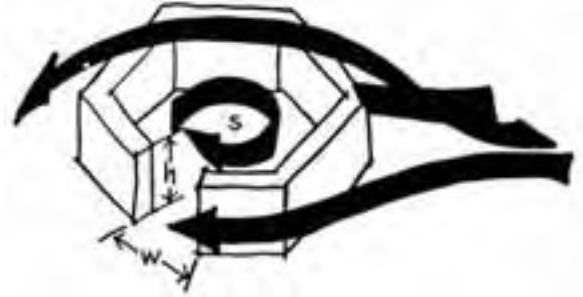
- the surface area of the courtyard (s)
- the mean height of the buildings forming the courtyard (h)
- the position of any courtyard opening with respect to the wind direction
- the width (w) of that opening, or total width of openings (w must be less than or equal to 25 percent of the total perimeter length of the linked buildings).

The protection value of the courtyard is felt when the average building height is five to eight storeys, no matter where the position of the opening is relative to the wind direction. So long as the area/height ratio (s/h^2) is no more than 10, then the courtyard area will be relatively sheltered.

When the average height of the surrounding buildings exceeds 10 storeys, the opening relative to the wind's direction plays an important part:

- when the opening is on the leeward side and the area/sheltered height ratio (s/h^2) is less than 30, the courtyard will be sheltered
- when the opening is on the windward side to within 45 degrees the air will be set into circular motion. With the opening parallel to the wind the courtyard will be sheltered.

Generally if the average height of buildings exceeds four storeys, then there will be an increase in comfort within the courtyard - even in a poorly defined courtyard system - where the system measures 50 to 60 metres across.



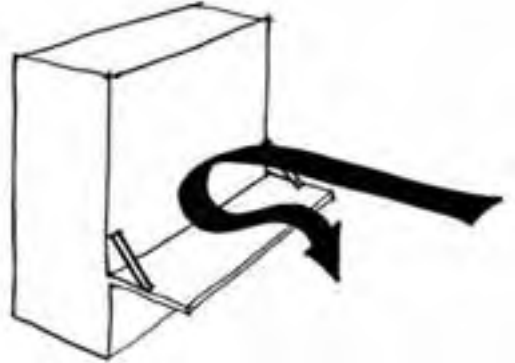
3.0 Guidelines

Architectural Detailing

Different, complex wind pressures caused by arcades, spaces under buildings or around corners can induce very rapid local flows, which give unpleasant, sometimes violent, wind effects.

Various features such as verandahs and channels on the outside of buildings can have a marked influence on combating downwash problems.

These should not be regarded as cosmetic remedies which can be subsequently applied, if necessary, to cure pedestrian-level wind problems for developments in sensitive areas. There is no adequate substitute for the careful consideration of wind design at pre-design stage. This could well consist of testing simple block forms in a wind tunnel.



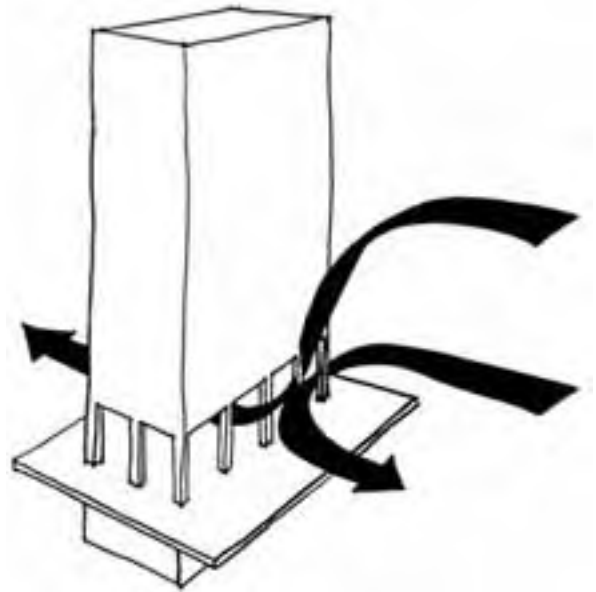
Verandahs and Canopies

Verandahs are substantial structures extending from a building to roof-in adjacent airspace, whilst canopies are minor extension covers over doorways, windows or similar.

