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INFLUENCE OF BASEBOARD HEIGHT ON WIND FORCE OF SCAFFOLDS AT BUILDING EDGE

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When scaffolds are installed in construction sites, their resistance against wind force needs to be calculated. Japanese design guidelines require a specific scaffold resistance against wind force, but such rules and regulations are applicable solely to old-style scaffolds. A number of risks are inherent in 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 of the effect of the wind force at the building edge. Finally, conventional designs feature the use of baseboards as scaffold components. While considering the aforementioned issues, a wind tunnel test was carried out as part of this study to examine the wind force exerted on scaffolds erected near a building edge. The parameters used in the test were baseboard height and the distance from the building edge. From the results, when the distances between the building's center and the scaffold's center are 180 mm, the wind force is high. Additionally, when the baseboard height is 130 mm, the wind force is high. This study examined the correction number for the wind force coefficient of scaffolds with baseboards that were positioned at building edge. Whenever the scaffolds were set near the building edge, we needed to revise 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. Statistics regarding fatal accidents in Japan that involve falls (2010–2014) are shown in Figure 1 (Ministry of Health, Labor, and Welfare 2003). Falls from scaffolds accounted for the highest proportion of accidents (162 people, or 21% of all fatal accidents).

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 regarding the installation of leading handrails mandate that handrails be erected before construction work commence, 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 2 shows an example of modern scaffolds used in construction sites.

Some studies address countermeasures for scaffold resistance against wind force (Yoshida *et al.* 1980, 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 such rules and regulations relate solely to old-style scaffolds. A number of risks are inherent in 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 on the effect of the wind force at the building edge. Finally, conventional designs feature the use of baseboards as scaffold components. Other countries have undertaken studies of wind pressure around scaffolds with sheets (Irtaza *et al*. 2012). However, no study has been undertaken on wind force around scaffolds with baseboards.

While considering the aforementioned issues, this study 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 from the building edge.

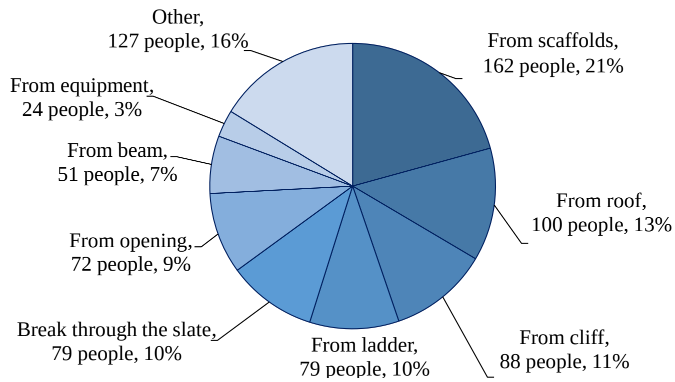


Figure 1. Fatal accidents in Japan involving falls (2010–2014).

Figure 2. Modern scaffolds used in construction sites.

2 OVERVIEW OF WIND TUNNEL TEST

2.1 Wind Tunnel Device and Model

The wind tunnel device is 74.9 m long, and the device interior is 2.3 m wide and 2.0 m high. The test setup is shown in Figure 3. A six-component force balance is used to measure wind force. The model is placed on the balance, as shown in Figure 4.

The model features scaffolds that are 1/10th the size of buildings and which are 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 5. 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 is situated on one side of the Y–Z face of the scaffolds. The scaffold model is placed in the wind tunnel, and the structure is positioned near the scaffold model. The distances between the building's center and the scaffold's center (D) range from 0 to 960 mm. To facilitate clear comparisons, only the results obtained on the scaffolds were examined during the test.

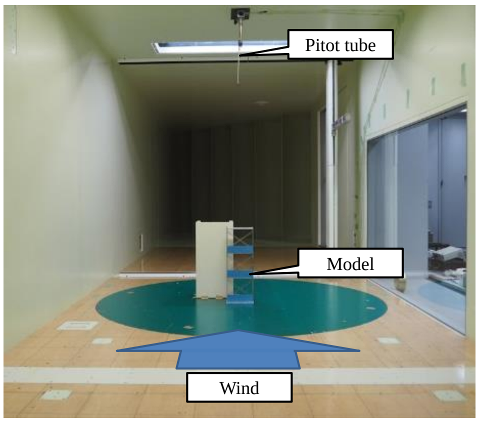


Figure 3. Wind tunnel test.

