IJEW 国际工程期刊 International Journal of Engineering Works

International Journal of Engineering Works
ISSN-p: 2521-2419
ISSN-e: 2409-2770
Vol. 5, Issue 9, PP. 163-166, September 2018
https://www.ijew.io/

Study the Effect of Transient Load on Pipeline Supported by Concrete Blocks

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Received: 18 August, Revised: 30 August, Accepted: 15 September

***Abstract*—**A three dimensional analysis of dynamic load-nonlinear soil-concrete blocks - pipeline have been investigated to study the major factors that influencing the response of whole system and which dominate on the interaction between different component of the problem. The present work consider the effect of pipe diameter, distance between applied force and whole system, distance between concrete blocks or span of pipe. Aspects which addressed in this study the effect of the previous factors on deformation which can be express as vertical displacement and bending moment , friction stresses between concrete blocks and soil and Also the behavior of concrete blocks with time and distance. ABAQUS software is used to reveal the effect of these factors on structural behavior of whole system.

***Keywords*—**pipeline, concrete blocks, dynamic load, finite element method

I. Introduction

Pipes and pipelines are utilized in different engineering application for example used to convey oil or gas in chemical engineering; it is also used to convey potable water, rainfall and sewage in civil engineering so it shows the direct effectiveness on modern life. Piping systems are supported by concrete blocks for pipes above the ground or they are under ground. In both cases because of their natural frequencies they can be affected by ground movement and cyclic load [1]. An earliest study with regard to stresses and deflections that take place in pipelines at the transition from fully restrained to unrestrained situation was achieved by Schnackenberg [2]. The vibration transmission forecast by ground represents a complex problem [3]. In conventional finite element it is assumed that motion and deformation are small and the material behavior as linear elastic. In some cases this situation cannot be convinced leading to include of non-linearity action to the model [4]. Neglecting the ground-structure dynamic interaction will reflect on the response of structure and may give an overestimated or underestimated response [5]. Generally for gravity and operational loads vertical support is sufficient to withstand the vertical seismic forces as compare with other vertical loads [6]. The insufficiency rate of pipeline various significantly depend on the variation in design consideration, construction situation and the environmental condition. Commonly when the period of applied load is short dynamic analysis can be consider more accurate.

II. Methodology

The present work concern with three dimensional dynamic load – nonlinear soil – concrete blocks – pipe line interaction model is built by using ABAQUS software to reveal the impact of many factors on structural behavior and stress distribution on whole system. The whole system consist of the following parts:

Pipeline: A 30m steel pipeline modeling by a three node beam element (B32: Quadratic beam in space) with linear elastic properties of material.

Soil: A solid brick element (C3D20R: Quadratic brick, reduced integration) with 20 nodes is used to model soil with nonlinear properties Mohr-Coulomb model is adopt for modeling nonlinear behavior.

Concrete blocks: A solid brick element is used to model support of pipeline with linear elastic properties of material.

For pipeline six different size are considered in the study with constant wall thickness (12.5mm) theses size are (250 ,500 ,750 ,1000 ,1250 and 1500)mm. Table (1) review the elastic properties of steel pipe. A concrete support of dimension (1 x 1 x 1.5)m with 1m embedment depth in soil with elastic properties shown in table(2). Table (3) reviews the nonlinear properties of soil. The size domain of current problem 10 diameter of pipe measured from center line of pipe and with depth equal to 10 diameter of pipe. Fixed boundary condition is considered for all side and bottom of domain except the top is free. Interface element is adopted as linkage element between soil and concrete support (Blocks) with tangential and normal behavior respectively and penalty with coefficient of friction equal to 0.36. Also tie constraint (node to node) linkage element is used between pipe and support and tie constraint (surface to surface) linkage element used between pipe joint. Dynamic load of magnitude (10KN) with amplitude shown in figure (1). The total period of applied load equal to 6 sec with time increase 0.1 sec. For all material damping ratio equal to 5%.

