Seismic Behavior and Design of Concrete Special Moment Frames Incorporating Ultra-high Performance Concrete

Background: In 2020, 858 million tons of our carbon emission came from cement production because its thermal combustion processes heavily rely on coal, a non-renewable energy resource. It is necessary to reduce the concrete volume in their major structural systems, e.g., special moment frames (SMF), to reduce cement usage and therefore reduce the associated carbon emissions and coal consumptions.

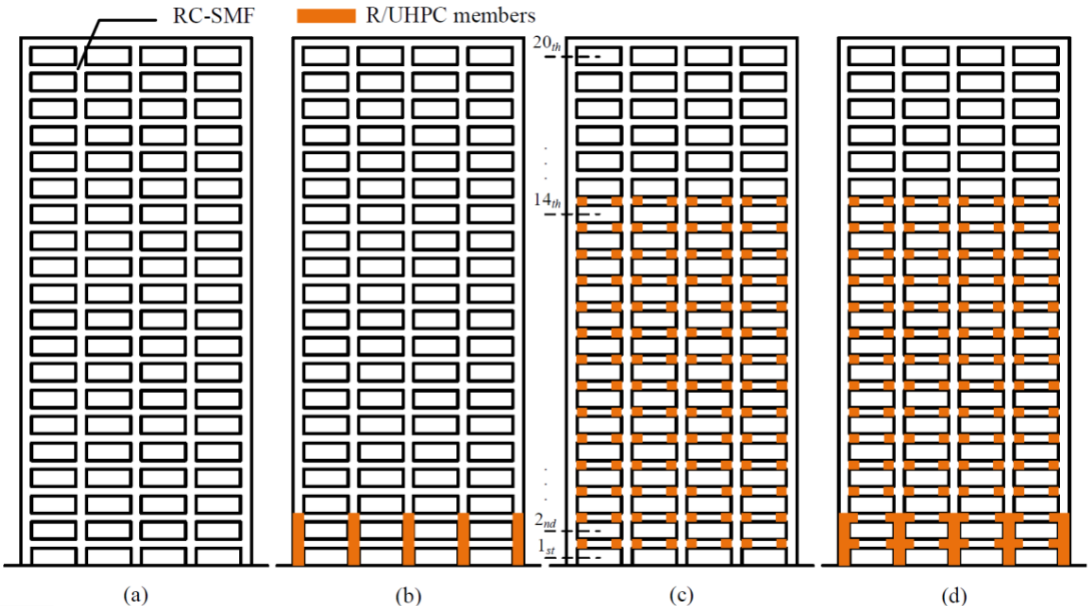
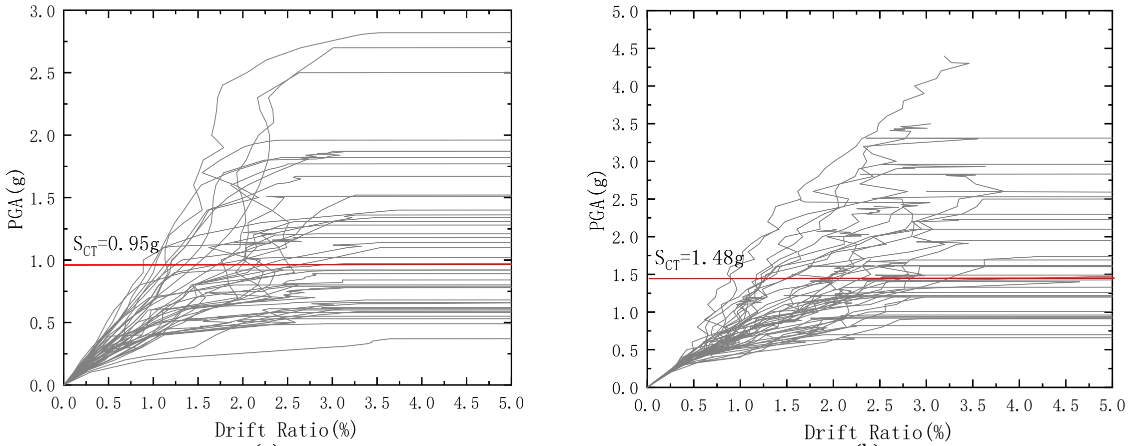


Fig.1 20-stories-tall SMFs using (a) only RC, (b) R/UHPC columns, (c) R/UHPC beams, (d) R/UHPC columns and beams.

Aim of this research: This project aims to innovate concrete SMFs by incorporating UHPC in strategically-selected locations. The new SMF frame system is expected to reduce the self-weight, concrete usage, and carbon footprint while increasing the seismic performance of a conventional concrete SMF. The developed techniques will contribute to the realization of carbon-neutral society, promotion of prefabrication techniques, and improvement of building seismic-resilience.

Research Methods: The initial step is exploring different deployment methods of UHPC members in SMF, including the position as well as the cross-section characteristics of the structural members. To limit the initial costs, R/UHPC will not be applied in the entire frame but in selected key positions, forming UHPC-Concrete composite frames (Fig. 1). Taking the SMF of a 20- story high-rise building as an example, the columns of the first two floors, the plastic-hinge regions of beams of the first fourteen floors or both may be replaced by R/UHPC, as shown in Fig. 1.

The second step involves the structural analysis of the prototyped frames. A R/UHPC test database will be collected from existing studies to calibrate simulation model parameters. Finite element models (FEM) of RC-SMF and SMF with R/UHPC components will be built in OpenSees. The structural analysis will include static analysis for service-level performance as well as dynamic analysis for seismic performance. Seismic waves with different intensities will be selected for nonlinear time-history analysis to evaluate the frame performance, such as story drift ratios in Fig.2.



(a) (b)

Fig.2 Drift ratios of (a) RC, (b) R/UHPC frames.

The final step is to calculate the carbon emission of the final qualified design and compare it with the original concrete SMF. The CO2 emissions based on the material resources and construction methods used for the two building models will be analyzed. Additionally, the power consumption associated with the use of electricity and fuels for the devices and equipment is considered in the analysis of the total CO_2 emissions.

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