DISCUSSION ON FULL-SCALE INTERNAL PRESSURE MEASUREMENT

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INTRODUCTION

The wind loading on most structural elements is made up of both an external and internal pressure. Internal pressures are also important for the design of naturally ventilated buildings. The internal pressure is the interaction between the external pressure propagating through the building envelope and any internal plant causing building pressurization. Although the external pressure field can be well defined through a series of wind tunnel tests, modeling complexities makes accurate prediction of the internal pressure difficult. For commercial testing for the determination of design cladding pressures, an internal pressure coefficient is generally assumed from wind loading standards. Several theories regarding the propagation of internal pressures through single and multiple dominant openings have been proposed for small and large flexible buildings (Harris (1990), Holmes, (1979), Liu & Saathoff (1981), Vickery (1986, 1994), Vickery & Bloxham (1992), Vickery & Georgiou (1991)).

Although the prediction of internal pressures could have an impact on the design loading of structures only a few full-scale measurement studies have been undertaken (Ginger et al. (1997, 1999), Hoxley (1991), Robertson, (1992)). These studies have generally been on small domestic sized buildings and no full-scale studies could be found on large buildings. The purpose of this paper is to discuss some of the inherent problems with full-scale measurement of internal pressures and to present some preliminary results from testing in a large building.

EQUIPMENT

Two types of pressure transducer are readily available for internal pressure measurements: absolute and differential. Absolute pressure transducers measure barometric pressure and would therefore appear to be ideal for the task at hand, as they measure internal pressure directly. They work by a diaphragm operating against a sealed volume of fixed pressure. They are small and only need one cable to link them to any signal conditioning. Since absolute transducers have to operate in atmospheric conditions they have a wide operating range: a minimum of 800 – 1200 mbar for measuring atmospheric pressure. When trying to measure typical internal pressure fluctuations of 1 – 100 Pa this range is excessive and the transducer may have insufficient accuracy. The transducer may also be dependent of temperature, and as the wind is generally being driven by a large-scale weather system the atmospheric pressure may easily fluctuate by more than 100 Pa per hour and therefore it is difficult to separate the effects of the weather pattern from the internal pressure measurements without a control barometric pressure transducer. However, any reference transducer needs to be housed away from any building or wind flow interference, which is generally impractical in a built up environment.

As the name suggests, differential pressure transducers measure the pressure difference between two points, with a diaphragm located between two small reservoirs. Differential pressure transducers come in a wide array of shapes and sizes, but for internal pressure measurement as small a range as possible is required, ideally ±1 kPa. These are more appropriate than absolute pressure transducers for the magnitude of pressure fluctuations being studied. As differential pressure transducers measure the pressure difference between two points, any effects of the large-scale weather system should affect both points similarly and any differences are caused by the wind. The problem with differential pressure transducers is how to connect them, as tubing has to be run between the points of interest. This may be easy if a nett pressure across a surface is required, but becomes problematic when trying to measure internal pressure directly, as a reference pressure needs to be found and all transducers connected to this common reference. Ideally this reference pressure should be atmospheric pressure, therefore needs to be remote from any wind induced pressure field around any building (preferably a pit located some distance from the structure). This is practically impossible in temporary full-scale applications as finding a remote location in an urban environment, accessing a hole in the ground, and running tubing that will not be interfered with (by nature or man) for the duration of the testing period is problematic. Using differential pressure transducers therefore requires some flexibility in the selection of a reference pressure.

TESTING

The subject large building is approximately 200 m by 70 m in plan. The building can be compartmentalized with the use of a partition wall, 12 m high. Each of the long walls has six equally spaced large bi-fold doors. Depending on the wind direction on the day of testing one of these doors was opened to create a dominant opening. Testing of the building concentrated on internal propagation through the entire hall after the creation of a dominant opening. Some additional tests were conducted with the halls divided to investigate the pressure differential across the partition. Access to the building for testing was limited to four visits and unfortunately the wind on each of these days was light.

