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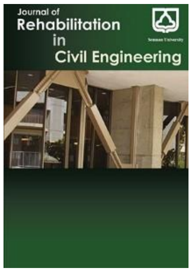

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Determination of Optimal Distance of Anchor-Blocks in Buried Oil Pipelines Considering the Effects of the Dynamic Soil-Pipe Interaction

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ABSTRACT

In this paper, by using direct modeling of the soil-pipe line system using finite element modelling (FEM) in OpenSEES software and integration with the particle swarm optimization (PSO) algorithm which is provided in MATLAB software in the reciprocating method, which is repeated in enough epochs, the optimal intervals of the anchor blocks has been gained and the effect of different parameters of pipe diameter, pipe length, burial depth, different soils and different earthquake stimuli on the seismic behavior of pipes having anchor blocks investigated. The results show that the change in the depth of the burial and the diameter of the pipe has no effect on the anchor block optimal intervals. Also, increasing the length of the pipe will cause to increase the proposed optimal distance between the anchor blocks. The levels of earthquake hazard and soil type, as well as the length of the pipe, are factors affecting on the distance between the anchor blocks. The simultaneous effect of softening the soil and increasing the level of the earthquake hazard increases the distance between the anchor blocks.

1. Introduction

Pipelines are one of the vital and important arteries. Transmission of oil and gas products by pipelines is one of the most appropriate, cheap, fast and reliable methods. In order to protect the pipelines against environmental conditions and to provide the necessary support for pipelines, they are often buried. The behavior of these vital arteries during an

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earthquake is one of the things that require more and more detailed studies. The damages caused by the earthquake on the pipes are direct or indirect. Direct effects such as earthquake-induced vibrations, ground motion at the fault location along the pipe, and ultimately land tectonics rise or fall. Damage due to vibrations caused by the propagation of waves may cause significant tensile stresses that cause breakage or detachment at the joints site or, by creating pressure stresses,cause fracturing or buckling of the pipe. It may also be caused by shear stresses, cracks in the pipes, or failure of joints or pipe failure due to exertion of bending strength. Indirect destructive effects, which are mainly due to the movement of earth mass during an earthquake, causing the permanent (sustained) deformations over the earth include landslide, soil liquefaction, earthquake-induced subsidence,accumulation of deposits with the low density. Reports on the 1997 earthquake in the city of Hizmet in Turkey [1], 1989 Lamapréta earthquake [2], 2001 earthquake in San Salvador [3], 2002 Alaska earthquake [4], 1994 earthquake in Northridge and earthquake in 1971 San Fernando [5] showing the damage to pipelines after earthquakes. In the LomaPrieta earthquake, the major destruction happened in a liquefaction-prone area, such as the San Francisco port area, and seriously damaged the old cast iron pipes and the low-pressure iron pipes of gas distribution system. In the San Francisco, Auckland, Berkeley and Santa Cruz, about 600 failures occurred in water pipes. The Northridge earthquake of magnitude 7.7 caused 1400 fractures in gas, water and fuel pipes in the San Francisco Valley. After the San Fernando earthquake, 80 pipes fracturing were observed in welded underground pipes. One of the effective ways to reduce the seismic hazard in the buried pipelines is the use of anchor blocks. Several studies have been conducted by domestic and foreign researchers about the seismic behavior of buried pipelines and the effects of various earthquakes on these lines.

Some of these studies were related to consideration of the effects of specific earthquakes on pipelines, and the behavior of pipelines against earthquake-induced impacts is considered in other studies.

In 2014, Fallah and Pazouki [6] examined the performance of the buried pipelines under the earthquake and expressed seismic hazards that directly linked to the pipeline failures. The result of this research was about the design considerations of buried pipelines at the fault location. In 2012, Arasto and Effati Daryani [7] described the possible types of seismic hazards on the buried pipelines, and proposed solutions to reduce the severity and extent of the buried pipelines' vulnerability. The results of this paper include consideration of following points to reduce the vulnerability of pipelines against the earthquake-induced forces; using pipes and fittings with the high ductility instead of pipes and brittle fittings, reducing the number of pipe joints due to the concentration of stress on knees and bends, using thick pipelines to prevent local buckling and pressure-related bumping. Brahman et al. [8] expressed the reasons for the need for the seismic assessment of pipelines from the economic, environmental and industrial perspectives in a research report, and provided examples of the damage on pipelines caused by various earthquakes, and finally mentioned the possible modes of failure of the pipes by the earthquake. Manshouri and Bastami [9] examined the behavior and criteria of the seismic design of pipelines with emphasis on gas pipelines as one of the vital arteries. One of the results of this study was that for the buried pipes, in addition to permanent deformation of the earth which some specific relations provided, maximum speed is used to check the pipe against earthquake wave propagation.

Goltabar Roshan and Mahdavi Omran [10] performed modeling to study the effect of soil liquefaction on the pipe.

In 2017 Khodakarami and Khakpour [11] investigated about soil-geogrid-interaction.

In 2018 Ganjavi et al [12] examined soil-structure interaction effects on hysteretic energy demand for stiffness degrading systems built on flexible soil sites.

In 2019 Ganjavi and Rezagholilou [13] investigated the seismic evaluation of flexible-base low rise steel frames.

Hazarian [14], while investigating the seismic evaluation of buried pipelines under the maximum velocity parameter of the earth and providing computational formulas in this regard, obtained results such that the temporal strains created on the ground has a direct relationship with the maximum velocity of the earth. The seismic response of underground pipelines was investigated by Hindi and Novak [15,16].

