Large-scale oriented use of concrete for a wave energy converter: dynamic interaction and structural feasibility

Abstract

Wave energy represents one of the most promising renewable energy sources explored to date. However, the use of this precious resource requires further development, in particular in identifying flexible, convenient and reliable production processes for conversion devices, especially with a view to future changes and improvements to existing prototypes.

The work performed in this thesis is part of the ISWEC innovation project, developed by MORE Lab. The Inertial Sea Wave Energy Converter (ISWEC) is an offshore floating device composed by a single body. It consists of a unique hull, that contains an equipped room completely tightened and protected from the marine environment. In the internal volume, two gyroscopic units are positioned, that together with Power Take Off (PTO) system, guarantee energy production.

However, the convenience of the ISWEC device is strongly influenced by the capital cost of the structure, which is the reason why other alternative technological solutions have been explored, above all as regards the material constituting the hull.

The objective of the research, described in this thesis, is in fact to identify the best design approach for the use of a cement conglomerate in the construction of the hull of the ISWEC device as an alternative to the consolidated use of steel. It is reasonable to believe that concrete, especially if used in the context of a large-scale industrial production, would allow the achievement of a significant reduction in the Levelized Cost of Energy (LCoE). The study focuses on the use of concrete as a base material for the structure, exploiting the skills deriving from technological and scientific areas where concrete is already notoriously advantageous. The main advantages of reinforced concrete compared to steel, include a low unit cost (cost per ton), easy availability on the international market and greater durability over time with minimal maintenance costs. In addition, offshore reinforced concrete structures typically have a minimum project life of 50 years, and therefore further cost savings can be considered if this feature is fully exploited

The mix design has also been carefully considered following laboratory tests on fresh and dried samples, and developing durability models. Typically, marine concrete has a low water/cement ratio (W/Cm <0.40) and involves the use of additives to facilitate its workability.

At the same time, the identification and quantification of the actions affecting the structure has represented another essential and innovative issue for the design purpose. The development and validation of a numerical model through a specific Finite Element software for reinforced concrete has been the final part of the research process. Several linear and nonlinear Finite Element structural analyses have been conducted through the application of limit states method, in order to define the operating behaviour of the structure respecting the safety requirements, with particular attention to cracking phenomenon.

Several skills have been brought together, specifically in structural analysis, hydrodynamics and reinforced concrete design.