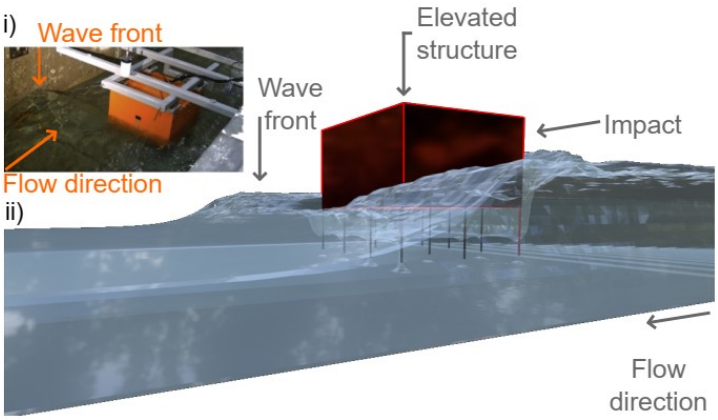
Structural behavior due to cascading earthquake and tsunami actions

Summary

The spatial distribution of the world population is uneven with privileged concentration on coastal regions. The trend is expected to continue in both demographic indicators and urban development rate, being many coastal cities in seismic- and tsunami-prone areas built through informal and unplanned settlements, exposing their population and assets to such hazards. The structural performance of the built environment is one of the man-controlled variables that can influence the social, economic and environmental resilience. Nonetheless, recent tsunami events raised the awareness for the threat of earthquake and tsunami cascading effects on coastal structures and highlighted the paucity of structural design criteria considering the cumulative effects of both. By being exposed to the ground-motion, the structures' resistance may decrease and become residual/non-existent to support the incoming tsunami, implying an underestimation of the risk. Yet, the characterization of the natural phenomena and the respective structural response is complex and multidisciplinary, involving various epistemic uncertainties, multi-scale domains and multi-physical processes. The key objective of this dissertation is to contribute for the characterization of structural behavior due to cascading seismic and tsunami actions. The conceptualization of the numerical methodology considers endogenous variables of the numerical models and exogenous variables intrinsically related to the physical processes along various stages, from the genesis of the tsunamigenic event to the corresponding structural response. Multiple numerical schemes and coupling techniques to model the various spatial-temporal scales were subjected to an exhaustive benchmarking process, correlating numerical solutions with data from analytic, laboratorial and instrumental records of real events. The proof of concept consists of characterizing the structural behavior of a pile-supported quay serving as terminal container at the Sines deep-water seaport due to the cascading effects of a 1755-alike earthquake and tsunami event. Moreover, the open-type wharf is in expansion phase to increase the cargo capacity and the port competitiveness globally. Multiple configurations resembling the current and future terminal infrastructure(s) were considered along the analyses performed to characterize the multi-hazard effects on the structure and the respective structural vulnerabilities, allowing to identify potential factors that jeopardize the port's activities, such as current operations and lifeline support, and predict both natech scalability and societal and ecologic impacts. From the analyses are inferred structural recommendations of preventive nature towards the sustainable development of critical coastal structures exposed to tsunamigenic hazard.

Keywords

Earthquake and tsunami multi-hazard, cascade seismic and tsunami loading pattern, successive structural response accounting cumulative effects, numerical fluid-structure interaction, multi-physics, multi-scales.



i) psysical setup of the experimental campaign developed at the large flume of Oregon State University, ii) corresponding model of the elevated structure subjected to a tsunami-like wave. Numerical simulations performed using a coupled configuration linked by Dirichlet boundary condictions, i.e., the linearish part of the domain is characterized using Eulerian Shallow-Water system of equations solved by Finite Volume method, while the highly non-linear fluid-structure interaction is characterized using Lagrangian Navier-Stokes system of equations solved by Smoothed Particle Hydrodynamics method.

PhD student
Cláudia Vanessa Dias Reis

PhD program
Civil Engineering (IST, University of Lisbon)

Supervisor
Mário Lopes (CERIS, IST, University of Lisbon)

Co-supervisors
Maria Ana Baptista (FC, University of Lisbon) and Stephane Clain (EE-UM, University of Minho)

Period
2017-2022

Funding
Lisbon University scholarship