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Towards a Common Approach to Pedestrian Wind Criteria for Comfort

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Abstract

There are a variety of published pedestrian wind effects criteria the consulting wind engineer may choose from, and agreement amongst them is not always as good as may be hoped.

A number of members of the working group who developed the Guidelines for Pedestrian Wind Effects Criteria, Australasian Wind Engineering Society (2014), indicated that achieving an agreed position on safety was a worthwhile project but that it was also important to develop a similar position on criteria for comfort.

Since there appears to be some willingness to develop and present guidelines on the selection of wind criteria for pedestrian comfort, this study presents a summary of the situation from the author's own perspective which might be used as a starting point for a conversation by a future Pedestrian Wind Effects Working Group if the Society approves it.

Introduction

The Australasian Wind Engineering Society has recently produced guidelines for the selection of pedestrian wind criteria, Australasian Wind Engineering Society (2014). In these guidelines, specific recommendations are made for pedestrian safety. Pedestrian comfort is discussed but without specific recommendations being made.

A number of members of the Working Group who discussed and prepared the Pedestrian Wind Criteria Guidelines, indicated the need to specifically address pedestrian comfort criteria.

There is significant variability and ambiguity in a number of aspects regarding the selection and application of wind criteria for pedestrian comfort. The choice of criteria, and the way in which they are applied to areas surrounding a new development, can have a significant effect on the outcome of an assessment.

To further complicate criteria for comfort, although wind conditions are a significant contributor to overall comfort in outdoor areas, there are other important contributors including solar radiation, temperature, humidity and type of clothing. These variables are coupled to wind; for instance, people are more tolerant of wind as temperature and/or solar radiation and/or humidity rises. We may not, therefore, be able to discuss each of these comfort variables and recommend suitable criteria in complete isolation to the others. Outdoor comfort and its assessment is, therefore, a complex problem dependent on many variables beyond wind alone.

If we accept this is the case, to produce a complete assessment of outdoor comfort, the consultant would need to consider various aspects of the local climate simultaneously, presumably using a similar approach to the statistical analysis of wind but including variations of temperature and solar exposure with wind, for example.

As this approach is substantially more onerous and complex than what the wind engineering community would generally provide and is not usually requested by clients or planning authorities, it is suggested that aspects other than purely wind-related comfort issues be left out of any guidelines the wind engineering community might propose.

In this case, if the wind engineering community are to propose a set of guidelines for wind comfort, we will need to be careful to address only the wind aspect of comfort, and not get involved in other aspects such as temperature, humidity and so on.

There are a number of aspects which would need to be agreed on before a set of guidelines on comfort criteria could be presented:

- What levels of activities for comfort would be included (eg seated comfort, strolling, business walking etc)
- A clear definition of each level
- A definition of what aspects of comfort will be considered: eg. whether thermal effects are included
- What averaging time for wind speed should be used to define comfort
- An appropriate probability level for comfort criteria
- What are the limiting wind speeds corresponding to those probability levels.

Each of these points are discussed in detail in the following sections in the hope this may help in the development of guidelines for comfort criteria.

Comfort Considerations

Comfort Levels

There is not a highly unified approach among researchers to the definition of comfort levels. Although some researcher's criteria levels bear close resemblance to one-another, the differences in labels and descriptors can contribute to ambiguity and confusion.

In order to achieve a consensus approach to comfort levels and remove much ambiguity, we should first reach agreement on suitably labelled and defined levels of comfort.

Most researchers have divided comfort criteria into limits associated with various types of activity (Melbourne 1978, Lawson 2001, Davenport Wind Engineering Group 2007). These can be generally divided into:

- "walking"; where a person's primary objective is to traverse the area to another destination, i.e. this area is not itself a destination
- "short exposure"; where a person's primary objective is to spend a short period of time in an area (of the

order of 10 minutes) perhaps waiting for transport, window shopping, enjoying the scenery
- "long exposure"; where a person's primary objective is to spend a longer period of time in an area (of the order of ½ to 2 hours), dining, watching outdoor theatre

It is suggested that these three levels could form the basis of a discussion of a consensus approach to comfort criteria levels.

