ABSTRACT

The flowline termination assembly (FTA) foundation is subject to complex load conditions in all six degrees of freedom during its operational life. The consolidation settlement of the FTA is generally determined by conventional one-dimensional (1-D) analytical method. However, this method has the tendency to overestimate the consolidation settlement, resulting in an unduly conservative estimate.

To reduce the conservatism, finite element analysis (FEA) is proposed. Abaqus’ two-dimensional (2-D) finite element analysis (FEA) is initially performed to “calibrate” the model and this is supplemented by three-dimensional (3-D) FEA to perform the rigorous analysis to determine the consolidation settlement of the FTA. The results are compared with the conventional 1-D analytical solution.

KEY WORDS: Consolidation; settlement; FEA; Cam-clay; void ratio; eccentric loading; Abaqus.

INTRODUCTION

The flowline termination assembly (FTA) foundation is subject to complex load conditions in all six degrees of freedom during its operational life. The loads are generated from self-weight of the structures, pipeline and spool loads, and loads from pipeline thermal expansion.

The consolidation settlement of the FTA is generally determined by conventional 1-D analytical method. This analytical method has the tendency to overestimate the consolidation settlement, resulting in an unduly conservative estimate. It has further limitations in accounting for eccentric loadings, permeability and complexity of the structure assembly.

To refine the 1-D settlement estimates and to reduce the level of conservatism, numerical analysis based on Abaqus’ 3-D FEA has been adopted. The FEA employed the “modified Cam-clay” soil model (Roscoe and Burland, 1968) based on the critical state plasticity theory to give an accurate determination of the consolidation settlement.

A 2-D FEA model is initially constructed to “calibrate” the mesh density and other pertinent parameters. This has the main advantage of low computational time in determining the sensitivity of the parameters and to ensure that the results obtained are comparable with those determined from the 1-D analytical solution before undertaking the complex 3-D FEA.

Parametric studies are conducted to identify the critical parameters in the evaluation of consolidation settlement and to provide recommendations for analysis and design optimisation.

Two case studies where the heavy FTAs in deepwater are supported by soils with very high void ratios are examined. The results indicate that the 3-D FEA gives a lower consolidation settlement as compared with the 1-D analytical solution, and it is capable of addressing eccentric loadings and associated rotational settlement from complex structures. The FEA is also able to provide consolidation settlement at different locations on the FTA for use in the design of spools.

ANALYSIS DATA

Flowline Termination Assembly

Two flowline termination assemblies (FTAs) are considered for the case studies, namely integrated foundation and independent foundation FTAs with details given in Table 1 and illustrated in Fig. 1. The independent foundation FTA is larger than the integrated foundation FTA and has potential larger eccentricity, and therefore rotational effects are more critical. A depiction of the FE model and the loading condition is given in Fig. 3.

Table 1 – Approximate Foundation Dimensions

<table>
<thead>
<tr>
<th>FTA</th>
<th>Length (m)</th>
<th>Width (m)</th>
<th>Skirt Depth (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Integrated Foundation</td>
<td>15</td>
<td>10</td>
<td>0.4</td>
</tr>
<tr>
<td>Independent Foundation</td>
<td>20</td>
<td>10</td>
<td>0.4</td>
</tr>
</tbody>
</table>

The loadings applied onto these FTAs are given in Table 2.