Concrete spalling damage detection and seismic performance evaluation for RC shear walls via 3D reconstruction technique and numerical model updating

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Highlights

- A novel method is proposed based on 3D reconstruction technique and numerical model updating.
- The proposed method can detect concrete spalling damage by using LiDAR point cloud data.
- The proposed method can evaluate the seismic performance degeneration of RC shear walls.

Abstract

Current three-dimensional (3D) reconstruction technique-assisted damage detection research focuses on identifying, classifying, and locating surface damage on concrete components, challenging to quantify the effect of the identified damage on structural capacity. This paper attempts to present a novel method based on the 3D reconstruction technique and numerical model updating to detect concrete spalling damage and evaluate the adverse effects of the detected damage on the seismic performance of reinforced concrete (RC) shear wall components. Through a new concept of information transition point matrix, the mapping relationship between the defective information concealed in the reconstructed 3D point cloud model of the inspected wall and the performance variation of its corresponding finite element model is established. Experimental results demonstrate that the newly proposed method can successfully locate the concrete spalling damage and quantify the bearing capacity variation of the inspected specimen, which has excellent potential for future applications in civil engineering.

As a solution, the three-dimensional (3D) reconstruction technique has been recommended by some researchers to obtain the depth information of concrete damage and quantify the healthy state of the inspected component [25,26]. Via the 3D reconstruction technique, the mathematical model of 3D objects can be established, providing the foundation for processing the spatial characteristics of actual objects in computers. By analyzing the spatial data obtained from the 3D reconstruction technique, damage detection for concrete components can be achieved [27]. For example, Yuan et al. [28] developed an inspection robot with deep stereo vision and used the classical mask region convolutional neural network to measure the dimensions of concrete cracks. Liu et al. [29] proposed a method based on the 3D reconstruction technique and depth cameras to quantify concrete surface damage volume. Even though the above research works have demonstrated their effectiveness, they still encounter challenges in evaluating the seismic performance variation of RC components caused by the detected damage, impeding their further application for post-disaster rescue and structural maintenance in actual engineering.

Recently, some researchers have attempted to utilize the 3D point cloud data obtained from the 3D reconstruction technique to establish finite element models of the inspected structures and components and update the characteristic information of the established finite element models [[30], [31], [32], [33]]. Since the capacity of finite element models in simulating the structural response has been validated by many research papers [[34], [35], [36]], the seismic performance variation of RC components caused by the detected damage is expected to be evaluated based on the computing results of finite element models before and after numerical model updating. For example, Yu et al. [37] utilized the collected 3D point data to automatically generate the numerical model of the inspected beam and analyzed the influence of initial cracks on the residual capacity based on three different models. Zhang et al. [38] proposed a method to automatically