Wind Engineering Joint Usage/Research Center
FY2017 Research Result Report

Research Field: Wind disaster and wind resistant design
Research Year: FY2017
Research Number: 162003
Research Theme: Aerodynamic coupling of wind-exited tall buildings with structural connections

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Budget [FY2017]: 400,000Yen

*There is no limitation of the number of pages of this report.
*Figures can be included to the report and they can also be colored.
*Submitted reports will be uploaded to the JURC Homepage and etc.....

1. Research Aim

   The primary goal of this research is to investigate the aerodynamic coupling due to structural links and its effects on the aerodynamic performance of wind-excited linked building systems (LBSs).

2. Research Method

   This is to be achieved by conducting a series of wind tunnel pressure tests to measure the spatiotemporal correlation of wind forces on an LBS. The flow patterns of the critical building configurations that cause the highest and lowest wind load correlations was investigated using particle image velocimetry (PIV). Proper orthogonal decomposition (POD) was then applied to investigate any systematic structure in the general flow and pressure fields.

   The primary emphasis of this study is to determine the inter-building aerodynamic correlations of LBs, occasionally in conjunction with qualitative flow visualization. For this reason, PIV was performed to obtain a horizontal velocity vector field around an LB model, and pressure measurements within the same horizontal plane provided the local pressure distributions. The PIV was carried out in the wind tunnel of the Shimizu Corporation in Japan. Figure 1 shows the setup for the PIV and a synchronous multi-pressure measurement system (SMPMS) tests.

Fig. 1. PIV and SMPMS test on the LB system

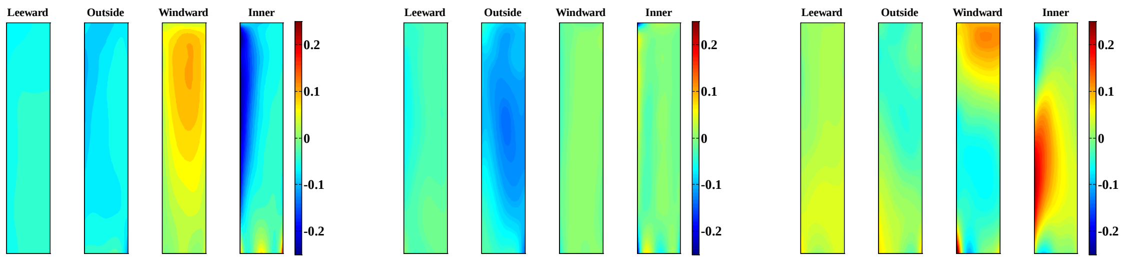
3. Research Result

   These results can be used to uncover the aerodynamic coupling mechanism. In this report, The LB model with the smallest gap distance ratios is discussed. In addition, for the wind direction, the two buildings in side-by-side arrangement and normal to wind direction is analyzed. When the LBs were in a side-by-side arrangement, the aerodynamic characteristics on the two buildings are statistically the same. Therefore, results of one of the linked buildings are presented, as shown in Figures 2.

The 1st mode shows that the pressure on the windward surfaces of the LBs shifts slightly inward, rather than being symmetric due to channeling between the two buildings. For the same reason, the negative pressure value on the inner surfaces in the area near the windward edge of the LBs is relatively large and, as a result, the suction force on the inner surfaces of the LBs is considerably high. In addition, channeling usually leads to an increasing local mean wind speed and cross-wind dynamic excitation of the two inner surfaces.

The 2nd mode is highly correlated with vortex shedding phenomena and the generation of cross-wind force on the outside surface. In addition, since the pressure distribution on inside surface is very weak, the gap flow between the two buildings is very weak, so the two buildings largely behave like a single bluff body.

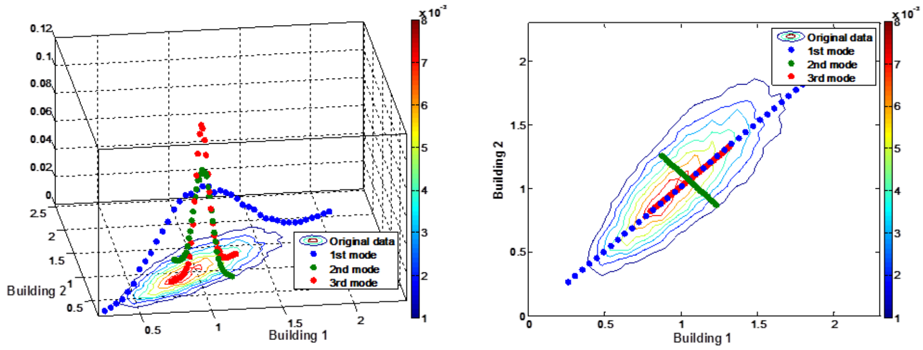
The 3rd mode shows that the along-wind forces are largely attributed to the approaching wind. This is because the wind flow is very weak between the two buildings of LB system with small gap distance. As a result, the wind force component is the fluctuation on the approaching wind flow on the windward surface.



