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# Effect of Machine Foundation Stresses on Gravity Retaining Wall Using FEM

Fatima M. Hassan[1,a*] and Waad A. Zakraia[1,b]

[1]Department of Civil Engineering, University of Diyala, Diyala, Iraq

[a]adammfa998@gmail.com and [b]waad_zakaria@uodiyala.edu.iq

*Corresponding author

**Abstract**. The dynamic reaction of the natural type of retaining wall is quite complex. Wall development and pressure rely upon the reaction of the soil underneath a retaining wall and the reaction of the backfill. The greater part of the present knowledge of the dynamic reaction of the wall has originated from the model test and numerical analysis. This paper aims to know the behavior of the retaining wall and the backfill. Also, under the effect of machine foundation, numerical modeling is used concerning a method of finite element. Two amplitudes of machine foundation subjected to three frequencies were used. The model used in the finite element was the linear elastic model (LE) for foundation and the Mohr-Coulomb model (MC) for soil. The results of this analysis for the amplitude of 25 kPa, the lateral displacement was 75% more than the active for the case of the amplitude of 40 kPa, the lateral displacement was 125% more than the active, and for the case of the velocity of 30 mm /sec very far higher than the maximum permissible velocity is 2.5 mm/sec and the acceleration was decreased by 52% between machine foundation and retaining wall.

**Keywords:** Machine foundation; retaining wall; vibration velocity; acceleration; lateral displacement.

## 1. INTRODUCTION

Studying the behavior of gravity retaining walls and backfill not connected to the wall when the machine is excited because of the weight of the foundation machine and its components, machine foundations must be given special consideration since they transmit both static and dynamic loads to the soil. Several previous studies included the retaining wall. Veiskarami1 [1] studied The parameters that affect the strength and position of the design loads are shown in the analysis of the dynamic earth pressure caused by machine foundations on a nearby retaining wall. The meshless local Petrov-Galerkin (MLPG) method can be used to investigate the issue for a range of retaining wall and machine foundation designs. The assumption was that the soil medium was homogeneous and viscoelastic. The idealized machine foundation is a harmonic sinusoidal dynamic force that is frequently observed in practice. According to the findings, there is a key frequency and location for which the passive pressure reaches its peak throughout the full dynamic load [2]. As a result study, the developed lateral earth pressure back of The cohesion backfill soil on the rigid retaining wall tilting outward near the base is estimated using a straightforward and realistic analytical approach. Many degrees of wall tilt are included, ranging from a minimal active condition to a maximal active state. The fully active state happens when all of the soil's particles along the wall's depth are in an active state. When the soil element at the ground surface experiences enough lateral displacement to enter an active situation, this is when its initial active state is described as a stage of wall tilting. The model test measurements are contrasted with the predictions made using the developed analysis method at several points. The comparison reveals very good agreements.

Talebpour [3] investigated the dynamic soil pressure on perimeter retaining walls of buildings using finite element nonlinear analyses modeling the behavior of soil in the near area using the nonlinear Drucker Prager failure criterion It is supposed that the middle structure and the far field soil will behave like linear elastic materials. Nonlinear interface components are used in the modeling of the soil-wall interface behavior. It is discovered that the angle of the internal friction of the earth, which was disregarded in earlier studies, plays a significant role in the dynamic lateral pressure. A new diagram is also suggested to determine lateral seismic soil thrust on rigid walls.