It is worth noting that in between many researchers' criteria for walking comfort and safety is a range of wind conditions which are not comfortable for walking but are also not considered dangerous. These wind conditions could be considered "acceptable" for walking but not "comfortable". This may obviate the need for various researchers division of walking into "strolling", "business walking", "waterfront walking" or the like.

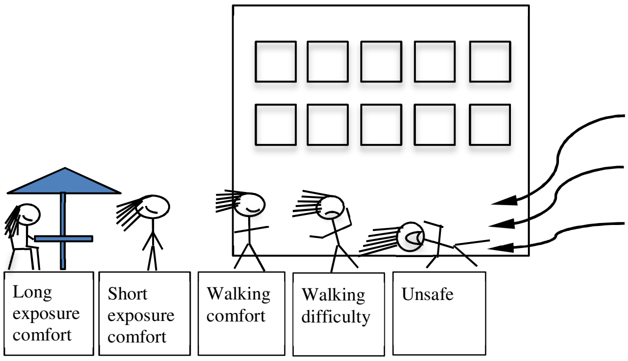

Figure 1. Suggested scale of wind comfort and safety levels.

Thermal Wind Effects

As noted by Arens et al. (2003), we can divide the consideration of comfort into 2 parts; "thermal" effects (the cooling effect of the wind) and "mechanical" effects (the ability of the wind to remove or disrupt items).

In cooler climates, people are generally trying to stay warm and any wind generally has a negative contribution to the perception of comfort. Conversely, in hot, humid climates people are often seeking to cool themselves and some level of wind is often welcome in this regard with people reportedly seeking out windier locations in capitals such as Singapore and Kuala Lumpur.

As stated by Arens et al. (2003), "…the effects of temperature and humidity [on comfort] are closely linked with wind conditions and cannot be treated in isolation…". Therefore, all three should be considered simultaneously to determine the level of thermal comfort.

The thermal effects of wind are therefore dependent on ambient conditions including temperature and humidity. Unless the wind consultant is proposing to embark on a full assessment of all of these aspects in conjunction with the wind climate assessment, it seems reasonable to say they may offer their professional judgement on wind conditions in relation to thermal effects and little more.

Whilst professional judgement can be very useful from an experienced consultant, it is not something that can be readily included in a set of guidelines. Since this discussion is centred around the production of guidelines on criteria for comfort, areas that must rely on professional judgement may be indicated as such in any guidance.

Mechanical Wind Effects

The "mechanical" effects of the wind are those effects which tend to pick up, remove or disrupt items. For example, the entire Beaufort Scale is based on wind speeds and descriptions of corresponding mechanical effects.

At lower wind speeds this may include disrupting or removing clothing such as hats, scarves, table settings, people's hair, newspapers, leaves, dust, beer froth etc. At higher wind speeds umbrellas maybe turned inside-out, people must modify their gait to maintain balance when walking and, eventually, people may be blown over.

It seems fair to say the majority of people generally perceive mechanical effects of the wind to be of some annoyance.

These mechanical effects of wind lend themselves well to criteria relating solely to wind speed and frequency of occurrence as they are independent of other variables such as ambient temperature.

Mean or Peak Wind Speed Criteria

As noted by Arens et al. (2003), mean wind speeds (averaged over 10 minutes to 1 hour) are more typically associated with the assessment of thermal effects and gust wind speeds (averaged over 3 seconds or less) with mechanical effects.

For example, wind chill is expressed as a function of mean wind speed in Arens et al. (2003).

This makes sense when one considers the thermal inertia of the human body. The human body will typically lose far more heat due to wind chill during an extended period with a given mean wind speeds than during the corresponding short-duration gusts (for example). In a cool climate, a short duration gust may produce elevated rate of heat loss but only for a short time resulting in a small overall heat loss. The major effect on the rate of heat loss will be the mean wind speed which will more accurately describe the heat loss rate over longer periods.

