different to undergraduates (novices) in that undergraduates don't know what they like or dislike while postgraduates usually do (They are either trying to escape their present profession or make their way in it.). For a new area of study there are usually plenty of good students looking for a place in heaven. The danger is that, in order to make a the course economically viable, the intake of students will be high, and unsustainable. There is also the danger that students who cannot handle the course will be enrolled. If these students are failed the course will not remain viable and if they pass then the course and the profession will get a bad name. Again the monasteries were in a much better situation than present universities as their "graduates" stayed in the monastery. That rarely happens in universities and even when it does happen it is often not the best graduates who stay to do research and subsequently to teach.

Like the monasteries before them the universities cannot survive without the support of the local population. This doesn't just mean that the business community has to express its support. It means that the profession must give the course time, effort, expertise and financial support. If the profession provides the food, clothing, shelter, wine, labour, noviciate, staff etc. then the universities, like any good Order, will offer the possibility of a place in heaven .....if even more support is provided in the future.

The final requirement for a Facilities Management course to be successful is a blessing. More correctly, it requires more than one blessing. The university must give its blessing and a faculty must also give its blessing. Often a department must also give its blessing. All are important. The reputation of the university, the faculty and the department, in which the course is run, will inevitably influence the reputation of the course. Because a wide range of knowledge and skills are required and because there are usually buildings and "design" involved, Facilities Management courses are usually located in Architecture and Design departments rather than in Management departments. This is a mixed blessing because, although many of the requirements for a successful Facilities Management course are represented in such departments they often have poor research outputs and a management ethos is often missing.

The Department of Architectural and Design Science is planning to start a postgraduate degree in Facilities Management in 1993. We feel confident that it has all the requirements, outlined above, to be successful but it also needs the good word to be spread (as do other Facilities Management courses) amongst the architecture, engineering and building professions and it needs help and visitors from other institutions so that it can grow in strength with the fledgling Facilities Management profession. In the final analysis however the success or failure of Facilities Management will depend on the abilities and personalities of those working in the profession.

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#6785

Studies on the Effect of Mean Wind Speed Profile on Rate of Air Flow Through Cross-Ventilated Enclosures

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The paper discusses wind tunnel studies on the effect of the mean speed profile of the on-blowing wind on the rate of air flow through cross ventilated enclosures. The mean wind speed profiles represented by a simple power law, with exponents ranging between 0.12 and 0.4, were generated in the test section of the tunnel. A model of a room was exposed to various wind profiles, and corresponding rates of air flow were measured. It was observed that average wind speed through the window decreases with an increase in the power-law exponent. An empirical relationship was also derived between the power-law exponent, the average wind speed through the inlet and the average outdoor wind speed at the window level.

Introduction

Provision of ample natural ventilation is an important consideration in the design of buildings in the tropics. Hence studies pertaining to the mechanism of air flow through buildings and of the various parameters governing air motion indoors have been carried out by several investigators [1-7] in the past. These studies yielded design guidelines for the optimum indoor utilisation of outdoor wind. These are useful for developing a functionally efficient and energy conscious design of buildings. The investigations were mostly devoted to quantitative studies of the influence of basic architectural features like orientation, window sizes, their number and location, plan form of buildings etc. on inducing air motion in the interior of buildings.

However, the mean speed profile of the incident wind was not covered in these investigations, even though it is also an important parameter governing the processes of wind-building interaction. Since the speed profile of the wind striking on a building varies with the type of terrain on the upstream side of the building, which necessarily is not identical in all situations, it is pertinent to study this aspect also. These findings would supplement the existing design data and lead to their wider application. The present investigation was carried out with this in view and an empirical relationship between the rates of air flow through buildings and the power-law exponent defining the mean wind-speed profile over common types of terrain was evolved.

