Integrated Solutions for Infrastructure Development
*Edited by* Lau, H. H., Tang, F. E., Ng, C. K., and Singh, A.

ISBN: 978-0-9960437-3-1

# INFLUENCE OF BASEBOARD HEIGHT ON RESISTANCE TO WIND FORCE OF SCAFFOLDS AT WINDWARD SIDE OF BUILDINGS

HIROKI TAKAHASHI[1], MIZUKI AOKI[2], KATSUTOSHI OHDO[3], and KAZUO OHGAKI[2]

[1]*Construction Safety Research Group/National Institute of Occupational Safety and Health, Kiyose, Japan*
[2]*Dept of Building Technologist/Institute of Technologists, Gyoda, Japan*
[3]*Industrial Accident Investigation Center/National Institute of Occupational Safety and Health, Kiyose, Japan*

The Japanese Industrial Safety and Health Law was revised in March 2009 to introduce new measures by which to prevent accidental falls in the construction industry. As part of this revision, regulations on the installation of guard rails, toe boards, mesh sheets, and other components in appropriate positions on scaffolds were established. When scaffolds are installed in construction sites, their resistance against wind force needs to be calculated. Japanese design guidelines stipulate a specific scaffold resistance against wind force, but such regulations are applicable to conventional scaffolds. The problem with outdated regulations is that scaffolds are used during building construction without practitioners knowing whether the existing guidelines are suitable for new-style scaffolds. Accordingly, this study was conducted a wind tunnel test to examine the wind force exerted on building scaffolds, with the parameters being baseboard height and distance between scaffolds and a building. The relationship between the wind force coefficient of the scaffolds and baseboard height was proportional only on the scaffolds. As the distance between the scaffolds and the building lengthened, however, the relationship between the parameters reflected a steeper curve as baseboard height increased. Whenever the scaffolds were set near the building, negative pressure acted on the scaffolds as a consequence of the downwind structure. This study was examined the correction factor of the wind force coefficient of the scaffolds.

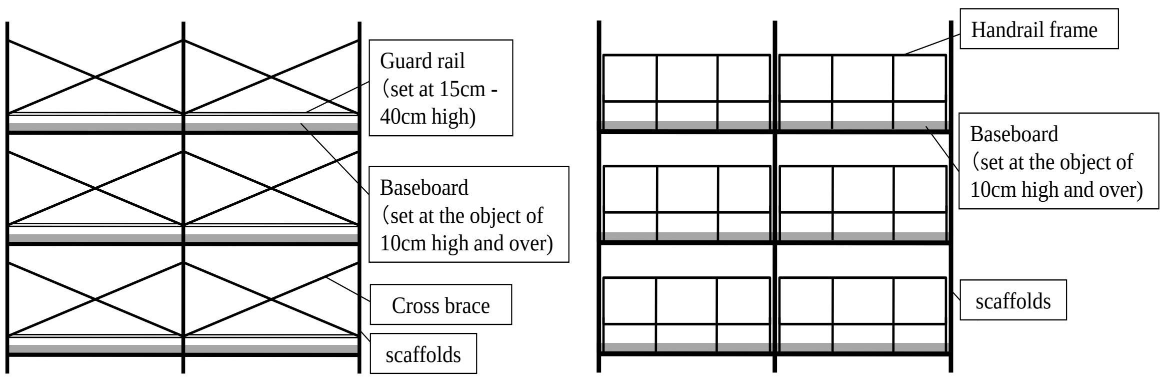
*Keywords*: Fall accident, Projected area, Wind force coefficient, Wind tunnel test.

## 1 INTRODUCTION

The Japanese Industrial Safety and Health Law was revised in March 2009 to introduce new preventive measures for accidental falls in the construction industry (Japan Construction Occupational Safety and Health Association 2009). Part of the revision was the establishment of regulations regarding the installation of guard rails, toe boards, mesh sheets, and other components in appropriate positions on scaffolds. Additionally, regulations on the installation of leading handrails mandate that handrails be erected before construction work commences to protect workers against falls (Ministry of Health, Labor, and Welfare 2003). To satisfy this requirement, practitioners use a special structure called a handrail frame. Figure 1 shows examples of modern scaffold designs.

