Wind Engineering Joint Usage/Research Center
FY2016 Research Result Report

Research Field: Wind disaster and wind resistant design
Research Year: FY2016
Research Number: 162003
Research Theme: Researches on characteristics of wind forces acting on high-rise buildings

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Budget [FY2016]: 310,000 Yen

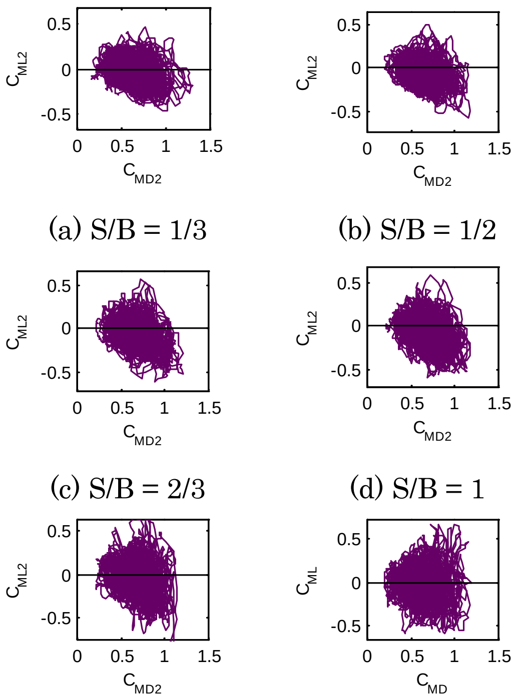
*There is no limitation of the number of pages of this report.
*Figures can be included to the report and they can also be colored.
*Submitted reports will be uploaded to the JURC Homepage.

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 will be further investigated using particle image velocimetry (PIV).

3. Research Result
   A series of synchronized PIV-pressure experiment has been carried out at Shimizu Corp. in late February 2017 using a synchronous multi-pressure measurement system (SMPMS) to obtain the wind force information and simultaneous flow patterns at the proximity using PIV. Models of different gap distances were employed in the test. Shimizu Corp. is currently converting the PIV images, which will be ready for subsequent analysis in late April or early May. Proper orthogonal decomposition (POD) will then be applied to investigate any systematic structure of the aerodynamic coupling hidden in the general fluctuating pressure field. These results can be used to uncover the aerodynamic coupling mechanism. Mapping of the correlation of wind forces between the buildings will be conducted for each test case. The interrelationship between structural and aerodynamic coupling and the aerodynamic performance of an LBS will also be investigated extensively by combining wind load correlation with structural dynamic properties for various building configurations.

   Other previous results are illustrated and discussed below. The intra-building aerodynamic correlation, i.e., the correlation between wind force components on a single building, is related to the combination of resultant directional wind-induced responses. The intra-building aerodynamic correlation is examined in this section. In this study, we focus on results for a critical wind direction, $\alpha = 0^{o}$. For $\alpha = 0^{o}$, the oncoming wind is normal to the face of the LBs and the two buildings are in a side-by-side symmetric arrangement. Therefore, the statistical characteristics of the aerodynamic forces on the two buildings are the same, and hence only results from one of the two building towers are discussed. The trajectories for the along-wind and cross-wind forces of all cases are shown in Figure 1. For the single building, an envelope of the trajectory is half-elliptic. Unlike the symmetric trajectory for the single building, however, those for the LB cases are negatively inclined, clearly indicating a negative correlation between the along-wind and cross-wind forces. Due to the channeling effect caused by the inter-building gap, the wind that flows through the gap accelerates. As a result, the pressure on the area of the windward faces close to the gap is increased. Meanwhile, suction on the area of the two inside faces near the windward edges is also enhanced.



(a) S/B = 1/3 (b) S/B = 1/2

(c) S/B = 2/3 (d) S/B = 1

(e) S/B = 3/2 (f) S/B = Single

Figure 1. Trajectories for the along-wind and cross-wind base overturning moments

The trajectories of the along-wind and torsional base moment are presented in Figure 2. The trajectory for the single building shows a normal elliptic envelope. In contrast, the trajectories for the LBs cases are rather contracted and negatively-inclined, clearly suggesting a strong correlation between along-wind base moment and torque. This is because the distribution of pressure on the windward faces in an LB is usually skewed, instead of being symmetric. In addition to causing the along-wind forces, the pressure with asymmetrical distribution will bring about torsional forces on the LBS. Therefore, the trajectories for the LB cases cluster within a rather narrow zone, although the zone becomes relatively wider when S/B is large, such as when S/B = 3/2.

Trajectories for cross-wind base moment and torsional moment are presented in Figure 3. It is usually believed that the cross-wind force and the torsional moment on a single building are well correlated, since they are both largely caused by the wake dynamics. As a result, the trajectory for a single building shown in Fig. 3(f) is an inclined ellipse, rather than a normal one. For the same reason, the trajectories for LBs also show similar envelopes to that for single building, indicating that the correlation between cross-wind and torsional force is similar for an LB and a single building. In addition, it can be observed that the gap distance ratio S/B has no significant effect on the trajectories.