(a) The 1st mode (b) The 2nd mode (c) The 3rd mode

Fig. 2. Hidden pressure patterns

Joint probability density function (PDF) of each POD mode provides aerodynamic characteristics of the inter-building aerodynamic correlations between the buildings. The joint PDF of the original data is presented as contour plots in Figure 3. It shows the positive inter-building aerodynamic correlation of the along-wind forces. The 1st mode is mainly correlated with a positive inter-building aerodynamic correlation. However, a negative inter-building aerodynamic correlation in both cases is highly composed by the 2nd mode. The 2nd mode is correlated with the cross-wind forces, and the along-wind forces have very weak effects as shown in Figure 2 (b).



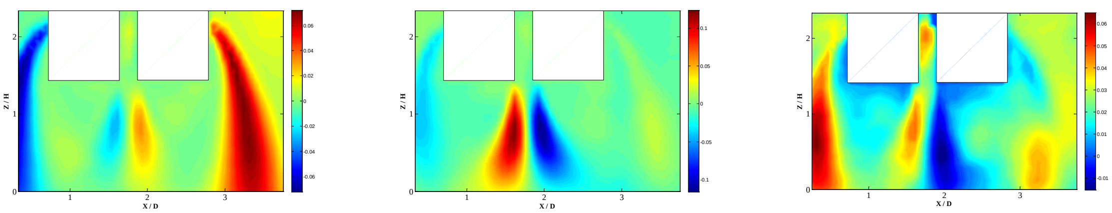
(a) Perspective view of joint PDF (b) Plan view of joint PDF

Fig. 3. Joint PDF of along-wind forces between the two buildings

POD analysis was applied to the measured data in order to extract the dominant structure from the overall phenomena observed in the wind velocity field as shown in Figure 4. With a small gap distance, the two tall buildings of the LB system behave in a similar fashion to a single bluff-body as shown in the 1st mode of Figure 4(a). A single vortex street is observed in the combined wake of the two tall buildings.

There is observed the inherently biased flow in the gap between the two tall buildings of the LB systems in the 2nd mode of Figure 4(b). The inherently biased flow in the gap between the buildings produced two different flow patterns around each building. The biased flow pattern switches intermittently from being directed towards on one building to the other, and the flow pattern is termed bistable.

In the 3rd mode, when gap distance is very small, an asymmetrical wake regime occurs, where the biased gap flow results in one wide wake and one narrow wake, as shown in Figure 4(c).



(a) The 1st mode (b) The 2nd mode (c) The 3rd mode

Fig. 4. Hidden flow patterns

4. Published Paper etc.
[Underline the representative researcher and collaborate researchers]
[Published papers]
1. None.

[Presentations at academic societies]
1. None.

[Published books]
1. None.

[Other]
Intellectual property rights, Homepage etc.

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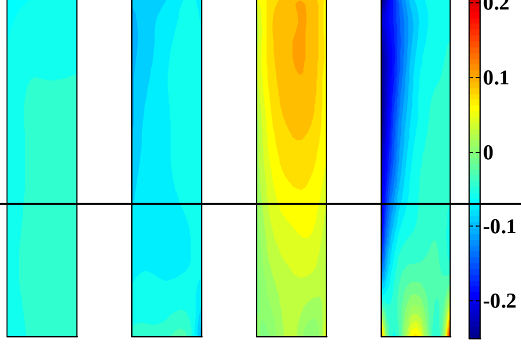
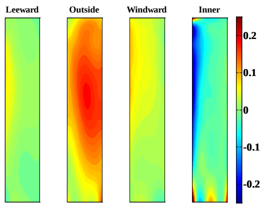


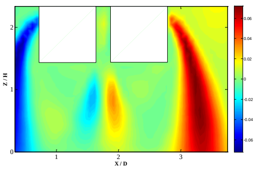
nd-exited tall buildings with structural

This study investigates the hidden aerodynamic characteristics on two tall linked buildings (LBs, i.e. tall buildings connected by horizontal structural links). Wind pressure and velocity on typical LBs with different gap distances between two buildings were measured in a series of wind tunnel tests, and proper orthogonal decomposition (POD) analysis was then applied to identify the hidden pressure and flow patterns and hence the associated excitation mechanisms.

Results show that effects of interference on wind loading of the LBs were observed in each (e.g. Figures (a) and (b)). From the contribution of each mode determined from the POD analysis, the wind force components and the intra-building aerodynamic correlation between wind force components can be more clearly understood.



(a) One hidden pressure pattern



(b) One hidden flow pattern