Study on the numerical predictive accuracy of wind pressure distributions and air flow characteristics. Part 2: Prediction accuracy of wind pressure distribution of various shaped buildings

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ABSTRACT

In Part 1, it is described that, in overall judgment, the reproduction accuracy is improved when computational fluid dynamics (CFD) is performed using RNG model and the modified model incorporating Durbin's limiter (α = 0.65). However, in Part 1, the study was performed on an object with extremely simple shape, and question may arise if this is applied on an actual building. In this respect, we attempted in this study to perform similar evaluation on an object with complicated shape. As a result, it was found that RNG model provides high reproduction accuracy just as in the case of the object with simple shape. Also, it was made clear that there is problem with the model incorporating Durbin's limiter (α=0.65) because the object has a complicated shape. Consequently, the modified model incorporating Durbin's limiter with a higher value for α shows better results compared with RNG model.

1. INTRODUCTION

The object for calculation were set to the three objects with the shapes shown in Figs. 1, 2 and 3, respectively. In Type A, calculation meshes are prepared in the orthogonal cross mesh as in Part 1, but the shape is more complicated. In Type B and Type C, actual house shapes are assumed. Compared with Type B, Type C has more complicated shape. Calculation mesh is prepared in hybrid mesh, which comprises of tetrahedron and hexahedron shaped mesh. Calculation was made on the condition where boundary layer flow is turned to approaching flow with 1/4th power distribution. Various types of k-ε models were tested for three shapes and the results were compared with these wind tunnel experiment.

2. RESULTS AND DISCUSSIONS

2.1 Type A

Figure 4 shows the results of experiment. Parameter in Durbin model was set to α=0.65,

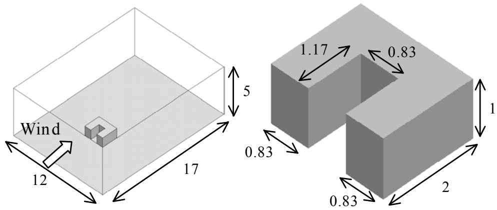

Figure 1: Building shape and flow geometry (Type A).

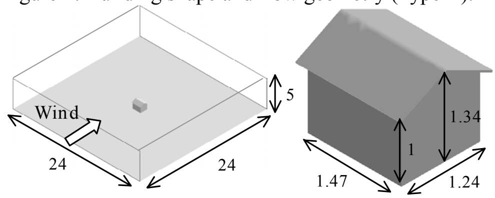

Figure 2: Building shape and flow geometry (Type B).

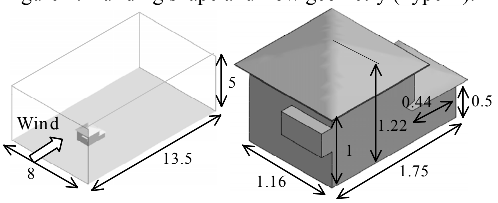

Figure 3: Building shape and flow geometry (Type C).

which showed the best reproducibility in Part 1. The results of calculation using RNG model and Durbin model are summarized in Figure 5 and 6. When the result of RNG model is compared with experiment, wind pressure coefficient on the front surface of the building is higher by an amount of 0.1 to 0.4. It is also higher by an amount of about 0.1 on lateral surface of the building. Compared with this, wind pressure coefficient is higher on the front surface and on the lateral surface of the building by an amount of 0.1 to 0.3 in Durbin model.

Figure 7 shows the correspondence of measured and predicted wind pressure coefficients at measuring points in the experiment both for Durbin and RNG models. Based on the standard deviation from the experimental values, significant difference is not observed between Durbin and RNG models. Because the standard deviation using the standard k-ε model is 0.219, quality of the prediction is improved by applying these models.

2.2 Type B

Figure 8 shows wind pressure distribution in the results of the experiment for Type B. Durbin model was made by setting α=0.65.

The wind pressure distribution in the results of RNG model and Durbin model are summarized in Figure 9 and 10. RNG model tends to overestimate wind pressure coefficient on the front surface of the building by an amount of 0.1 to 0.4. It is also higher by an amount of about 0.1 on lateral surface of the building

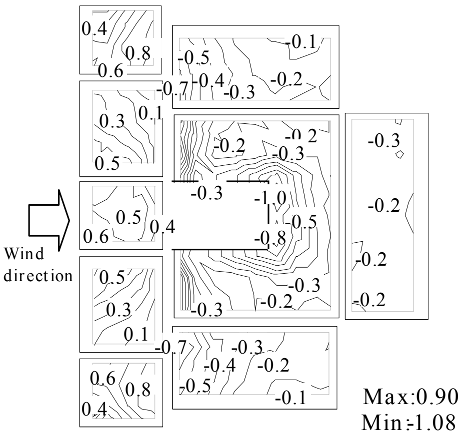

Figure 4: Observed wind pressure distribution for Type A.

