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Effect of Multi-directional Wind Force on Wind-induced responses of Base Isolation Layers of the 3D Models

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KEYWORD
Residual deformation, Base isolation layer, 3D model, MSS model, Multi-directional wind force, Torsion

1. Introduction

In recent years, the number of base-isolated tall buildings has been increasing[1]. However, the wind force on a building increases with the increasing height of the building. And residual deformation of steel dampers in the base isolation layer is easy to occur after a strong wind. Residual deformation may cause dysfunction of seismic isolation devices and affect isolation performance. So, it is necessary to estimate the residual deformation of base isolation layers.

Qian et al.[2] considered long-term wind force with wind speed and direction changes to analyze the residual deformation, but they still used MDOF models with one-directional wind. However, for closer to reality, not only the building suffers from wind forces of multiple directions (along-wind, across-wind and torsion), but also the residual deformation might be different at different positions on the same story.

Thus, this paper compares the maximum displacement and residual deformation of different nodes in the base isolation layer of a 3D model under wind forces from multiple directions.

2. Outline of the analytic model

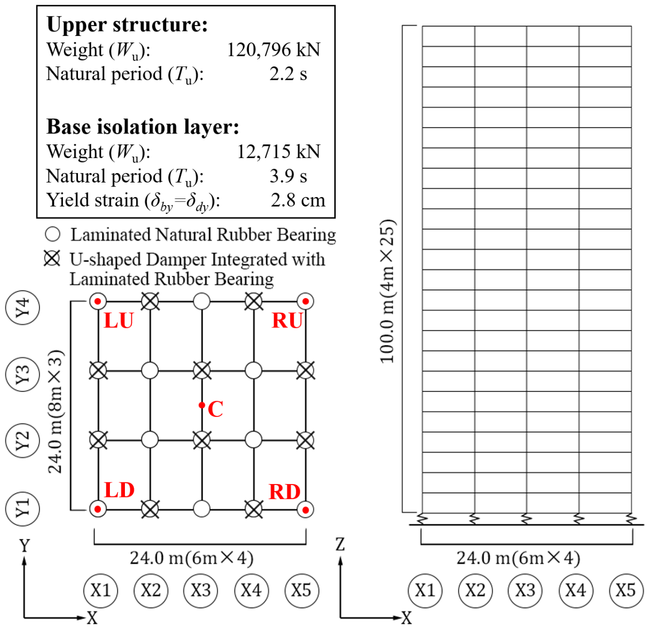

Fig.1 Analytic model

The structural parameters of the analytic model and the layout of seismic isolation devices are shown in Fig.1. It is an 3D model consisting of a 25-story upper structure and a base isolation layer. SM490 steel is used for the upper structure. The upper structure is assumed to be an elastic structure whose damping ratio (initial stiffness-proportional) ξ_u = 2%. The base isolation layer includes 20 laminated natural rubber bearings, 10 of which are incorporating U-shaped dampers. The yield shear force coefficient of damper α_{dy} = 3.5%. The seismic isolation devices are modeled as MSS model.

In order to investigate the response of the base isolation layer, this paper selects 5 representative nodes which are the node at the center (C) and the nodes at the four corners (LU, RU, LD, RD) shown in Fig.1.

3. Outline of the wind force

The 9-hour wind force with changes in wind speed and direction is used in this paper. As shown in Fig.2, the average wind speed at the top of the building varies at intervals of 10 minutes[3], and the maximum is 50.41 m/s (basic wind force of 10 m/s, height of 100 m, roughness III and return period of 500 years). The wind direction is obtained from the typhoon simulation[4], and the wind direction is fixed at 0 when the wind speed reaches its maximum. Wind direction 0° is along axis x in Fig.1. The wind force is made for 5 waves respectively in 3 directions.

According to the input wind direction x, y, θ (around z-axis) and the response direction X, Y, the results are analyzed by 6 cases: x(X), xy(X), xyz(X) , y(Y), xy(Y), and xyz(Y).