Newmark [17] presented a simple method to diagnose and determine the pipeline response due to the release of earthquake waves, which later was developed other researchers. This method is based on the assumption that the pipe and the soil are not slipping, in other words, it is equal to know the strain of the ground and the pipe. In the following, Sakura and Takahashi [18] developed a simple analytical method for a direct pipeline surrounded by an extremely elastic soil. Quiche and Shinozuka [19], corrected the equation presented by Takahashi, and provided a conversion factor (β_0) between the strain of the ground and the strain of the pipe for a state which there is no sliding between the pipe and the soil in the interface, i.e., the elastic soil springs are left. In this regard, El hemdy and Orurkeh [20] used another method to estimate the maximum axial strain created in a continuous pipeline due to the propagation of waves, they modeled the soil resistance in the direction of axial movement of the pipeline by a linear spring with a hardness.

Data et al. [21] according to the theory of crust, taking into account axial symmetry, carried out a three-dimensional analysis of buried pipe to determine the dynamic response of the pipeline in contact with compressive waves propagating through the pipeline.

Anchor block functions in pipelines is to prevent axial deformation along pipelines, prevent pipe rotation and movement due to friction strength between the pipeline and anchor block, pressure transfer from pipe to soil, resistance to the pressure and tensile strength and elongation the life of the pipelines [22].

Despite the extensive research carried out on buried pipelines, unfortunately, no research has been done to optimize the distance between anchor blocks in buried pipelines. Since Iran is a country of oil and seismicity, and the pipelines are too large, these lines are affected by waves during the earthquake. On the other hand, pipelines are considered as vital arteries, where damage to them during the earthquake has severe consequences, and on the other hand, one of the parameters that are affected by the earthquake is the longitudinal strain and pipeline stress that is depending on intervals of anchor blocks, Therefore, the set of factors mentioned above, as well as the fact that so far the method that can automatically control tensions and strains of pipelines and suggest the optimal distance is not done, it is necessary to carry out an investigation in which the optimum distance between the anchor blocks is determined. Ghods and Khodakarami [23] investigated the impact of the gap between the anchor blocks on buried pipelines. The results showed that the change in intervals of anchor blocks and the level of the risk of earthquakes produced a significant difference in the amount of strain of the pipeline. In 2009 Al-Gahtani [24] presented a simple procedure for the optimum design of a pipeline block anchor. Yan Y et al. [25] in 2016 was analyzed a single-slope tunnel pipeline considering the effects of vertical earth pressure, horizontal soil pressure, inner pressure, thermal expansion force and pipeline—soil friction. Considering the deformation compatibility condition of the pipeline elbow, the push force of anchor blocks of a single-slope tunnel pipeline was derived based on an energy method. In 2015 Zhang L et al. [26] investigated the parameter analysis of the thrust and displacement of anchor blocks including the buried depth for anchored pipeline side, the pipeline–soil friction coefficient, the volume of anchor block, the block–soil friction coefficient, the soil reaction coefficient, and the buried depth of anchor block.

The goal of this paper is to optimize the distance between the anchor blocks. The concept of optimization is such that, among the parameters of a function, we look for the values that minimize or maximize the function. The goal of optimization is to find the best acceptable answer, given the constraints and needs of the problem. Kennedy, a social psychologist, and C. Aber Hart [27,28], electrical engineer, are the main owners of the idea of the PSO algorithm. Initially, they intended to use a combination of social models and existing social relationships to create a kind of computational intelligence that does not require individual individual abilities. Their first simulation was carried out in 1995, leading them to simulate the behavior of birds to find seeds. This work was influenced by the work of Hepner and Gernander, which was carried out in 1990 to simulate the behavior of birds as a nonlinear system. Kennedy and Eberhart's work led to the creation of a robust algorithm for optimization, called particle optimization algorithm or PSO [29, 30, 31]. In the PSO algorithm, there are a number of organisms that are referred to as particles, and are distributed in the search space of the function that we intend to minimize and (or optimize) its value. Each particle calculates the value of the target function in the position of the space in which it is located. Then, using the combination of its current location and the best place it used to be in the past, as well as the information of one or more particles of the best particles in the collection, it chooses a direction for motion. All particles selected a direction to move, and after completing the move, a phase of the algorithm ends.

These steps are repeated several times to get intended answer. In fact, the mass of particles those search for the minimum value of a function act like a bunch of birds looking for food [27-36]. Amini Moghadam and Khodakarami obtained the optimum distance between two steel frames using PSO algorithm [36]. Nadjafi et al used PSO algorithm to minimize the error function for damage identification in beam-like structures [37].

The method used in this paper is to first describe the modeling of soil and buried pipe in a two-dimensional fashion using the finite element method and direct method in OpenSEES software. Then the PSO optimization algorithm was programming in MATLAB software. Subsequently, using two software integration and multiple back and forth between two software that has enough defined repetitions in the PSO algorithm, the optimum distance was obtained between the anchor blocks in different conditions of the soil, pipe, earthquake, depth of burial and pipeline diameter. And the effect of each of them on the optimal distance between the anchor blocks was investigated separately. The optimal distance from the MATLAB software is the distance that, if we put the anchor blocks in the pipeline with it, the maximum strain across the pipeline does not exceed the maximum strain permitted by the regulation. Also, the maximum stress of the pipeline does not exceed the yield resistance of the steel pipe, and the minimum stress in the pipeline is greater than the buckling resistance of the pipe.

