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WIND TUNNEL TEST OF SCAFFOLDS SET WITH WALL CONNECTERS WITH BASEBOARD HEIGHT AS A PARAMETER

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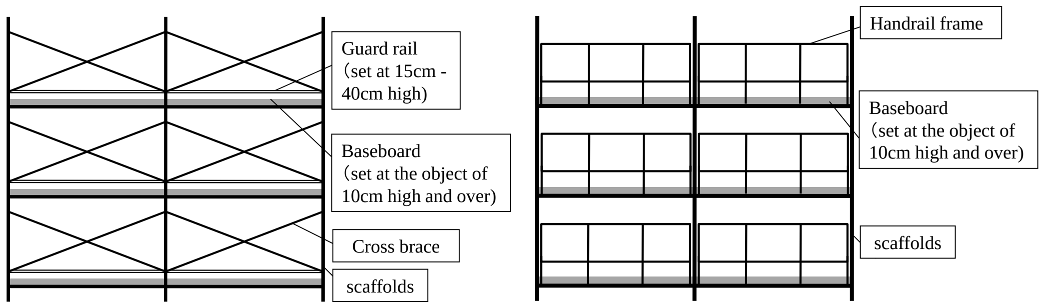
The Japanese Industrial Safety and Health Law were revised in March 2009 to introduce new measures by which to prevent accidental falls in the construction industry. As part of this revision, authorities established regulations on the provision of guard rails, toe boards, mesh sheets, and other components in appropriate positions on scaffolds. When scaffolds are set in construction sites, their strength against wind force needs to be calculated. Japanese design guidelines regulate the strength of scaffolds against wind force; however, the design guidelines were written with old-style scaffolds in mind. It is not known whether the design guidelines are appropriate for new-style scaffolds. At the construction sites, the scaffolds connect to structures through the use of wall connecter, to keep scaffolds from falling down. The wind load that acts on the scaffolds was supported by the wall connecter at the construction sites. On the other hand, in conventional designs, a baseboard is used on construction sites. In this study, to set scaffolds at construction sites while using baseboard height as a parameter, we performed a wind tunnel test to examine the wind load that acts on scaffolds that have been set with wall connecters. 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. The load sell to set the wall connecter was used to measure wind load. The models, each of which was 1/10 in size, were used on scaffolds at general construction sites. The scaffolds were three stories high and one span wide. A baseboard was situated on one side of the long face of the scaffolds. The wind speed was set at a uniform flow of 10 m/s, because the wind force coefficient of a cylinder is stable at this speed. The characteristic length was positioned 5 mm along the diameter of a leg member. The Reynolds number was approximately 3.5×103. From our results, the wind force coefficient was found to increase as the baseboard height increased. With regard to efficient scaffold design, calculations of the wind force coefficient should therefore consider baseboard height.

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

1 INTRODUCTION

The Japanese Industrial Safety and Health Law were revised in March 2009 to introduce new preventive measures with regard to accidental falls in the construction industry (Japan Construction Occupational Safety and Health Association 2009). As part of this revision, the authorities have established regulations regarding the provision of guard rails, toe boards, mesh sheets, and other components in appropriate positions on scaffolds. Additionally, the installation of leading handrails requires that handrails be erected before construction work commences, to protect against falls (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 designs for scaffolds, and Figure 2 shows an example of modern scaffolds used at construction sites.



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

Figure 1. Examples of modern scaffolds.

Figure 2. Modern scaffolds used at construction sites.

When scaffolds are set at construction sites, their strength against wind force needs to be calculated (Scaffolding and Construction Equipment Association of Japan 2004). Japanese design guidelines regulate the strength of scaffolds against wind force; however, those design guidelines were written with old-style scaffolds in mind. It is not known whether the design guidelines are appropriate for new-style scaffolds. Additionally, at construction sites, scaffolds connect to the structure through the use of some kind of wall connecter, to keep the scaffolds themselves from falling down. The wind load that acts on the scaffolds is supported by the wall connecter at the construction site; on the other hand, in conventional designs, baseboards are used at construction sites.

