International Journal of Engineering Research and Development
e-ISSN: 2278-067X, **p**-ISSN : 2278-800X
Volume 4, Issue 9 (November 2012), PP. 21-26

Effects of High Rise Building Complex on the Wind Flow Patterns on Surrounding Urban Pockets

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Abstract:- The urban influence on winds manifests in several ways: some act to increase wind speed, others, to decrease it and all acting to alter wind directions from the overriding weather pattern. Such influences act on weather special scales which range in size from tens of kilometres down to metres and less. The full influence of urban areas on the regional wind flow patterns has many facets. This research paper is focussed on such phenomenon associated with Wind Flows around High Rise buildings. The case taken is that of a Building Complex situated in the heart of Bhopal city and wind modelling is done with the help of WAsP software to record the Wind Flows in areas around the building complex.

Keywords:- Wind Flow Pattern, Urban Roughness, Complex Topography

INTRODUCTION

Urban Roughness acts to slow the wind, through aerodynamic drag, and increase its turbulence. Its impacts are related to the height of the roughness elements: trees, buildings, etc. that make up the city. Because cities vary greatly in the heights of their buildings, each city has its own unique roughness character. Mumbai, for example, would be rougher than Bhopal which would, in turn, be rougher than a small rural town which has few buildings over three stories. The high rise buildings in an area within the city produces localized low pressure cell relative to the suburban or rural surroundings and generate an urban wind flows that is superimposed on the regional wind field. Urban winds are most noticeable when regional winds are light such as at night, and like roughness, each high rise building complex has its own wind flow pattern around it giving it a typical wind character. When wind hits the face of the building, the flow splits and is diverted into several streams, the orientation and number depending on the angle of wind incidence relative to building edges and the "flatness" of the upwind building surface. For the simplest situation — a cube or rectangular solid — one flow path rises over the building and two go around it. The fourth diverts downward along the upwind face, eventually meeting the ground and then travelling back upstream to form a reverse eddy in the flow. When the main point of flow separation is high on the building or when the winds are strong, the downward stream can be strong enough to cause hazards — tossing debris and pushing pedestrians — along the upwind base of the building, particularly in narrow, tall urban canyons. And generally, the stronger the regional wind, the greater the building impacts within the urban canyons and around semi-isolated buildings. The situation becomes even more complex in the typical High rise complex where many different shaped buildings are situated at varying distances from each other. Urban planners and architects are concerned over the areas of strongest winds within an urban canyon, which can be strong enough to knock off feet, blow objects around, and even pull glass from windows during stormy weather. Often these areas of high winds can be fixed or reduced with engineering/architectural solutions such as adding a wind break or building addition to alter the wind flow speed or direction.

Wind Effects

Disturbance of airflow near the earth's surface creates turbulence in all directions. The Turbulence Intensity is greatest close to the surface roughness which creates it and decreases with height above ground. Reduction in wind speed upto 20% is witnessed in complex terrain areas and urban areas due to high turbulence. (Daniel V Hunt) Retardation of mean wind speed near the ground due to obstacles such as trees, buildings in case of high density areas this retardness can effect the air flow up-to height of 1600 feet known as gradient height. (Ansley 1998). Fig.1

The Wind flow characteristics variation with type of terrain is as follows:

- In less rough terrain such as suburban areas the retardation extends 1300 feet.
- In open flat terrain such as ground airports retardation extends to 1000 feet.
- In flattest terrain over open sea retards wind speed up-to a height of 800 feet. This increase in speed with height is not a linear relationship. (Fig. 1)
- In lower levels of boundary the velocity profile extends to follow a logarithmic relationship.
- While at higher levels a simple power law developed by Davenport in 1960, describes the velocity distribution.

