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Article

Action of Vibrating Foundation on Adjacent Static – Load Foundation Having Rectangular Shape

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Abstract. This paper presents an experimental study on the dynamic response of the rectangular foundation, under effect of dynamic load which results from an adjacent footing called (the source of vibration), having square shape and excited by a well-known source of vibration put on the top it. The purpose being to study the effect of dynamic motion on a nearby foundation called a second foundation. Both foundations are founded on collapsible soil (gypseous soil) with a content of gypsum 60%. The research is conducted in dry and soaked conditions with a large experimental program. The first basis (source vibration) and the second footing are made out of steel, respectively in the sizes (80x80x40), (160x40x40) mm with (L/ B= 4). After that the soil had been prepared in layers in steel containers with (1000x 500x500) mm, then the two foundations positioned centrally over the ground. The first footing excited by the rotating mass type mechanical oscillator to generate vertical harmonic loading, produces a comparable impact of dynamic loads and the second footing is loaded with only static weight under dynamic excitement. The tests were conducted under dynamic response for three frequencies (10, 20, 30) Hz, Displacement amplitude and acceleration of the second foundation were determined, at a different distance between the foundation (2B, 4B, 6B). The results have shown that, when the distance between the foundation increases, the amplitude and the acceleration for the second foundation decreased. Furthermore, the value of these parameters at dry state is higher than their value at soaked state.

Keywords: Dynamic load, machine foundation, model test, rectangular foundation, vibration.

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1. Introduction

The Dynamic loads can be generating from moving cars, heavy machines, or by moving the train etc. which cause under these loads the foundations to be in a different mode. The problem of interplay between nearby foundations has great practical relevance, as in fact, many status foundations are not isolated and interact with each other predominantly depending on their distance, which often leads to strong and dynamic damage to structures, particularly in serviceability. This means that a streamlined technique must be developed to study the impact of dynamic excitement-prone foundations on neighboring foundations. Many researchers have conducted several studies for a single isolated foundation, ranging from the (simple) spring mass dashboard system up to the (rigorous elastic half-space model) suggested by many researchers such as [1-3]. Analytical and numerical research has been carried out to understand a group's dynamic relationship with the soil-structure interactive behaviors, such as [4-6].

One form of collapse soil is gypesous soil; its surroundings are broad in Iraq. This soil has a high capacity for dry wearing, but it falls after saturation due to the dissolution of cementation and binding of particles. Structures supported on unstable soils should guarded against such danger, therefore be protected from such hazard. Usually, these issues have caused the associated structure to crack, tilt and crumble [7]. This sort of land in Iraq comprises approximately 31.7% with gypsum levels of between 10-70% [8].

Ladhane and Sawant (2012) carried out study to analysis of laterally dynamic loaded vertical pile group considering the three-dimensional nature of the soil-pile system. Piles and soil are modelled using three-dimensional finite element techniques treating them as linear elastic. The interface of soil and pile under the lateral load has been accounted for by incorporating interface elements in the modelling. They found that fundamental frequency is decreasing with increase in pile spacing for piles in series arrangement whereas marginal reduction was observed for piles in parallel arrangement and maximum amplitude is a complex phenomenon and depends on stiffness of pile soil system, the external frequency and natural frequency. Also, they concluded that the mass involved in vibration is major governing factor and the fundamental frequency increases with increase in the soil modulus. In addition, it observed that frequencies in the parallel arrangement are higher than those compared to series arrangement [9].

Chen (2014) investigates the problem of cross-cooperation in a straight viscoelastic medium at small shear strains between multi foundations. The fundamentals are divided into different sub-square components in the exam. The dynamic response within each substructure is shown by the ability of the Green. The dynamic impedance and consistency elements of the fundamentals are consolidated by the movement limit and the balance of the power of the foundations. Broad results are implemented for two unbending roundabout foundations placed in different segments. The dynamic collaboration between the adjacent foundations and the findings on a few firmly dispersed foundations are being investigated parametrically [10].

The dynamic interaction of tightly spaced square foundations under machine vibration has been experimentally explored by Abhijeet and Priyanka in 2016. A series of large-scale model tests in the field were performed in dynamic circumstances including a wide range of isolated study and the interactive footing reply on the local soil at Kanpur, India. The dynamic interaction of distinct combinations (size) of two-foot assemblies has been examined by causing vertical Harmonic Load on one of the footings (active footing), where the other footing (passive footing) has only the static weight.

