Outdoor Comfort Criteria and Planning Controls for Wind

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Introduction

Historically, planning controls for wind in outdoor environments have been developed from observation[1] or calculation of the mechanical effects of wind on pedestrians[2,3]. While much of the early development was focused on considerations of pedestrian safety, some observations of comfort, such as hair being blown about or steadiness of walking, were used to establish wind criteria for comfort[4]. Refinements to these comfort criteria have been introduced that take account of thermal comfort, which include the physical effects wind speed, ambient temperature, radiation (i.e. sun/shade), activity (such as sitting/standing/walking) and clothing (measured using 'clo' values). However, little has been done to establish the actual comfort that is perceived by people using outdoor spaces, and the degree to which their comfort is affected by the wind. The modern demand for better, more liveable, urban environments is increasing the importance of comfort considerations in the planning process to the point where comfort needs to be established with some rigour. Two aspects of this process are discussed in this paper, firstly the definition of appropriate comfort criteria, and secondly the communication of the measured/calculated conditions to non-technical people who are involved in the planning process.

This paper reports a study that was done in Wellington, New Zealand, which measured the extent to which comfort is affected by the physical weather conditions[5]. These conditions, including wind speed (mean and gust), ambient temperature, and mean radiant temperature were measured in an inner city park, while people using the park were surveyed to find out how comfortable they felt and how they perceived the park environment. A model is presented that can be used to determine people's comfort in different weather conditions, including a variety of wind conditions. Finally a brief discussion is given of planning controls for wind that are to be introduced in Wellington City. These wind rules have been developed with a strong emphasis on making them more easily used in urban design decision making involving non-wind-engineering people.

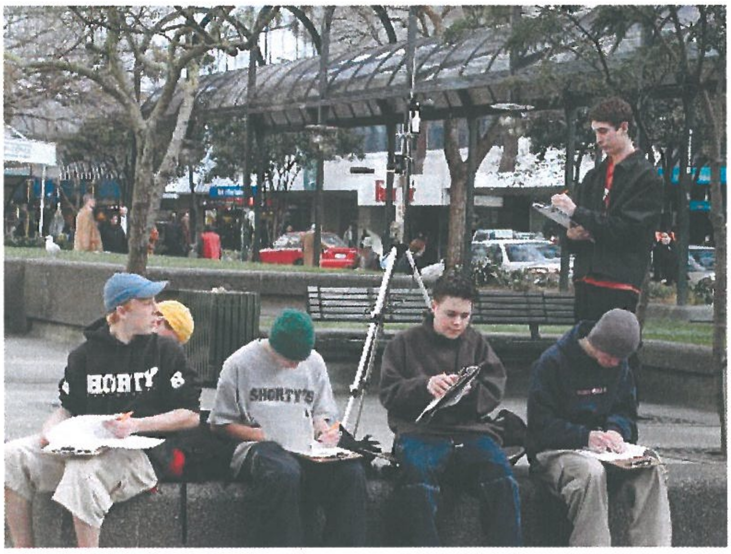
Comfort Study

In 2001 a survey was undertaken to investigate the effect of wind, temperature and sun on peoples comfort in outdoor spaces. A fundamental problem with trying to measure comfort in outdoor public areas, particularly those with high amenity value, is that there is usually only a small variation in the level of comfort amongst people. If a person is uncomfortable, then they will generally move to a more comfortable location (e.g. move into or out of the sun), or adapt to the conditions (e.g. put on a jacket) so that they feel comfortable. There are exceptions to this principle, such as smokers, who in New Zealand, are forced to smoke outside in public areas. During inclement weather, this may result in smokers tolerating uncomfortable conditions that would otherwise make them move indoors. The fundamental hypothesis of the study is that people in outdoor areas are essentially comfortable, and that they will adapt, by choosing locations, clothing and exposure times, that preserve their comfort within a given set of weather conditions. This level of adaptation is used as an indirect measure of the comfort of an outdoor space and the associated weather conditions. There are of course groups of people, such as smokers, who may at times choose to redefine what is uncomfortable, and weather conditions that will require too much adaptation to be acceptable. This study did not include these groups or severe weather conditions.

Members of the public were surveyed in three different locations within Wellington City, comprised of two small inner city parks and an outside mall. 649 questionnaires were completed over a nine month period, which included a range of weather conditions, with temperatures ranging from 10 – 28°C, wind speeds ranging from 0 – 7 m/s, and sunny and overcast days. The wind speed (both mean and gust speed), ambient temperature, mean radiant temperature and relative humidity were measured during each survey using a central weather station at a fixed location in each area. Mobile anemometers were also used to measure the wind speed at each location where participants in the survey were seated. The comfort survey used a questionnaire, comprised of 33 items that asked participants for their perceptions of wind, sunlight, warmth of surroundings, wetness, noise, air quality, clothing, length of exposure, preferences of warmth / wind / sunshine, and preferences of location. A further factor that affects a person's comfort is the level of activity, which was assumed to be constant during this survey as all the participants were seated. Observations were also made by the surveyors of where the participants were seated (i.e. concrete walls, wooden bench, grass, etc) and their exposure/orientation to the wind and sun.

