

Summary of Comments on nhessd-1-389-2013print.pdf

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Number: 1 Author: Subject: Highlight

^{The} abstract reads more like an introduction. Please go through this and add more quantitative facts as to data used, methods applied, and conclusions.

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Each of these sentences needs references. Please go through here, and the rest of the paper, and add references as appropriate whenever 'facts' are given.

End of this paragraph, please change "should be carefully examined" to "is examined in this paper" so it is clear to reader the subject of this paper.

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Unclear language. Was this carried out by you, or by Wang and Cheng (1979). If by you, then please state "was carried out here". If by Wang and Chang, then start the sentence with "Wang and Chang (1979) carried out a simplified ...". "They found that the behavior..."

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^BBecause of the way you have written this paragraph, it is difficult to follow who did what.

Perhaps you could try the sentences something like the following:

(a) Start the paragraph with something like, "There have been a number of studies related to buried pipelines. For example, Wang and Cheng (1979) performed a simplified quasi-..." "They found..." In another study, Takada and Tanabe 91987) found... A third study by O'Rourke and Liu (199) found that...

This might make it easier for the reader to separate out the studies, paragraph by paragraph.

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been developed (Takada and Tanabe, 1987). The wave propagation hazard for a particular site is characterized by the peak ground motion parameters as well as the appropriate propagation velocities. The ground strain and curvature due to wave propagation were analyzed and the influence of various subsurface conditions on ground strain was

- discussed (O'Rourke and Liu, 1999). Transient ground strains are recognized to govern the response of buried elongated structures, such as pipelines and tunnels, under seismic wave propagation. The shear strain and the longitudinal strain variability with depth were investigated through qualitative examples and comparisons with analytical formulas (Scandella and Paolucci, 2010). In Korea, earthquake time-history analyses
- were performed for a buried gas pipeline using various parameters such as the type of buried gas pipeline, end restrain conditions, soil characteristics, single and multiple earthquake input ground motions, and burial depths (Lee et al., 2009).

Buried pipeline damage correlations are a critical component of loss estimation procedures applied to lifelines expected to experience future earthquakes. Buried

- pipelines are damaged by transient ground motions and permanent ground deformation. Pipeline damage induced by wave propagation for relatively flexible pipe materials was found to be somewhat less than damage of relatively brittle material (O'Rourke and Ayala, 1993). Permanent ground deformation and its effect on pipelines has been extensively investigated (O'Rourke et al., 1998), especially in countries of high seis-
- micity. During representative earthquakes, including the Loma Prieta earthquake in 1989, buried pipelines were damaged mostly in landfill areas by means of joint pullout failures and pipeline cracking. In addition to these damage patterns, artificial connections between relatively rigid pipelines and largely deformable plastic pipe experienced damage during the Kobe earthquake in 1995. Trunk pipeline damage and cracks in
- the axial direction of concrete pipelines were assessed. Pipeline repair rates following the 1994 Northridge earthquake were evaluated and explained (Jeon, 2002; Jeon and O'Rourke, 2005).

Seismic fragility analysis of underground polyvinyl chloride (PVC) pipelines was performed and demonstrated that there was no significant difference between the analyses

results and the empirical equation used by HAZUS (Hazard in US), earthquake loss estimation software developed by the Federal Emergency Management Agency (Shih and Chang, 2006). Pipeline damage was estimated for each damage relationship and earthquake scenario. The results show that the variation in ductile pipeline damage es-

- timations by various relationships was higher than the variation in brittle pipeline damage estimations for a particular scenario earthquake (Toprak and Taskin, 2007). A new seismic intensity parameter utilizing peak ground velocity (PGV) and peak ground acceleration (PGA) to estimate damage in buried pipelines due to seismic wave propagation was proposed (Pineda-Porras and Ordaz, 2007).
- The probability of system serviceability was estimated as the ratio of the number of networks that were found to be serviceable to the sample size used for simulation. The water transmission network was adopted and analyzed to serve as a numerical example demonstrating how to assess the probabilities of system unserviceability under a set of assumed parameter values deemed reasonable (Tan and Chen, 1987). A decision support system for the management of geotechnical and environmental risks in oil pipelines was developed using GIS (Filho et al., 2010).

Historical data and recorded data sets after 1905 show that Korea is in a zone of low to medium seismicity but it has a high frequency of earthquake occurrences. In this study, pipelines were classified by their mechanical properties followed by a numerical analysis which examined the behavior of the buried pipelines constructed by the design criteria and construction specifications of Korea and the US. The analysis considered seismic parameters including PGA achieved from previous earthquake records, pipeline types, and in-situ ground conditions.