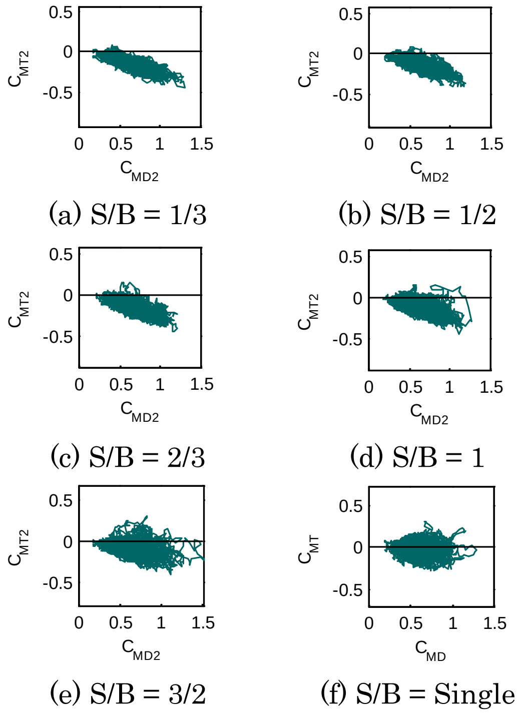


Figure 2. Trajectories for the along-wind and torsional base moments

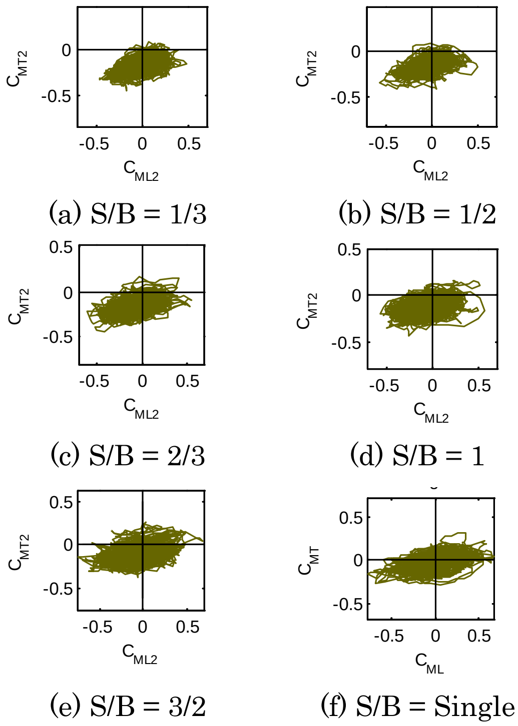
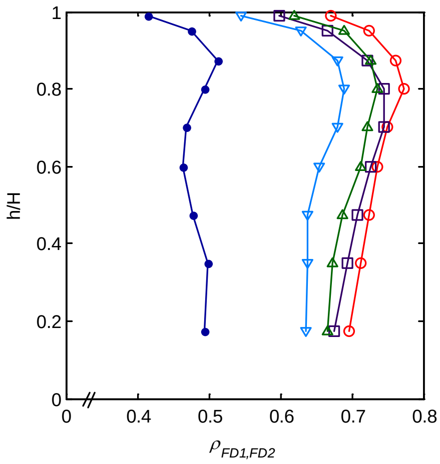


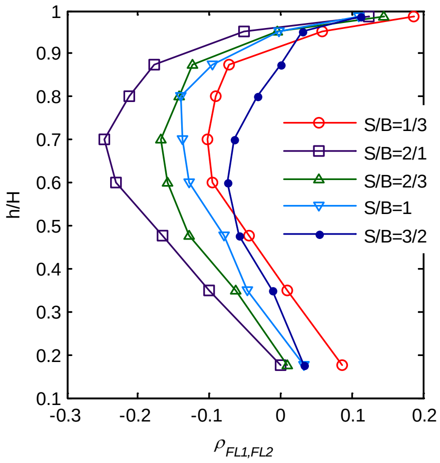
Figure 3. Trajectories for the cross-wind and torsional base moments

The inter-building correlation is also investigated quantitatively, to show how the correlation varies with gap distance. The inter-building aerodynamic correlation is calculated in terms of the correlation coefficient between local wind force components. Figure 4 shows the correlation coefficients between the local wind forces on the two buildings for the five cases with $\alpha = 0^{o}$. The correlation coefficients of the along-wind forces decrease with increasing S/B, as shown in Figure 4 (a). This decreasing trend can be explained by the fact that along-wind forces are mainly attributed to the approaching wind, the correlation of which decays with an increase in the lateral separation distance. Therefore, it can be anticipated that for $\alpha = 0^o$, when S/B is very large (> 3/2), the correlation between along-wind forces on two buildings will become relatively weak.

Unlike the inter-building correlation between along-wind forces, the correlation between cross-wind forces does not continuously decrease or increase with gap distance, as shown in Figure 4 (b). In the range 0.3 < h/H < 0.9, the absolute values of the correlation coefficients increase with increasing S/B from 1/3 to 1/2, whereas further increasing S/B from 1/2 to 3/2 leads to gradual decrease in the absolute value of the correlation coefficients. The increase in the correlation coefficient can be explained by the increased gap flow—accelerated wind passing through the gap may increase the correlation between the two suction forces on the two inner faces. The decrease in the correlation coefficient, on the other hand, is due to the fact that increases in S/B above 1/2 can gradually allow the shear layers from the two inner edges to roll up into the rear region of the two towers through the gap, interrupting the original cross-wind correlation in S/B = 1/2.



(a) Along-wind



(b) Cross-wind

Figure 4. Correlation coefficients between two wind force components on the two building towers at the same level

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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