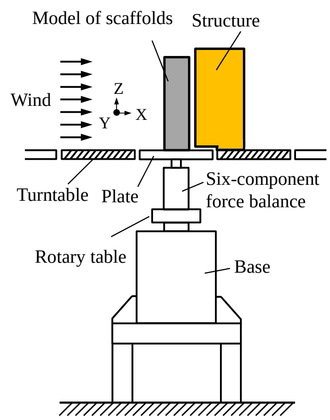
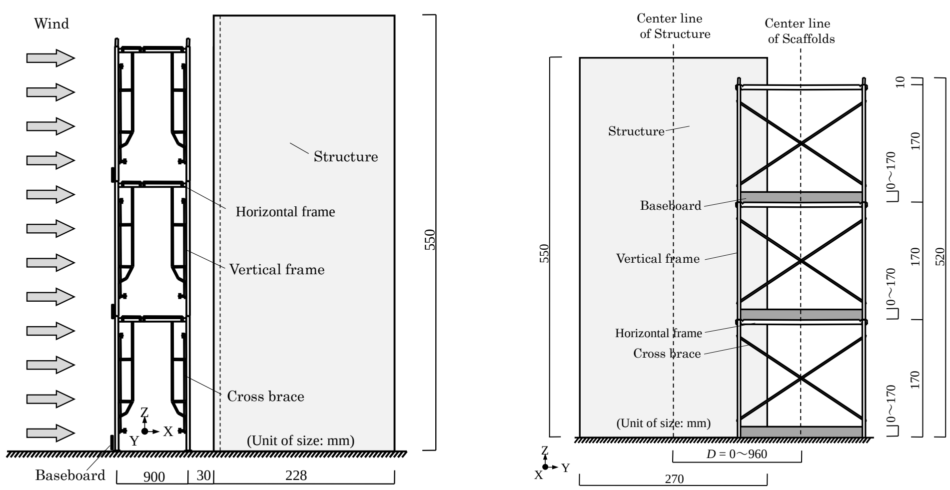


Figure 4. Six-component force balance.



(a) X–Z face (b) Y–Z face

Figure 5. 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 in Eq. (1) τ is the ratio of the baseboard height, h_b is the baseboard height, h_V represents the height of the vertical frame. In Eq. (2) η 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 scaffolds with a 170-mm baseboard. Figure 6 shows the relationship between η and τ—that is, η increased as τ increased.

The pitot tube was positioned 550 mm from the ceiling of the wind tunnel, after which the wind speed was measured. The wind speed was set at a uniform flow of 10 m/s. The characteristic length *B* was positioned 5 mm along the diameter of a leg member. The Reynolds number, *Re*, was approximately 3.5×10^3, and was determined as follows, Eq. (3):

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

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

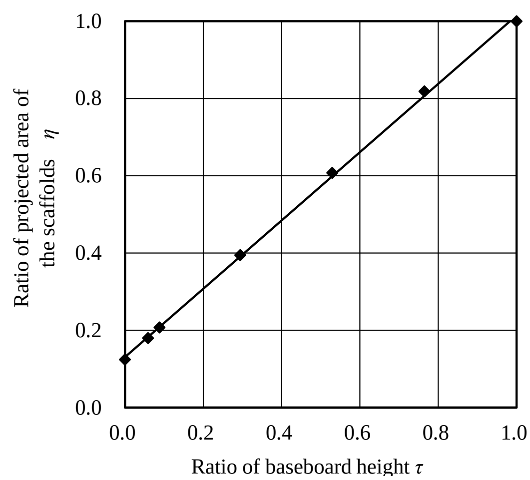


Figure 6. Relationship between the ratio of the projected area of the scaffolds and the ratio of the baseboard height.

