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Dynamic Behavior of Sheet Pile in Sand under the Influence of Vibration

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ABSTRACT

This article includes an experimental investigation into the behavior of a vibratory force-exposed sheet pile set in sand. The study goal is to provide a parametric study. Regarding how vibrations affect the sheet pile's movement and rotation after layering the soil in a steel container with internal dimensions of 900 mm length, 400 mm wide and 400 mm high, a steel sheet pile with the dimensions of 350 mm length, 20 mm width and 0.5 mm thickness was inserted into the soil. The results showed that the speed, acceleration, and displacement increased with increasing the frequency of the vibration source when the source of vibration was situated at a distance of (D distance = H height of the sheet pile) and exposed to varied frequencies (5, 10, 15) Hz. As frequency is a type of energy, increased frequency will thus eventually cause more disturbance. The disturbance and its consequences on the soil will eventually increase as the frequency rises.

1. Introduction

A sheet pile wall is created by installing a row of vertical pile segments that interlock to create a relatively straight wall that offers stability and a wide margin of safety, when used as earth retaining structures along shorelines or slopes, sheet piles can be made from a range of materials, including wood, concrete, steel, or aluminum. Their interlocking edges form a wall that can support soil. Applications for these diverse materials are numerous. Basically, there are two types; an anchored sheet pile which is a barrier supported by one or more mechanical anchors, interactions between the surrounding soils, and a cantilevered sheet pile is a barrier that is entirely supported by the earth around it [1]. Numerous scholars have researched cantilever sheet pile walls with no surcharge on the backfill in depth for earth pressures and bending moments [2-4]. studies on the deflection of sheet pile walls and ground settlement [5]. In sandy soil, cantilever sheet pile walls have also been designed using an inverse dependability approach [6].

Model studies have been carried out on embedded walls by [7]. Evaluated the influence of numerous parameters including surcharge, the position of anchors, dredging level, type of soil, the flexibility of pile and distribution of soil pressure on the flexible retaining wall [8]. Research on anchored sheet pile was done experimentally by taking into account a few key elements, such as anchor geometry, the initial design premise, soil density, wall flexibility, and

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initial stress state, flexible retaining walls can be constructed in sand by [9].

Ground vibrations can be caused by both natural phenomena or by human action. Natural occurrences, ocean waves and earthquakes are the sources of most interesting ground vibrations. When there are earthquakes the magnitude of the ground tremors can be high enough to cause significant structural harm, or possibly the collapse of constructions with a fatality toll. The study of everything incidence of earthquakes and the related factors impacts on soil and ground structures are the focus of geotechnical earthquake engineering [10]. Human activity-related ground vibrations are called artificial vibrations, and they range widely in intensity based on the specific vibration source [11]. Peaceful human activity that produces vibrations in the ground may be categorized into the following major groups: machine operation, railroad, road traffic, and work in construction [12]. The majority of ground vibrations caused by (heavy machine) operation is continuous and periodic, and they have been thoroughly investigated over the past 50 years using both analytical and experimental techniques [13]. The earliest centrifuge model of the seismic response of retaining structures was reported by their study about the centrifuge response of micro concrete cantilever walls that retained a dry cohesionless backfill, the walls were fixed to the loading frame and subjected to harmonic accelerations up to (0.22) *g*. The results suggested that the wall inertial forces must be taken into account in addition to M-O earth pressures [14]. studied the response of flexible cantilever walls in medium dense sand, the container was subjected to earthquake-like motions, which resulted in seismic pressures consistent with M-O theory, and a seismic resultant located at 1/3 H [15]. An experimental study of the responses of embedded retaining walls to seismic stresses. There were nine centrifuge tests performed on reduced-models of two retaining walls in dry conditions.

