Performance Assessment of Multi-Column Piers Subjected to Vehicle Collision

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In the event of a vehicle collision to a bridge pier, collision-induced forces can result in a drastic loss of the load-bearing capacity of a column, leading to the collapse of individual bridge components or even the entire bridge in extreme situations. Although many studies have been performed to investigate the performance of reinforced concrete columns subjected to vehicle collision, only limited research is available on the vulnerability of multiple-column bents under vehicle collision. This study investigates the effect of longitudinal and transverse reinforcement on the performance of two-column frame pier systems under vehicle collisions. Longitudinal and transverse reinforcements are found to be an important design factor for transferring the loads from the superstructure to the column and then from the column to the substructure. To investigate this critical factor, a finite-element (FE) model of bridge pier consisting of piles, pile cap, two-column frame pier, and two span superstructure is generated. Different vehicle types with mass ranging from 8 to 16 tons are utilized for in-depth understanding of the damage induced to the bridge pier. In order to ensure the adequacy of the FE results, the FE simulations are first validated against the existing crash tests on bridge piers. Following the design concepts, a comprehensive set of simulations are conducted to evaluate the sensitivity of damage levels to the key design factors for two-column frame pier. The damage levels are defined by considering four limit states, including serviceability, operability, life safety, and critical failure. The effect of longitudinal reinforcement is investigated by varying the reinforcement ratio between 1% and 4%. A detailed investigation on the effect of transverse reinforcement is conducted by performing a comparative assessment of hoop and spiral reinforcement with focus on hoop spacing/spiral pitch. The effect of extending spiral reinforcement into the pier cap and footing on the performance of the pier system is also studied in detail. For each set of representative vehicle impact scenarios, the performance of the two-column frame pier system is investigated to evaluate the expected extent of damage, shear and moment profiles, and lateral displacement experienced by such columns. The outcome of this study will help with finding the minimum requirements for satisfactory performance of the pier systems in the bridges vulnerable to vehicle collision.

Keywords: Vehicle Collision; Bridge Column; Impact Simulation; Transverse Reinforcement; Vulnerability Assessment