Wind Microclimate on Balconies: Designing Climate-sensitive Outdoor Spaces

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1 INTRODUCTION

Wind microclimate assessments in the UK (and elsewhere throughout the world) are required to demonstrate that wind conditions are safe and suitable for thar area's intended uses. In principle, this should apply to both public spaces around buildings and the private amenity spaces within a new design (such as balconies and terraces), however the latter of these has historically received less attention than the public realm. However, in the UK, the design of balconies and terraces has become increasingly important in the past few years due to the desire of urban planners to provide enjoyable amenity spaces at elevated private areas as well as public realm. The BSI's 'Guide to the design of balconies and terraces'[1] specifically includes a section on designing for an appropriate wind environment. It is therefore important that these spaces are robustly assessed during design, in much the same way as the public realm at ground level.

There are several constraints to the assessment of balconies in the wind tunnel, such as the physical size of these areas, fitting instrumentation into the wind tunnel model and achieving a suitable coverage of balcony locations with a limited amount of instrumentation. As a result, the critical limitation of appropriate balcony instrumentation is not only achieving the necessary accuracy but also doing so efficiently, such that the service is feasible for building designers and developers to undertake. Computational Fluid Dynamics (CFD) methods are a potential alternative, however these suffer from their own distinct limitations (including the need for a very fine mesh resolution around the relatively small balcony features, within an overall domain size of the order of a kilometer). Specific local guidelines (such as in the City of London[2]) prescribe the particular use of one or other method (and sometimes both), meaning that both kinds of methodology must be capable of robustly assessing balconies and terraces.

As part of a wind microclimate assessment, it is likely that wind mitigation measures will also need to be tested. Where wind mitigation is required to alleviate unsuitable wind conditions, options for potential measures are restricted due to the size of the space, as well as the balcony being a private amenity area where tenants can opt to adapt non-permanent features such as provided landscaping. As a result, wind mitigation measures typically involve adaptation of the balustrade design; either by increasing the height or modifying the porosity. Therefore, consideration of instrumenting or simulating these small balcony areas also needs to factor the interaction of balustrades of varying heights and porosities, which will dramatically alter the wind characteristics within the space.

Over several years RWDI has conducted research into measurement techniques and methodologies at balcony locations, with the intention of improving our practices for balcony assessments. These assessments include consideration of different instrumentation which may be used at balconies, as well as the optimal approach to use specific instrumentation at balconies. RWDI are conducting further work with the aim of understanding the accuracy of wind microclimate assessments at balconies further, however these are not completed at this time.

2 EXISTING LITERATURE

Existing literature on the assessment of wind conditions at balconies is extremely limited, particularly with a focus on the wind microclimate within the balcony area. The majority of papers focus on the mean, rms and peak surface pressures around the balcony. Furthermore, of the studies which considered the mean wind velocity at the balcony, of which a summary of existing research can be found in Xing Zheng (2021)[3] none of these studies were undertaken using wind tunnel assessments. The majority of wind tunnel assessment which consider balconies specifically use pressure taps to assess wind pressures (such as Zhu, 1988[4] and Martura, 1998[5]) which is not applicable to wind microclimate assessments.

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Furthermore, of the studies reviewed, few consider the impact of balustrades as part of the assessment. As balustrades design is often the only option for wind mitigation measures when wind conditions are found to be unsuitable, the impact of balustrades is a key factor for effective balcony assessments. (Xing Zheng, 2021) demonstrate the importance of the consideration of balustrades having compared balconies of different depths and balustrade heights as well as the number of separations along the balcony space (modelled as a long balcony extending the length of the façade). Regarding balustrade height specifically, it was noted that including a 1m tall solid balustrade along the balcony would result in an increase in Cp, however a further increase of the balustrade height to 2m would reduce Cp. This highlights that the impact of balustrade on the wind conditions within and around the balcony is not linear, and therefore when conducting research at balconies not only should balustrades be considered but several heights of balustrade should be assessed.

