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INVESTIGATIONS ON THE DYNAMIC BEHAVIOUR OF A WIND PRESSURE MEASURING SYSTEM FOR FULL-SCALE MEASUREMENT

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Summary

This paper presents some of the problems in the reference back-pressure system for full-scale dynamic wind pressure measurement. Effects such as excessive damping caused by the air trapped in the pressure-balancing tubings and interference between transducers are discussed. Modifications of the measuring system to overcome these problems are also described.

Introduction

This paper describes some of the problems encountered when the full-scale wind pressure measuring system in the experimental building of the High Building Research Centre of the University of Hong Kong [1] was being set up.

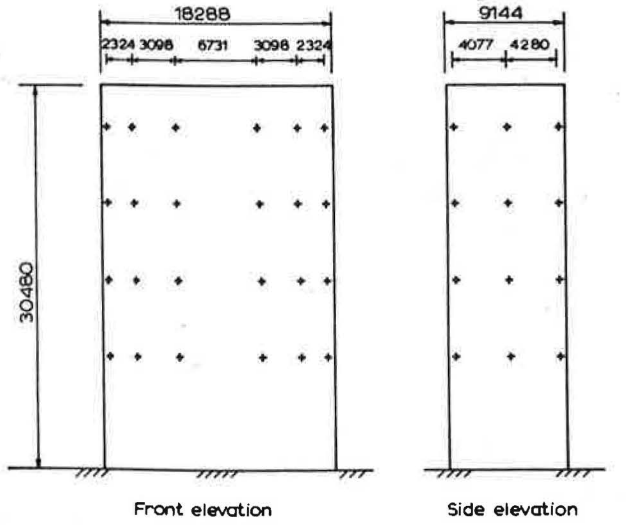
Immediately after the installation of the wind pressure measuring system as described in ref. 2, and before the commencement of any full-scale recording, it was noticed that the dynamic response of the wind pressure transducers [3] was affected by the P.V.C. tubings which connected the interior cavities of the transducers pneumatically to the region of the reference pressure. Tests were then carried out to study the influence of these tubings, acting either singly or in a group, on the behaviour of the transducer, with the aim of finding a more reliable way to provide the reference back-pressure so as to improve the response of the transducer to instantaneous local pressure change.

The results of the tests and the methods adopted to modify the initial system are described in this paper.

Wind pressure measuring system before modification

The experimental building mentioned above has been described in detail [4, 5]. It is situated on a piece of lowland in an open area at Cape D'Aguilar on the south-east coast of Hong Kong Island, where it is exposed to winds blowing from all directions.

At the initial stage of measurement, distribution of wind pressure over the four building faces was measured by 72 pressure transducers flush-mounted



+ Location of pressure transducers on the full-scale building

Fig. 1. Location of pressure measuring points on the full-scale experimental building.

at selected points (Fig. 1) in the glass wall panels approximately at the 3rd, 5th, 7th and 9th floor levels (9.1, 15.2, 21.3 and 27.4 metres above ground). These pressure transducers were of the strain-gauge type originally designed by the British Building Research Station [6]. Each level consisted of 18 transducers so arranged that there were 6 at varying intervals on each of the major faces and 3 equally spaced on each of the minor faces.

Since the transducers were intended to measure the differences between the external pressure and that within their body cavities, a common reference pressure was provided so that pressures at different points could be compared. The body cavities of all the transducers were vented through P.V.C. tubings to a 150-mm diameter pipe-stack running down the height of the building. At ground level this pipe ran horizontally for about 60 m to an open space near the northernmost steel tower where it was bent into a hook opening downward to the atmosphere, so that ideally the common reference pressure was that of the static atmospheric.

Pressure fluctuations inside the vertical pipe were monitored by pressure transducers at the top and the 1st floor levels. Each of these two transducers was mounted onto a 0.61-m, cubical, hollow air-tight metal box, with the load-detecting surface facing the interior and the body cavity vented to the vertical pipe. Since the sealed rigid box was shielded from large temperature variations, the pressure inside it was assumed to be reasonably constant over the recording period.

