International Journal of Offshore and Polar Engineering
Vol. 11, No. 2, June 2001 (ISSN 1053-5381)

Development and Validation of Mooring Line Analysis in Cohesive Seafloor

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ABSTRACT

An analytical solution method capable of determining the geometric configuration and tensile forces of the mooring lines associated with fixed plate/pile or drag anchors has been proposed. The solution method is capable of analyzing multisegmented mooring lines that can consist of either chains, cables, or wires embedded in layered seafloor soils. It utilizes a systematic iterative search method based on specific boundary conditions. This paper describes the principles associated with the solution for the mooring line analysis. Calibration of input data has been made through the centrifuge model tests on mooring lines. Comparisons between the analytical predictions and the results from a series of field tests of mooring lines have then been made for various types of drag anchors. The comparisons of the tension at the anchor shank, the length of the mooring line on the bottom, and the angle of the mooring line at the water surface buoy indicate that the analytical solution method is capable of predicting the behavior of mooring lines with a high degree of accuracy.

INTRODUCTION

The U.S. Navy has developed an analytical solution method that can analyze offshore and deepwater mooring lines associated with embedded drag and fixed anchors (Bang, 1996). Mooring lines may be comprised of multisegments with different material and/or geometric properties and embedded in a general seafloor soil having either cohesion or friction or both. Any number of sinkers can also be added to the suspended portion of the mooring line in water. Solutions can be obtained with a fixed total length of the mooring line, a fixed horizontal length of the mooring line, or a fixed exit angle of the mooring line at the seafloor surface.

The calibration of input data for the solution method of analyzing mooring lines embedded in cohesive seafloor soils was made through laboratory centrifuge model tests (Bang et al., 1996; Bang et al., 1999). Although this analytical solution (Bang et al., 1996) was compared with the full-scale field test results, it did not account for the case of a portion of mooring line on the seafloor surface.

This paper briefly describes how the present analytical solution accounts for a portion of the mooring line on the seafloor surface. The results of the field tests conducted in cohesive seafloor soils and the resulting comparisons between the measured and calculated values are presented in detail.

MOORING LINE ANALYSIS

The analysis of the static mooring line geometric configuration is based on the limiting equilibrium method, in which the detailed solutions are obtained from the static equilibrium conditions. Fig. 1 shows a schematic diagram of a mooring line element embedded in the seafloor. Let T and ϕ be the axial tensile force and the inclination angle at the ends of the element, and N ($f\,ds$) and ($w\,ds$) the normal force, the tangential force, and the buoyancy of the mooring line element, respectively. From the static equilibrium conditions of forces along the (n, t) coordinates and the moment about the point "o", one can solve for unknowns, N, T and ϕ. Note that the previous solutions of the embedded mooring line analysis only considered the force equilibrium conditions (Brian Watt Associates, 1983; Degenkamp and Dutta, 1989; Vivatrat et al., 1982). Because the present solution method utilizes complete equilibrium conditions, it permits an additional degree of freedom in each mooring line element.

In the analysis, it is assumed that the soil tangential forces ($f\,ds$) remain at their limiting state at all times, as the dominant mode of the mooring line movement during deployment is sliding. The normal soil forces N, however, remain unknown because of the available additional degrees of freedom, so they can be less than those defined by the limiting state (the soil-bearing capacity). It is also noted that the assumption of the mooring line element form-

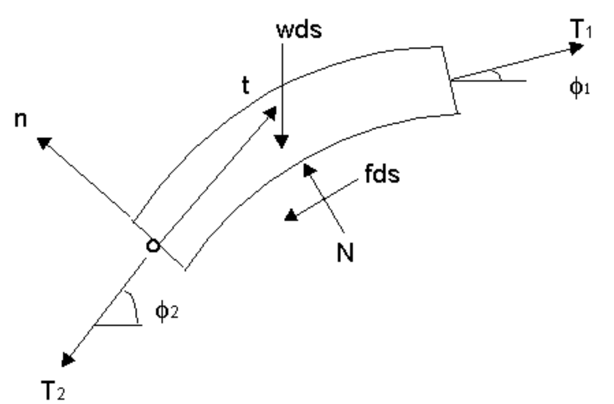

Fig. 1 Mooring line and free body diagram

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Received June 23, 2000; revised manuscript received by the editors December 11, 2000. The original version (prior to the final revised manuscript) was presented at the Tenth International Offshore and Polar Engineering Conference (ISOPE-2000), Seattle, USA, May 28–June 2, 2000.
KEY WORDS: Anchor, mooring line, cohesive seafloor, chain, cable, tension.