THE PREDICTION OF WIND LOADS ON BUILDING ATTACHMENTS

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ABSTRACT

Building attachments, such as window sunshades and parapets, are commonly found on present day buildings. However, due to difficulties in directly modeling and measuring the pressures on the attachment, little information exists in regard to their wind loading. This paper illustrates, through a general discussion, the problem of determining loads on building attachments and illustrates solutions through typical case studies involving estimated loads on parapets and complex sunscreens.

1. INTRODUCTION

The growth of architectural flair in design has led to buildings being designed with increasing complexity and nonconformity. Along with the trend to move away from a simple building geometry, a common method of visual enhancement and to control solar heating is to attach elements to the exterior walls and roof of the building. Window louvers, sunshades and parapets are all commonly found on present day buildings. Often these elements are constructed of lightweight and flexible materials that make it important to correctly estimate their wind loading. However, attempting to accurately predict the wind loads on these attachments, often in regions of complex building geometry, is not a simple task.

Despite recent advancements in computational fluid dynamics, wind tunnel simulation of a scaled model is still the most common tool used to predict wind loading. However, the relatively small size of attachments compared to the dimensions of the building makes it extremely difficult to directly model and measure its wind loading in a wind tunnel. Due to height restrictions of the wind tunnel test section and the minimum upwind fetch distance required to properly develop the atmospheric boundary layer, the geometric length scale for modeling a high rise building, for example, is typically limited to a scale between 1:200 to 1:500. For low-rise buildings it is not usually possible to have models larger than about 1:25. Even at this scale the attachment itself is very difficult to model and often cannot be directly instrumented with pressure taps.

In addition, the building attachments are commonly located away from the face of the building, where the magnitude and direction of the local wind may vary strongly in both time and space. In this case, the traditional pressure measurements on the nearby building surface do not generally provide any useful information for an attachment, like a sunshade, located away from the building surface.

For example, the pressure recorded by the wall tap will be more or less the static pressure in the wind flowing near to the building surface, as shown in Figure 1. If the local flow speeds are small, such as when the sunshade is located in the downstream wake of the host building, then the wall pressures will be an adequate estimate for the sunshade. In this case, the pressures will be more or less the same over the entire sunshade and hence will not contribute any net loading. However, if the sunshade is located in a region of strong local flows, such as on a windward face, the pressure on the sunshade will vary over the element due to the pressures induced by the flow around the element. It is these pressures that are required to accurately calculate the loading on the sunshade, but it is these pressures that cannot be recorded by the pressure tap on the building surface.

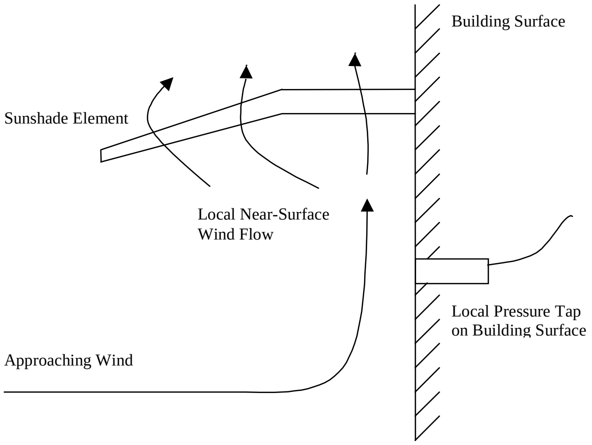

Figure 1. Schematic drawing of typical sunshade element.

Hence, an alternative technique of measurement is required. At the Boundary Layer Wind Tunnel Laboratory such problems have been approached through directly measuring the wind fields in which the attachment exists using hot wire anemometry, and then estimating loads either from existing aerodynamic coefficients from the literature, or from special purpose measurements on a larger scale model of the attachment. In addition, smoke visualization and other novel techniques are used as aids to better understand the directionality of the wind in proximity to the sunshade elements on complex building shapes.

Two case studies, where this problem was encountered, will be briefly discussed, detailing the procedure adopted to, first, measure the wind loads on two high rise building sunshades and, second, wind loading on a parapet.

