A PERFORMANCE-BASED COASTAL ENGINEERING FRAMEWORK

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Coastal regions are exposed to both chronic and punctuated hazards, such as sea level rise and hurricane events, that can jeopardize entire coastal communities. For instance, Hurricane Katrina, which made landfall in 2005 on the coast of Louisiana, displaced around a million people in the Gulf Coast Region and caused damages estimated at $161 Billion, making it the costliest hurricane in the United States on record (NOAA 2018). The continuous and accelerated growth of population in coastal regions coupled with the rise in property value and in the frequency and intensity of natural hazards due to climate change (Field et al. 2012), exacerbates the challenges that coastal communities face now and into the future. Therefore, to effectively assess the risk and resilience of coastal communities subjected to multi-hazard environments, evaluation of the capacity of individual structures and infrastructure systems to withstand the different time-varying demands imposed in coastal settings is of paramount importance.

In recent years, performance-based engineering approaches have been used to evaluate the performance of different structures during a natural hazard event for design, retrofit, and risk assessment purposes. The framework for performance-based engineering, originally proposed in the earthquake engineering community, has been recently extended to other types of natural hazards such as hurricanes, tsunamis and even multi-hazard scenarios (Attary et al. 2017, Barbato et al. 2013, McCullough and Kareem 2011) to perform probabilistic risk assessment of structures. Performance-based design methodologies have also been implemented for specific types of coastal structures (Do et al. 2016) by leveraging fragility functions and evaluation of mitigation strategies. While past studies have addressed performance-based methodologies for specific coastal hazards (e.g. hurricanes and tsunamis) or types of structures, a generalizable framework is still needed to address key complexities inherent in performance assessment of coastal structures and infrastructure systems.

Thus, the objective of this paper is to formulate a probabilistic Performance-Based Coastal Engineering (PBCE) framework for design, risk and resilience assessment of coastal structures. This framework should be flexible to accommodate the multi-hazard and cascading hazard effects, temporal nature, and range of performance objectives of interest. The description of each component within the framework, including the assumptions, sources of uncertainty and parameter definitions, are also discussed. As a proof of concept, the performance assessment of a case study elevated coastal structure is presented. The case study corresponds to a typical Gulf Coast residential structure subjected to wave and surge loads.

Overall, this study proposes a comprehensive probabilistic framework for the design, risk and resilience assessment of coastal structures. The methodology also provides useful tools to inform decision-making, facilitate recovery efforts and improve resource allocation. This study will open the path for future research studies addressing fully-probabilistic multi-hazard modeling, structural performance modeling of coastal structures, characterization of uncertain performance outcomes, and integration of different infrastructure systems in the context of coastal engineering performance analysis.

Figure 1 – House pushed over by flood loads during Hurricane Ike. The failure occurred at the connection level between the floor beam and the piles (FEMA 2009).

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