Structural Health Monitoring and Impact Force Identification of Ferry Quays and Dock Bridges

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Abstract

Ferry quays are common infrastructure in Norway's transport network. They provide essential connections across fjords where fixed links such as bridges and tunnels are technically and financially challenging. The rise in population and tourism has placed greater demand on ferry quays, which has led to modern ferries being larger and operating more frequently than the vessels for which many quays were originally designed. Ferry quays are exposed to harsh marine conditions and repeated docking impacts, which accelerate their deterioration. Traditional inspection routines are unable to capture the onset of damage and consistently track its progression over time. As a result, some deterioration may go unnoticed between inspection intervals. Consequently, a deeper understanding of their structural response is essential for reliable assessment and effective long-term monitoring. Structural Health Monitoring (SHM) offers a means to address this challenge by providing real-time data on the structural behavior. Through the use of sensors and data analysis techniques, SHM enables the timely identification of structural changes that may indicate damage or degradation. SHM also provides valuable insights into structural behavior, particularly during key operational events such as ferry dockings. By employing quantitative metrics that capture the dynamics of these impacts, SHM can help identify locations that are more susceptible to rapid deterioration and guide the prioritization of maintenance. However, despite its potential, only a limited number of quays, harbors, and ports have been instrumented compared to infrastructure such as bridges. This talk presents the instrumentation of the Magerholm ferry quay in Norway with a permanent SHM system. This represents one of the first long-term monitoring installations on such infrastructure. The work focused on four main aspects: (i) the practical preparation and deployment of the SHM system, (ii) the development of automated methodologies to monitor modal parameters under varying environmental conditions and to filter out their influence, (iii) the use of Digital Twin (DT) models for virtual sensing, enabling the estimation of responses at locations where no physical sensors are installed, and (iv) the characterization and estimation of ferry impacts through both simple statistical tools and more advanced force identification frameworks integrated with DT models. In conclusion, these studies demonstrated how SHM can complement traditional inspections by providing quantitative tools to track structural performance, identify changes, and characterize docking impacts. The permanent monitoring system at the Magerholm quay, together with the long-term dataset it provides, establishes a foundation for further developments in SHM applications for ferry quay infrastructure.

Biosketch

Dr. Luigi Sibille has recently completed a PhD in Structural Engineering, with a thesis entitled "Structural Health Monitoring and Digital Twin Approaches for the Dynamic Assessment of Ferry Quays." He holds a Master's degree in Structural Engineering from Politecnico di Torino. Dr. Sibille was a visiting researcher at the University of Cambridge, where he worked on physics-enhanced machine learning approaches for force and response estimation in structural systems. He will soon begin a postdoctoral position at Princeton University, focusing on AI-driven form finding of structural surfaces under extreme loading. His research interests include structural health monitoring (SHM), operational modal analysis and system identification, finite element model updating, impact force estimation, and AI-driven form finding.

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