Figure 1

Photograph of a user survey in Midland Park, Wellington.



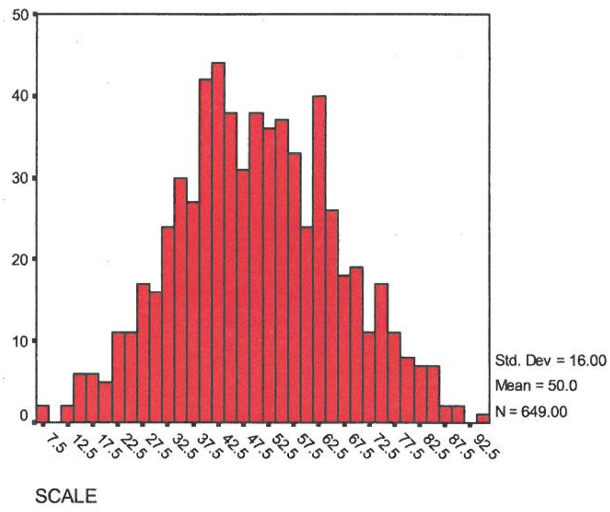
Measures of adaptation to achieve comfort, which include clothing, duration of exposure, choice of location, and attitudes and expectations of users, were entered into a principal component factor analysis to form a 'comfort' index. This index is approximately normally distributed and has been scaled, for convenience, so that it has a mean of 50.0 and a standard deviation of 16.7, as shown in Figure 2. The comfort index was then regressed against the physical measures of wind, sun and temperature taken at the time of the survey to establish the influence of these physical conditions on the comfort of park users. The resulting equation is shown below, and it allows the relative Adaptation to Achieve Comfort (AAC) to be determined for an outdoor area.

Adaptivity to achieve comfort = 25.5 + 10.7Mwind - 5.8Gwind + 0.9MRT + 0.5Temp

Where
Mwind = mean wind speed (10 minute average, m/s)
Gwind = gust wind speed (maximum instantaneous speed, m/s)
MRT = Mean radiant temperature (exposed to direct sunlight, °C)
Temp = Ambient temperature (°C)

Figure 2

Histogram of the comfort index derived from the survey data. The AAC score is plotted along the x-axis and frequency is plotted up the y-axis.



Analysis shows that the physical weather conditions account for 50% of the variability in the comfort of people surveyed. As the ACC equation is empirically derived, it should only be applied within the conditions that occurred during the surveys and extrapolating significantly beyond these conditions may produce erroneous results. For example, temperatures in Wellington are relatively cool, which make people more likely to seek out the sun as compared to a city such as Brisbane where temperatures are higher and people are more like to seek shade to be comfortable.

An absolute definition of comfort is still elusive as the AAC score describes the relative comfort of different weather conditions, but does not indicate what score is acceptable, or unacceptable. In order to set such limits, it is assumed that people will adapt to 80% of the conditions described by the AAC index, which then implies that 20% of conditions will be uncomfortable. The 80% satisfaction / 20% dissatisfaction criteria has been selected as it corresponds to that used by ASHRAE for indoor comfort.

Given that the AAC index is approximately normally distributed (mean of 50 and a standard deviation of 16.7), 80% of the AAC scores will lie between the values 29 and 71. Using the lower AAC score of 29, and substituting this and representative values for temperature into the AAC equation allows the wind speed limit for comfort to be calculated. A mean wind speed of 2.8 m/s is found to correspond to the limit of comfort for 80% of the time. This value compares closely with that reported by the ASCE[6] for comfortable conditions when seated of 0-2.6 m/s mean wind speed (20% probability of exceedance).

Planning controls for wind and comfort

In New Zealand, the Resource Management Act (RMA)[7], requires the effects developments to identified, and where these effects are adverse, to be mitigated. In doing so, the RMA requires a decision to be made as to what is a substantial effect, and what is considered to be an insignificant effect. In the case of wind, this decision is relatively straight forward, if slightly subjective, for wind specialists to make. It is also widely accepted that the interpretation of wind tunnel data is difficult, and generally flawed, for non-specialist people, as Soligo et al[8] note: "*Many past and present criteria have defined the comfort categories and their associated wind velocity patterns, in terms of infrequently occurring wind velocities, e.g. wind velocities occurring 1% of the time. It is the authors' experience that criteria based on these infrequent wind velocities are misunderstood by individuals not knowledgeable in wind engineering.*" Planners and designers often need a sound understanding of the significance of wind conditions and wind effects, in order to be able to make the necessary trade-offs between conflicting factors, such as wind effects and heritage design. Even more critical to the success of the Wellington City Council process of working with development teams to obtain the best environment is that the team understand the wind effects of their development. Soligo again: "*A developer does not find it easy to understand why a project fails a comfort criterion because a particular velocity is exceeded 1% of the time. The frequent reaction is 'well, this must mean it is comfortable 99% of the time; so what is the problem?'*"

