Full Scale Measurements of Pressure-equalization In Curtain Wall Systems

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ABSTRACT

Pressure-equalized aluminium curtain wall system is becoming popular in South East Asia. The back panels of such systems are usually thin and flexible. To improve the understanding of the behaviour of such systems and to evaluate design parameters, full scale studies are carried out. This paper describes experimental study on pressure equalization of two curtain wall systems. Results for static and sinusoidal exterior pressure fluctuations are reported.

INTRODUCTION

Many curtain walls, built in South East Asia make use of the pressure equalization or rainscreen method as a means to eliminate or reduce rain penetration. Essentially, an open rainscreen wall which is also known as the two barrier systems, consists of two leaves of wall: a rainscreen as the outer leaf and the air barrier (back-panel) as the inner leaf. The two leaves are separated by a cavity which is vented to the outsides by openings on the rainscreen. Normally the cavity is compartmentalized to prevent air movement over zones with large pressure gradients.

Since the introduction of the rainscreen wall system over twenty years ago, studies on the pressure equalization performance of such wall system have been carried out[1],[2]. Many of the investigations are on brick-veneer or double brick systems. For such systems the volume of the internal cavity is usually large and both the rainscreen and the air barrier are very rigid. Results of investigations on pressure-equalization of rigid wall systems are reported e.g. [3]. The back panels of curtain walls are normally made of thin flexible steel sheet, the internal volume of cavity will change under the action of internal pressure. This will have a great influence on the pressure equalization and the performance of the curtain wall.

EXPERIMENTAL ARRANGEMENT

The experimental study involves the investigation of the performance of two curtain wall systems constructed by P D Manufacturing International Pte Ltd. The first test specimen (CW I) consists two bays of 1.2m width. Each bay is 2.35m high and divided into 3 compartments as shown in Figure 1. The middle compartment with a height of 1.19m is the larger one and is selected for pressure equalization (p-e) investigation. The front panels of the middle compartments are different for the 2 bays, one is 3mm thick aluminium and the other is 8.76mm laminated glass. The back panels are made of 1mm thick galvanized steel. The internal cavity volume is 0.0699m^3 and there are weep holes venting to the outside. Two sizes of weep hole area can be configured, 0.0003m^2 or 0.0012m^2. The second test specimen (CW II) consists 3 bays of width 1.414m width each. There are 3 compartments in each bay with the top and bottom compartments having heights of 2.65m (Figure 2) and they are selected for p-e study. The front panels are 6mm thick reflective glass and the back panels are 1mm thick galvanized steel sheeting. The internal cavity volume is 0.2476m^3 with a weep hole area of 0.0006m^2.

The specimen was mounted in the test chamber facing inwards such that the exterior face of the curtain wall was subjected to the sinusoidal pressure fluctuation generated in the chamber. The interior face of the curtain wall was exposed to atmospheric pressure. Pressure taping points were connected to various locations in the cavity as well as to the exterior face so as to monitor the internal and external pressures.

Testings of the two curtain walls was carried out using static pressure as well as dynamic (near) sinusoidal pressure fluctuations. The frequency, mean and amplitude of pressure fluctuation were varied in the experiment.