2. Statement of the problems

The research methodology is that after writing the buried pipe and soil code in OpenSEES software and the PSO optimization algorithm code in MATLAB software [38], first, the random distance is selected in the range of zero to pipe lengths for the placement of the anchor blocks in the buried pipeline by the algorithm PSO optimization. The coding is done such that if these random distances are not multiple of length, the anchor blocks are inserted in a distance from the beginning of the pipeline to preserve symmetry in the geometry of the problem. Also, anchor blocks in the pipeline are in fact the points where the pipe is fixed to the ground, and in other places where there is no anchor blocks, there is a free pipeline. Then earthquakes are applied to the model in the OpenSEES program based on this distance, and the maximum values of compressive stress and tensile stresses and the strain of the pipeline are calculated. These values are returned to the optimization algorithm, and after calculating the accuracy of the stress and strain criteria, the value of the objective function is calculated according to permitted values. This process continues with the number of repetitions we consider to solve the problem, so that at the end, the optimal distance determined between the anchor blocks (space in Fig. 1), which has the smallest value of the target function, and also in which the maximum capacity of the pipe used. The operation was repeated for buried pipes with different stones, different soil types, and earthquakes with different levels of danger, depth of burial and different lengths of the pipe. Fig.1. shows a schematic view of the soil environment and the buried pipe.

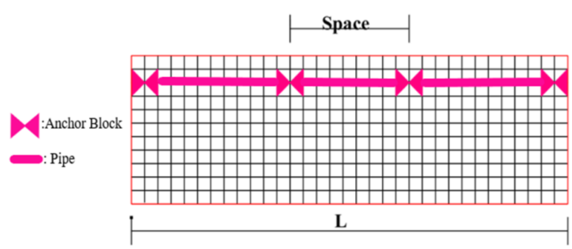


Fig. 1. Schematic of problem definition.

The target function defined in this algorithm minimizes the amount of distance between the two anchorblocks; so the statement of the optimization problem in this study is as,

Minimize: $Cf = 3 - \frac{0.03-|\varepsilon_{max}|}{0.03} + \frac{f_y-\sigma_{max}}{f_y} + \left|\left(\frac{f_{buc}+\sigma_{min}}{f_{buc}}\right)\right|$

(1)

Subject to: $0 \leq Space \leq L$ & $|\varepsilon_{max}| \leq 0.03$ & $\sigma_{max} \leq f_{y,pipe}$ & $\sigma_{min} \geq f_{buc,pipe}$ (2)

where; Cf is Cost function , $Space$ is Distance between anchor blocks , $f_{y,pipe}$ is Yield resistance of steel pipe, ε_{max} is Maximum strain of pipeline, σ_{max} is Maximum stress of pipeline, σ_{min} is Minimum stress of pipeline, $f_{buc,pipe}$ is Buckling resistance of pipeline.

Mathematical statement of this optimization problem is

The process of research in the flowchart is shown in Fig.2.