In 2004 the Wellington City Council started a revision of their District Plan, which included wind controls for the inner city area. This revision was viewed as an opportunity to create a more user friendly set of wind rules that could be easily understood and interpreted. Like many environmental wind ordinances, the current Wellington wind rules set out wind speed limits, of 10 m/s, 15 m/s and 18 m/s, beyond which existing wind speeds should not increase. These are annual maximum gust speeds, which makes their occurrence very small and not readily experienced by most people in the city. Hence most people have difficulty weighing pros and cons of a development when the wind environment impact when 1) there are clearly 8759 other hours in the year 2) the reported gust speed does not relate to anything they regularly experience.

New draft rules have been developed that describe the number of hours that certain 'threshold' wind speeds occur for in a typical year. These threshold wind speeds correspond approximately to the existing wind speed limits, but are mean speeds with a 20% probability of exceedance. In essence, the wind speed has been fixed as a criteria and hours of exceedance will be reported. Past experience has indicated that planners and designers find it considerably more intuitive to consider an increase of 3 weeks per year of "uncomfortable" wind conditions, than an increase from 15 m/s to 17 m/s in the annual maximum gust speed. By making wind data more easily interpreted and making the effects of changes in wind conditions more easily understood it is hoped that designers and planners can proceed with more confidence in their assessments and decisions.

Proposed draft wind rules for Wellington City

(a) SAFETY: The safety criteria shall apply to all public space

The maximum gust speed shall not exceed 20 m/s. If the speed exceeds 20 m/s with the development, it must be reduced to 20 m/s or below.

(b) CREEP: The creep criteria shall apply to all public space

Mean wind speed	**Change** in annual hours of occurrence with the development *	Requirements on developer
3.5 m/s	If hours that 3.5 m/s is equalled or exceeded increases by more than 170 hr/yr (i.e. 2 % of the year)	Reduce change in hours to a maximum of 170 hours.
2.5 m/s	If hours that 2.5m/s is equalled or exceeded increases by more than 170 hr/yr (i.e. 2 % of the year)	Reduce change in hours to a maximum of 170 hours.

* While hours exceeded at some locations may increase and decrease, the overall impact of a building on the wind conditions shall be neutral or beneficial.

(c) COMFORT: The comfort criteria **shall only apply to the parks and malls listed in rule 13.1.2.7**

Mean wind speed	Annual hours of occurrence with the development	Requirements on developer
2.5 m/s	If hours that 2.5 m/s is equalled or exceeded increase above 1700 hours.	Reduce number of hours to existing levels, or below 1700 hours.

Conclusions

A survey of outdoor park users was undertaken in Wellington New Zealand, to quantify the influence of wind, sun and temperature on people's perceived comfort. Direct measurements of comfort are difficult to achieve, which dictated that this study measured comfort indirectly, using a person's 'Adaptation to Achieve Comfort' (AAC). This AAC score was related to physical measurements of wind, sun and temperature that were made during the surveys and an empirical equation has been produced that relates these factors. From this, it is found that a mean wind speed of 2.8 m/s relates to the limit of comfort, for 80% of the time.

Wind ordinances for Wellington City are currently being revised to improve their clarity and understanding. Proposed wind rules have been presented that are intended to make the interpretation of wind tunnel data more imitative for non-specialist people involved in the design and planning process.

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References

1. Peter Jackson, P. S. (1978). "The Evaluation of Windy Environments", *Building and Environment* 13: 251-260.
2. Hunt, J. C. R., Poulton, E. C., Mumford, J. C (1976). 'Effects Of Wind On People; New Criteria Based On Wind Tunnel Experiments', *Building and Environment*, **11**(1).
3. Penwarden, A.D., Grigg, P. F., and Rayment, R. 'Measurements of wind drag on people standing in a wind tunnel'. *Building and Environment* Volume 13, Issue 2, 1978, Pages 75-84.
4. (for example) Penwarden, A. D., Wise, Alan Frederick Edward (1975). 'Wind environment around buildings', *Building Research Establishment Report*, Dept. of the Environment, Building Research Establishment: H. M. Stationery Off. 52pp. ISBN: 0116705337.
5. Walton, D., Dravitzki, V and Donn, M., 2006, 'The relative influence of wind sunlight and temperature on user comfort in urban outdoor spaces', Accepted for publishing in *Building and Environment*.
6. ASCE, Task Committee on Outdoor Human Comfort, 2004, 'Outdoor Human Comfort and its Assessment', *American Society of Civil Engineers*
7. Resource Management Act, 1991. Last accessed: New Zealand Government online: http://www.legislation.govt.nz/.
8. Soligo*, Michael J., Irwin, Peter A., Williams, Colin J., Schuyler, Glenn D. 'A comprehensive assessment of pedestrian comfort including thermal effects.' *Journal of Wind Engineering and Industrial Aerodynamics,* 77&78 (1998).