Sustainable Solutions in Structural Engineering and Construction
Edited by Chantawarangul, K., Suanpaga, W., Yazdani, S., Vimonsatit, V., and Singh, A.

ISBN: 978-0-9960437-0-0

WIND TUNNEL TEST FOR CALCULATING WIND FORCES ON SCAFFOLDS WITH BASEBOARD HEIGHT AS A PARAMETER

HIROKI TAKAHASHI, KATSUTOSHI OHDO, and SEIJI TAKANASHI

Construction Safety Research Group, National Institute of Occupational Safety and Health, Kiyose, Japan

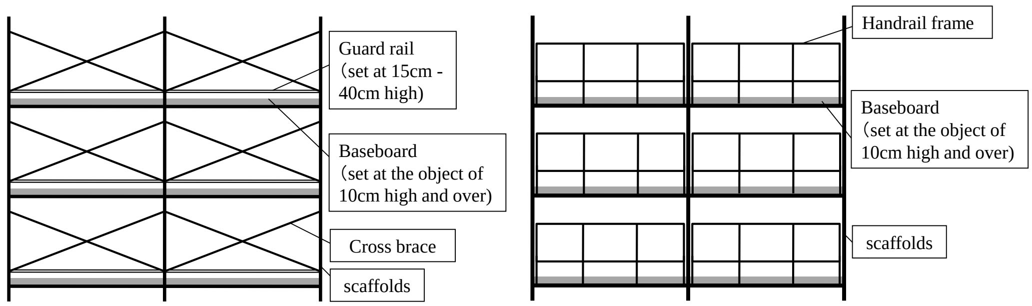
The Japanese Industrial Safety and Health Law was revised in March 2009 to introduce new measures concerning accidental falls in the construction industry. This revision mandates the use of guard rails, handrails, and other scaffold components. The wind load criteria and structural specifications of scaffolds are regulated by current design codes. Nevertheless, these provisions do not necessarily comply with the newly incorporated legal requirements because they apply to old-style scaffolds. This study examined the wind force on scaffolds by wind tunnel test, with baseboard height used as a parameter. The wind force coefficient of one story of scaffolds was calculated. Wind force coefficient increased as baseboard height increased. The wind force on the scaffolds equipped with baseboards is 9.2 times that on the scaffolds without baseboards. The baseboard must be greater than or equal to 15 cm to satisfy regulation requirements. The wind force coefficient of scaffolds with a 15 cm baseboard is 1.5 times that of the scaffolds without a baseboard. In scaffold design, baseboard height should be considered to guarantee a suitable wind force coefficient.

Keywords: Fall accident, Wind force coefficient, Projected area.

1 INTRODUCTION

The Japanese Industrial Safety and Health Law was revised in March 2009, with new preventive measures for accidental falls in the construction industry introduced (Japan Construction Occupational Safety and Health Association 2009). As part of this revision, authorities established regulations on the provision of guard rails, toe boards, mesh sheets, and other components in appropriate positions on scaffolds. Conversely, the installation of leading handrails requires that handrails be erected before construction work commences because these structural elements also serve as support during scaffold disassembly (Ministry of Health, Labor, and Welfare 2003). For this purpose, a special structure called a handrail frame is used. Figure 1 shows examples of modern scaffolds and Figure 2 displays the modern scaffolds used in construction sites.

Scaffolds often fall during strong winds, prompting the consideration of wind loads in the setup of these structures. The wind loads and structural specifications of scaffolds are regulated by current design guidelines (Scaffolding and Construction Equipment Association of Japan 2004), but these provisions do not necessarily comply with revised legal requirements because they are applicable to traditional scaffolds. In such conventional designs, a baseboard is used in construction sites.



(a) Cross brace＋guardrail＋toe board. (b) Handrail frame＋toe board.

Figure 1. Examples of modern scaffolds.

Figure 2. Modern scaffolds used in construction sites.

With baseboard height as a parameter, this study performed a wind tunnel test to examine the wind forces that act on scaffolds.

2 INTRODUCTION

2.1 Wind Tunnel Device and Models

The wind tunnel device has a total length 74,900 mm, while the device interior is 2,300 mm wide and 2,000 mm high. A six-component force balance was used in measuring wind force. The models were placed on the balance. The wind tunnel device is shown in Figure 3. The right angle to the wind direction is denoted by X, wind direction by Y, and height by Z.

The models were used on the scaffolds in general construction sites. The models are 1/10 in size, as determined on the basis of model weight and scale. The scaffolds are three stories high and one span wide. The scaffolds used for the wind tunnel test are shown in Figure 4. The vertical frame direction of the scaffolds is denoted by X, cross brace direction by Y, and height by Z. A baseboard was situated on one side of the Y–Z face of the scaffolds.