The finite element analysis is applied to determine how interfering affects the dynamic response of machine foundations. The use of well-established and accurate analytical methods for wave propagation and vibration from machines has verified the finite element analysis methodology. In the analyses, medium and loose sand were used., and dense sand. In addition, the frequency ranging from 0.51-21.0 Hz was considered. The result is that, with a range of 1 to 77% in percentage terms, the interference caused by two active machines greatly increases the dynamic settlement. This proportion grows with an increase in soil stiffness as these events become more frequently occurring, but it reduces to an increase in the vibration of frequency or the length of space between foundations [4]. Fattah et al. [5] studied the dynamic analysis of the stripped machine foundation. Vertical harmonic stimulation is employed while taking into account the growth of the high pour water pressure of finite elements programs and a foundation of different thicknesses taken at various depths set up saturated sand in a range of states loose and medium, and dense sand). The dynamic reaction is quantitatively performed using PLAXIS 2D. It presumes that soil is an elastic, fully flexible medium that meets the Mohr-Coulomb yield requirement. Parametric research is used to evaluate how much the machine of foundation depends on several parameters, including the frequency, amplitude, and embedment of a dynamic load. Raising the embedment was found to be the solution It was found that increasing the embedment percentage reduces the dynamic response on a certain embedment depth; as the embedment depth increases

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over 1 m, the result diminishes, and as soil strength increases, the effect becomes less pronounced similarly see a deterioration in embedded depth's ability to decrease dynamic response.

Additionally, three types of (D/B) relations (0, 1/3, and 2/3) are used in the study conducted by Javdania [7], together with three cases of foundation depth (at resting on the upper layer of the ground, between 0.51 and one meters below the surface), all subjected to earthquake loading stress. The results of the study showed that a square form of footings had a lower settlement and higher bearing capacity compared to other footing forms, that there was a linear relationship between foundation depth and settlement beneath the influence of earthquake load, and that the foundation's shape had an impact on the magnitude in dynamic bearing capacity and a settlement. Das [8] used numerical finite-difference modeling, FLAC on sandy soil, and the dynamic bearing capacities of nearby shallow strip foundations were evaluated. The effects of soil strength factors, shallow foundation geometry, and cyclic loads at various distance ratios on the bearing capability of foundations were assessed. The findings showed that behavioral interference had a discernible impact on shallow foundations' ability to withstand cyclic stress. The interference effect increased and then dropped as the distance ratio between the foundations increased. At a distance ratio of 2, behavioral interference had the largest impound on the foundations' dynamical bearing capacity. The impact of the interaction is eliminated at distance ratios greater than 5. In addition, the action interference's impact on a foundation's ability to support the weight was shallowly decreased as foundation depth, soil elastic modulus, and the angle of internal friction rose.t. The interference coefficient decreased as the foundation breadth and loading frequency increased. The findings show that the interference effect must be taken into account when determining bearing capacity in shallow foundations subjected to cyclic stress, such as vibration machine foundations.

Patel [9] investigated the analysis and construction of a machine's foundation, which must consider both static and dynamic stresses generated by the machine's operation. That needs more consideration. The most crucial factors to consider while analyzing a machine are its operating frequency and limit amplitude. Foundation. The natural frequencies and amplitudes of foundation vibrations can be obtained by connecting coupled modes of vibration with the Elastic half-space analogy approach with embedding coefficients. The natural frequency of foundation vibrations has increased concerning embedment depth, but their amplitude has decreased. Several types of foundations, such as pile groups surrounded with grout, quay walls, circular tunnels, and disconnected piles under different intensities of earthquakes, were analyzed using PLAXIS software [10-15]. In this study, the effect of machine foundation has several frequencies on the performance of retaining wall and backfill material using PLAXIS software.

## 2. SOIL CHARACTERISTICS AND FINITE ELEMENT ANALYSIS FOR CASE STUDY

The two parts in the study's model are the soil and the retaining wall. An elastic, completely plastic soil domain displays three square soil layers using the Mohr-Coulomb model. Elastic soil behavior turns into plastic soil behavior. Mohr-Coulomb is more frequently employed than other models for geotechnical problems because it is basic, simple to apply, and computes fairly quickly [16,17]. The (model of linear elasticity), which is based on Hook's law of isotropic elasticity, molds another portion of the concrete wall. Several situations feed the flow. Deformation of analysis in the PLAXIS program, the analysis of the long-term reaction of the drained soil, and the analysis of the short-term response of the undrained soil did not take into account the evolution of the pore pressure as a function of changing stress. Sand layer with a long-term behavior (drained), a high level of permeability, permeability and clay soil with short-term behavior (undrained A), in which the features are inefficient state, can be represented in PLAXIS software as the water table is 30 meters below the surface of the ground. The parameters of the soils and foundation materials are shown in Tables 1 and 2.