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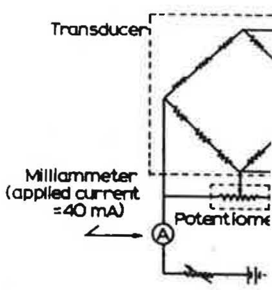

Fig. 2. Circuit diagram o

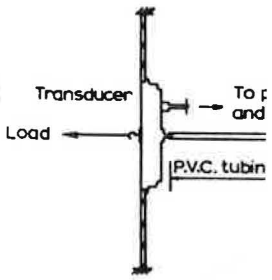

Fig. 3. Pressure transduc

Effect of back-pressure equalizing tubing on individual transducers

A series of laboratory tests were carried out with a transducer placed vertically and connected electrically to a circuit in the same way as when it was used in the experimental building (Fig. 2). A light hook of negligible mass was fixed to the centre of the movable pressure-detecting plate of the transducer and a horizontal pull was applied to this plate via a piece of cotton thread. The load was suddenly released by burning the thread at a position near the hook and the load-detecting plate was allowed to vibrate freely. The output signal from the transducer was recorded by an ultraviolet light-ray recorder with a moving mirror galvanometer. The amount of damping provided by the electrical circuit to the galvanometer was ~0.64 of the equivalent critical viscous damping.

The above experimental procedure was repeated with different lengths of 6-mm diameter P.V.C. tubing fixed to the air hole at the back of the transducer. Figure 3 shows the arrangement of the transducer and the tubing in this set of tests.

The traces recorded on paper sensitive to ultra-violet light were studied. The recovery time (i.e. the time elapsed between the instant of unloading and the first return to zero) and the fundamental frequency of the subsequent fluctuating motion were measured and the results were as shown in Table 1. From these results, it was found that the recovery time increased from 21 to

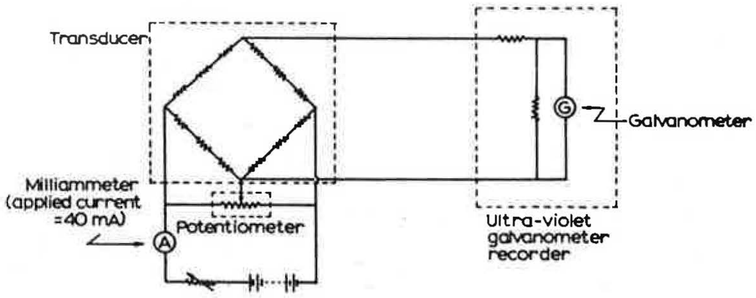

Fig. 2. Circuit diagram of pressure transducer, power supply and recorder.

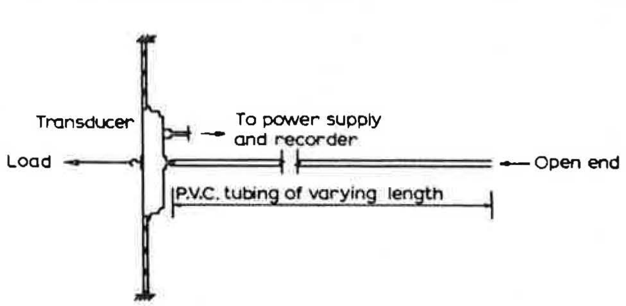

Fig. 3. Pressure transducer with P.V.C. tubing, without air reservoir.

TABLE 1

Response characteristics of transducer with different lengths of tubing

	Length of tubing (m)					
	0.30	0.61	0.91	1.52	3.05	9.14
Recovery time (s)	0.021	0.025	0.029	0.035	0.047	0.074
Frequency of damping wave (Hz)	26.0	18.2	15.5	11.0	7.2	3.8

74 ms and the natural frequency of the transducer decreased from 26.0 to 3.8 Hz when the length of tubing was varied from 0.30 to 9.14 m. This indicates that the dynamic response of the transducer would be intolerably affected when the length of tubing was ~9 m, which was the approximate average length of tubing used in the experimental building to connect the transducers to the central pipe-stack. It was believed that the air trapped in the tubing produced undesirable excess damping. In order to avoid this, a shorter length of tubing had to be used. In practice, however, the distance between the transducer and the central pipe-stack could not be changed. One possible solution was to provide an air reservoir inbetween the transducer and the stack.

Subsequently, another series of laboratory tests were carried out with the transducer loaded in a similar way but instead of having the free end of the tubing open to the atmosphere, it was connected pneumatically to a nozzle on a 0.3-m cubical metal box, which was air-tight and had only two inlet/outlet nozzles at the centre of two opposite faces. One end of a second piece of tubing having a fixed length of ~9.1 m was connected to the remaining nozzle on the box and the other end was left open. The general arrangement was as shown in Fig. 4. Various lengths of tubing ranging from 0.30 to 9.14 m were used between the transducers and the box. The results of the tests were as shown in Table 2.

