Wind Engineering Joint Usage/Research Center
FY2014 Research Result Report

Research Field: Indoor Environment
Research Period: FY2014 ～ FY2016
Research Number: FY2015 WERC/JURC-TPU
Research Theme: Study on wind-driven natural cross ventilation of a building

Representative Researcher:
1. HeeChang LIM (Pusan National University·School of Mechanical Engineering·Professor)
2. Kunio Mizutani (Tokyo Polytechinic University)
3. Kenji Tsukamoto (Tokyo Polytechinic University)
4. Haeyoung Kim (Tokyo Institute of technology)
5. YoungTae LEE (Pusan National University·School of Mechanical Engineering·PhD Student)
6. SooIl BOO (Pusan National University·School of Mechanical Engineering·Msc Student)
7. SiYeol LEE (Pusan National University·School of Mechanical Engineering·Msc Student)

Budget [FY2014]: 700,000 Yen

1. Research Aim

In order to build an energy-saving structure aiming to minimize energy consumption, we'll analyze the thermal buffering phenomena between the ventilation flow inside and the unsteady wind flow outside the building, and suggest an optimized design criteria. Therefore, this proposal aims to (i) obtain comprehensive mean and fluctuating thermo-fluid properties in order to delineate more clearly the link between unsteady motions of the wind flow and the shape of the obstacles, (ii) analyze the mechanism of natural/forced ventilation similarity (e.g. Grashof & Rayleigh number) in the modelling of turbulent flows inside generic three-dimensional obstacles of a wide variety of heights and aspect ratios, (iii) make a flow modelling between the unsteady flow outside of the obstacles and the natural/forced ventilation inside and herein analyze the thermal buffering, and (iv)thus secure the core technologies of the structural design criteria.

2. Research Method

First, the wind tunnel tests were conducted in the turbulent boundary layer wind tunnel (Fig. 1) of the Wind Engineering Research Center at Tokyo Polytechnic University (TPU) in Japan. This wind tunnel is an open-circuit, low-speed wind tunnel designed for wind environmental assessment and ventilation studies. Most of the experiments were conducted in the end-part test section of the tunnel, where the sectional dimensions were 1.2 m width, 1.0 m height, and 14 m length, with a maximum wind speed of approximately 30 m/s. Table 1 gives the dimensions of the group of surface roughness blocks used in the wind tunnel to generate the simulated turbulent boundary layer. The details of the generated turbulent boundary layer are illustrated in the Fig. 2.

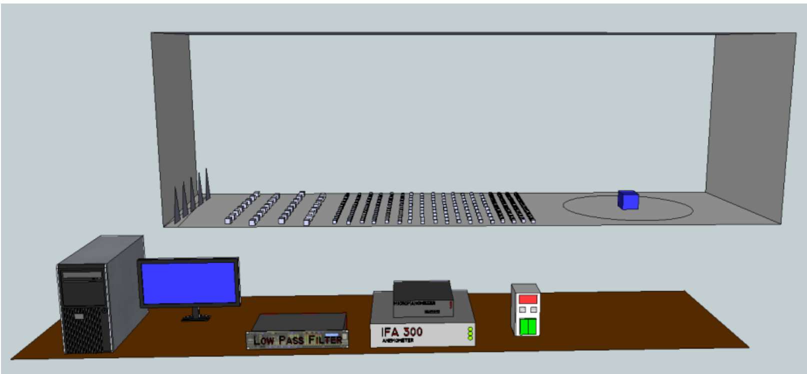

Figure 1 Wind tunnel measurement and test apparatus

	A	B	C	D	E	F
Size [WxH] $[mm^2]$	30x30	50x50	50x50	50x50	98x98	70x700
No. Elements	60	60	128	108	36	3
Length [mm]	240	525	1,780	1,435	2,450	450

Table 1 Group of surface roughness blocks used in the tunnel

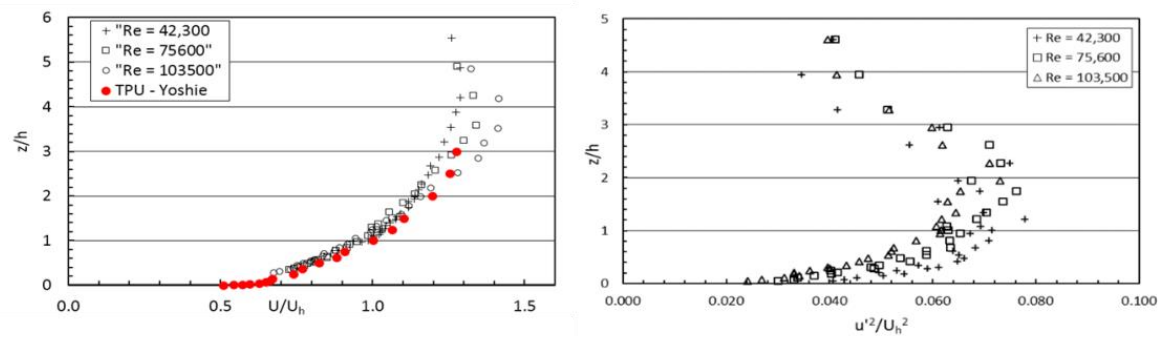

Figure 2 Mean velocity and axial stress profiles

The work involved covers a combination of microclimate measurements, numerical microclimate simulations and studies of the urban planning process. If possible, field measurements would be conducted in areas with significantly differing characteristics, including variations in urban geometry and distance to the sea, to map variations in microclimate and outdoor thermal comfort within each city. To cover a wider range of urban design, to test the impact of different design parameters on outdoor thermal comfort and to achieve optimum design solutions, microclimate simulations using Computational Fluid Dynamics (CFD) software will be conducted in the near future. The results obtained will be studied and examined as well as analyzed carefully for preparing • Criteria of urban ventilation and • Thermal comfort criteria for outdoor environment

