The 2020 World Congress on
Advances in Civil, Environmental, & Materials Research (ACEM20)
25-28, August, 2020, GECE, Seoul, Korea

Performance-based wind design of shear wall building by nonlinear time history analysis

*Seung Yong Jeong[1)] and Thomas Kang[2)]

[1), 2)] *Department of Architecture & Architectural Engineering, Seoul National University, Seoul, Korea*
[2)] *tkang@snu.ac.kr*

ABSTRACT

Recently, researches on performance-based wind design (PBWD) have been carried out, but studies on practical applications are still deficient. In this study, PBWD of a residential building with reinforced concrete shear walls is carried out. The resonant component of the design wind load for initial elastic design is reduced to half to introduce inelastic behavior. Time history wind loads are generated from power spectral density functions. Nonlinear time history analysis is carried out to evaluate the wind-resistant performance of the building. Shear walls remained elastic and coupling beams showed minor inelastic damage under time history wind loads.

1. INTRODUCTION

Inelastic behavior is assumed in most of the seismic design, while the elastic design is the main principle of wind design in the current codes. There are many well-developed guidelines for an application of performance-based seismic design (PBSD) using nonlinear analysis. Unlike PBSD, a new guideline for performance-based wind design (PBWD) that allows inelastic behavior in wind-resistant design has been published recently (ASCE, 2019). In the guideline, performance objectives and acceptance criteria are proposed, but no specific applications are presented. Most of the researches on PBWD rely on wind tunnel tests to obtain time history wind loads, but a wind tunnel test is inappropriate for preliminary PBWD practice due to frequent design changes and their cost. Thus, in this study, time history wind loads are generated from given power spectral density (PSD) functions, and performance evaluation of a case study building by nonlinear time history analysis is carried out.

[1)] Graduate Student
[2)] Professor

2. CASE STUDY BUILDING

A residential building with ordinary reinforced concrete shear walls shown in Fig. 1 is selected for a case study building. The building has 30 stories with each story height of 3 m. Concrete strength of 40 MPa and reinforcing bar yield strength of 400 MPa are used. The initial elastic design by KBC 2016 (2016) is conducted. The resonant component of wind loads is reduced to half to introduce inelastic behavior (El Damatty and Elezaby, 2018).

For a nonlinear model, expected strengths by AIK (2019) are used. Fiber elements and plastic hinges are employed for the inelastic modeling of shear walls and coupling beams, respectively. Unlike the performance-based seismic design (PBSD), minor or no inelastic behavior of coupling beams is expected for the PBWD. Hysteresis models of coupling beams used for the analysis are shown in Fig. 2. A shear hinge at the center of beams is used for coupling beams with a span-to-depth ratio *l*/*d* less than 2, and moment hinges at each end of beams are applied to coupling beams with *l*/*d* larger than 2, where *l* and *d* are the length and effective depth of a coupling beam, respectively.

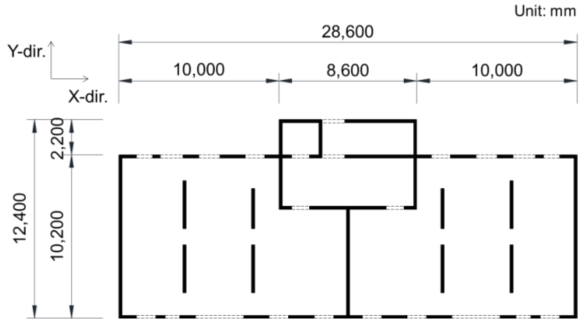
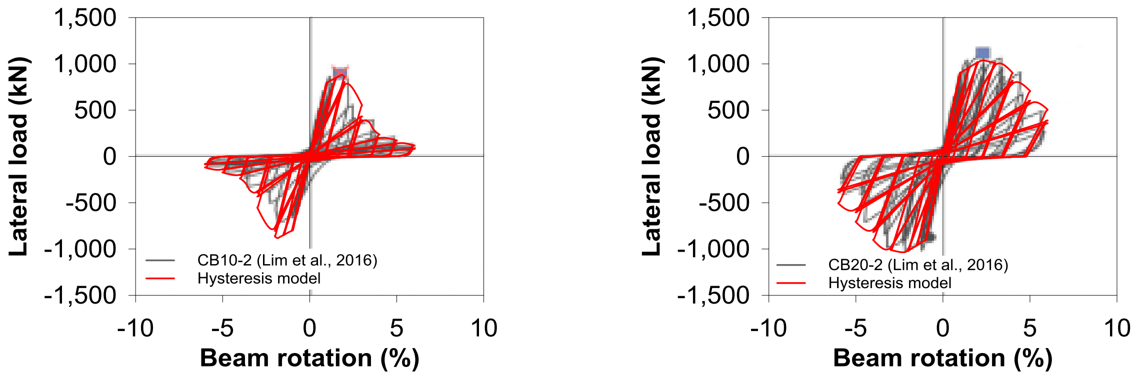