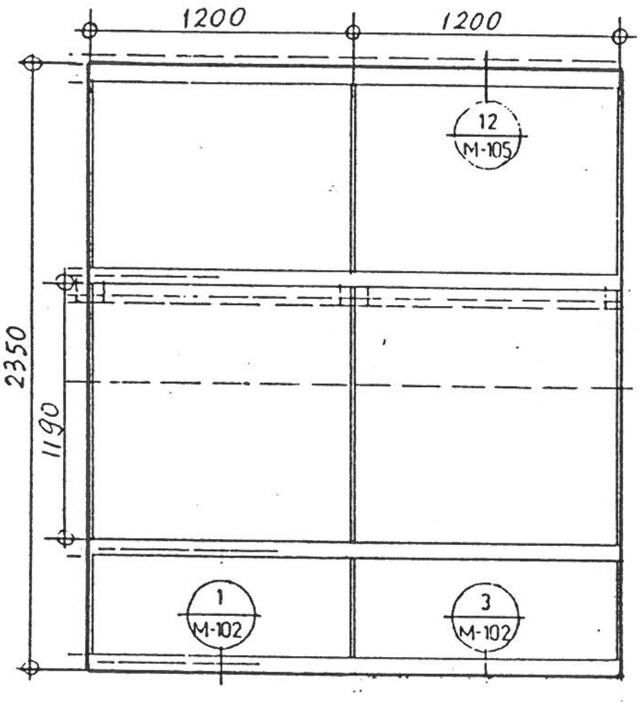


Figure 1

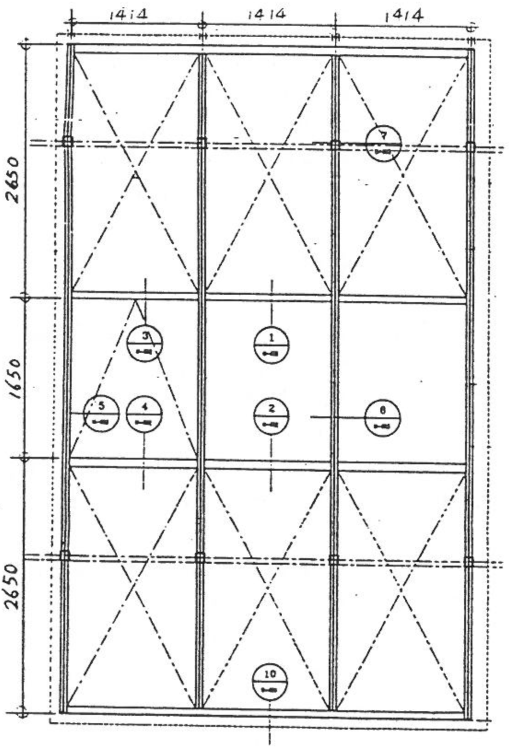


Figure 2

EXPERIMENTAL RESULTS AND DISCUSSIONS

One of the major differences between an aluminium curtain wall p-e system and a brick veneer p-e system is the flexibility of the back panel. This can significantly change the response characteristic of the internal pressure. Thus it is important to obtain the load-deflection characteristics of the back panel of the curtain wall. Figure 3 shows the stiffness function of the back-panel of CW I obtained from static pressure test. It is noteworthy that the deflection versus pressure

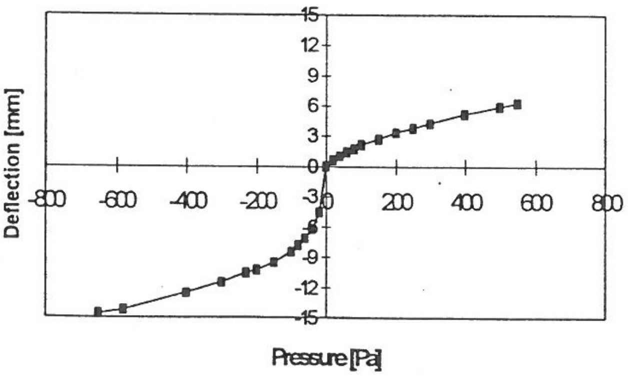


Fig. 3 Stiffness function of back-panel

curve is highly nonlinear which is quite typical for curtain wall systems. There shows a highly flexible region near the zero pressure which is due to the popping action of a thin plate. The two branches (positive and negative pressure) of the curve can be well fitted by the exponential functions $\delta = \alpha \cdot P^{\beta}$. The two parameters α and β obtained in metric units are as follows.

$$\alpha = 0.0100; \quad \beta = 0.740; \quad \text{if } P > 0,$$
$$\alpha = 0.0178; \quad \beta = 0.324; \quad \text{if } P < 0.$$

One of the objectives of the study is to investigate the effect of venting area on the system response. Two sizes of area were used for CW I. However it was realized that other than the weep holes there were other unintentional openings (e.g., holes for screws not properly sealed up) which also vent into the cavity. Thus a test was carried out first with all the weep holes blocked up (WP1). Result of the test given in Figure 4a shows the time history of the external pressure (Pe) and cavity pressure (Pc). Figure 4b shows another test carried out with the same frequency but with the weep holes open at 0.0003m^2 (WP2).

