11th Australasian Fluid Mechanics Conference
University of Tasmania, Hobart, Australia
14-18 December 1992

A FORMULA FOR PREDICTING RESULTANT COMFORT PARAMETERS AROUND AND BETWEEN BUILDINGS

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ABSTRACT

Wind tunnel measurements have been conducted on 4 of the Salford University Campus (SUC) building models in a simulated boundary layer of suburban type in the university 2.14m x 1.53m environmental wind tunnel. The comfort parameters for 8 compass point wind directions at 11 selected locations due to the interaction of wind flow with each and also with 6 combinations of these models (ie 3 groups of 2, 2 groups of 3 and one group of 4 buildings) were determined. From the analysis of these comfort parameters, a general formula for predicting the resultant comfort parameters has been established. The wind tunnel measurements, and the establishment of the general formula are summarised and discussed in this paper.

NOTATION

I	Turbulence intensity or local turbulence intensity
I_r	Turbulence intensity at the reference point
K	Ratio of the local to the reference velocities
n	Number of buildings
U	Wind velocity or wind speed or air velocity, (m/s)
U_r	Velocity at reference point, (m/s)
ψ	Comfort parameter at pedestrian level
ψ_i	Comfort parameter at particular location
ψ_r	Resultant comfort parameter.

INTRODUCTION

This research concerns mainly with the finding of a suitable equation for determining the resultant comfort parameters at pedestrian level around and in between buildings due to the interaction of wind flow with any two buildings. Knowing the comfort parameters at different locations for the same area caused by two individual buildings separately, then by using this equation, the resultant comfort parameters at the same locations could be predicted when the two individual buildings are brought together. In addition, this relationship has also been tested for its suitability in finding the resultant comfort parameters due to the interaction of wind flow with two, three and four groups of buildings aiming at the establishment of a general formula. This equation will be very useful for predicting the effects on pedestrian discomfort due to the erection of a new building in the vicinity of an existing one.

EXPERIMENTAL DETAILS

4 SUC building models [Newton (N), Cockroft (C), Peel (P) and Tower (T) Buildings] were tested in a simulated boundary layer of suburban type in the university 2.14m x 1.53m environmental wind tunnel. The effects of each building, on the comfort parameters at 11 selected locations (see Figure 1) were determined by measuring the wind velocities and turbulence intensities at the different locations by using a DISA 55A01 constant temperature anemometer, and then comparing them with their corresponding values if the buildings were not there. The formula used was

$$\psi = \{ [K(1+I)] / [1+I_r] \} \qquad \text{..........(1)}$$

These were then repeated for 3 groups of 2 buildings [Newton+cockcroft (NC), Newton+Peel (NP) and Tower+Peel (TP)], 2 groups of 3 buildings [Newton+Peel+Cockcroft (NPC) and Tower+Peel+Cockcroft (TPC)] and a group of 4 buildings [Newton+Peel+Cockcroft+Tower (NPCT)]. All the above measurements were repeated for 8 compass point wind directions.

DATA ANALYSIS

i). The comfort parameters obtained from each set of 2 buildings (called the resultant comfort parameters) and the comfort parameters produced by individual component buildings of each group at each of the 11 selected locations for 8 compass point wind directions were plotted as wind roses to identify locations with outstanding difference between the resultant and the individual component comfort parameters and to suggest possible relationships between them.

ii) The suggested relationships were then plotted on graphs of comfort parameters versus wind directions for all the selected locations of each of the 3 groups of 2 buildings. The experimental resultant comfort parameters were also plotted on the same graph to investigate the agreement between comfort parameters produced by the suggested relationships and the one obtained from experiment. The results from the group of Tower and Peel buildings (TP) were used as the determining factors while the results from the other two groups of buildings (NP and NC) as the comfirmatory factors.

iii). The equation determined in (ii) above, was then used to predict the resultant comfort parameters due to the interaction of wind flow with the various other combinations of two, three and four groups of buildings. These values were then compared to their corresponding experimental ones. The equation was adjusted as necessary.

iv). Finally, based on the findings in steps (i), (ii) and (iii) a general formula for was established.