In this study – with reference to the method by which scaffolds are set at construction sites with the baseboard height as a parameter – we performed a wind tunnel test to examine the wind load that acts on scaffolds that are set with some kind of wall connecter.

2 OVERVIEW OF WIND TUNNEL TEST

2.1 Wind Tunnel Device and Model

The total length of the wind tunnel device is 74,900 mm, while the device interior is 2,300 mm wide and 2,000 mm high. The test setup is shown in Figure 3.

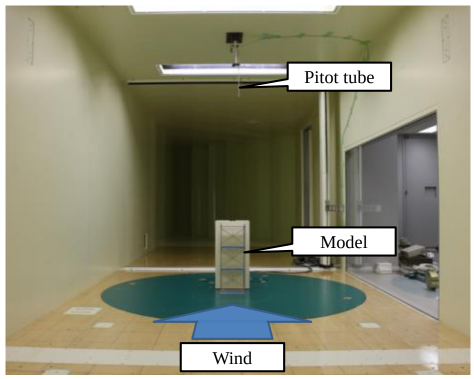
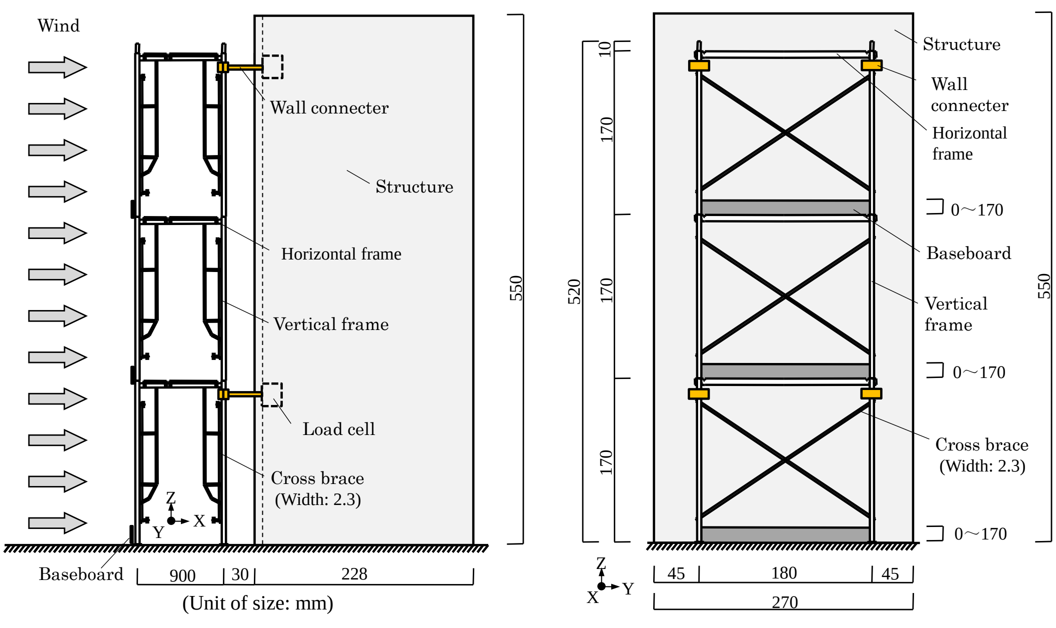


Figure 3. Wind tunnel test.



(a) X–Z face (b) Y–Z face

Figure 4. The scaffolds and the structure used for the wind tunnel test.

The model reflects scaffolds used at general construction sites, and it is 1/10 in size. The scaffolds are three stories high and one span wide. The scaffolds and the structure used for the wind tunnel test are shown in Figure 4. The vertical frame direction of the scaffolds is denoted by X, while the cross-brace direction of the scaffolds is represented by Y; the height of the scaffolds is Z. The scaffold model was put into the wind tunnel, and the structure was placed near the scaffold model. The scaffolds were separated from the floor, and the structure was connected to the floor. Wall connecters were set at four places on the scaffolds. Some load cells were set to the structure, and the wall connecters were connected to the load sells. The load sells were used to measure wind force. A baseboard was situated on one side of the Y–Z face of the scaffolds.