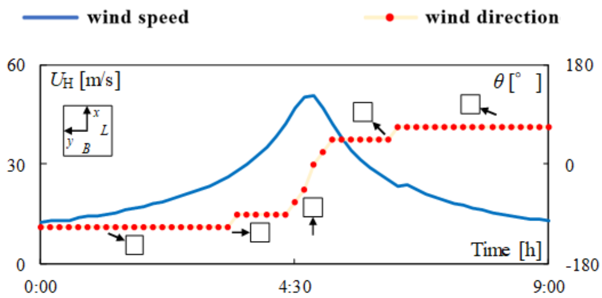

Fig.2 Wind speed and direction

4. Comparison of wind-induced response

Fig.3 shows the maximum displacement δ_{max} of the base isolation layer(ensemble average) considering different cases and nodes. The maximum displacement in x-direction (blue) is larger than that in y-direction (red). This is because the wind force in x direction has the average component. In addition, the maximum displacement of 3-directional wind ■/■ at different nodes is close to 2-directional wind ▲/▲, indicating that the wind-induced torsion has little effect on the maximum displacement.

However, it can be found that the maximum displacement in x-direction input wind force x(X) ● is obviously smaller than that of multi-directional input wind force xy(X) ▲, xyz(X) ■. Maybe the coupling effect of the wind forces in 2 directions causing a larger response. In other words, compared to the maximum displacement of one-direction wind input, multi-direction is unsafe. Therefore, it is necessary to consider multi-direction wind input.

Fig.4 shows the residual deformation δ_r of 5 waves (ensemble average) considering different cases and nodes. Because the wind force in x-direction has mean component, the residual deformation in x-direction (blue) is larger than that in y-direction (red). Thus, this paper only discusses the residual deformation in the x direction.

The residual deformation in the case of wind in one direction x(X) ● is smaller than that in the case of wind in 2 directions xy(X) ▲. This is because the MSS model used in this analysis that the wind forces in two directions produce a coupling effect. In other words, compared to the residual deformation of one directional wind input, multi-directional wind is unsafe. Therefore, it is necessary to consider multi-directional wind input.

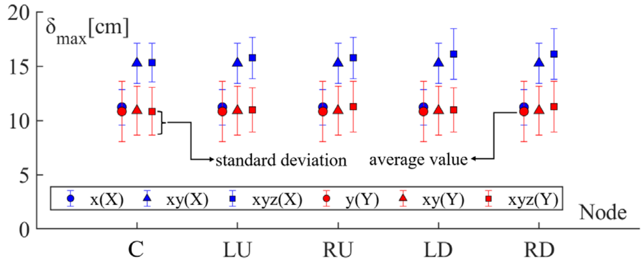

Fig.3 Comparison of maximum displacement

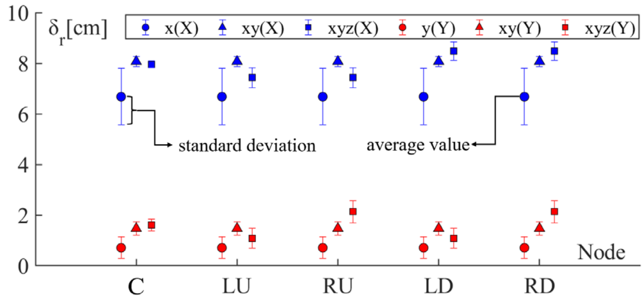

Fig.4 Comparison of residual deformation

The residual deformation in the case of wind in 2 directions without torsion xy(X) ▲ is close to that in the case of wind in 3 directions xyz(X) ■. It indicates that torsion has little effect on residual deformation.

There are different residual deformations at different nodes when the input wind force is in 3 directions xyz(X) ■. With the location of central node C as the origin, the residual deformation of node LU&RU in +y direction is smaller than that of node C, and the residual deformation of node LD&RD in -y direction is larger than that of node C. In other words, due to the influence of torsion, the residual deformation at different positions of base isolation layer is not the same. It has possibility to be larger than the center.

5. Conclusion

This paper compares the maximum displacement and residual deformation of different nodes of the base isolation layer of a 3D model (B/D = 1, Aspect ratio = 4.2) under long-term wind input in 1~3 directions. The conclusions are drawn as follows:

1) Compared with the maximum displacement and residual deformation in base isolation layer of one-directional wind force, the coupling effect of multi-directional wind force will lead to larger response. For the sake of safety, it is necessary to consider the input of multi-directional wind force when estimating residual deformation.

2) The wind-induced torsion has little effect on residual deformation of the base isolation layer. However, under the influence of torsion, the residual deformation at different positions of the base isolation layer will be different, and may be larger than that at the center. Thus, for safety, it is necessary to use a 3D model and consider the position affected by the torsion.

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