3. Research Result

One of the priorities of this study was the validation of the surface pressure around square models with different height. To achieve this, we carried out pressure measurements and precise analysis based on the non-dimensional parameter Cp. Fig. 3 depicts the variation of the averaged surface pressure Cp along the axial centreline of the cube obtained in the wind tunnel. It also graphically compares our results to those obtained by others in previous studies. As shown in the figure, the current surface-pressure profile is reasonably well located in the middle of the others, which means that the turbulent intensity and other inflow conditions are slightly different, but not identical, so that it can be easily conjectured that the surface-pressure distribution around the cube could be different based on the inflow boundary condition. For example, CR's result was obtained under a specific inlet flow condition of high turbulent intensity, whereas LCH's was obtained under relatively lower turbulent intensity (Castro and Robins, 1977; Lim et al., 2006; Lim, 2009).

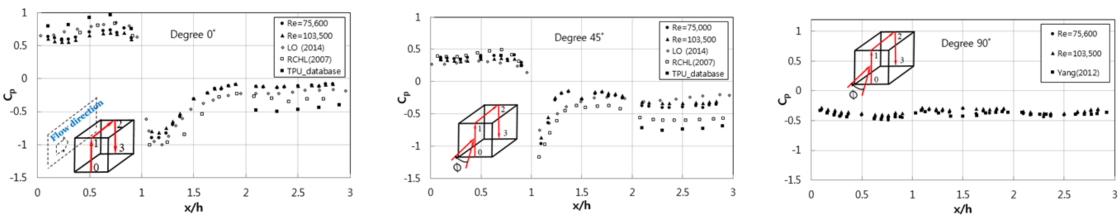

Figure 3 Mean surface static pressure along the central section with different wind direction

In order to observe the effect of different height on the surface pressure around the building, we performed three different buildings.

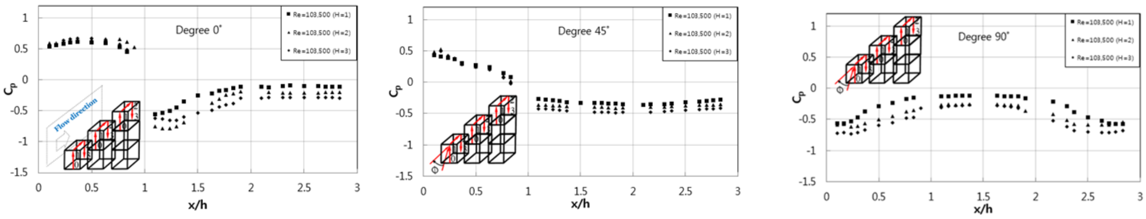

Figure 4 Mean surface static pressure along the central section with 3 different heights

These surface profiles are the fundamental pressure to estimate the impact of wind load inside the building, which can be used to estimate the thermal comfort for the indoor environment. The current results were not fully described, but the relationship between the wind load and thermal comfort inside the room will be parametrically estimated for the future work.

4. Published Paper etc.

[Published papers]

1. <u>**Y. T. Lee**</u> and <u>**H. C. Lim**</u>, "Effect of a turbulent wind flow on the surface pressure of trench cavities", Journal of Mechanical Science and Technology, Vol.27, pp.2673-2681 (2014).
2. <u>**H. C. Lim, K. Tsukamoto, M. Ohba, and K. Mizutani**</u>, "Study on the surface pressure distribution of cubes in cross-wind arrays", J. of Wind Engineering and Industrial Aerodynamics, Vol.133, p.18-26 (2014).
3. <u>**H. C. Lim**</u> and <u>**M. Ohba**</u>, "Interference effects of three consecutive wall-mounted cubes placed in deep turbulent boundary layer", Journal of Fluid Mechanics, Vol.756, pp.165-190 (2014).
4. <u>**H. C. Lim**</u>, and <u>**M. Ohba**</u>, "Detached eddy simulation of flow around rectangular prisms with different aspect ratios", Wind and structure, Vol.20(1), pp.37-58 (2015).

5. Research Organization

1. Representative Researcher

Name: HeeChang LIM

Organization: School of Mechanical Engineering, Pusan National University
Contact address: San30, Jangjeon-dong, Guemjeong-gu,Busan, South Korea
Tel: +82-(0)51-510-2302, Fax: +82-(0)51-512-5236, E-mail: hclim@pusan.ac.kr

2. Collaborate Researchers

Name: Kunio Mizutani

Organization: Tokyo Polytechnic University
Tel: +81-90)46-242-9923, Fax: +81-90)46-242-9923, E-mail: mizutani@arch.t-kougei.ac.jp

Name: Kenji Tsukamoto

Organization: School of Mechanical Engineering, Pusan National University
Contact address: San30, Jangjeon-dong, Guemjeong-gu,Busan, South Korea
Tel: +81-90)46-242-9923, Fax: +81-90)46-242-9923, E-mail: tsukamoto@arch.t-kougei.ac.jp

Name: HaeYoung KIM

Organization: Tokyo Institute of technology

Name: YoungTae LEE

Organization: School of Mechanical Engineering, Pusan National University
Tel: +82-(0)51-510-3085, Fax: +82-(0)51-512-5236, E-mail: ytlee@pusan.ac.kr

Name: Soo-Il BOO

Organization: School of Mechanical Engineering, Pusan National University
Tel: +82-(0)51-510-3085, Fax: +82-(0)51-512-5236, E-mail: qntndlf@gmail.com

Name: SiYeol LEE

Organization: School of Mechanical Engineering, Pusan National University
Tel: +82-(0)51-510-3085, Fax: +82-(0)51-512-5236, E-mail: cowish@naver.com