2 Repair rate of pipelines

The damages of water pipelines in HAZUS were assessed by historical data of pipeline repairs from previous earthquakes. As shown in Fig. 1, the algorithm of 2R for brittle and ductile pipelines in HAZUS was developed by O'Rourke and Ayala (1993). They

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Please add a paragraph to this section. "This paper is organized as follows. First, the repair rate of pipelines is examined by... (Section 2). Then, ... (Section 3)."

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developed the empirical relationship of RR with peak ground velocity (PPV) based on the damage reports of the pipelines from previous earthquakes (FEMA, 1999).

Since the mechanical characteristics of pipelines, design criteria, and construction specifications of both Korea and the US are very similar, the pipeline damages induced

by seismic loadings in Korea has been predicted by repair rate (pipeline repairs/pipeline length (km)), RR, suggested in HAZUS. As the seismic loading was applied to buried pipelines constructed based on the design criteria and construction specifications in Korea and the US, the mobilized stresses and strain rates of pipelines were examined and compared.

As listed in Table 1, buried utilities in Korea, including water, gas, and communication pipelines, were classified into two categories; ductile and brittle (Ministry of Environment, 2010a, b).

3 Design criteria and construction specifications

The burial depth, the backfill compaction ratio, and the diameter and thickness of pipelines listed on the construction specifications were used in a numerical analysis 15 to examine the dynamic behavior of pipelines as seismic loading was applied.

3.1 Korea

As listed in Table 2, the burial depths, considering traffic loading, should be greater than 1.2 and 1.5 m for the 900- and 1000-mm diameter pipelines, respectively (Ministry

of Land, Transport, and Maritime Affairs, 2010). 1 he burial depth for large diameter pipelines should be greater than their diameter but, in the case that a burial depth of 1.2 m is not available due to spatial constraints associated with adjacent underground structures, the burial depth can be reduced to 0.6 m with permission from the officer in charge of roadway management.

3.2 The US

Table 3 lists the specifications for the burial depth of pipelines with respect to construction sites where there are no special conditions (Office of Pipeline Safety Community (OPS), 2010). Pipeline burial depth should be greater than the frozen ground depth or

frost line. High guality soil is used as backfill material for buried pipelines. Each layer of backfill should have a thickness less than 0.3 m and a compaction ratio of greater than 90%. At important construction sites, the water content of backfill materials should be around the optimum water content and at most 0.2-m lifts with high compaction ratios are required. Sands used as trench backfill material should have a high compaction 10 ratio with moisture near the optimum water content and the use of soil lifts is recommended.

2 ft thickness of 20 to 50% of the minimum diameter of a pipeline are required in Korea. A lift thickness corresponding to one-eighth of the minimum diameter of the pipeline or 100 mm is required in the US.

4 Evaluating dynamic behavior of the pipeline using numerical analysis

In this study, a numerical analysis using the commercial finite element software ABAQUS (2006) was carried out to analyze the dynamic behavior of pipelines subjected to seismic loading3 The analyses results show the strain rates and stresses of buried pipelines constructed by the design criteria and construction specifications sug-

- gested by both Korea and the US. The applied seismic loadings were generated from 20 real PGV time records measured at strong motion stations (SMSs) No. 24436 and CHY080 for the 4994 Northridge and 1999 Chi-Chi earthquakes, respectively. Figures 2 and 3 show the measured PGV time records of Northridge and Chi-Chi earthquakes, respectively (COSMOS, 2010). In addition to these, the virtual values of various PGAs,
- such as 0.2, 0.4, 0.6, 0.8, 1.0, and 1.2 g, at a period of 0.5 s and earthquake duration of 10 s were applied as seismic loadings.

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This is an example of a sentence with 'facts' but no reference.

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These two sentences are each examples of sentences with facts, but no references. Please go through ALL sentences

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and check they have appropriate citations.

