



Investigation of the laboratory models scales in the analysis of the buried pipeline behaviors

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Abstract

For analysis the buried pipelines behaviors and recognition of interactions between the buried pipeline and the surrounded soil and real simulation and for recognition of sensitivity of parameters are in need of some experiments. Generally, researchers would use small laboratory models and in laboratory site with dimensional scales that included of variation of dimensional scales and some times the combination of the small models and site models is considered for the analysis of the parameters behaviors. For overtaking the high amount of parameters, finding the dimensional proportion from the site model is difficult that for preventing from these calculation difficulties, usually unit scale was considered and because in most scientific research the parameter effectiveness is important so the laboratory models with regarded to the possibility power should prepare real conditions. In these articles besides introducing the laboratory models of underground pipelines, the site models, included of site models and laboratory models the variation gages model would be analysis according to the type of load or phenomena and purpose.

Keywords: Pipe line, buried, interaction, laboratory model, scale

Introduction

For recognizing and more understanding the behavior of the buried pipelines which transfer the fluid inside the soil, some investigations have been done in the laboratory and site experiments. Generally, we can divide experiments in to two groups; one dynamic experiments in the real scale and the others dynamic experiments on the small models.

In the experiments with real scale, it has been operated with earthquake loading on the real sizes of pipe that from the results of these experiments the dynamic results of the pipe function and the surrounded soil would be obtained. In these experiments, the pipes with the common sizes are buried under the ground and the axis strain of the pipe would be measure by the strain gages that install in internal partitions. Also the land acceleration changes would be achieved by the accelerometer which is installed on the internal and surface of land and internal of pipe. In this mode the land loading would be simulated by two methods [1, 2 and 3]. One of these methods is creating oscillations through the driving of trunk or explosion. In these experiments, similar loading with earthquake loading would be stimulated through the trembling factor such as firing a gun with 140 times more than atmosphere pressure and driving a 30 tone trunk on the land surface. The vibration arising from these methods is real like an earthquake [1, 2 and 3]. The other method of creating harmonic vibration is through a vibrator. In this method we can take action directly and indirectly. In the direct experiments, pipes deformed due to the vibrated waves from an engine that install on the concrete base. This experiment would give us an acceptable approximate form the spreading of the earthquake waves but the amplitude of the pipe movement and surrounding strain is much smaller than the amounts which would acquire by the real earthquake and the causes of such issue is the small amplitude of the vibrator and its great distance to the installed pipe for preventing the soil flowing around the pipe. In the indirect experiment, for preventing from such matters we would install a vibrator at the end of the pipe. In this method the change in soil and pipe and the movement amplitude is as much as the time of earthquake and these experiments would help us in finding the particular of reaction force of the soil around the pipe [1, 2 and 3].

Dynamic experiments on the small models of laboratory would have the maximum application in determining the soil and pipe behavior. In most of these experiments, a model with a scale smaller than the buried pipe would be made. In order that the soil features can be a damage factor in case of earthquake, generally a model would be

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making in soil which is located in the case and their function would compare together. Generally, these scales are small and sometimes we use equivalent structure with smaller hardness such as PVC pipes or a plastic spring instead of iron pipe and sometimes we use soil or gelatin material for soil model. We put some mark on the model surface that we can obtain the amount of movements. In this mode, generally loading would be done in two ways. One of these methods is the vibrated table which would be vibrated and the other method is using one pipe which is movable and is at the beginning of the pipe [1, 2 and 3].

Laboratories models and scales

In this section the different laboratory models would be view as the dimension magnitude which is used by the real scale and laboratory scales by the researchers.