The experimental results show that the retaining walls experience significant permanent displacements under increasing structural loads for maximum accelerations that are less than the critical limit equilibrium value, whereas for greater accelerations the walls rotate under seismic actions [16]. The used of shake-table test to investigate the dynamic reactions of anchored sheet piling quay walls that were buried in liquefaction-prone soil [17]. Several studies relate to sheet pile deflection carried out due to the drilling process or sheet pile deflection. However, the deflection behaviour of sheet piles due to vibration forces is still very limited. To understand and predict the deflection of sheet piles due to the vibration force that occurs is very important in planning the structural design stability of sheet piles. For this reason, this study focuses on elucidating the behaviour of sheet piles subjected to vibrational forces in sandy soils.
To give a parametric study of the effect of vibrations on the rotation and displacement of sheet pile.

2. Materials and methods

2.1 Soil

In this study, a sample of sandy soil was collected from the Karbala Governorate in central Iraq; Figure 1 depicts the location of the sample collection; numerous tests have been conducted to ascertain the characteristics of a sample; Table 1 and Figure 2 explain the sample characteristics:

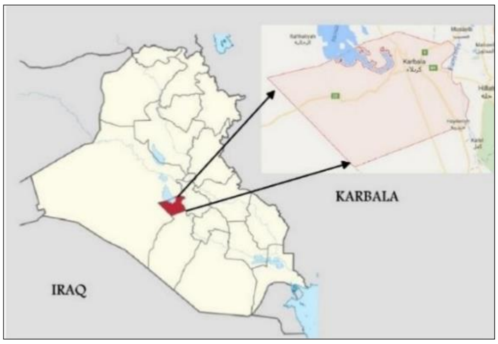


Figure 1. The site from which the sample was taken

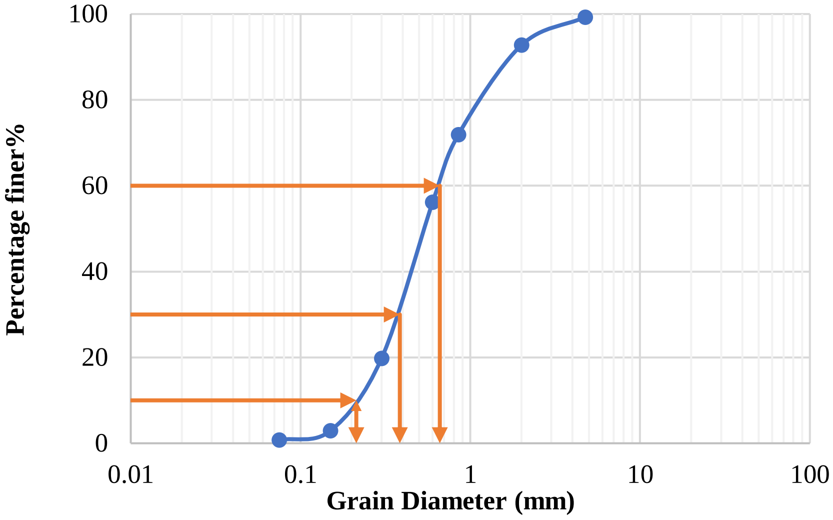


Figure 2. Curve of particle size distribution of sand

Table 1: Properties of sand

Properties	Values	Standards
Effective size, D10 (mm)	0.21	ASTM D 422 and ASTM D 2487 (2006)
D30 (mm)	0.38	
Mean size, D50 (mm)	0.64	
D60 (mm)	0.66	
Coefficient of uniformity, Cu	3.14	
Coefficient of curvature, Cc	1.03	
Classification (USCS)	SP	
Specific Gravity, Gs	2.66	ASTM D 854 (2006)
Angle of Internal Friction (Ø)	35.5	ASTM D3040-04(2006)
γd (max.) (kN /m^3)	18.1	ASTM D 4253 - (2006)
γd (min.) (kN /m^3)	16.20	ASTM D 4254 - (2006)
Maximum void ratio, *emax*	0.8	………
Minimum void ratio, *emin*	0.52	………
Field dry unit weight, γd (kN/m3)	17.5	……….
Relative density, Dr.%	70%	……….