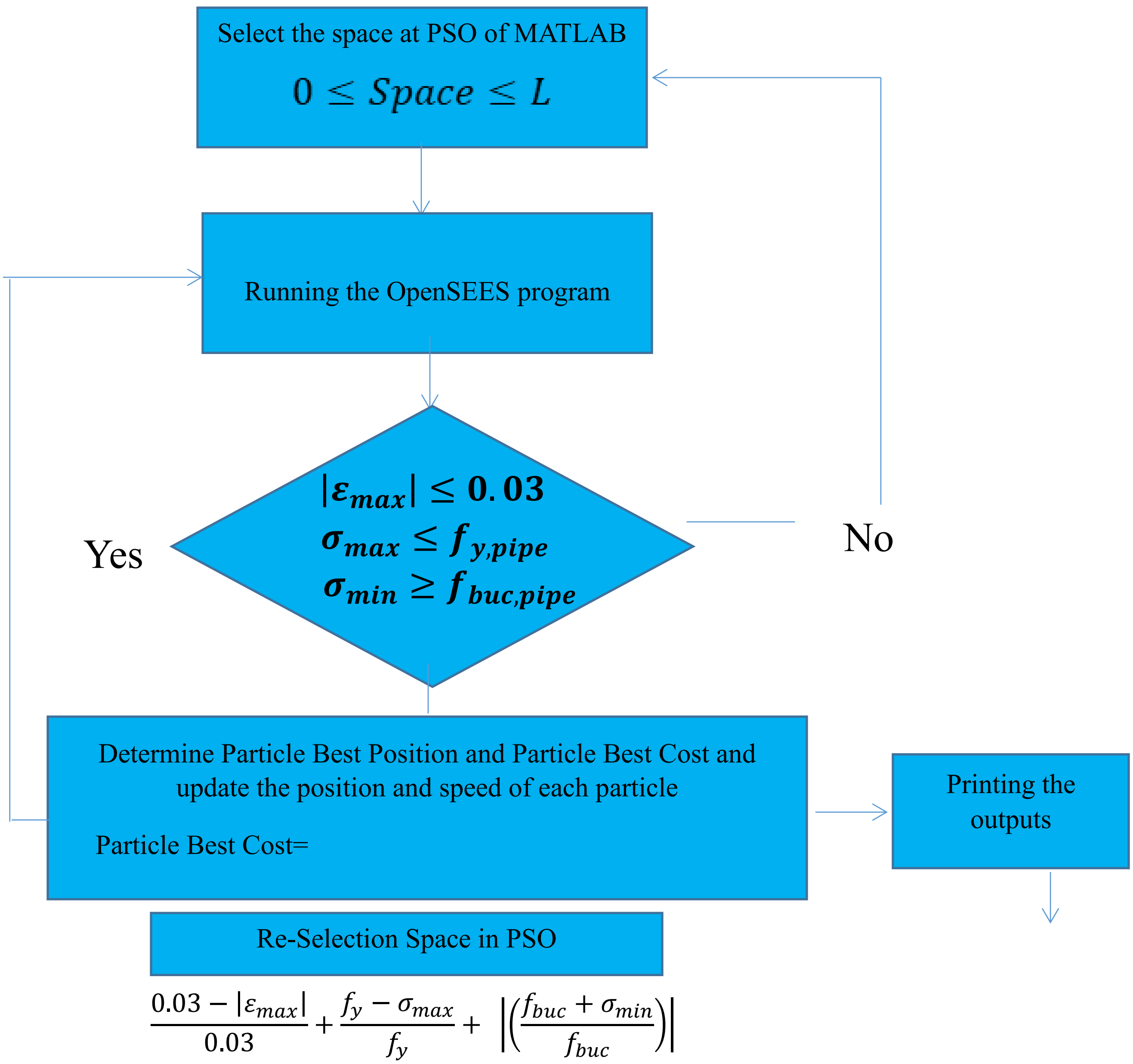


Fig. 2. Statement of optimization algorithm in this study.

3. Soil-pipe system

In this research, the modeling of the soil and buried pipe was carried out in two-dimensional and direct way in the open-ended finite element software with assumption of nonlinear soil behavior. Four-node elements were used to model the soil and the material used in this modeling was PressureDependMultiYeild, which is used to model the response of pressure-sensitive soils (sandy soils). The behavior of these materials in the gravitational loading stage is linearly elastic and in the dynamic loading stage (fast loading) the stress-strain response is elastic-plastic. The plasticity of this material is based on the concept of multilevel stresses. Yield levels are based on Drager-Prague theory. The pipeline behavior under the influence of earthquake wave propagation is assumed to be nonlinear [39]. In Fig.3., a general form of soil and pipe modeling is presented.

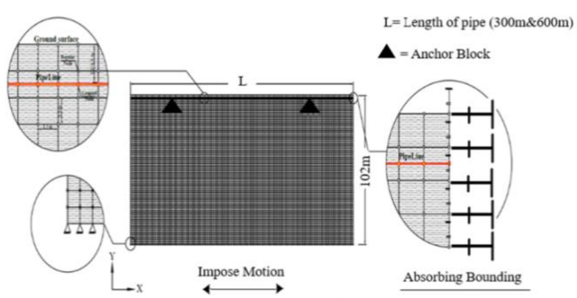


Fig 3. Modeling of soil-pipe-system with absorbing boundaries based on [40]

3.1. Soil modeling

The soil environment is considered homogeneous, isotropic, and single-layer. The soil block is modeled as two rectangles once with a depth of 102 meters and a length of 300 meters and again with a depth of 102 meters and a length of 600 meters. These dimensions are chosen in such a way that the return wave does not occur. Identification of elements of the soil is a quadratic quad squared element based on the concept of shear wave propagation at a specific frequency, with the assurance of the existence of a suitable number of elements in the shear wavelength and a dimension of 1.5 × 1.5 m. This method ensures that the dimensions of the element are so well-adjusted that the wave propagation is well represented in the analysis. Accordingly, the dimensions of the element must be such that it satisfies the Courant's condition and that its dimensions are less than one eighth of the earthquake's wavelength. Selection of soil type was done based on the velocity of the shear wave in the soil and according to 2800 Iran's standard, and the rest of the required parameters for soils are calculated based on the velocity of the shear wave. For the soil type selection, soil type I is removed from the modeling due to its high hardness and very low impact on buried pipelines. In Table 1, the mechanical characteristics of the three soil types used in modeling are presented. Which in there E is modulus of elasticity, G is shear modulus, γ is soil density, υ is poisson's ratio, V_s is shear wave velocity and V_p is pressure wave velocity.

Table1. The mechanical characteristics of the soil types [41]

Soil types	E $(^{kN}/_{m^2})$	G $(^{kN}/_{m^2})$	γ $(^{Kg}/_{m})$	υ	V_s $(^{m}/_{s})$	V_p $(^{m}/_{s})$
$S2$	2,000,000	769,230	2000	0.3	614.25	1149.16
$S3$	500,000	192,310	1900	0.35	309.22	643.68
$S4$	75,000	26,790	1800	0.4	120.82	295.95

3.2. Modeling of absorbent boundaries

In order to model the semi-infinite space of the soil, in order to prevent the reflection of waves, the energy adsorbent boundaries have been used. The adsorbent boundaries must be modeled so that earthquake waves do not reflect on the boundaries of the earth after encroachment on these boundaries. In order to model the adsorbent boundaries, viscous dampers (zero length elements) are used in horizontal and vertical directions (X and Y directions). The parameters used for these boundaries are shown in

$$\sigma = a\rho V_p \dot{w} \quad (3)$$

$$\tau = b\rho V_S \dot{u} \quad (4)$$

As a result, two damping forces with a damping coefficient of Eq (5) and (6) are placed in the normal and tangential boundaries:

$$C_P = a\rho V_P A \quad (5)$$

$$C_S = b\rho V_S A \quad (6)$$

In the above relations, V_S and V_p respectively were the shear S and compressive wave velocity P and are b and a dimensionless parameters. The A cross-section is located in the domain of each damper (unit width) and ρ is the density of the environment and u and $\dot{w}$ were the normal and shear velocities. These boundaries have the highest energy absorption values for values of $a = b = 1$. In dynamic analysis, the absorbent boundaries or dampers is commonly used to prevent the reflection of the energy of shear waves through the boundaries into the model geometry.

