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Investigation of Traffic Load on the Buried Pipeline by Using of Real Scale Experiment and Plaxis-3D Software

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Abstract: In some cases, traffic load are effected pipelines so in this study, effects of truckload on the buried pipeline were done with numerical and experimental methods. In numerical method, model is assumed half extreme and length of them are considered extreme, mathematically. For performing of numerical method, 3D model were used in Plaxis-3D software. For comparison and checking of results, Experimental model was prepared and with using of electrical strain gages and computer, results of experimental model were recorded. Results show experimental and finite element models are compatible. In continue, effects of other parameters are studied with Plaxis-3D software.

Key words: Buried pipeline, experimental model, finite element, traffic load

INTRODUCTION

Transmitting system of fuel and water and etc. are essential facilities that pipeline are partial of it and are called lifeline. Ordinary, Pipelines are buried and in parallel to ground surface. Length of pipeline is long and was considered extreme. So it faces with many conditions and we should consider several parameters in design of it. Internal press due to fluid, external load, thermal stress, earthquake and dynamic load such as truckload and etc. are very important in design of pipeline.

First researches on the buried pipelines were performed in 1930 and then other researches continue this study with attention to science of their time. These researches were numerical, analytical and experimental. For study of this issue several models were considered that some of them are in continue: beam on the elastic bed model (Winkler model), half extreme elastic space, plane strain model, membrane cylindrical model and cable model. Classic method of Marston (1930) was first study on this issue. In his research, vertical load on the pipeline was considered and his purpose was that pipeline was design in rigid form and he proposed a definite value for earth pressure for calculation of horizontal stress. Ariman and Muleski (1981) modeled pipelines and soil in finite membrane cylindrical and in winkler theory model, respectively. They use stoks equations for modeling of wave propagation. Coushy static method was used for solving of problem. Chang and Ger (1989) study pipelines in 3D model and with 6-freedom degree and equation of model is assumed dynamic. By consideration of damping and inertia effect, they acclaimed that number of entrance component of earthquake and direction of it are effective. Chang and Ger (1989) used beam model for pipelines and around soil are modeled with axial and lateral spring. Then earthquake are exerted to model in frequency area and by using of spectral method, they solved this model.

Loh and Hwang (1989) studied membrane cylindrical model for modeling of pipe in soft and severe soils. They gain 3D dominant equation of pipe with consideration of soil in half extreme and extreme form and solved it with Bessel function. By comparison of membrane and beam models, they acclaimed that axial stress in beam model is smaller that membrane model. Takada (1983) performed a static study on the PVC pipe and effects of large displacement of ground are perused. In his model, length of pipe, diameter of pipe, thickness of pipe and area of it are 250mm, 100mm, 7 mm and 23.5cm^2, respectively. Also Poisson ratio and elastic module and inertia moment are 0.38, 3×10^4 kg/m^2 and 3.4×10^2 cm^4, respectively. In this paper, effects of truckload are studied for various conditions in numerical and experimental methods. Wong *et al.* (1989) studied effects of surface (Rayleigh) wave propagations on the buried pipelines. Their studies show that properties of surround soil, frequency, angle of intersection of wave and depth of pipe are effective on the results.

Numerical study of traffic load on the buried pipeline with Plaxis-3D software:

Assumption of analysis

- Top surface is horizontal.
- Because of small effect, slippage of pipe line and soil were ignored.
- Depth and extreme effects were identified according to analytical study and exert as boundary conditions.
- Hydrodynamic effect of fluid is ignored.
- Software transmitted weight of soil of 3D model to pipe.

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Table1: Properties of soil

Poisson ration (p)	Special weight KN/m^2	Elasticity modelu KN/m^2	Friction angle (ϕ)	Cohesion (C)
0.25	17	7000	26	1.5

Table 2: Properties of steel pipe

Poisson ratio (p)	thickness (cm)	Elasticity module KN/m^2
0.33	0.3	2.1x10^8

Table 3: Properties of PVC pipe

Poisson ratio (p)	thickness (cm)	Elasticity module KN/m^2
0.3	0.3	30000

Loading: Truckload has static and dynamic effect that in this paper load of truck is assumed statically and move in pipe direction. It should be mentioned that in Plaxis-3D software, we can't exert vehicle load, so many models were made and load of truck was put on the model and was shifted in direction of pipe and finally these result combined. Loads of truck transmits to ground by its wheels and Fig. 4 shows properties of it in analysis.