The dynamic interaction between the active and passive footings was noticed by investigating the transmission ratio (T+) variation with the frequency ratio (fr). The passive footing is resonant owing to its vibrant excitement on the active footing, which however takes place at a stage lag of the resonant frequency of the active footing. In identifying the dynamic interaction of a foundation group this phase delay is a vital parameter. The deferment of the phase lag is noted to reduce when the spacing between the footings decrease [11].

Chen (2016) calculated the dynamic reaction by the numerical approach technique for a group of solid surface foundations. The formulation is completely stable and computationally simple with algebraic calculations. It does not impose any limitations on footing form, footing segmentation, layered medium thickness, and frequency magnitude. In the assessment it is separated in several sub-square-regions from the foundation-footing interface. By using the Green feature acquired through the transform and accurate integration method of Fourier–Bessel, the dynamic reaction of each sub-region is calculated [12].

Sbartai in 2016, explored the dynamic interaction for two adjoining rigid foundations in a viscoelastic layer. The vibrations come from one of the rigid soil layer foundations which have a harmonic load of translation, rocking and torsion. By taking into account their interaction, the dynamic responses to the rigid surface foundations are solved by the wave equations. The solution has been developed using the BEM (Bound Element) Frequency Domain technique.

The evaluation of this research shows that the dynamic interactions between the two adjoining foundations have not had a negligible impact on multiple parameters. Particularly in relation to the other parameters, the dominant influence is obvious such as the heterogeneity of the soil, the shape of the foundation and the load intensity, [13].

Suraparb and Senjuntichai (2017) investigated the dynamic response of two rigid foundations resting on a poroelastic medium with multi-layered time-harmonic load. This research assumes soft, fully permeable contact surface between foundations and the layered medium. A discretization method and an exact stiffness matrix system are used to examine this dynamic interaction issue. They noted that the current solution's precision was checked and that numerical results were also presented for two square foundations impedance. They found that frequency of excitation and the distance between the two footings were obviously affected by the impedance features, [14].

Han et al. (2017) explored the dynamic interaction among two or more adjoining foundations on a laminated soil surface. A number of parametric studies were performed to clarify the effects of depth layer, soil dampening, spacing between adjacent foundation and support structural mass and moment of inertia and wave propagation velocity on the dynamic behaviour of the three-dimensional. Also, the study provides numerical examples to assess the accuracy and computational stability of the proposed approach, [15].

Ali et al. (2018) determined the dynamic compressor foundation evaluation by using the ANSYS commercial finite element software. The model used a three-dimensional finite element model. The impact of the ground foundation interaction in this study was taken into account in the model, which modelled soil as vertical and lateral spring and damper components. The soil foundation scheme determined basic natural frequencies and the respective mode shapes and mass involvement ratios. The soil foundation reaction under forced excitation was calculated and displayed by the machine uneven load at distinct spanning frequencies [16].

In 2018, Vicencio and Nicholas determined the effects of the structure-soil-structure interaction (SSSI) between two buildings, with different building parameters and spacing and the kind of soil. By using a (two-dimensional simple discrete) nonlinear model and a set of non-linear differential movement equations has been defined. The results showed that both unfavourable and advantageous settings of the two structures generate substantial distinctions between nonlinear SSSI and nonlinear SSI (uncoupling construction case) for the soil immediately below foundations. A linear rotational interaction between the structures and linear conduct of structures is assumed. The adverse effects of SSSI are shown to be more pronounced when nonlinear soil conduct is taken for granted [17].

Andersen (2018) examined two polypod foundations dynamically interacted on the surface of the soil and two flexible embedded piles. In both cases, a layered ground with a soft top soil was considered over a rigid half-space. A Fortran effective implementation of a semi-analytical approach was analysed in the frequency field by a soil foundation interaction using Green for a distributed load acting on a surface or an interface of a linear viscoelastic half-area with horizontal layers. The piles were modelled on the beams by finites and the soil at structure- soil-structure nodes, assuming the cross-sections of the piles were rigid. [18].

Bayat et al. (2018) studied the nonlinear vibration of Euler-Bernoulli beams resting on linear elastic foundation. They had been tried to prepare a semi-analytical solution for whole domain of vibration. Only one iteration leads us to high accurate solution and the effects of linear elastic foundation on the response of the beam vibration were considered. Also, the effects of important parameters on the ratio of nonlinear to linear frequency of the system were studied. The results were compared with numerical solution using Runge-Kutta 4th technique. They concluded that the Max-Min approach can be easily extended in nonlinear partial differential equations, [19].

