AMPLITUDE DEPENDENCE OF DAMPING RATIO OF REINFORCED CONCRETE SLAB UNDER DIFFERENT LOADING STATES

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1. INTRODUCTION

Vibration-based structural health monitoring (SHM) is based on the fact that changes in structural properties are associated with structural damages, which lead to changes in the dynamic characteristics of structures, such as natural frequency, mode shape, and modal damping ratio. Of all modal characteristics, damping has been proven to be sensitive to damage in some previous studies (e.g., Curadelli et al. 2008). Although changes in the modal damping ratio can be used as damage indicators in the field of SHM, its amplitude dependence remains a concern (Dammika et al. 2015; Mustafa et al. 2018). In this research, the focus was laid on the amplitude dependence of modal damping ratio of reinforced concrete (RC) slab models at different loading states. Free vibration tests were performed on slab specimens at different locations and loading states, and the relation between modal properties identified and vibration amplitude was investigated.

2. EXPERIMENTAL SETUP AND PROCEDURE

Two RC slab specimens with the same structural details have been tested. A hard vinyl chloride plate of 750 x 500 x 0.5 mm was installed in Specimen 2 to model a horizontal crack as shown in Fig. 1. To investigate the mechanical response of reinforcement and concrete, strain gauges were installed. Deflection gauges were used to measure the deflection at the bottom of specimens. On each specimen, free vibration tests were performed at five different loading states from 0 kN to the last load after failure. Peak loads observed in the Specimens 1 and 2 were 507 kN and 460 kN, respectively. For the vibration measurement, fifteen accelerometers were attached at the bottom of each specimen in an arrangement shown in Fig. 1. Impacts were applied by an impact hammer with a 1.5 kg head from the top of specimen at eight sensor locations around the loading plate. The acceleration responses were recorded at a sampling rate of 6.4k samples/s. From the vibration data, the modal properties were identified using the Continuous Wavelet Transform (CWT) approach. Using the results obtained from CWT, variations of modal damping ratio with the amplitude of vibrations were investigated.

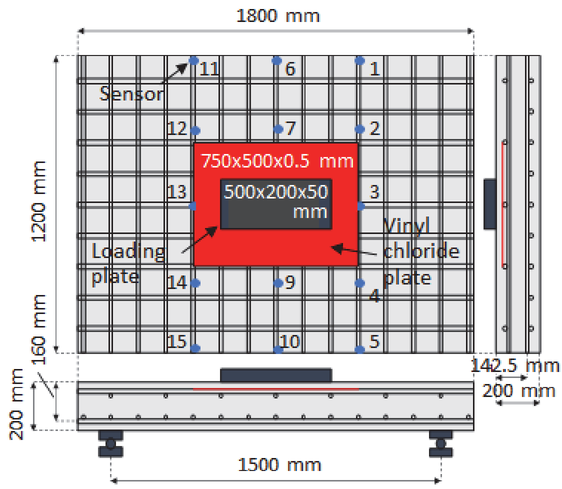

Fig.1 Model Dimensions

3. RESULTS AND DISCUSSIONS

Modal natural frequencies and damping ratios of the first bending vibration mode at five loading states, where State 1 represents the state at 0kN load and State 5 represents the state after failure, are shown in Fig. 2. These properties were determined with data for a time length of 0.077 seconds that had similar wavelet coefficients in each state. For Specimen 2, variations in natural frequency and damping ratio with different loading states can be attributed to change in structural properties due to increased load and damage in each subsequent loading state. Variations in the model properties of Specimen 1 with different loading states shown in Fig. 2 need further investigation. Damping was found to be more sensitive to damage as the percentage rate of change in the modal damping ratio between two adjacent loading states was much higher than that in the natural frequencies as shown in Fig. 2. Natural frequency for the first bending mode of Specimen 2 with the artificial horizontal crack was observed to be higher than that of Specimen 1. This does not mean the stiffness of Specimen 2 was greater than that of Specimen 1, because the corresponding mode shapes differed in the two specimens. The Fourier amplitude of acceleration responses at all the sensors to an impact load was found to be smaller for Specimen 2 than that for Specimen 1 at the frequency of first bending mode as shown in Table 1. If the modal properties are dependent on vibration magnitude, the modal properties of two specimens shown in Fig. 1 may not be compared directly.

