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Seismic Risk of Buried Pipelines

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Abstract. A pipeline is a tubular section or hollow cylinder, usually of circular cross-section, used mainly to convey substances which can flow (fluids). It plays a crucial and essential role in human life and in economic development. The resilience ofthose systems under extreme events as earthquakes is a primary requirement, especially when largeamount of toxic and flammable material is transported.So, the present work will treat the seismic risk on the buried pipelines with respect to the seismic hazard and the vulnerability.

Keywords. Pipelines, Earthquakes, Seismic risk, Seismic hazard, Vulnerability.

INTRODUCTION

Earthquakes are natural phenomena that can be destructive. An earthquake is a vibration of the ground transmitted to the structures caused by a sudden fracture of rocks at depth creating faults in the ground and sometimes on the surface.

The seismic loading cannot be determined strictly too. Available methods of assessment of seismic risk and hazard of defining parameters of seismic action for structural design are based on experience from past earthquakes damages, laboratory and terrain research of specific materials, soil and structures.

Very often in everyday engineering praxis, sometimes even in professional literature, terms seismic risk and seismic hazard are identified although they have quite different meanings in defining earthquake effect as natural phenomenon. After that, seismic risk is defined as the combination between the seismic hazard, the populations subject to it and their vulnerability to this hazard.

The seismic impact on buried pipelines is different from free-field structures. Buried pipelines are exposed to different seismic impacts: wave propagation, fault rupture displacement, soil liquefaction, landslides, soil compaction. Stresses are mainly caused by differential displacement along the pipeline and by soil structure interaction. This is why analysis to assess the seismic risk of buried pipelines is crucial.

ABOUT THE PIPELINE SYSTEM

The majority of pipelines probably will pass through the regions with different (changeable) seismicity because of their length. Earthquakes with magnitude of 7 degrees, or stronger, are possible only on, or near, certain existing faults, in which movements have been manifesting in last 50000 or 100000 years.

Earthquake with magnitude less than 7 degrees can occur in regions where faulting has not been manifested or has not appeared at the ground surface jet and the buried pipelines usually follows soil deformations. While treating the seismic risk in the world; each year, there are more than one hundred and fifty earthquakes of magnitude greater than or equal to 6 (i.e., earthquakes with enough energy to potentially destructive) (Zdravković et al., 2011).

Pipelines are considered to undergo the same movements as surrounding soil, namely equal curve and equal longitudinal deformations. In order this condition to be valid, the soil that surrounds the pipeline has to remain unchanged (for example, if soil stiffness is too much changed, because of liquefaction, thesedeformations have to be taken into account later).

SEISMIC RISK

The risk is distinguished by two distinct ones:

- The hazard is the probability of occurrence of a given event;
- The vulnerability expresses the seriousness of the effects or consequences of the event.

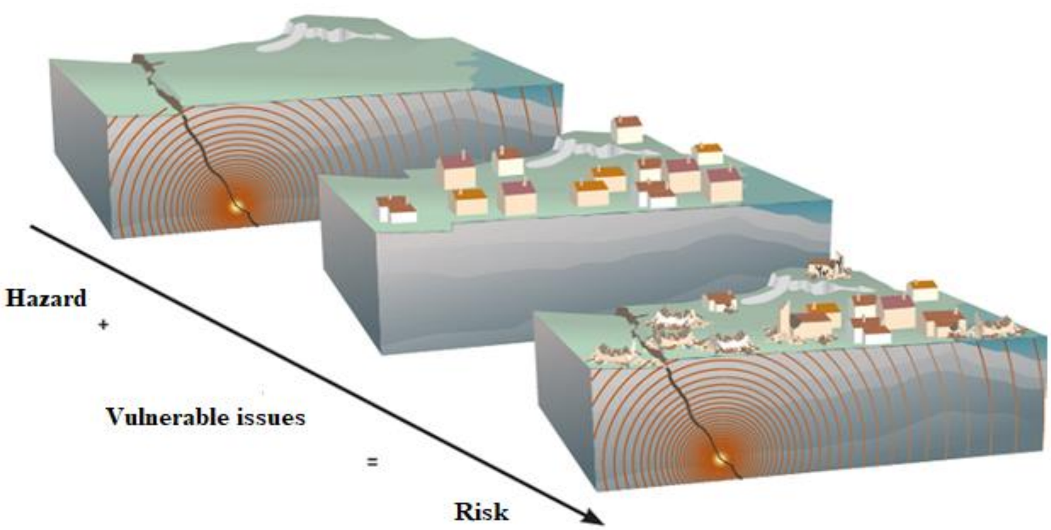

Fig. 1. Schematic representation of the seismic risk.

The seismic risk chain R is the conjunction of a seismic hazard H at a given point and the vulnerability V of the issues (Masrouri and Pantet, 2009).

R = H x V (1) (Masrouri and Pantet, 2009).