2.2 Projected Area and Reynolds Number

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

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

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

where τ is the ratio of the 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 of the scaffolds, A_b is the projected area of the scaffolds with a baseboard, and A_0 is the projected area of the scaffolds with a 170 mm baseboard.

Figure 5 shows the relationship between the ratio of the projected area of scaffolds and the ratio of baseboard height. The ratio of the projected area of the scaffolds η was found to increase as τ increased.

The pitot tube was positioned 550 mm from the ceiling of the wind tunnel, and thereafter, the wind speed was measured. The wind speed was set at a uniform flow of 10 m/s. The characteristic length D 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:

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

where U is the wind speed (in m/s), D is 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 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.

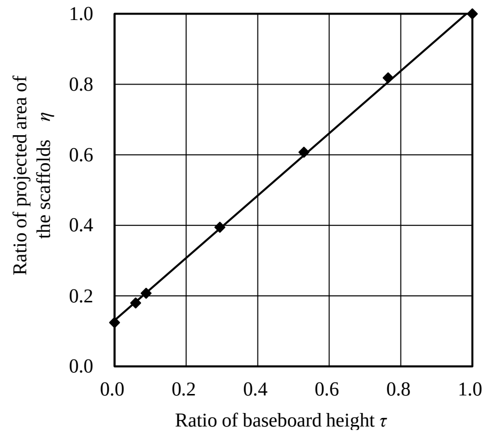


Figure 5. The relationship between the ratio of the projected area of the scaffolds and the ratio of baseboard height.

3 RESULTS AND DISCUSSION

Figure 6 shows the wind tunnel test results. The vertical axis in this figure pertains to the wind force coefficient of the scaffolds C, while the horizontal axis pertains to the ratio of baseboard height τ. 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 on the scaffolds, q_F is 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 directions of the scaffolds).

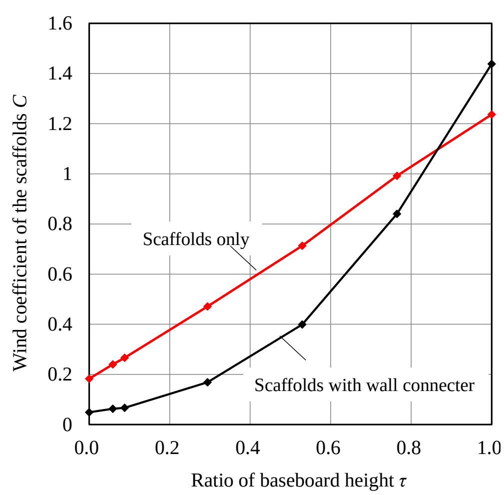


Figure 6. Relationship between the wind force coefficient and the ratio of baseboard height.

Only in the scaffolds was the relationship between C and τ proportional (Takahashi *et al.* 2013). However, in scaffolds with a wall connecter, the relationship between C andτ became steep as τ increased. Negative pressure acted on the scaffolds as a consequence of the structure downwind. We think that this has an influence on the distance between the scaffolds and the structure, and so we need to examine this distance. Whenever the scaffolds were set near the structure, we needed to revise the wind force coefficient of the scaffolds. We need to examine ways of making revisions while bearing in mind the wind force coefficient of scaffolds.

4 CONCLUSION

The wind force acting on scaffolds that feature a wall connecter equipped with baseboards was investigated, through the use of wind tunnel testing.

The relationship between the wind force coefficient and the baseboard height, when plotted, became steep as the baseboard height increased. The wind force coefficient differed only with respect to the scaffolds: when the scaffolds were set near a downwind structure, we needed to revise their wind force coefficient. Our future work will examine ways of making revisions while keeping in mind the wind force coefficient of scaffolds.

Acknowledgments

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