Table 1: Properties of the soil layers in the model.

| **Type of soil layer** | **Firm clay** | **Stiff clay** | **Dense sand** |
|---|---|---|---|
| **Interface** | Rigid | Rigid | Rigid |
| **Elastic modulus (kN/m$^2$)** | 25 | 55 | 50 |
| **UnitWeight of soil (kN/m$^3$)** | 19 | 16.8 | 17 |
| **Poisson ratio** | 0.4 | 0.4 | 0.3 |
| **internal friction angle** | - | - | 33 |
| **Cohesion (kN/m$^2$)** | 55 | 100 | - |

Table 2: Properties of the retaining wall and machine foundation

| **Property** | Elastic modulus | Unit weight | Poisson's ratio |
|---|---|---|---|
| **Value** | 2x10$^7$ kN\m$^2$ | 23 kN\m$^3$ | 0.17 |

A retaining wall embeds the geometry model used in this study for analysis with dimensions (B=2 m and H=4 m) in a (60x60x30) m soil media. PLAXIS software was used to analyze the retaining wall and the backfill under the machine foundation in Baquba soils. A retaining wall and soil layers make up the model's shape. In addition, the multiplier loading of the machine is shown in Figure 1.

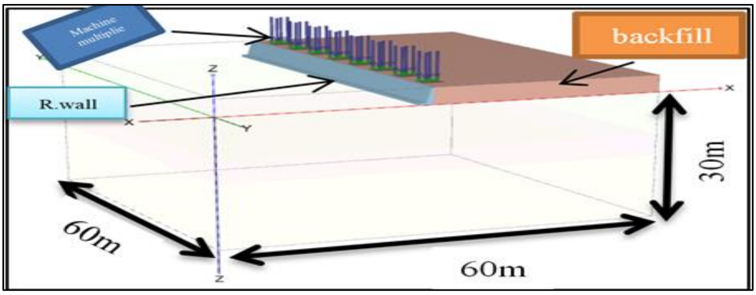

Figure 1: Geometry model and load multiplier of the machine foundation.

### 2.1 Elements and Meshing

After completing a geometry model, PLAXIS 3D enables a mesh to be fully automatically generated by segmenting the model into volume elements and fully accounting for loads, all structural elements, soil stratification, and even boundary conditions. A mesh is a collection of finite elements. Tetrahedral elements with ten nodes were employed, and the degree mesh can range from very coarse to very fine. As stated by [6], strain is constant in the element, so a very fine mesh was used for accurate results, but the medium mesh was used to save time on time-consuming calculations. There is no relative displacement since the foundation of the wall and the earth surrounding it have a strict relationship that defines the interaction between materials.

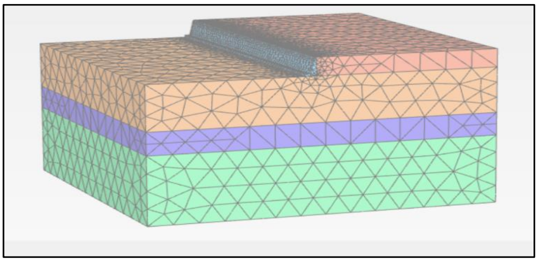

Figure 2: Medium mesh of retaining wall and soils.

