Dynamic Strain Monitoring for Local Damage Detection in Steel Structures: Part II. Test Results

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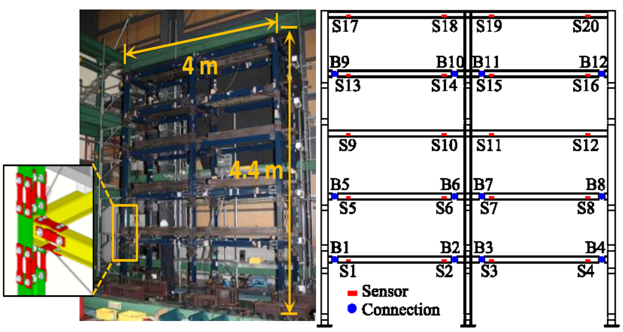
4. Test frame and Measurements

A series of vibration tests were conducted in the structural laboratory at DPRI for evaluating the performance of the dynamic strain-based local damage detection method. A 1/3.75-scaled steel frame was constructed referencing to the test frame standing at DPRI (Fig. 1(a)). Seismic damages were simulated by removing steel links that connect beams and columns with joints. PVDF sensors were bonded to the bottom flange of wide flange beams with strong adhesive; Fig. 1(b) shows the location of twenty PVDF sensors. The frame was excited by a modal shaker installed at the 5th floor.

5. Test Results

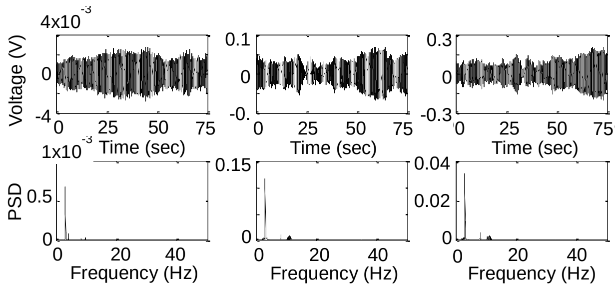
The steel frame was excited in the longitudinal direction using three excitations: (1) ambient excitation; (2) small amplitude white noise; and (3) large amplitude white noise. Strain time history was measured for 75 sec with the sampling rate of 100 Hz. Fig.2 shows the dynamic strain responses of S2 for three excitations under undamaged condition which were filtered by 1-45 Hz band-pass filter. The power spectral densities of signals indicate that the structural vibration was mainly dominated by the first mode motion. Since the first modal frequencies of all damage cases were close to 3 Hz, the band-pass filter of 2.7-3.3 Hz was selected to obtain the dynamic strain associated with the first mode. The power of the obtained strain responses were normalized with the power of strain data measured at the location considered to be away from damage location.

Fig. 3 shows a damage index as the changes in the power of strain data; the top plot corresponds to undamaged condition and the bottom plot corresponds to a damaged pattern where all links of bottom flange and web at B10 were removed. Comparing damage case with undamaged condition, the change of damage index at S14 and S15 are more than 20%, appearing abnormal behavior around these two sensors, which is completely identical to the fact that all links of bottom flange and web are removed at B10. The damage index at S14 decreases by 90%, which can be selected as an indicator to detect the nearby damage at B10.



(a) (b)

Fig. 1 Steel test frame: (a) overview and removable joints; (b) location of beam connections and sensors.



(a) (b) (c)

Fig. 2 Measured signals at S2: (a) AmbE; (b) WN1; (c) WN2.

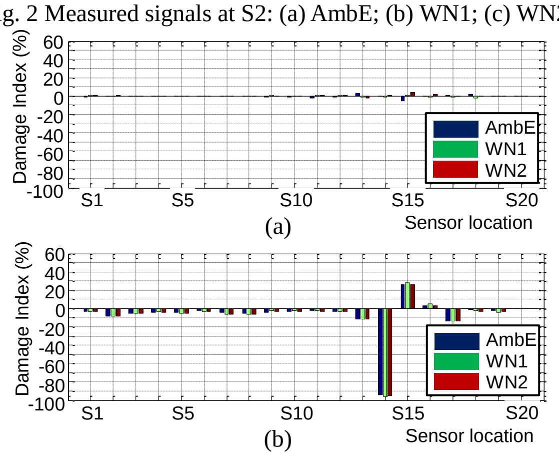


Fig. 3 Damage index: (a) undamaged; (b) damage at B10.