For testing it was decided to use absolute transducers for internal pressure measurements, due to the practical difficulties with the differential transducers, and six of these were placed along the centerline of the building. A board for measuring the external pressure was placed near the bi-fold door that was to become the dominant opening. An anemometer was mounted on the roof of the building.

RESULTS

Fig. 1 shows a 5-minute pressure trace of the external and 2 internal pressure transducers located at either end of the building. A windward door was opened at scan 300. It is evident that the external pressure drifts significantly. The external pressure transducer was placed inside the bi-fold door, but when the door was opened the transducer was sitting in direct sunlight. Thus the sensitivity of absolute pressure transducers to temperature is highlighted. It is also evident that the two internal pressure transducers drift relative to each other. This is considered to be caused by the small range of pressure being used in the testing. Notwithstanding the signal drift it is evident that the shape of the curves are similar indicating that the internal pressure follows the external pressure directly. The remaining internal pressure time series were similar in shape to those shown, but all drifted relatively to one another.

Fig. 2 shows the situation when the wind is blowing obliquely to the building axes. The windward door opened at scan 180 and a leeward door is opened at scan 2200. It is evident that between these scans all traces follow each other governed by the external pressure. When the second door is opened the internal pressures drop relative to the external pressure measured near the windward opening. This would be as expected as the external pressures at both openings now govern the internal pressure. Unfortunately the external pressure at the second door was not measured. Also plotted on Fig. 2 is the dynamic pressure recorded at the anemometer located on the building. The dynamic pressure trace has been displaced to try and take account of the special difference between the anemometer location and the external pressure transducer. The traces show a reasonable relationship considering the highly fluctuating nature of the wind speed and direction over the test period.

Fig. 3 shows a comparison between the absolute and differential pressure transducers when measuring across a partition. The building was internally split in two and transducers placed on either side of the partition. A bi-fold door on the more windward side of the building was opened at scan 1800. The wind speed was again reasonably low averaging about 4 m/s. The nett pressure measured using the absolute and differential transducers were similar and followed the external pressure. However, there is significantly more noise with the absolute transducers. This is due to the small range of pressure being measured in comparison to the full range of the instruments, and two instruments rather than one are being used in the calculation.

From a more detailed investigation of the single dominant opening results no Helmholtz resonance or pressure overshoot was found, but this expected due to the large flexible nature of the building, and the low winds speeds experienced during testing. Internal pressures do not occur simultaneously, but radiate from the opening. There was a time lag of about 0.5 s from one end of the building to the other, which agrees well with theory. The results were also compared against wind tunnel testing and reasonable correlation was found. This comparison is beyond the scope of this paper.

CONCLUSIONS

Internal pressures were measured reasonably successfully in a large building. Experimentally internal pressures are awkward to measure accurately. From a comparison between the performance of absolute and differential transducers it is considered that absolute pressure transducers are not accurate enough for internal pressure measurements, due to lack of sensitivity over the required small pressure range. However, logistical problems with differential transducers also cause significant problems. With a single dominant opening internal pressure fluctuations follow the external pressure essentially simultaneously. Comparison between

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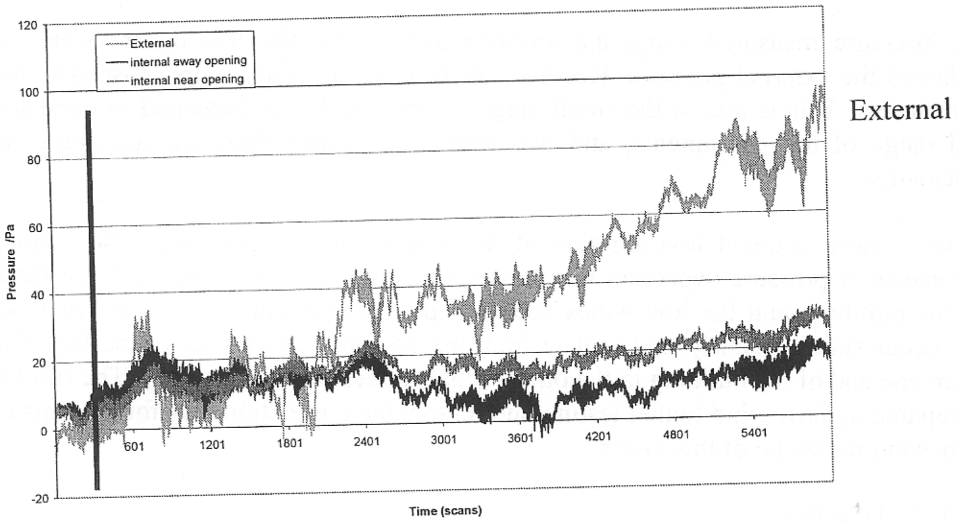