There are some papers on countermeasures for scaffold resistance against wind force (Yoshida *et al.* 1980, Ministry of Labor the Research Institute of Industrial Safety 1981, Chino 1998). When scaffolds are installed at construction sites, their resistance against wind force needs to be calculated (Scaffolding and Construction Equipment Association of Japan 2004). Japanese design guidelines require a specific scaffold resistance against wind force, but these papers and regulations are applicable to old-style scaffolds. A number of risks are presented by the existing guidelines. First, new-style scaffolds are used in construction sites without practitioners knowing whether the design guidelines are appropriate for modern building components. Second, scaffolds are set near buildings, but workers are unaware that the distance between scaffolds and buildings affects the resistance of the former against wind force. Finally, conventional designs feature the use of baseboards as scaffold components.

With consideration for the above-mentioned issues, this study was carried out a wind tunnel test to examine the wind force exerted on scaffolds erected near a building. The parameters used in the test were baseboard height and the distance between the scaffolds and the building.




(a) Cross brace, guardrail, and toe board.

(b) Handrail frame and toe board.

Figure 1. Examples of modern scaffolds.

## 2 OVERVIEW OF WIND TUNNEL TEST

### 2.1 Wind Tunnel Device and Model

The wind tunnel device is 74,900 mm long, and the device interior is 2,300 mm wide and 2,000 mm high. The test setup is shown in Figure 2. A six-component force balance was used to measure wind force. The model was placed on the balance, which is shown in Figure 3.

The model features scaffolds that are 1/10 the size of buildings and used at general construction sites. Specifically, the scaffolds are three stories high and one span wide. The scaffolds and the structure used for the wind tunnel test are illustrated in Figure 4. The vertical frame direction of the scaffolds is denoted by X, the cross-brace direction of the scaffolds is represented by Y, and the height of the scaffolds is Z. A baseboard was situated on one side of the Y–Z face of the scaffolds. The scaffold model was placed in the wind tunnel, and the structure was positioned near the scaffold model. The distances between the scaffolds and the structure ($D$) are 30 and 200 mm. For a clear comparison, only the results obtained on the scaffolds were examined in the test.

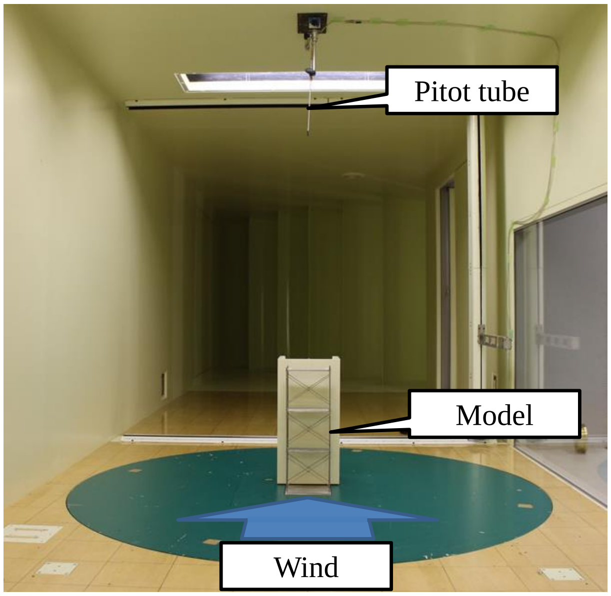



Figure 2. Wind tunnel test.