Canopies, unless extensive, do little to protect the area from high wind speeds.

- G1** Verandahs should be used to deflect downwards-travelling wind flows, in effect lifting the vortex above pedestrian level.
- G2** They can be used in conjunction with columns, although the associated spaces should not be open to pedestrian movement.

Verandahs are not as effective for wind flows which are parallel to the building face to which they are attached. Extra problems can arise where verandahs are not continuous and large gaps between verandahs lead to additional wind currents.

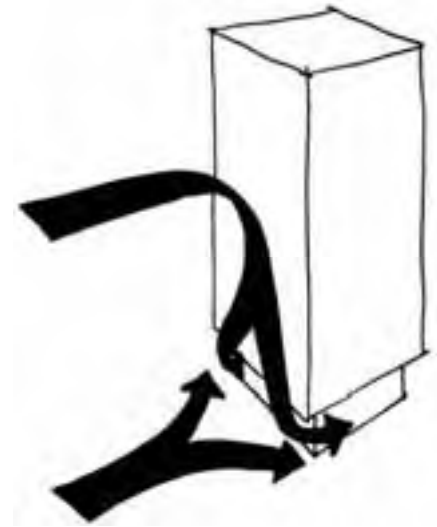


Building Setbacks

Setbacks around the building may improve the pedestrian comfort level, but usually worsen it. The effect depends on the depth and height of the setback.

Recessed entries may provide a degree of protection at pedestrian level. The degree of protection depends upon the height and depth of the recess, and the wind patterns experienced locally.

GI Particular care should be taken when a recessed corner entrance is contemplated as these may accentuate wind effects at corners.



Arcades and Colonnades

Arcades and colonnades at the base of exposed buildings can provide openings between the higher pressures of the windward face and lower pressures at ground level through which high wind speeds would be induced.

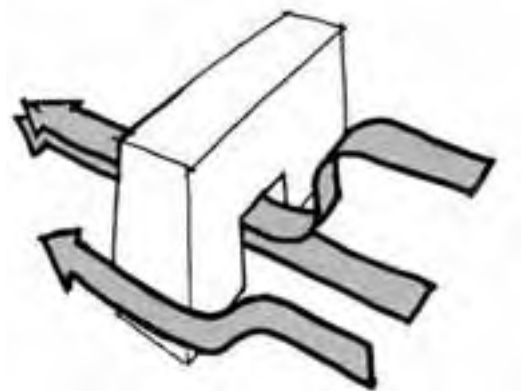
GI Arcades and colonnades should not be designed as main public access-ways, or as window-shopping precincts unless one is certain of adequate protection from wind.

Passageways and Slots through Buildings

In narrow passages designed to be used specifically for vehicular access, adverse wind conditions may be accepted more readily. The more serious impact is upon pedestrians. Ground-level passageways through buildings create a level of discomfort. The higher the building, the greater the discomfort level due to the effect of the lower pressure on the lee side:

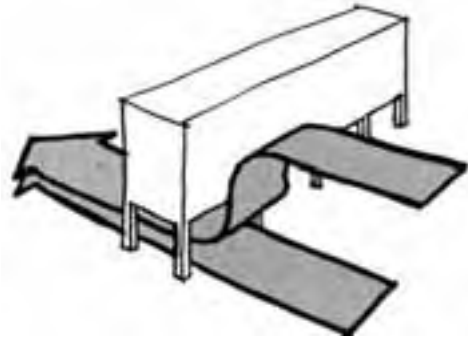
- for buildings of less than five storeys, there may be little added discomfort
- for buildings of seven storeys, a 20 percent increase may be experienced
- for buildings of 16 storeys, a 50 percent increase may occur.