Models with real scale

N.Nasu and S.Kazama [4] have been implemented some of the axial, torsion and bending experiments on the steel pipes with great diameter and soft cast iron pipes in the open space and from the results of these experiments they have used for calculating the axial, torsion and bending hardness and maximum cyclic loading capacity and for study the effect of piping depth and they believe that the soil would prepare the excess power of friction toward the axis changes of the installations. Haward [5] reached to some information and data for pipe changing during several experiments. In these experiments he has been used of some pipes with different diameter and kind which had been in pressure in different depth of the soil. Iwamoto et al [6] have been prepared the experimental model with the real scale in three points and from 1975 they achieved the results from different earthquake. They considered to the dynamic behavior and earth movement raised from the earthquake. The type of pipe was iron cast and their diameter had been 1500 and 1200 and 1000 millimeter. They considered different buried depths and they used different soils according to the especial weight and they recorded the results under the several earthquakes. N.Ogawa [7] had been studied a laboratory research for recognizing the dynamic reaction of full of fluid pipe in the real scale. He used the big vibration table and the experimented system had 40 meter length and 38 millimeters thickness and had the harmonic wave. The experimental results with the analysis results were similar. He believes that the counter effect of the fluid is effective on the dynamic behavior. Isenberg et al [8] have been prepared some site laboratory for study the performance and behavior of the pipe near the fault line. They have been used of some seismograph which had the computer LCD system that had 36 strain gages graph and 94 displacement gages. They chose the region which contains the buried pipes in the real scale in order to record the result from earthquake. Paulin et al [9] prepared a real laboratory model for study the pipe and soil interaction in one clay soil in axial direction. They equipped the laboratory model in lateral and axial directions. The side study experiments have been operated in the space with 1.4 meter depth, 3 meter width, 3 meter length and the pivotal(axial) studies in space with 1.4 meter depth, 0.63 width and 6 meter ling. They have been used the dynamic generator form one side of the pipe and two linear displacement gages former in two sides of the pipe. Rizkalla et al [10] have been prepared a laboratory model for study of interaction of the pipe and adhesive soil in the axial direction and they research about this issue for some years. In these laboratories program and study they have been used about 36 pipes with the real length of 12 meter and with the cover depth of 0.9, 1.7 and 1.5 meters and for preparing a axial force they used of two automatic pumps which had been worked with the oil pump. The displacements have been measured by the displacement's sensors which had a computer screen. Nishio et al [11] for study the buried pipe which are under the earthquake condition, prepared the real and laboratory model that in real model the length of pipe was 20 meter and in the net work it was 20*20 meter. Proportion of laboratory model to the real model was 1.25 to 1.200. The wave which is entered to the system was in harmonic and was in the way of past earthquake waves. In the small laboratory models the length of pipe was 2 meter and its diameter was 9 cm and it was from the steel type and the width of the box was 30 cm and its height was 15 cm. the soil density was 1.35 lp/m^3 and the shear modulus was 344 lb/ m^2 and the Poisson coefficient was 0.5 and the young modulus was 1033 lb/ m^2 . They compared the results of the laboratory with the site results and they have been used of the finite element method for numeral analysis.

Small laboratory models

Goto and Takada [12] have been implemented some experiments on the buried pipes with small diameter which were affected by the wave distribution with high phases differences in axial direction, they could find the time history of displacement for the steel pipes and for the iron cast pipes with the mechanical connections. Takada [13] have been studied a static laboratory research on the pipeline from the type of PVC. In his model, the pipe length was 250 cm and the pipe diameter was 100 millimeter and the pipe thickness was 7 millimeter and its cross section was 23.5 cm^2 and Poisson coefficient was 0.38 and elasticity modulus of the pipe was $3*10^4 \text{ lb/ m}^2$ and its Inertia moment was $3.4*10^2 \text{ cm}^4$. In his laboratory, His model has been used of manometer, strain gage and displacement gage and has been used of nonlinear equation of material resistance and elastic theory and connected curvatures and strains to the stresses. Merrit et al [14] have been implemented the axial and bending



