Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 161 (2016) 324 – 331

Procedia Engineering

www.elsevier.com/locate/procedia

World Multidisciplinary Civil Engineering-Architecture-Urban Planning Symposium 2016, WMCAUS 2016

Allowable Span Length of Submerged Pipes Under the Effect of Hydrodynamic Forces

Pakhshan Ahmadian[a,]*, Umut Türker[a]

[a]*Eastern Mediterranean University, Civil Engineering Department, Gazimağusa, 99450, North Cyprus,Turkey*

Abstract

This study aims to calculate the maximum spanning lengths of different size High Density Polyethylene pipes (HDPE) at the intermediate zone of coastal environments. In order to do so, Reynolds number less than 3.5×105 and Keulegan Carpenter number between 4 and 7 at intermediate depth are accepted as the limitations of the work. The assigned limitations were useful to analyse the behaviour of submerged pipes in the absence of vortex induced vibration. Therefore, the velocity of sea current and the wave orbital velocity at intermediate depth are computed to determine the in-line and cross-flow net forces acting on spanning submerged pipes. Finally, comparing the yield stresses of pipes with the bending stresses due to external forces, the critical spanning length of high density polyethylene pipes are deduced. At constant diameter, the free spanning length of the pipes was increasing as the wall thickness of the pipes increases. The ratio of external forces to the weight of the pipe was not effective while deciding on the magnitude of spanning length of the pipes, which shows 0.5% changes while 30% changes occurred on the pipe diameter.

Peer-review under responsibility of the organizing committee of WMCAUS 2016

Keywords: drag force,inertia force, lift force, span length;

1. Introduction

A marine pipeline designed at the bottom of the sea bed is generally accepted to be stable since the anchored blocks positioned at a predefined and calculated intervals are strong enough to attain the stability and the underlying soil is capable to withstand the weight and the hydrodynamic forces in the system. However, the idealized behaviour of

* Corresponding author. Tel.: +90 5338800935;
E-mail address: pakhshan.ah@gmail.com

Peer-review under responsibility of the organizing committee of WMCAUS 2016
doi:10.1016/j.proeng.2016.08.566

pipeline to be in contact with a stable seabed throughout its lifetime sometimes fails. This failure is generally due to the settlements of the sea floor or erosion of the seafloor due to currents around the pipes. This separation of the sea bed from the surface of the pipeline generates suspended spanning lengths. Free spans sometimes occur due to the irregularities of the sea bed. In such case depending on the length of the span, lift forces, inline forces and the properties of the pipeline, significant deflections occur that disturbs the natural frequency of the pipelines. The behaviour of free spanning pipes has been defined and set out in various codes and standards ([1], [2], [3], [4]) and also defined in detailed in a broad collection of books and papers ([5], [6], [7]). Most of these studies are focused on the analyses of vortex induced vibrations at spanning lengths for steel pipes in which Keulegan Carpenter number is greater than seven, and the pipe is located at the shallow water depths. However, at intermediate depths, the oscillatory effects of the sea waves are still dominating the hydrodynamic forces and failure of the pipeline is still possible due to the hydrodynamic forces and changes in the natural frequency of the pipes.

Different studies have been conducted to analyze flow field around submerged pipelines. Among them Sumer and Fredsoe in [1981] carried out detailed analyses on submarine pipes [5]. They focused on hydrodynamic around cylindrical structures in which both orbital velocity and normal velocity components were taken into consideration. It was clear that vortex induced vibration, due to spanning of pipes were occurring when KC was greater than 7. Chen Ong et al. [8] in 2004 had investigation about high Reynolds number flows around a circular cylinder near to a flat seabed while using the k–ε model with different gap ratio. They focused on high Reynolds number flows regime at Re=3.6×106 with different gap ratio by using the numerical simulation and they found that if the gap ratio is equal to 1, the sea bed has no effect on the formation of vortex shedding around cylinder. Zhi-Peng Zang et al. in 2007 [9] simulated the effect of wave height on wave force on submarine pipeline with finite volume method using two-dimensional Navier–Stokes equations. They compare the theoretical findings with experimental results and finally concluded that the horizontal wave force varies relatively linear with the wave height and found that the effect of seabed on horizontal wave forces is not remarkable. In addition, they found that when the gap ratio is bigger than 0.5 the drag coefficient and inertia coefficient are constant. Zheng et al. in 2008 [10] focused on investigating frequency range due to effects on drag and lift forces around oscillating cylinder. Havar et al. in 2014 [11], conducted a research by semi-analytical method for multi-spans by allocating the finite element models and concluded that the in-line and cross-flow fundamental frequencies may undertake a considerable decrease due to attendance of neighbouring spans.

2. Methodology

The requirement of this study was to extract reliable, accurate and physically possible results. The methodology followed was initiated by finding the interval in which the limitations of pair of vortex around the spanning pipe starts. This was achieved at intermediate zone where due to the small effects of orbital velocity of the waves, the Reynolds Number and Keulegan-Carpenter number are small. In this regard, various boundary conditions, Reynolds Number less than 3.5×105 and Keulegan Carpenter number in between 4 and 7 were considered. Later, the ratio between the inline forces and lift forces are examined. This was necessary to understand at which conditions vortex induced vibration dominates due to inline forces and at which level a pair of vortex occurs where lift forces are dominant. As long as the required limitations were dominating the flow characteristics the natural frequency of the pipes are compared with the vortex shedding frequency of the pipes. Finally, the results of the analyses, failure limits of HDPE pipes, and the corresponding maximum possible span lengths are evaluated and discussed.

3. Hydrodynamic forces and their effects

A pipe subject to an oscillatory flow experiences two kinds of forces namely in-line force and the cross flow forces (Figure 1). With the intention of reducing the failure possibility of subsea pipeline systems stable design conditions should be guaranteed even under the worst case conditions. In order to maintain the stability, it is important to delineate the total net in-line force acting on a submerged pipe. This can be achieved by combining two well-known equations; drag in a current and hydrodynamic inertia in an accelerating flow. In steady open channel flows or currents, the force that acts on different cylindrical shapes in the inline direction is generally defined as drag force and it is given by