TABLE I. ELASTIC PROPERTIES OF PIPELINE

Modulus of Elasticity (GPa)	Poisson's Ratio	Yield Stress (MPa)
200	0.15	415

TABLE II. ELASTIC PROPERTIES OF CONCRETE BLOCKS (SUPPORT)

Modulus of Elasticity (MPa)	Poisson's Ratio
432000	0.2

TABLE III. SOIL PROPERTIES

Modulus of Elasticity (MPa)	Cohesion (KPa)	Poisson's ratio μ	Angle of internal friction Ø
21200	40	0.35	0

It is required to reveal the influence of the following:

- 1-Effect of pipe diameter on vertical displacement and bending moment
- 2-Effect of distance between applied load and system (pipe and concrete blocks) on vertical displacement and bending moment
- 3-Effect of distance between supports on response of pipe on vertical displacement and bending moment
- 4-Effect of pipe diameter on development of friction stresses between soil and support
- 5- Effect of distance between applied load and system (pipe and concrete blocks) on development of friction stresses between soil and support
- 6- Effect of distance between supports on development of friction stresses between soil and support
- 7-Effect of time on vertical displacement of concrete support

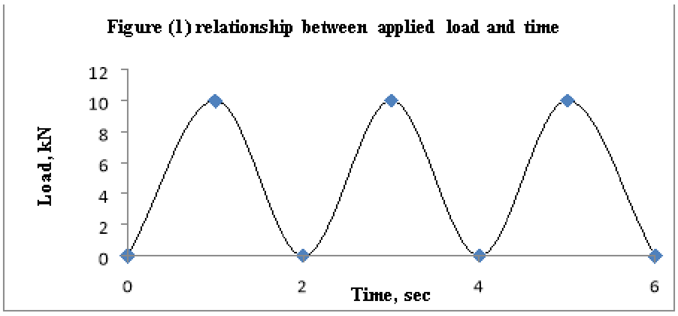

Figure 1. Relationship between applied load and time

III. RESULT AND DISCUSSION

It is clear from figure (2) as the pipe diameter increase the vertical response increase due to combined effect of applied dynamic load with self-weight of pipe which increase with increasing in pipe diameter in addition to gravity weight of support these load dominate on the vertical response. Also as vertical displacement increase the bending moment will increase due to fact as the displacement or deflection increase the bending moment will increase and this appear clearly in figure (3).