Keawsawasvong et al. (2019), explored the dynamic response of rigid footings having arbitrary shapes on multi-layer poro- elastic half space under time - harmonic moment loading by using a method of discretionary process and a stiffness matrix approach. They founded when the distance from the neighbouring footing is twice greater than the width, rocking vibration can be examined as a single footing. Rather, even though the distance between these two footings increases, an unloaded foundation would still have radiated energy dissipated from a loaded foundation. [20].

Therefore, the absence of experimental studies on the behavior of the footing adjacent to the machine's foundations encourages the study underway, explaining how two closely spaced foundations resting on gypsum soil are dynamically interfering with small-scale models.

The urgent need for machinery and equipment in the development of cities is considered to be the main source of vibration which transfers soil and affects their engineering properties. The aims of the present work are therefore to study the dynamic response of the foundation on a sandy soil of gypsum under the effect of dynamic load installed in both the state (dry and socked) on the adjacent foundation. The dynamic answer includes amplitude of displacement, vibration speed and acceleration.

This article provides a dynamic response analysis of a single footing with a static load close to another footing with a dynamic load, such as (source of vibration), one of foundations is of square form and the other having rectangular form, on a gypsum soil. The study discusses the impact of vibrations of the first foundation on the nearby foundation. On surface soil both foundations rest.

2. Definition of Problem

Two closely spaced foundations, as shown in Fig. 1, are placed on gypsum soil. The load intensity belonging to the first footing (source of vibration) was retained as 6 kN / m^2, while the second foundations are positioned in a load range equivalent to 30 kN / m^2 and the distance between the two foundations(S). The aim is to determine dynamic responses of the second footing (displacement amplitude acceleration) due to application dynamic excitation on the first footing at both state dry and watered.

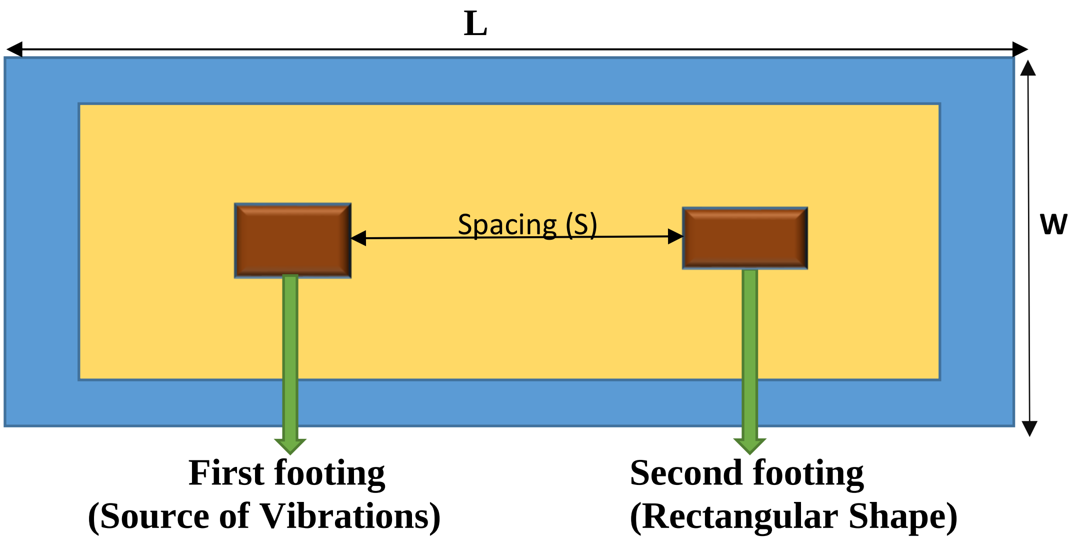

Fig. 1. Layout of experimental model.

