Scour and Liquefaction at Foundations of Floating Offshore Turbines

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INTRODUCTION

Offshore wind energy is one of the most important renewable energy resources. Offshore wind farms (OWFs), bottom-fixed or floating, are used to harvest offshore wind energy. Floating OWFs, with water depths of O(20-30) m or larger, are the energy production sites where wind turbines are installed on floating platforms. Floating platforms are held in place with a system of mooring lines (likely chains) and anchors (Fig. 1). There are mainly three types of anchors, namely, conventional drag embedment anchors (DEAs), suction caisson anchors, and gravity anchors, all involving dimensions of O(10) m. For semi-submersible and spar-type floating offshore wind turbines, DEAs are the optimum choice, given their high holding capacity against lateral loads.

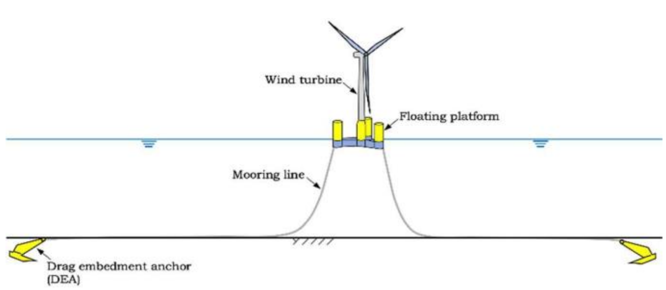

Figure 1. Floating offshore wind turbine anchored to the seabed by DEAs.

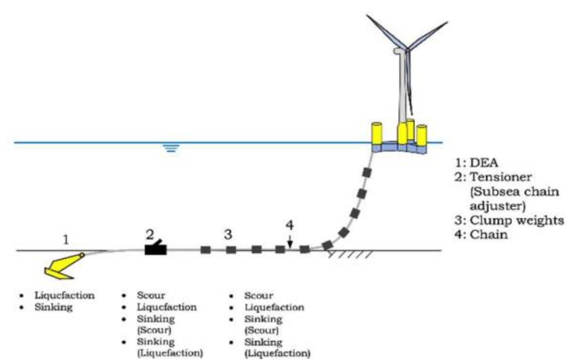

Fig 2. Anchoring system of a floating platform with subsea structures, with modes of failure (scouring and liquefaction) indicated.

Fig. 2 displays a detailed illustration of a typical DEA ("1" in the figure) and its associated subsea structures, namely, a tensioner (or subsea chain adjuster) ("2" in Fig. 2), clump weights ("3" in Fig. 2) and chains ("4" in Fig. 2). DEAs and the aforementioned subsea structures may be subject to unfavorable effects of scouring and liquefaction (Fig. 2). The purpose of this presentation is to review scouring and liquefaction issues for foundations of floating offshore wind turbines, two effects expected to be potential threats for the stability and integrity of floating offshore platforms.

SCOURING ISSUES

Scouring is not an issue for DEAs themselves because they are completely buried in the seabed. However, it is an important issue for other subsea structures associated with DEAs, such as tensioners, clump weights, and chains (Fig. 2). The scouring process described in the following is given with reference to tensioners.

When a tensioner is placed on the seabed and exposed to the flow, scour and eventually undermining develop at the tensioner. As a result of the combined effect of scour and undermining, the tensioner sinks in the soil. This sinking process stops when the tensioner sinks to such levels that the tensioner is protected against the scour. In this scouring and sinking sequence, the structure may experience a tilting towards the upstream direction in currents, due to the relatively larger scour depths at the upstream side of the structure, largely caused by the strong presence of the so- called horseshoe vortex. In waves, however, the scour hole is more symmetric with respect to the offshore-onshore direction. Therefore, the aforementioned tilting is practically nonexistent, revealed by the recent experiments of Kirca, Ghasempour & Sumer (2023, to be presented in this conference). Engineering projects essentially call for prediction of time series of scour and sinking depths under given metocean conditions.

LIQUEFACTION ISSUES

Seabed soil may undergo liquefaction under waves where the effective stresses between the individual grains vanish. Therefore, the water-sediment mixture acts like a liquid with catastrophic consequences. There are two types of seabed liquefaction: residual liquefaction and momentary liquefaction (Sumer, 2014, Liquefaction Around Marine Structures). Liquefaction (residual) is also a threat to the stability and integrity of the foundations of the floating offshore turbines. (Momentary liquefaction, limited to the top O(10) cm of the seabed, and only relevant to small- size structures such as small pipelines, small protection blocks, is not included in our discussion.) Engineering projects require for check for liquefaction for given metocean conditions.

Additionally, it is required to make assessments about sinking of subsea structures such as those of the present problem (Fig. 2), including DEAs. The presentation will describe an integrated mathematical model, comprising a sub-model for check for liquefaction, a second sub-model for sinking of subsea structures in liquefied soil, and a third one for assessing the upward progression of compaction front, the sequence in the post-liquefaction stage.

CONCLUDING REMARKS

The presentation also discusses relationship between scouring and liquefaction, including the case where the soil is liquefied in which case the entire concept of scour obviously breaks down.

An extended version of the presentation has been published in: B.M. Sumer and V.S.O. Kirca: Water Science and Engineering, 2022, 15(1): 3-14.