2.2 Test container

The steel container is a box made of steel plate with internal dimensions of 900 mm length, 400 mm wide and 400 mm high. Three sides and bottom are made of 4mm thick steel plate, since the width of the footing of the machine is 10 cm only, it will not inter feel with the side of the container and will not reach a depth of 3 B, which is negligible in the soil mechanics sense, on both sides of the container, pieces of rubber (5 mm thick) are placed as a vibration absorbent to reduce wave reflection and refraction at the ends of a typical test, a thick layer of absorbent pad is placed on three of the inner walls of the tank [18]. One side of the box is made of transparent polymer material to see the drilling process after installing the plate support, Figure (3) shows the steel container:

Figure 3. Test container

2.3 Sheet pile

In the model test, the sheet pile is 350 mm in height, 0.5 mm in thickness, and 20 mm in width, and made from steel.

Figure 4 shows the model of sheet pile, which was made domestically of steel, exactly the same dimensions and materials as the real sheet pile, which is, selected with dimensions (6m long, 0.5m wide, and 0.012m thick).

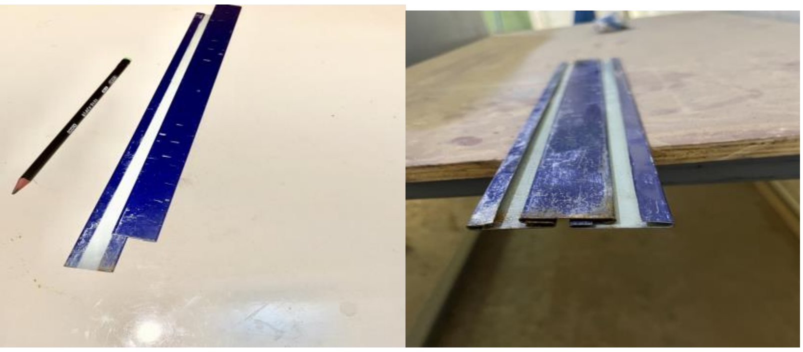
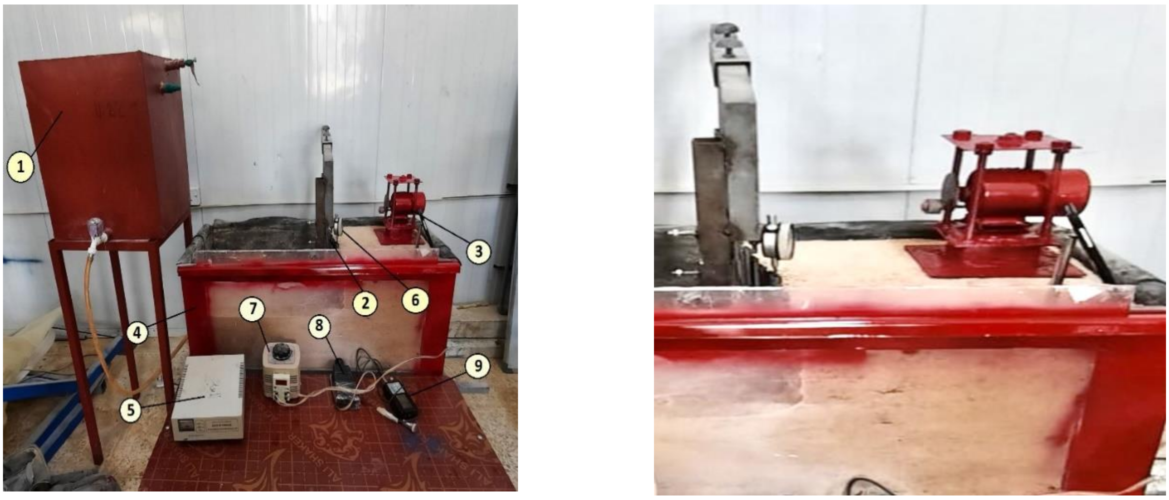