### 2.2 Definition of The Machine Foundation and Boundary Condition

As shown in Figure 3, the research's input movement is defined as a dynamic surface loading (load multipliers) at the surface of the model's foundation machine. The machine loading is applied to the backfill beside the retaining wall above three soil layers. Two amplitudes of the machine are studied: the first one is the amplitude of machine=25 kPa with frequencies of 30 Hz, 60 Hz, and 90 Hz, and the second amplitude of the machine is 40 kPa with the same frequencies the duration of the vibration is 15 sec. Figure 5 shows the amount of the lateral displacement resulting from the amplitude of the machine is 25 kPa and 40 kPa It's used at the upper edge of the 3-D object along the z-axis. In actuality, Xmax, Xmin, and Ymin determine the absorbent limitations (viscous boundaries), and there are no viscous boundaries.

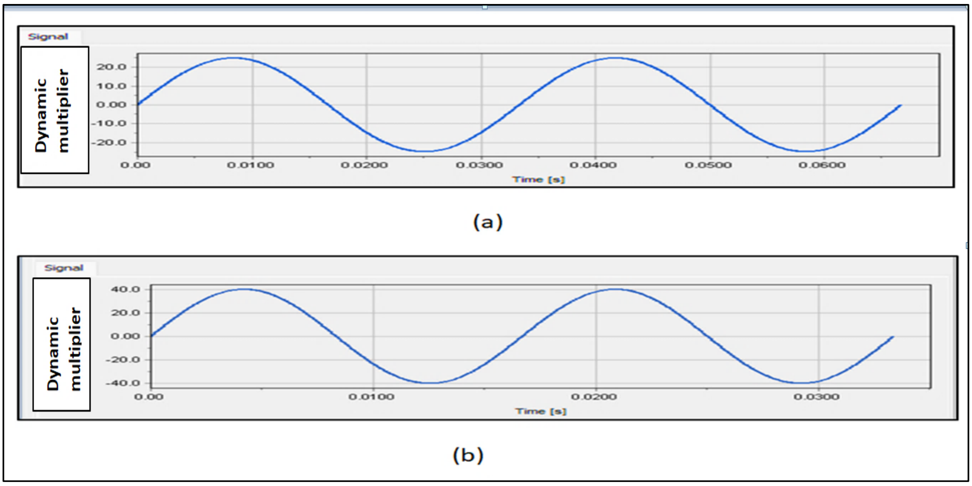

Figure 3: Amplitude –time of machine foundation.

## 3. RESULTS AND DISCUSSION

The results of a numerical analysis of the model following the completion of all calculations for the construction stage, the construction of the retaining wall, and the static and dynamic loads that are used in a paper using the finite element method. The analysis is done to forecast how the retaining wall would behave in terms of lateral displacement, vertical settlement, and acceleration and velocity under two amplitudes with different frequencies: the first amplitude of the machine is 25 kPa with frequencies of 30 Hz, 60 Hz, and 90 Hz, the second amplitude of machine is 40 kPa with same frequencies that duration of the vibration is 15 sec. the conversations that follow parts:

### 3.1 Lateral Vibration and Displacement of Concrete Retaining Wall

Figure 4 shows a location on the top side of the retaining wall where a lateral displacement with vibration for two amplitude is shown in Figure 4; it can be seen there is a drastic increase in the lateral displacement of approximately up to 7 sec for two curves. After that, the lateral displacement will decrease at a very low rate. The vibration constant is not changed in the total period of vibration; the lateral displacement of the top due to vibration is a value of 7 mm when the amplitude is 25 kPa and it has exceeded the lateral displacement according to the active state of soil [12] from this Figure, it can be found that the most dangerous is only in few minutes due to the author believes that this curve well level of at some quantity near 7mm. after that the lateral displacement for amplitude is 40 kPa will decrease and the vibration same constant and it start the change in 4 sec in very low rate to some quantity near 8 mm at time 15 sec.

