Study on Airflow around Building Roof for Design of Natural Ventilation by Chimney
- Part1 Distribution of wind pressure coefficient on a building roof -

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ABSTRACT

There are some ways to promote natural ventilation, but this research focuses on chimney which is traditional ventilation method used for industry or fireplace. The goal of this research is to establish the guidelines for the design of chimney for natural ventilation of rooms. This paper reports the result of the wind tunnel test to study airflow around building roof.

As a result of wind tunnel tests, some tendencies were obtained. Wind pressure distribution maps on a rooftop of two models whose windward walls had the same size to each other were not similar; however, the half part of the distribution map on 100mm×200mm roof was similar to that on a 100mm×100mm roof. The maximum wind pressure was observed at about 5mm from the edge on the windward for each model, and for each wind direction.

Table 1. Model Scales

	Model Name					
	1L	1M	1H	2L	2M	2H
Roof plan (mm)	100×100	100×100	100×100	100×200	100×200	100×200
Height (mm)	100	200	400	100	200	400

Table 2. Average Wind Pressure Coefficient

		Model Name					
		1L	1M	1H	2L	2M	2H
Wind Angle [°]	0	-0.391	-0.531	-0.705	-0.219	-0.297	-0.410
	90	-	-	-	-0.487	-0.610	-0.707

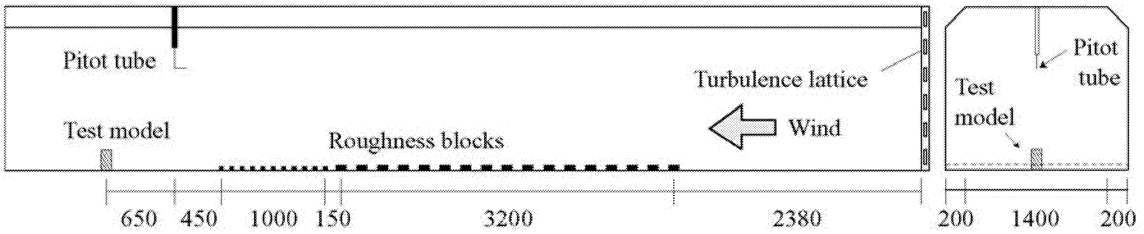
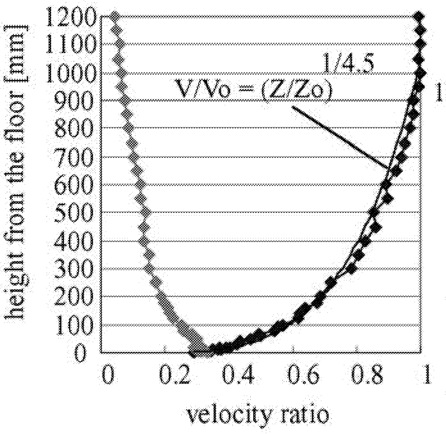


Figure 1.Section of Wind Tunnel



V : Velocity at measurement point Vo : Velocity at pitot tube
Z : Height of measurement point Zo : Height of pitot tube