3.3. Modeling of pipeline

Non-linear element of Nonlinear Beam Column has been used for pipeline modeling in open sees software [38], based on the distribution of plastic anchor along the element. The pipeline is modeled as an axial and bending element within the soil. Pipeline modeling is considered as a non-linear beam of 1.5 m length (equal to the length of the soil element) with a circular cross section, and the node at the beginning and end of the beam is free. Due to the fact that steel pipelines were used, Steel02 material was used to model the pipe, which is a material with hardening strain. The behavior of these materials under the monotonic load is shown in fig.4. The pipeline without internal pressure is modeled. Anchor blocks are the points where the soil and pipe are tied together. The burial depth and pipeline specifications are selected according to the existing regulations. The studies carried out on steel pipes with a diameter of 8 and 20 inches and a burial depth of 1.5 m and 3 m. In this study, in order to investigate the behavior of the pipeline under the influence of shear wave propagation, the length of the pipe must have at least one earthquake wave length. Characteristics of pipes according to API 5L standard [42] are given in Table 2. Considering earthquake effects on pipelines, such as permanent earth deformation or wave propagation, the axial strain can be cited as a suitable acceptance criterion which the permitted strain in steel pipes is 3 percent.

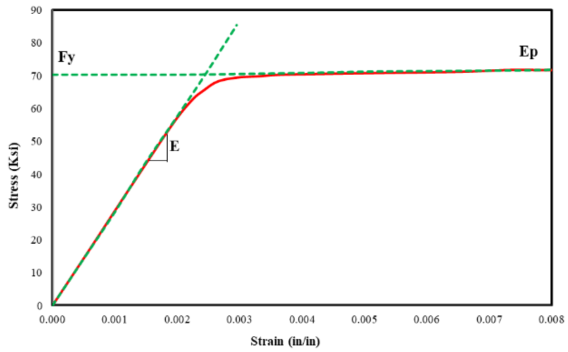


Fig 4. The behavior of Steel02 materials under monotonic load [43].

Table 2. Characteristics of pipes according to API 5L

Nominal Pipe Size (Inches)	**Nominal Pipe Size** (mm)	**OD** (mm)	**Grade**	**Yield Strength** (kPa)	**Wall Thickness** (mm)	**kg/m**
8	200	219.1	X42	290,000	12.7	64.64
20	500	508	X56	386,000	12.7	155.12

4. Input motions

According to this research assumptions, earthquake records was selected in three hazard levels, i.e. low, middle and high.The selected earthquakes from Pacific Earthquale Engineering Research Center [PEER] website was presented in Table 3:

To determine the seismic hazard level of earthquakes used FEMA356 [44]. According to the horizontal acceleration response spectra if $S_{xs} \geq 0.5g$, the earthquake has a high seismic hazard level. If $0.167g \leq S_{xs} < 0.5g$, the earthquake has an intermediate seismic hazard level and finally if $S_{xs} < 0.167g$, the earthquake has a low seismic hazard level.

Table3. Earthquakes input motion

The name of the earthquake record	**Year**	**PGA (g)**	**Magnitude (R)**	**Effective time (s)**	**Seismic hazard level**
Tabas	1978	0.047	7.35	24.2	Low
Loma Prieta	1989	0.09	6.93	13.0	Intermediate
Friuli	1976	0.35	6.5	10.4	High

Because the earthquakes presented on the PEER site are recorded on the soil surface and in the modeling of these records should be applied to the bedrock, thus, records received from the PEER site returns to the surface of the bedrock by using the Deepsoil software, and the records obtained for the analysis of the models soils and structure were used. The spectrum of the selected earthquakes is presented in Fig.5. After applying the earthquake records, intended model was placed under time history analysis on the OpenSEES software.

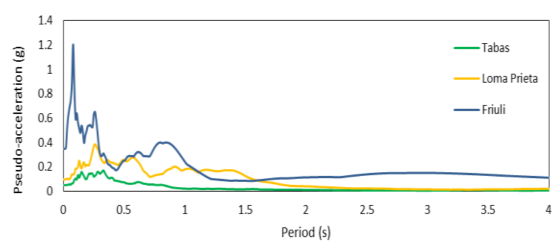


Fig 5. The spectrum of the selected earthquakes at bedrock.

4.1. Models name

Model naming was done as $SiEjDkPlLm$. In the naming, S represents the soil. i represent the type of soil that numbers 2, 3 and 4 can be. E represents the earthquake that has occurred. j represents the type of earthquake, and numbers 1, 2, and 3, respectively, represent the earthquake symbol of Tabas, Loma Perieta and Friuli. D represents the depth of the pipe burial. k is a symbol of the depth of burial, and can be 1.5 meters and 3 m. P is indicating the type of pipeline and l is indicator of pipeline diameter which includes numbers 8 inch and also 20 inch. L is representation of pipeline length and finally m is numbers 1 and 2 that respectively are length of 300 meter and 600 meter. As example, the model of S*2*E*3*D*1.5*P*8L1 is showing that* Friuli earthquake was exerted on pipes with 8 inch of diameter and 300 meter of length that are placed in depth of 1.5 meter with the soil of 2 type.

5. Verification of simulation

For the verification of the modeling performed in the OpenSEES software, the contents of Lee's work was used as a benchmark [45]. The pipeline used in this paper is a buried pipe API 5L grade X65, that the Yield strength is 445MPa, the Outer diameter is 762mm, the Thickness is 17.5mm, the unit weight is $7.85(^{t}/_{m^3})$ and the Friction coefficient is 0.8. The pipe is buried on soil type 4, Pipeline length is equal to 1200 meter and 1994 North rich earthquake is applied into the model.

In this paper, soil behavior and structures is nonlinear and the substructure method is used and the soil is modeled with nonlinear spring elements.

According to the figures given in the paper, which shows the maximum horizontal displacement graph in terms of pipe length, the maximum horizontal displacement of the pipe was extracted in the model made in the OpenSEES software. Then, the graph is plotted in terms of pipe length in Excel software and compared with the chart in the paper, which is presented in Fig. 6.