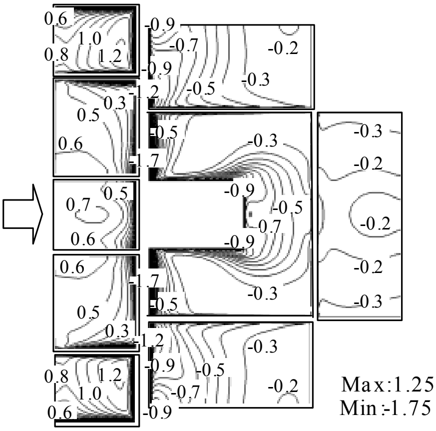

Figure 5: Predicted wind pressure distribution for Type A (Durbin model).

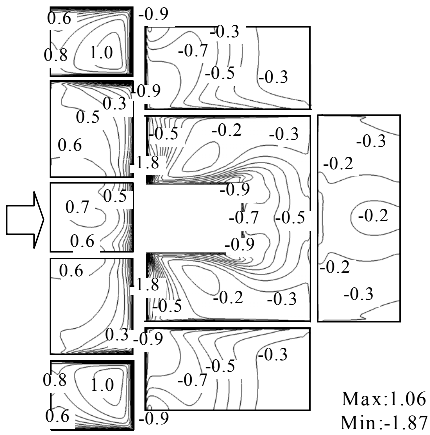

Figure 6: Predicted wind pressure distribution for Type A (RNG model).

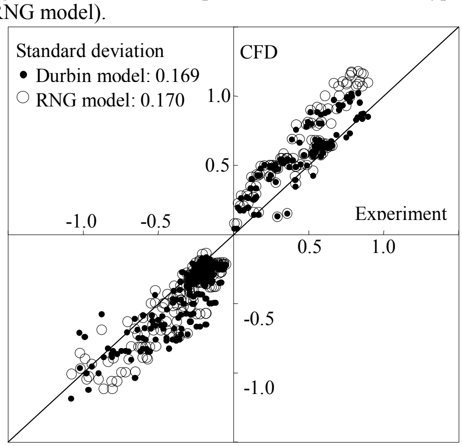

Figure 7: Correspondence of observed and predicted wind pressure coefficients.

similarly with Type A. Durbin model clearly improve the distribution on front surface of the

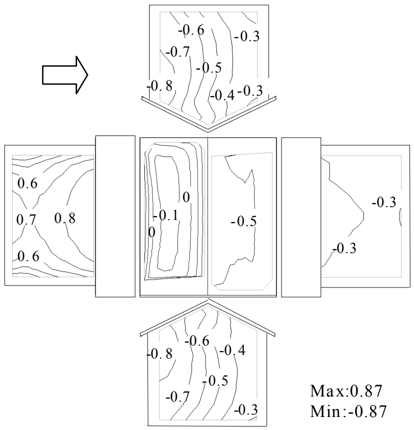

Figure 8: Observed wind pressure distribution for Type B.

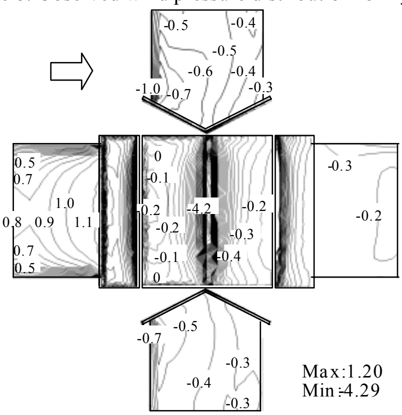

Figure 9: Predicted wind pressure distribution for Type B (RNG model).