Figure 2. Profile of Velocity of Approach Flow

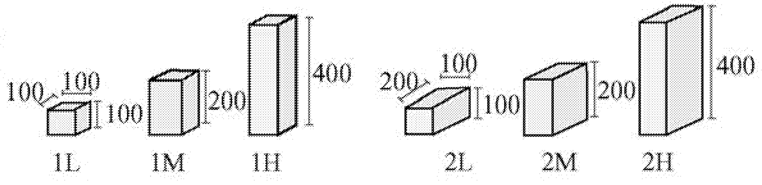
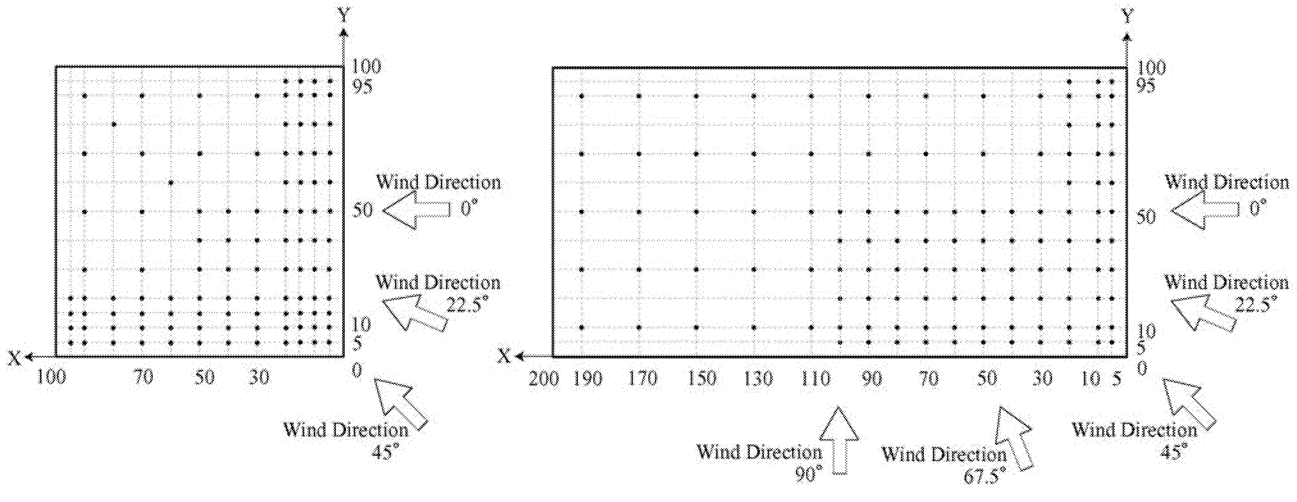


Figure 3. Models (unit is mm)



(1) 1L, 1M, 1H

(2) 2L, 2M, 2H

Figure 4. Measurement Point of Wind Pressure

1. INTRODUCTION

Recently the buildings with natural ventilation are more and more increasing for saving energy and utilization of natural energy. Many researchers in Japan studied on roof ventilators or monitor roofs as assistant equipment for natural ventilation. Besides, there are some examples of architectures which are ventilated by chimneys on the rooftop. Komatsu et al. (2007) calculated ventilation rate brought by natural ventilation through chimneys of a school building located in west part Japan. This natural ventilation system is driven by negative pressure on the rooftop due to separated airflow and buoyancy force brought by heat generation from many occupants inside rooms. Authors aim to establish the guidelines for designing natural ventilation chimneys. Wind tunnel tests were done to grasp the better point to set up a chimney. Airflow around a building rooftop has been studied by some researchers. Lawson (2001) presented stream lines on 1×1×2 cuboids in the wind direction of 0º, 22.5º, and 45º. Airflow on a rooftop and walls are grasped only for the model which has 1×1×2 aspect ratio. There are no results of models which have other aspect ratios. Ueda et al.(1993) showed distributions of wind coefficient of some buildings which have different aspect ratios. However, measured points were not enough for the purpose of this study because it was a study of wind-resistant of a building for the calculation of wind load.

Therefore wind pressure coefficient on many measurement points and the wind velocity around a building were measured for this research. Authors used 6 different models. This paper reports the result of a wind tunnel test to understand the distribution of wind coefficient on a building rooftop.

2. WIND TUNNEL AND MODELS

The wind tunnel test was conducted at Osaka University wind tunnel. Figure1 shows the section of the wind tunnel. Roughness blocks and a turbulence lattice were set up to make the Surface Boundary Layer of 1/4.5 power law. The profile of velocity of approach flow is shown as Figure 2. Figure 3 shows 6 building models used for this study. There are three levels of model heights, there are a couple dimensions of roof plan. Table 1 gives the scales of models.

3. WIND PRESSURE

3.1 Method

Wind pressure coefficients were measured at 73 – 114 points on the rooftop for each condition. The reference external wind velocity is 10 m/s at the height of 1000 mm above the tunnel floor. The pressures were measured by the pressure transducer during 30 seconds with the sampling frequency of 100Hz and those averaged values at each measurement point were calculated. The wind pressure coefficients were obtained from dividing these values by the dynamic pressure at the building height.

3.2 Experimental conditions

Measurement points were shown in Figure 4. An X-axis and Y-axis were decided irrespective of wind direction.