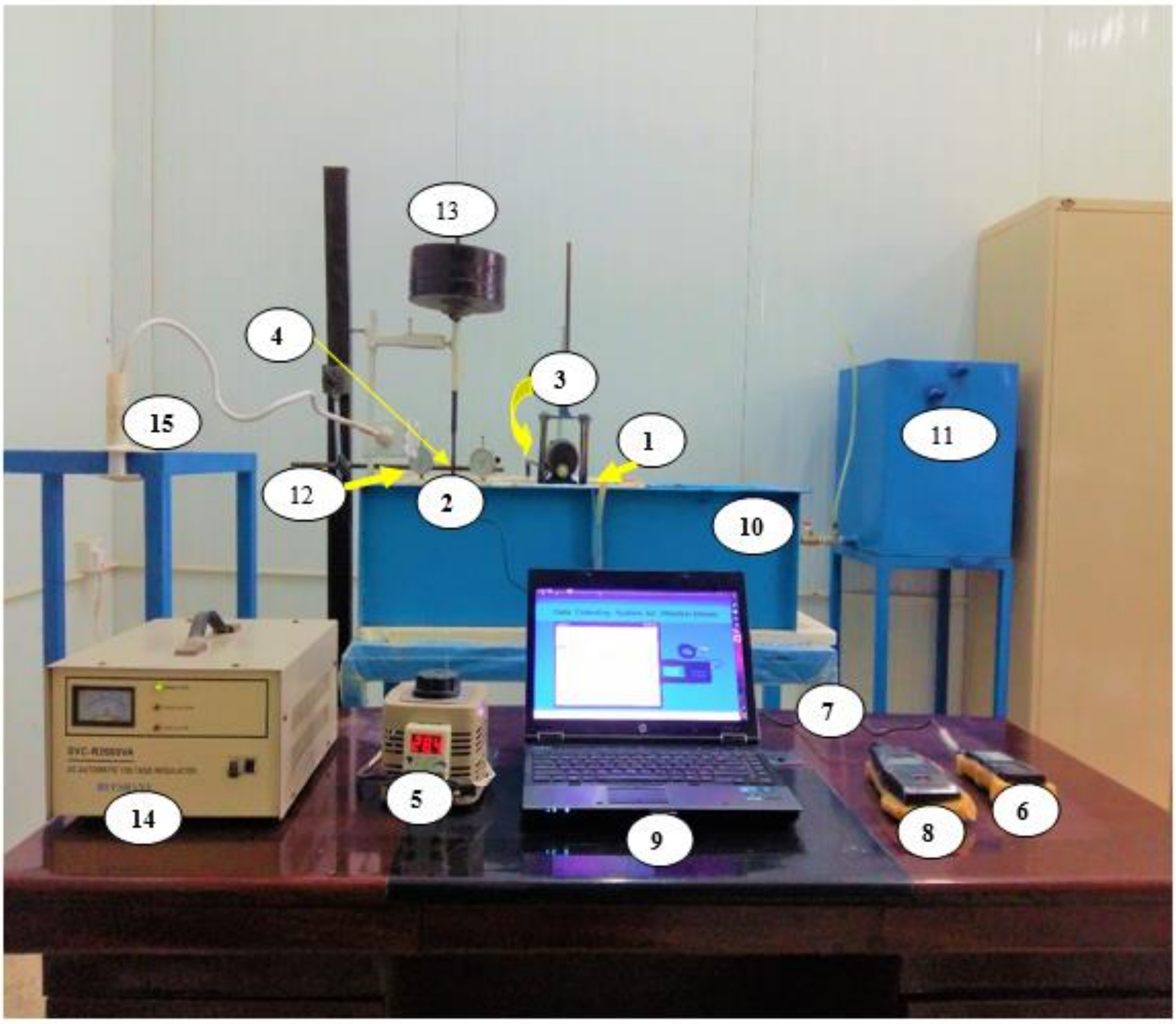

Fig. 2. The model with apparatuses.

3. The Material and Method

3.1. Apparatuses of Model

The apparatuses of model include the followings:

1) Steel box with dimension (1000x500x500) mm
2) Two foundations with dimensions (80x80x40) mm, for first foundation as a machine foundation, (160x40x40) mm, for second foundation which manufactured from steel
3) Mechanical oscillator
4) Piezoelectric accelerometer
5) Two dial gauge
6) Variable frequency drive
7) Vibration meter
8) Digital tachometer
9) Computer device
10) Steel Mold
11) Water tank
12) Static weight
13) AC automatic voltage regulator
14) Camera

3.2. Test Setup

After the examination of past studies by diverse researchers, like [21 -26], the experimental model set-up was designed. A two square steel foundation of the first one as machine-footingd basis with dimensions (80x80x40) mm (vibration source), the second footing with dimensions (160x40x40) mm is only subject to the static load. Circular weights 20kg in mass of 25cm in diameter used for loading the second footing statically, a rotating mass mechanical oscillator instead over the first footing to generate a varying dynamic load. The mechanical oscillator, be composed of a rotating disc create from steel, with diameter 60 mm and, thickness 13 mm. With small eccentricity mass (me) is instead on rotating disc at an eccentricity (e) of 15 mm from the axis of rotation. In this study, only one type of eccentric settings is utilized with value 50 gm. DC motor is utilized to turn the mechanical oscillator at different frequency with ranging from (100rpm – 12000) rpm. Controller unit is put outside the model to control the speed of the DC motor.