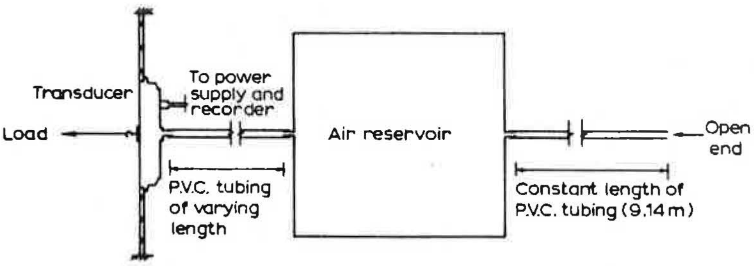

Fig. 4. Pressure transducer with P.V.C. tubing and air reservoir.

TABLE 2

Response characteristics

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Recovery time (s)	0.023
Frequency of damping wave (Hz)	23.0

*Remaining outlet open

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Based on the results
system was modified.

TABLE 2

Response characteristics of transducer with different lengths of tubing and air reservoir

	Length of tubing between transducer and reservoir (m)					
	0.30	0.61	0.91	1.52	3.05	3.05*
Recovery time (s)	0.023	0.027	0.033	0.039	0.054	0.053
Frequency of damping wave (Hz)	23.0	20.0	14.5	10.8	7.2	7.3

*Remaining outlet open to atmosphere without 9.14-m tubing.

Comparison of the results in Tables 1 and 2 shows that the difference between the response of the transducer to instantaneous loading with and without the air reservoir followed by ~9 m of tubing is small (to within 10%). This indicated that the response characteristics of the transducer with 0.91 m of tubing were very close to those of the same transducer with the same length of tubing but with an additional air reservoir followed by another 9-m length of tubing. From this experimental evidence, it is obvious that the 0.3-m cubical box had a volume large enough to eliminate effectively the ill-effects produced by excessive length of tubing.

Interference between transducers

Besides affecting the response characteristics, the tubings also produced some undesirable interference effects between the transducers. The forward and backward movement of the load-detecting plate caused the air trapped in the tubing to oscillate and this oscillatory motion was transmitted to other transducers. In some severe cases, the interference error could be as much as 20% of the actual pressure difference measured. These occurred when a number of transducers were vented to a common tubing using T-connectors.

Some fluctuation in pressure was also detected in the central pipe-stack. It was believed that such movement was caused by the in-phase deflexions of the load-detecting plates of the transducers on the same face of the building. By the application of gas laws, it could be shown mathematically that the total internal volume provided by the central pipe-stack was not adequate. To eliminate the interference effects, the methods described in the paragraphs below were found to be satisfactory.

Modifications to initial system

Based on the results of the laboratory tests, the back-pressure equalizing system was modified. Each transducer was connected pneumatically by an equal length (0.91 m) of tubing to one of the two nozzles of a 0.3-m, cubical, air-tight metal box similar to the one used in the above tests. Another set of tubing connected the remaining nozzle of each box to the central pipe-stack. By the introduction of one such air reservoir for each transducer, the response characteristics of the transducers were improved and unified. The natural frequency was ~15 Hz and the recovery time 33 ms.

The volume of the central pipe-stack was also increased by adding eight 0.61-m cubical metal boxes, one at each of the 2nd to the 9th floor levels. A removable lid was installed at the top of the pipe-stack so that the air in the pipe could be vented to the building whenever necessary. At the bottom of the pipe-stack, a control valve was installed so that the whole back-pressure system could be sealed off from the external air pressure during recording periods to obtain a real steady-state back pressure for the transducers.

After these modifications, the interference effect was checked and found to be negligibly small.

Conclusions

The tests described in this paper show that for dynamic wind pressure measurement, factors of the measuring system additional to those for static measurement have to be taken into consideration. Effects such as excessive damping caused by the air in the pressure-balancing tubings, interference between transducers through the air trapped in the tubings acting as a transmission medium, and inadequate dead-volume of air sealed to provide the pressure-reference datum, have to be investigated thoroughly before a back-pressure system can be properly designed to carry out the required function.

Acknowledgement

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BOUNDARY LA

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Summary

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