High-Cycle Fatigue Damage In A High-Rise Benchmark Structure Under Wind Loads

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Proper recognition of the structural behavior, response, and collapse under extreme wind loads is necessary, especially after the increasing occurrence of extreme wind events (e.g., hurricanes) and growing interest in performance-based wind engineering. Studies conducted in recent years on wind hazards have shown that some failures in connections and members of structures led to extensive and catastrophic damage. Although studying the nonlinear response of buildings under wind hazards can lead to safer structures and inform future economic designs, evaluation of critical points in a structure, controlling and mitigating the responses of structures, and avoiding structural damage such as high-cycle fatigue are critical. The main objective of this paper is to determine the remaining life of a 20-story steel moment-resisting frame, from the SAC project, under fatigue loads at different wind velocities corresponding to different return periods, and also present an appropriate solution to mitigate the effects of these hazards. In this study, an adaptive control algorithm is used to alleviate the high-cycle fatigue damage in the structure equipped with MR dampers, and the performance of the controlled structure is compared with a corresponding system without dampers. It should be noted that although active, semi-active, or passive control systems are installed in the building, only the semi-active control design has been confirmed to reduce responses. In this paper, first, the optimum parameters of the adaptive control method, called the Simple Adaptive Control Method (SACM), are calculated. Next, the efficiency of using SACM to mitigate the structural response of the benchmark structure under wind loads is studied. Finally, reducing fatigue damage on the structure subjected to various wind loads is examined to extend the fatigue life of the structures. The rain-flow counting technique and the Miner rule are used to calculate the cumulative fatigue. To determine the cumulative fatigue, primarily, a time history analysis based on the measured records of the wind velocity is performed, and the stress value on each floor is extracted. Having processed the data in MATLAB and filtering additional data to remove noise and reduce ineffective data, the number of stress cycles is counted by the rain-flow method and arranged according to the average and range of these stresses. Finally, the cumulative fatigue failure (i.e., Miner rule) is determined by matching the S-N curve and calculating the ratio of the number of cycles in each stress level to the number of cycles at the ultimate fatigue limit, representing the remaining life of the members. Based on observations, the adaptive control system directly affects fatigue damage of elements as it has reduced the fatigue in the beam and column of the first story in benchmark structure subjected to the wind load by the amount of 80 percent and 70 percent on average, respectively. Overall, the study reveals that the adaptive control system can reduce fatigue damage in elements and extend fatigue life in structures significantly, compared with the other control systems. Also, the dynamic characteristics of a structure are affected by using the semi-active adaptive control approach.