Before proving the dynamic response as displacement amplitude, velocity, or acceleration, the piezoelectric accelerometer connected directly to the computerized model of the (6063) digital vibration measure then, predefined to the computer. The DT-2234A+ (digital tachometer) model was applied to guarantee that frequencies are not altered. See Fig. 4.

3.3. Preparation and Test Procedure

The soil for this study has been derived from the northern Iraqi Governorate, namely Tikrit, for the test program; see Fig. 5. The physical properties of the soil can be found in Table 1, and the chemical properties are shown in Table 2. The results of laboratory tests performed on the sample soil used in the present research were shown in Figs. 6 and 7. Test water content at (45) °C to prevent loss of gypsum-soil crystal. The 60 percent sample of gypsum soil is classified as moderately severe (ASTM D5533-2003). The gypsum soil (sieve no. 4) has been put in six layers of steel container with a uniform field density by means of a hummer. A bubble ruler (equilibrium) system checks the surface and levels them. Both footings are centrally positioned over the prepared soil. Figure 8 illustrates the test program for this study.

The system's focus of gravity and the foundations must be kept vertically in line with the container's center of gravity. After investigating results obtained by researchers and performing preliminary tests for 1-hour testing time, 30-minute dry-zone operation test and 30-minute soaking testing time, it should be noted that the steel container left for (24) hours for the soaking test to ensure that the soil was fully soaked, and in some cases soaked., and in the second day the test is continue.

In this study, the dynamic load is simulated with eccentric (me) setting 50 gm. The oscillator is then slowly operated by means of a velocity control unit, to avoid elevated dynamic load from occurring suddenly. The first foundation was therefore subjected to vertical vibration.

The dynamic reaction (displacement amplitude and acceleration) of the second footing is evaluated and registered simultaneously using a Piezo-electrical accelerometer. The functioning frequency (600, 1200, 1800) is regarded equal to (10, 20, 30) Hz, the dynamic response parameters were recorded every five minutes during operation test duration.

4. Results and Discussion

The current research examines the dynamic response of the rectangular footing in a dynamic exciting force which came from a neighboring footing as a machine foundation.

On the second footing, dynamic analysis is conducted by exciting the First footing with a vertical load intensity generated by the vibratory device after checking the stability of footings under a static load. The displacement amplitude and acceleration of the second foundation at different distances (S= 2B, S=4B, S=6B) are measured, and for both state (dry and soaking) the two foundation is established on gypsum soil in presence of the dynamic excitation applied at the first foundation. Figures 9-12 show the dynamic response of the second footing at separate distances for three frequencies (10, 20, 30) Hz.

Table 1. Physical property of gypseous soil which is used for testing.

Test	Properties	Value	Specification
	Specific Gravity (Gs)	2.41	ASTM D 854 (2006)
Atterberg's limits	Liquid limit (L.L) %	21.1	ASTM D4316-84
	Plastic limit (P.L) %	N.P	
	Plasticity Index (P.I)	N.P	
Compaction characteristics	Compaction characteristics:		ASTM 698-00
	Max. dry density (KN/m3)	16.23	
	Optimum Moisture content %	12.33	
	Water content %	2.8	ASTM D2216-02
Grain size analysis	D10 (mm)	0.07	ASTM D422-02
	D30 (mm)	0.14	
	D60 (mm)	0.35	
	Coefficient of uniformity, Cu	5	
	Coefficient of curvature, Cc	0.8	
	Passing sieve No. 200 (%) (using kerosene)	24	
	Classification of soil footingd on (USCS)	SM	
	The collapse potential	7.9	ASTM D5533-2003
Direct Shear Test	Angle of Internal Friction (Ø) in dry	38	ASTM D 3080-98
	Soil Cohesion (C) (KN/mm^2) in dry	14	
	Angle of Internal Friction (Ø) in soaked	34	
	Soil Cohesion (C) (KN/mm^2) in soaked	5	
	Test unit weight (kN/m3), γd test	15	
	Field density ((kN/m3), field	14.6	ASTM D1556-07

Table 2. Results of chemical properties of gypseous soil used for testing (BS 1377: 1990, Part 3).

Composition	Value %
Total soluble salts (T.S.S.) %	67.2
Gypsum content %	50
Sulphate content (SO3) %	30.5
Organic matters (O.M) %	0.22
Chloride content (CL) %	0.062
pH value	8.1

Fig. 3. Devices used for measuring vibration response.