experiments on the buried pipes and they have been used of one and ¼ inches pipe diameter pipe and the proportion of the length to its diameter was 28 and 9. E.Kuribayahi et al [15] have been studied on the buried pipes during the liquefaction of the saturation sand. In their model the depth of the buried pipes was 100cm and they used of vibrated table for lateral excitations. J.Koski et al [16] in the study of the flotation effect and liquefaction effect of the superfluidities pipes have been operated some experiments and for dynamic force they used the vibrated table. The type of the excitation wave was in harmonic form and was with the 5 Hz frequency and 20 to 100 cycles. The soil was sand and experiments was with the PVC pipes with 5cm diameter and buried depth of 35 cm and with the length of 250 cm and the distance from the level of land to the under pipe was 15 cm. sekiguchi et al [17] have been studied on experimental researches for study the stability of the pipe which are affected the liquefaction effects. In their model, they have been used of vibrated table. The length of the model was 3 meter and its width was 1 meter and its height was 0.5 meter. They have been used of accelerator, manometer and displacement gage in different parts. Wang et al [18] for study the interaction of soil and pipe have been done some static and dynamic studies in the Oklahoma University. They used the dynamic generator for excitation and for measuring the force they have been used of load cell and for measuring the displacement they used the strain gage. The force and displacement of them were harmonic. In this model, the pipe has been buried in the soil and has been come out of the soil from the other side. The size of the box was 7*3.5*3 feet. The harmonic wave frequency was 2,1,0,5 and 0.1 Hz. The pipe diameter was 12 inches and was steel type and its buried depth was similar to the length of the box. The soil type was sandy. H.Madi and Oroutke [19] believe that with generalization of the Colton method which had been presented in 1981 and with assuming the linear behavior for interaction of soil and pipe, we can improvise one buried pipe inside the box and with simple experiments and force measurement we can find the interaction coefficient of the soil and pipe. In this modeling, they have been used of axis differential for solving the numeral equation. Akiycshi [20] for study and recognizing the friction force between pipe and soil has been used of one experimental model with the dimensions of 30*45 cm which the buried pipe was PVC and has been connected to the vibrated generator from one side. Inside the box they had been used of the strain gage sensors and accelerometer that the loading frequency was 7 Hz. With measured results and use the equation dominant, he could solve it. For preparation to obtain the experimental information for recognizing the soil behavior such as static hardness between soil and pipe, damping between soil and pipe, added mass to the soil and also determining the dynamic hardness and effective parameters, a experimental model have been introduced in the following. In this model, pipe cross the box in the start and end and in one side connect to a generator, xformer and damper and other side connect to the gage system and damper. The plan and schematic form of it illustrate in figures 1 and 2.

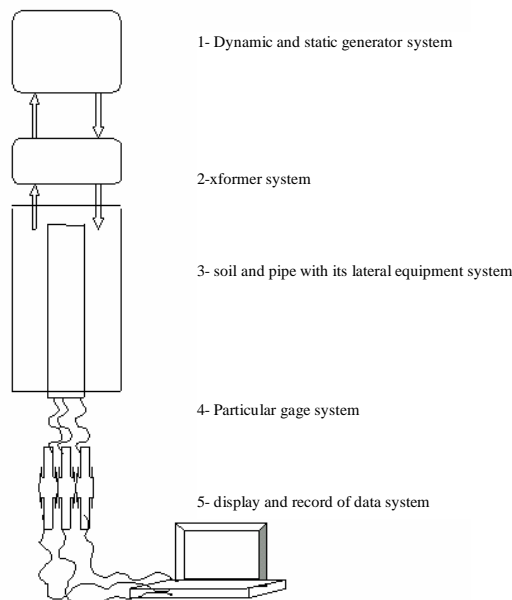


Figure 1 – plan of variation part of model

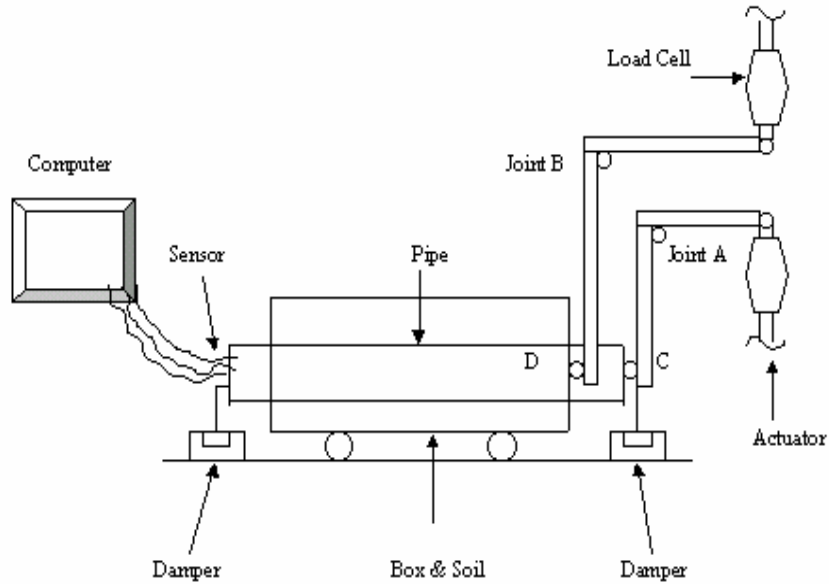


Figure 2 – Schematic view of variation part of model

In this model the box dimension is 180cm*80cm*75cm and the pipe diameter was 26 cm and it has been used of steel and PVC pipes. The method of applied power and system excitation has been implemented by the dynamic generator which had been entered to the one side of the pipe. In using the loading system and statistical excitations, the tool of Servo-Hydraulic have been designed which would act vertically in order to transform the vertical mode to the horizontal mode (figures 3,4).