RESULTS AND DISCUSSION

1. From the comparisons between the resultant comfort parameters (ie those obtained from the group of NC, NP and TP) and their corresponding individual component comfort parameters (ie those obtained from N, C, P and T) the following results were obtained:-

(a). The wind flow had not been affected either by any of the two component buildings or by the combination of the two buildings,

(b). The wind flow had been affected by either one or both the component and also by the combination of the two buildings,

(c). The wind flow had been affected by both the individual component buildings and their combination,

(d). The wind flow had not been affected by both the component buildings but being affected by their combination. The higher comfort parameters were caused by certain aerodynamic effects (eg. venturi efect etc.) due to the setting of the component buildings. A particular example of such location is location 18 in NC grouping.

2. 8 of the 30 cases that fell into catagories 1(ii), 1(iii) and 1(iv) gave significant difference between the resultant and the individual component comfort parameters. These were locations 18 (from NC grouping), 3, 5 and 37 (from NP grouping) and 3, 5, 7 and 10 (from TP grouping). For these locations the wind roses were enlarged and the comfort parameters were plotted against the wind directions. An example of such wind rose and plot is shown in Figure 2. The broken circles represent the comfort parameters, ψ, with the increments of 0.5 in the radial directions. The innermost circle have the value of $\psi = 0.5$. From these 8 enlarged wind roses, four possible relationships had been identified. They were:

$$\psi_r = \psi_1^2 + \psi_2^2 \quad (2)$$

$$\psi_r = (1/\psi_1^2) + (1/\psi_2^2) \quad (3)$$

$$\psi_r = ((1/\psi_1^2) + (1/\psi_2^2))^{0.5} \quad (4)$$

and

$$\psi_r = (\psi_1^2 + \psi_2^2)^{0.5} \quad (5)$$

3. For each location, the resultant comfort parameters predicted by the above 4 equations and the experimental comfort parameters were plotted against the wind directions. From these graphs, in most cases equation (5) seemed to give reasonable predictons but smooth and better curve fittings were still necessary. Different indices (0.45, 0.4, 0.35, 0.3 and 0.25) and several reduction factors (ie from 0.1 to 0.4) had been tried. To the best, equation (5) ended up to:

$$\psi_r = (\psi_1^2 + \psi_2^2)^{0.35} - 0.235 \quad (6)$$

Equation (6) was used to predict the resultant comfort parameters for all the combinations of two single or two groups of buildings and the results were compared to their corresponding experimental values. These results are shown in Table 1.

BUILDING GROUPS	SUITABILITY OF EQUATION $\psi_r = (\psi_1^2 + \psi_2^2)^{0.35} - 0.235$ n/tn	%
T+P	9/11	82
N+C	8/11	73
N+P	8/11	73
TP + C	9/11	82
NC + P	8/11	73
NP + C	7/11	64
TPC + N	8/11	73
NCP + T	8/11	73
NC + PT	9/11	82

Key: n = number of locations in favour of particular equation
tn = total number of locations

TABLE I THE SUITABILITY OF EQUATION (6) TO PREDICT RESULTANT COMFORT PARAMETERS BETWEEN TWO INDIVIDUAL OR TWO GROUPS OF BUILDINGS.

The prediction accuracies were as follows:-

Percentage of Predictions	Accuracy of Predictions
≥ 80%	± 15%
≥ 50%	± 10%
≥ 30%	± 5%

4. Equation (6) was used to predict the resultant comfort parameters due to the interaction of wind flow with a number of 3 single or 3 groups and 4 single or 4 groups of buildings. In the same fashion, equations (7) and (8) below were established for the 3 and 4 individual and groups of buildings respectively.

$$\psi_r = (\psi_1^2 + \psi_2^2 + \psi_3^2)^{0.35} - 2\text{x}0.235 \quad (7)$$

$$\psi_r = (\psi_1^2 + \psi_2^2 + \psi_3^2 + \psi_4^2)^{0.35} - 3\text{x}0.235 \quad (8)$$

Table II and III show the suitability of equations (7) and (8) to predict the resultant comfort parameters for their respective cases. The same accuracy criteria mentioned in no.3 had been used.

