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The Effect of Trees in Environmental Wind Studies.

Damon Moloney BE (Hon)+, Colin Paton+
+ - Vipac Engineers and Scientists Ltd.

ABSTRACT

This study investigates the effect of planting and porous screens on the pedestrian level wind environment around tall buildings. Limited information currently exists which quantifies the effect of windbreak ameliorative measures such as trees. Field measurements and wind tunnel tests of a range of individual trees have been conducted. The experimental results provide information on the expected wind speed reduction behind a sample of trees. A model tree has been developed for use in wind tunnel testing, which simulates the wind speed reduction due to street planting.

INTRODUCTION

Through numerous environmental wind effects assessments, Vipac has recommended the use of planting and/or porous screens to absorb wind energy and control unpleasant wind gusts around tall buildings. Recent experiences have highlighted a desire to more accurately prescribe wind control devices and quantify their effect on annual return period wind conditions. At present there is very limited information available which describes how planting increases the acceptability of wind conditions within a streetscape.

The aim of this investigation is to generate information about the characteristics of trees, which would be suitable, as wind breaks around tall buildings. The study expects to define the contribution of planting to the amenity of a site in terms of the area of protection provided. With knowledge of how full scale trees attenuate wind velocities, it is envisaged that a scale model tree can be developed which simulates the effect of wind reduction and may be used in model wind tunnel studies. These results provide various benefits to building developers such as the accurate and confident planning of wind break features around a building prone to adverse wind conditions.

A difficulty arises in trying to accurately define the aerodynamic characteristics of a tree in terms of its geometric parameters. Thus, before progressing to testing of trees, this study extended from existing knowledge of square mesh porous screens into diagonally woven mesh screens.

Some definitions.....

Porosity is a measure of the ratio of empty space to the total occupied volume of the subject.

Wind reduction is the percentage decrease in wind velocity after passing through a tree.

Viscous permeability, B (m^2), is a measure of the ease with which wind can travel through a medium.

$$B = U \eta z / \Delta P \qquad (1)$$

Loss coefficient, K_r is a measure of the pressure drop through the medium referenced to the approach dynamic pressure:

$$K_r = \Delta P / 0.5\, \rho\, U^2 \qquad (2)$$

Where:

U = mean approach velocity, m s^{-1} , z = thickness of medium,
ΔP = pressure loss across medium, Pa, ρ = the density of the medium, kg m^{-3}

η = absolute viscosity of fluid, 1.85×10^{-5} N s m^{-2} for air

PREVIOUS STUDIES

Previous studies of the aerodynamics of trees have been conducted although many of these investigations have focused on wind forces on shelterbelts and wind loading of trees. Mayhead 1973, has measured drag coefficients for a range of trees in a wind tunnel, the coefficients were found to alter within and between species and to decrease with increasing wind speed. Such effects are attributed to streamlining of the leaves at higher velocities. Judd, et al 1996 studied windbreaks within a wind tunnel measuring the mean velocity profiles in the streamwise direction. The CSIRO[1] is currently investigating the effect of trees on erosion and water vapor flux as part of the National Wind Breaks Program.

EXPERIMENTS ON POROUS WINDBREAKS

This investigation first focused on and measured loss coefficient data for several porous square mesh screens. Results of porous screen studies are not presented explicitly as part of this paper as there are many references available on that topic. The study was then extended to diagonally inter-woven mesh screens and finally to field and wind tunnel studies of single trees. The foliage of a tree may be considered as a randomly distributed three dimensional resistor to wind flow. Mean velocity in the stream wise direction was measured during each test upstream and downstream of the subjects.

Field Studies of Trees

During field studies of single trees, measurements were made of windward and leeward 10min mean velocity in the streamwise direction. Measurement locations were at approximately 0.5h either side of the tree at pedestrian level at distances upstream and downstream of between 0-2h. The experiment does not consider any slowing effect upstream of the tree as described by Nord 1991, but rather considers the wind reduction during the passage through the foliage. Mean wind velocities recorded during each test were in the range of 1-7m/s with an upstream turbulence intensity of around 0.19.

Wind tunnel Testing

Streamwise velocities were measured in front of and behind a short pine tree in the wind tunnel. Measurements were made at numerous locations vertically and horizontally upstream and downstream of the tree. Turbulence intensity of the approach flow was around 0.15.

Scale Model Testing

A range of 3-dimensional scale models were constructed which were deemed suitable for simulating the wind reduction contours of street planting. Models were tested and developed until the wind reduction at points between 0.5h and 5h downstream of the model was matched to that of the full-scale measurements.

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[1] Commonwealth Scientific and Industrial Research Organization - Dept of Land and Water.

RESULTS

Field and Wind Tunnel Studies of Full Scale Trees

Table 1 below summarizes the measurements made of field trees.

	Description	Maximum Wind Reduction %
Tree 1	3m high, med density leafy tree.	57
Tree 2	2m high, dense conifer	64
Tree 3	3m high, med density leafy tree	66
Tree 4	Dense, 1m high bush	31
Tree 5	Christmas Pine Tree	72

Table 1: Wind Reduction comparison at 0.5h of a few similar trees.

