# 論文 / 著書情報
# Article / Book Information

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| 題目(和文) | |
| Title(English) | Strain-Based Damage Evaluation of Structural and Non-Structural RC Walls for Performance-Based Seismic Design |
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| 出典(和文) | 学位:博士(学術),<br>学位授与機関:東京科学大学,<br>報告番号:甲第400号,<br>授与年月日:2025年3月26日,<br>学位の種別:課程博士,<br>審査員:河野 進,石原 直,西村 康志郎,吉敷 祥一,佐藤 大樹 |
| Citation(English) | Degree:Doctor (Academic),<br>Conferring organization: Institute of Science Tokyo,<br>Report number:甲第400号,<br>Conferred date:2025/3/26,<br>Degree Type:Course doctor,<br>Examiner:,,,, |
| 学位種別(和文) | 博士論文 |
| Category(English) | Doctoral Thesis |
| 種別(和文) | 論文要旨 |
| Type(English) | Summary |

（博士課程）
Doctoral Program

# 論 文 要 旨

THESIS SUMMARY

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| 系・コース：<br>Department of, Graduate major in | Architecture and Building Engineering, Urban Design and Built Environment | 系<br>コース | 申請学位（専攻分野）：<br>Academic Degree Requested | 博士<br>Doctor of （Philosophy） |
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要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）


Reinforced concrete (RC) walls are essential components of buildings, serving as either lateral load-resisting elements (structural RC walls) or as infills (non-structural RC walls). While traditional seismic design philosophies have largely succeeded in preventing building collapse, damage to both structural and non-structural RC walls remains widespread after earthquakes. Such damage reduces the functionality of buildings, leading to costly repairs and significant socio-economic consequences. Despite their importance, existing methods for evaluating earthquake-induced damage in RC walls remain limited. This research addresses these gaps by developing strain-based damage evaluation methods for both structural and non-structural RC walls, contributing to performance-based seismic design frameworks that aim to limit damage and enhance the post-earthquake functionality of RC buildings.

Numerical simulation plays a crucial role in the damage evaluation of RC walls, enabling efficient predictions of seismic performance without the need for experimental testing. Suitable numerical modeling techniques are selected to simulate the behaviors of structural and non-structural RC walls under lateral loads. These modeling approaches are chosen to meet specific requirements, such as capturing global and local responses, ensuring computational efficiency, maintaining applicability across diverse RC wall designs, etc., making them well-suited for integration into performance-based seismic design workflows.

For structural RC walls, a force-based beam-column element model with a modified Gauss-Radau integration scheme and regularized material models is chosen to simulate the lateral load behavior for its ability to capture axial-flexural interaction and capture responses up to failure. Validation against 27 experimental tests demonstrates its accuracy in predicting both local and global responses, including strength degradation. Strain-based damage evaluation criteria corresponding to the conceptual damage levels (damage levels I, II, III, and IV) outlined in the Japanese Post-Earthquake Damage Evaluation Guidelines are established. The strain limits are in the form of concrete and longitudinal reinforcement strains, with the drift ratio at the limit of each damage level determined by the minimum of the drift ratios corresponding to the proposed strain limits for that damage level. These strain limits are found to effectively capture drift ratios at the limits of different damage levels based on experimental damage observations from the 27 specimens. This method allows for predicting damage that directly impacts the post-earthquake usability of buildings, enabling functionality evaluation during the design phase using numerical tools. The proposed strain-based limit states are compared with the ASCE/SEI 41 acceptance criteria for three performance levels. The comparison provides insights into how these strain-based criteria align with the performance levels in the established standard.

A parametric study further analyzes the effects of material properties (concrete compressive strength and yield strength of longitudinal reinforcement), reinforcement ratios (longitudinal boundary and web reinforcement), and loading conditions (axial load ratio and shear span-to-wall length ratio) on different damage levels and ultimate displacement of structural RC walls. The results highlight that loading conditions significantly influence both damage progression and ultimate deformation and offer practical insights for optimizing wall designs to meet desired damage targets under the considered seismic hazards.

For non-structural RC walls, the Shear-Flexure Interaction Multiple Vertical Line Element Model (SFI-MVLEM) is adopted for its ability to capture the shear-flexure interaction of the stocky non-structural walls, which are typically bounded within a single floor. Validation against eight full-scale specimens demonstrates the model's accuracy in reproducing global and local responses, including the average shear contribution to displacement. Four damage states, ranging from minor to severe, are defined for non-structural RC walls based on the progression of visible damage and the level of repair effort required to reinstate the component. The concrete and longitudinal reinforcement strain limits are proposed to predict these damage states and are found to effectively capture the drift ratios at the limit of experimental damage states.

As non-structural walls are classified as secondary elements and often excluded from detailed seismic analysis, conducting numerical simulations for every such wall in a building can be infeasible. To address this, practical tools in the form of predictive equations and fragility curves are developed. These tools simplify damage prediction without requiring numerical simulations and assist in design revisions to achieve desired damage targets. They are derived from sensitivity analyses and numerical simulations performed on representative models of non-structural walls commonly used in Japanese construction.

This research provides a comprehensive framework for evaluating and mitigating seismic damage in structural and non-structural RC walls. Integrating strain-based damage criteria with validated numerical models enables predictions of seismic damage during the design phase. The contributions of this research bridge critical gaps in damage evaluation for both structural and non-structural RC walls, advancing performance-based seismic design to ensure buildings meet specific damage and functionality targets under seismic hazards. Furthermore, it lays a foundation for future research aimed at designing buildings to achieve the required functionality.