Tunnelling and Underground Space Technology 40 (2014) 192–202

Contents lists available at ScienceDirect

Tunnelling and Underground Space Technology

journal homepage: www.elsevier.com/locate/tust

Modeling and optimization of a trench layer location around a pipeline using artificial neural networks and particle swarm optimization algorithm

Asskar Janalizadeh Choobbasti, Hamidreza Tavakoli, Saman Soleimani Kutanaei *

Department of Civil Engineering, Babol University of Technology, P.O. Box 484, Babol, Iran

ARTICLE INFO

Article history:
Received 26 March 2013
Received in revised form 23 September 2013
Accepted 8 October 2013
Available online 12 November 2013

Keywords:
Artificial neural networks (ANN)
Particle swarm optimization algorithm (PSOA)
Optimal location
Trench layer

ABSTRACT

The main objective of the present work is to utilize particle swarm optimization algorithm (PSOA) integrated with feed-forward multi-layer perceptron (MLP) type of artificial neural networks (ANN) to find the optimum positions of a trench layer around a pipeline in order to obtain the minimum liquefaction potential. The mesh free local radial basis function differential quadrature method (LRBF-DQ) was used to solve the governing equations of seismic accumulative excess pore pressure containing pore pressure source term. This data was used to train the ANN using back propagation weight update rule. Then the trained ANN predicts the liquefaction potential and PSOA was used to find the best location of the trench layer. The results obtained by the MATLAB codes of LRBF-DQ, ANN and PSOA are showed that there was a linear relation between the location of the pipeline and the optimum location of the trench layer. Moreover the minimum liquefaction potential has been occurred when the trench layer placed beneath of the pipeline.

1. Introduction

Investigation of the seismic response of buried pipeline has been the topic of interest for many researchers during the last two decades because it has wide industrial and engineering application. Submarine pipelines are a convenient means to transport natural oil or gas from offshore oil wells to an onshore location and they are widely used in marine engineering. Recent earthquakes have caused damage to the pipelines, especially utility lifelines (e.g. Chou et al., 2001). Under earthquake loading, granular materials such as sands are susceptible to compaction. In saturated deposits, reduction in volume is prevented by the presence of pore fluids. Lack of drainage due to low permeability and short duration of loading result in a nearly undrained condition. This undrained condition that is accompanied by a tendency to reduction in volume of soil skeleton builds up the pore fluid pressure. Consequently, the effective stress and so the shear resistance of these cohesionless soils reduces. By continuing generation of excess pore fluid pressure, gradually the effective stress diminishes the process in which liquefaction could occur. Seismic performance of pipelines has been studied by Trautmann et al. (1985) and Lee et al. (2009). Also, there are the results of studied effects of wave and soil characteristics and pipe geometry on excess pore pressure generation for seabed installation of pipelines (Maotian et al., 2009; Zhang et al., 2011; Kutanaei and Choobbasti, 2013). Karamitros et al. (2007) presented an analytical methodology to simulate buried pipeline behavior under permanent ground-induced actions. Liu and Jeng (2007) developed a simple semi-analytical model for the random wave induced soil response for an unsaturated sandy seabed of finite thickness. Azadi and Hosseini (2010a,b) evaluated the effects of several factors in uplifting behavior of shallow tunnels within the liquefiable soils.

Recently soil improvements became an attractive topic for engineers (Zahmatkesh and Choobbasti, 2012; Choobbasti et al., 2013, 2011). Pipeline protection is one of the major concerns in offshore pipeline projects. In general, pipeline engineers use a trench layer for the protection of a buried offshore pipeline, which will involve the following design parameters: (1) the fill in material; (2) configuration of the trench layer. Different mitigation strategies have been proposed to eliminate or alleviate uplift damage, which includes densification or replacement of the surrounding liquefiable soils (Taylor et al., 2005), installation of gravel drainage (Orense et al., 2003), grouting (Tanaka et al., 1995), and installation of cut-off walls (Hashash et al., 2001; Azadi and Hosseini, 2010a,b).

In light of difficulties of the meshing-related issues various meshfree methods have been developed. Among them smooth particle hydrodynamics (SPH) (Liu and Liu, 2003), meshless local Petrov-Galerkin approach (MLPG) (Sladek et al., 2005, 2007), least-squares meshfree method (LSMFM) (Sladek et al., 2007; Xuan and Zhang, 2008), etc. Recently, a new mesh-free method is proposed based on the so-called radial basis functions (RBF)

* Corresponding author. Tel./fax: +98 111 3234205.
E-mail address: samansoleimani16@yahoo.com (S.S. Kutanaei).