Weight of truck is 8.73 tons that share of back wheels and front wheels are 4.8 and 3.93 tons. This load is exerted to ground as a uniform load on the surface. In this paper, surface of back wheels and front wheels are 0.2*0.6 m^2 and 0.2*0.2m^2.

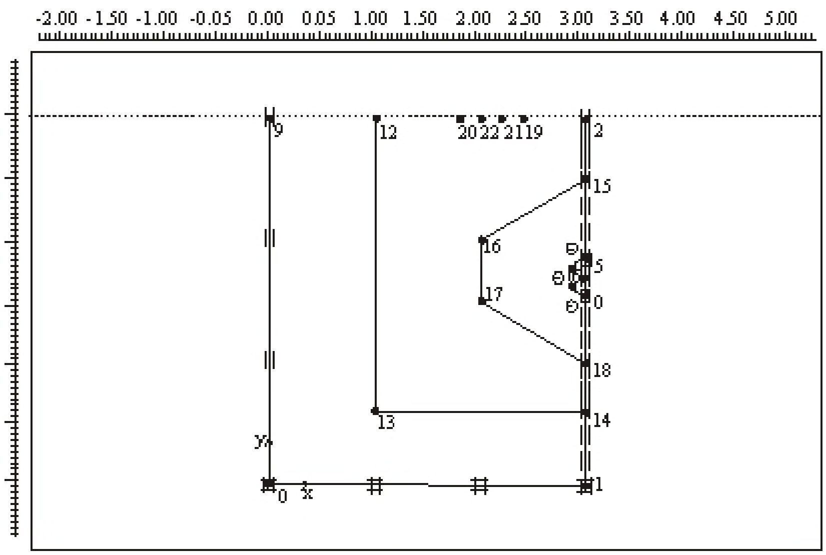

Fig. 1: First 2D model of soil-pipe

Modeling: Vital and most important part of soil-pipe modeling is meshing of them, because accuracy and certitude of analysis has right relation to meshing of them. Size of mesh should be proper. If mesh is small, accuracy is high and we need much time for analysis but with enlarging of element, accuracy of analysis is decreased. The best method for meshing is that size of element should be small in near of pipe and in far of pipe size of element is increased. In this modeling, since load of truck is symmetrical, it is sufficient that half part of model is made. Fig. 1 shows 2D model of it. Other properties of pipe and soil should be entered that these properties are according to soil and pipe, which are used, in experimental model. Entered properties of soil, steel pipe and PVC pipe are presented in Table 1 - 3.

It should be mentioned that properties of contact elements in software are entered according to properties of soil and pipe with software.

As it is shown in Fig. 1, cross section of model (2D surface) is divided to three part that these part help us for better meshing. As we near to pipe, size of mesh is decreased. In continue, 2D meshing and 3D meshing are done, respectively that are shown in Fig. 2 and 3.

MATERIALS AND METHODS

Experimental study in real scale: Experimental models are design in kermanshah city (in Iran) by Shekarchi (2005). Purpose of experimental study is measurement of stress and strain in pipe. There are various methods for measurement of stresses and strains of structure due to load. In site, possible of right measurement of stress is bounded and expensive and ordinary with using of equations between stress and strain, stress is calculated. So according to this paper model conditions and prospected result, using of electrical strain gages is suitable method. In this method, prospected strains in various parts and directions of model can be obtained and needed instruments are in access.

Selection of best location of strain gage installation: Middle of pipe is suitable for installation of strain gages, because: 1- middle point of pipe has larger displacement and strain than other points. 2- with attention to

