World Academy of Science, Engineering and Technology
International Journal of Geotechnical and Geological Engineering
Vol:14, No:02, 2020

A Study of Seismic Design Approaches for Steel Sheet Piles: Hydrodynamic Pressures and Reduction Factors Using CFD and Dynamic Calculations

Authors : Helena Pera, Arcadi Sanmartin, Albert Falques, Rafael Rebolo, Xavier Ametller, Heiko Zillgen, Cecile Prum, Boris Even, Eric Kapornyai

Abstract : Sheet piles system can be an interesting solution when dealing with harbors or quays designs. However, current design methods lead to conservative approaches due to the lack of specific basis of design. For instance, some design features still deal with pseudo-static approaches, although being a dynamic problem. Under this concern, the study particularly focuses on hydrodynamic water pressure definition and stability analysis of sheet pile system under seismic loads. During a seismic event, seawater produces hydrodynamic pressures on structures. Currently, design methods introduce hydrodynamic forces by means of Westergaard formulation and Eurocodes recommendations. They apply constant hydrodynamic pressure on the front sheet pile during the entire earthquake. As a result, the hydrodynamic load may represent 20% of the total forces produced on the sheet pile. Nonetheless, some studies question that approach. Hence, this study assesses the soil-structure-fluid interaction of sheet piles under seismic action in order to evaluate if current design strategies overestimate hydrodynamic pressures. For that purpose, this study performs various simulations by Plaxis 2D, a well-known geotechnical software, and CFD models, which treat fluid dynamic behaviours. Knowing that neither Plaxis nor CFD can resolve a soil-fluid coupled problem, the investigation imposes sheet pile displacements from Plaxis as input data for the CFD model. Then, it provides hydrodynamic pressures under seismic action, which fit theoretical Westergaard pressures if calculated using the acceleration at each moment of the earthquake. Thus, hydrodynamic pressures fluctuate during seismic action instead of remaining constant, as design recommendations propose. Additionally, these findings detect that hydrodynamic pressure contributes a 5% to the total load applied on sheet pile due to its instantaneous nature. These results are in line with other studies that use added masses methods for hydrodynamic pressures. Another important feature in sheet pile design is the assessment of the geotechnical overall stability. It uses pseudo-static analysis since the dynamic analysis cannot provide a safety calculation. Consequently, it estimates the seismic action. One of its relevant factors is the selection of the seismic reduction factor. A huge amount of studies discusses the importance of it but also about all its uncertainties. Moreover, current European standards do not propose a clear statement on that, and they recommend using a reduction factor equal to 1. This leads to conservative requirements when compared with more advanced methods. Under this situation, the study calibrates seismic reduction factor by fitting results from pseudo-static to dynamic analysis. The investigation concludes that pseudo-static analyses could reduce seismic action by 40-50%. These results are in line with some studies from Japanese and European working groups. In addition, it seems suitable to account for the flexibility of the sheet pile-soil system. Nevertheless, the calibrated reduction factor is subjected to particular conditions of each design case. Further research would contribute to specifying recommendations for selecting reduction factor values in the early stages of the design. In conclusion, sheet pile design still has chances for improving its design methodologies and approaches. Consequently, design could propose better seismic solutions thanks to advanced methods such as findings of this study.

Keywords : computational fluid dynamics, hydrodynamic pressures, pseudo-static analysis, quays, seismic design, steel sheet pile
Conference Title : ICEGE 2020 : International Conference on Earthquake Geotechnical Engineering
Conference Location : London, United Kingdom
Conference Dates : February 13-14, 2020