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UNPLEASANT PEDESTRIAN WIND CONDITIONS AROUND BUILDINGS

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ABSTRACT

Wind velocity closed to the earth surface is quite close to zero and it increases with increase in height. However, construction of tall buildings in a locality of low-rise buildings alters the street level wind environment. The wind which strikes tall building surface get deflected towards the ground causing high speed winds on the windward side as well as near the corners of the buildings at street / pedestrian level. This leads to discomfort to the pedestrian walking and also to the cyclists and two wheeler drivers. This paper describes the comfort criteria for pedestrians within a built environment and also enumerates the recent research work done in this area.

Keywords: built environment, pedestrian level wind, comfort criteria, tall buildings

1. INTRODUCTION

When the planners prepare blue prints of an urban area, they generally consider including schools, hospital, post office, bus terminus etc. along with residential area. Children Park, shopping plaza, cinema hall, temple, church and mosque locations are also appropriately marked in the drawings. For the purpose of the transportation, planners advise different width of the roads and passages depending upon the number of lanes and use.

After the functional/architectural drawings are prepared by the architect for various types of buildings, it is the turn of the structural designer to prepare structural / construction drawings for the purpose of the execution of work. While designing those structures for different loads, the designers refer to relevant code of practice. For instance Indian Standard on Wind Loads [1] is referred for the purpose of wind loads in India.

Whereas low speed wind called 'breeze' is welcomed by the human beings, high speed winds such as gales and cyclones are not. Presence of tall buildings near low-rise ones may alter wind environment resulting in unpleasant wind conditions around tall buildings. While planning a human settlement, it is therefore, essential to consider this aspect in order to

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avoid wind-induced discomfort.

2. DESIGN FOR WIND LOADS

While designing a building or other structure for wind loads, Indian Standard on Wind Loads [1] is referred. As per this code, the design wind load or force on a structure is determined as

$$F= A\times P \tag{1}$$

where F= wind force,
P= wind pressure acting uniformly on area A.

The wind pressure, P, is related to the design wind velocity, V_d, as

$$P=0.5\ C_p\ .\rho\ .V_d^2 \tag{2}$$

where C_p = pressure coefficient which is also called shape factor,
ρ =density of air =1.2 N-sec^2/m^4.

Values for C_p can be obtained from national codes on wind loads and various books on the same. In case of buildings with openings, which causes internal pressure, C_p is given as

$$C_p= C_{pe} - C_{pi} \tag{3}$$

where C_{pe} = external pressure coefficient,
C_{pi} = internal pressure coefficient.

Therefore,

$$P= 0.6\ (C_{pe} - C_{pi})\ .V_d^2 \tag{4}$$

Value of wind velocity ,V_d, for design purpose is evaluated from the value of basic wind speed, V_b, which depends upon the locality where the building is to be constructed. National codes of various countries divide their respective country into various zones and recommend values of V_b for those zones. V_b thus obtained is modified using modification factors namely k_1, k_2 and k_3 to obtain V_d as

$$V_d= V_b.\ k_1.\ k_2\ .k_3 \tag{5}$$

The standard [1] enlists values of modification factors. k_1, risk coefficient (probability factor), depends upon class and the design life of the structure. Value of k_1 ranges from 0.67 to 1.08. k_2, terrain, height and size factor, depends on the class of the structure and terrain category of the particular location. Its value ranges from 0.67 to 1.40. As far as k_3, topography factor is concerned, it is depending upon the upwind slope of the site and the value varies from 1.00 to 1.36.

3. PEDESTRIAN LEVEL WIND

As can be seen in Figure1, wind velocity closed to the earth surface is quite close to zero and it increases with increase in height. The height above which there is a constant velocity is called boundary layer depth and corresponding velocity of wind is known as free stream velocity. However, construction of tall buildings in a locality of low-rise buildings alters the street level wind environment. The wind which strikes tall building surface get deflected towards the ground causing high speed winds on the windward side as well as near the corners of the buildings at street / pedestrian level (Figure 2).