GROUPS OF 3 BLDGS & 3 GROUPS OF BUILDINGS	SUITABILITY OF EQUATION $\psi_r = (\psi_1^2 + \psi_2^2 + \psi_3^2)^{0.35} - 2\text{x}0.235$ n/tn	%
T + P + C	8/11	73
N + C + P	8/11	73
TP+N+C	9/11	82
NC+T+P	8/11	73
NP+C+T	9/11	82

Key: n = number of locations in favour of the particular equation
tn = total number of locations

TABLE II THE SUITABILITY OF EQUATION (7) TO PREDICT COMFORT PARAMETERS BETWEEN THREE OR THREE GROUPS OF BUILDINGS.

GROUP OF 4 BUILDINGS	SUITABILITY OF EQUATION $\psi_r = (\psi_1^2 + \psi_2^2 + \psi_3^2 + \psi_4^2)^{0.35} - 3x0.235$	
	n/tn	%
T+P+C+N (TPCN)	9/11	82

Key: n = number of locations in favour of the particular equation
tn = total number of locations

TABLE III THE SUITABILITY OF EQUATION (8) TO PREDICT COMFORT PARAMETERS BETWEEN FOUR OR FOUR GROUPS OF BUILDINGS

Although it may seen to be too little evidence for this case (i.e only one group of four buildings being tested) but it gave a percentage of suitability of 82% which is of the same order given by the earlier tests on two and three individual buildings as well as on two and three groups of buildings.

5. From equations (6), (7) and (8) it could be seen that a constant multiple of downward shift of 0.235 [i.e 2x0.235 for equation (7) and 3x0.235 for equation (8)] has to be added to equation (5) when the number or groups of buildings being increased from its original value of 2. Thus a general formula for predicting the resultant comfort parameters between and around any number of single or groups of buildings due to the interaction of wind flow with them could be written as follow:

$$\psi_r = (\psi_1^2 + \psi_2^2 + \psi_3^2 + \psi_4^2 + \ldots + \psi_n^2)^{0.35} - (n-1)x0.235$$

or

$$\left[\sum_{i=1}^{n} \psi_i^{\;2}\right]^{0.35} - [(n-1) \times 0.235] \qquad (10)$$

where n = the number or groups of buildings and $n \geq 2$.

6. Parts of the graphs of comparison between the predicted and experimental comfort parameters for two, three and four groups of buildings are shown in Figures 3, 4, and 5 respectively.

CONCLUSION AND SUGGESTION FOR FUTURE WORK

1. A general formula for predicting the resultant comfort parameters around and in between buildings has been established. This formula could only be used if the number or groups of buildings is ≥ 2 and the comfort parameters around each single or group of buildings have been known.

2. The established formula could be applied to solve real life problems such as to predict the resultant comfort parameters at several locations around and in between buildings due to the erection of a new building in the vicinity of a built-up area.

3. Further experimental work has to be performed on a number of 4 groups of buildings in order to give a sound basis to the general formula.

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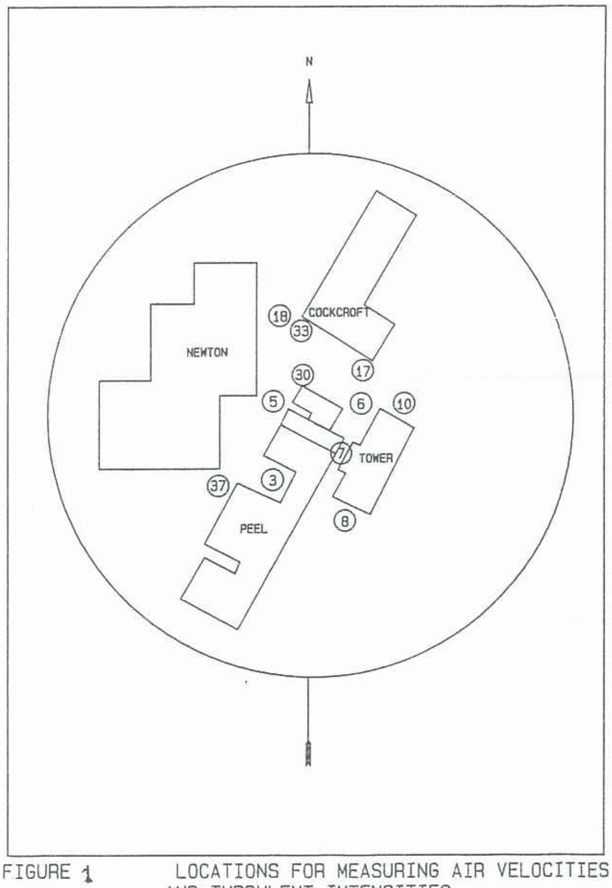