Fig.1: Signal drift due to temperature

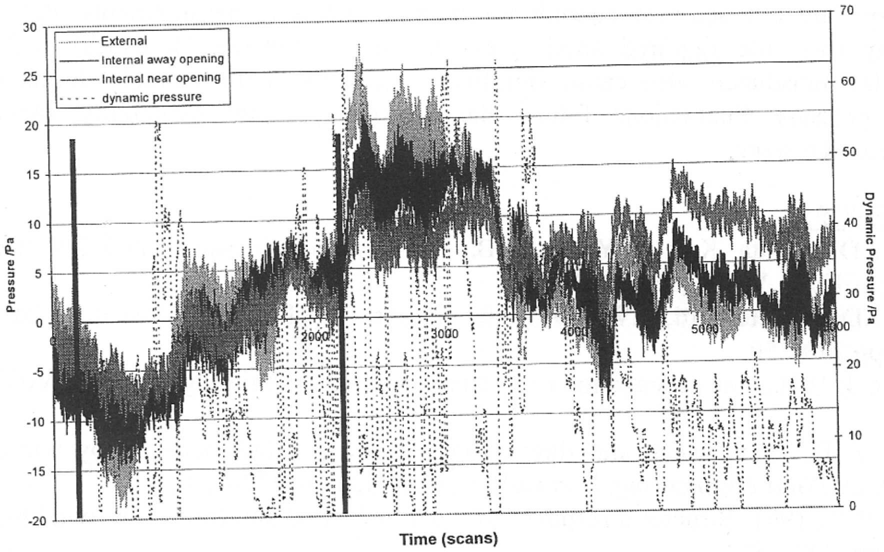

Fig. 2: Internal and external pressure measurements during two door openings

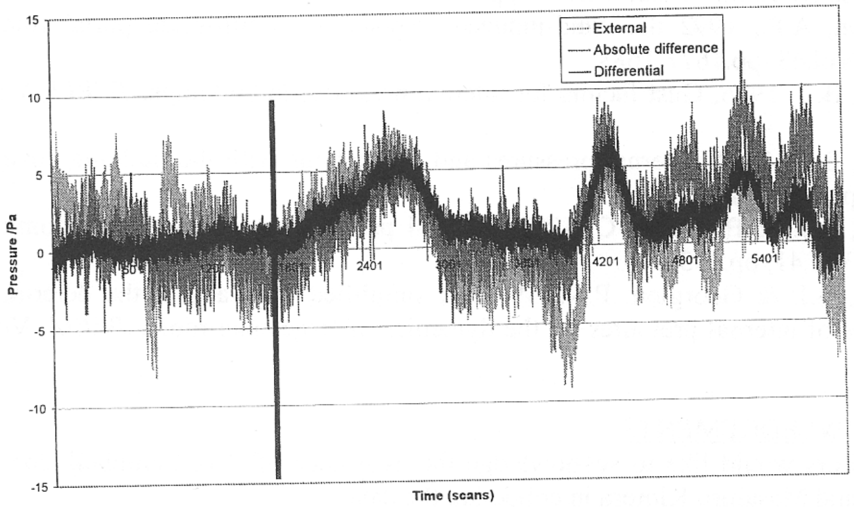

Fig.3: Comparison of nett pressures using absolute and differential transducers