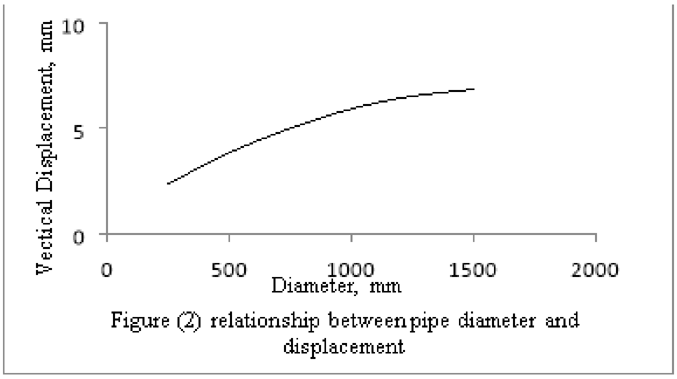

Figure 2. Relationship between pipe diameter and displacement

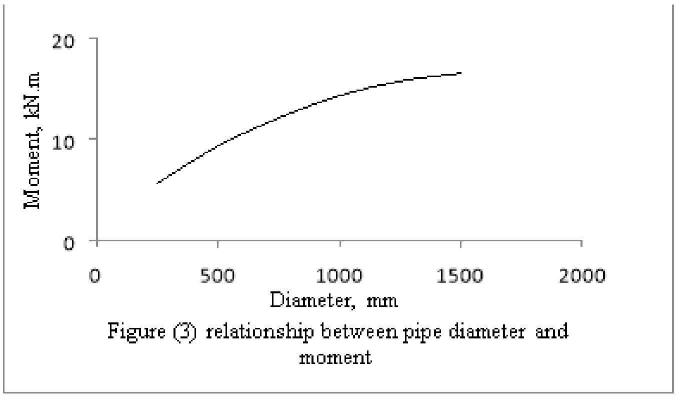

Figure 3. Relationship between pipe diameter and moment

It is difficult to determine the effect of distance on response of whole system but as distance between the applied load and whole system increase the response will decrease because of dissipation in load intensity that transfer by soil to whole system and this will reflect on response which represented by displacement and bending moment so it is appear from figures (4) and (5) as distance between load and whole system increase the displacement and bending moment decrease.

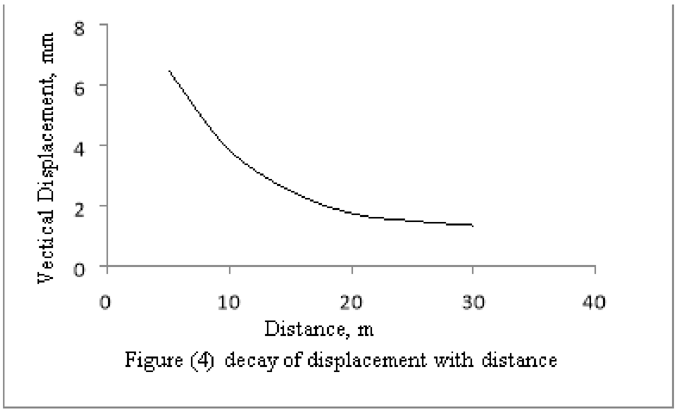

Figure 4. Decay of displacement with distance

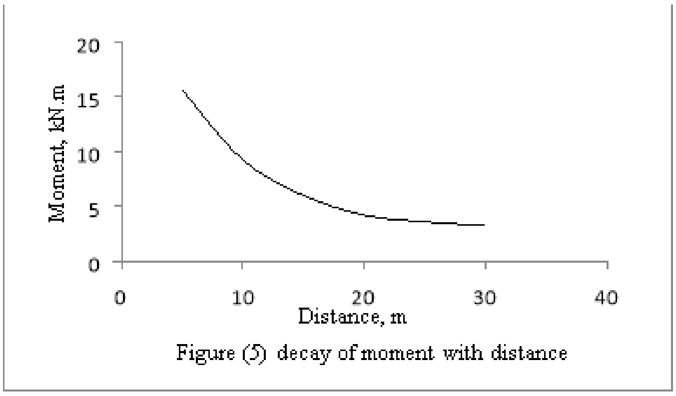

Figure 5. Decay of moment with distance

Figure (6) review as the distance between the supports (increase the pipe span) increase the vertical displacement increase due to increase in the load which represent by the weight of pipe in addition to the effect of applied load. Also figure (7) review as the distance between support increase the bending moment increase take inconsideration as deflection of span increase lead to increase in bending moment.