The mechanical effects of the wind, and any discomfort that may be associated with mechanical effects, are more typically associated with the gust wind speeds.

To illustrate how mechanical effects of wind comfort are dominated by gust wind speeds consider the following hypothetical situation: on a hypothetical day it is warm (i.e. no thermal discomfort due to wind chill) and the wind is picking up as the day progresses. Wind conditions in a popular outdoor café terrace area are beginning to increase as a result. The location is in an urban environment, where mean wind speeds are relatively low compared to gusts. As a result, the outdoor seating area is beginning to experience disruption of table settings during some of the stronger gusts causing discomfort for patrons. As wind conditions continue to increase the gusts capable of lifting newspapers, napkins and dust are now occurring frequently enough to cause a level of discomfort which results in most patrons retreating to a more sheltered location or perhaps indoors or perhaps leaving.

If the wind conditions at a point in time in this hypothetical situation were at a level where the mean wind speed was capable of lifting napkins, newspapers and dust and blowing them around, you could be quite sure the gusts would have reached this level beforehand and caused a general retreat.

In this hypothetical scenario, one can see it is the gusts which generate the discomfort initially and result in the response of the patrons. This can be readily explained by the important fact that mechanical effects are a result of the wind pressure which is a function of the square of the wind speed. Typical gusts occurring every few minutes may only be 50% higher in terms of speed than the mean wind speed but cause 130% more wind pressure. The result? The 10 minute, or hourly, mean wind speed may cause little or no discomfort while the gusts may cause significant disruption and discomfort.

Probability of Exceedence

It appears to be a common experience of wind engineering consultants working in the field of pedestrian wind effects that many lay-people have difficulty in understanding the frequency of occurrence parameter when it is stated in terms of fairly low probabilities of exceedence (eg. less than 1%). As noted in Arens et al. (2003) and as experienced personally by the author, the response to this probability level may often be: "So the wind conditions will be comfortable 99% of the time? Surely that is acceptable?", or words to that effect.

To this end, it would seem appropriate to state any comfort criteria in terms of higher probabilities of exceedence, perhaps of the order of 5% to 20%.

Limiting Wind Speeds

The limit wind speeds and associated frequency of occurrence is likely to be the most difficult variable to achieve concensus on.

Ratcliff and Peterka (1990), Koss (2006), Sparks and Elzebda (1983), Fricke and Holmes (2012) all found significant disagreement amongst various published criteria.

The mere fact that there are so many published criteria suggests disagreement, since, if many were in good agreement, there would seem little need for a researcher to publish another set of criteria. They could, instead, simply indicate a good level of agreement with previously published criteria had been achieved.

The author suggests it may be helpful to look at the problem of defining wind comfort criteria by considering three potential scenarios and what advice wind engineers and the wind engineering community could reasonably offer for each:

Consider a scenario where the climate is warm and thermal comfort due to wind is not an issue. With no thermal effects to consider, the upper limit of wind speeds for comfort are purely those which begin to cause unacceptable levels of disruption due to mechanical effects. This is purely a wind speed and frequency issue and the wind engineering community should be able to offer guidance here.

Secondly, consider a very cold climate. In this case it may be that thermal effects dominate and so, well before the mechanical effects of the wind begin to cause discomfort, wind chill effects render a location uncomfortable. The consultant may assess both mechanical effects against gust wind speed criteria and thermal effects (wind chill) due to mean wind speeds and determine which dominates comfort. Again, this is more-or-less purely a question of wind speed and frequency and the wind engineering community should be able to offer guidance here.

Now consider a cool-temperate climate. Thermal effects (wind chill) may be an issue at some times of the year and not others. The wind speeds at which the wind chill may be unacceptable will depend on ambient conditions which vary during the day and during the season. The consultant may assess both mechanical effects against gust wind speed criteria and thermal effects (wind chill) due to mean wind speeds and determine which dominates comfort at given times of year.

