Evaluation of Suction Piles and Plate Anchors from Current Deepwater Mooring Applications

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ABSTRACT

In the last decade, mooring systems have been selected for the production units and mobile drilling rigs required to operate between about 300 and 3000m of water. The paper emphasizes on the empirical evaluation and installation behavior of suction piles and plate anchors, which currently appear as the two main anchor solutions in soft deepwater clays. Regarding the vertically loaded plate anchor (VLA) solution, several VLA concepts are in competition, including the ‘Stevmanta’ and ‘Dennla’ drag-in plate anchors, and the direct embedment ‘SEPLA’ anchor installed by means of a suction follower. From the current experience with deepwater moorings, general trends are suggested with respect to the design of plate anchors in soft clays.

KEY WORDS: Soft clay; deepwater mooring; suction pile; plate anchor; holding capacity; installation behavior.

INTRODUCTION

In about a decade, reliable and cost effective mooring systems have been selected for the floating production units (FPUs and FPSOs or FSOs) and mobile drilling rigs (MODUs) required to operate between about 300 and 3000 metres of water. Improvement in the station-keeping area of oil production floaters in deep waters included both the mooring lines and anchors, in particular with the use of anchors with a vertical loading capacity and fibre ropes in taut leg mooring (TLM) configurations (Colliat, 2002; Ehlers-Young and Chen, 2004). In front of the conventional driven pile solution, now applicable in up to about 2000 metres of water (present limitation of underwater hammers), the paper emphasizes on the empirical evaluation of suction piles and plate anchors, which currently appear as the two main anchor solutions in soft deepwater clays. In the Gulf of Mexico and in West Africa, the suction pile is the preferred option for permanent mooring of production units, including semi-submersible FPUs and deep draught SPARs in the Gulf of Mexico, or FPSOs in the Gulf of Guinea. Suction piles have also been used for several pre-installed MODU moorings in the Gulf of Mexico (El-Gharbawy-Olson and Shaeby, 1999; Dupal-Eberstein-Loeb-Xu-Grant and Bergeron, 2000). On the other hand, the vertically loaded plate anchor (VLA), applied firstly and rather extensively offshore Brazil in both temporary and permanent moorings (Barusco, 1999), has also found its place more recently in the mooring market in the Gulf of Mexico (Wilde-Treu and Fulton, 2001). The suction anchor pile, typically with a height-to-diameter ratio ranging between 3 and 6, is capable of resisting mooring loads with a significant vertical loading component in taut leg configurations. Its larger success as anchor solution in permanent moorings is attributed to a higher confidence in the design procedure and long term ultimate holding capacity, based on prediction methods calibrated against model test data and detailed numerical analyses (Andersen et al., 2005).

Regarding the plate anchor solution, several VLA concepts are in competition, including drag-in plate anchors (‘Stevmanta’ and ‘Dennla’ anchors), and direct embedment anchors installed by means of a suction follower (‘SEPLA’ and ‘SEA’ anchors) or by driving (‘VELPA’ anchor). The ‘Stevmanta’ (Agnevall, 1998), ‘Dennla’ (Foxton-Bruce and Craine, 1998) and ‘SEPLA’ (Wilde-Treu and Fulton, 2001) anchors are now well established in the deepwater mooring market, with a field proven experience record (Colliat, 2002; Ehlers-Young and Chen, 2004). Based on this experience, general trends are suggested regarding the design of plate anchors in soft deepwater clays. The ‘SEA’ (Riemers and Kirstein, 1999) and ‘VELPA’ (Alhayari and van Focken, 2003) anchors, still in the course of their development and lacking full-scale field testing, are not considered in the present paper.

SUCTION PILES IN DEEPWATER MOORINGS

Suction Piles in Deepwater Clays

Andersen et al. (2005) give an exhaustive list of moorings utilizing suction piles, including about 500 suction anchors installed at more than 50 locations in water depths to nearly 2000m by the end of 2003. From this list, a selection of permanent moorings with steel suction piles in soft deepwater clays is summarized in Table 1, covering different types of oil production floaters in worldwide spread deepwater petroleum development provinces, with well documented design soil data and installation behavior of the suction piles.