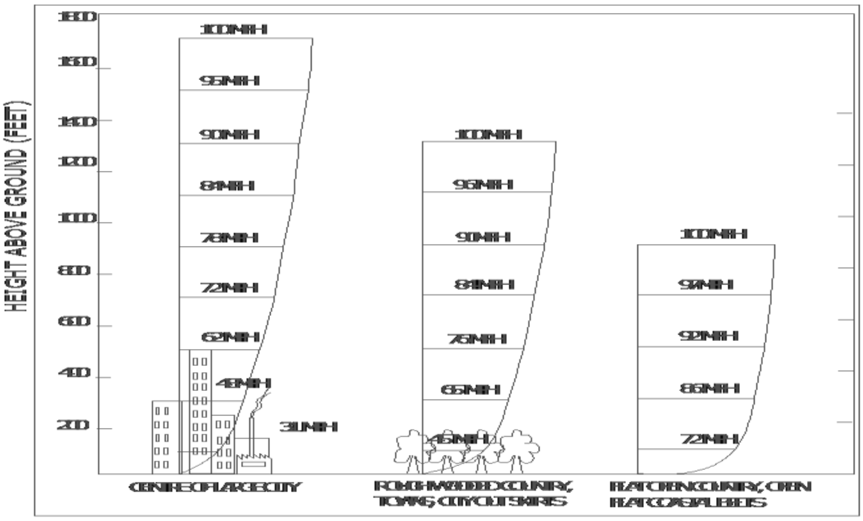


FIG. 1 The Wind Speeds at Ground and Higher Levels (Ansley1998)

Role of High Rise Buildings in Shaping the Urban Winds

Airflow around buildings with sharp corners (Bluff-bodies) can be divided into three regions. They are the undisturbed flow region, the wake region and the leeward side and the turbulent shear layers that separate these two major flow regions. Static pressure- local atmospheric pressure extending to 500 miles up from the surface of the earth. Static pressure acts equally in all directions. It is maximum around 14.7 psi when wind is calm in the region of high pressure. Suction or negative pressures are local air pressures in high- speed flow where static pressures fall below local atmospheric pressure.(Ansley, 1998) A stagnant point occurs when on the windward face where the flow parts to flow around both sides of a body. At stagnant points the velocity is zero, and all energy in the flow is in the form of static pressure. Stagnation points experience the maximum positive wind pressure (acting towards the surface) on a building.(2) Maximum negative wind pressures (suction, acting away from a surface) are experienced where wind speeds parallel to a surface are maximum. The highest suctions occurs downwards edges of roofs, where strong vortices form in the flow. Thus the form and shape of the building effects the wind behaviour around the roughness element. Fig.2

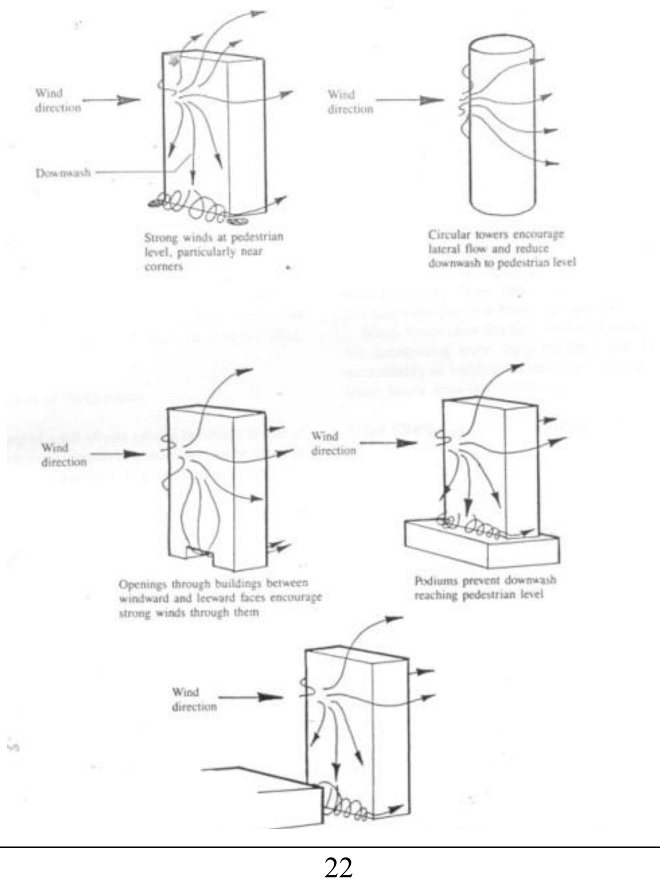


FIG.2 Effect of Wind Gusts on Streamlined and Bluff Bodies (Ansley, R. 1977)