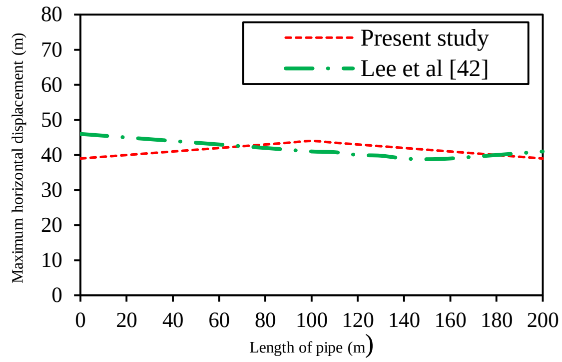
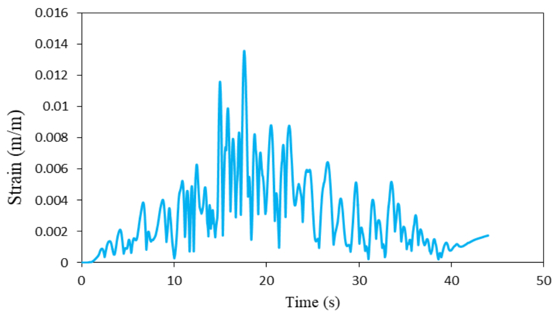


Fig 6. Comparison of variation of the maximum displacement along the pipe length in this study on [45].

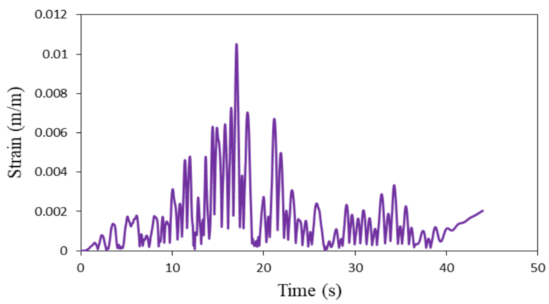
As it shown in this figure, the results have good agreement together.

6. Results and discussion

After modeling and making the samples, a total of 72 soil and buried pipe models were analyzed and the most optimal distance between the anchor blocks, which caused the pipe to fail due to the propagation of waves caused by the earthquake and the maximum pipe capacity which was used and calculated and the influence of different parameters on this optimal distance, such as: soil type, depth of burial, pipe diameter and earthquake hazard, were investigated. Strain diagrams in terms of time are presented in Fig.7. for a number of research models at optimal intervals for anchor blocks.



(a)



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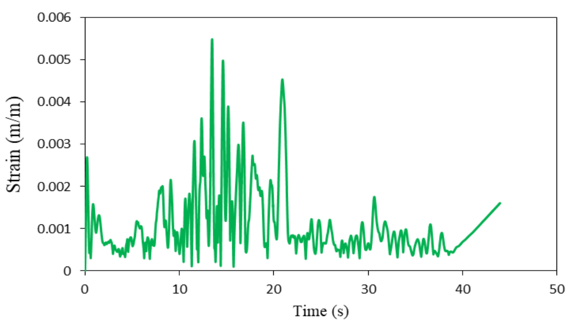

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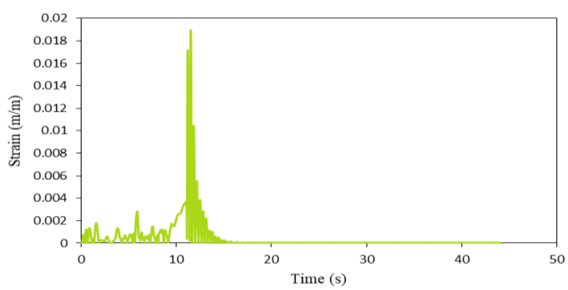

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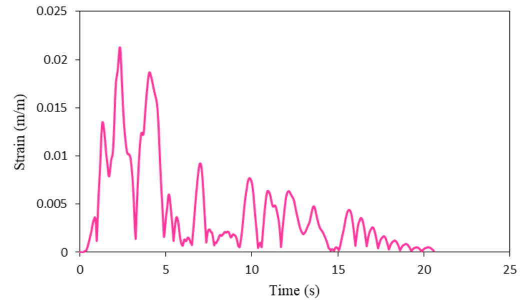

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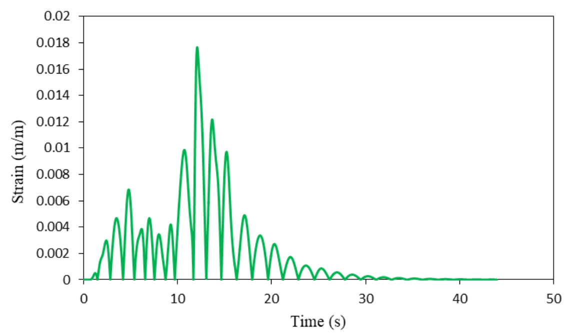


(f)

Fig 7. Variation of strain level respect to time period; (a) S4E2D1.5P20L1, (b) S3E2D3 P8L1, (c) S2E2D3P8L1, (d) S2E1D3P8L2, (e) S3E3D3P20L2 and (f) S4E1D1.5P8L2.

Fig.8. shows several examples of particle convergence charts in the PSO algorithm. According to the convergence diagrams, it is observed in most models, from the second repetition, the graph converges to a constant number, which indicates that the number of 3 rounds of repetition defined in the PSO algorithm for execution of the program is sufficient.