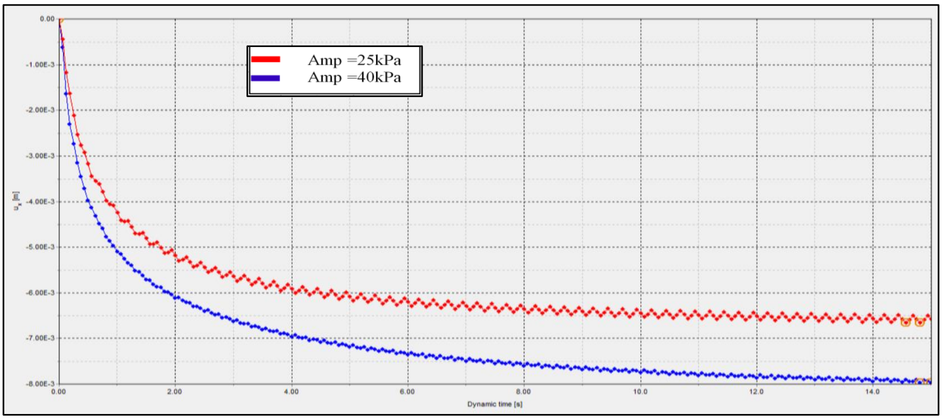

Figure 4: Lateral displacement versus dynamic time of foundation under two amplitudes of the machine is 25 kPa and 40 kPa.

Figure 5 shows the retaining wall with a height of 4 m due to the effect of machine foundation loads; the vertical settlement of soil types with three layers of firm clay, stiff clay, and dense sand is investigated. Generally speaking, the results show that the highest value of the vertical settlement for three frequencies, 30, 60, and 90Hz, is well down below the maximum settlement for general failure, which is 200 mm; for retaining wall, the vertical settlement is safe against this type of failure.

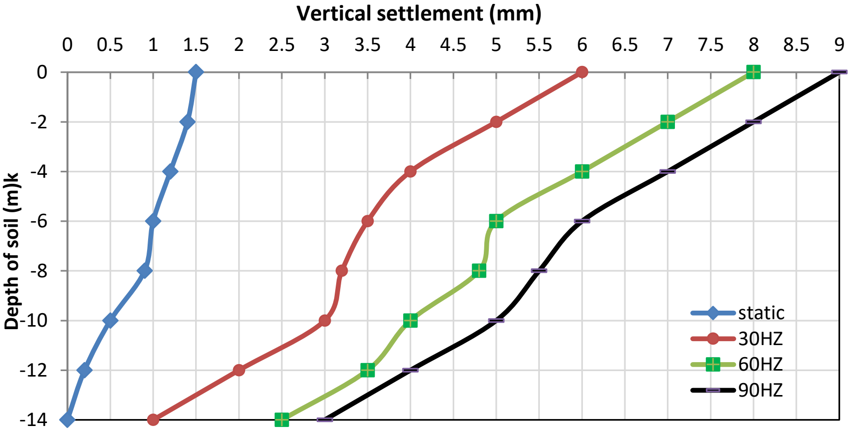

Figure 5: Vertical settlement versus depth with different frequencies placed on soil layers under the retaining wall.

### 3.2 Effect of Retaining Wall on Acceleration and Velocity

Figure 6 shows the acceleration ($a_x$) versus dynamic time under the amplitude of the machine is 25 kPa. Placed in point in the retaining wall, this acceleration shows the maximum acceleration of the wall due to the effect of the machine that is equal to 9 m/s$^2$. e acceleration of the backfill under the machine is 19 m/s$^{2,}$ which means 52% of acceleration transfer from the backfill under the machine to the retaining wall.