Wind Speed Profile on Various Types of Terrains

Various elements like trees ,shrubs, buildings etc. projecting above the earth's surface make it uneven and aerodynamically rough. These cause a frictional force to be exerted between the earth's surface and the wind flowing thereon. As a result the layer of air adjacent to the ground loses momentum. The viscous and eddy stresses in the air transmit the frictional force to the outer layers, creating thereby a velocity gradient in the wind flowing over the earth's surface. The height above which the friction from the earth's surface no longer affects the windspeed is called the gradient height, and the velocity at that height is known as the gradient velocity. Below the gradient height the mean wind profile follows the power law which is represented by the expression

$$\frac{V_z}{V_g} = \left(\frac{Z}{Z_g}\right)^{\alpha}$$

where V_z = Wind velocity at a height Z from the ground

V_g = Free stream gradient wind velocity
Z_g = Gradient height

α is an exponent whose value depends upon the roughness of the terrain (Table 1)[8].

Table 1
Values of α and z_g

Description of terrain	α	Z_g (metres)
1. Open terrain (typical farm land with few trees)	1/7	275
2. Suburban terrain (with building from 10 to 15 metre high or wooded areas)	1/4.5	400
3. Metropolitan areas (Centres of large cities with tall buildings)	1/3	460

It is worth mentioning that the power law has no theoretical justification. It fits in the upper region of Ekman's layer, and the fitting becomes poorer near to the ground where a log law model is regarded as more accurate. In spite of these shortcomings the power law is extensively used, because of its simplicity, for describing the wind velocity gradient over different types of terrain.

Theoretical Considerations

Cross ventilated enclosures are provided with large size windows to facilitate the exchange of indoor air by fresh outdoor air without the aid of mechanical or electrical power. In that case wind provides the motive force for propagation of air streams indoors. When wind strikes a building, a region of excess pressure is created on the windward wall, while the sides, leeward wall and roof are all subjected to reduced pressure. A pressure difference is thereby created across the building in the direction of the incident wind. This pressure difference causes the air to flow through the building from openings in the region of higher pressure to openings located in the lower pressure zone. Hence all those parameters, which influence distribution of wind pressure over building surfaces, have a bearing on the rate of air flow through buildings.

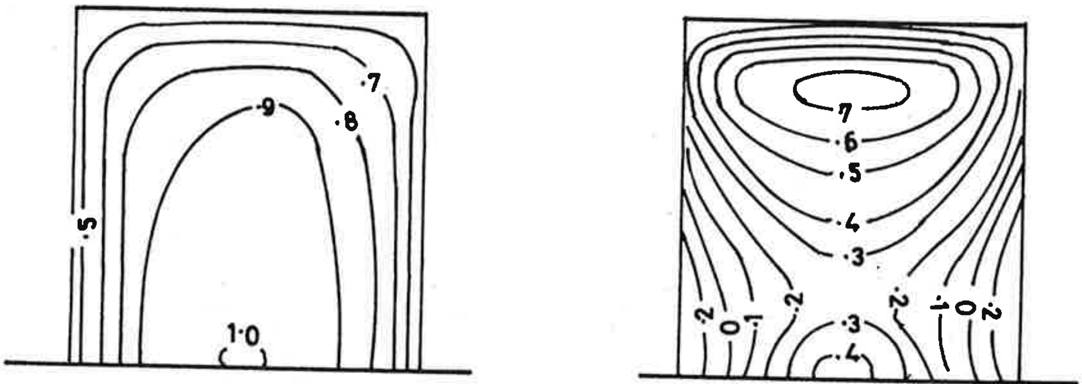
Wind velocity is one of these parameters, and a typical illustration of its effect on the distribution of pressure coefficients on the windward face of a bluff body is depicted [9] in Fig.1. The variation in pressure distribution is a consequence of the change produced in the flow patterns around the bluff body due to a change in the incident wind profile. When the wind incident on a building has a uniform profile, the wind passes atop the front face, and maximum pressure equal to the incident dynamic pressure is created at the ground in the centre of the face.

In the case of wind having a speed profile similar to the atmospheric boundary layer, the flow at about two-thirds to three-quarters of the building height comes to rest to form a stagnant point. Above this point the flow goes up and over the top of the building. Below this point the flow moves downward until it reaches the ground, where it possesses more momentum than the incident wind at that level. It therefore moves against the on-blowing wind and comes to rest at some point on the upstream side of the building, when the flow rolls upwards and forms a vortex in front of the windward face. The formation of this vortex contributes significantly to the development of a difference in pressure distribution patterns on a wall due to its exposure to wind having different types of speed profiles.