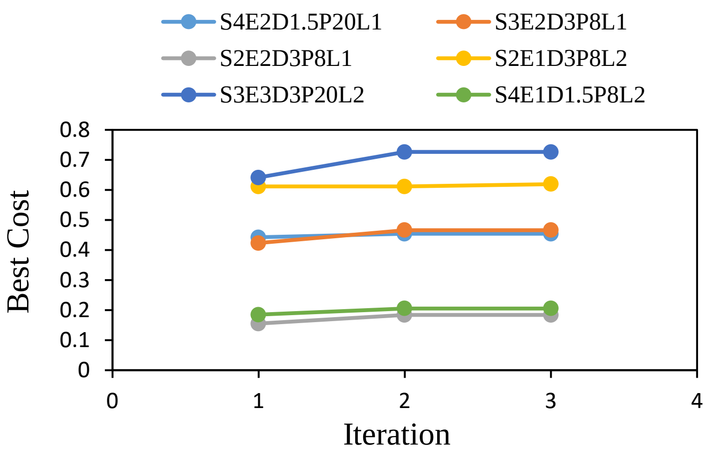
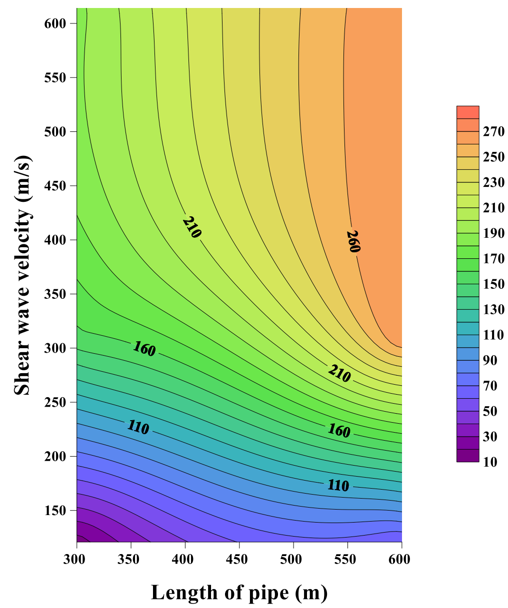


Fig 8. Convergence diagrams.

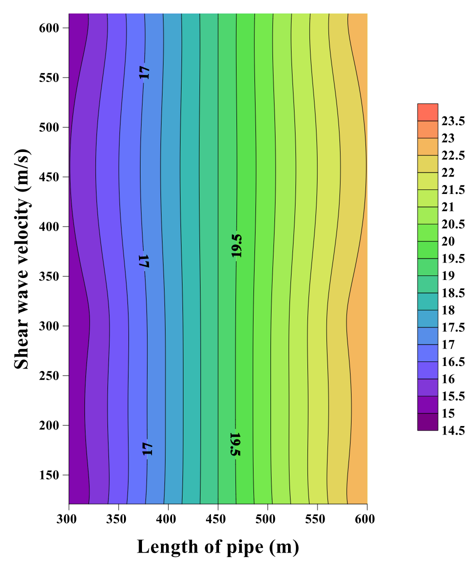
Fig.9. shows proposed research distances for different lengths of different seismic pipeline. As shown in Fig. 9 (a), using an earthquake with low-risk level on the model, the harder the soil and the length of the pipe, the distance between the anchor blocks increases.

In accordance with Fig. 9 (b), with a moderate earthquake effect applied on soil and pipe models, the suggested interval for anchor blocks does not change, but the distance increases are along with increasing pipe length.

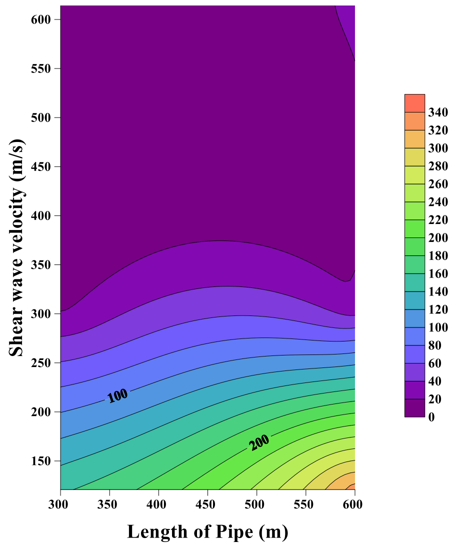
According to Fig. 9 (c), with applying the earthquake with a high level of danger on the soil and pipeline model; the soil becomes softer and the length of the pipe increases, the suggested distance amount increases.



(a)



(b)



(c)

Fig. 9. Optimal distance between anchor blocks for various pipe length and soil type in; (a) Tabas Earthquake, (b) LomaPrieta Earthquake and (c) Friuli Earthquake.

Fig.10. shows proposed research distances for different pipeline lengths on different soils.

As shown in Fig. 10 (a) and 10 (b), the diameter and depth of the pipe burial have no effect on changing the distance between the anchor blocks, and also in the soil type 2 and 3, the increase in the level of earthquake hazard reduces the distance between ~~the~~ anchor blocks. But according to Fig. 10 (c) in Type 4 soil, an increase in the level of earthquake hazard has increased the distance between the anchor blocks. Another point is that by increasing the length of the pipe, the proposed distance in each of the 3 types of soil has increased.