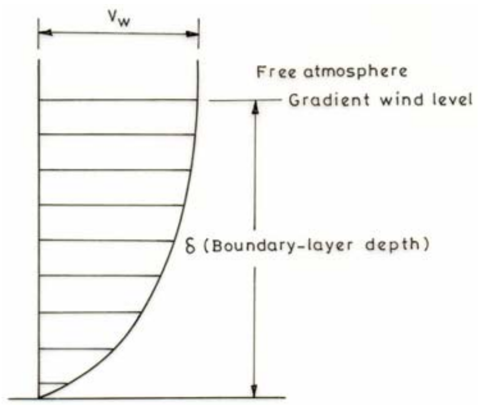

Figure 1. The atmospheric boundary layer [2]

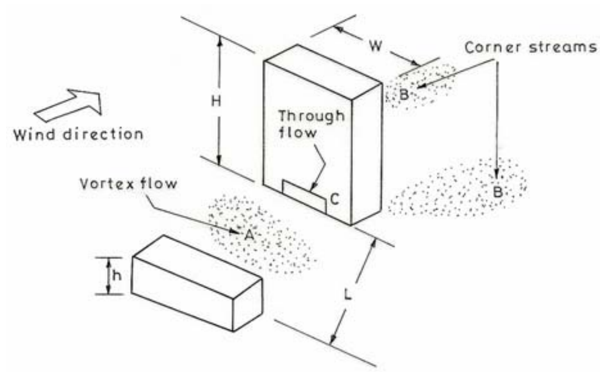

Figure 2. Regions of high surface wind speeds around a tall building [2]

4. COMFORT CRITERIA

As mentioned above, presence of one or few tall buildings near a group of low-rise buildings result in high speed wind in the passages and streets around tall buildings. This leads to discomfort to the pedestrian walking and also to the cyclists and two wheeler drivers.

Comfort or discomfort is an abstract as well as relative phenomena. It is not possible to exactly define comfort or discomfort level of various physical quantities like temperature, humidity and wind speed. Whereas an individual may feel quite comfortable at a temperature and humidity condition, another individual may complain for his/her discomfort. Similarly wind speed, which may cause discomfort to one person may be accepted by another person without any complain.

It is not only a particular value of wind speed, which may cause discomfort, but there are other parameters which combinely result in discomfort. They include gustiness, duration, mean wind speed, frequency of occurrence and also the fact that the mean wind speed is achieved in a short duration, i.e. relatively sudden or over a long duration.

Generally a wind speed (V) above 5m/s is considered as uncomfortable wind speed. However wind speed above 10 m/s definitely causes unpleasantness and a speed above 20 m/s is dangerous (Table 1).

Table 1. Summary of wind effects [2]

Description of wind	Speed (m/sec)	Description of wind effects
Calm	Less than 0.4	No noticeable wind.
Light airs	0.4-1.5	No noticeable wind.
Light breeze	1.6-3.3	Wind felt on face.
Gentle breeze	3.4-5.4	Wind extends light flag.
		Hair is disturbed.
		Clothing flaps.
Moderate breeze	5.5-7.9	Wind raises dust, dry soil, and loose paper. Hair disarranged.
Fresh breeze	8.0-10.7	Force of wind felt on body.
		Drifting snow becomes airborne.
		Limit of agreeable wind on land.
Strong breeze	10.8-13.8	Umbrellas used with difficulty.
		Hair blown straight.
		Difficulty to walk steadily.
		Wind noise on ears unpleasant.
		Windborne snow above head height (blizzard).
Moderate gale	13.9-17.1	Inconvenience felt when walking.
Fresh gale	17.2-20.7	Generally impedes progress.
		Great difficulty with balance in gusts.
Strong gale	20.8-24.4	People blown over by gusts.

As mentioned above, experiments carried out by researchers suggest that the discomfort is not only a function of the mean speed (V), but of wind gustiness as well. It is therefore reasonable, in principle, to study wind effects on people in terms of an effective wind speed V_e defined as follows.

$$V_e = V\,[1+kV_{rms}/V] \tag{6}$$

where V = mean wind speed,
V_{rms}= r.m.s velocity of longitudinal velocity fluctuation,
k = constant reflecting the degree to which the effects of the fluctuations are significant.