The air entering the vortex escapes around the sides of the building forming a horseshoe pattern. Thus the flow over the lower two-thirds of the sidewalls is faster than the free wind speed at that level. The flow over the top third of the sides is not changed by a change in the velocity profile. Further, the vertical mixing caused by the vortex tends to make the flow more uniform vertically on the sides. As a result, the vertical variation in pressure is generally small.

The leeward side is subjected to negative pressure which has a maximum negative value near the top of the wall and diminishes slowly towards the ground. The pressure becomes less negative, but its distribution pattern remains unchanged [10] by an increase in the non-uniformity of the profile of the incident wind.

The aforesaid observations refer to solid blocks, and are subjected to a significant change when large size openings are provided on the walls. In that case a part of the incident wind



(a) Uniform incident mean velocity profile

(b) Boundary-layer incident mean velocity profile

Figure 1. Distribution of pressure coefficient on the windward face of a bluff body.

strikes on the window and tends to flow straight through it, while the wind incident on the solid portion of the wall tends to get deflected in the abovementioned manner. The interaction of these two flows controls the rate of airflow through the window. The process of interaction of flows is too complex to be predicted theoretically. Hence an experimental technique was adopted for studying this problem.

Experimental Setup

The investigations were carried out on a 1/30 scale model of a room 4.2 x 3.6 x 3m high. It was provided with identical windows, each covering about 15 per cent of the floor area, in the centre of the two longer walls. The sill heights of the windows were kept 0.9m, whereas their heights were 1.1m, these being the optimum dimensions established by earlier studies [11-12]. A low speed wind tunnel was used for testing the model.

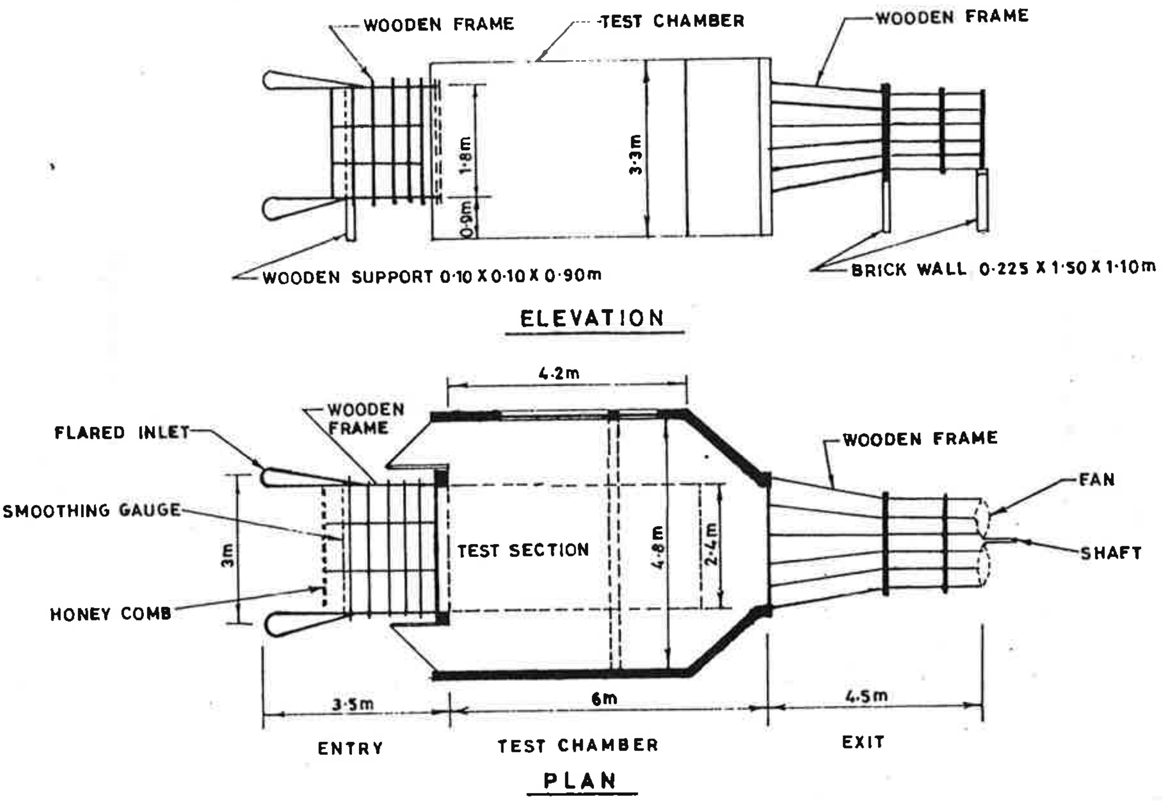


Figure 2. Plan and elevation of wind tunnel.