3 RESULTS AND DISCUSSION

Figure 7 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 distances between the building's center and the scaffold's center (*D*). The wind force coefficient of the scaffolds in the X direction was calculated as follows, Eq. (4):

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

where F is the force exerted on the scaffolds, q_F denotes the reference speed pressure ($=1/2\rho V_H^2$, where ρ 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).

When τ ranged from 0.29 to 0.76 and D ranged from 180 mm to 300 mm, C was the height. When D ranged from 180 mm to 300 mm, the scaffolds were placed near the building edge. The separated flow acted on the scaffolds near the building edge. When τ was 0.10 and the D ranged from 0 mm to 350 mm, the C was low. When τ was 0.10, there was no opening at the X–Y face of the scaffolds; therefore, the negative presser acted on the scaffolds through the separated flow.

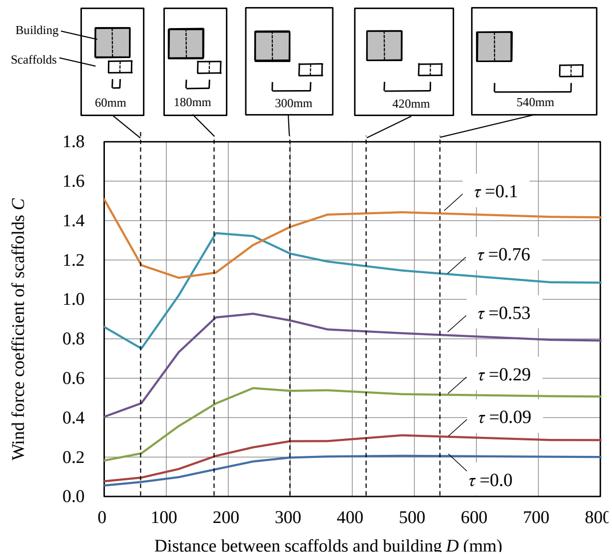


Figure 7. Relationship between the wind force coefficient and the distances between the building's center and the scaffold's center.

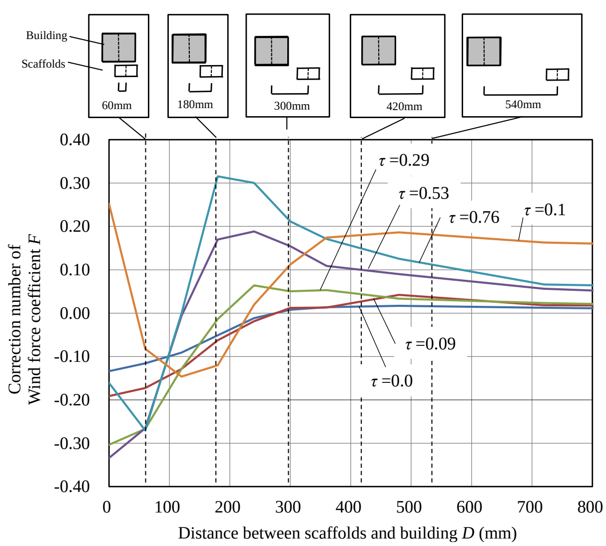


Figure 8. Relationship between the correction factor of wind force coefficient and the distances between the building's center and the scaffold's center.

This study examined the correction number for the wind force coefficient of the scaffolds with baseboards at the building edge. The calculation was performed as follows: (*C* from Figure 6) – (*C* for only on the scaffolds) = (Correction number of the wind force coefficient of scaffolds for the results of test F') at the building edge. Figure 8 illustrates the relationship between *F* and *D*. When τ ranged from 0.53 to 0.76 and *D* ranged from 150 mm to 350 mm, *C* was the height. We believe that F relates to one of the correction numbers (*C*) at the building edge.

4 CONCLUSION

The wind force that acts on scaffolds equipped with baseboards was investigated through wind tunnel testing.

From the results, we determined that when the distance between the building's center and the scaffold's center is 180 mm, the wind force is high; it is also high when the baseboard height is 130 mm. The separated flow acted on the scaffolds near the building edge. This study examined the correction number for the wind force coefficient of scaffolds with baseboards that were positioned at building edge. Whenever the scaffolds were set near the building edge, we needed to revise the wind force coefficient of the scaffolds.

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