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INNOVATIVE COASTAL STRUCTURE SOLUTIONS AND THE ROLE OF PHYSICAL MODELLING IN THE DESIGN PROCESS (DAWLISH, MOG2, CASINO)

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1 INTRODUCTION

With the increase in storminess due to climate change induced sea level rise, coastal protection solutions need to be able to contend with larger storms, resulting in larger incident waves, on a more regular basis. Many traditional coastal protection systems like vertical seawalls are proving to be expensive to design for the increased overtopping associated with this change in coastal conditions. As such, engineers are developing more bespoke and innovative design solutions, such as the use of bullnoses and the use of multiple seawalls located one behind the other. Examples of the former can be found in the new Dawlish seawall (see Figure 1) built to replace the old seawall that was damaged during a storm surge in February 2012. For the later, recent examples include the Middelkerke CASINO stilling basin (see Figure 2) and the new energy island being developed by Elia in Belgium (MOG2). The latter consists of two vertical seawalls (see Figure 3), each with a bullnose to reduce overtopping rates. CASINO and MOG2 have in common the novel approach of allowing significant overtopping of the first seawall but instead using the second wall as the safety line, to ensure safe overtopping limits are achieved at this location, thus reducing the required height of the front wall.

Moving towards alternative design solutions is associated with its own set of design challenges. The primary challenge is the lack of consistent design guidelines within the field of coastal structures. In Europe, EurOtop is commonly used for overtopping estimates in design (van der Meer *et al.,* 2018). In the US, the Coastal Engineering Manual is used instead (USACE, 2002). Both of these guidelines rely on empirical equations and the variations between the two are primarily a question of preference. However, the empirical equations can have large variations in their solutions (a factor of 3 for the overtopping rate is commonly accepted), the value of which can be heavily dependant on the geometric configuration being used for the seawall, toe protection and bathymetry, limiting their applicability to novel solutions. There is limited research currently available investigating novel geometries such as bullnoses (Dong *et al.*, 2021, Castellino *et al.*, 2018) and stilling basins, and much of the existing literature is limited in scope, thus limiting its wider applicability. In the case of MOG2 and CASINO, the use of the two seawall configuration, combined with drainage solutions, means that there is no suitable guidance in neither of the aforementioned design guides. As a result, coastal designers often turn to physical modelling in order to identify the specific design loads and overtopping values of their proposed design. Physical modelling performed in collaboration with research organisations allows design engineers to benefit from the expertise of researchers working with state-of-the-art techniques informed by the most recent research. However, the physical modelling phase is often not fully integrated into the design process meaning that is it not fully utilised. Integrating physical modelling fully into the design cycle can help to optimise the design as well as identifying the structural loading and verifying the overtopping performance.

The three aforementioned examples, Dawlish, MOG2 and CASINO, are examples of coastal designs where collaboration between designers and research organisations through physical modelling was used, in several different stages, to inform the choice of design as well as verify its performance. Particularly when identifying expected design forces on the structures, the expertise of researchers can prove invaluable, as there is a lack of a consistent approach. For CASINO, design loads were identified using a statistical approach using repeated experiments with different timeseries realizations of the same wave conditions, whereas for MOG2 this was done by calculating an averaged $F_{1/250}$ for each individual experiment. The presentation will show that, by integrating physical modelling and the expertise of research organisations, from the conceptual design phase through to the final design, novel engineering solutions can be developed and implemented without the need to wait for the development of an overarching set of design equations, thus promoting faster innovation in the development of coastal and offshore structures without increasing design uncertainty and risk.