As shown in Fig. 2 and Fig. 3, the tunnel is an open-circuit-sucking-type tunnel about 14m in length. It has an open working section about 2.4m wide, 1.8m high and 4.5m long, surrounded by a test chamber 4.8m wide, 3.3m high and 6m long. A heavy wooden table with its top flush with the level of the entry section is placed centrally in the chamber. This acts as a ground level for the models under test.

Air in the tunnel is set in motion using a 1.6m axial-flow fan with variable-pitch blades. The fan is coupled to a 37kW motor by belts and pulleys of three different diameters. The wind speed in the test section is varied with a variable-speed mechanical transmission system and by the adjustment of the variable pitch of the fan blades. Variation in the velocity profile of the air stream in the tunnel is accomplished through various combinations of the three devices, namely the vortex generators, the grid of horizontal slats, and the roughening of the floor of the test section.

Five equally spaced vortex generators each about 1m high are mounted rigidly on the tunnel floor behind the wire mesh screens in the entry section. These are followed, on their down-stream side, by a grid made up of unequally spaced horizontal slats. Two pieces of galvanised steel sheet, each 150 mm wide, 2mm. thick, and 1.8m long, having half-cut grooves with centre-to-centre spacing of 10mm over their entire length, are mounted along the vertical sides of the entry section. Slats can be easily inserted into or removed from these grooves, and spacing between them can be varied at will.

Small wooden blocks each 10 x 10 x 10mm in size fitted with headless nails atop them, are used to develop undulations on the tunnel floor. By inserting the nails in the pieces of the hard-board spread over a part of entry section and also over the test table, the blocks can be arranged in any desired pattern without being blown away by the wind during the operation of the tunnel. Thus the floor roughness can be easily manipulated to simulate the desired ground roughness.

For the present study an array of squares, each with 100mm side, was drawn on the top of the working table, and wooden blocks were mounted at each of the corners of the squares. Thus the centre-to-centre spacing between the blocks in the