Fig. 4. Digital tachometer.

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Fig. 5. The location of the soil sample (google earth image).

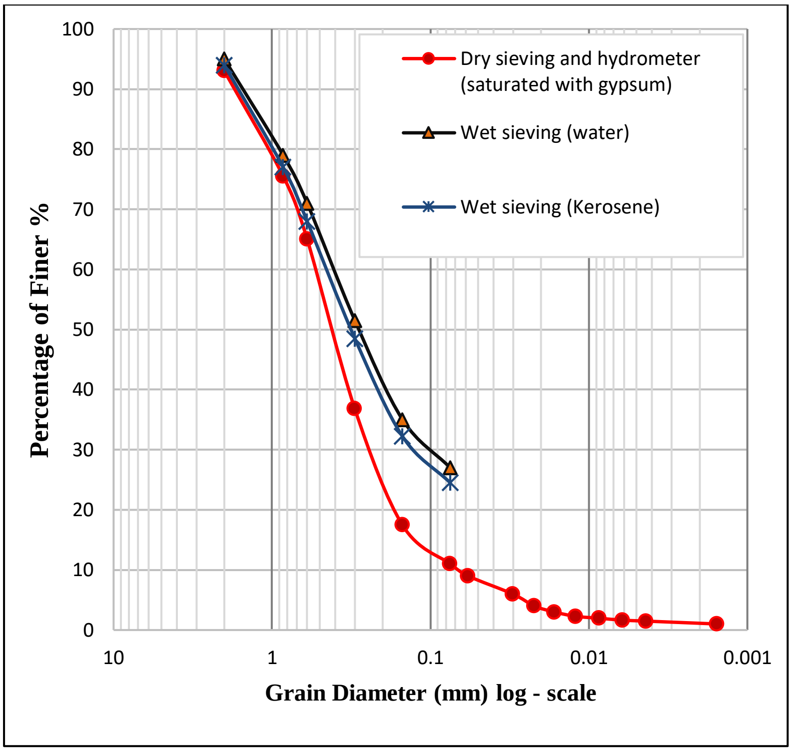


Fig. 6. Grain size distribution for gypseous soil.

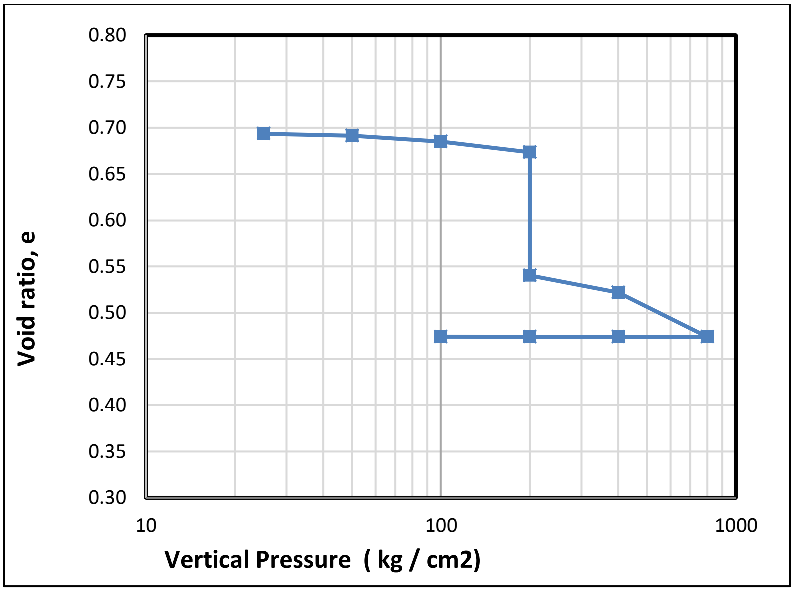


Fig. 7. Results of single oedometer.