3 COMPARISON OF INSTRUMENTATION TECHNIQUES (METHODOLOGY)

There are currently no guidelines that pertain specifically to the best approach for instrumentation at balconies for wind microclimate assessments. Instrumentation such as cobra probes or hotwires are often used as it is assumed that this will produce a more accurate result; however, the practical limitations of using these instruments include an increase in testing time and a reduction in the number of balcony locations which can feasibly be assessed to fit project timescales. Furthermore, these will typically increase the cost of the assessment for the client. Alternatively, Irwin probes[6] are also used within balcony spaces which is more time and cost effective, as well as meaning more balcony locations could be assessed. However, Irwin probes were initially developed for use at ground level spaces where there would (in theory) be a local, well-formed boundary layer, and were not investigated at balconies. There is therefore some uncertainty as to whether it is appropriate to use Irwin probes in these spaces. The aim of RWDI's research was to a) understand if different instrumentation methods would produce different results, b) determine if the most efficient instrumentation method (Irwin probes) are adequate for balcony assessments and c) if any precautions or consideration are required for the balcony instrumentation methodology.

3.1 Comparison of Instrumentation

The comparison of instrumentation tests were conducted using an existing wind tunnel model used for a pedestrian level wind microclimate assessment. The intention was to use a "real case" scenario which would be more realistic in terms of balcony design, the surrounding context of the assessment buildings and the practical benefits and limitations of testing with particular instrumentation, compared to a simplified model. At the instrumented balconies it was important to ensure the readings were taken at the same location within the balcony space, meaning the tip of the Irwin probe, the tip of the cobra probe ad the centre of the hotwire needed to be places in approximately the same location.

Up to ten balconies were assessed for each model tested. It was important to ensure several types of balcony location were assessed to ensure that different flow fields would be accounted for. Therefore, corner balconies were assessed both upwind and downwind of the prevailing wind direction (i.e. the direction where winds occur most frequently based on meteorological data, such as southwest in most of the UK), and balconies within chamfers were also instrumented for this assessment (see Figure 1).

As discussed above, there are significant time constrains when using cobra probes or hotwires for balcony testing, and as the purpose of the assessment was to compare measured wind conditions between the two options of instrumentation rather than conduct a complete assessment, the testing time was optimised by testing the most significant angles at each balcony which would contribute most significantly to the overall wind conditions. Several wind angles were selected for each balcony to be measured based on the wind exceedances noted in the Irwin probe assessment. The stand and support of the hotwire were located such that they would not interfere with the wind flow, which also meant the hotwire did not have to be repositioned for each angle.

As the design of the Proposed Development used for these tests is not currently in the public domain, images of the wind tunnel model cannot be shared.

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3.2 Instrumentation of Irwin Probes in varying orientations and configurations

To assess the wind conditions on the balconies, a 1:300 scale model of a square tower of dimensions 500mm tall and floor plan of 190mm2 were constructed. The model was symmetrical with wall mounted probes on one side and floor mounted probes on the opposite side.

The wind tunnel model was instrumented with 48 sensors in total. Locations 13 to 30 were wall mounted, and locations 31 to 48 were floor mounted. Both the sides included 18 sensors each – three rows each having six balconies. At each level, three locations would be projecting balconies and three locations would be recessed. The size of the balconies were 12mm2 to incorporate the sensor. The tip of the brass tubes of the sensors were placed in such a manner that the wall and floor mounted sensors are measured at the exact same location irrespective of how the sensors were mounted.

Control probes (locations 1 to 12) at the grade level were used on the disc to check its repeatability between various iterations.

Wind speeds were measured for 36 directions in 10-degree increments. Therefore, the wall and floor mounted results could be compared at 0° and 180°, 10° and 190°, etc (wall and floor mounted respectively), as the cube and probe layout were symmetric. A profile matching a suburban surrounding area was used to provide a more likely turbulent environment. However, no surrounding buildings were included as the intention was to assess the balcony measurements with no other influence. The wind tunnel test was conducted for the following configurations:

- Configuration 1: No balustrades (representative of very porous railings)
- Configuration 2: Solid balustrades 1.2m
- Configuration 3: Solid balustrades 1.5m