Figure 4. Sheet Pile model

2.4 Soil preparation and test device

Figure 5 shows the Apparatuses of model, the soil is put into a steel container with the following measurements dimensions: 900 mm * 400 mm * 400 mm, the container is positioned on a table 500 mm above the floor's surface to minimize friction and absorb waves in relation to the container, the interior of the container is lined with rubber. The compaction of the soil was conducted in the following manner: Each layer, which has a thickness of 100 mm, was compacted using a compactor with a water content of 0.08, and after it has been left, another layer is put in which is about 100 mm thick and compacted in the same sense, and so forth to the end of the tank. to achieve a relative density of 73% in order to create a dense sandy soil. The substrate (sheet pile) is gently pushed with a rubber mallet once the container has been entirely filled with sandy soil with a density of 73%. The sheet piles are interlocked with one another to guarantee stability and non-slip together and pushed in a straight line to ensure that they overlap closely. A dial gauge is attached to the free end of the sheet pile to test vertical stability after it has been pushed or stitched, with a second dial gauge attached to the side to ensure the integrity of construction, the horizontal wall's displacement is monitored and kept within the allowable value suggested by [19] before the earth is carefully and slowly dug or excavated.

In order to prevent abrupt increases in dynamic load, the speed controller then gradually drives the vibration source until the desired frequency is obtained. The dynamic interaction (displacement amplitude and acceleration) of the sheet pile was evaluated and recorded using a piezoelectric accelerometer at frequencies of (300, 600, and 900) rotations per minute, or (5, 10, and 15 Hz). Dynamic response characteristics were captured for a half-hour during the process test, every two minutes.



a) Details of Apparatuses

b) Zooming of the distance between the source of vibration sheet pile

Figure 5. Apparatuses of model

1- Water tank,
2- steel sheet pile with dimensions (350 × 20 × 0.5) mm
3-Mechanical oscillator
4-Steel box with dimension (900x400x400) mm,
5- AC automatic voltage regulator
6-Two dial gauge
7-Variable frequency drive, Vibration meter,
8-Digital tachometer, Steel Mold
9-Piezoelectric accelerometer, Steel Mold, Camera,

3. Results and discussion

The current study investigates the effect of vibration forces on the sheet pile after being immersed in sandy soil and pits, and placing the source of vibration at distance (D=H) where:
D = distance between the source of vibration and the sheet pile
H = height of the sheet pile tested at three frequencies (5, 10, and 15) Hz, recording speed, acceleration, displacement amplitude, and sheet pile rotation.

3.1 Displacement amplitude

Figure 6 shows the relationship between the amount of displacement amplitude with time for steel sheet pile (D = H) at different frequencies of (5, 10 and 15) Hz. The magnitude of displacement amplitude at frequency (15) Hz is greater than other values because the magnitude of displacement amplitude rises as the frequency of the source increases.

At displacement amplitude of the vibration, the direction of the behavior can see that almost identical with a small difference between them while the displacement for (15 Hz) is high and has a peak at about (25 minutes) then it decreases again to (0.02).

3.2 The Acceleration

Figure 7 explains the relationship between the acceleration and the time of the steel sheet pile, the distance between the source of vibration and the sheet pile (D = H), and the different frequencies of (5, 10, and 15) Hz. The acceleration due to (5 HZ to 10HZ) are almost identical unlike the acceleration due to (15) HZ but in actually all correspond at the end of the test

3.3 Velocity

The velocity here refers to the velocity of vibration of the sheet pile recorded at the top of the sheet pile.

Figure 8 depicts the relationship between velocity and time during machine operation for various frequencies (5, 10, and 15) Hz. It can be seen that the velocity for (5) Hz is smaller than that of (10) Hz and the latter smaller than that of (15) Hz. There's not much fluctuation in the two curves except for the period from (13 to 22) minute. A small jump is noticeable in the frequency of (5) Hz.