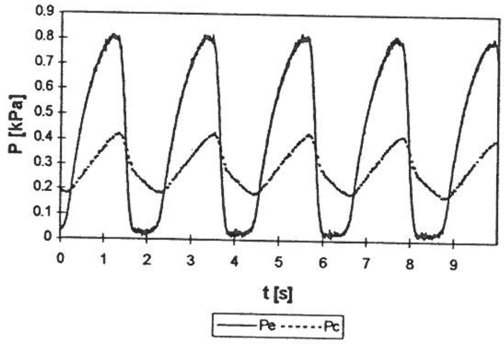


Fig.4a Weep hole fully blocked (WP1)

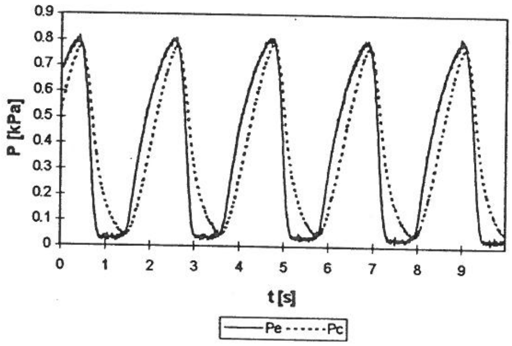


Fig.4b Weep hole (WP2)

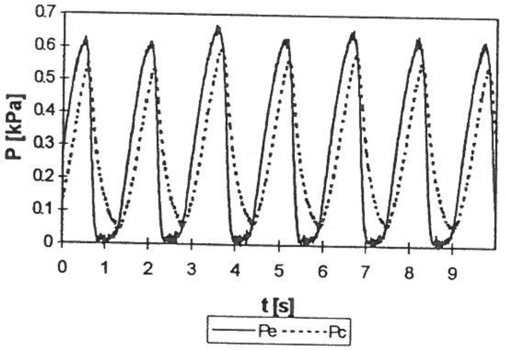


Fig.4c Weep hole (WP2)

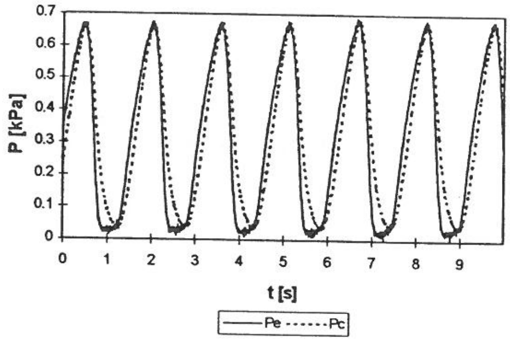


Fig.4d Weep hole (WP3)

It can be seen that the cavity pressure for 4a is not stationary which indicates that air is getting into the cavity. The amplitude ratio of Pc/Pe is 0.275. The same ratio for Figure 4b is 0.935. Test was also carried out at a higher frequency with the same weep hole configuration as 4b. The pressure time histories are shown in Figure 4c and the Pc/Pe ratio is 0.81. Changing the weep hole area to 0.0012m^2 and testing at the same frequency, the ratio becomes 0.99 as shown in Figure 4d. The above figures indicate that the cavity pressure varies with the frequency of pressure fluctuation as well as the area of the weep holes.

The cavity pressures as plotted in Figures 4 were measured from the bay with the glass front panel. Similar measurements were obtained for the bay with the aluminium front panel. For the case of blocked weep holes (same configuration for both bays), Pc for the glass and aluminium front panels are plotted in Figure 5. It seems that Pc for the aluminium front panel has a faster response than that for the glass panel, especially during the low pressure cycle. This is probably due to the less stiff and more elastic of the aluminium panel.