3.3 Result

3.3.1 Average wind pressure on rooftop area

The averaged values of wind pressure coefficient on the entire rooftop area are listed on Table 2. The tendency was found that the models with higher height tend to have higher wind pressure. Comparing these average wind pressure coefficient of 1L to 2L, the absolute value of negative pressure of 1L is larger than that of 2L. In the same way, the average wind pressure coefficient of 1M or 1H is larger than that of 2M or 2H. As long as the height and the wind direction are the same, the negative pressure of the model with shorter depth is larger than the model whose depth is long. It is interesting to compare 1L at the wind direction of 0° with 2L at the wind direction of 90°. 2L of 90° has double size of windward wall of 1L of 0°. The depth is the same but 2L of 90° has larger negative pressure than 1L of 0°. The absolute value of negative pressure of 2M or 2H of 90° is larger than that of 1M or 1H. Although the gap is not so notable, it is thought that the larger the size of the windward wall is, the larger the negative pressure is.

3.3.2 Effect of model height on wind pressure coefficient

Figure 5 shows wind pressure coefficient maps of model 1L, 1M, 1H. The dots on the maps show the positions of actual measurement points. The tendency was found that as the model height changes

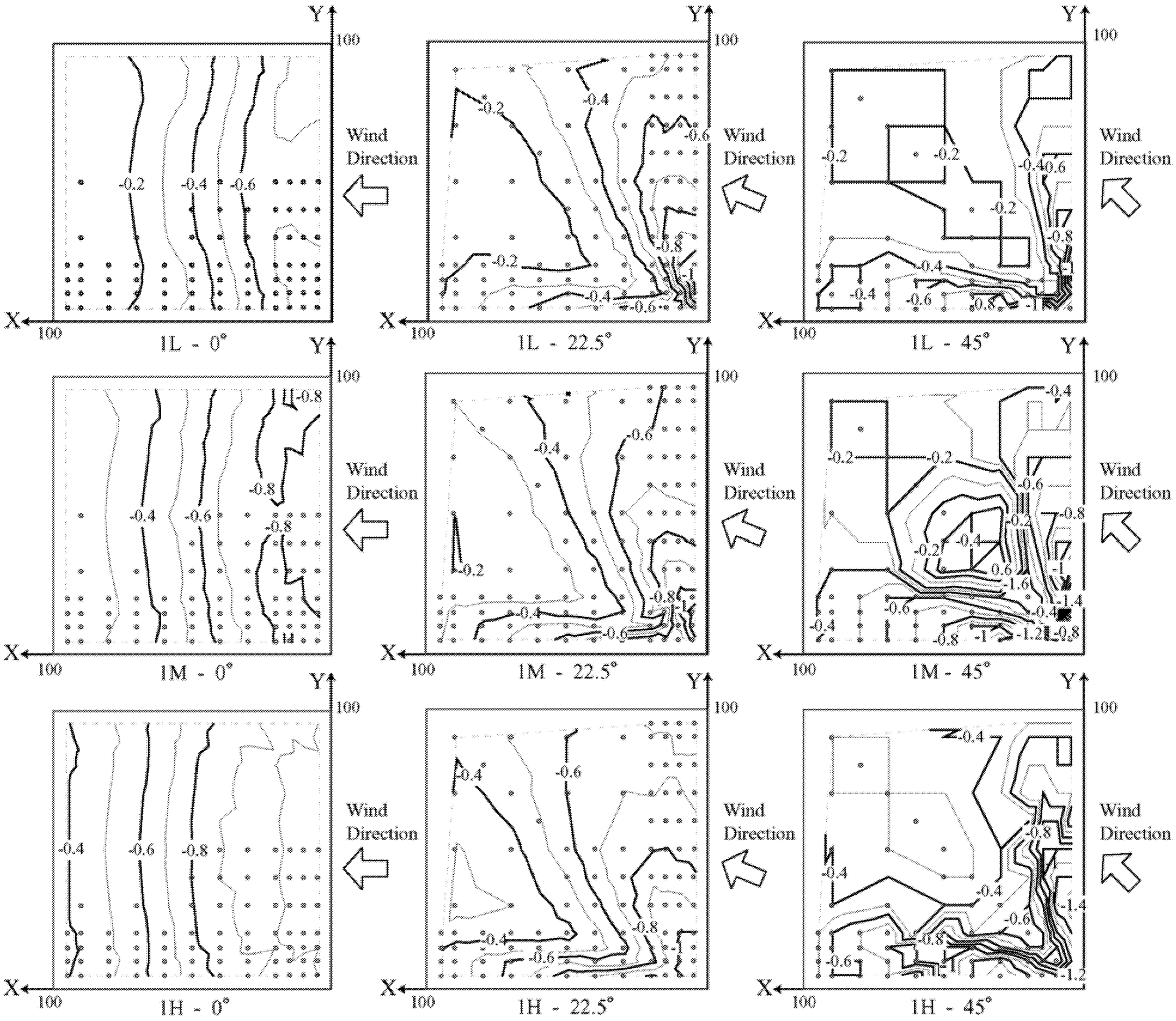


Figure 5. Distribution of Wind Pressure Coefficient on Rooftop