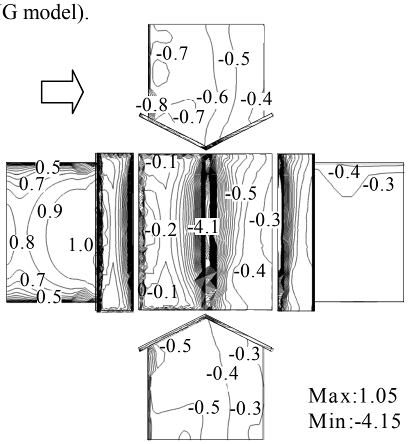

Figure 10: Predicted wind pressure distribution for TypeB (Durbin model).

building, while it is evident that the distribution on lateral surface of the building does not correspond well to the results of experiment. Fig. 11 and 12 shows the correspondence of measured and predicted wind pressure coefficients. Here, points of each surface are distinguished due to different trend of matching.

Standard deviation of both models is large compared with Type A because the results of calculation on the roof do not correspond well to the experimental result. However, as in the case of Type A, it is confirmed that reproduction accuracy is higher when Durbin model is used based on the value of standard deviation is concerned. However, it is thought that the separation air flow structure originated from the edge of front surface is not reproduced well with Durbin model.

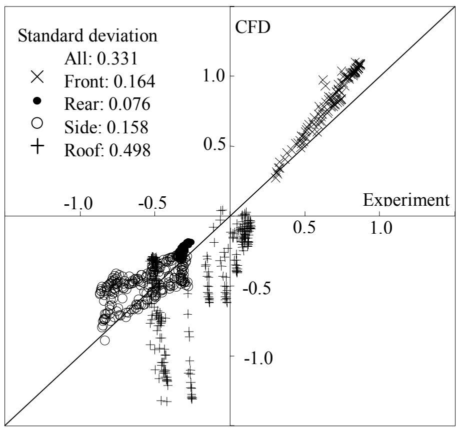

Figure 11: Correspondence of observed and predicted wind pressure coefficients (RNG).

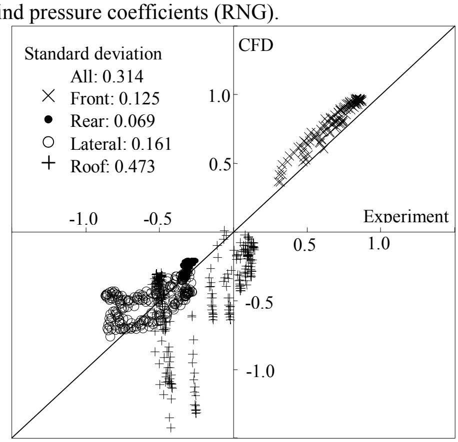

Figure 12: Correspondence of observed and predicted wind pressure coefficients (Durbin).

Reproduction of flow structure near lateral wall can be more important than general accuracy of wind pressure when optimal design of cross-ventilation is a matter of concerned. From this reason, further calculation was then made by changing the value of α. The wind pressure distribution in the results of calculation on Durbin model (α=0.80) and Durbin model (α=1.00) are summarized in Fig. 13 and Fig. 14. Similarly, Fig. 15 and 16 show correspondence of wind pressure coefficient with experiment. The tendency of the improvement is different for each surface for different value of α. Therefore, standard deviations in the results of each surface are summarized in Table. 1.

In the front surface, Durbin model (α=0.65) produces the best result. On the other hand, in the

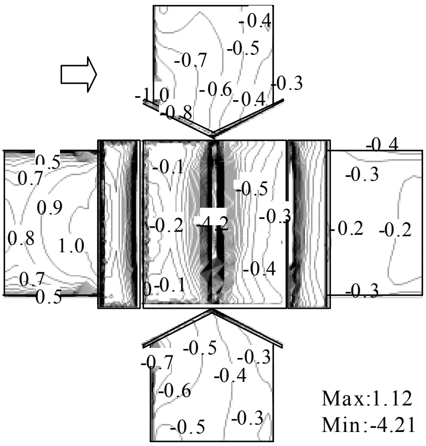

Figure 13: Predicted wind pressure distribution for TypeB (Durbin α=0.80).

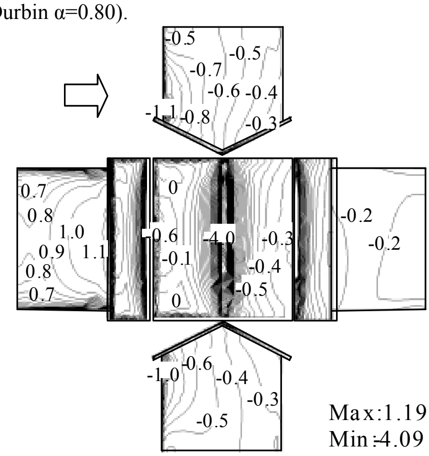

Figure 14: Predicted wind pressure distribution for TypeB (Durbin α=1.00).