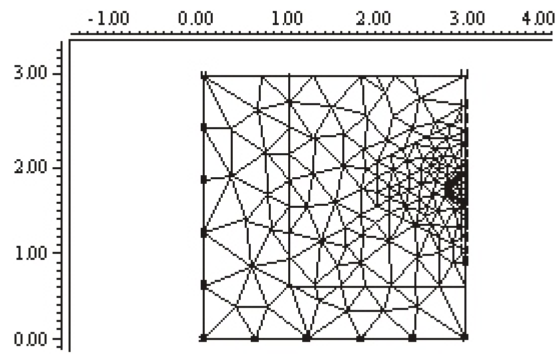

Fig. 2: 2D mesh of soil-pipe model

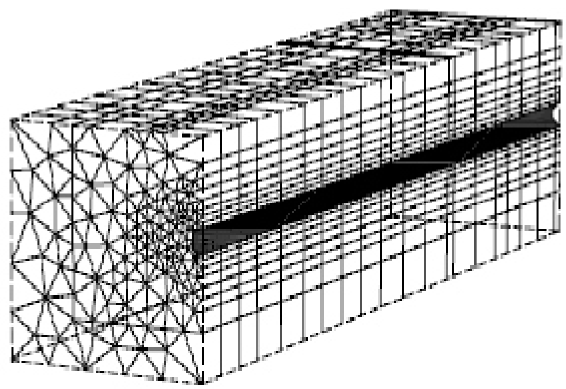

Fig. 3: Final 3D mesh of soil-pipe model

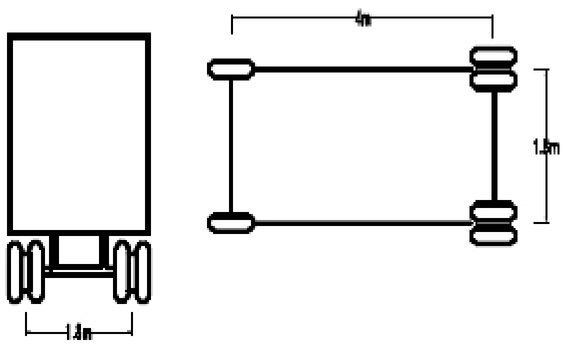

Fig. 4: Distance of wheels in truck

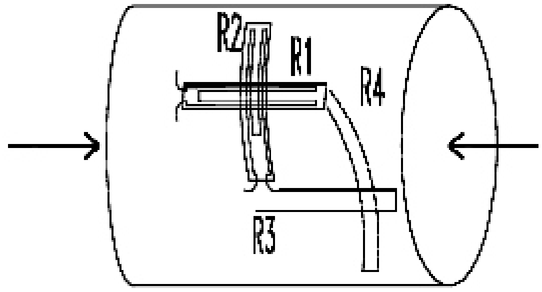

Fig. 5: Perpendicular strain gages

centralization stresses in connection point of pipe, for measurement of usual stresses, middle point is best point. In this paper, four points were selected for study and controlling of stresses. These points are 1- three points in top, middle and bottom in middle of pipe length and 2- one point in distance 1 meter of pipe middle and in top of it.

It should be mentioned that strain gages sow strain in one direction but we need strain in two directions for calculation of circumference stresses, so in each point, two strain gage are installed in circumference and longitudinal directions, as shown in Fig 5. Locations of strain gages are shown in Fig. 6, schematically.

Since load of truck is related to time, for reading and transforming of data to computer, one dataloger is used that read strain and records these data to computer and draws its graph. This set is connected to computer with Recorder software.

Performing of experiment: First with using of mechanically spade, conduit was excavated and pipes are installed in the conduit. Properties of conduit are shown in Table 4. Figure 7 and 8 shown excavated conduit and installed pipe in conduit.

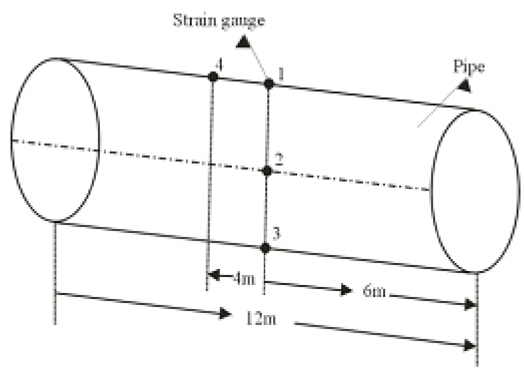

Fig. 6: Location and distance of strain gages

Fig. 7: Excavated conduit

After excavation of conduit, two steel and PVC pipe were installed. These pipes are parallel and have suitable distance together. Than pipes were buried expect in points

Table 4: Properties of conduit

Depth (m)	Width (m)	Lenght (m)
1.5	1	30

Fig. 8: Installed pipe in conduit

Fig. 9: Sample of prepared sample

Fig. 10: Loading of truck on the pipe

that we need to measure theirs strains. For better installation of strain gages, surface of pipe cleaned, than strain gages installed and for protection of them, one protection layer was set on them. By using of Terminals and installation of wires, we can load this system. Fig. 9 shows sample of prepared sample.