2. CASE STUDY 1 – WIND LOADS ON A HIGH RISE BUILDING SUNSHADE

Recently, attempts were made to predict the wind loads acting on the sunshade elements on the high rise building shown in Figure 2. As the figure suggests, rather than attempt to directly model and measure the wind loads on the sunshades, a simple 1:200 scale and relatively inexpensive foam model of the building and surrounding built-up environment, that excluded the sunshades, was examined.

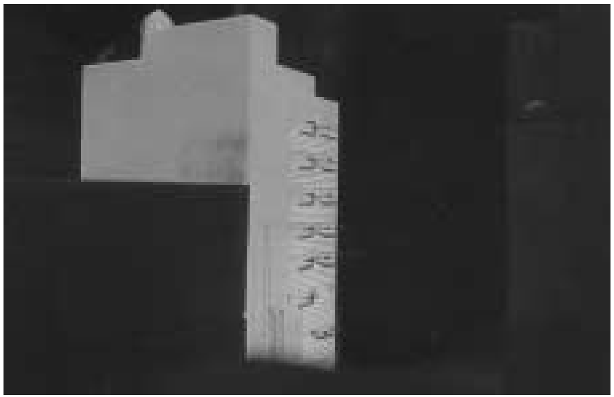

Figure 2. Photograph of 1st case study model with hot-wire probes attached.

Initially, a smoke visualization study was performed to determine which wind directions yielded winds on the front face of the building with a strong vertical component, perpendicular to the proposed sunshade elements. The study found the surrounding buildings strongly influenced the flows, with the critical wind direction being observed to come from behind the test building. From this direction, the wind passed over the top of the building, contacted the taller building across the street and formed a vortex with strong up-flow on the downstream face of the test building.

With this information, the model was instrumented with twelve single wire hot-wire probes sensitive to winds moving up and down the front face of the building, the results of which could be used to obtain the peak wind speed in the direction normal to the sunshade blades. The peak wind speeds were then combined with knowledge of the local wind climate to obtain the peak local wind speed affecting the sunshades for a 1 in 50 year storm event. This was found to be approximately 90% of the mean wind speed at roof height.

Since the sunscreens were made of typical aerodynamic shapes, it is a relatively simple task to estimate and apply a force coefficient to the measured peak wind speed (e.g. Hoerner[1]).

A similar procedure was also adopted to calculate the wind loads acting on the sunshade elements of a second high rise building. Again, the blades themselves were not modeled, but wind loads were implied from a hot-wire study of a 1:400 scale model of the building and its surroundings, as shown in Figure 3.

Figure 3. Photograph detailing a portion of the second sunshade model.

Smoke visualization of the wind flow around the building revealed wind speeds normal to the blades were strongly influenced by the openings at the corners of the building. In particular, a strong speed-up of the normal velocities was observed at the base of the building, where the flow was channeled through the bottom openings.

Hot-wire anemometers were placed at regular intervals on the surface of two wall faces to determine the peak wind speeds normal to the sunshades. The probes were placed about 7-mm from the surface of the model so that they protruded beyond the corner columns to the location that the outer edge of the sunshades would occupy. The peak velocities affecting the sunshades that were recorded in the wind tunnel were then combined with the wind climate information to predict the 1 in 50 year peak wind speeds expected on the sunshades. This was found to be approximately 10% greater than the mean wind speed at roof height.

To calculate the full scale loading on the sunshade, the peak wind speeds were then multiplied by a worst case force coefficient. The results were found to be significantly less than those previously estimated, making the design feasible for construction.

3. CASE STUDY 2 – WIND LOADS ON A LOW-RISE BUILDING PARAPET

A 100 x 150 x 15 ft tall warehouse was tested with a variety of parapet heights to determine wind loading on a parapet [2]. In the two previous examples, the size of the attachment relative to the dimensions of the building made it impossible to directly measure the attachment loading. However, in this case, the overall size of the building is considerably smaller, making it possible to properly model the parapet and measure the applied pressures through traditional pressure tap techniques, as shown in Figure 4, by using a larger scale model.

