Computer simulation-based analysis of wind load effect on structural capacity of skywalk between Hyatt Regency hotel and multipurpose building complex Iset Tower in Ekaterinburg

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Abstract. This article contains a computer-aided analysis of bearing capacity under wind load for a standard attachment fixture which one is most frequently used for mounting transparent structures. The analysis results of peak positive and negative wind loads acting on the enveloping structure are presented. The stress-strain state of the skywalk facade fixture unit in the elastic strain stage is analyzed. Maximal values of force influence on the plastic deformation of the fixture unit components arise. They are determined on the basis of a nonlinear analysis. The object of the research is a skywalk between the Hyatt Regency hotel building and the Iset Tower high-rise building in Ekaterinburg that is being designed currently. Simulation models and computational experiments were made in ANSYS CFX software complex.

1. Introduction
Translucent structures are often used as main enveloping structures of modern buildings. One of the main concerns while designing such structures is the calculation of maximum external forces affecting the attachment points. It is also necessary to pay special attention to the wind load pressure calculation on the transparent structure. This article contains a computer-aided analysis of bearing capacity under wind load for a standard attachment fixture which one is the most frequently used for mounting transparent structures. The object of the research is a skywalk between the Hyatt Regency hotel building and the Iset Tower high-rise building in Ekaterinburg that is being designed currently (Figure 1).

Simulation models and computational experiments were made in ANSYS CFX software complex. At the first stage, peak positive and negative wind loads acting on the envelope structure were calculated. The second stage of analysis includes a stress-strain state calculation of the skywalk facade attachment fixture at the elastic strain stage.

2. Stage 1 of wind load analysis
The analysis of wind loads on the skywalk structures was conducted taking into account the results of wind speeds calculations and wind loads previously made for the Iset Tower building [1,14]. The analysis was performed in ANSYS CFX software package installed on an HP workstation with four 1.86 Hz CPUs. The domain included the Hyatt Regency building, Iset Tower building, and the
skywalk itself. The Figure 2 shows the building models and their spatial orientation. The Figure 3 shows a separate computer model of the skywalk surfaces.

Figure 1. Project of a skywalk between the Hyatt Regency hotel building and the Iset Tower, Ekaterinburg.

Figure 2. Model of buildings and skywalk. Domain size: Z – 4150 m, Y – 2130 m, and X- 1200 m.

Figure 3. Computer model of skywalk surfaces. Buildings are not shown for convenience. The Hyatt Regency building is located on the left, and Iset Tower is located on the right.

The analysis was performed using finite volume method, high-order numerical schemes for convective and shear members, and the SST turbulence model (Shear-Stress-Transport) k-ω [3,4,15] that made it possible to simulate separation-free flows as well as flows with developed turbulent separations.
The following types of boundary conditions were used on the computational domain boundaries: "Inlet" (wind flow can only enter the domain), "Opening" (flow at the boundary may be directed inside or outside the domain), and "Wall" (at the surface of the building and the ground).

Wind loads acting on the facade surfaces of the buildings were determined for six possible wind directions. The Table 1 shows maximum head and separation pressures on transition surfaces.

**Table 1.** Head and separation pressures for different wind directions.

| Direction | Separation | Pressure |
|-----------|------------|----------|
| NE        | -239.5     | +10.4    |
| N         | -76.2      | +10.8    |
| E         | -88.1      | +10.8    |
| S         | -147.5     | +14.53   |
| SW        | -149.5     | +5.4     |
| W         | -168.8     | +17.2    |

The analysis showed that the most adverse direction is the North-East, while the wind blows from Iset River. The Figure 4 shows the distribution of separation and head pressures for NE (North-East) wind direction.

**Figure 4.** NE direction. Max. Separation pressure: -233 kg/m², head pressure: + 10.4 kg/m². The model is turned-over for convenience.

The pressure distribution pattern shows that the maximum separation pressure occurs on the lower surface of the skywalk, above the parking lot near Iset Tower (Figure 5).

In the result of the analysis it was recommended to adopt the following design values for the separation and head pressure on the enveloping transparent structures of the skywalk: separation pressure of 239.5 kg/m² and head pressure in accordance with data obtained [2,10,13].
Figure 5. The max. separation pressure occurs on the lower surface of the skywalk.

3. Stage 2 of wind load analysis
The attachment fixture is an element made of metal plates bolted together. The 3D model of the fixture was prepared in compliance with its geometry parameters. Since the fixture is axially symmetrical, the model is implemented in the half form of the fixture, and the second half is set up using the symmetry function [6-8] (Figure 6).

Figure 6. Finite element model of the fixture unit.

Finite element mesh consists mainly of hexahedrons providing for the best quality and stability of the structure. The whole unit was built using 3D 20-node finite elements SOLID186 [3]. More complicated geometry areas have smaller mesh spacing. Mesh spacing is within the range of 1 to 8 mm [9] (Figure 7). Frictional contact conditions are set for the contact points between parts of the fixture (Figure 8). Metal friction factor without lubrication was taken as 0.175 [5].
Figure 7. Finite element mesh in the bolt location.

Figure 8. Contact area between the parts 1 and 2.

Loading was applied in steps in the structure displacement form (Figure 9). The force was calculated as reaction displacements. The nonlinear analysis of the fixture unit showed that the elastic behavior of the unit occurs under the load up to 1023 kgf. Part 4 (M20 bolt), under the load equal or higher than 1023 kgf starts to deform plastically (Figure 10).

Figure 9. Load- displacement diagram.

Figure 10. Equivalent plastic strains in the part 4.

Starting from 1275 kgf load, plastic strains appear in the contact points of the parts 1 and 2 due to friction (Figure 11). Starting from the load of 2978 kgf, plastic strains appear in the part 1 [11-13] (Figure 12).

Figure 11. Equivalent plastic strains in the contact area between the parts 1 and 2.
4. Conclusion
The values of wind load on the facade surfaces of the skywalk for six possible wind directions were analyzed in this work. The analysis performed at the first stage showed that the most dangerous wind direction is the North-East one while the wind blows from Iset River. The values of design separation pressure and the head pressure acting on external enveloping structures were also determined. At the second stage of analysis, the limit bearing capacity of the fixtures of transparent enveloping structures was determined. The elastic behavior of the fixture unit occurs under the load up to 1023 kgf, as it follows from the analysis. Plastic strain appears in the fixture unit when the load exceeds 1023 kgf. Basing on the abovementioned findings it may be concluded that service loads of the structure are within the bearing capacity of the examined fixture unit.

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Figure 12. Equivalent plastic strains in the part 1.