higher, the absolute value of the wind pressure changes higher when the same measurement points were compared. The maximum wind pressure was obtained at the distance of about 5mm from the edge on the windward for each model, and for each wind direction. 1L and 1M shows that the negative pressures near y=50, especially in the range of 5<x<30, were smaller than their neighborhood. It can be supposed that the measurement points near the center axis(y=50) were less influenced by the separated flow from the two side walls. The possible cause is that separated flow is caused by not only the surface of the windward wall and the rooftop, but also the surface of side walls.

The shape of distribution maps of 1L, 1M, 1H were similar each other in the wind direction of 22.5°, and 45°. The intervals of contour lines were densely in the area of 5<x<15, 5<y<15 in the wind direction of 45°. The inclination of the wind pressure coefficient was gentle in the downwind side. From the result of visualization, it was found that the approach flow does not detach on the diagonal line of the wind direction of 45° (It means that the line which links (x, y) = (5, 5) and (x, y) = (90, 90)). It seems that the negative pressures on this diagonal line were caused by the collision of the flow which detached from the wall edge including the X-axis and the flow separated from another wall edge including the Y-axis. The high pressure areas of 1L in the all wind direction were (x<10, y<20) and (x<20, y<10). That of 1M were (x<30, y<40) and (x<40, y<30). That of 1H were (x<20, y<70) and (x<60, y<20).

3.3.3 *Effect of plane dimensions of model on wind pressure coefficient*

To understand the effect of plane dimension size of the models, authors laid the dimension map of 1L on the map of 2L. (Figure 6) In the same way as that,

