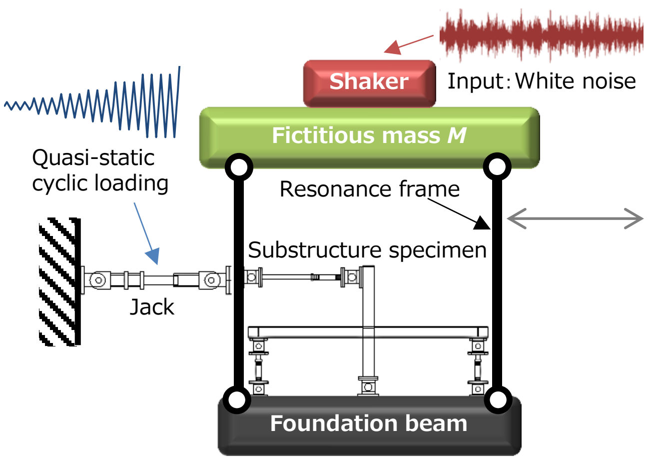
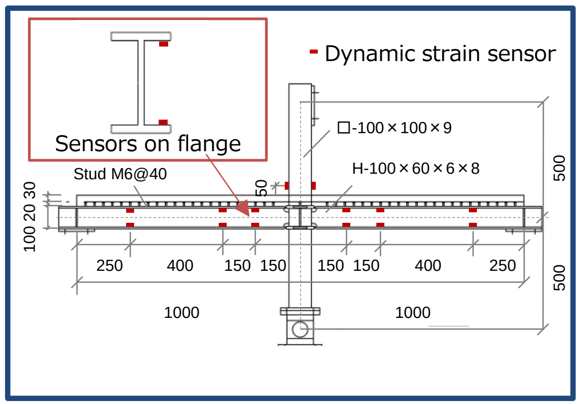
# Development of a damage quantification method with a substructure oscillation apparatus

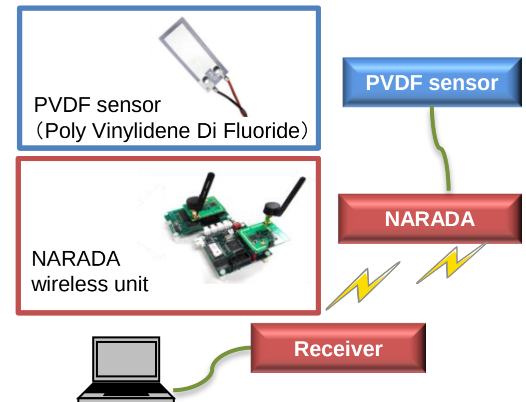
**Background and Objectives:** Quantitative evaluation of remaining load-carrying capacity of buildings enables us to make reasonable decision on re-occupancy of buildings following a damaging earthquake. This research aims to develop a quantification method for local damage in individual members of steel structures, which produces objective estimates on the location and extents of damage and the structures' remaining capacity.

**Methodology:** (1) Check influence of seismic damage on the vibration characteristics of beam-column connections; (2) Evaluate the extent of concrete slab cracking and steel beam damage; (3) Develop analysis models and associated model-updating methods for estimating the remaining earthquake-resisting capacity of building structures. Using the substructure oscillation apparatus illustrated below, the natural mode of mid-rise steel buildings is simulated. The beam-column specimen is connected to a frame with a fictitious mass on top. Various levels of realistic seismic damage are gradually reproduced by cyclic loading using hydraulic jack. A vibration test using a shaker is conducted at each damage level after removing a jack.



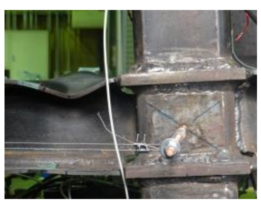




1/4 scaled specimen




Wireless measurement system

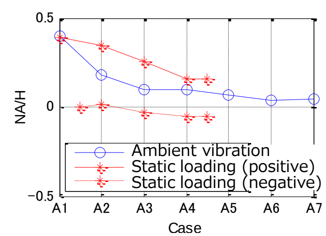
Crack on concrete floor slab



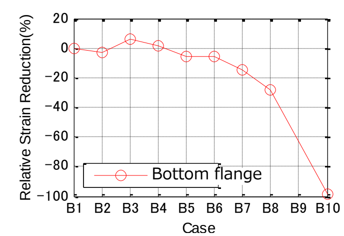
Local buckling on beam

Crack and Fracture on beam

**Vibration characteristics**




Change of neutral axis height




Change of dynamic strain

**Conclusion:** The location of the neutral axis in the composite beam identified in ambient vibration was sensitive to the progress of concrete slab cracking. The changes in the relative RMS values of the strain responses on the bottom flanges were promising as a damage-related features for seismic fractures in steel beams. Model updating based on these features succeeded in estimating the remaining load-carrying capacity of beam-column connections.