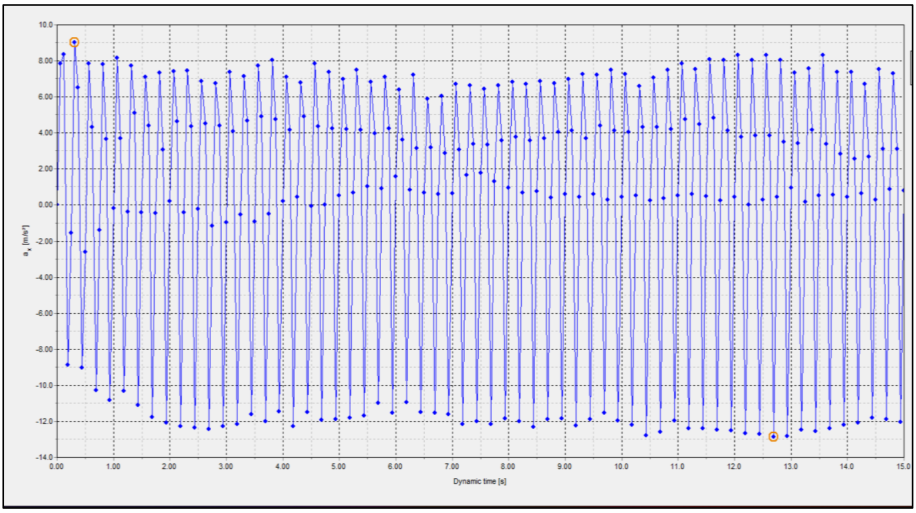

Figure 6: The acceleration (ax) versus dynamic time under the amplitude of the machine is 25 kPa.

As shown in Figure 7, the velocity (Vx) versus the dynamic time under the amplitude of the machine is 25 kPa placed at a point in the retaining wall. This velocity shows the maximum velocity of the wall due to the effect of the machine that equals 0.03 m/s in time 15 sec, which is far beyond the maximum Permissible velocity of 2.5 mm/sec [18].

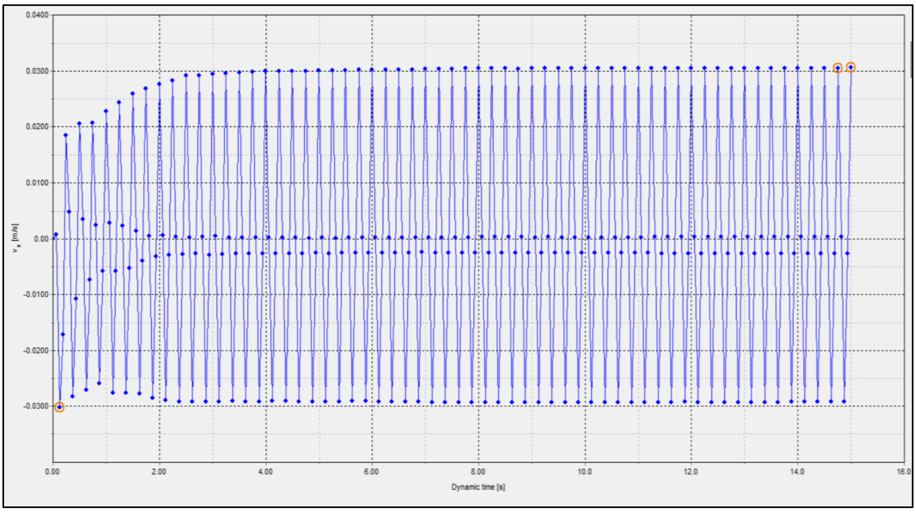

Figure 7: The velocity (Vx) versus dynamic time under the amplitude of the machine is 25 kPa.

Figure 8 shows the acceleration (ax) versus dynamic time under amplitude of machine = 40 kPa placed in point in the retaining wall; this acceleration shows the maximum acceleration of the wall due to the effect of the machine that is equal to 10 m/s if the acceleration of backfill under the machine is 25 m/s$^2$ that means 60% from acceleration transfer from backfill under the machine to retaining wall.