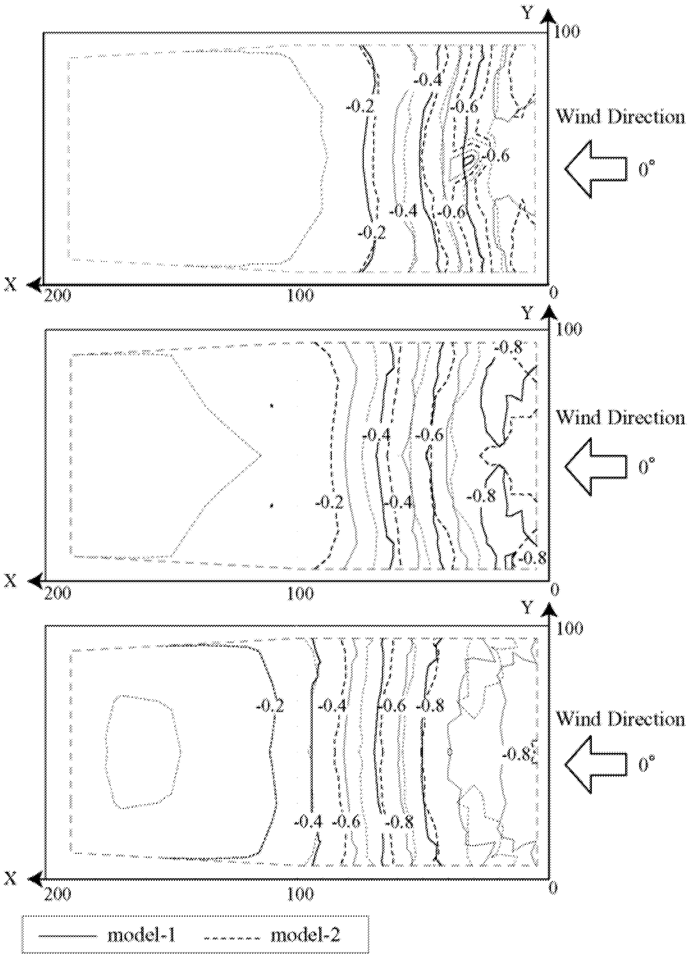


Figure 6. Distribution of Wind Pressure Coefficient on Rooftop

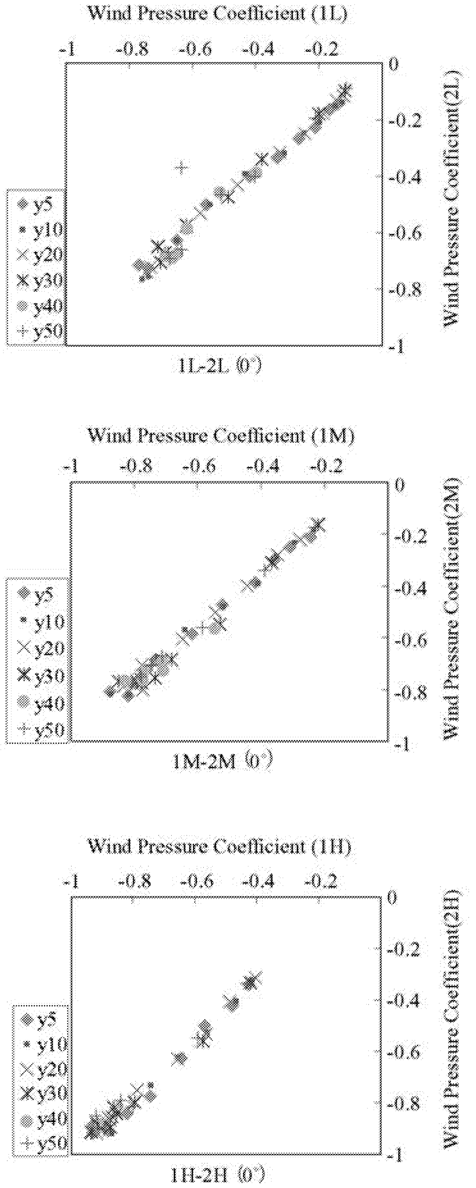


Figure 7. Correlation of Wind Angle of 0°

1M on 2M, 1H on 2H. Figure 8 and Figure 10 show that those two dimension maps of the same wind direction and of the same height are similar. A distribution map on the windward side is less influenced by the depth. There is a correlation in the range of $x<100$, $y<50$.

Figure 7 shows correlation charts between 1L and 2L, 1M and 2M, 1H and 2H. On 1L - 2L chart, almost all points are correlative but only one point is uncorrelated. This point is $x=30$, $y=50$. One of supposable reasons is that the measurement point on 2L was affected by contracted flow. As previously described, the negative pressures near $y=50$ were smaller than their neighborhood. It is imaginable that the flow on the line of $y=50$ is more complicated. 1M-2M chart is correlated. 1H-2H chart is also correlated.

Figure 9 shows correlated charts of wind direction of 22.5°. Data variation is more than that of wind direction of 0°. Strength of correlation is weaker in the range of $80<x<90$, $5<y<10$. It is thought because the size of windward wall is different in this area.

Figure 11 shows correlated charts of wind direction of 45°. Data variation is more than other directions. In the range of $5<y<10$ has especially weak correlation. It means the degree of correlation at the windward side is low. It will also be said that the size of the windward wall affects the wind coefficient distribution on the windward side, especially in near the edge. The influence of the size of the wall which includes an X-axis is not so large on the downwind rooftop.

There is possibility to organize the best positions of natural ventilation chimneys systematically. One of significant components for the system will be the size of windward wall.

4. CONCLUSIONS

By understanding a distribution of wind pressure coefficient, authors grasped the best point to set up a

