THE INFLUENCE OF THE NATURAL WIND ON THE EFFICIENCY OF ROOF LEVEL INTAKES FOR PRESSURIZATION SYSTEM

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ABSTRACT

The wind induced pressures on a roof may reduce the efficiency of a pressurization system. A simple model building was used to determine the pressure coefficients on the roof surface for several wind directions with and without a parapet. The model was placed in an open jet wind tunnel for the measurement of pressure and the observation of flow(s). Pressure coefficient contours are presented and the results indicate the possibility of a complete failure for both positive and negative induced wind pressures.

INTRODUCTION

The effect of natural wind on smoke control systems has been investigated widely by wind tunnel studies over the past several years[2-5]. An amount of data on pressure coefficients has been collected for buildings of sample geometry[6-7].

Pressurization system for smoke control in building require significant quantities of fresh air, it is essential that the air supply used should never be in danger of contamination by smoke from a fire in the building. Two locations for air intakes are suggested in the code[1] for the design of pressurization systems. These locations are near to ground level and at roof level. The air intake from near ground level normally works effectively in all situations that have a simple geometry. Air intake from the roof will have an influence on the effectiveness of pressurization system because of the adverse pressures that can be developed by the natural wind.

WIND TUNNEL AND MODEL CHARACTERISTICS

The model building was designed to be tested in the open-jet type wind tunnel which is shown in Fig.1. The elliptical wedges and the rectangular blocks generate a turbulence and a velocity profile at the opening that is similar to the properties of the natural wind in an urban location [3]. A working table was placed immediately downstream of the opening.

The basic dimensions of the model building are shown in Fig.2. holes were available at the different locations of air intake for the pressurization system. A parapet of 30mm high was fitted to two sides of the roof. As the scale of the model building was about 1:30 the

30mm parapet represents a real scale parapet of about 900-1000mm. The design code [1] recommends that roof level intakes for pressurization systems should be associated with 1 meter high upstands (parapets).

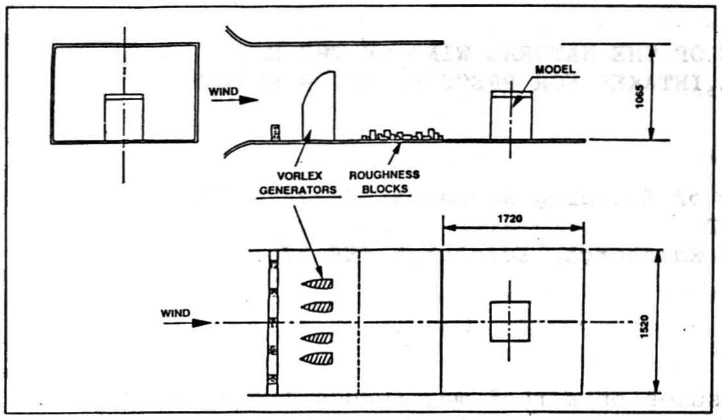


Fig.1. Wind tunnel and model layout (mm)

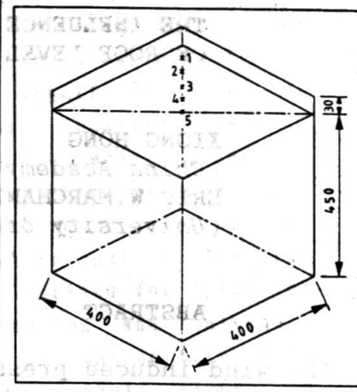


Fig.2. Building model (mm)

RESULTS AND DISCUSSION

1. The Measurements of Pressure Coefficient(C_p) at the Roof Level

The flow of wind over the roof of a building causes some areas to be under positive pressure and other area to be under negative pressure. The pressure coefficient (C_p) can be positive or negative which depending upon the geometrical relationship between the part of the building under consideration and direction of the wind. The pressure coefficient (C_p) is given by:

$$C_p = (P - P_o)/0.5*p*U_r^2 \quad (1)$$

where P is total pressure measured (Pa); Po is reference static pressure (Pa); p is density of air (Kg/m^3); U_r is reference wind speed measured at a height equal to that of the building in free wind (m/s).