According to the results obtained during the study, value of K may vary between 1 and 3. As a result, following criteria is suggested to measure wind induced discomfort [2].

V_e = 6 m/s ….. onset of discomfort, V_e = 15 m/s ….. control of walking affected,
V_e = 9 m/s ….. performance affected, V_e = 20 m/s ….. dangerous.

5. WIND TUNNEL STUDIES

Review of codes of practice of various countries dealing with wind load indicates that there is no such provision to consider an unwind speed in the streets and passages due to the construction of tall buildings in the vicinity of low rise buildings. However, some researchers have carried out experimental study in the wind tunnels in order to suggest certain norms of building planning in order to avoid pedestrian discomfort [3-8].

Cochran [6-7] has given in details the design features of the buildings in general and of high rise buildings in particular, which might cause discomfort to the pedestrians moving around such buildings. The author has also suggested the remedial measures, as detailed below, so as to minimize the discomfort.

5.1 Local topography

Local topography is one of the factors, which will have an impact on the wind conditions around a building.

5.2 Downwash

When a stream of wind strikes the surface of a tall building, a large portion of it will move downward thus reaching to the level of street / pedestrian, the mechanism being called as downwash (Figure 3). Ground-level corners of the building (Figure 4) are also subjected to high wind due to this reason.

5.3 Effect of canopy

In high wind area, once the wind reaches the ground it is then accelerated around the ground-level corners. 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. But, this approach may have the effect of transferring the breezy conditions to the other side of the street. The large canopies are a common feature near the main entrance of office buildings (Figure 5).

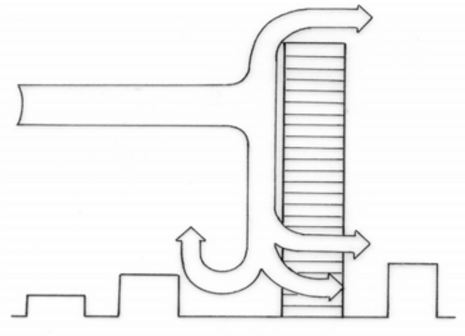

Figure 3. Downwash to street level [6]

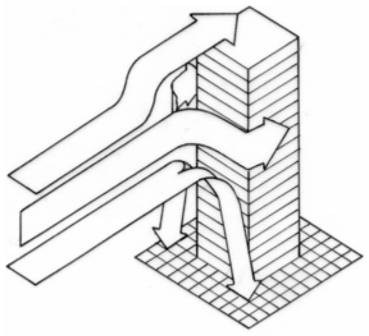

Figure 4. High wind at the ground-level corners [6]

5.4 Effect of podium

High-rise buildings may be provided with a raised platform i.e. a podium (Figure 6), if there is sufficient land and it complies with the design mandate. This will reduce wind speed at the pedestrian level. However, it may be counterproductive if the architect wishes to use the podium roof for long-term activity such as pool or tennis court.

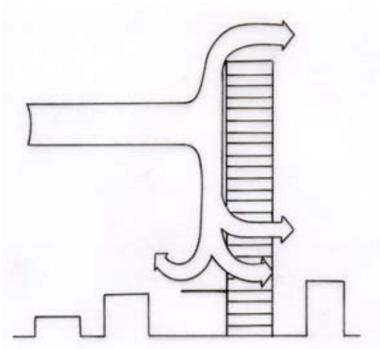

Figure 5. A large canopy as a solution to the pedestrian-wind problem [6]

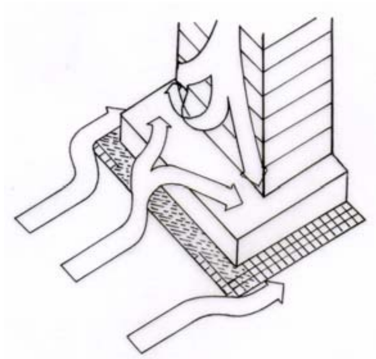

Figure 6. The Tower-on-podium [6]

5.5 Effect of arcade

An arcade or thoroughfare opening from one side of the building to the other (Figure 7) effectively connects a positive pressure region on the windward side with a negative pressure region on the leeward side. It often results in a strong flow through the opening. Similar phenomenon occurs with a high-rise building is raised up on columns.

