別紙４－１（課程博士（英文））

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Abstract（Doctor）

Title of Thesis	Development of Displacement-Based Design Method of Coupled Shear Wall Structure with Vibration Control System

Approx. 800 words

The seismic performance of reinforced concrete (RC) coupled shear wall (CSW) systems can be significantly enhanced through the integration of energy dissipation devices, which mitigate structural damage and improve post-earthquake functionality. This research presents a comprehensive investigation into the displacement-based design method (DBDM) for CSW structures equipped with supplemental damping systems, combining analytical, experimental, and numerical approaches to validate and optimize the proposed methodology. The study addresses two primary aspects: (1) the theoretical development and analytical validation of DBDM for damped CSW systems, and (2) the experimental and numerical evaluation of viscoelastic (VE) and rotational friction (RF) dampers to assess their effectiveness in real-world applications.

The DBDM framework simplifies seismic design by converting a complex multi-degree-of-freedom (MDOF) structure into an equivalent single-degree-of-freedom (SDOF) system based on a target displacement. This approach ensures that the structure achieves a predefined performance level under design-level earthquakes. Two types of dampers metallic and viscoelastic are incorporated into the analytical study to evaluate their impact on reducing structural damage and downtime. The DBDM procedure begins with the determination of a target displacement corresponding to a story drift ratio of 1/250, selected due to the inherent stiffness of CSW systems. Nonlinear static pushover analysis is employed to establish the relationship between lateral forces and displacements, ensuring that the structure's response aligns with the desired performance objectives. The effective damping ratio is derived from the energy dissipation capacity of structural members, accounting for both inherent and supplemental damping contributions. The effective period of the structure is then obtained from displacement spectra corresponding to design-level seismic demands. Finally, the required damper capacity is calculated based on the target deformation and effective stiffness, ensuring that the system meets performance targets.

To validate the DBDM, design earthquakes are generated in accordance with the Japanese seismic code (Level 2), incorporating three distinct ground motion records: Kobe, El Centro, and a

random-phase accelerogram. Nonlinear time history analyses are conducted to compare the performance of DBDM-designed structures against conventional force-based approaches. The results for 6-, 12-, and 18-story CSW systems demonstrate that the proposed methodology effectively controls inter-story drifts, reduces base shear demands, and minimizes residual displacements, confirming its superiority in achieving performance-based design objectives.

In parallel with the analytical study, an extensive experimental program is undertaken to evaluate the real-world effectiveness of VE and RF dampers in enhancing the seismic resilience of CSW systems. The experimental investigation consists of two phases: (1) element-level testing to characterize the hysteretic behavior, energy dissipation capacity, and fatigue resistance of VE and RF dampers under cyclic loading, and (2) large-scale shake table testing of a CSW structure equipped with these dampers under various dynamic excitations, including white noise, sinusoidal, and the Kokuji wave. The element tests provide critical insights into the force-displacement relationships and degradation characteristics of the dampers, ensuring their reliability under repeated seismic loading. The shake table tests, conducted on a representative CSW specimen, assess the global system performance, including inter-story drift distribution, acceleration response, and energy dissipation mechanisms.

The experimental results are further validated through high-fidelity numerical simulations using STERA 3D, a nonlinear finite element analysis software capable of capturing the complex dynamic behavior of damped CSW systems. The numerical model incorporates material nonlinearities, damper hysteresis, and soil-structure interaction effects to ensure accurate representation of the experimental setup. Key performance metrics, such as peak inter-story drift ratios, base shear forces, and cumulative energy dissipation, are compared between experimental and numerical results, demonstrating strong correlation and validating the model's predictive capabilities. The findings reveal that VE dampers are particularly effective in controlling high-frequency vibrations, while RF dampers provide stable energy dissipation across a wide range of displacement amplitudes, making them suitable for varying seismic intensities.

The synergy between analytical, experimental, and numerical approaches enables the optimization of damper configurations for performance-based seismic design. The validated numerical model facilitates parametric studies to evaluate the influence of damper placement, stiffness ratios, and damping coefficients on overall system performance. These studies provide practical guidelines for engineers to tailor damping systems to specific structural and seismic demands, ensuring optimal performance under both frequent and rare earthquake scenarios.

This research contributes to the advancement of seismic design methodologies for RC coupled shear wall systems by integrating displacement-based principles with advanced energy dissipation technologies. The DBDM framework offers a rational and efficient alternative to conventional force-based design, ensuring predictable and controllable seismic performance. The experimental and numerical validation of VE and RF dampers underscores their effectiveness in enhancing structural resilience, reducing repair costs, and improving post-earthquake functionality. The combined findings provide a robust foundation for the implementation of damped CSW systems in high-seismic regions, promoting safer and more sustainable building practices.

By bridging the gap between theoretical design and practical implementation, this study offers a holistic approach to performance-based seismic engineering, ensuring that future structures can withstand seismic events with minimal damage and rapid recovery. The insights gained from this research are applicable not only to new construction but also to the retrofit of existing buildings, contributing to the broader goal of enhancing urban seismic resilience worldwide.