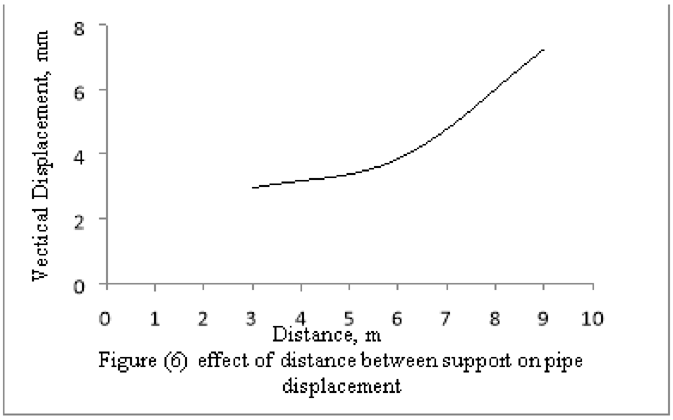

Figure 6. Effect of distance between support on pipe displacement

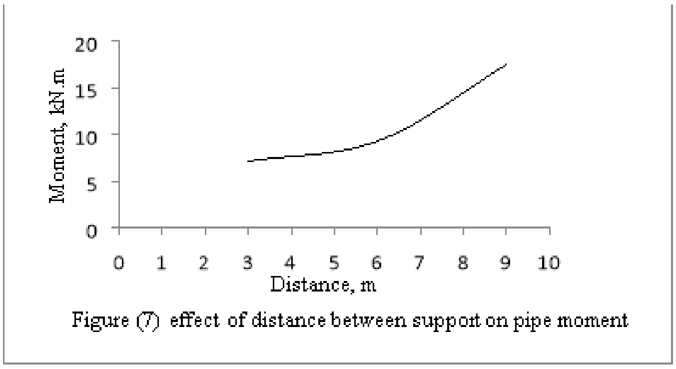

Figure 7. Effect of distance between support on pipe moment

Figure (8) shows as the diameter increase this mean the circumference of pipe increase and the contact area between pipe and concrete blocks support increase so when this area increase the development of friction stresses between pipe and concrete block also concrete block and soil increase respectively with increase in diameter. Figure (9) shows as distance between the whole system (pipe and concrete blocks) and applied load increase the development of friction stresses between soil and concrete blocks decrease due to dissipated in load transfer by soil to the system so the response will decrease with increase the distance between load and system. Figure (10) shows as distance between neighboring supports increase the friction stresses between soil and concrete blocks increase due to increase in load between the span this load represented by self-weight in addition to applied load which have major effect on response.

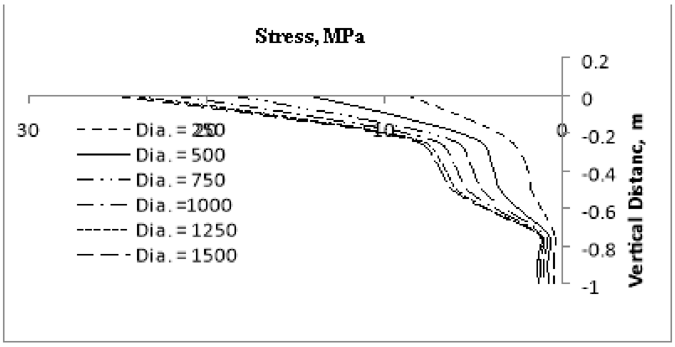

Figure (8) relationship between friction stress between soil and concrete blocks with vertical depth considering various diameter.

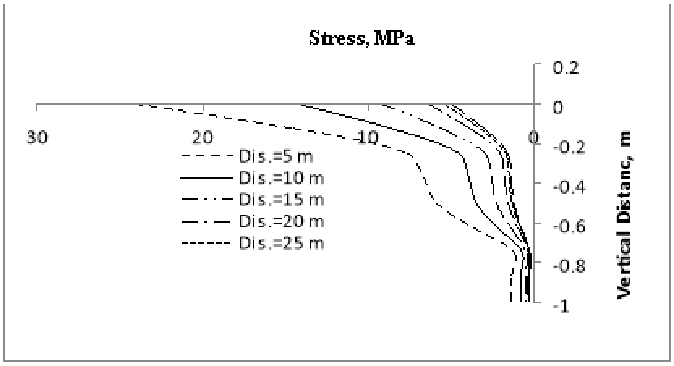

Figure (9) relationship between friction stress between soil and concrete blocks with vertical depth considering various distance between applied load and system.

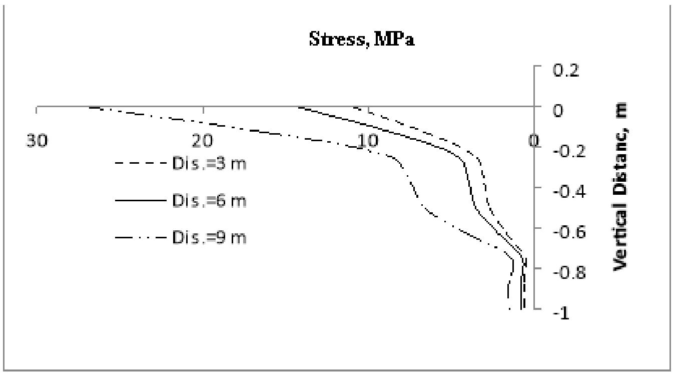

Figure (10) relationship between friction stress between soil and concrete blocks with vertical depth considering various distance between concrete blocks.