Wavelet coefficient was used as an index of vibration amplitude in this study. At different loading states, different relations

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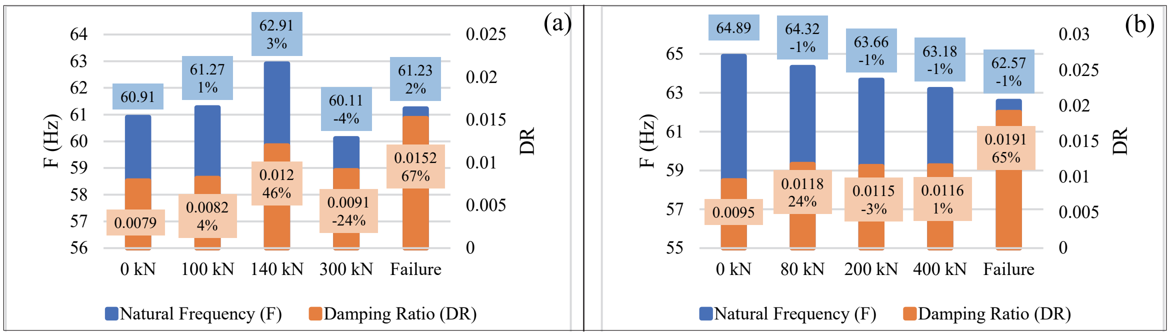

Fig. 2 Modal properties of first bending mode for all loading states for (a) Specimen 1; (b) Specimen 2

Table 1: Fourier amplitude for similar mode at all sensors' locations at loading state 1 (unit: m/s^2/Hz)

Sensor No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Specimen 1	75	135	105	165	187	74	88	103	112	124	63	59	53	51	41
Specimen 2	46	36	41	36	36	36	34	31	28	27	25	23	22	19	16

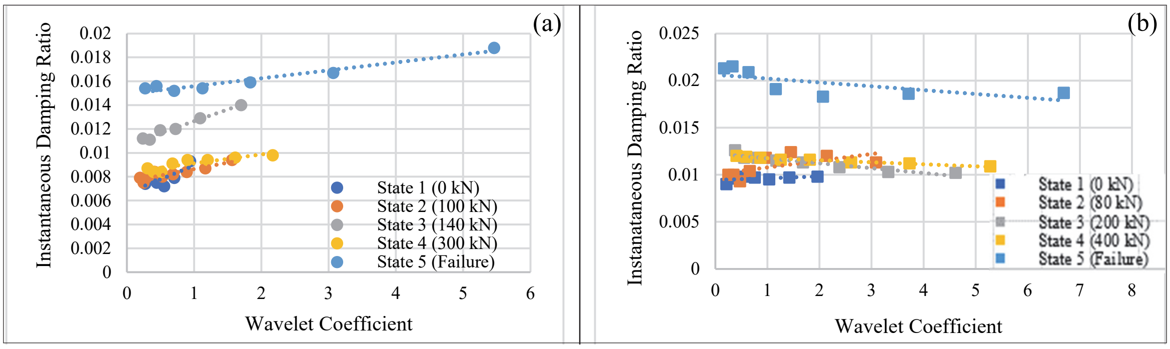

Fig. 3 Correlations for all loading states for (a) Specimen 1; (b) Specimen 2

between the damping ratio and wavelet coefficient were observed as shown in Fig. 3. For Specimen 1, positive correlations observed between the damping ratio and wavelet coefficients at all loading states indicated an increase in damping ratio with the increase in the vibration amplitude. For Specimen 2, the trend did not remain the same at all states of loading as shown in Fig. 3. At loading states 1 and 2, an increase in damping ratio with the wavelet coefficient was observed, while, negative correlations between the damping ratio and wavelet coefficient were observed in the last three states. Attributed to artificial horizontal crack in Specimen 2, damage in the similar state of both specimens differs, and thus amplitude dependence of damping ratios shown in Fig. 3 may not be compared.

4. CONCLUSIONS

This study led to conclude that the correlations between damping ratio and the amplitude of vibration vary with different loading states. At initial states, an increase in damping ratio with the increase in wavelet coefficient (an index of vibration amplitude) was observed for both specimens. The correlations did not remain the same at all states of loading and became negative in the last three states for Specimen 2.

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