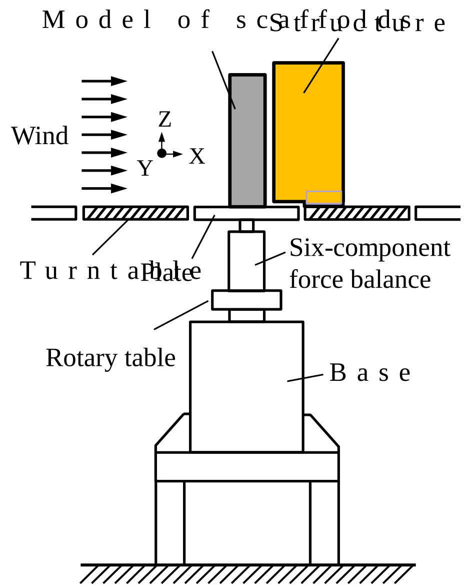
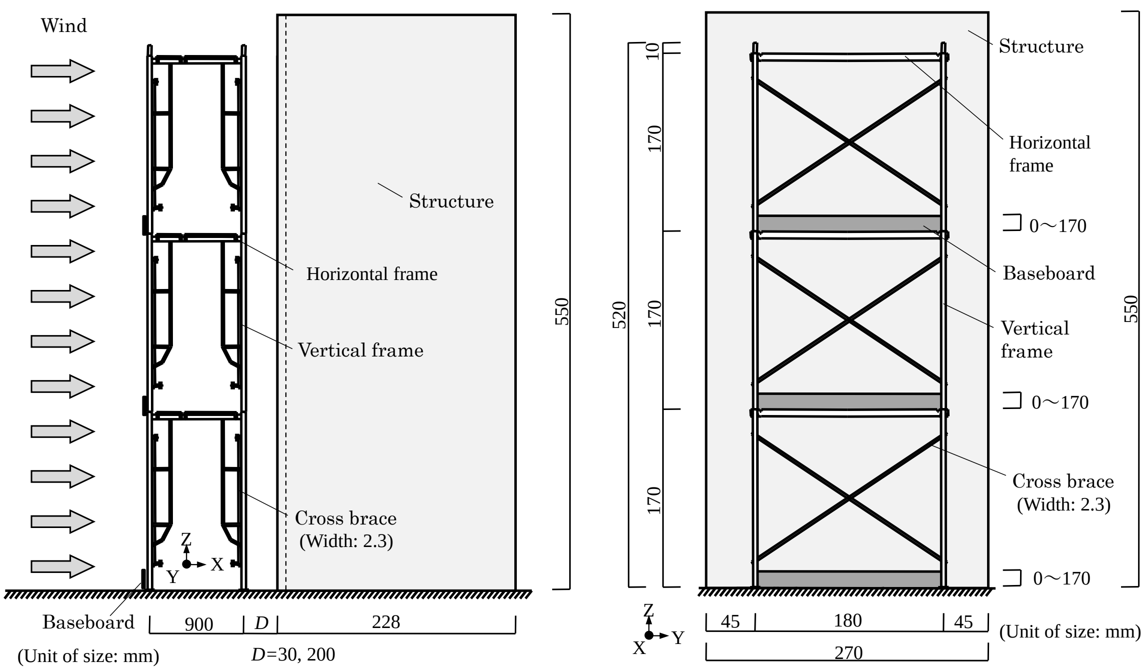



Figure 3. Six-component force balance.




(a) X–Z face

(b) Y–Z face

Figure 4. Scaffolds and structure used for the wind tunnel test.

## 2.2 Projected Area and Reynolds Number

The ratios of the baseboard height and the projected area spanned by the scaffolds are expressed as dimensionless coefficients, thus:

$$\tau = h_b / h_V \tag{1}$$

$$\eta = A_b / A_0 \tag{2}$$

where $\tau$ is the ratio of the baseboard height, $h_b$ is the baseboard height, $h_V$ represents the height of the vertical frame, $\eta$ denotes the ratio of the projected area of the scaffolds, $A_b$ is the projected area of the scaffolds with a baseboard, and $A_0$ is the projected area covered by the scaffolds with a 170-mm baseboard. Figure 5 shows the relationship between $\eta$ and $\tau$; that is, $\eta$ increased as $\tau$ increased.