The following sections describe the various distribution of pressure coefficient values over the roof:

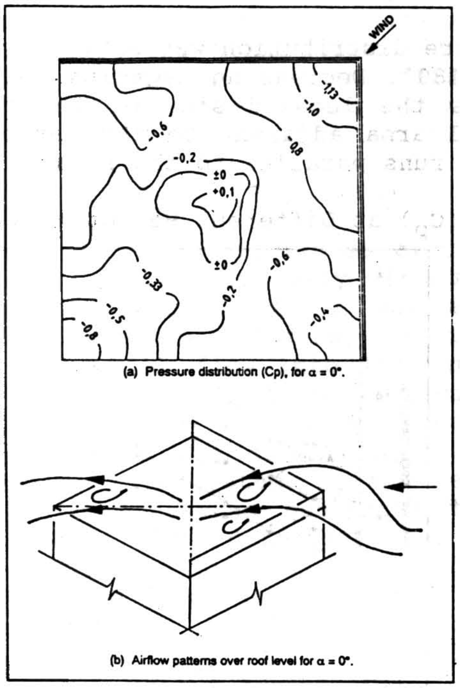
A. *Wind incidence a=0°* -- Fig.3(a) shows that the pressure coefficient values are mostly negative with a small "island" of positive pressure coefficients in the centre of the roof. The values of the negative pressure coefficients towards the enclosed corner of the parapets are the highest of the values across the roof.

The air flow pattern for this situation is given in Fig.3(b). A strong uplift of air was observed near the windward corner of roof.

B. *Wind incidence a=45°* -- Fig.4(a) shows a pressure distribution over the windward side of the roof. It is clear that the parapet provided a strong interference to the air flow causing the generation of higher negative C_p than would be expected without the presence of parapet.

Fig.4(b) gives an air flow paths for this wind direction, but the movement pattern for the windward corner was more complex than other direction.

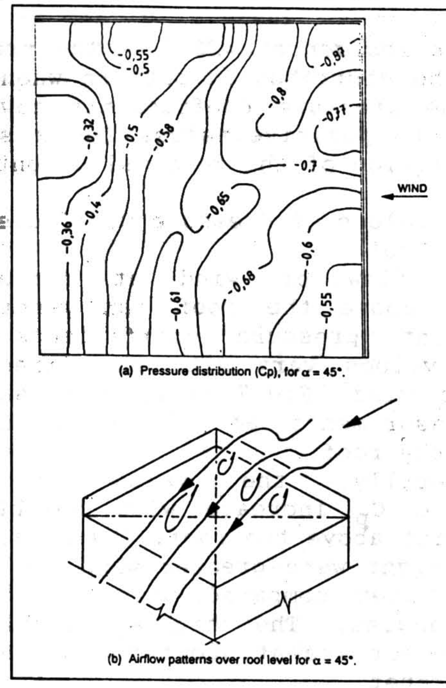
C. *Wind incidence a=180°* -- Fig.5(a) shows that both positive and negative values existed across the roof. The negative values have



(a) Pressure distribution (Cp), for α = 0°.

(b) Airflow patterns over roof level for α = 0°.

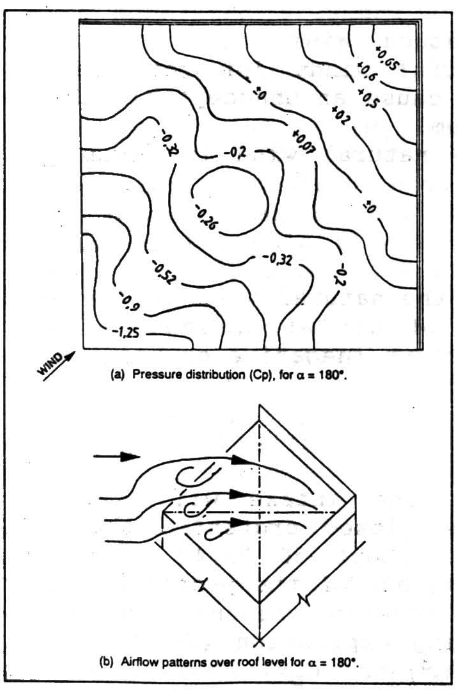
Figure 3.



(a) Pressure distribution (Cp), for α = 45°.

(b) Airflow patterns over roof level for α = 45°.