The shape of the buildings is a prime determinant of airflow patterns around buildings. This extends from overall building geometry to projections from its surfaces such as eaves columns, beams, and floor slabs, to attached elements such as sun screens. The variety and scale of such projections prevents a detailed description, but detailed wind tunnel studies have been conducted to measure local wind pressure distributions near such architectural details. Parapet walls tends to give some protection to flat roof from high suctions generated by vortex flows at roof edges. Projecting eaves, walls and floors, slabs, used together prevent cross- flow across the surface of the windward walls. And provide more and even distribution of positive wind pressure for more efficient natural ventilation of buildings (8). Projecting floor slabs on tall buildings encourage lateral flow around buildings which minimizes flow of strong winds down windward faces. This strong downward flow referred to as downwash, can create undesirable, and sometimes even dangerous, conditions for pedestrians at street level. Projecting columns are used on tall buildings with curved surfaces to prevent streamline flow and to ensure the presence of turbulent layer of air flow near the buildings surface. Projecting columns can also create the undesirable effect of channelling strong winds down a windward face to street level. To overcome this effect podiums are often formed at the lowest few floors to deflect this downwash laterally above ground level. Before estimating the modification effects of the general wind flow, it is necessary to map the spatially continuous wind flows. Such maps can be obtained solely by using wind models. The WAsP model (Mortensen et al., 1993) developed at Risø National Laboratory, Roskilde, Denmark has been selected for this reason.

The Pilot Study: Platinum Plaza Bhopal

Platinum Plaza is a residential cum commercial High Rise Complex having 10 floors with a overall height of 10 mtrs and is considered highest buildings of Bhopal. Bhopal is the capital of the Indian state of Madhya Pradesh and the administrative headquarters of Bhopal District and Bhopal Division. The city was the capital of the former Bhopal State. Bhopal is known as the City of Lakes for its various natural as well as artificial lakes and is also one of the greenest cities in India. A B-1 class city, Bhopal houses various institutions of national importance. Platinum Plaza is situated in the area developed in 1956 of this city.

Description of the Monitoring Site

Survey of India, Topo Sheet 55-E/7 -E/8 (1:50,000 Scale). has been obtained from the Geological Survey of India in which the contours of the site near Bhopal are shown. This site has been chosen for the study (Fig. 3). The site under consideration covers an area of approximately 56 square kilometres in linear topography, interspersed with thick vegetation roads and urban dwellings. These areas were marked off separately in the vector map giving roughness values as defined by WAsP and given in Table 1.The map of the whole area was digitised.

Fig. 3 Study Site with Platinum Plaza and 12 samples in four cardinal directions

Table 1. Roughness class and terrain surface characteristics

*z*0 [m]	Terrain surface characteristics
1.0	Urban areas with moderate building density
0.8	Semi Urban areas
0.50	Suburbs
0.20	many trees and/or bushes
0.10	farmland with closed appearance
0.005	bare soil (smooth)

0.0001	water areas (lakes, open sea)

Preparation of Vector Map

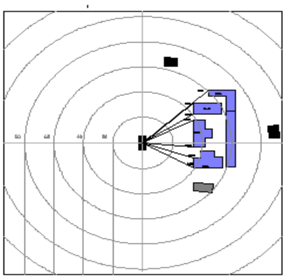
(Mortensen et al) have reported that it is possible to obtain accurate assessment of stable wind flows which are close to the measured values with maps of 8 x 8 sq. km and the influence of contour interval on the accuracy of wind speed prediction [5]. Prediction errors can be reduced with smaller contour intervals with a contour interval of 20 m or less. In the present study area within 500 mtrs around Platinum Plaza has been considered. The topography map has been obtained from Geological Survey of India and the detailed surface features based on aerial photography conducted by the National Remote Sensing Agency were available as 2 x 2 sq. km tiles in the AutoCAD dwg format. These 6 layer map provide contours at 1 m intervals, trees, buildings, temples, tombs, electric and telegraph poles, waterways, marshy areas, roads, footpaths etc in different layers. Information relevant to WAsP, namely contours, open areas, trees, water bodies and buildings were retained by switching off the unwanted layers. Such tiles were joined together in the AutoCAD software and saved as dxf files (drawing exchange format), which could be imported into the WAsP Map Editor. In this study, contour intervals at 5 m were retained and imported into the WAsP Map Editor for calculating the wind flows throughout the area. The map was transformed to the Universal Transverse Mercator (UTM) projection with the datum of WGS 1984. The area falls in Zone 43 with the central meridian of +75° E.

