Numerical Modeling of Square Steel-tubed Reinforced Ultra-high-strength Concrete Columns Under Axial Compression

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Background

Ultra-high-strength concrete (UHSC) columns are frequently in high-rise buildings in Japan and they are often encased with a steel tube to prevent the brittle failure and spalling of the cover concrete. However, limited studies have been done on such columns and the behavior of the concrete under the confinement from both the steel tube and the reinforcement remains unknown, especially when the cross-section is square. Due to the limitation of experimental data, a valid numerical model is necessary to gain a better understanding of the compressive behavior of steel-tubed reinforced ultra-high-strength concrete columns (STR-UHSC).

Finite Element Modelling

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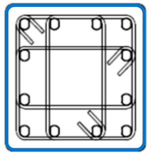


Models were developed based on four 170 MPa class UHSC specimens tested under axial compression to study the effect of the amount of transverse reinforcement and the presence of steel tubes on the performance of the concrete. Our aim is to simulate the global (axial load-displacement) and local response (concrete behavior under confinement) including the interaction between the steel tube and concrete.

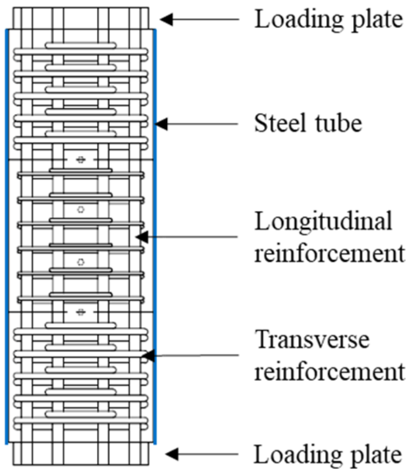


Figure 1. STR-UHSC column

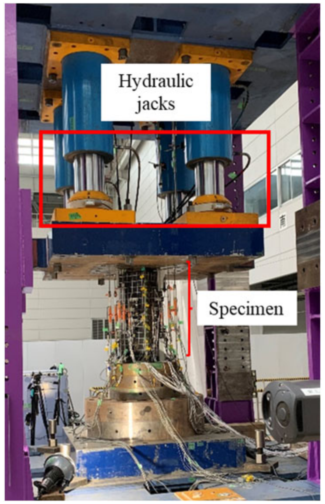


Figure 2. Loading system

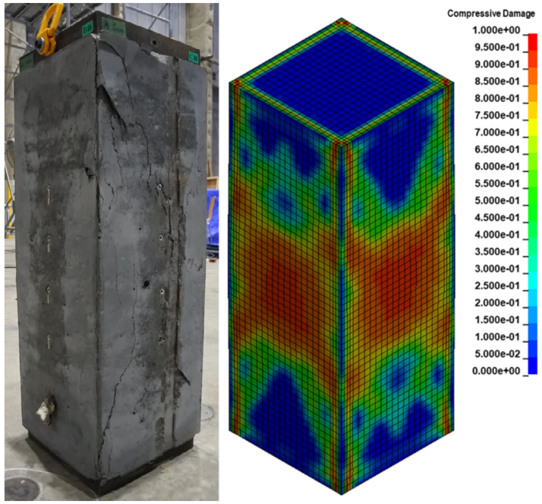
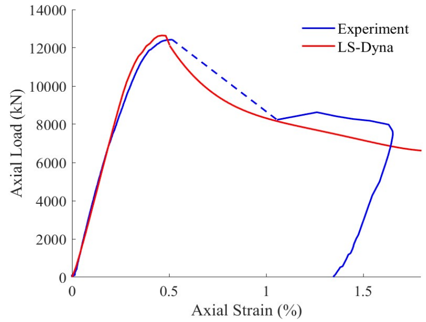


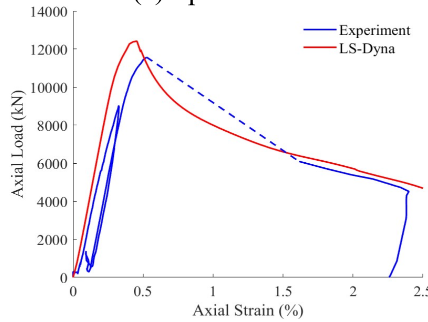
Figure 3. Concrete damage of Specimen 1

Result

The finite-element model developed in this study well simulated the axial load-axial strain relationships, the strain development of the steel tube, and the failure modes such as the diagonal cracking and crushing of the concrete, transverse reinforcement rupture, longitudinal reinforcement buckling, and steel tube tearing of STR-UHSC columns under axial compression. Even though the CDPM used in the study could not simulate the abrupt softening and severe bulging behavior of UHSC, it has little influence on the axial capacity and the failure modes of the specimens. Therefore, the established modeling approach can be used for further parametric studies to develop design methods for STR-UHSC.



(a) Specimen 1



(b) Specimen 2

Figure 4. Comparison of axial load-axial strain relationship

Contribution to Society

With the help of numerical models, engineers can gain a more detailed understanding of the mechanisms of STR-UHSC columns under different loading conditions and conduct parametric studies to investigate the influence of different variables to design more economical and safer structural components. This can ultimately help to protect people's lives and property, and reduce the economic impact of natural disasters or other extreme events on society. Additionally, the use of more efficient and cost-effective structural components can help to reduce the overall cost of building and maintaining infrastructure, benefiting the public by making such projects more affordable and accessible.