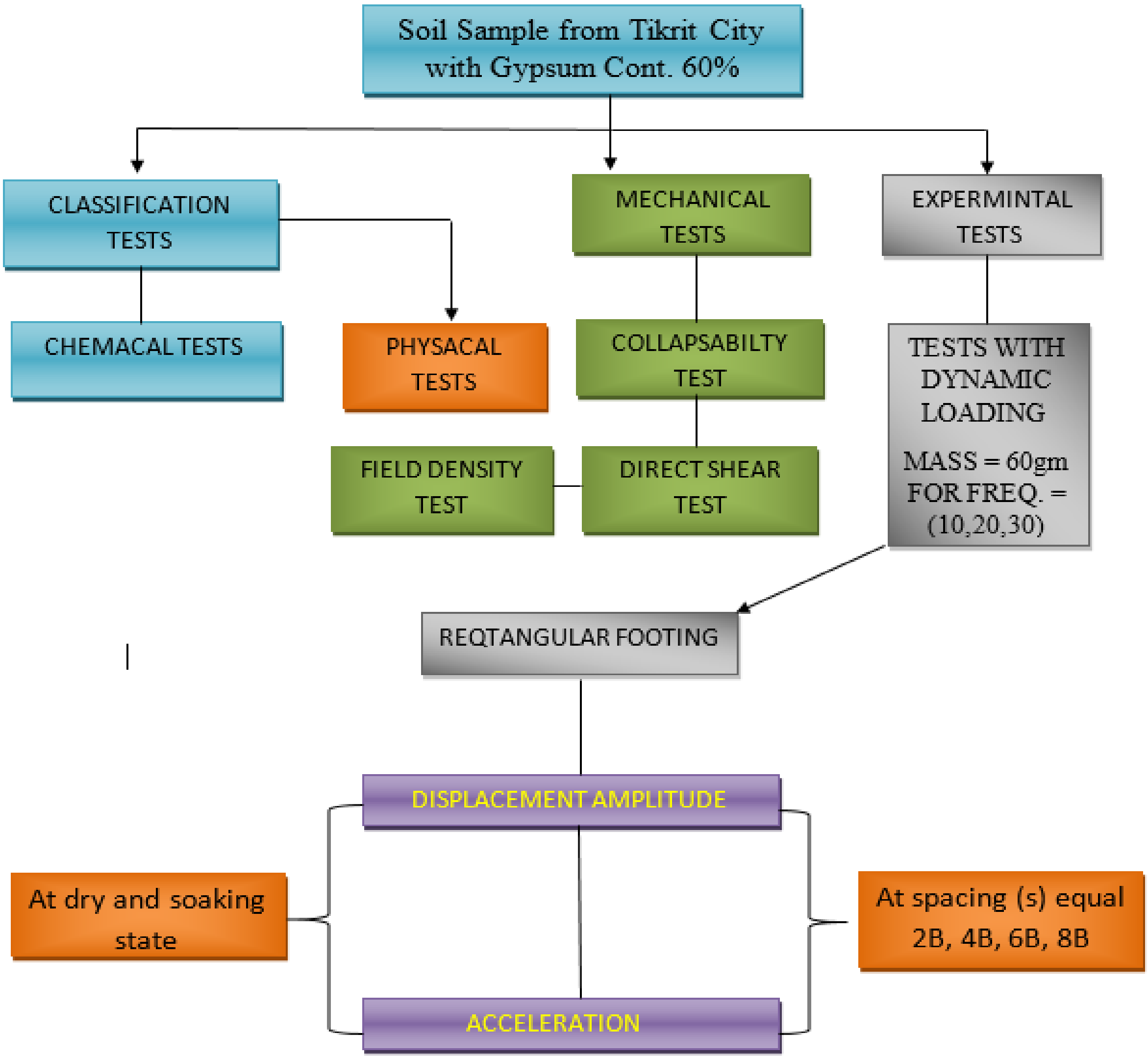


Fig. 8. Test program.

4.1. Displacement Amplitude

In Figs. 9 and 10, Maximum and minimal amplitude of displacement plotted versus frequency for both state dry and soaking condition, the magnitude of displacement amplitude at (S= 2B) increase when the frequency of operation rises for both state (dry and soaking) is observed. This increase is small if it passes from 10 Hz to 20 Hz and is bigger if it gets to30 Hz for the maximum amplitude at dry and soaked condition. In contrast, when 10 Hz to 20 Hz or 30 Hz at a dry state, the minimum amplitude indicates a slight increase, but at soaking condition, it is doubled in value.

In soaking conditions, it is observed that the value of the displacement amplitude decreases as compared to dry condition for the three frequencies, this due to the existence of the water which acts as a wave inhibitor. During soil transfer at soaking, the energy of the vibrations generated from the first foundation was lower and the displacement amplitude of the second foundation was reduced.

At spacing equal 4B, the magnitude of the displacement amplitude is decreasing compared to (S= 2B) in both state(s). The reason for this is that the vibrations cut off long distance from the source vibration (the first foundation) to the adjacent footing (second foundation). In other words, increasing the distance causes an amplitude to decrease; the propagation of the vibrations through the soil causes the energy of those vibrations to decrease.