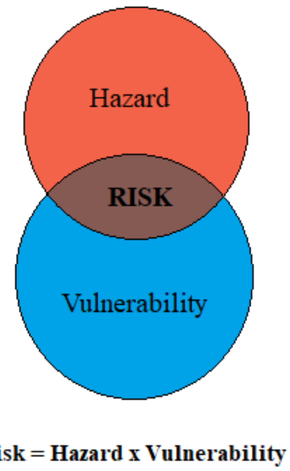

Fig. 2. Theoretical scheme of seismic risk (Masrouri and Pantet, 2009).

Depending on geodynamic, political, social and economic situations, the earthquake risk in the world is very variable, depending on the regions considered. In order to define the seismic risk, seismologists must characterize: the hazard, the stakes, which designate the infrastructures subject to the hazard; vulnerability.
Obviously, the occurrence of an earthquake (hazard) cannot be prevented. There is also no reliable way to predict where, when and how the next earthquake will occur. It arrives without any warning signs and will surprise you in your sleep, at work, or at home. Unlike meteorological risks, no alert is possible! To reduce this risk and to be protected from the consequences of an earthquake, it is therefore essential to reduce the vulnerability, by adopting the right actions and developing a habitat that is as earthquake-resistant as possible.

Seismic hazard

The seismic hazard is defined as the possibility, for a given site, of being exposed to earthquakes of given characteristics in certain time and place (generally expressed by parameters such as acceleration, intensity, response spectrum, etc.).
Evaluating the seismic hazard means estimating the nature, location and extent of these effects which can induce disorders and damage to the installations. To assess this hazard, scientists are sometimes forced to use the marks left in nature by ancient earthquakes.
It is a discipline called paleo seismology, which involves reconstructing the seismological history of a region over the largest possible period of time, often of the order of a thousand or ten thousand years. The seismic hazard determined by instrumental and historical seismology, arche seismology or paleo seismology.
It can be evaluated by a deterministic or probabilistic method, the characteristics are that of a real event, possibly accompanied by a safety margin (historically known strong earthquake, for example). And in the probabilistic approach, all the data allowing the estimation of the hazard are examined in a statistical framework, and the hazard is then expressed as a probability of exceeding a fixed level.

Vulnerability

Based on the post-earthquake observations many empiricalfragility functions have been proposed to quantify seismic induced pipeline damages (Eidinger, 2001; Pineda-Porras and Ordaz, 2007; O'Rourke et al., 2012; Maruyama and Yamazaki, 2010).

Fragility formulations express pipeline damage as a function of seismic intensity parameter (e.g., PGA, PGV, PGV/PGA, and so on) and pipeline characteristics (diameter, material, etc.).

The vulnerability of pipelines is measured by RR (RepairRate) which reflects the number of repairs per kilometer following an earthquake. Thisparameter shows a number of pipe repairs in a given segmentrelated to the length of this segment (Lanzano et al., 2013, 2014, 2015).

The objective of this part is to propose a damage relation of the buried pipes noted RR from the Ground Motion PredictionEquations (GMPE) having for limit of validity the magnitude of moment between 5 and 7.5. In this work, mostcommonly used parameters include peak ground acceleration (PGA), peakground velocity (PGV), modified Mercalli intensity (MMI), peak grounddisplacement (PGD) and ground strainε_g (Wijaya et al., 2019).

Figure 3 gives an overview of the estimates and the arrows refer to the limit of applicability of a given relation, approximated from the knowledge of the dataset from which it comes.

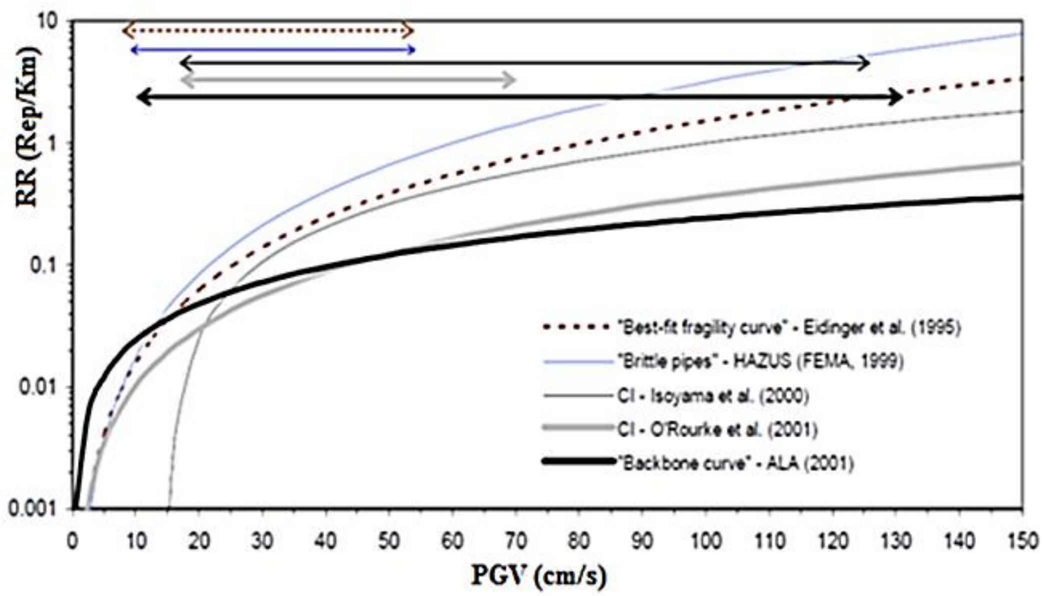

Fig. 3. Repair rates in function of PGV (Tromans, 2004).

