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Wind resistance performance of tall RC buildings with corner modification

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ABSTRACT

In this study, performance-based wind design on building frame system tall RC buildings with three types of corner shapes (square, chamfer, and recession) was conducted by nonlinear time history analysis. A wind load reduction factor, which is a similar concept to the R factor in seismic design, was applied, considering the nonlinear behavior of non-gravity load resisting structural members such as coupling beams. The applied wind load factor (R_{WR}) was 1 and 2. For performance-based wind design, two types of time history wind loads, which were acquired from wind tunnel tests and generated based on power spectral density (PSD), were used. High-frequency force balance (HFFB) tests were conducted to obtain the former (measured time histories). For the latter, PSDs of along, across, and torsional-wind loads were taken from the current design code of Korea of KDS. The two types of time history wind loads and corresponding nonlinear time history analysis results were thoroughly compared and discussed.

1. INTRODUCTION

The current national and international design codes, such as KDS, ASCE, and ISO, are based on elastic design process against wind load. While seismic design is typically based on nonlinear response, where structural members are expected to yield under design seismic load, elastic wind design often contradicts the philosophy of seismic design. In case where coupling beams of reinforced concrete (RC) tall buildings that are not supposed to yield under extreme seismic loads as a result of elastic wind design, unexpected damage of nearby vertical members or connections would occur instead and become brittle eventually. Kang et al. (2019) reported that the magnitude of design wind load often becomes larger than that of design seismic load (i.e., load reduced by response modification factor, R) if an RC structure is built with more than 30 stories in Korea. To resolve such conflicts, performance-based wind design, which partially allows

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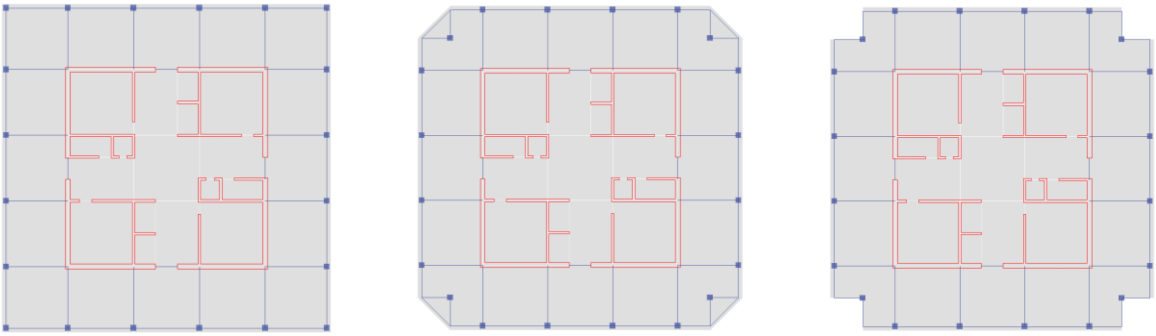
nonlinear behavior in wind design, has recently been studied, and related guidelines and codes are also being developed worldwide. Therefore, in this study, a tall RC building was designed using the wind load reduction factor, R_{WR}, and nonlinear time history analysis was conducted using two kinds of time history wind loads. Analysis results according to the corner shape were also compared.

2. NUMERICAL MODEL

In this study, three types of plan shapes were adopted for numerical analysis as shown in Fig. 1. The height of building was fixed as 160 m, and the floor height was 4 m so that a total number of story was set to be 40 stories. The structural system was designed as dual systems with intermediate moment frame and ordinary RC shear wall and the compressive strength of concrete was assumed to be 40 MPa for whole members. For seismic design, the effective ground acceleration and site classification were assumed to be 0.22g and S_4, respectively. And the basic wind speed and roughness category for wind design were assumed to be 38 m/s and C, respectively.



(a) Square (b) Chamfered (c) Recession

Fig. 1 Architectural plan of numerical analysis model

3. NUMERICAL ANALYSIS RESULTS

A series of pushover analyses were performed to compare the ductility of the structural system according to R_W factor. The performance curve of structure according to R_{WR} factor equals to 1 and 2 are depicted in Fig. 2, and each performance objective is also shown. As a result, the ductility of structural system with R_{WR} =2 was determined as 8.51, which was larger than that (5.14) of R_{WR} = 2. The overstrength factor (Ω) was also compared, and the overstrength factor of system with R_{WR} = 2 was determined as 4.61, which was also larger than that (2.63) of R_{WR} =1. Here, the ductility was calculated as ratio of displacement at collapse ($\delta_{collapse}$) to displacement at yield (δ_{yield}), and the overstrength factor was calculated as ratio of maximum base shear (V_{max}) to base shear at yield point (V_{yield}). However, the current Korean design code, KDS 41:2019, specifies that the overstrength factor and ductility for dual systems with intermediate moment frame (Ordinary RC shear wall) are 2.5 and 5.5, respectively, and in case of R_W = 1, the ductility is lower than the value presented in KDS 41:2019.

Next, a nonlinear time history analysis was performed, and the maximum plastic rotation of the coupling beam and moment frame of each story is shown in Fig. 3. The maximum plastic rotation of each story of coupling beam was slightly increased with R_{WR} = 2 compared to R_{WR} = 1, and on the contrary, that of the moment frame was slightly decreased. However, in both R_{WR} = 1 and 2, the maximum plastic rotation was significantly small, and most of the coupling beams and moment frames were in an elastic state. Therefore, even the wind design with R_{WR} factor of 2 was applied, horizontal members such as coupling beam were found to have sufficient strength margin. In addition, all of the vertical members remained in an elastic state.