Fig.1 Structural plan of the case study building



(a) Shear hinge for *l*/*d* ≤ 2 (b) Moment hinge for *l*/*d* > 2

Fig.2 Hysteresis modeling of coupling beams

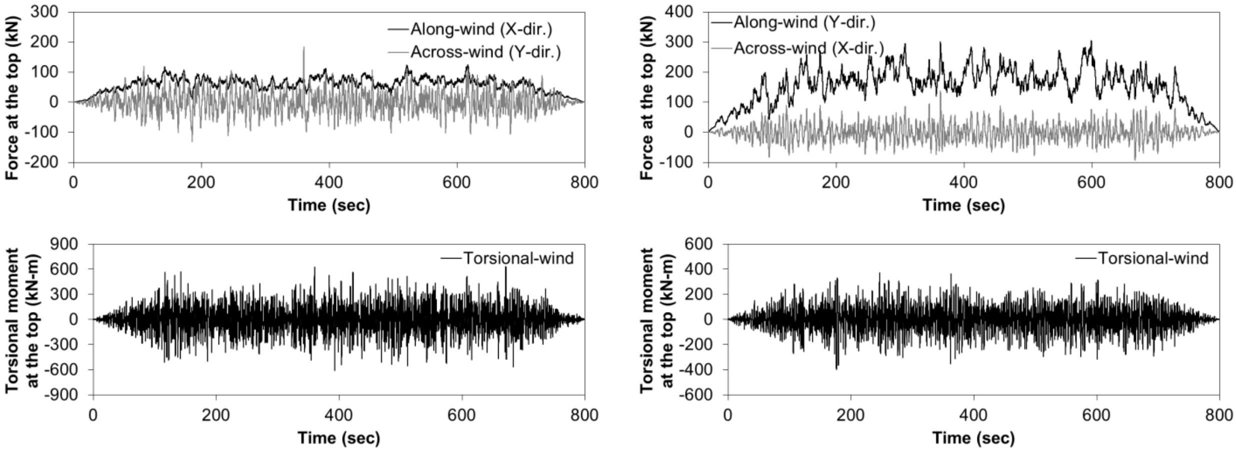
3. GENERATION OF TIME HISTORY WIND LOADS

Hwang et al. (2015) suggested a generation of time history wind load from power spectral density (PSD) function as the following equation.

$$X(t)=\sum_{i=1}^{n}\sqrt{2S(f_i)\Delta f}\cos(2\pi f_i t+\theta_i) \quad (1)$$

where $S(f)$ is one-sided PSD, Δf is the interval of frequency, and θ is randomly generated phase angle.

The PSDs for along-, across-, and torsional-wind loads are determined by KBC 2016. The PSD of along-wind is based on the PSD of wind speed and aerodynamic admittance function. The PSDs of across- and torsional-wind loads are forms of base overturning moment and base torsional moment, respectively. The generated time history wind loads at the top are shown in Fig. 3.



(a) X-dir. along-wind (b) Y-dir. along-wind

Fig. 3 Time history wind loads generated from PSD functions

4. ANAYSIS RESULTS AND CONCLUSION

Fast nonlinear analysis (FNA) (Wilson, 2002) is conducted for the two load cases. All shear walls remained elastic. As shown in Fig. 4, coupling beams showed minor inelastic behavior which is much less than the acceptance criteria for PBSD. Low-cycle fatigue failure and ratcheting are not expected due to limited inelastic behavior. The maximum displacements at the top are 57.4 mm for X-dir. and 89.9 mm for Y-dir., which are less than the drift limit of *H*/300 (= 300 mm) in ASCE (2019). Despite the reduction of resonant components of the design wind loads, the inelastic behavior is negligible, because the current elastic design code has inherent large redundancies by strength reduction factors, minimum requirement of reinforcing bars, expected strengths of materials, etc.

By applying the design approach of reducing the resonant components of wind loads, design forces and quantities of reinforcing bars and other materials can be effectively reduced without sacrificing structural performance. A preliminary PBWD or post-wind tunnel test adjustment of the design can be carried out using time history wind loads generated from the code-specified or known (or similarly known) PSD functions. If the code-specified or similarly known PSD functions are used, performance verification by wind tunnel test results may be needed at the final stage of PBWD.

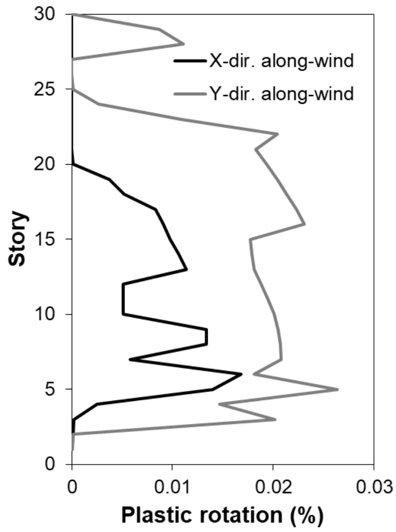


Fig. 4 Plastic rotation of coupling beams

ACKNOWLEDGMENTS

This work was supported by the Korea Agency for Infrastructure Technology Advancement (KAIA) grant funded by the Ministry of Land, Infrastructure and Transport (Grant No. 20CTAP-C151831-02).

REFERENCES

AIK (2019), *Guidelines for performance-based seismic design of residential buildings*, Architectural Institute of Korea. (in Korean)

ASCE (2019), *Prestandard for performance-based wind design*, American Society of Civil Engineers, Reston, VA.

El Damatty, A. A., and Elezaby, F. Y. (2018), "The integration of wind and structural engineering," Proceedings, *The 2018 World Congress on Advances in Civil, Environmental, & Materials Research (ACEM18)*, Songdo, Korea, 27-31.

Hwang, J. S., Lee, S. H., and Ha, Y. C. (2015), "Time history analysis of building structure using load generation of design wind load spectrum," *Journal of the Wind Engineering Institute of Korea*, **19**(2), 43-49. (in Korean)

Lim, E., Hwang, S.-J., Wang, T.-W., and Chang, Y.-H. (2016), “An investigation on the seismic behavior of deep reinforced concrete coupling beam,” *ACI Structural Journal*, **113**(2), 217-226.

Ministry of Land, Infrastructure and Transport (Korea), Korean building code (KBC 2016), 2016. (in Korean)

Wilson, E. L. (2002), *Three-dimensional static and dynamic analysis of structures*, Computers and Structures, Inc., Berkeley, CA.