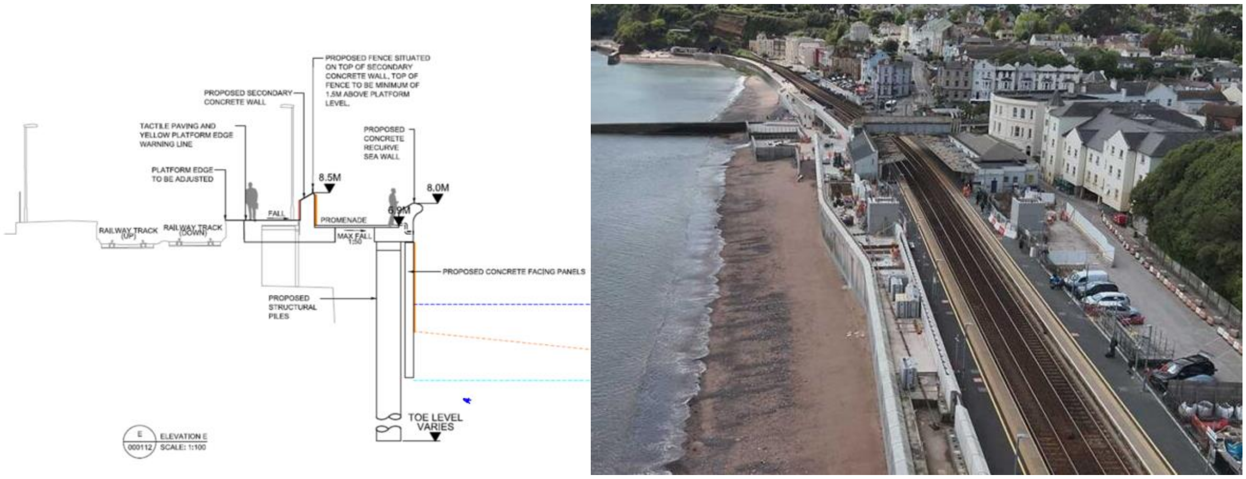

Figure 1. New bullnose seawall installed at Dawlish, UK (Network Rail, 2023)

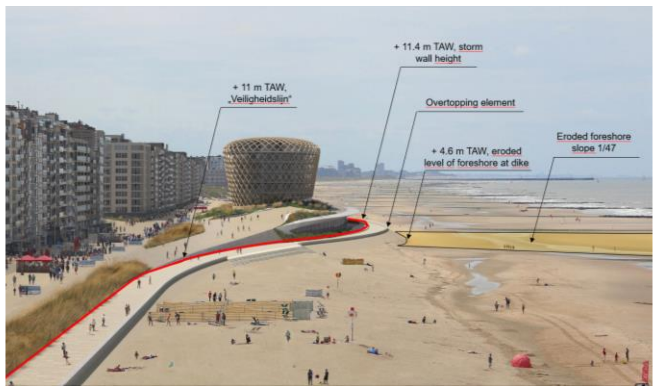

Figure 2. CASINO stilling wave basin in Middelkerke, Belgium (Adapted based on source: Witteveen + Bos)

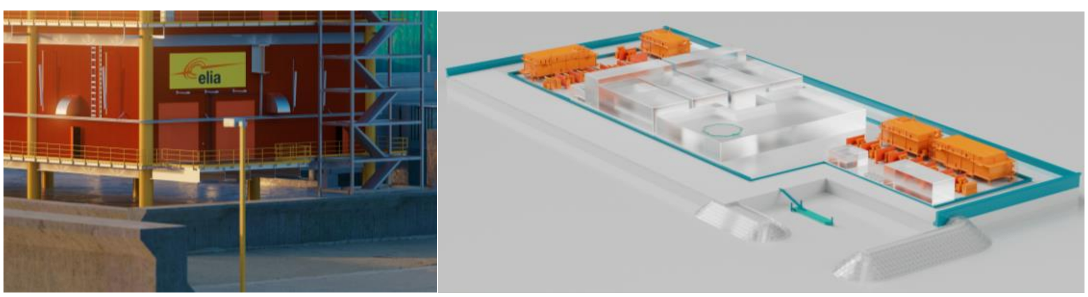

Figure 3. EPCI Energy Island for MOG2 Project, showing the two seawall configuration (Elia, 2023)

2 CONCLUSIONS

There is a rapidly growing need to develop novel and innovative design solutions to replace traditional coastal defences such as vertical seawalls. However the lack of uniform design guidelines that can be used reliably to inform the design criteria and performance of these new solutions creates a significant barrier to their development and use in practice.

The presentation discusses three examples, Dawlish, CASINO and MOG2, where physical modelling has been used in conjunction with expertise from research institutions to inform the design at a variety of stages throughout the design development process. By looking at the lessons learned from these three projects, it is proposed that the use of physical modelling to inform design is a solution to the problem presented by the lack of guidelines applicable to the rapidly changing field of coastal structures design.

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