The pitot tube was positioned 550 mm from the ceiling of the wind tunnel, after which wind speed was measured. The wind speed was set at a uniform flow of 10 m/s. Characteristic length *D* was positioned 5 mm along the diameter of a leg member. The Reynolds number, *Re*, was approximately $3.5 \times 10^3$, determined as follows:

$$\mathrm{Re} = \frac{UD}{\nu} \tag{3}$$

where $U$ is the wind speed (in m/s), $D$ represents the characteristic length (in mm), and $\nu$ denotes the coefficient of kinematic viscosity [$\nu = \mu/\rho$, where $\mu$ is the coefficient of viscosity ($\mu = 1.82 \times 105$(N s/m$^2$), and $\rho$ is the air density].

The scaffolds are made of ring-shaped steel pipes, whose lengths are proportional to their diameters. These features necessitate the calculation of the wind force coefficient of two-dimensional cylinders (Scaffolding and Construction Equipment Association of Japan 2004). The wind force coefficient of each cylinder changes in accordance with the Reynolds number.

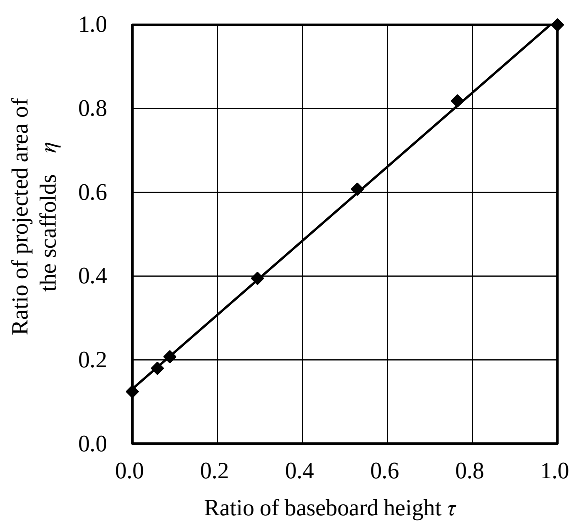



Figure 5. Relationship between the ratio of the projected area of the scaffolds and the ratio of the baseboard height.

## 3 RESULTS AND DISCUSSION

Figure 6 presents the results of the wind tunnel test. In the figure, the vertical axis pertains to the wind force coefficient of the scaffolds ($C$), and the horizontal axis refers to the ratio of the baseboard height ($\tau$). The wind force coefficient of the scaffolds in the X direction was calculated as follows:

$$C = \frac{F}{q_F A} \tag{4}$$

where $F$ is the force exerted on the scaffolds, $q_F$ denotes the reference speed pressure ($=1/2\rho V_H^2$, where $\rho$ denotes the air density, and $V_H$ is the wind speed), and $A$ represents the reference area (projected area by the Y–Z direction of the scaffolds).

Only on the scaffolds was the relationship between $C$ and $\tau$ proportional. On the scaffolds by the building, however, the distance $D$ between the scaffolds and the building was longer, thereby producing a stronger (steeper curve) relationship between $C$ and $\tau$ as $\tau$ increased. Negative pressure acted on the scaffolds as a consequence of the downwind structure.

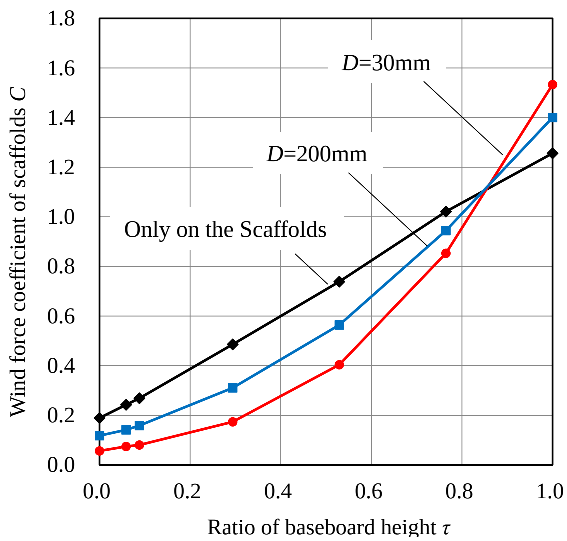



Figure 6. Relationship between the wind force coefficient and the ratio of the baseboard height.