GI Unprotected passageways should not be aligned with the direction of the prevailing wind.



The zone of discomfort is not confined to the passages themselves but could extend over approximately the same area as that of the opening on the lee side, the air being released in the form of a localised jet. These "slots" under buildings make for more directional airflows than when the building has guide walls or is on columns.

If the building is on columns, the deflection of wind from its face can cause discomfort levels of up to 100 percent increase around the columns. This can increase up to 200 percent if there is a low building to windward of the tall building.



G2 Areas around columns are undesirable for pedestrian usage.

Pedestrian Corridors and Foyers

The designer's responsibility for adverse wind effects does not end once wind conditions in the street have been addressed. The entrances to buildings, foyers and pedestrian corridors can also be areas where there is pedestrian discomfort or even danger.

Discomfort can be experienced both inside and outside entrance doorways. There may be a high fluctuating wind pressure outside the doorway, which creates a high pressure upon the door itself, and given the opportunity, generates a wind flow into the building. Wind whistles through gaps, and doors bang. There are both damage and safety risks, and there can be difficulty in operating doors and lifts. In extremely bad situations, it is not unknown for lift doors to jam because of the severe local wind pressure.

Increases in wind pressure can turn stairwells and corridors into unpleasant wind tunnels, and can disrupt heating and ventilation systems. Buildings adversely affected by wind may require three to four times more heating than unaffected buildings.

G1 Entrance-ways to building foyers and pedestrian corridors should be designed or located to avoid users experiencing adverse wind conditions.

Site Exposure

Whereas a building of similar height to its neighbours may be protected from large wind loads, and cause minimal pedestrian-level wind discomfort, this situation is lost when either:

- a building is introduced that is significantly taller than its neighbours
- a compatibly-sized building is demolished, to be replaced by either a relatively low building, or an open space. The degree of increase in discomfort depends upon the scale of the open space created.

The sites where simple form buildings have the greatest potential for creating adverse wind conditions are those which are in areas with drastic variations in building height. The greater the area of the windward face, the greater the potential problem, because of the absence of shelter from similar buildings.

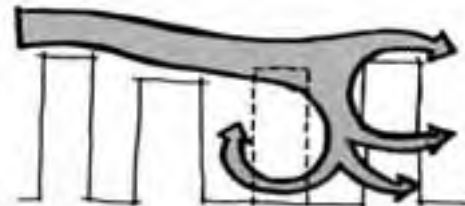
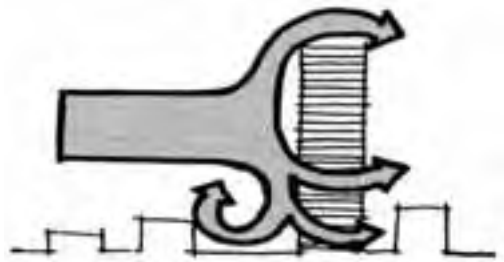
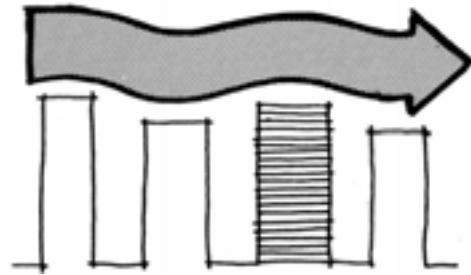
A cluster of buildings of similar height will give shelter to pedestrians within the cluster.

Buildings will induce high-velocity ground-level winds if a significant part (that is, one-third the building's height or more) is clearly above the height of buildings located upwind.

G1 Where a new building is planned the design should consider:

- the wind environment created by the surrounding buildings
- the impact the building will have on the existing wind patterns
- the impact the building will have on the balance of the site.

G2 Where there is a likelihood that re-development of adjoining sites or sites within the localised wind environment may occur designers should recognise the potential for the wind patterns effecting the building to alter, by making the building as robust as possible in relation to securing pedestrian safety and comfort.