3.4 Rotation

In soil mechanics sense, it is customary to relate settlement, rotation and ales of fundamental analysis to neutralized form (dimensionless) from in this paper the rotation is related directly to the rotation of sheet pile in active failure case. Thus, the rotation measured in this study is directed divided by rotation causing active state of soil. in this sense the rotation is only a percentage of active rotation of sheet pile in active state. this will give a comprehensive aspect of sheet pile movement the sheet pile rotation rises with higher frequencies, as seen in Figure 9, which shows the relationship between sheet pile rotation and time at different frequencies (5, 10, and 15) Hz. At the initial time from 0 to 15 min, the three detailed cases are almost identical and close, but after 15 min of time, we can see that the rotation frequency of 15 HZ has increased to a very high degree, while the other two continue at a constant level, which means that the difference in rotation between the five hertz and the ten hertz is almost negligible, unlike the fifteen hertz, which reflex hazardous condition

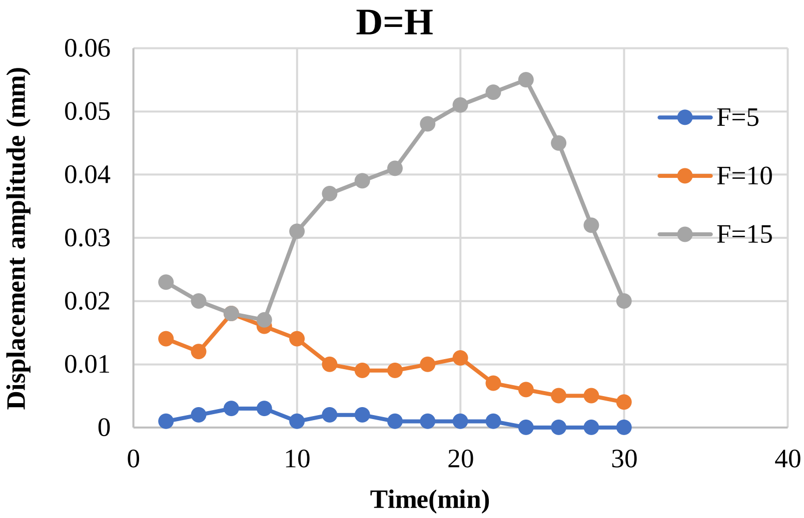


Figure 6. Variation displacement amplitude with time for three values of frequency for distance D= H

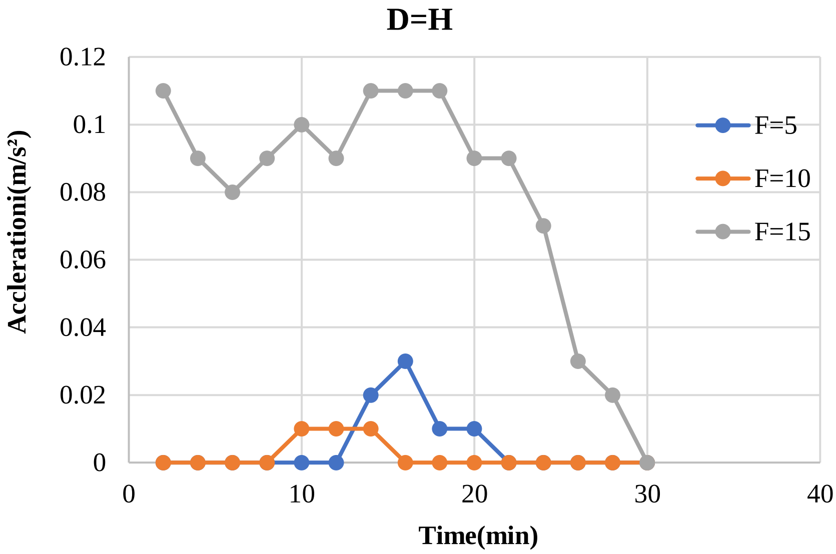


Figure 7. Variation of acceleration with time for three values of frequency for distance (D= H)