## 4 EXAMMINATION OF CORRECTION FACTOR

This study was examined the correction factor of the wind force coefficient of the scaffolds with baseboards at the windward side of the building. From Figure 6, the calculation used was ($C$ for distance $D$ = 30 mm) - ($C$ for only on the scaffolds) = (Correction factor of the wind force coefficient of scaffolds for results of test $S'$ ) at the windward side of the building). Figure 7 illustrates the relationship between S' and τ. The points in the figure refer to the test results, and the curved line is the approximate value derived using the least squares method. The approximate equation was as follows:

$$S = 1.76\tau_0^2 - 1.41\tau_0 - 0.1 \tag{5}$$

Equation (5) can be reflected in one of the correction factors of $C$ at the windward side of the building.

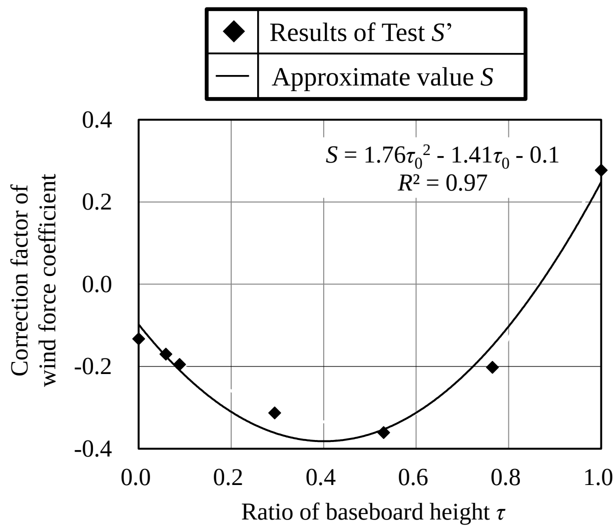



Figure 7. Relationship between the correction factor of the wind force coefficient of the scaffolds and the ratio of the baseboard height.

## 5 CONCLUSION

The wind force acting on scaffolds equipped with baseboards was investigated by wind tunnel testing. On the scaffolds at the windward side of the tested building, the plot of the relationship between the wind force coefficient and the baseboard height reflected a steep curve as the baseboard height increased. The wind force coefficient differed only in accordance with modifications to the scaffolds, that is, when the scaffolds were set near the downwind structure.

Figure 7 shows the correction factor of the wind force coefficient of the scaffolds with baseboards at the windward side of the building.

**Acknowledgments**

This work was supported by the JSPS Grant-in-Aid for Scientific Research C (grant number 15K01238). We are grateful for the financial aid provided.

## References

Chino, N., A Study on Basic Design Wind Speeds for Scaffold, *Summaries of technical papers of Annual Meeting Architectural Institute of Japan. B-1*(in Japanese), Architectural Institute of Japan, 223-224, 1998.

Japan Construction Occupational Safety and Health Association, *Yearbook of Safety and Health in Construction 2009* (in Japanese), Tokyo, 75–110, 2009.

Ministry of Health, Labor, and Welfare, *Guidelines on the Handrail Preceding Method* (in Japanese), Tokyo, 2003.

Ministry of Labor The Research Institute of Industrial Safety, Special Research on Countermeasures for Safety of Scaffolds etc. against Strong Wind, *Special Research Report* (in Japanese), 1981.

Scaffolding and Construction Equipment Association of Japan, *Recommendations for Safety Technology of Scaffolds to Wind Loads* (in Japanese), Tokyo, 2004.

Yoshida, M., Sanada, H., Hongo, T. and Nakamura, O., Experimental Study of Wind Forces on the Scaffold with the Protective Sheets or Soundproof Panes, *Annual report of Kajima Institute of Construction Technology* (in Japanese), Kajima Corporation, 129-136, 1980.