Dense trees with a large wind reduction were also found to provide less overall wind protection as distance from the tree increases. Pressure recovery behind dense trees is generally faster than those of more porous wind breaks.

The contour plot below shows measured normalized velocities for the tree in the wind tunnel. Some corrections have been made to account for blockage effects in the wind tunnel.

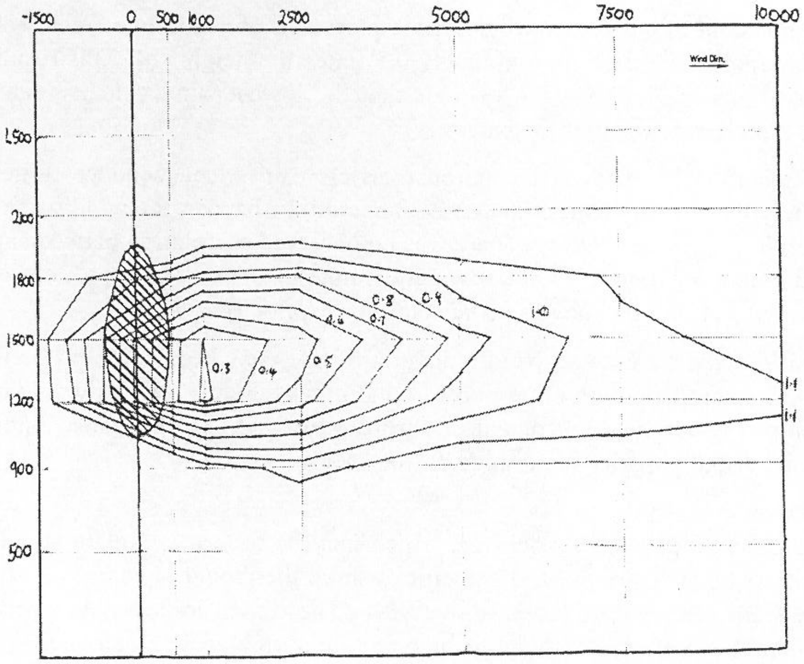

Fig 1. Cross Sectional Contour Plot of mean velocities referenced to approach velocity.

It was observed during this study that a single medium density tree with height to crown ratio of around 2:1 creates a 40% wind reduction in approach wind speed to around 2-2.5h behind the windbreak. .

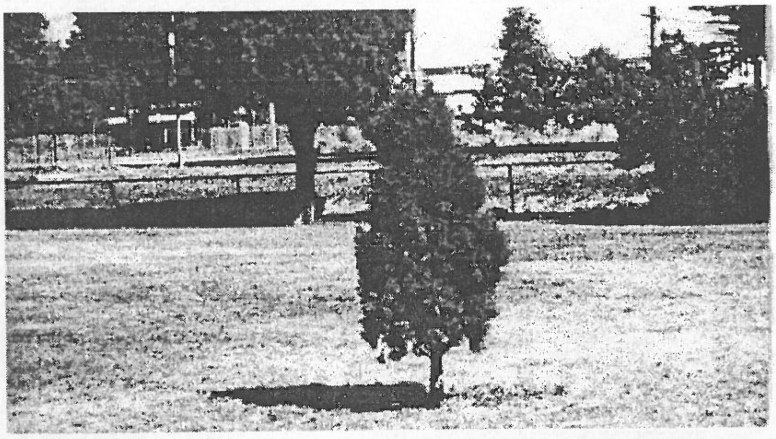

Fig. 2 Example of tree studied in field measurements.

DISCUSSION AND CONCLUSION

For all porous wind breaks it is desirable to minimize any local flow accelerations and maximize the area of protection and the wind reduction afforded by the obstruction. It was found that the acceleration around the edges of the porous screen decreases with increasing porosity. Therefore an optimal porosity and permeability exists for the ideal windbreak to protect pedestrians.

In the wind tunnel, the lowest wind speeds measured at 1m above floor were recorded at a distance behind the tree of approximately 0.5 times the height (h). This result compares with the observations of Nord 1991 who finds that the lowest wind velocity behind a shelterbelt occurs at 2-5h downstream of the barrier.

This investigation has shown that porous barriers can reduce wind velocities by up to 70% immediately behind the obstruction. At 2-3h behind the barrier, the wind velocity is still as low as 40% of the approach velocity. There was no observed correlation between approach velocity and wind reduction although some researchers note that streamlining of leaves may produce a change in wind reduction above a critical approach velocity.

Measured loss coefficient and wind reduction of trees has been found to be the most suitable measure of comparison with other porous wind breaks. Future studies would aim to define the relationship between loss coefficient or permeability and an easily measurable or predictable quantity, eg visual porosity for a range of tree species.

Model Trees

This study has produced a model tree, which may be used to simulate street trees close to a building test site. The normalized velocities behind the model have been matched to those for full-scale trees with a correlation above 90%. The dimensionless loss coefficient and wind reduction has been used as a model parameter with normalized velocities matched between full scale and model trees.

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