0886-7798/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.tust.2013.10.003

Nomenclature

P	pore pressure
γ_f	weight of pore water
k	permeability coefficient of soil
E	deformation modulus
K'	bulk modulus of pore fluid
ν	Poisson's ratio of the soil
f	accumulative excess pore pressure source term
T_{eq}	period of equivalent cyclic stress
t_d	denotes the initial mean effective stress.
σ'_0	initial mean effective stress
γ	unit weight of soil
z	depth of calculation point to the surface
g	gravitational acceleration
$a_{\max}$	maximum ground acceleration
r_d	reduction coefficient of stress
$x^{p(t)}$	position of particle
$v^p(t+1)$	new velocity (at time $t+1$)
S	population size
$\kappa 1$	weighting factor
$\kappa 2$	cognitive parameter
$\omega_{1,j}(t)$ $\omega_{2,j}(t)$	random numbers
NE	network error
Est	estimated output
$NO_1, \ldots, NO_n$	outputs of n neurons
$W_{1N}, \ldots, W_{nN}$	weights
LR	learning rate parameter
r	radius of the pipeline
h	thickness of homogeneous seabed
x_0 and z_0	center coordinates of the pipeline
l	width of the computation region
$\hat{y}(t)$	best position of particle
b	burial depth of the pipeline
n_s	porosity
I_N	activation function
R	liquefaction potential

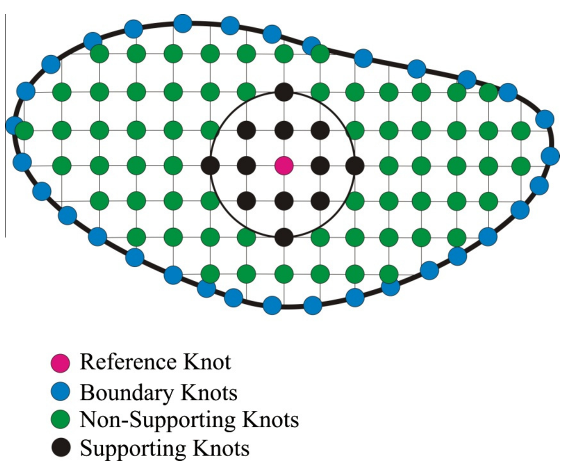

Fig. 1. Supporting knots around a centered knot.

(Liu et al., 1995; Franke, 1982). Kansa (1990a, 1990b) introduced the direct collocation method using RBFs. It is found that RBFs are able to construct an interpolation scheme with favorable properties such as high efficiency, good quality and capability of dealing with scattered data. To approximate derivatives by using RBFs, Shu et al. (2005, 2003) proposed the RBF-DQ method, which combines the differential quadrature (DQ) approximation (Shu et al., 2005) of derivatives and function approximation of RBF. Previous applications (Soleimani et al., 2011a,b,c; Soleimani et al., 2010; Jalaal et al., 2011; Bararnia et al., 2010) showed that RBF-DQ is an efficient method to linear and nonlinear PDEs and proved that, the local RBF-DQ method is very flexible, simple in code writing and it can be easily applied to linear and nonlinear problems. In this method the problem of ill-conditioned global matrix has been removed by replacement of global solvers by block partitioning schemes (Local RBF-DQ) for large simulation problems as shown in Fig. 1.

In practical terms, ANN are essentially computer programs that can automatically find nonlinear relationships and patterns in data without any pre-defined model form or domain knowledge. Today, the application of ANN in the engineering world is well known to engineering sciences (Azadi et al., 2013; Mahdevari and Torabi, 2012; Gajewski et al., 2013; Farrokhzad et al., 2011; Choobbasti et al., 2011a,b). These ANN transfer the latent knowledge or laws in the related inputs to the network's site by processing the inputs and in fact they include general laws based on the calculations performed on the numerical inputs or examples. Among the applications of ANN in seismic geotechnical engineering, we can mention the studies conducted respect of soils' dynamical analysis (Kamatchi et al., 2010), dissipation of seismic waves (Ziemian, 2003). Baziar and Jafarian (2007) explored the possibility of using ANN to Assessment of liquefaction triggering using strain energy concept. Cha et al. (2011) developed ANN to prediction of maximum wave-induced liquefaction in porous seabed.

Nowadays, optimization play an important role in many industrial procedures (Soleimani et al., 2011a,b,c). Considering the increase in cost of industrial products along with shortage pure material, the importance of optimization is now more pronounced. PSOA belongs to a class of stochastic algorithms for global optimization and its main advantages are the easily parallelization and simplicity. PSOA has very deep intelligent background and it is suitable for science computation and general engineering applications. Yuan et al. (2009) have demonstrated PSOA worked on seismic wavelet estimation and gravity anomalies as well. Song et al. (2012) present the application of PSOA to interpret Rayleigh wave dispersion curves.

In this work, the optimum position of a trench layer is obtained in order to minimize the liquefaction potential around a pipeline using the combination of PSOA and ANN based on the obtained results by LRBF-DQ.

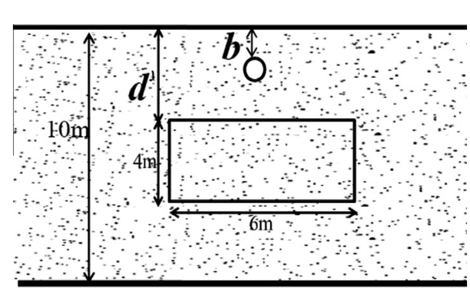

Fig. 2. Physical model of the present investigation.