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After this first sentence, tell the reader how the section will be organized. Or, do it at the end of this first paragraph. "Numerical modeling will first be examined (Section 4.1), followed by"

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"1994 Northridge (*M* = *.*) and 1999 (*M* = *.*) earthquakes"

4.1 1 umerical modeling

The numerical analyses for brittle and ductile pipelines greater than 1000-mm diameter and constructed based on the design criteria and construction specifications of both Korea and the US were carried out. Since a compaction ratio of 90 % for backfill mate-

rials is required in both countries, dense sand soil properties were used. The analyses were performed considering various in-situ ground conditions such as clay, loose sand, medium dense sand, dense sand, and sand with gravels. In Korea, the diameter and thickness of the brittle and ductile pipelines used in the analyses were 1050 and 75 mm and 1130 and 16 mm, respectively. For the US, these values were 1058 and 75 mm and 1144 and 16 mm, respectively.

Figures 4 and 5 show the configuration and finite difference meshes of numerical analysis associated with pipeline, ground conditions, and boundary conditions. The figure shows an in-situ ground depth of 30.5 m with a width of 120 m. No horizontal displacements are allowed at the left and right sides and no horizontal nor vertical

displacements are allowed at the bottom. In Korea and the US, pipeline cover depths (h_{B1}) of 1.5 m and 0.9 m and thickness of bedding beneath pipelines (h_{B2}) of 0.25 m and 0.15 m, respectively, were used in numerical analysis. Tables 4 and 5 list the mechanical properties of the soils and pipelines, respectively.

2 Dynamic behavior of the pipeline

20 4.2.1 Ductile pipeline

Figure 6 shows the maximum mobilized stress for ductile pipeline subjected to various ground conditions. As shown in the figure, the mobilized stress in pipelines linearly increases as PGA increases and ground stiffness decreases. The mobilized stress of pipelines in Korea relative to the US is slightly smaller. Differences mobilized along the pipelines range from 4.7 to 11.3 %, 4.7 to 11.8 %, 4.7 to 10.1 %, 2.6 to 11.7 %, and 3.9

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to 10.7 % for in-situ ground conditions of clay, loose sand, medium dense sand, dense sand, and dense sand with gravels, respectively.

Figure 7 shows the maximum strain mobilized on ductile pipelines for various ground conditions. As shown in the figure, the strain rate mobilized along the pipelines in-

⁵ creases as PGA increases and ground stiffness decreases. The strain rate of pipeline in Korea relative to the US is slightly higher. The strain rates differ from 6.4 to 8.9%, 7.4 to 9.8%, 4.8 to 9.7%, 3.5 to 9.1%, and 4.5 to 8.8% for in-situ ground conditions of clay, loose sand, medium dense sand, dense sand, and dense sand with gravels, respectively. As the seismic loadings of Northridge and Chi-Chi earthquakes were applied, the mobilized pipeline strains were 1.9 and 4.5%, respectively.

4.2.2 Brittle pipeline

Figure 8 shows the maximum mobilized stress for brittle pipeline subjected to various ground conditions. As shown in the figure, stresses in pipelines linearly increases as PGA increases and ground stiffness decreases. The mobilized stress of pipelines in Ko-

- rea, relative to the US, is slightly smaller. Stress differences mobilized along pipelines range from 4.2 to 9.3%, 4.4 to 9.3%, 4.7 to 7.8%, 4.7 to 9.1%, and 4.9 to 8.2% for in-situ ground conditions of clay, loose sand, medium dense sand, dense sand, and dense sand with gravels, respectively.
- Figure 9 shows the maximum mobilized strain for brittle pipeline subjected to various ground conditions. As shown in the figure, strain rates mobilized along pipeline increases as the PGA increases and ground stiffness decreases. Pipeline strain rate in Korea relative to the US is smaller. Strain differences mobilized along pipelines range from 3.8 to 8.5%, 3.0 to 9.9%, 2.8 to 8.9%, 2.2 to 9.9%, and 4.5 to 9.8% for in-situ ground conditions of clay, loose sand, medium dense sand, dense sand, and dense
- sand with gravels, respectively. As the seismic loadings of Northridge and Chi-Chi earthquakes were applied, the generated strains were 6.5 and 3.8 %, respectively. Tables 6 and 7 present the differences of the strain and strains applied by using the strain and strains.

Tables 6 and 7 present the differences of the strain and stress, calculated by using Eqs. (1) and (2), respectively.

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With your numerical modelling, I do not get a feeling for how much uncertainty there is, as the diameter and thickness are varied. Is there any way to give some feeling of uncertainty for if you vary one item, how much the results in Figures 4 and 5 might change, and/or how much these will effect later measurements and discussions further down? I think this is the part of the paper I am least convinced by, in terms of sensitivity analysis of the outcomes to the starting parameters.