The parapets were modeled by attaching a movable exterior wall shell around the perimeter of the model building. The shell was then stepped up at pre-defined increments. Four separate parapet heights were examined, with a constant nominal width of 1.0 ft, ranging from 1.5 ft to 9.0 ft tall.

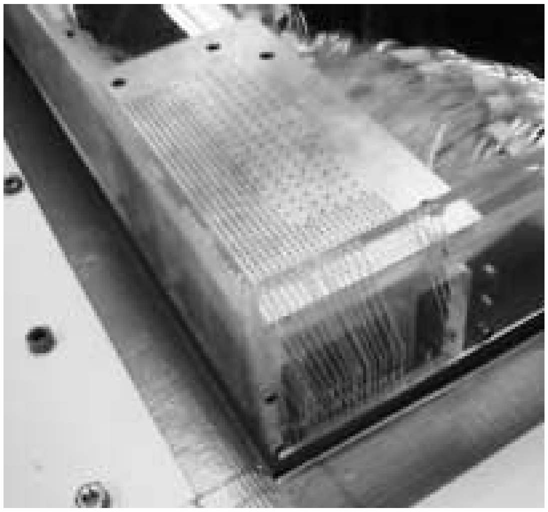

Figure 4. Photograph of pressure tap model with 3 ft parapet attached.

A total of 108 pressure taps were present on each of the model configurations, the majority of which were located on either the front or rear surface of the parapet, or the external wall surface of the building. By simultaneously recording the pressures on both parapet surfaces, the results could be combined to produce instantaneous structural loading and area-averaged coefficients over the parapet.

Due to difficulties in directly instrumenting the parapet section, in particular short parapets, it is not common for wind tunnel studies to attempt a direct examination of parapet wind loads. Instead, the pressures on the parapet are inferred by assuming that the pressures on the front surface of the parapet are the same as the wall pressures and the inside parapet surface pressures are identical to the roof suctions.

The experimental results suggest this may be a reasonable approximation. Instantaneous structural loads, acting on a 6 ft tall parapet, were developed to produce the true parapet loading. These were then compared with estimates derived using only the wall/roof taps in the proximity of the parapet. Two estimates were calculated and compared, as shown in Figure 5.

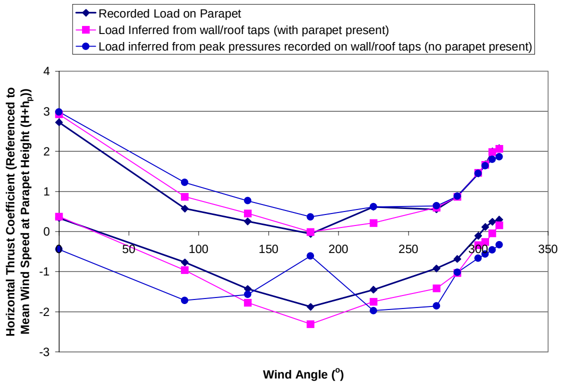

Figure 5. Horizontal thrust coefficients for a 6 ft parapet.

First, instantaneous estimates were developed using the wall/roof pressure taps with the parapet present. A second, and more simplified model, was also compared. In this case, the structural loads were derived using only the peak pressures recorded on the wall/roof taps with no parapet present. This reflects the common approach adopted in past codified standards for extending non-parapet data to the design of parapets. Both methods were found to overestimate the true loading on the parapet, with the peak structural loads overestimated by approximately 15%. It is believed this difference is due to the lack of correlation between the pressures on the inside parapet surface and those on the roof.

4. CONCLUSIONS

This paper has discussed the difficulties involved in predicting loading on building attachments through wind tunnel testing. In particular, building attachments that are located away from the face of the building, such as sunshade blades, cannot be accurately estimated through traditional pressure tap techniques or measurements made on the nearby building surface. This problem has been overcome by directly measuring the peak wind speeds in which the attachment exists using hot-wire anemometry, and then estimating loads from existing aerodynamic coefficients from the literature. This has proven to be a simple, effective and economic method to increase the level of confidence in predicting wind loads on attachments.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

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