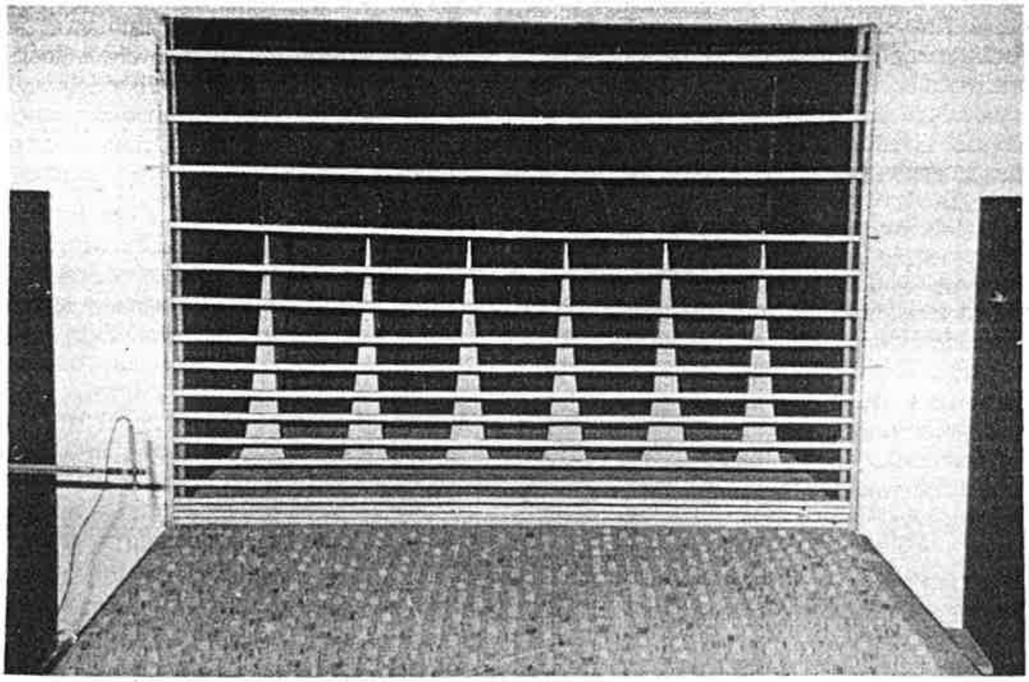


Figure 3. Internal view of wind tunnel

direction of wind, and also in the cross-wind direction, was kept equal to 100mm. The slats used near the bottom of the grid were thicker and mounted in the successive grooves, while thinner slats were used higher up, leaving a varying number of grooves vacant at different heights above the floor. Thus the clear spacing between two adjacent slats was a minimum near the floor, and a maximum near the top of the test section. The variation in the position of the slats contributed significantly to the development of different velocity profiles in the air stream in the test section of the tunnel.

For a quantitative measurement of these profiles, windspeeds were measured along vertical lines passing through the axis of the tunnel at 1m, 1.5m and 1.8m down-stream from the grid. Measurements were carried out with the help of a constant-current hot-wire anemometer having a measuring range from 0 to 10 m/sec with an accuracy of ±3 %. Wind velocities were measured right at the top of the test table, and subsequently upwards by raising the probe in steps of 10mm till a constant velocity was achieved. A plot of a few of the profiles is depicted in Fig 4.

It is found that the power-law exponent representing these profiles lay between 0.12 and 0.4, corresponding to the simulation of the gradients occurring over various types of terrain ranging from sites in open country to the heart of urban areas. The model under test was mounted on the tunnel floor, so that the centre of its windward wall coincided with one of the lines over which the free wind velocity gradients were determined. The speed of the wind entering through the window was measured at five uniformly spaced points, located centrally along the height of the window. Similar measurements were also taken by placing the model in other positions, for which the wind-profiles were predetermined. In each case the average speed of the wind through the window, as also the average free wind speed over the height the of inlet, were determined, and the ratios of the two were computed. The variation of this ratio with the power-law exponent is depicted in Fig 5.