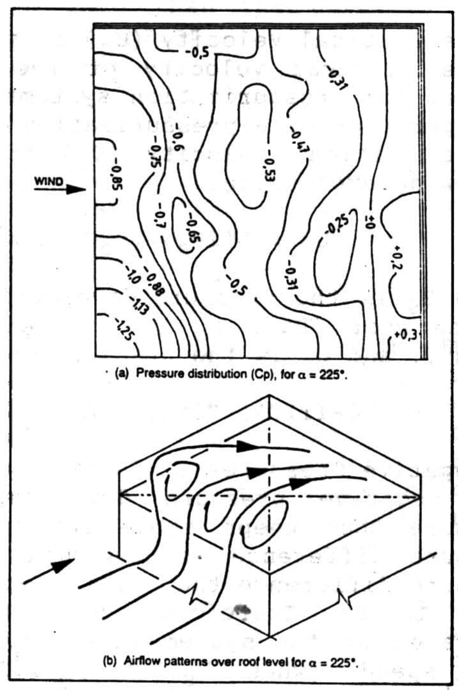
Figure 4.



(a) Pressure distribution (Cp), for α = 180°.

(b) Airflow patterns over roof level for α = 180°.

Figure 5.



(a) Pressure distribution (Cp), for α = 225°.

(b) Airflow patterns over roof level for α = 225°.

Figure 6.

generated at the windward corner, the positive pressure area on the roof surface at the leeward corner could produce an adverse pressure regime for a pressurization system.

The airflow pattern shown in Fig.5(b) indicates a strong uplift at the windward corner and streamlines pushing into the leeward corner.

D. *Wind incidence $\alpha=225^\circ$* -- The pressure distribution was similarities with the distribution pattern when $\alpha=180^\circ$. Decreasing negative values for the pressure coefficients towards the leeward side of the roof change to positive values for a small area adjacent to the parapet. The position of the zero value contour runs parallel to the parapet.

2. The Values of Pressure Coefficient (C_p) at Different Height Above the Roof

The flow of wind at different levels above the roof can generates different pressure coefficients(C_p). These values vary with the direction of the wind. Fig.7 shows the results of measurements at different levels above the roof.

Generally, the value of the negative C_p increase with height of the point above the roof. These values with height were greater when $\alpha=0^\circ$ and $\alpha=180^\circ$ when compared with the other wind angles. The highest level of measurement was at about the height of the parapet.

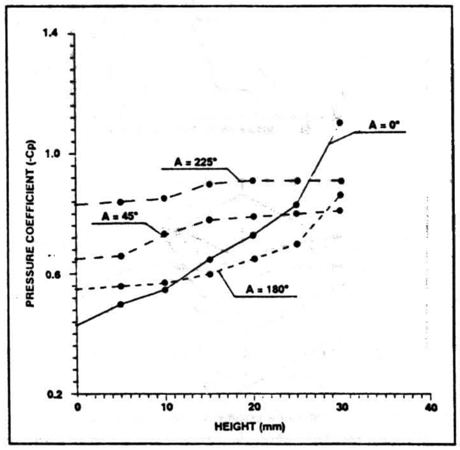


Fig.7. The graph of Cp vs various height

3. The Critical Velocity (U_c) of the Natural Wind

The critical velocity of the natural wind, for roof level air intakes for pressurization systems can cause an unacceptable change in the operation of a pressurization system.

The critical velocity (U_c) of the natural wind is given by the following expression:

$$U_c = [(2P_s)/(p_o C_p)]^{0.5} \qquad (2)$$

where P_s is the pressure developed by the natural wind on the surface of the roof (Pa); p_o is the density of air at ambient temperature (Kg/m^3); and C_p is the pressure coefficient (negative or positive).

CRITICAL CONDITIONS

1. Negative Pressures at Intake

A negative pressure developed at the intake will reduce the pressure that keeps smoke out of the closed protected shaft. This pressure difference is designed to be about 50 Pa[1]. The minimum pressure difference that will keep smoke out of the protected shaft is about 15 Pa. Therefore the maximum adverse pressure that can be tolerated by the system is 35 Pa. Using expression (2) the critical wind speed (when P_s=35Pa;p_o=1.25Kg/m^3;and C_p=1.2)would be about 6.8m/s. For wind speed less than 6.8 m/s, the condition would be "subcritical", that is the pressure difference between the protected shaft and other area would be reduced, but not less than 15 Pa.