Figure 3 – Lateral view of arraying the Servo-Hyd. , xformer and pipe, soil and box system



Figure 4 – General view of arraying the Servo-Hyd. , xformer and base and computer system



The main excitations of the experimental model were Servo-Hydraulic that this machine is able to excitation the experimental model in the statistic and dynamic way with various types of frequency and amplitude and it can show the information on its monitor (figures 5-8).



Figure 5 –View of generator, xformer and frame system

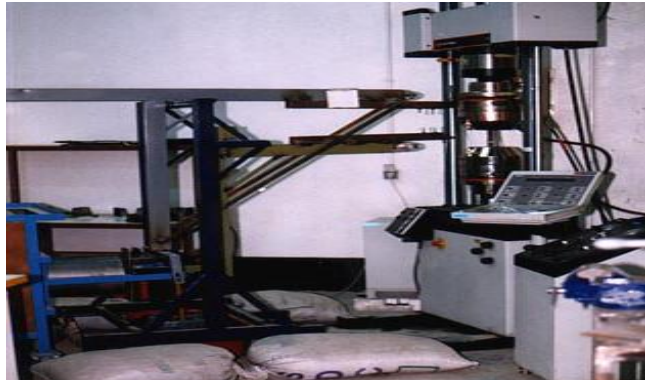


Figure 6 –Lateral view of generator and xformer system and situation of frame

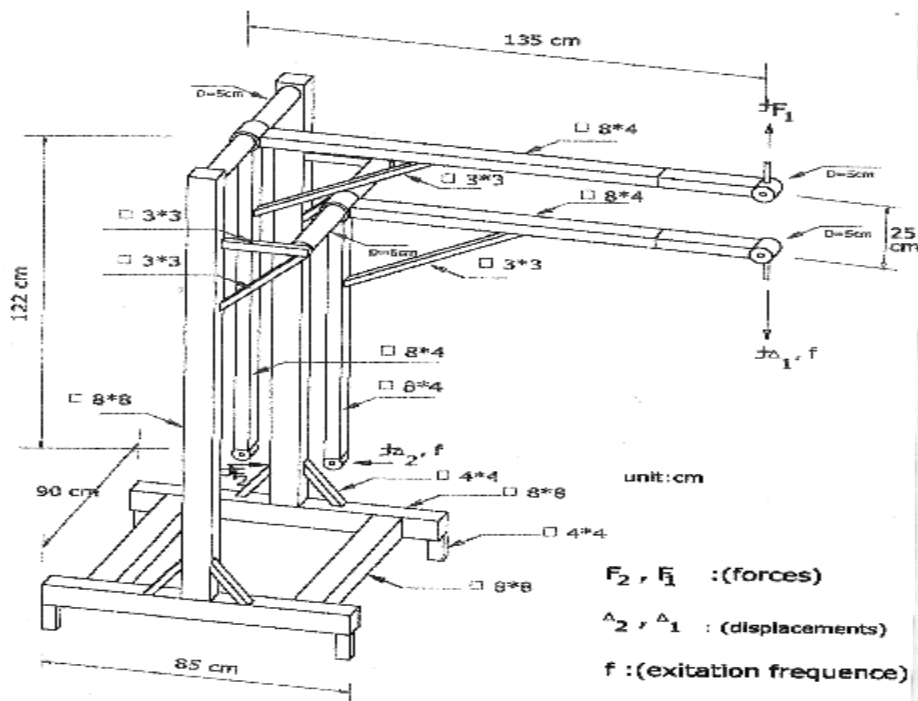


Figure 7 –Schematic view of fixed and animated generators and frame

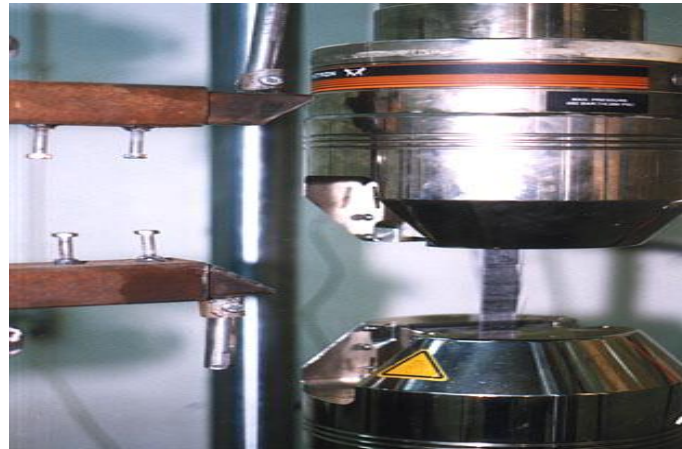


Figure 8 –Detail of generators and pinned connection linked

In the construction of the laboratory models, the force and displacement generator would be installing in to the one side of servo-hydraulic system and other side connected to the pipe and soil system. The amount of force, displacement, incoming amplitude and frequency would be show and measured by the main generator; but amount of displacement in length of pipe record with sensors and computers, because it is sensitive. In figures 9 and 10 show situation of sensors and view of it.

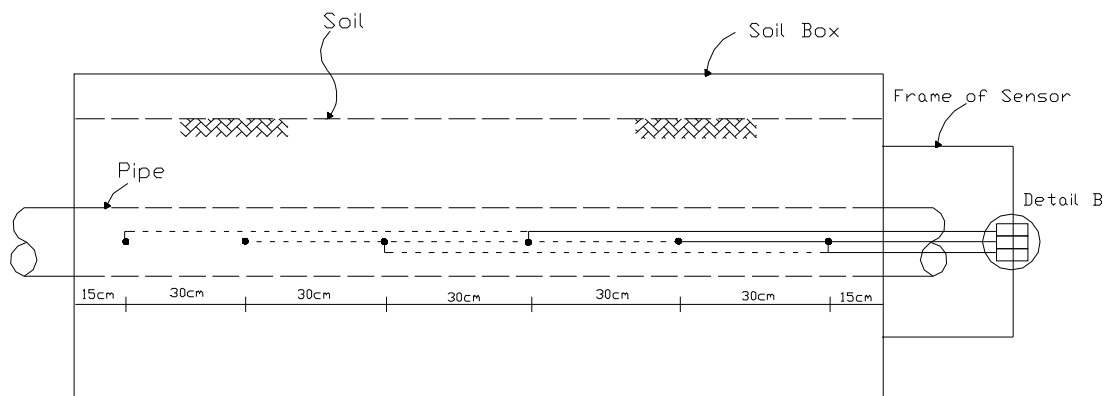


Figure 9 –Section of situation of sensors



Figure 10–View of displacement gage sensor

Some Damping has been designed for reducing the wave reflection (figures 11 and 12).



Figure 11 –Detail of connection of generators and front damper



Figure 12 –Detail of arraying and connection of end damper

