Research Project Highlight

A Critical Examination of Material Strain Limits for Performance-based Seismic Design of Modern Pier and Wharf Structures

TSRP Topic: S3 - Study of ports, high-speed rail, & airports

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Start-End Dates:
8/1/2021-8/1/2022

Abstract:
In recent years, steel pipe-piles have become a prominent choice in the seismic design of foundation systems for pier and wharf structures on the west coast of the United States. Practicing engineers refer to ASCE/COPRI 61-14 [1] to determine material compressive strain limits for the pile plastic hinges, which are used as a performance metric for a given seismic hazard; however, no guidance is provided on preventing local buckling for either hollow or concrete-filled steel pipe pile. A recent review of available experimental data revealed that steel pipe piles commonly used in practice are susceptible to local buckling and fracture at compressive strains significantly below the strain limits in ASCE 61-14 (Harn et al. 2019) [2]. Although most of the available experimental data was obtained through 3 and 4-point "in-air" bending tests, which do not represent realistic in-situ pile conditions, this observation suggests a potential pitfall in conventional design approaches, where the stipulated compressive strain limits may lead to unconservative estimates of displacement ductility. Due to the limited research on the in-ground behavior of steel pipe piles, there is a lack of research-supported recommendations for the next generation of ASCE 61-14 [1]. This gap in the body of knowledge warrants an urgent investigation into the adequacy of the prescribed strain limits, and the effect of variables (e.g. D/t ratio, open-ended, close ended piles, soil stiffness etc.) that drive the development of local buckling, fracture, and subsequent strength loss. A comprehensive probe is proposed to examine the behavior of steel pipe-piles through detailed numerical analyses on a stand-alone pile. By studying the influential variables and parameters which guide the pile to failure, the model will then be extended to system-level simulations in which the redundancy in multi-pile systems will be taken into account.

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Deliverables

A PEER report discussing the steel-pile material characterization tests, implementation of material subroutine, validation of single pile FE model, parametric study results, and multi-pile system analysis.

Research Impact

To better understand contemporary engineering practices, the research team will be guided by an industry advisory group consisting of Omar Jaradat, Ph.D, P.E., Arul Arulmoli, Ph.D., P.E., G.E., and Carlos Ospina, Ph.D., P.E.. The outcomes of this investigation will be utilized to inform the structural engineering design community regarding the adequacy of the current strain limits stipulated in ASCE/COPRI 61-14 [1] for performance-based design of steel pipe-pile foundations. Furthermore, the numerical results will be used to assess the Life Safety performance level strain limit proposed by Harn et al. (2019). Ultimately, recommendations will be provided for improvements to the strain limits in ASCE/COPRI 61 [1]. The models developed throughout this research effort will be made available to practicing engineers and researchers with the aim to broaden the body of knowledge regarding pipe-pile foundation systems.

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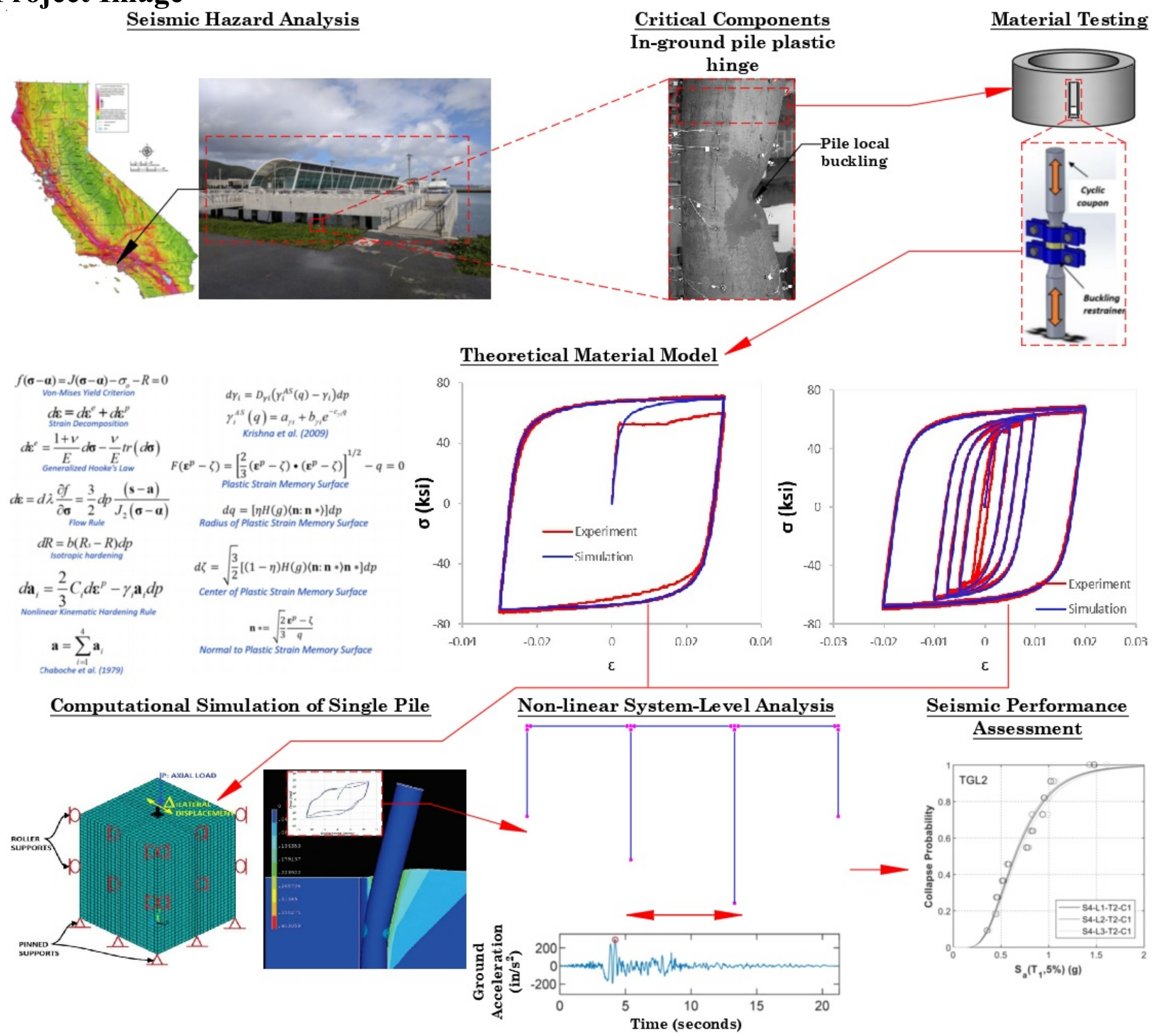
Project Image



References

[1] American Society of Civil Engineers (ASCE), "ASCE/COPRI 61-14 Seismic Design of Piers and Wharves," ASCE Standards, Reston, VA, 2014.

[2] R. Harn, C. E. Ospina and D. Pachakis, "Proposed Pipe Pile Strain Limits for ASCE 61-19," in *Ports 2019: Port Engineering*, Reston, VA, 2019.