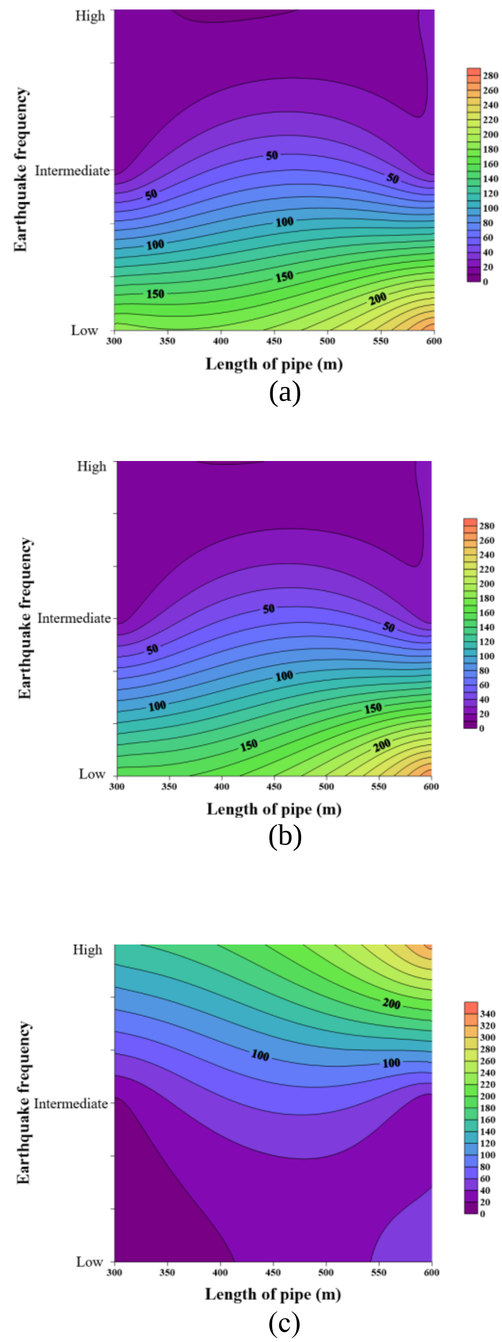
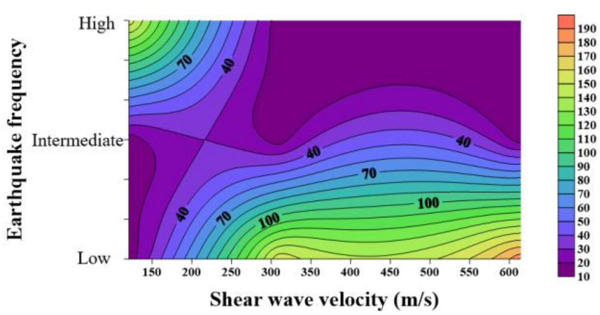


Fig. 10. Optimal distance of anchorblocks for buried pipes under varies earthquakes in; (a) S2, (b) S3 and (c) S4.

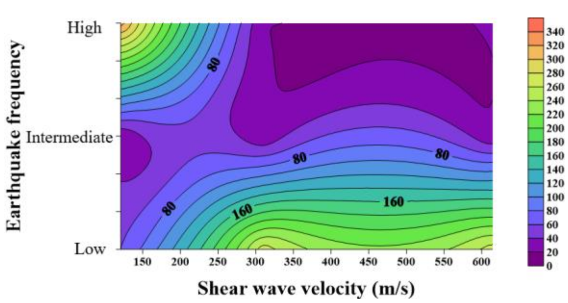
Fig. 11. shows suggested research distances for different pipe lengths. According to Fig. 11 (a), by applying the various earthquakes on different types of soil and 300 meters pipe buried that was observed in the soft soils, with increasing earthquake hazard level, the

proposed distance increases, but with hardening of the earth, applying the earthquakes with a low level of hazard, it increases the gap between the anchor blocks.

According to Fig. 11 (b), applying different earthquakes on different types of soil and 600 m buried pipelines, it was observed in the soft soils, with an increase in the level of the earthquake hazard, the proposed distance increases, but with the hardening of the earth, earthquakes with a low level of risk, it increases the gap between the anchor blocks. However, the proposed volume increases to 300 meters in length.



(a)



(b)

Fig 11. Optimal distance of anchor blocks for different pipeline lengths; (a) Length of pipe=300m, (b) Length of pipe=600m.

7. Conclusions

In this study, we find the optimal and suitable distance between the anchorblocks units embedded in the oil pipelines. For this purpose, pipelines with lengths of 300 and 600 meters and deep burial grounds of 1.5 and 3 meters were directly modeled in OpenSEES software, and three types of soil type II, III and IV were used. 3 earthquake record with high, medium and low risk of earthquake after depletion of soil in Deepsoil software has been applied to the bedrock of soil models and pipes.

The analysis of the results can be mentioned as follows:

1. The diameter of the pipe and the depth of the buried pipe do not affect the optimal distance between the anchor blocks

2. Increasing the pipe length will increase the recommended optimum distance.

3. The level of earthquake hazard and the type of soil, as well as pipe length, are factors affecting the distance between the anchor blocks.

The simultaneous effect of softening the soil and increasing the level of the earthquake hazard increases the distance. Because the constrained the structure is, the greater the probability of a stress and its expansion, while our goal is to reduce the stress and strain of the pipeline during the release of the earthquake wave, thereby Prevent of destroying the pipeline due to the excess of strain from the permitted strain that being allowed. Therefore, in the softest soil, type 4 soil, increasing the level of earthquake hazard increases the distance between anchor blocks.

4. The suggested distance of the PSO algorithm for buried anchor blocks in harder soils where earthquakes with a low level of risk are applied are more than those that were subjected to equidistant earthquake conditions with high hazard level.

5. In hard soils, increasing the distance between the constraints increases the slimming coefficient of the pipeline, which ultimately makes the pipeline unable to withstand the compressive stress caused by the earthquake. Therefore, in Type 3 soil, which is one degree harder than Type 4 soil, increasing the earthquake risk level reduces the distance between the anchor blocks.

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