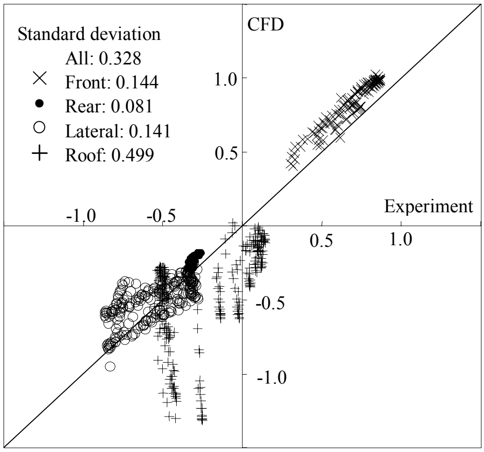

Figure 15: Correspondence of observed and predicted wind pressure coefficients (α=0.80).

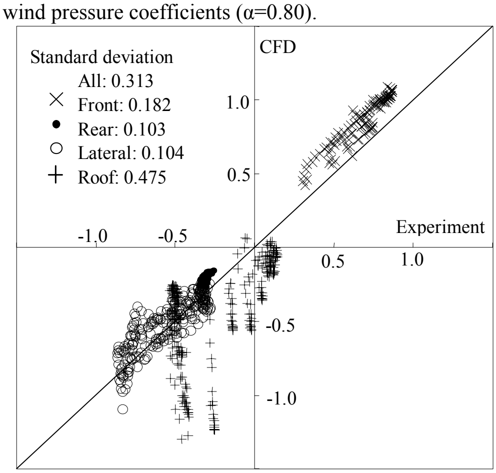

Figure 16: Correspondence of observed and predicted wind pressure coefficients (α=1.00).

Table 1: Standard deviation (Type B).

	RNG model	Durbin model		
		α =0.65	α =0.80	α =1.00
Front	0.164	0.125	0.144	0.182
Rear	0.076	0.069	0.081	0.103
Lateral	0.158	0.161	0.141	0.104
Roof	0.498	0.473	0.499	0.475
All	0.331	0.314	0.328	0.313

lateral surface, Durbin model (α=1.00) produces the most accurate result. Durbin model (α=0.80) doesn't produce the least accurate result both for front and lateral surfaces. A value of 0.8 would be a practical compromise. At this point, similar investigation was attempted in type A to check the universal appricability of this value. Table 2 shows standard deviation in the results of each surface in Type A.

Roughly the same tendency of matching for each surface is observed. The result of calculation on Type A using Durbin model (α=0.80) is summarized in Fig. 17 and 18. Roof surface wind pressure is reproduced better in type A than in Type B, probably due to better representations of flow domain near the roof covered by orthogonal mesh system.

2.3 Type C

Figure 19 shows the results of the experiment. Fig. 20 and 21, 22 shows wind pressure distribution when Durbin model α=0.65, α=0.80 and α=1.00 are used. Similar tendency of matching with Type B is seen in the front surface. No significant difference is observed on

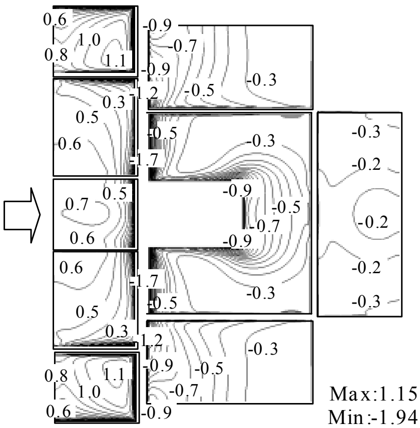

Figure 17: Wind pressure distribution (Durbin α=0.80).

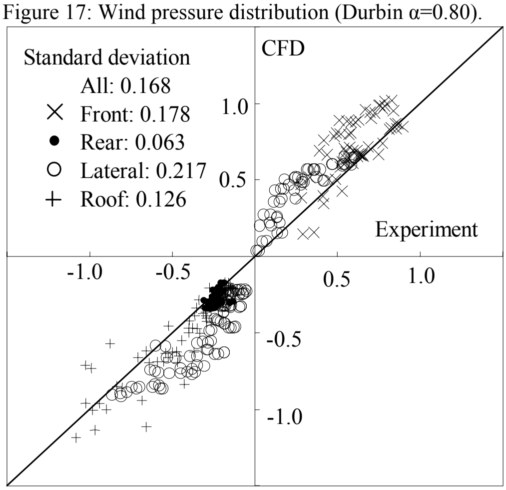

Figure 18: Correspondence of observed and predicted wind pressure coefficients (Durbin α=0.80).