4.0 Conclusion

The design guide gives an indication of the wind effects which may be avoided - or markedly reduced - if wind design is an important consideration during the initial stages of building design.

The guide is not intended to offer a set of answers; the subject is complex, and complicated wind patterns are experienced in the Wellington central area.

Wind tunnel tests should be an early feature of the design process.

Council's reaction to development proposals is based upon the premise that a new building should not make the wind situation worse, and performance standards have therefore been included as rules in the District Plan.

Appendix 1.

Remedial Treatment for Existing Situations

The modification of "final" drawings or subsequent alterations to existing buildings may sometimes be necessary to improve the local environment for the building's users and the general public.

Remedial treatment is never a reasonable substitute for proper consideration of wind effects at the design stage of a project.

Vegetation

The growth of trees in the area adjacent to the buildings can be prevented or distorted by the wind. However, resistant vegetation can act as a porous fence and lend a measure of protection, whereas a solid shield such as a wall or fence could encourage further pressure variations.

Structures

Where buildings prove to be windy after construction, various remedial works may substantially reduce the wind effects. Two approaches may be taken: people can be protected by shields, or redirected through safer areas, for example by establishing gardens and architectural features within the danger zones.

In more extreme situations, the second course is recommended.

- **Verandahs**

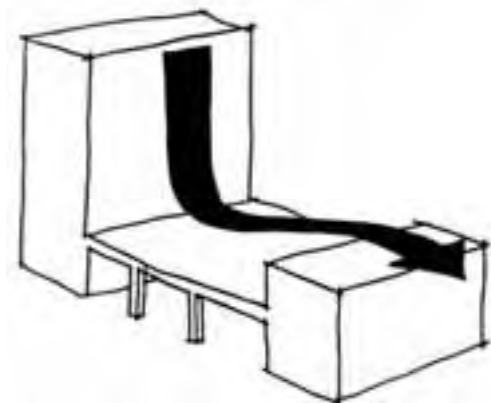
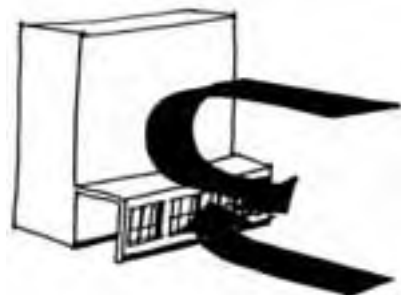
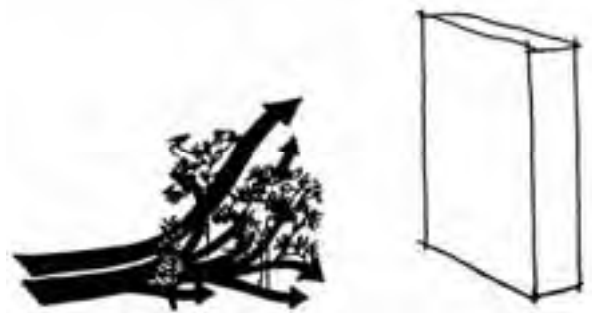
A substantial verandah may prevent high wind speeds descending to ground level. Care must be taken not to transfer the discomfort to another pedestrian area.

- **Enclosed Walkways**

The verandah can be extended by the addition of a side wall.

- **Roofing Over the Open Spaces**

High pedestrian-usage areas such as shopping precincts can be roofed over.



- **Pedestrian Corridors and Foyers**

Although enclosing the walkways improves the situation, there may be significant discomfort from winds blowing the entire length of the enclosed walkways.

These may be reduced by putting up screens, or eradicated by building doors at the end of the walkways. Although the addition of such doors will eliminate the wind problems in the corridor, there may well be major problems at the doors - people may have trouble passing through the doors, or the doors may jam. Electronic doors often cannot operate under serious wind pressures.