Truck loading: In this paper, effect of truck movement on the buried pipeline, was considered. This load is function of revised Coushy method and dynamic behavior of it wasn't considered. For this purpose, truck should be moved slowly. This equation is:

$$K\Delta(t)=f(t) \tag{1}$$

Values of load and other properties are the same value in Plaxis-3Dmodel. Time of truck movement in direction of pipe (12 meters) was 30 (seconds). Figure 10 shows loading of truck on the pipe. After loading and recording of values, stresses were obtained and compared with finite element method.

RESULTS

Results of numerical and experimental analysis: If load is entered to model, displacements are occurred that Fig 11 shows vertical displacement of steel pipe when front wheel is in distance 6 m from outset of pipe. Circumference stress and longitudinal stress of steel pipe in top condition are shown in Fig. 12 and 13. Also circumference stress and longitudinal stress of PVC pipe are shown in Fig. 14 and 15.

Stresses of steel and PVC pipe from finite element and experimental methods are obtained and results of experimental method are shown in Table 5 and 6. For comparison, stresses of steel pipe in point 2 are shown in

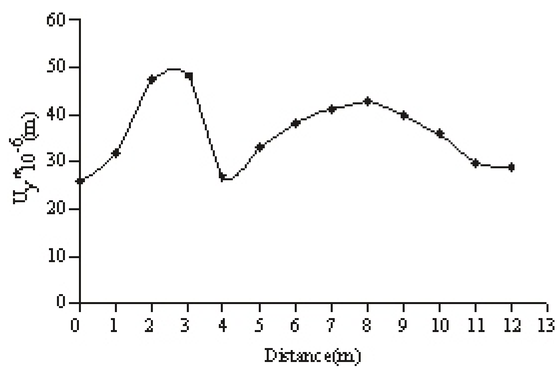

Fig. 11: Vertical displacement of steel pipe when front wheel is in distance 6 m

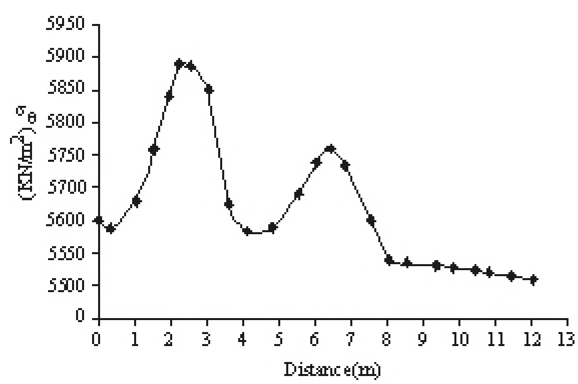

Fig. 12: Circumference stress of steel pipe when front wheel is in distance 6 m

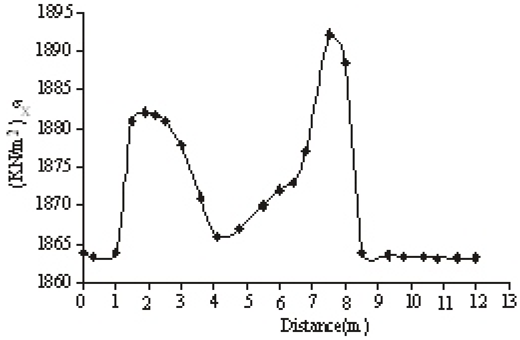

Fig. 13: Longitudinal stress of steel pipe when front wheel is in distance 6 m

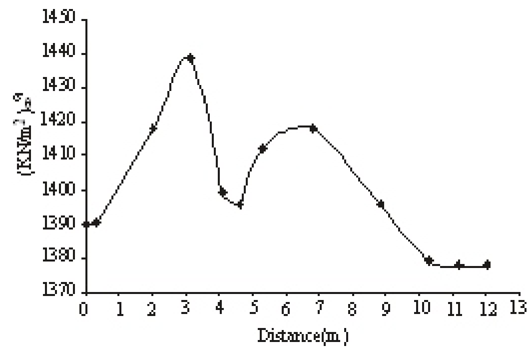

Fig. 14: Circumference stress of PVC pipe when front wheel is in distance 6 m

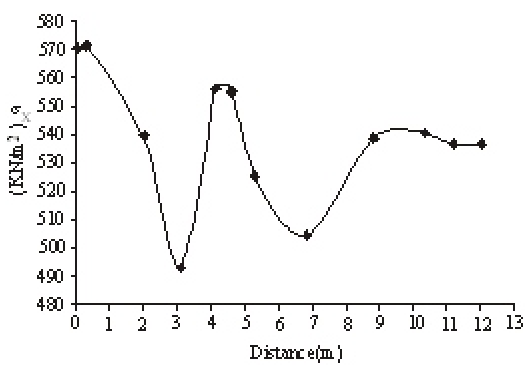

Fig. 15: Longitudinal stress of PVC pipe when front wheel is in distance 6 m

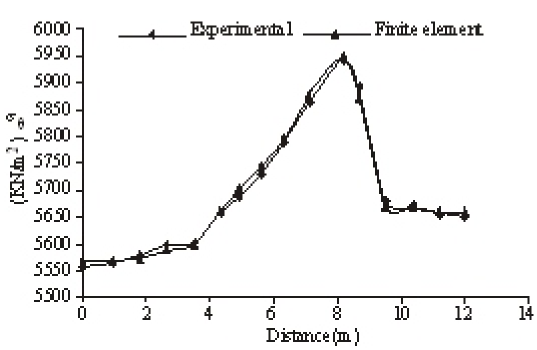

Fig. 16: Circumference stress of point 2 in steel pipe

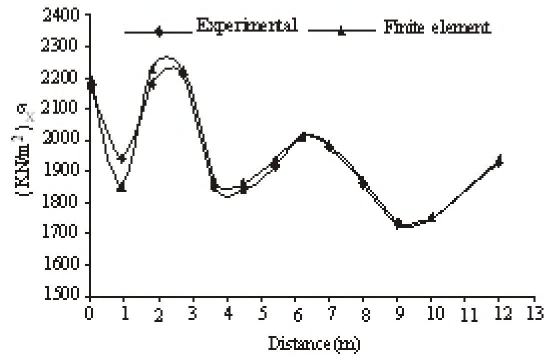

Fig. 17: Longitudinal stress of point 2 in steel pipe

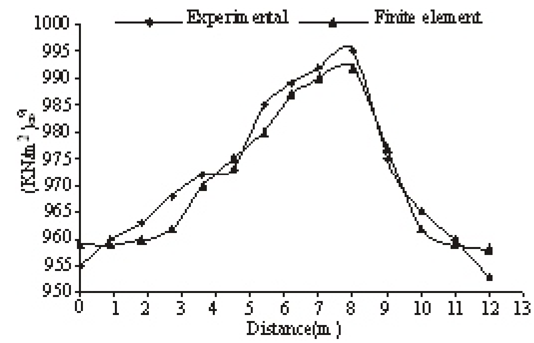

Fig. 18: Circumference stress of point 4 in PVC pipe

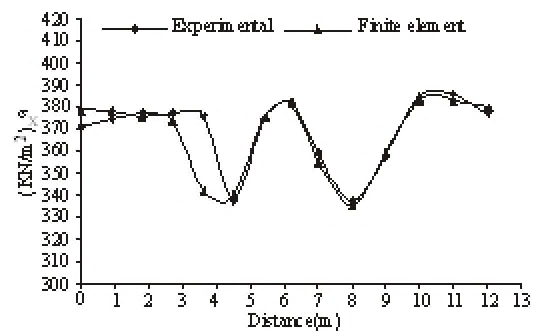

Fig. 19: Longitudinal stress of point 4 in PVC pipe

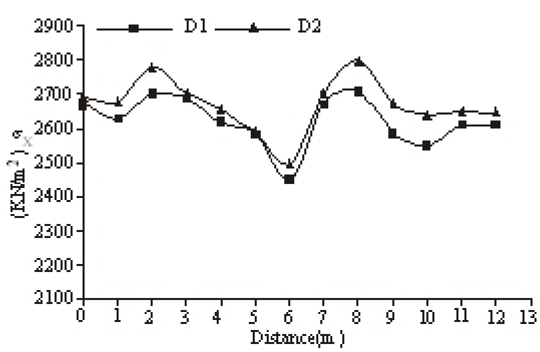

Fig. 20: Effect of pipe diameter on the longitudinal stress of point 1 in steel pipe