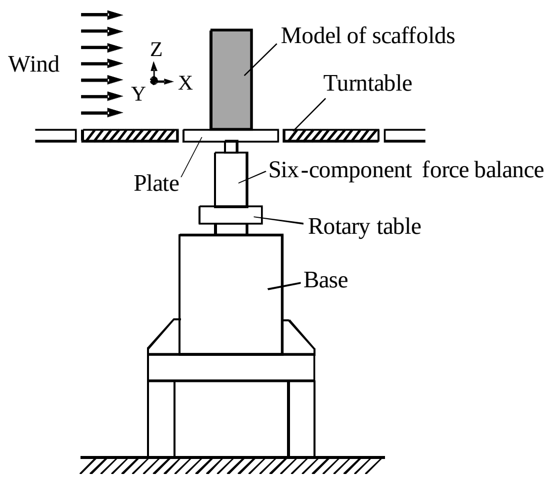


Figure 3. Wind tunnel device.

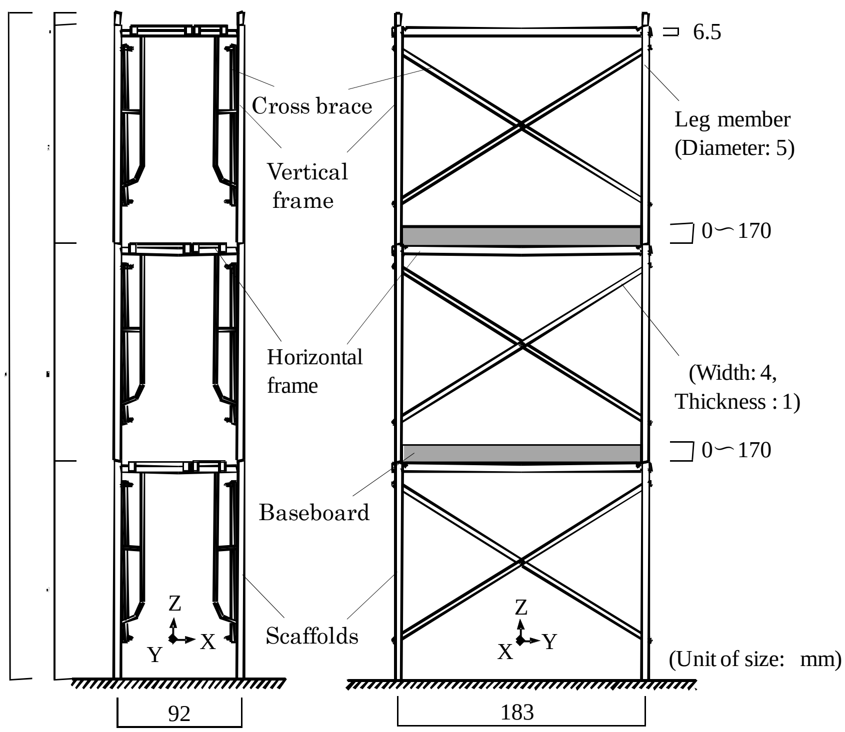


Figure 4. Scaffolds used for wind tunnel test.

A baseboard must be greater than or equal to 15 cm to satisfy regulation requirements. The relationship between baseboard height and wind force coefficient of scaffolds is unknown. Such relationship was therefore also examined, with baseboard height as a parameter. A baseboard must not be placed on the lowest story of scaffolds; thus, the baseboards used in this work were positioned at the second and third stories.

The ratio of baseboard height and that of the projected area to one scaffold story are expressed as dimensionless coefficients as follows:

$$\hat{o} = h_b / h_V \quad (1)$$

$$\varsigma = A_b / A_0 \quad (2)$$

where τ is the ratio of baseboard height, h_b is the baseboard height, h_V is the height of the vertical frame, η denotes the ratio of the projected area to one scaffold story, A_b represents the projected area to one scaffold story with a baseboard, and A_0 is the projected area to one scaffold story with a 170 mm baseboard.

The ratio of the projected area to one scaffold story η and the ratio of baseboard height τ. η grew larger as τ increased (Figure 5).

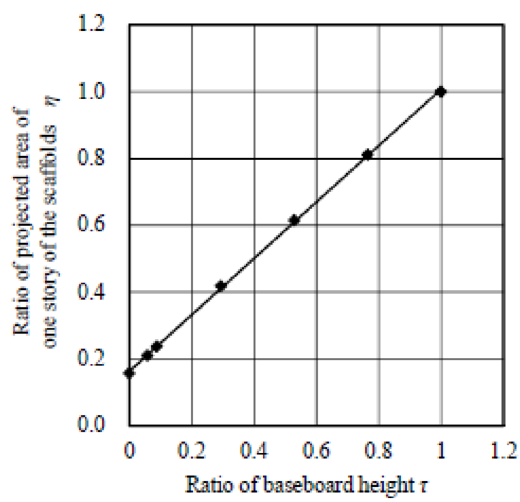


Figure 5. Relationship between the ratio of the projected area to one scaffold story η and the ratio of baseboard height τ.

2.2 Wind Speed and Angle

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 on 5 patterns at a uniform flow of 2, 4, 6, 8, and 10 m/s because the wind force coefficient of a cylinder is stable at this speed.