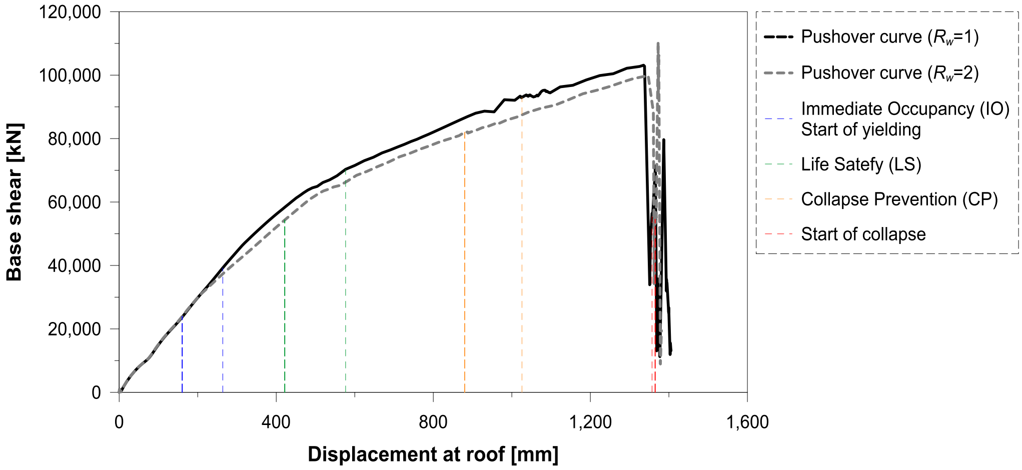
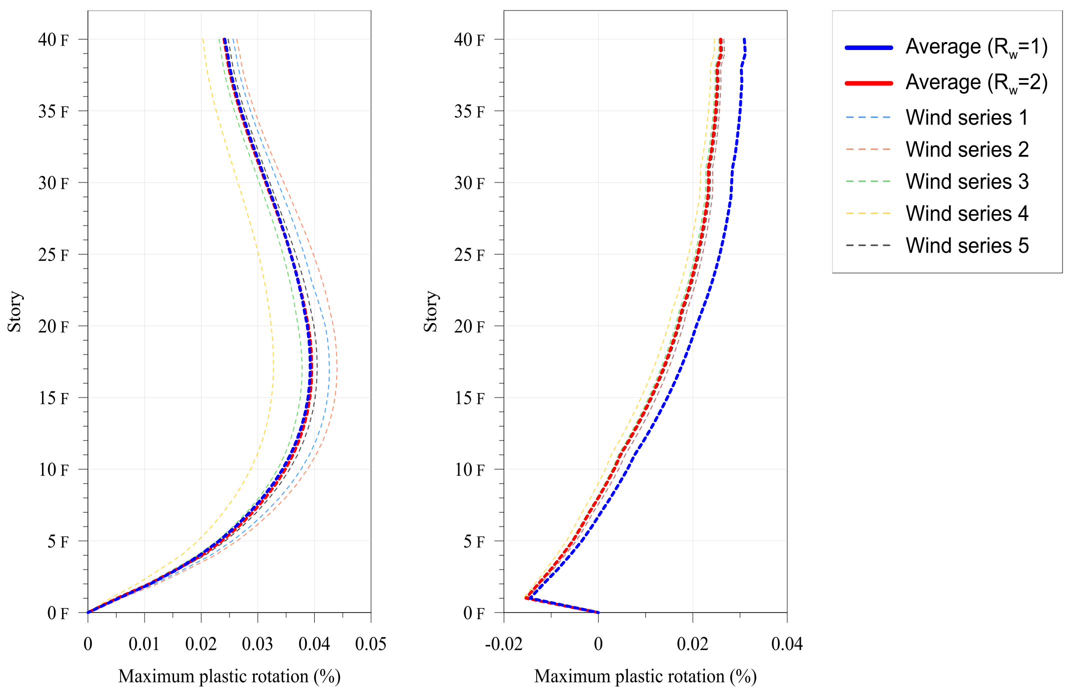


Fig. 2 Pushover performance curve



(a) Coupling beam (b) Moment frame

Fig. 3 Maximum plastic rotation

4. CONCLUSION

In this study, wind design was performed by applying the wind load reduction factor, R_{WR}, and nonlinear time history analysis was performed using time history wind load. In addition, pushover analysis was performed to compare the system ductility according to the R_{WR} factor. As a result, the ductility was improved when R_{WR} = 2 was applied compared to that of R_{WR} = 1. And as a result of nonlinear time history analysis, the maximum plastic rotation of the coupling beam was slightly increased with R_{WR} = 2 than that of R_{WR} = 1, but most of the members still remained in an elastic state. Based on this result, it is considered that the current philosophy of wind design has general conservatism in terms of the strength of coupling beams and structural systems, and the application of wind load reduction factor, R_{WR}, for nonlinear wind design can be introduced.

ACKNOWLEDGEMENTS

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