Table 5: Stress of steel pipe

Steel pipe	Point 1		Point2		Point3		Point 4	
Location of load from start of pipe (m)	Circumference stress (KN/m^2)	Longitudinal stress (KN/m^2)	Circumference stress (KN/m^2)	Longitudinal stress (KN/m^2)	Circumference stress (KN/m^2)	Longitudinal stress (KN/m^2)	Circumference stress (KN/m^2)	Longitudinal stress (KN/m^2)
0	4435	1180	5560	2190	4553	1650	4430	2020
1	4442	1920	5567	1850	4556	1320	4435	1765
2	4467	2180	5590	2230	4585	1600	4485	1715
3	4497	2205	5595	2220	4589	1635	4520	1701
4	4525	1850	5601	1870	4598	1290	4560	1515
5	4530	1841	5660	1865	4620	1590	4565	1220
6	4556	1912	5690	1935	4651	1902	4580	1621
7	4560	2010	5730	2010	4712	1640	4610	1531
8	4597	1974	5790	1985	4875	1400	4680	1298
9	4627	1859	5865	1870	4800	1850	4704	915
10	4684	1738	5945	1740	4838	2280	4660	1266
11	4602	1792	5680	1750	4795	2150	4570	1650
12	4467	1940	5665	1940	4620	-	4465	-

Table 6: Stress of PVC pipe

PVC pipe	Point 1		Point2		Point3		Point 4	
Location of load from start of pipe (m)	Circumference stress (KN/m^2)	Longitudinal stress (KN/m^2)	Circumference stress (KN/m^2)	Longitudinal stress (KN/m^2)	Circumference stress (KN/m^2)	Longitudinal stress (KN/m^2)	Circumference stress (KN/m^2)	Longitudinal stress (KN/m^2)
0	955	370.8	1370	522	957	370	955	370
1	956.5	376	1386	537	960	374	960	375
2	963	351	1395	485	963	408	963	377
3	970	380	1400	522	965	389	968	375
4	975	373	1406	514	966	370	972	372
5	1003	332	1410	498	974	338	973	336
6	1012	345	1413	520	982	320	985	376
7	1025	380	1425	562	986	401	989	382
8	1030	381	1446	560	993	100	992	359
9	1012	340	1499	522	990	364	995	336
10	991	331	1540	492	980	305	975	357
11	973	365	1406	540	960	378	965	386
12	962	382	1392	565	958	392	960	387

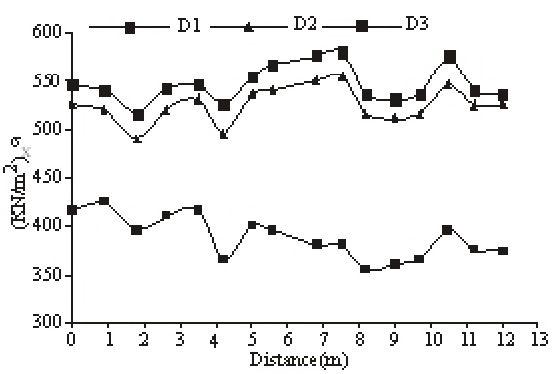

Fig. 21: Effect of pipe diameter on the longitudinal stress of point 1 in PVC pipe

Fig. 16 and 17. Results of PVC pipe in point 4 are shown in Fig. 18 and 19.

In many cases, stresses are equal in two methods, but there is some error for some points. This error is more obvious in PVC pipe than steel pipe. Since in PVC pipe, we used connection in 3 and 9 (m) of pipe length (because there is PVC pipe with 6 m length), error of PVC pipe is greater than steel pipe. Despite these cases, results of two methods are near together. It shows that we can use finite element method for study of buried pipeline due to truck loading.

For study of diameter effect on the stresses of pipe, two diameters are used for steel pipe, that are D_1=20cm and D_2 = 25cm. for PVC pipe three diameters were used that are D_1= 20 cm, D_2 = 24 cm and D_3 = 30 cm. results of this case are shown in Fig. 20 and 21. Graphs show that with increasing of pipe diameter, displacement of middle point decreases.

CONCLUSION

Modeling of pipeline and soil is very important in specification of stresses in pipe. According to modeling of this paper, results of finite element method and experimental method are near together. So for study of other effective parameters on the pipeline stresses, finite element methods can be used. In confine of this study, following results are obtained: 1- maximum displacement and stresses are occurred in middle of pipe. 2-with using of proper length for pipe, boundary condition are ineffective. 3-with increasing of pipe plasticity, damage of it decreases.4- with increasing of pipe diameter, displacement of middle point decreases that increasing of pipe-soil interaction and inertia moment of pipe are the main reason of it.

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