5.6 Effect of alcove entrance

An entrance alcove behind the building line at a mid building location (Figure 8) will generally produce a calmer entrance area. In some cases a canopy may not be necessary with this scenario, depending on the local geometry and directional wind characteristics.

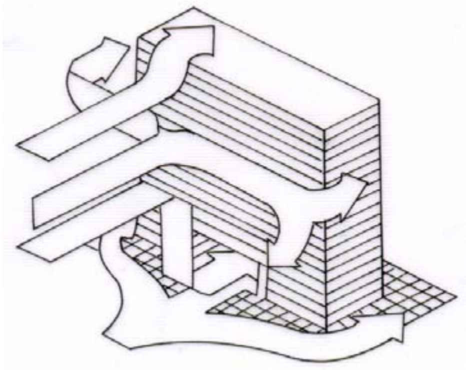

Figure 7. An arcade in a building [6]

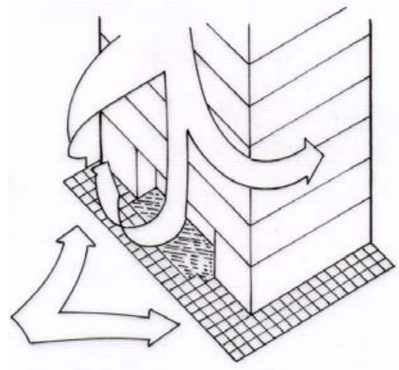

Figure 8. A mid-building alcove entrance [6]

5.7 Effect of corner cut

The architects prefer to provide entrance door to a building fronting on two adjacent streets by making a cut at the corner of the building (Figure 9). If there is strong directional wind preference at the city under 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 the local building geometry and the strong winds that may occur in the city, both influencing the exposed corner entrance.

5.8 Effect of landscaping

Horizontally accelerated flows between two tall towers may cause an unpleasant windy ground level pedestrian environment (Figure 10), which could also be 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 building on the site so as minimize these accelerated flows in highly populated pedestrian areas. Use of porous screens and proper plantation can also improve wind environment.

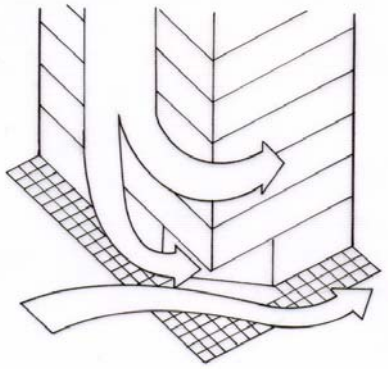

Figure 9. Accelerated corner flow from down-

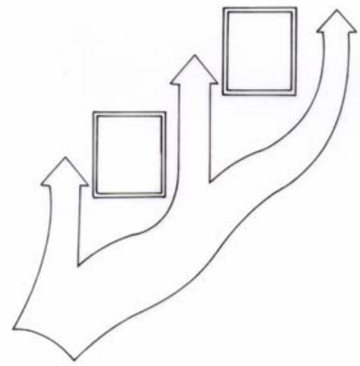

Figure 10. Accelerated horizontal wind

wash [6] between buildings [6]

6. CONCLUSIONS

From the description given in this paper, following conclusions are drawn with regard to wind-induced discomfort.

1. 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. The knowledge gained from the studies provides useful guidance to the architect in the design phase.
2. There are two principal types of flow that adversely affect the pedestrian environment i.e. (i) downwash flow bringing higher energy wind to lower elevations and (ii) horizontally accelerated flow.
3. Provision of a large canopy at the main entrance to a tall building will develop comfortable area for pedestrian.
4. A building constructed on a podium will result in comfortable pedestrian wind condition.
5. A mid building alcove entrance (lobby) results in calm location.
6. An arcade will increase the wind velocity in the arcade portion.

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