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Development and Analytical Validation of Embedded Steel Plate-Concrete (ESPC) Shear Wall System

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Extended Abstract

The Embedded Steel Plate-Concrete (ESPC) shear wall system represents an innovative approach aimed at enhancing constructability and cost-efficiency compared to conventional shear wall systems. By embedding steel plates within concrete without the need for boundary elements, the ESPC system offers advantages such as reduced construction complexity, lower initial costs, and improved fire resistance. Traditional reinforced concrete (RC) shear walls, widely used in high-rise buildings, require increased thickness or reinforcement to meet seismic demands, leading to construction challenges, reduced usable space, and increased self-weight. Composite shear wall systems like Steel-Reinforced Concrete (SRC) walls address some of these issues but introduce complexities due to boundary elements. The ESPC system eliminates these challenges, embedding steel plates within concrete to achieve structural performance and simplicity.

This study employed finite-element analysis (FEA) using ABAQUS to investigate the structural performance of ESPC shear walls.[1] To validate the FEA model, experimental data from prior studies on steel plate-embedded shear walls were utilized for comparison.[2] The FEA results showed high consistency with experimental data, with an error margin of approximately 4% for most parameters, confirming the accuracy and reliability of the developed model. Based on this validation, parametric analyses were conducted for variables such as steel plate thickness, concrete thickness, stud spacing, and aspect ratio. The findings reveal that increasing steel plate thickness significantly improves stiffness and strength, but this effect plateaus beyond 12 mm due to stud shear capacity limitations. Proper design of stud connections is essential to prevent premature failure. Concrete thickness, in contrast, has minimal influence on overall system strength, contributing only about 2%. Stud spacing also plays a critical role, as overly narrow spacing can cause concrete damage, while wider spacing reduces composite action. Optimized spacing is vital for effective load transfer and adherence to design standards. Aspect ratio was found to be a critical factor, with higher ratios leading to flexural failure before the shear wall could fully utilize its shear capacity. This highlights the importance of aspect ratio selection in achieving desired failure modes. The study also compared four nominal shear strength equations with the analytical results. The combined shear strength equation (Concrete + Steel plate) (V_{n1}) proved accurate for thinner steel plates, while the steel plate-only equation (V_{n2}) was more suitable for thicker steel plates. Other equations, such as those for SPSW (Steel plate shear wall) (V_{n3}) and SC shear wall (V_{n4}), exhibited significant discrepancies due to assumptions of buckling and composite behavior that do not align with the ESPC system.

The ESPC shear wall system achieves high structural performance while addressing challenges of constructability, cost, and fire resistance. Its design must carefully account for stud shear strength, steel plate thickness, and aspect ratio to ensure optimal performance. Current shear strength equations are insufficient for this system, necessitating the development of new formulas tailored to its unique behavior. This study provides foundational data for designing ESPC systems and paves the way for future experimental research to validate and refine these findings, ensuring practical application in the construction of efficient and resilient structures.

References

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