Into this third, rather complex, scenario the wind consultant may boldly go if they wish, however, it is more than a purely wind-related problem, and, indeed, it is beyond what is normally requested by designers, and planning authorities, at least in Australia.

It seems a significant step for our society to produce guidelines covering work in this third scenario. However, what our Society should be able to provide (at least initially) is clear guidance on the criteria for limiting values of wind speeds for the mechanical effects component of comfort as this is purely wind speed and frequency related.

Summary of Recommendations

Based on the discussion presented in the preceding sections the following simplified approach is suggested:

a) We may leave thermal effects to the professional judgement of individual consultants at least for the time-being.
b) If we accept mean wind speeds are mostly associated with thermal aspects of comfort, we may focus on gust wind speeds and their associated mechanical effects on comfort for the criteria.
c) We may define upper limit wind speeds as gust wind speeds which cause unacceptably high disruptive effects for that activity and an associated return period that the lay-person will be able to readily relate to.

If this approach was accepted, the following table would summarise the areas that need to be addressed (in italics):

Criteria	*Long exposure comfort*	*Short exposure comfort*	*Walking comfort*	*Walking difficulty*	Unsafe
Limiting mech effects	*Napkins and beer froth frequently removed by gusts*	*Hair disrupted, hats removed, difficulty hearing*	*Average person forced to change their gait for balance*	*Walking is possible but difficult for the average person.*	Average person forced to the ground
Peak gust wind speed limiting mech effects begin	*Value to be agreed*	*Value to be agreed*	*Value to be agreed*	*Value to be agreed – safety limit*	>23m/s Value as agreed previous ly
Frequency of occurrence	*Value to be agreed*	*Value to be agreed*	*Value to be agreed*	*Value to be agreed*	0.1% Value as agreed previous ly

Table 1: Possible basis for discussion of wind criteria for comfort

Conclusions

This study has presented some considerations on the selection and application of appropriate pedestrian wind criteria for comfort. Suggestions have been made for an approach toward achieving some consensus on wind criteria for comfort.

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References

Alan G. Davenport Wind Engineering Group (2007) Wind Tunnel Testing: A General Outline, The University of Western Ontario, Faculty of Engineering Science

Arens E, Aynsley R, Cochran L, Durgin F, Hayashi Y, Irwin P, Isyumov N, Murakami S, Soligo M, Stathopoulos T, Wu H (2003) Outdoor Human Comfort and its Assessment, American Society of Civil Engineers

Australasian Wind Engineering Society (2014), Guidelines for Pedestrian Wind Effects Criteria, http://www.awes.org/archives/news/pedestrian-wind-effects-criteria/

ESDU International (2002) Strong winds in the atmospheric boundary layer. Part 2: discrete gust speeds. ESDU Data Item 83045, issued November 1983, revised March 2002.

Fricke H, Holmes J (2012) A Comparison of Pedestrian Wind Comfort and Safety Criteria, Australasian Wind Engineering Society Workshop Proceedings

Koss H (2006) On differences and similarities of applied wind comfort criteria, Journal of Industrial Aerodynamics, Vol. 94 pp 781-797

Lawson (2001) Building Aerodynamics, Imperial College Press

Melbourne W (1978) Criteria for Environmental Wind Conditions, Journal of Industrial Aerodynamics, Vol. 3 pp 241-249

Ratcliff M, Peterka J (1990) Comparison of Pedestrian Wind Acceptability Criteria, Journal of Industrial Aerodynamics, Vol. 36 pp 791-800

Sparks P, Elzebda J (1983) A comparison of pedestrian comfort criteria applied to a city center, Journal of Industrial Aerodynamics, Vol. 15 pp 123-132

Standards Australia (2011) Structural Design Actions, Part 2: Wind Actions, Standards Australia