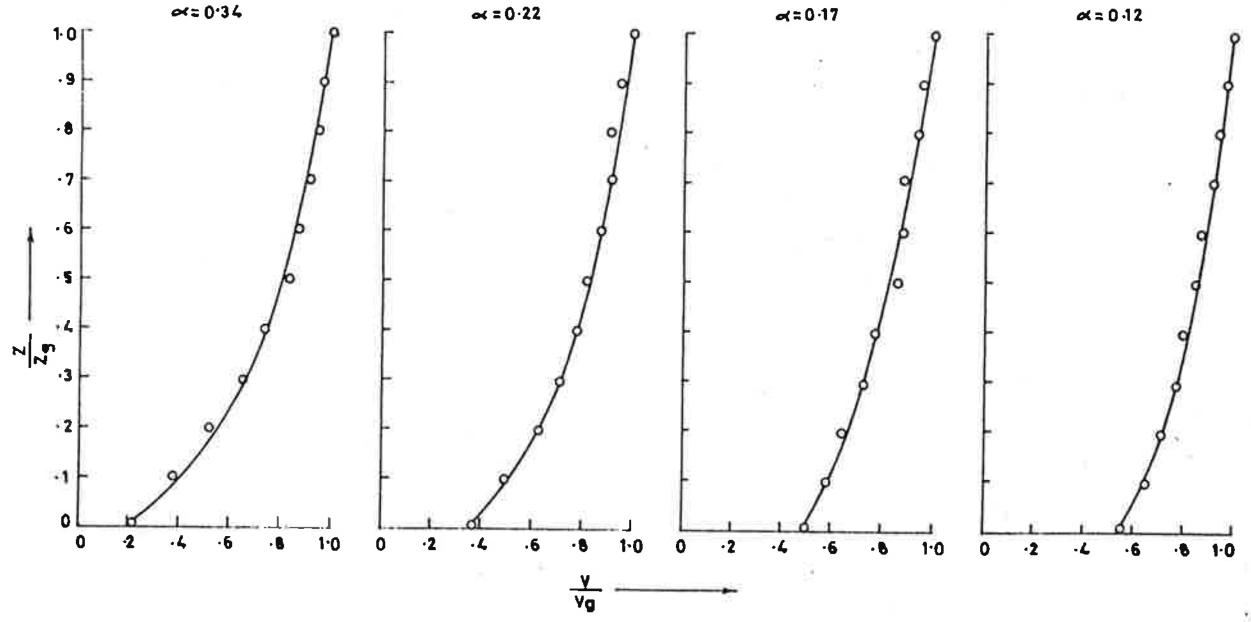


Figure 4. Free steam velocity profiles.

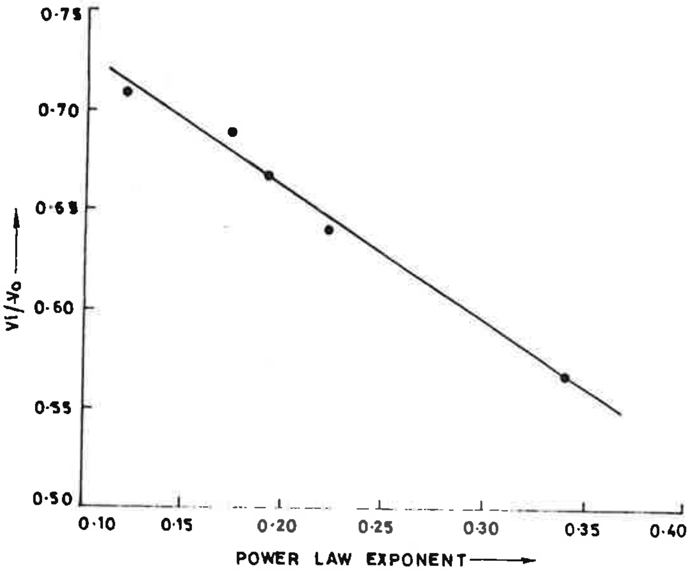


Figure 5. Effect of velocity gradient on wind speed through window.

It is noted that the rate of air flow through a cross-ventilated enclosure decreases with an increase in the value of the power-law exponent. This variation may be represented by the equation,

$$\frac{V_i}{V_o} = k\,(1 - 0.82\alpha)$$

where V_i = Average wind speed through the window
V_o = Average free wind speed over the window
α = Power law exponent,

k is a constant which takes into account the effect of the shapes and relative sizes of openings.

The value of k for different shapes of opening is determined experimentally by measuring the values of V_i and V_o for a known value of the power-law exponent. However, for simple rectangular openings, an approximate value of k may also be determined using the relationship,

$$k = 1.1\left(1 + (A_i / A_o)^2\right)^{-0.5}$$

where A_i and A_o are the sizes of inlet and outlet respectively.

This makes it possible to work out data on the ventilation performance of windows for various types of terrain from existing data, which usually refer only to typical types of terrain.

It is interesting to compare the ventilation efficiency of buildings of similar design, but located on different types of terrain. Data for power-law exponents 1/7, 1/4.5 and 1/3 are given in Table 2.

Table 2.
Values of V_i/V_o for different types of terrain

Type of terrain	α	V_i / V_o
Open country	1/7	0.88 k
Suburban	1/4.5	0.82 k
Urban	1/3	0.73 k

It is noted that the values of V_i/V_o for buildings located on suburban and urban sites are about 90 per cent and 80 percent respectively of the value achievable in the case of a building exposed to wind incident from a site in the open country. Since the free wind speed at window level available at open sites is reduced to about two thirds in suburban regions, and to about one-third in the heart of big cities, the wind velocities through windows are reduced proportionately. Accordingly the average wind speed through the windows of cross-ventilated buildings in suburban and urban areas are respectively about 60 and 30 percent of the speed that would have been induced if same building was located in open country.