It is clear from figure (11) that the vertical response of concrete blocks increases with time and then reduces due to dissipated in load transmitted by soil with time. Also it is appear from figure (11) the middle support have higher response as compare with the remainder support. Figure (12) shows the deformations occur in concrete support it is obvious that the middle support have higher response as compare with the remainder support. Also figure (13) shows the lateral stresses transmitted by concrete blocks to soil. Take in consideration F1 represent the middle support while F3 represent the third support which located at distance 12m from the first support F2.

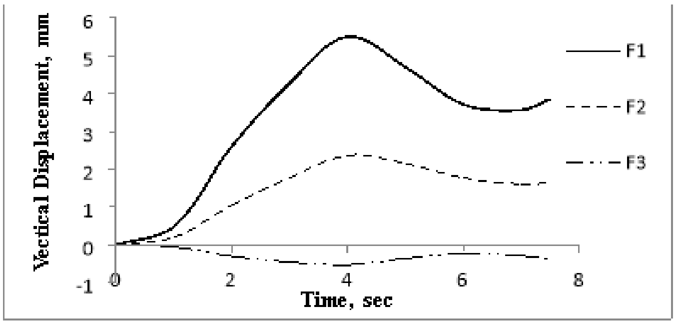

Figure 11. The vertical response of support with time.

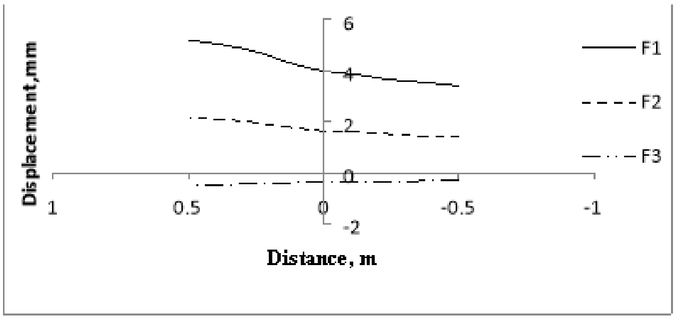

Figure 12. Relationship between vertical deformation and distance

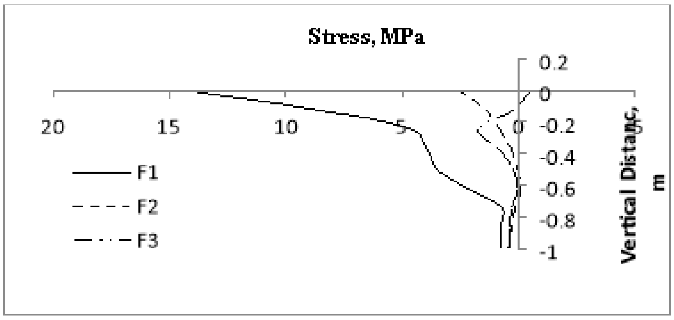

Figure 13. Rreview the lateral stresses transmitted to soil

CONCUSLION

1-The vertical displacement and bending moment increase with increasing in pipe diameter

2- The vertical displacement and bending moment decrease with increasing the distance between the applied load and whole system

3- The vertical displacement and bending moment increase with increasing in pipe span

4- The friction stresses between soil and concrete blocks increase with increase in pipe diameter

5- The friction stresses between soil and concrete blocks increase with decrease in distance between applied load and whole system

6- The friction stresses between soil and concrete blocks increase with increase in pipe span

7-The response of concrete support varying with time due to dissipated in load transmitted by soil

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