Prediction of River Pipeline Scour Depth Using Multivariate Adaptive Regression Splines

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Abstract: In this study, the multivariate adaptive regression splines (MARS) technique was applied to estimate scour depth around pipelines. To this purpose, 90 data sets related to effective dimensionless parameters on pipeline scouring phenomena were gathered from literature. A gamma test (GT) was used to define the most-effective parameters on scouring phenomena below pipelines. Performance of MARS model was compared with multilayer perceptron (MLP) neural network and empirical formulas. Results of the GT showed that e/D, τ*, and y/D are the most important parameters for scour depth. Results of MARS model with coefficient of determination (0.91) and root-mean square error (0.05) indicated that this model has suitable performance for predicting scour depth under pipelines and results of this model are more accurate compared to empirical formulas. Comparing results of MARS model and MLP showed that accuracy of MARS model is slightly lower than that of the MLP. DOI: 10.1061/(ASCE)PS.1949-1204.0000248. © 2016 American Society of Civil Engineers.

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Introduction

Scouring under pipelines in rivers and oceans is a major hazard that has been discussed in the hydraulic engineering field. Therefore, investigators have studied this phenomenon using experimental and numerical approaches (Çevik and Yüksel 1999; Yang et al. 2012; Yasa 2011). Pipelines are important structures used to convey water, oil, and gas. They pass through various obstacles in their path such as rivers and trenches etc. (Liu 2003; Whitehouse 1998). Scouring overall is a complex phenomenon due to interaction of flow, structure, and sediment of a river bed. Several hydraulic and sediment parameters as well as the pipeline’s geometry interact in scouring phenomenon around pipelines in rivers (Najafzadeh et al. 2014). Fig. 1 shows the scouring process under pipelines and summarized the influencing parameters.

As seen in Fig. 1, depth and velocity of flow as aspects of flow properties, external diameter of pipeline as a reflection of the structure’s geometry, and material of river bed sediment all influence scour depth below the pipelines (Azamathulla and Mohd. Yussoff 2013; Azamathulla et al. 2014). Other parameters are effective as well, which are collected in Eq. (1)

\[ d_s = f(U, y, \rho, \rho_s, \mu, S_0, B, d_{50}, D, e, g) \]  

where \( U \) = mean velocity of flow; \( y \) = depth of flow; \( \rho \) = density of flow; \( \rho_s \) = density of sediment; \( \mu \) = dynamic viscosity; \( S_0 \) = longitudinal slope of river; \( B \) = width of river; \( d_{50} \) = mean diameter of material sediment of river bed; \( D \) = external diameter of pipeline; \( e \) = initial distance between pipeline and undisturbed bed; and \( g \) = acceleration due to gravity (Najafzadeh et al. 2014). Hydraulic engineers have conducted extensive studies on scouring phenomena around pipelines to define the most-effective parameters. Maximum depth of scour happens when the interaction of the flow, pipeline, and river bed materials reach equilibrium (Cao et al. 2015; Yang et al. 2012). In most studies, regarding Eq. (1) and using Buckingham’s theorem, investigators tried to present dimensionless parameters as Eq. (2) and studied the effect of these dimensionless parameters on scour depth below pipelines

\[ \frac{d_s}{D} = f\left( F, R, \tau^*, \frac{y}{D}, \frac{e}{D}, \frac{S_0}{B}, \frac{y}{D} \right) \]  

where \( F = U/\sqrt{g y} \) is Froude number; \( R = U D/v \) is Reynolds number; and \( \tau^* = u_0^2/g (\frac{D}{2} - 1)d_{50} \) is nondimensional Shields parameter (Azamathulla and Ghani 2011; Azamathulla and Mohd. Yusoff 2013; Azamathulla and Ghani 2010; Luan et al. 2015). Since flow in most natural streams is fully turbulent, during experiments, investigators have not recorded the effect of variation of \( R \) on scouring phenomena. Moncada and Aguirre-Pe (1999) stated that for wide rivers, the effect of \( y/B \) on scour depth could be negligible and mentioned that variation of bed slope during scouring is rare. Therefore, this parameter can be assumed as constant. Thus, it has no obvious effect on scour depth. During pipeline projects, especially in practical works, engineers have attempted to place pipelines in tangent to the river bed due to reduction of drag force and increase of stability; therefore, the effect of \( e/D \) could be disregarded, and in most studies, it was reported to be equal to zero. Regarding these mentioned points, researchers proposed the most influential parameters as Eq. (3). This equation is also used for modeling scour depth below pipelines under clear-water conditions

\[ \frac{d_s}{D} = f\left( \frac{e}{D}, \frac{D}{d_{50}}, \frac{y}{D}, \tau^*, F \right) \]  

Regarding Eq. (3), several empirical formulas have been proposed for calculating depth of scour under pipelines that pass across rivers. Moncada and Aguirre-Pe (1999) proposed Eqs. (4) and (5) for calculating the scour depth under pipelines, respectively

\[ \frac{d_s}{D} = 0.9 \tan (1.4F) + 0.55 \]  
\[ \frac{d_s}{D} = 2 \sec h (1.7 \frac{e}{D}) \]