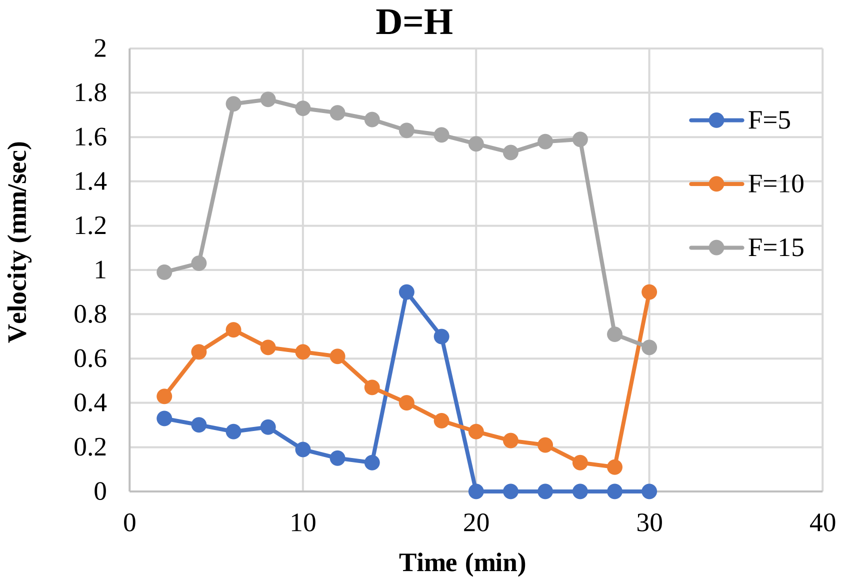


Figure 8. Variations of Velocity with Time for Three Values of Frequency at distance (D=H)

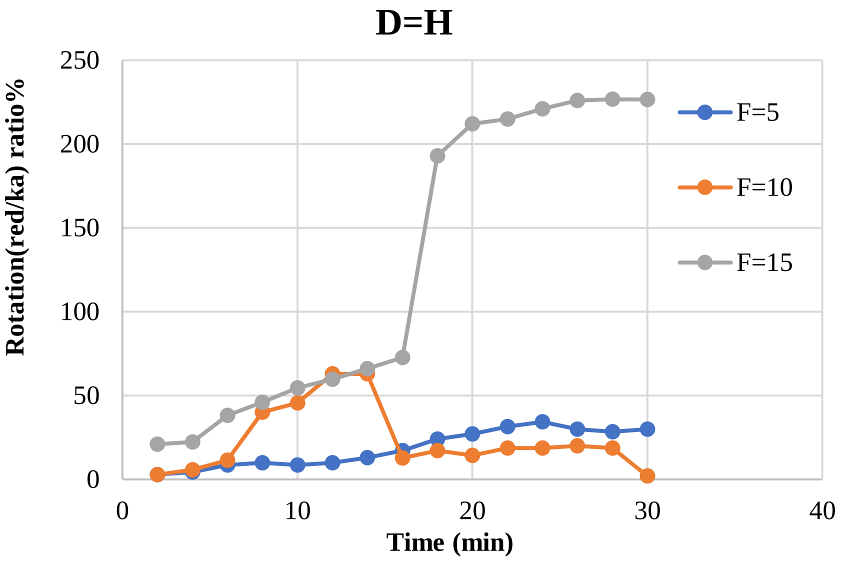


Figure 9. Variations of rotation (read/ka) with Time for Three Values of Frequency for distance (D=H)

4. Conclusions

In this study, a laboratory experiment is conducted to study the effect of different frequencies on the dynamic behaviour of the sheet pile in sand soil under vibration through wall displacement and rotation of the sheet pile. Based on the results obtained, the following conclusion can be drawn:

1. In terms of frequency, at 15Hz, it has very high (Displacement Amplitude, acceleration and velocity).
2. The experiment test indicates that acceleration converges after thirty minutes.
3. After twenty-two minutes, a peak in the displacement amplitude was observed at 15 Hz, but no peak was observed at the other two frequencies.
4. The rotation, which is the most critical in this study, is identical for (5 to 10) HZ, while the rotation for (15) Hz increased with time and levelled off at 200%, which reflected dangerous conditions for the case of the frequency of (15) Hz in terms

of rotation. only one distance was conducted in this research, which is (H) from the sheet pile. And the frequency of 15Hz was to be more severe and it is recommended to this distance not to use this frequency (15Hz) found to be the most severe and dangerous

5. The velocity of (15) Hz has dominated for a large period of time and finally decreased a little after (27) min.

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