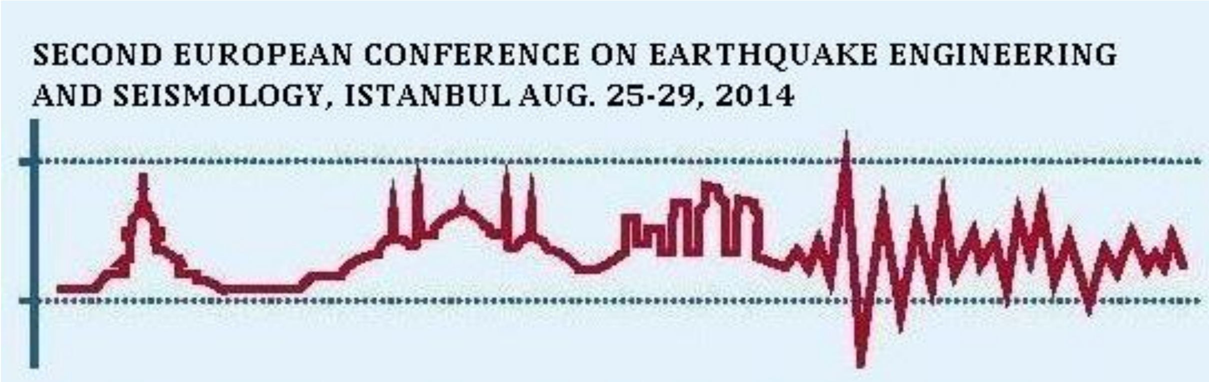

SOIL EFFECT ON RESPONSE OF BURIED STEEL PIPES AT STRIKE-SLIP FAULT CROSSINGS

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Buried steel pipes are commonly used in industry for transmitting oil and gas from the sources to the end points. High quality steel pipes with welded joints are usually preferred in oil and gas industry. There are two main ground hazard parameters for buried segmented and continuous pipes to estimate the pipe damage; a) wave propagation (WP), b) permanent ground deformation (PGD). For high quality and high strength continuous pipes, the strains associated with transient waves (WP) are much smaller than the strain limits of such pipes. Therefore, the results from WP-based analyses do not have much practical meaning from the designer's point of view. Critical conditions for such pipes occur when the pipes are in PGD zones and subject to critical ground hazard such as liquefaction-induced lateral spreading; landslides; road, river and fault crossings (O'Rourke 2014, NATO-SfP 2013). Among these, the fault crossing is considered as one of the most important extreme events for buried pipes since the axial strains can reach to very high levels as a result of excessive bending and axial elongation due to stretching due to static fault offset (fault movement) (Vazouras et al. 2012, Takada et al. 2001).

Past earthquakes (1999 Kocaeli earthquake, Turkey; 1999 Chi-Chi earthquake, Taiwan) revealed the fact that the strain demand on pipes crossing active faults may be quite extreme due to relative movement of the fault with respect to the pipe axis (Takada et al. 2001). When a continuous pipe is subjected to permanent ground deformation due to fault rupture, the damage pattern depends on the type of the fault and type, material and geometric properties of the pipe. Pipes with high D/t ratios and low internal pressure are usually more vulnerable than the pipes with low D/t ratios, where D and t are the diameter and thickness of the pipe, respectively (Vazouras et al. 2010, Vazouras et al. 2012). During the 1999 Kocaeli Earthquake, a welded steel water transmission pipe with large diameter was wrinkled due to local buckling at the fault crossing in the city of Kocaeli in Turkey (Fig. 1) (Takada et al. 2001, Suzuki 2002, Bilham et al. 2003, Durukal and Erdik 2008). Liquefied natural gas (LNG) pipes with low D/t ratios and high pressure may suffer from bulging due to buckling or tension failures. The failure of a LNG pipeline can cause human loss, disruption of energy, environmental pollution and may have a cascading effect on the overall system.

The limit states for buried steel pipes are: a) the maximum tensile strain, b) local buckling due to axial compressive strain (critical buckling strain), and c) distortion of pipeline cross section (Vazouras et al. 2010). The amount of the strain depends on the type and orientation of the fault with respect to the pipe axis, geometric and material properties of the pipe (steel grade, pipe diameter and

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thickness), burial depth (deep or shallow), and the properties of the surrounding soil (Vazouras et al. 2010, Karamitros et al. 2011).

This paper presents a simplified numerical model to investigate the effect of soil nonlinearity on the seismic demand on steel pipes at strike-slip fault crossings. Soft and stiff clays are selected as soil types. Two steel pipes with different geometric and material properties are used. Critical length of the pipeline, L_{cr}, and strain demand on compression and tension sides of the pipes are selected as the major response parameters. Large displacement analyses are verified on a benchmark problem. The analyses are carried out assuming linear/nonlinear soil behavior and the results are compared. The analyses results indicate that soil nonlinearity reduces the seismic demand on steel pipes.

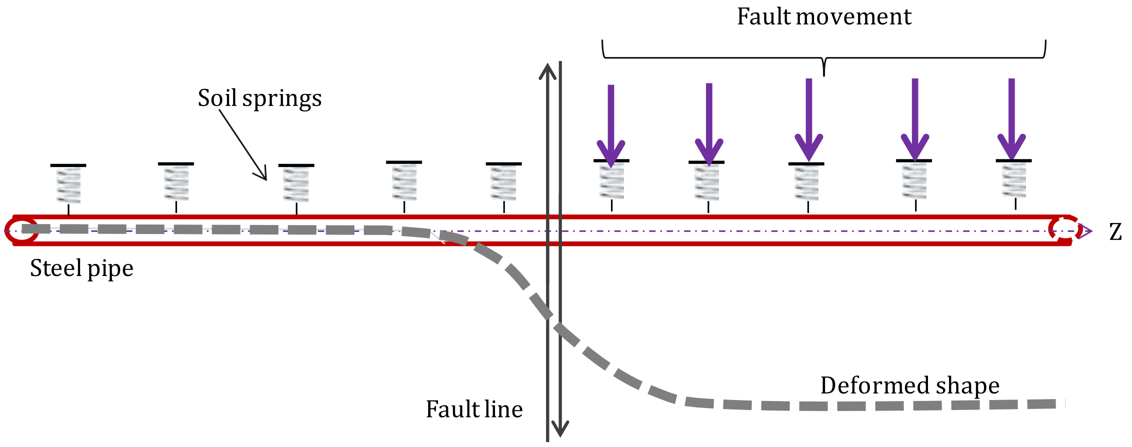

Figure 1. A plan view of the simple model representing pipe behavior under prescribed fault movement perpendicular to the pipe axis (Z axis)

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