Discussion

An experimental study was undertaken on the effect of the mean-speed profile of free outdoor wind on the rate of air flow induced in a cross-ventilated enclosure. An empirical relationship was then derived between the power-law exponent representing the mean wind-speed profile and the average wind speed through the window, expressed as a fraction of the average outdoor wind speed over the plane of the window. This formula is applicable for the range of wind-speed profiles observed over sites in the open country, suburban areas and urban areas. Hence it helps to enlarge the scope of application of various earlier studies on window design, for natural ventilation in the tropics. The study makes use of the power-law model for describing the mean wind-speed profile. The choice of the model is justified because of its simplicity, and its current widespread use in wind engineering. However, in the region close to the ground the log law is regarded as a more accurate model. Hence a similar study using the log law model is proposed for future research.

Conclusions

1. The average wind velocity through the windows of a cross-ventilated building does not bear a constant ratio to the corresponding free outdoor velocity at the window level. The ratio decreases with an increase in the value of the power-law exponent defining the speed profile in the on-blowing wind. However, the reduction due to a change in terrain from open sites to the heart of the cities is limited to 20 per cent.
2. For evaluation and prediction of the functional efficiency of buildings provided with natural ventilation, the speed of windflow through a window can be expressed as a fraction of the free wind-speed at the window level, without introducing practically significant errors in the results due to a variation in the type of terrain.
3. The rate of wind flow in buildings located in suburban and urban areas are 60 per cent and 30 per cent respectively of the rate of air flow that would be induced in a similar building located on an open site.

Acknowledgement

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Low Cost Alternatives to Mineral Fibres for Acoustic Insulation in Plasterboard Walls

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The acoustic performance of stud-framed lightweight partition walls is strongly affected by the presence or absence of sound-absorbing materials in the cavity. Fibreglass, a commonly used cavity absorbent, has come under criticism over potential adverse health effects owing to its fibrous nature. This paper investigates some low cost alternatives that might be used for providing cavity absorption in such walls and yet offer sound insulation similar to that achieved by using fibreglass. A minimum improvement in the STC rating of 4 points was observed by using different cavity absorbents, with some options offering STC ratings similar to those achieved with conventional fibreglass. The effect of adding an extra layer of plasterboard with a corresponding equivalent reduction in the stud width was also studied.

Introduction

Sound insulation of various building elements such as walls and floors is a factor that requires careful consideration during the design of buildings. The Building Code of Australia [Ref. 1] incorporates sound transmission class (STC) as a criterion to ensure minimum acoustical privacy is available to occupants of different units. In many instances, architects specify the sound transmission permissible through partition walls or facades of commercial and industrial buildings. If lightweight framed construction is to be used, double-leaf configuration is the preferred choice as it can yield higher sound insulation than an equivalent single-leaf form of construction.

For many commercial buildings, lightweight partition systems are used which consist of a steel frame (in the form of steel studs and channels) with a layer or layers of plasterboard screwed on both sides. To further improve the acoustic performance of such constructions, extra insulation in the form of mineral fibre is inserted in the cavity between the two leaves. This is beneficial from a thermal point of view as well because of the excellent thermal resistance of mineral fibre batts and blankets. The single-number STC rating is commonly used to characterise the sound insulation of partition walls [Ref. 2]. Generally walls with an STC rating of 45 and higher are regarded as suitable for many situations in buildings. Results of sound transmission loss tests indicate that typical plasterboard walls with a single skin on both sides and with unfilled cavities, do not achieve the minimum STC of 45 but do so with the addition of mineral fibre in the cavity.

Because of known health risks involved in working with asbestos, workers at building and construction sites have expressed concern about adverse health effects from working with fibrous materials such as mineral fibres. Because of this concern, a national code of practice for the safe use of synthetic mineral fibres [Ref. 3] has been prepared by the National Occupational Health and Safety Commission. The Commission has declared that a time weighted average exposure limit be set not to exceed 0.5 respirable fibres per millilitre of air. In addition, a secondary exposure of 2 mg/m³ of inspirable dust is applied in certain situations to minimise respiratory tract irritation. The code also recommends the use of half-face respirators (Class L or M) during work in enclosed or poorly ventilated spaces. It has been suggested that, due to their much higher average fibre size, mineral fibres, such as fibreglass, differ from asbestos in the health risks posed.

In view of the potential industrial conflict over the use of fibreglass-type materials, it is valuable to investigate other materials and options that could be utilised in plasterboard walls without significantly lowering the target STC rating of 45. As fibreglass can be manufactured fairly cheaply in batt or