NUMERICAL EVALUATION OF THE STRIKE SLIP FAULT EFFECTS ON THE STEEL BURIED PIPELINES

Mohsen DAVOODI MOGHADDAM
M.Sc. Student, The University of Kashan, Kashan, Iran
Mohsendm67@gmail.com

Hossein TAHGHIGHI
Assistant Professor, The University of Kashan, Kashan, Iran
Tahghighi@kashanu.ac.ir

Keywords: Buried Pipeline, Fault Motion, Strike Slip Fault, Nonlinear Response

Pipelines are often referred as “lifelines” indicating that they play an important role in human’s life. Due to huge length and wide geographical distribution of pipelines, they are subjected to more seismic hazards. Buried steel pipelines with continuous joints are commonly used for transporting oil, gas and water over long distances. Such a pipeline crossing an active fault zone may be subjected to large, abrupt differential ground movement due to the fault rupture. Based on the damage mechanism of buried pipelines, seismic effects can be either caused by transient strain and curvature in the ground due to traveling wave effects or caused by permanent ground deformations; such as fault deformation, landslide, and liquefaction-induced soil movements. Among them, the ground movements of active faults can have the most severe earthquake effects on buried pipelines (e.g. ALA, 2005; Karamitros et al., 2007; Vazouras et al., 2010; Joshi et al., 2011; etc.).

In this paper the effects due to difference in ground motion from surface faulting has been studied using 3D finite element method and Winkler model as well. The structural response of steel pipelines under strike-slip fault movement is examined numerically using the general purpose FE program ABAQUS. The pipeline is embedded in an elongated soil prism. Four-node reduced-integration shell elements (type S4R) are employed for modeling the cylindrical pipeline segment, and eight-node reduced-integration ‘‘brick’’ elements (C3D8R) are used to simulate the surrounding soil in 3D FEM. Soil–pipeline interaction is modeled rigorously through FEM which account for large strains and displacements, nonlinear material behavior and special conditions of contact and friction on the soil–pipe interface. The Winkler pipe model is also applied using 3D elastic-plastic beam elements (type B31) orientated along the pipe longitudinal axis. The surrounding soil medium was modeled as discrete elasto-plastic springs in the axial, lateral and vertical (up/down) directions. Steel pipe material and the physical parameters of soil are shown in Tables 1 and 2 respectively.

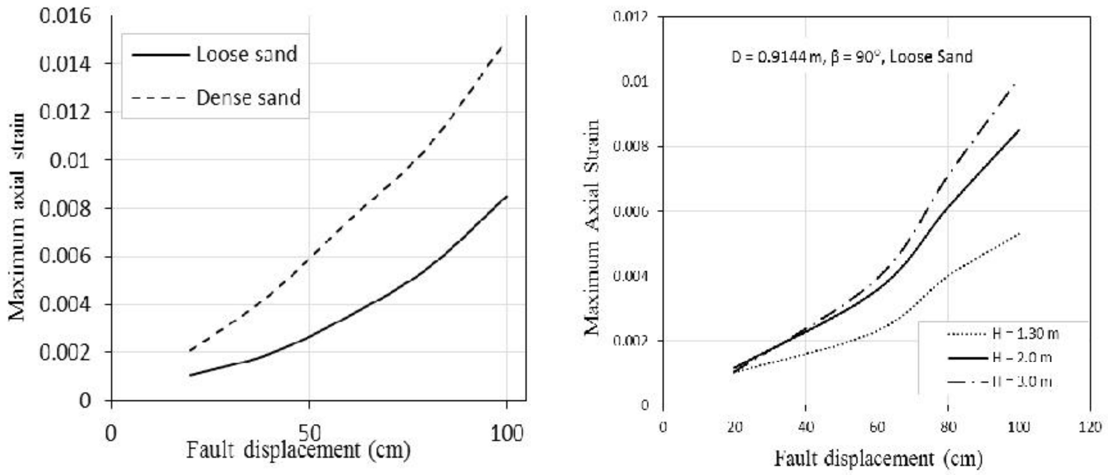
The nonlinear seismic response of buried pipeline under permanent ground deformation is analyzed using pseudo-static analysis method without considering the fracture of the soil. Some influential factors, such as fault-pipeline crossing angle, pipe diameter and its wall thickness, backfill type and burial depth are considered in the analysis in order to draw some regular conclusions. In Figure 1, the simulated 3D FEM results for the two representative factors have been compared. Figure 1a shows the effect of backfill type (i.e. Loose and dense sand) on maximum total axial strain in the pipeline at various fault offset magnitudes. It can be seen that while density increases with increasing hardness of the soil, amount of axial strain in the pipe increases. As shown in Figure 1b, an increase in burial depth results in higher maximum strain for a constant magnitude of fault displacement. Thus, burial depth as shallow as possible is preferable in the fault crossing zone. Furthermore, the other obtained results show that the decrease in fault displacement, increase in the pipe thickness, and increase in the diameter of the pipe and pipe-fault orientation angle decrease the response of the pipe and will lead to reduce damage to pipes. It was also concluded that the use of Winkler model may not be sufficient for proper pipeline seismic design and may lead to over-simplistic results.

Table 1. Properties of AP15L-X 65 pipe

Yield stress (σ_1)	490 MPa
Failure stress (σ_2)	531 GPa
Failure strain (ε_2)	4.0%
Elastic Young's modulus (E_1)	210 GPa
Yield strain ($\varepsilon_1 = \sigma_1/E_1$)	0.233%
Plastic Young's modulus ($E_2 = (\sigma_2 - \sigma_1)/(\varepsilon_2 - \varepsilon_1)$	1.088 GPa

Table 2. Physical parameters of the soil

Type	Density ρ (Kg/m^3)	Elastic Young's modulus (MPa)	Friction angle Φ (°)	Poisson's ratio υ
Sand I	1850	8	30	0.3
Sand II	2100	50	40	0.3



(a) (b)

Figure 1. Maximum axial strain in the pipeline versus fault displacement due to the effects of (a) backfill type and (b) burial depth

REFERENCES

American Lifelines Alliance- ASCE (2001) Guidelines for the Design of Buried Steel Pipe, (with addenda through February 2005)

Joshi S, Prashant A, Deb A and Jain SK (2011) Analysis of buried pipelines subjected to reverse fault motion, Soil Dynamics and *Earthquake Engineering*, 31: 930–940

*Karam*itros DK, Bouckovalas GD and Kouretzis GP (2007) Stress analysis of buried steel pipelines at strike-slip fault crossings, *Soil Dynamics and Earthquake Engineering*, 27: 200–211

Vazouras P, Karamanson S and Dakoulas P (2010) Finite element analysis of buried steel pipelines under strike-slip fault displacement, *Soil Dynamics and Earthquake Engineering*, 30: 1361 –1376

Vazouras P, Karamanson S and Dakoulas P (2012) Mechanical behavior of buried steel pipes crossing active strike-slip faults, *Soil Dynamics and Earthquake Engineering*, 41: 164 –180