With study the history of the laboratory models, the issue of the simulation of reducing the reflection effect didn't consider very much and its better that in modeling the experimental, we consider to the deletion or improve of the wave reflection. In order that to design the models in small shape; the largeness of the buried pipe is important. Generally, we are encounter to the limited spaces but we should use our models in limit dimensions that are effective in the result. Practically in the pipes with the limited lengths they would encounter to the wave reflection that is resulted from incorrect simulation. Physically, the existence of resistant force that is the velocity function would be affecting on the movement and would make it zero that in this case they would change into the damping movement and this system can act as the damper [2]. For better simulation, shear plate in the liquid was used.

Conclusion

for recognizing the pipe performance with the surrounded soil and find a basis for considering the related assumption in expansion the formulation of constructed analysis and finding the entrance information for numeral analysis by the software. Some of the results achieved from these experiments are including: 1- vibration of pipe was like the surrounded soil. 2- The slippage between soil and pipe was negligible and can be taking it equal. 3- The effect of the long length which is used finite in the laboratories and it should be take it real by the damping designs. 4- The dynamic features between soil and pipe is depending on the earthquake excitation frequency. 5- Parameters such as pipe buried depth, pipe diameter, pipe type, soil accumulation and soil moisture are affecting in related to the pipe function with surrounded soil.

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