Characteristic length D was positioned 5 mm along the diameter of a leg member. Reynolds number R_e was approximately 3.5×10^3, expressed as follows:

$$Re = \frac{UD}{\acute{\imath}} \quad (3)$$

where U is the wind speed (m/s), D represents the characteristic length (mm), and v denotes the coefficient of kinematic viscosity [$v=\mu/\rho$, μ is the coefficient of viscosity (μ=1.82×10^5 N s/m^2), ρ is the air density].

The scaffolds are composed of ring-shaped steel pipes, whose lengths are proportional to their diameters. These features require 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.

Wind blows from every angle. To derive important data, wind angle was also used as a parameter, for which four values (0°, 30°, 60°, 90°) were set (Figure 6).

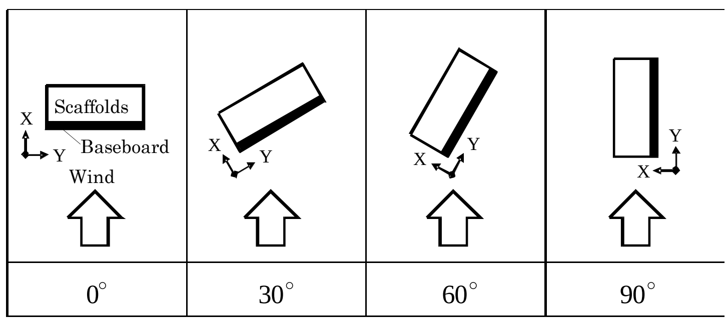


Figure 6. Wind angles used for wind tunnel test.

3 RESULTS

Figures 7 and 8 show the wind tunnel test results. The vertical axis in Figure 7 is the wind force coefficient of one scaffold story C. The horizontal axis in the image represents the wind angles, and the values are the baseboard heights. The vertical axis shown in Figure 8 is the wind force coefficient of one scaffold story C. The horizontal axis in this figure is the ratio of baseboard height τ. The wind force coefficient in the X direction for one scaffold story was calculated as follows:

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

where F is the force on one scaffold story, q_F is the reference speed pressure=$1/2\rho V_H{}^2$, ρ denotes the air density, V_H is the wind speed, and A represents the reference area (projected area by the Y−Z directions of the scaffolds).

Figure 7 shows that a wind force coefficient of 0° was the highest value within 0°–90°. Wind force coefficient decreased as wind angle increased within 0°–90°. Figure 8 indicates that wind force coefficient rose as baseboard height increased. The wind force acting on the scaffolds equipped with baseboards was approximately 1.35–1.46 times the wind force acting on the scaffolds without baseboards. The wind force coefficient of the scaffolds with a 15 mm baseboard was approximately 1.5 times the coefficient of the scaffolds without baseboards. Thus, calculations of wind force coefficient should consider baseboard height for efficient scaffold design.

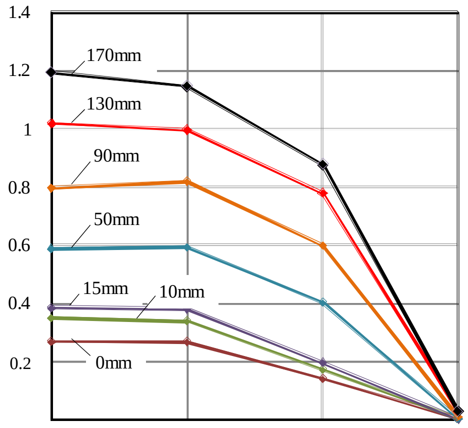


Figure 7. Relationship between the wind force coefficient and the wind angles.

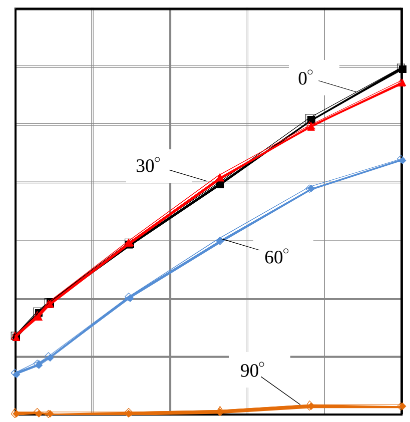


Figure 8. Relationship between the wind force coefficient and the ratio of baseboard height.

4 CONCLUSION

The wind force acting on scaffolds equipped with baseboards was examined by wind tunnel test. The wind force coefficient of the scaffolds with 15 mm baseboards (satisfying regulation requirements) was approximately 1.5 times that of the scaffolds without baseboards. In calculating wind force coefficient, researchers should take baseboard height into account for efficient scaffold design. Our future work will involve examining the calculation method for wind force on scaffolds with baseboards.

Acknowledgments

This work was supported by the JSPS Grants-in-Aid for Scientific Research (©) under grant number 24510242. We are grateful for the financial aid provided.

References

Japan Construction Occupational Safety and Health Association, *Yearbook of Safety and Health on Construction 2009*, pp. 75-110, 2009, in Japanese.

Ministry of Health, Labour, and Welfare, *Guidelines on the Handrail Preceding Method*, 2003, in Japanese.

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