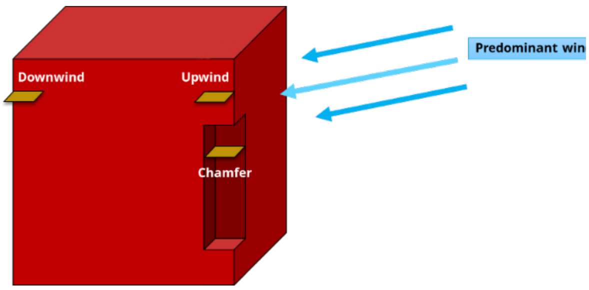

Figure 1: Diagram of notable balcony location types

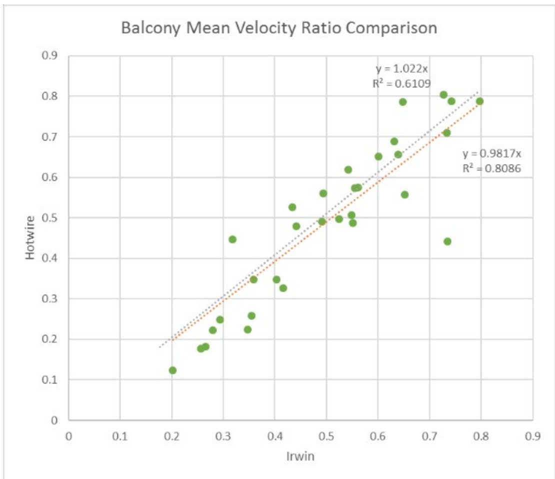

Figure 2: Comparison of mean velocity ratios from the hotwire and Irwin probe

4 COMPARISON OF RESULTS

Cobra probes were found to be impractical to use for balcony assessments. Despite being more robust that hotwires, the size of the instrument means it is extremely difficult to measure in the correct space for the balcony. This would lead to results which were too windy and, although embracing the most conservative methodology for balcony assessments in lieu of knowing the most accurate method is useful, the wind conditions were unrealistic.

Hotwires and Irwin probes were more apt for assessments in the small balcony spaces, however testing using hotwires took more for both acquisition and set up. The comparison of results showed that there was no consistently conservative option between hotwires and Irwin probes, and furthermore for the

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majority of balcony locations there was a strong correlation between the instrumentation methods. The results were similar enough that when processed using the Lawson Comfort Criteria[7] the overall wind conditions would remain the same. Therefore, it is recommended that, if used appropriately, Irwin probes are just as suitable for balcony assessments as alternative instrumentation options.

The appropriate method for instrumentation of Irwin probes at balconies was also investigated. The results indicated that wall mounted probes are preferable in many cases, however it is important to consider several features of the balcony when installing any instrumentation such as balustrades, projecting/recessed designs and location on the building. For example, the assessment at recessed corner balconies may be more conservative if instrumented in the floor depending on how high up the building the balcony is located, which corner the balcony is located on and if there is a balustrade. In these scenarios an experienced wind engineer would need to consider the balcony features in addition to the prevailing wind direction to determine the most appropriate method for installing the Irwin probe.

5 CONCLUSIONS

Due to the significant gaps in available research for the assessment of wind microclimate at balconies there currently are no informative procedures and methodologies to advise on these assessments. Of the research conducted with a focus on wind microclimate, there is little consideration for the inclusion of balustrades, the location of the balcony on the building, or the practicality of the assessment for the purposes of industry. RWDI has undertaken several studies to understand the difficulties of assessing balconies as part of a wind microclimate study, and to work towards improving our methods. This is an area of limited current research and will be the focus of ongoing work with the potential to develop practical guidelines following further assessments. The aim of the guidelines would be to outline what methods should be used for efficient and precise results which the wind consultant can be confident would not underpredict the overall wind conditions. Further research is required to determine the most accurate methods for balcony assessments.

Based on the comparison of instrumentation there is no clear conservative options between using hotwires and Irwin probes. However, due to the practicality of using Irwin probes in comparison to hotwires, our recommendation would be that Irwin probes are more effective when used for wind microclimate assessments. The ease of use and ability to test more balconies more efficiently not only saves cost for the client but also means a wider selection of balconies can be considered. Methods for the most effective and appropriate use of Irwin probes within balconies were also assessed. In many cases wall mounting the Irwin probe within the balcony is preferable, as this will give the more conservative and/or sensible results.

5.1 REFERENCES

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