In addition, the smoke could be introduced into the protected shaft is from the outside of the building. For example, during a fire the glass in the window of the fire room is mostly to break and smoke will flow out of the building and will be dispersed by the wind. However, on the windward side of the building the smoke may flow upwards; then be blown over the parapet towards and around the intake for the pressurization system. If the overall pressure regime at the inlet is:

$$|P_3| > |P_1| > |P_2|$$

then smoke that has flowed over the parapet will flow away from the intake location, into a volume of higher negative pressure, and fresh air can still flow into the intake for the pressurization system. In Fig.8. the P_1 is the pressure developed by the fan system for a pressurization system; P_2 and P_3 are the wind pressures generated which are point at different heights, above the same location.

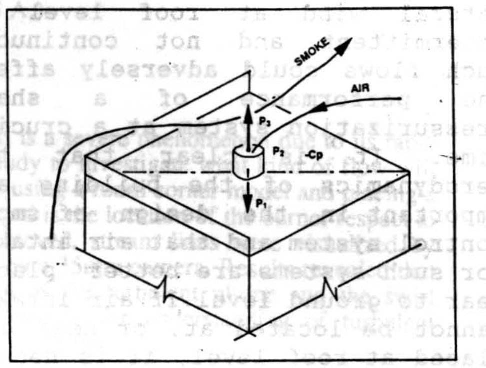


Fig.8. For negative Cp condition at the roof level.

A second condition could exist where:

$$|P_1| > |P_3| > |P_2|$$

Here, it can be assumed that the external smoke is flowing at P_3. As the wind generated pressure could be zero then the external stray smoke could mix the fresh air at the intake point.

A third possible condition could be when:

$$|P_3| > |P_2| > |P_1|$$

This condition suggests a high wind speed will generate a negative pressure higher than 50 Pa, that is faster than 8.2 m/s. In this condition no air would flow into the pressurization system and smoke in the accommodation may flow into the staircase.

2. Positive Pressures at Intake

As with the negative pressure regimes, two modes of failure associated with the flow of the natural wind can be distinguished. Firstly, there is the possibility that the additional pressure from the natural wind will increase the design pressure in a protected shaft although the practical limit is a pressure difference of 66 Pa. If pressure above this occur, escape though the doors onto the staircase should not be made more difficult as a pressure relief system should operate [1].

Secondly, a positive pressure regime around the inlet would encourage any smoke that flows over the parapet to flow towards the inlet and, possibly, into the protected space. An example of the unacceptable situation is given in Fig.9. With zero velocity for the external wind, or a position located on a 0 Cp contour, the velocity pressure of the air flow at an inlet for pressurizing air is about 3 Pa. Critical velocity can be reached when no flow into the building takes place. With a positive pressure area around the inlet any stray smoke flowing across the roof may be attracted to the inlet for pressurizing air.

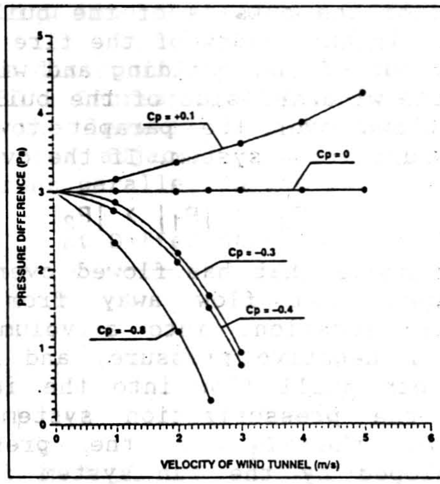


Fig.9. The graph for the pressure of extracted fan vs critical velocity.

CONCLUDING REMARKS

Although the effect of the natural wind at roof level is intermittent and not continuous such flows could adversely affect the performance of a shaft pressurization system at a crucial time. It is clear that the aerodynamics of the building are important in the design of smoke control system and that air intakes for such systems are better placed near to ground level.If air intakes cannot be located at, or near ground level and therefore need to be placed at roof level, it is necessary to design the intake opening(s) (including the local aerodynamics of the roofscape) as important features of the design process. Where inlets are subject to negative pressures, it may be necessary to fit dampers to shut the inlet or to use a cowl that reduces or eliminates the effect(s) of the negative pressure. Similarly, inlets that are under positive pressure could be fitted with smoke detectors so that the inlet is closed on detection of smoke.

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