FIGURE 1 LOCATIONS FOR MEASURING AIR VELOCITIES AND TURBULENT INTENSITIES

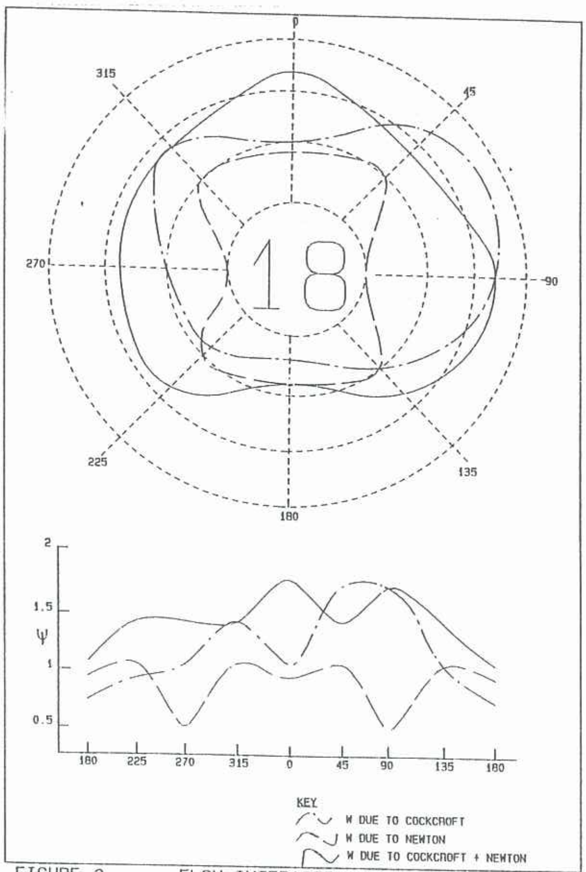

FIGURE 2 FLOW INTERACTION WITH COCKCROFT AND NEWTON BUILDINGS AT LOCATION 18

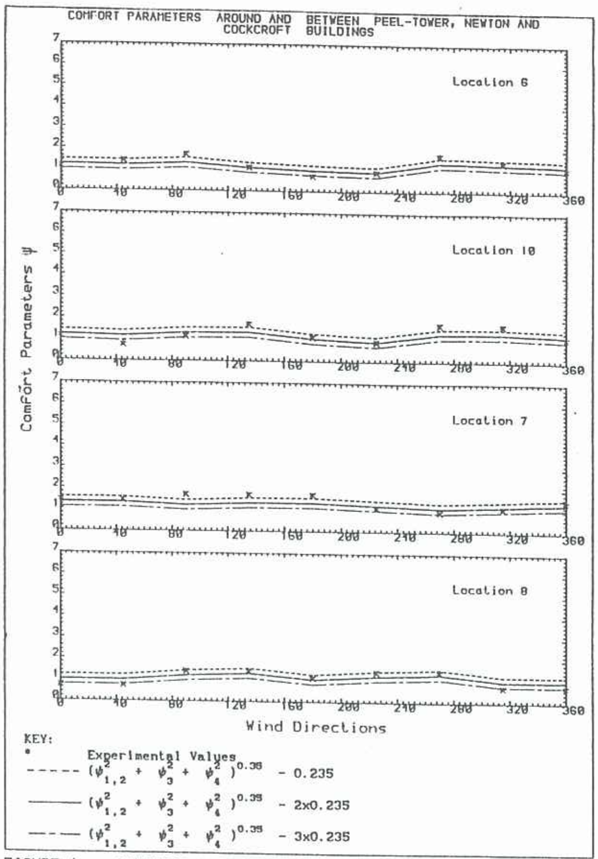

FIGURE 4 COMPARISON BETWEEN THE EXPERIMENTAL AND THEORETICAL VALUES OF COMFORT PARAMETERS OBTAINED FROM VARIOUS EQUATIONS FOR THE SPECIFIED LOCATIONS AROUND AND BETWEEN 3 GROUPS OF BUILDINGS.