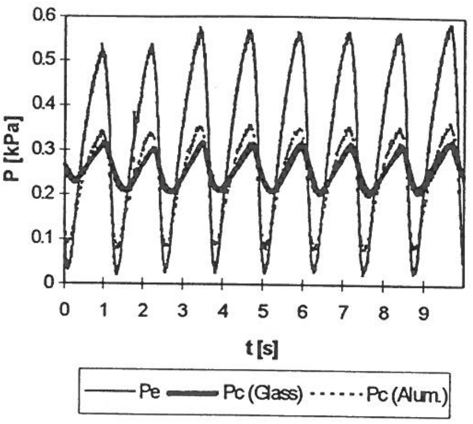
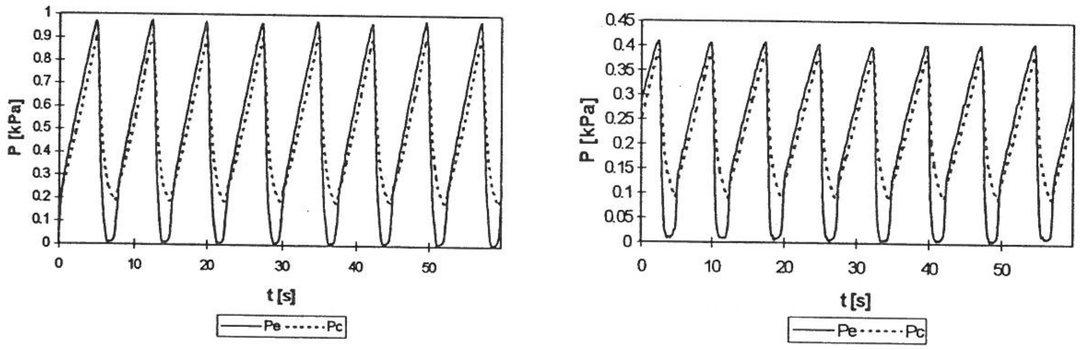
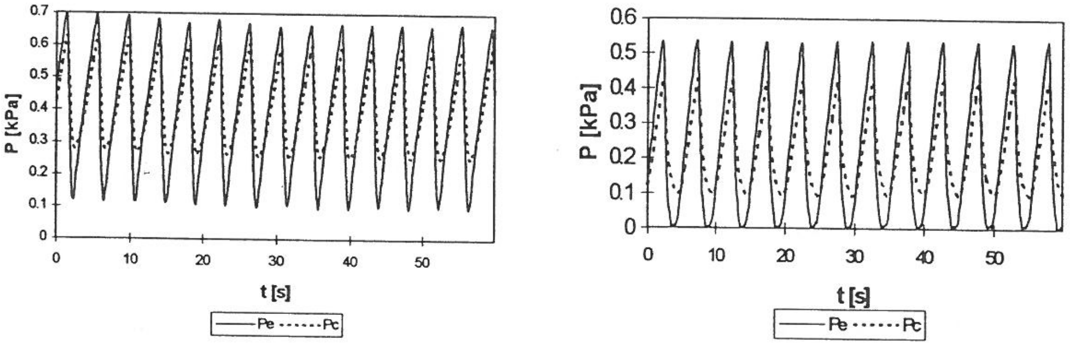


Figure 5 Response for different front panels

As the stiffness of the back panel is highly non-linear as shown in Figure 1, the response of the system will therefore depend on the level of the pressure acting on the system. Studies were carried out on CW II to investigate the effects of mean pressure and fluctuation amplitude on the cavity pressure.



Figures 6a & 6b System response for different amplitudes of pressure fluctuation



Figures 6c & 6d System response for different mean pressure values

Figures 6a and 6b are results of tests having the same frequency of pressure fluctuation but with different amplitudes of fluctuation. The amplitudes of Pe are respectively 0.49kPa and 0.2kPa. The Pc/Pe amplitude ratios for the two cases are 0.7 and 0.75 respectively. It seems there is a slight decrease of the ratio with increase of Pe amplitude. Figures 6c and 6d are test results for different mean pressures. The Pc/Pe ratios are 0.58 for both cases. It seems the mean pressure and the amplitude of fluctuation only affects slightly the Pc/Pe ratio.

From the above discussions clearly the major factors affecting the response of the cavity pressure is (a) the ratio of vent area to cavity volume and (b) the frequency of pressure fluctuations. Results of tests for different frequencies and different area to void (A/V) ratios are summarized in Figure 8. It shows clearly the trend of variation of the Pc/Pe ratio. The ratio decreases with increasing frequency and also decreases with decreasing area to void ratio. It is important to note that to have good pressure equalization, the Pc to Pe ratio should be close to unity.

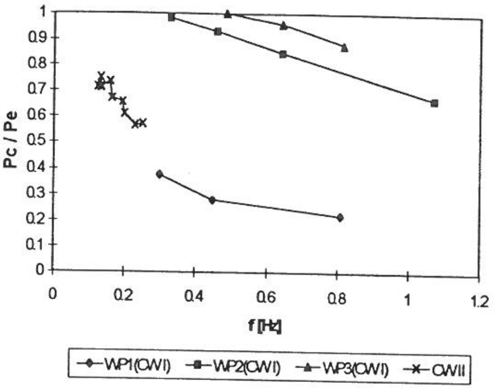


Fig.8 Summary of measured results

CONCLUSIONS

The present paper reports the observations of a full scale investigation of the pressure equalization response of aluminium curtain wall systems. Results of the study indicate that the pressure in the cavity can be significantly lower than the external pressure. This depends on the frequency of fluctuation of the pressure and the vent area to cavity volume (A/V) ratio. It seems that pressure equalization is satisfactory for CW I but not for CW II. That means an A/V ratio of 0.017 m^{-1} is satisfactory but a value of 0.0024 m^{-1} is not.

This paper is a preliminary study presenting the field observations. The data are used for the calibration of an analytical model in a further study of the pressure equalization problem.

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