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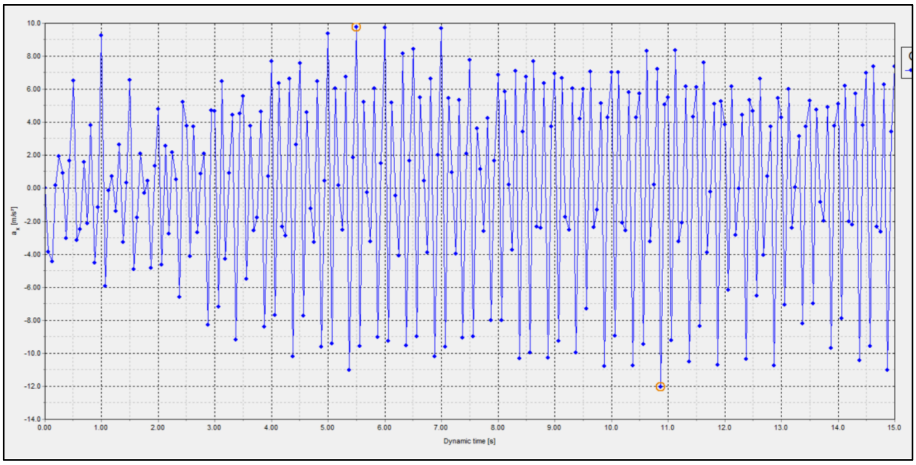

Figure 8: The acceleration (ax) versus dynamic time under the amplitude of the machine is 40 kPa.

Figure 9 shows the velocity (Vx) versus dynamic time under amplitude of machine = 40 kPa placed in point in retaining wall. This velocity shows the maximum velocity of the wall due to the effect of the machine that equals to=0.004 m/s in time 15 sec, which is higher of the maximum permissible velocity.

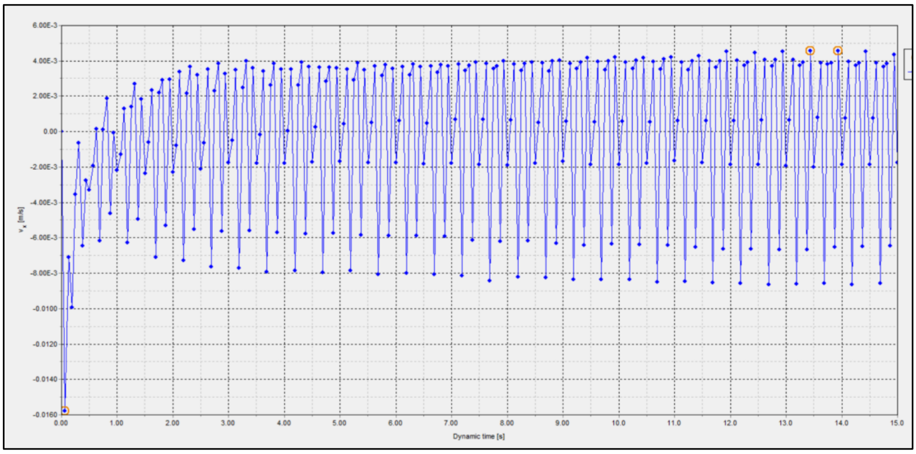

Figure 9: The velocity (Vx) versus dynamic time under the amplitude of the machine is 40 kPa.

## 4. CONCLUSIONS

Simulations were carried out for the dynamic behavior of the retaining wall on layered soil under a machine foundation. The most important observations from this simulation are the following points that can be derived from the study findings.

- The maximum lateral displacement for two amplitudes, 25 and 40 kPa, has exceeded the lateral displacement according to the active state of the soil, which is equal to 4 mm.
- The maximum vertical settlement is well below the maximum settlement for general failure, which is 200 mm; for retaining walls, the vertical settlement is safe against this type of failure.
- The maximum acceleration of 52% from amplitude 25 kPa is a transfer from backfill under the machine to retaining wall when the acceleration of the wall due to the effect of the machine equals nine m/s$^2$ and 60% transfer from backfill under the machine to retaining wall for amplitude 40 kPa.
- The regression of acceleration between the machine foundation and retaining wall can be approximately linear regression for the first amplitude from backfill that equals 52% to the retaining wall, and the same linear regression of 60% for the second amplitude.
- The maximum velocity of the wall is far beyond the maximum permissible velocity of 2.5 mm/sec due to the effect of the machine that velocity is equal to 0.03 m/s and 0.004 m/s.

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