The relationship between the damage of buried pipes and the intensity parameters of ground movements has been studied since the mid-1970s. In the literature there is a detailed list concerning the models set up for the determination of the RR in function of the PGV (Table 1, Fig. 4).

Many authors have studied various seismic intensity measures to correlate with the pipe repair rate in developing the seismic demand model. For pipeline infrastructure; the damage/demand is commonly quantified as number of repairs per unit length of pipe (also known as repair rate). The application of seismic risk and reliability analysis is highly crucial given its purpose for minimizing seismic damage, service interruptions and severity when seismic event occurs (Wijaya et al., 2019).

Table 1. The models set up for the determination of the RR of PGV function (Soulimane and Ameur, 2018).

Curve number	Authors (Investigators)	RR= f(PGV)
1	Eidinger et al. (1995)	3.2*10-4*PGV1.98
2	“ALA” Eidinger, J. et al. (2001)	0.00187*PGV
3	“ALA” Eidinger, J. et al. (2001)	0.00108*PGV1.173
4	“ALA” Eidinger, J. et al. (2001)	0.01427+0.001938*PGV
5	Eidinger et autres (1998)	0.0001658*PGV1.98
6	O’Rourke et Ayala (1993)	0.0001*PGV2.25
7	Isoyama et autres (2000)	3.11*10-3*(PGV-15)1.3
8	O’Rourke et autres (2001)	e1.55*ln(PGV)-8.15
9	“ALA” Eidinger, J. et al. (2001)	0.002416*PGV

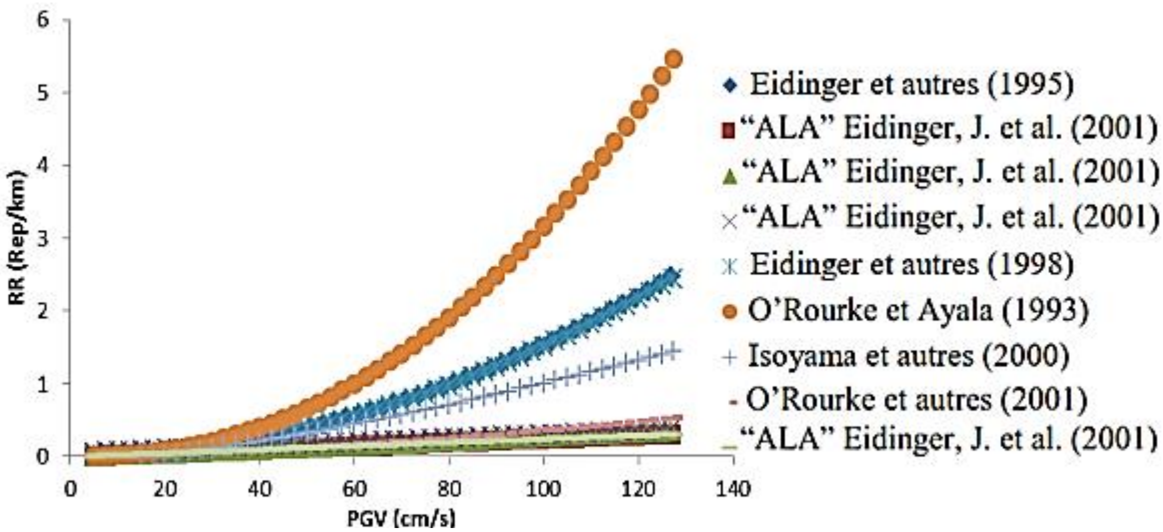

Fig. 4. Determination of the RR of PGVfunction for different authors (Soulimane and Ameur, 2018)

THE PREVENTION STRATEGY OF PIPELINE

Pipeline is one of the critical infrastructures in today civilization and spreads over a large area with varying soil conditions. The failure in pipe network causes significant economy losses to asset owners and environmental impact to the society. Therefore, it is important to ensure the safe operation of a pipe network during its lifetime. In addition, the seismic risk analysis of buried pipelines assesses the risk probability and the impact of an earthquake in a given geographic area. This process is therefore carried out to calculate and, in turn, minimize the risk.

CONCLUSION

Earthquake is a serious natural accident and it is characterized by numerous victims, significant damage, harmful impacts on our environment and whose foreseeable effects exceed the capacities of reaction of the bodies directly concerned.

Since water, oil or gaspipeline systems are a key part of modern development, Pipeline structural analysis is a well-developed topic in engineering and research practice, therefore criteria that are adopted in earthquake resistant design of pipelines have to take into account seismic movements and seismic generated forces that have significantly high probability level of effecting the pipeline as these criteria has to include an acceptable level of seismic hazard. So, it is said that the researchers in earthquake engineering need to take the major risk in the heavy hand to have more and more prevention and to save more lives in the world.

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