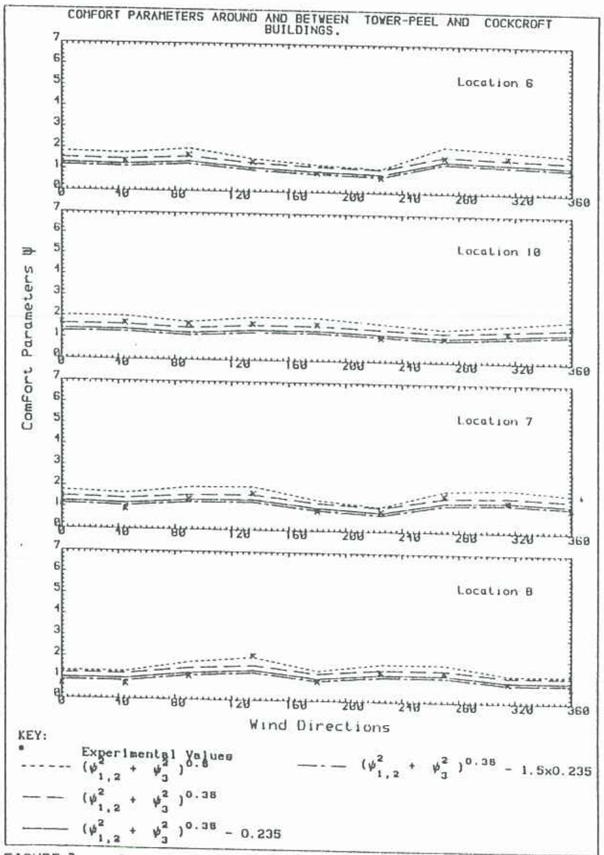

FIGURE 3 COMPARISON BETWEEN THE EXPERIMENTAL AND THEORETICAL VALUES OF COMFORT PARAMETERS OBTAINED FROM VARIOUS EQUATIONS FOR THE SPECIFIED LOCATIONS AROUND AND BETWEEN 2 GROUPS OF BUILDINGS.

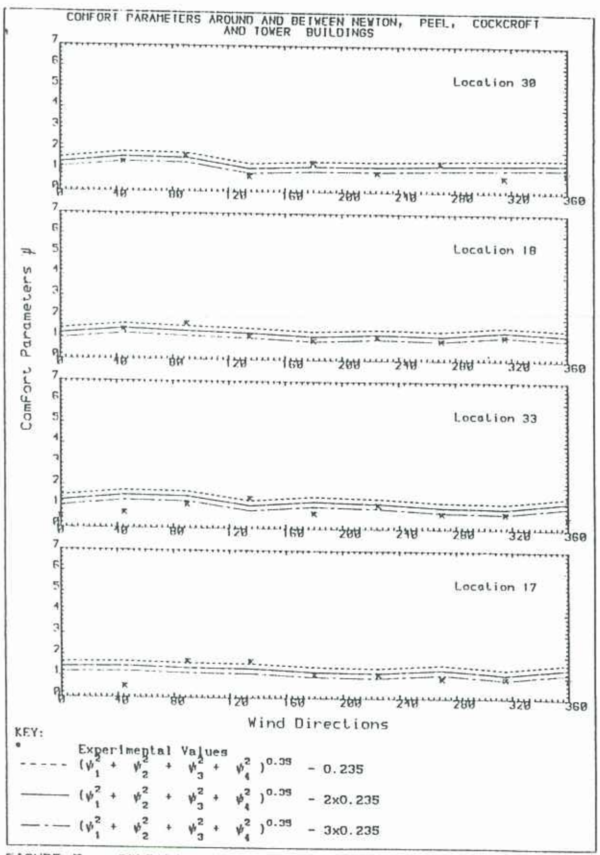

FIGURE 5 COMPARISON BETWEEN THE EXPERIMENTAL AND THEORETICAL VALUES OF COMFORT PARAMETERS OBTAINED FROM VARIOUS EQUATIONS FOR THE SPECIFIED LOCATIONS AROUND AND BETWEEN 4 GROUPS OF BUILDINGS.