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論 文 要 旨

THESIS SUMMARY

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要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）

The outrigger system has been an effective solution in mitigating seismic response in the core-tube type tall buildings. It increases the overall building lateral stiffness by mobilizing the perimeter columns' axial stiffness. However, the elastic design concept of the conventional outrigger usually results in large force demands on the outrigger members, increasing both complexity and costs in engineering practices. The concept of damped-outrigger was proposed to increase the damping, instead of increasing the stiffness, by incorporating energy dissipation devices such as viscous dampers. This research studies the seismic behavior of structures with damped-outrigger incorporating buckling-restrained brace (BRB) as energy dissipation device (BRB-outrigger). When viscous dampers are adopted in damped-outrigger system in order to control responses induced from wind and seismic loads, the design requirements and velocity ranges corresponding to these two demands are usually different. The wide axial force capacity range and feasible stiffness of BRB allows the BRB-outrigger system to be an alternative in resisting seismic loads. A properly designed BRB-outrigger can function as a conventional outrigger through the BRB's high elastic stiffness during frequent small earthquakes, and it can dissipate energy during moderate to maximum considered earthquake through the BRB's stable hysteretic behavior. The outrigger elevations and the relationships between the axial stiffness of the BRB, the perimeter column, and the flexural stiffness of the outrigger truss are in close relation with the seismic performance. The main objectives of this research are to investigate the seismic performance of structure incorporating single or double layers of BRB-outrigger, and to propose optimal design method in order to minimize seismic response by performing a series of parametric study.

The analytical model used in this research is simplified from a real core-tube type building and contains only the core structure, the BRB, the perimeter columns, and the outrigger truss. The analytical models have heights of 64 m, 128 m, 256 m, and 384 m. Two types of dimensionless parameters are developed. The first type of parameter is the outrigger effect factor, which indicates the magnitude of outrigger effect. The shorter outrigger truss span and the stiffer perimeter column axial stiffness enhance the outrigger effect. The second type is the BRB stiffness parameter, which indicates the relationships between the axial stiffness of the BRB, perimeter column, and the flexural stiffness of the outrigger truss. By using the proposed dimensionless parameters, the analytical model can be constructed. In addition, the BRB yield deformation is crucial as it determines when the BRB starts dissipating energy. Too large or too small BRB yield deformation could cause low energy dissipation efficiency or early fracture of the BRB during the earthquakes. A method to determine a proper BRB yield deformation is proposed.

The spectral analysis (SA) is used to evaluate seismic response in the parametric study. The equivalent damping ratio to incorporate the effect of BRB's yielding and energy dissipation mechanism is included. The base shear and roof displacement relationship of each mode is obtained by applying modal pushover analysis, as the BRBs in different outrigger levels may not yield simultaneously. The responses of the first four modes are calculated separately, and then combined together by using square root of the sum of the squares method. The smoothened design spectrum is used as seismic input in SA. The SA results are validated by performing nonlinear response history analysis (NLRHA). Both SA and NLRHA results show similar responses and trends.

The maximum roof drift, the maximum inter-story drift, the maximum overturning moment at core structure base, and the maximum perimeter column axial force are utilized as indicators to indicate the seismic performance. Based on the analysis results, the optimal outrigger elevation in order to minimize seismic response in a single BRB-outrigger system is 70% to 80% of the building height. In a double BRB-outrigger system, the optimal outrigger elevations are 70% to 80% and 30% to 60% of the building height for the upper and lower BRB-outriggers, respectively. The BRB-outrigger in the structure with greater outrigger effect factor is more efficient to reduce seismic response. In addition, the larger axial stiffness ratio of the BRB to the perimeter column improves the seismic performance in reducing roof and inter-story drift responses. However, the efficiency in seismic reduction becomes lower with the increasing BRB stiffness, and the acceleration responses can be increased. According to the analysis results, a step-by-step design recommendation and design charts are proposed for engineers to design the structure with either single or double layers of BRB-outrigger in the preliminary design stage without the needs of time-consuming iteration tasks. Furthermore, this research introduced three different types of BRB-outrigger configurations in order to meet different architecture requirements and economical solutions.