Specifying obstacles near measuring site

For the study 12 buildings structures situated in four cardinal directions around Platinum plaza were selected out of which one in cardinal direction was modelled taking Platinum Plaza as an obstacle . Obstacle present near the measuring site affect the wind data collected and it depends Upon Building porosity and roughness of the area. Obstacles are considered by WAsP as ―boxes" with a rectangular cross-section and footprint. Obstacle must be specified by its position relative to the site and its dimensions and must be assigned a porosity value. The position of an obstacle is specified in a local, polar coordinate system. Angles (bearings measured with a compass) are given clockwise from north; distance is the radial length from the site to the corner of the obstacle (measured with a measuring tape or a range finder). The list and location of obstacles for the wind monitoring station for incorporation as a WAsP obstacle file is shown in Table 2 and the plot shown in Fig. 4. As a general rule, the porosity can be set equal to zero for buildings and ~ 0.5 for trees. A row of similar buildings with a separation between them of one third the length of a building will have a porosity of about 0.33. For windbreaks the characteristics defined in WAsP may be applied. The porosity of trees changes with the level of foliation, i.e. the time of year and similar to the roughness length, the porosity should be considered as a climatologically influenced parameter.

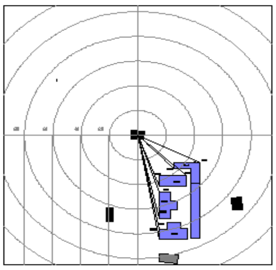
Observation and conclusions from the study

It is seen from the analysis of observed wind Flow Patterns for the six peak wind months for the site that the site is endowed different kind of wind patterns around it. However, it is also seen that the average wind speed calculated for different months owing to uneven wind speed distribution due to a strong influence of the Obstacle Platinum Plaza in the urban area is modifying the wind flow patterns. The wind rose showing the wind direction, duration and speed are shown in table 2 with their associated wind climate chart. For the sample 1 situated on the East of Platinum Plaza wind flow from modelling shows that there is disturbed wind showing turbulence and sudden fluxes of wind. Fig. 4 sample 1 For sample 2 situated on the North of Platinum Plaza wind flow from modelling shows that there is increase of 90% in the wind speed as compared to the prevailing wind the direction remains the same from west Fig. 4 sample 2 For sample 3 situated on the West of platinum Plaza there was a reverse flow of wind, the wind was blowing from East direction where as the velocity was reduced to 20% of the prevailing wind. Fig. 4 sample 3 For sample 4 situated on the South of Platinum Plaza wind flow from modelling shows that there is increase of 90% in the wind speed as compared to the prevailing wind the direction remains the same from west. Fig. 4 sample 4.



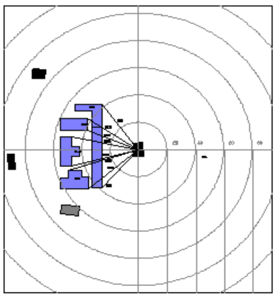
Sample 1

sample	A1 [°]	R[1] Distance from site [m]	A2 [°]	R[2] Distance from site [m]	Height [m]	Depth [m] greater value	Porosity
Obs1	227	61	--	--	12	12	0.33
Obs2	227	45	236	42	30	12	0.33
obs3	242	36	274	34	30	9	0.33
Obs4	289	35	298	39	30	12	0.33