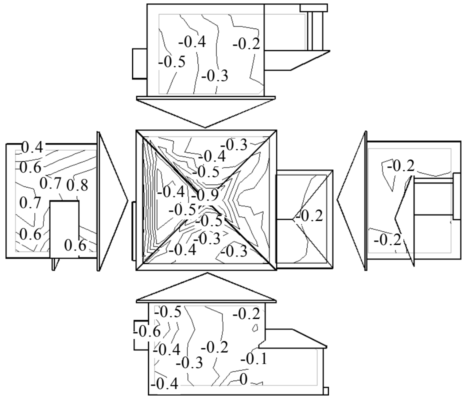

Figure 19: Observed wind pressure distribution for TypeC.

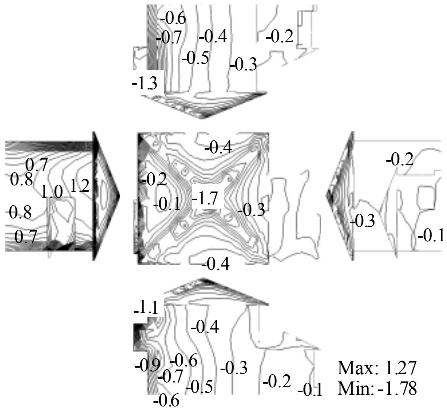

Figure 20: Predicted wind pressure distribution for TypeC (Durbin α=1.00).

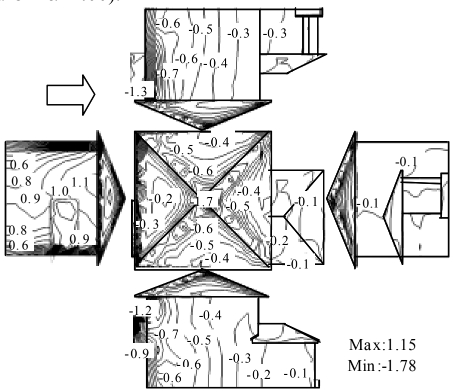

Figure 21: Predicted wind pressure distribution for TypeC (Durbin α=0.80).

predicted pressure distribution on lateral surface. Although the quality of prediction is not fully satisfactory, general patterns of pressure

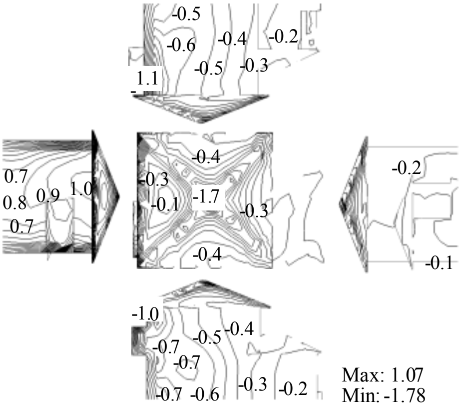

Figure 22: Predicted wind pressure distribution for TypeC (Durbin α=0.65).

Table 2: Standard deviation (Type A).

	RNG model	Durbin model		
		α =0.65	α =0.80	α =1.00
Front	0.247	0.177	0.178	0.213
Rear	0.060	0.064	0.063	0.067
Lateral	0.197	0.224	0.217	0.207
Roof	0.095	0.120	0.126	0.098
All	0.171	0.169	0.168	0.168

contours are well reproduces in all results.

3. CONCLUSION

The results obtained from this study are summarized as follows.

- By applying RNG and Durbin models, quality of prediction of wall surface wind pressure distribution of various buildings is improved comparing with the standard k-ε model.
- As for parameter α of Durbin model, smaller value suppresses overestimation of pressure at frontage surface, while larger value improve quality of prediction on lateral surface. A value of 0.8 would be a practical compromise not to reproduce the least accurate prediction on each surface.
- Relatively poor prediction on pressure distribution in inclined roof surface may be originated from poor quality of mesh system to represent the actual shape of flow domin near roof. Further research is needed to handle complicated flow geometry by sophisticated mesh system.

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