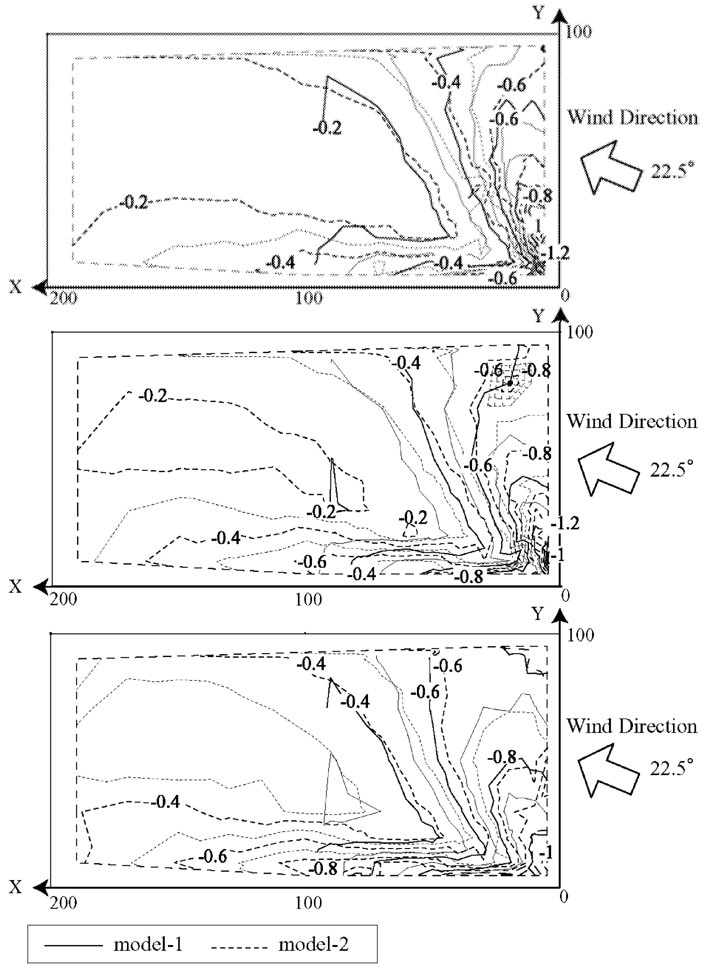


Figure 8. Distribution of Wind Pressure Coefficient on Rooftop

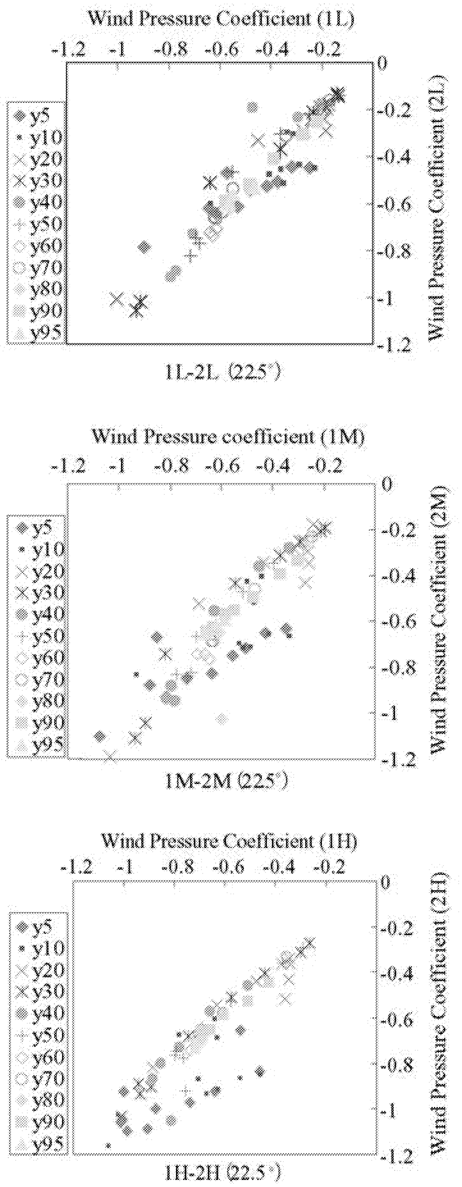


Figure 9. Correlation of Wind Angle of 22.5°

chimney. The interesting characteristics of a distribution of wind pressure coefficients are also obtained. Authors got following knowledge.

- The two models whose shapes of the rooftops are same compared, as the model height changes higher, the absolute value of wind pressure changes higher.
- The flow on the central axis can be more complicated in the wind direction of 0º.
- Two distribution maps of the same wind direction and the same height are similar even though their plane dimension figures are different. Although the strength of correlation at the windward side is low in the wind direction of 22.5º and 45º.
- A separated airflow mainly depends on the size of the windward wall. The effect of the depth of models is little.

There is possibility to organize the best positions of natural ventilation chimneys systematically by the size of windward wall.