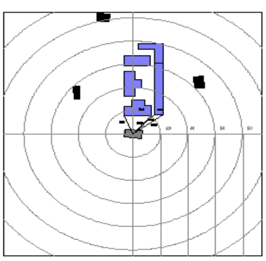
Sample 2

sample	A1 [°]	R[1] Distance from site [m]	A2 [°]	R[2] Distance from site [m]	Height [m]	Depth [m] greater value	Porosity
Obs1	297	51	317	36	12	12	0.33
Obs2	314	47	340	42	30	12	0.33
obs3	342	44	346	64	30	15	0.33
Obs4	349	76	351	83	30	12	0.33



Sample 3

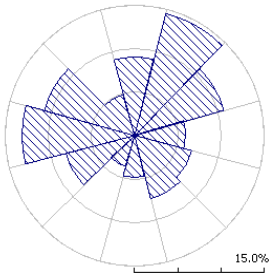
sample	A1 [°]	R[1] Distance from site [m]	A2 [°]	R[2] Distance from site [m]	Height [m]	Depth [m] greater value	Porosity
Obs1	142	41	42	39	12	12	0.33
Obs2	122	42	112	37	30	12	0.33
obs3	102	46	75	44	30	15	0.33
Obs4	72	56	51	46	30	12	0.33

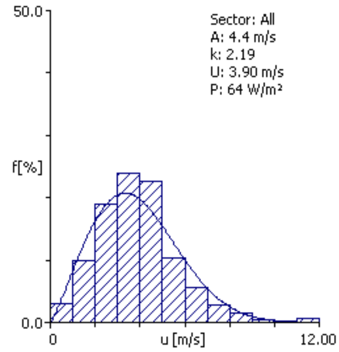


Sample4

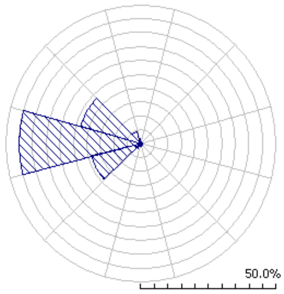
sample	A1 [°]	R[1] Distance from site [m]	A2 [°]	R[2] Distance from site [m]	Height [m]	Depth [m] greater value	Porosity
Obs1	158	15	220	21	12	12	0.33
Obs2	225	23	234	29	30	28	0.33

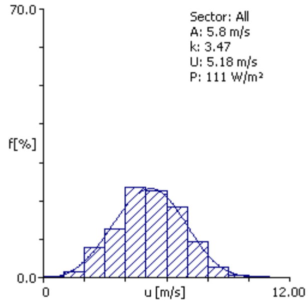
Fig 4. WAsP Plot of platinum Plaza and four samples



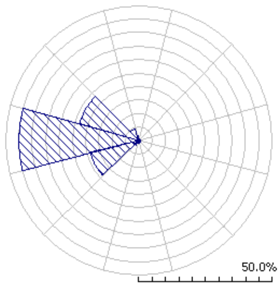


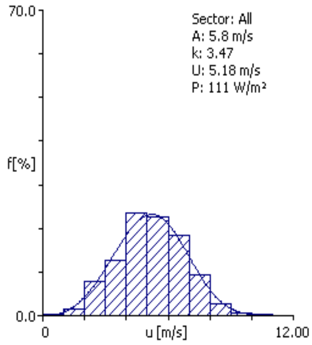
Observed wind Climate for Sample 1



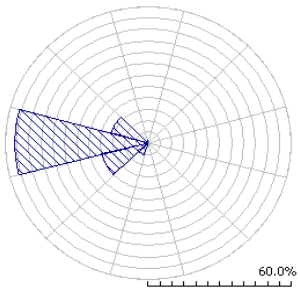


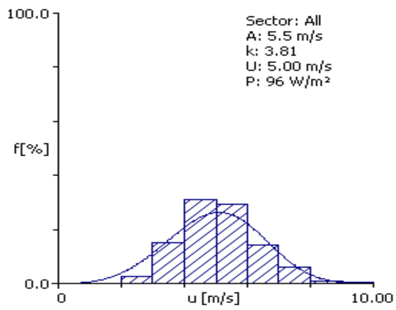
Observed wind Climate for Sample 2





Observed wind Climate for Sample 3





Observed wind Climate for Sample 4

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