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Related comment as previously, but now regarding Figures 6-9. Is there anyway to put some sort of 'error bars' in the x- or y-directions of Figure 6 to 9, so the reader has some idea of how much values might vary by due to inherent errors in the variables?

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Table 3. Minimum	embedded	depth for	^b uried	pipeline	(Office	of Pipeline	Safety	Community
(OPS), 2010).								

Location	Embedded depth for normal excavation (mm)
Industrial and Residential Areas	914
30-m width stream	1219
Public roadway and railway ditch	914
Port areas in deep water	1219
<u>Mexico</u> Bay and water depth (ebb tide) ≤ 4.6 m	914
1 ater depth (ebb tide) $\leq 3.6 \text{m}$	914
Other areas	762

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Table 4. Mechanical characteristics of soils used in numerical analysis.

Soil types	γ <mark>2</mark> Νm ^{−3})	E (MPa)	v	c (kPa)	φ (°)
Clay	15	5	0.35	10	20
Loose sand	19	15	0.3	0	25
Medium dense sand	19	25	0.3	0	28
Dense sand	19	45	0.3	0	30
Dense sand and gravel	20	120	0.25	0	35

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Make beginnir	ng of each line uppercase?	
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Ensure there is really a "space' between units.

Pipeline	Soil/PGA (g)	0.2	0.4	0.6	0.8	1.0	1.2	Avg ^a	SD^{b}
Ductile	Clay	11.3	8.8	5.2	7.2	5.7	4.7	7.2	2.53
Pipe	Loose sand	11.8	9.7	7.1	5.9	4.9	4.7	7.3	2.84
	Medium dense sand	10.1	7.9	9.3	5.9	6.3	4.7	7.4	2.10
	Dense sand	11.7	9.2	4.1	5.9	2.9	2.6	6.1	3.69
	Dense sand and gravel	10.7	4.6	5.9	5.4	6.1	3.9	6.1	2.39
Brittle	Clay	8.0	9.3	7.2	7.5	5.6	4.2	7.0	1.82
Pipe	Loose sand	7.2	9.3	6.4	6.6	5.1	4.4	6.5	1.73
	Medium dense sand	7.8	6.1	6.3	6.4	4.8	4.7	6.0	1.15
	Dense sand	7.0	9.1	8.0	6.5	6.8	4.7	7.0	1.49
	Dense sand and gravel	6.9	7.5	8.2	4.9	6.7	7.1	6.9	1.08

 $\label{eq:table_$

^a Avg: Average; ^b SD: Standard Deviation.

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1g. 1, Fragfing du Freedingunger pibellines provided by 2 ad USHAEMA, (FBOD), 1999)

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(a) In tables and text, your units are "s" not "sec".
(b) In tables and text you use cm s^-1 not cm/sec.

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Add to end of sentence "with the repair rate (RR) given as a function of the peak ground velocity (PGV)."



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Fig. 2. Histoly With growing raweleration record During Northidgee earthquaks (COSMOS, 2010).





Fig. 3. History diground sceleration tecord 2 during Chi Chi sathnaka (COSMOS) 2010).

Number: 1Author: Subject: Highlight.:28:56"during the 17 January 1994 Northridge (moment magnitude M_W = 6.7) earthquake"

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Fig. 4. 1 pnfiguration of numerical model associated with pipeline and ground conditions.



Fig. 4. Configuration of numerical model associated with pipeline and ground conditions



2 g. 5. Finite element mesh mantian cation and boundary manditiona for repeating

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^{This} figure caption, and the next one, need to be much more 'self-standing' so the reader can figure out what the figures are without having to do a detailed reading of the text.

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See Fig. 4, and make the figure caption much more complete.

Make sure the difference in this figure for the triangles and circles are clear (remember your audience is both experts in your domain, but also intelligent outsiders in the broader community, so they will not know what the circles/ triangles mean, and they will be unsure of what the scales are here, and what is being represented).



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Fig. 6. Stress of ductile pipeline mobilized by earthquake loadings with respect to peak ground **1g. 6.** Stress of ductile pipeline mobilized by earthquake loadings with respect to peak ground acceleration (PGA) in various in-situ ground conditions.

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See text comments, for Figures 6-9. Is there anyway to add some representation of uncertainty?

I would also expand just a tad the figure captions, if you feel it would help, although these are pretty well done. For example, you could add one sentence, "Values derived from ***** and ***** (see Fig. * and Section. * for further details).