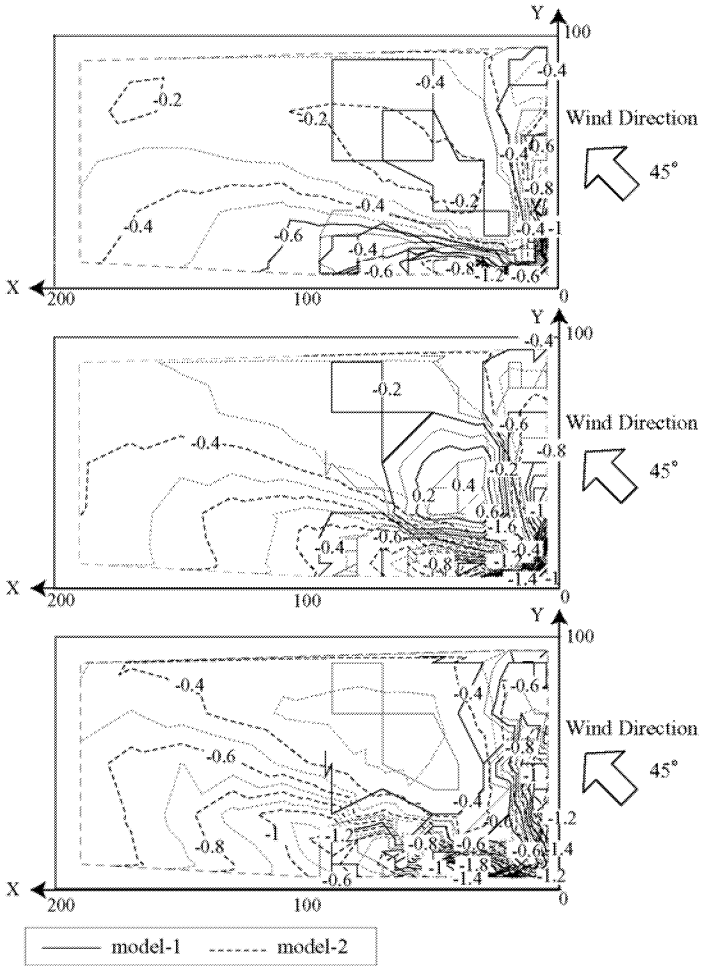


Figure 10. Distribution of Wind Pressure Coefficient on Rooftop

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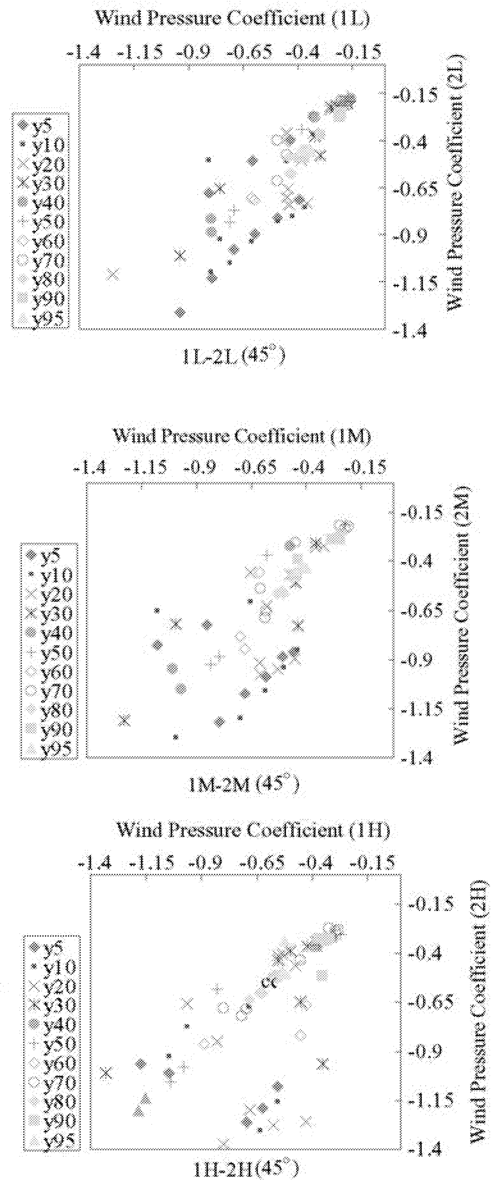

Figure 11. Correlation of Wind Angle of 45º