At spacing equal 6B, the magnitude increased by half from 10 Hz to 20 Hz for the maximum displacement amplitude at dry state and increased by two and a half times in value at 30 Hz. For the minimum displacement amplitude, the value has doubled from 10Hz to 20Hz or 30Hz

At soaking condition, the magnitude of displacement amplitude is decreased as compared with dry condition. The maximum amplitude is slightly higher when it goes from 10 Hz to 20 Hz but has doubled when it goes to 30 Hz. The minimum amplitude of the displacement is different; the amplitude is doubled when it rises from 10 to 20 Hz. But increased by three times at a value of 30 Hz.

Here the value of the displacement amplitude was decreased by when comparing the magnitude of the amplitude at (S= B) and (S=2B) for both state (soaked and dry).

4.1.1. Convert results into mathematical equations

Figures 11 and 12 show the results of the maximum and minimum displacement amplitude as a mathematical equation for both dry and soaking state.

4.2. The Acceleration

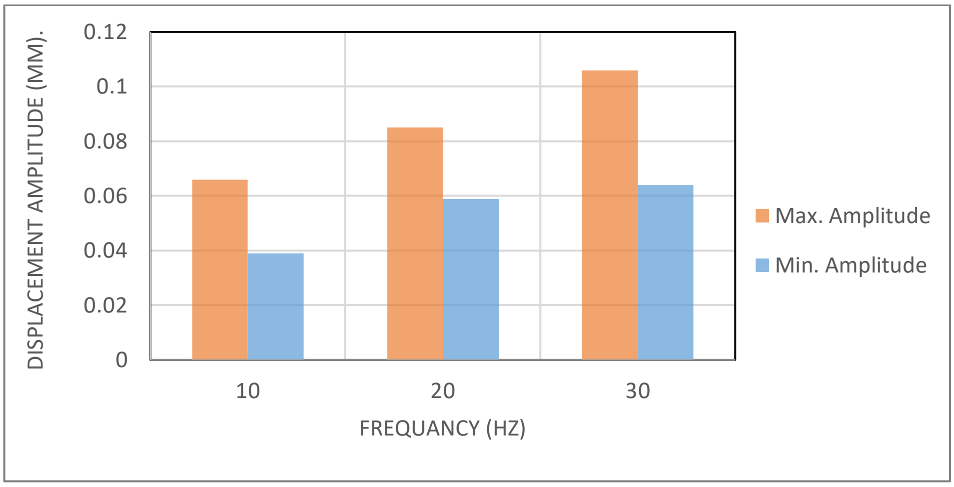
The maximum and minimum acceleration versus frequency are shown in Figs. 13 and 14. It was recorded in dry and soaked condition for three spacing, (S= 2B, S=4B, S=6B). The behavior trend is similar in dry and soaked condition for maximum and minimum accelerations. The value of the accelerations increases with the increase in frequency at dry and soaked conditions. The impacts from an increased distance between the footings on the accelerating magnitude are comparable to that of displacement amplitude and, increasing distance causing acceleration to reduce, because the propagation of the vibrations through the soil causes energy to decrease and thus, the acceleration decrease. We also observe that the magnitude of the acceleration is higher at dry state than at soaked state.

The magnitude of acceleration in dry state increases nearly linearly when the frequency increase from 10 Hz to 20 Hz or 30 Hz, at distance (2B). The same applies to (4B) and (6B) intervals. And the gap between the maximum and the minimum is increased when the frequency rises and the gap decreases when the gap between the two foundations increase. Refer to Fig. 13.

In soaking condition, the acceleration rate increases only slightly for maximum and minimum acceleration when frequency increases from 10Hz to 20 Hz, but is about double in value for 30 Hz, which applies to the acceleration magnitude at a distance between the two footings as 2B, 4B and 6B. When the frequency increases the gap between the maximum and the minimum acceleration increase, and decreases with increasing the distance between the two foundations. In comparison with their values at dry level, the acceleration values at soaked state for three frequencies (10, 20, 30), Hz, at a spacing of 2B, 4B and 6B, have fallen because of the presence of water, which acts as a wave inhibitor in soil (as already mentioned) and increase when the frequency increases, irrespective of whether its state is wet or dry. When the distance between the two foundations increases the acceleration is reduced for both soaked and dry conditions, see Fig. 14.

4.2.1. Convert Results into Mathematical Equations

Figures 15 and 16 show the results of the maximum and minimum acceleration as a mathematical equation for both dry and soaking state.



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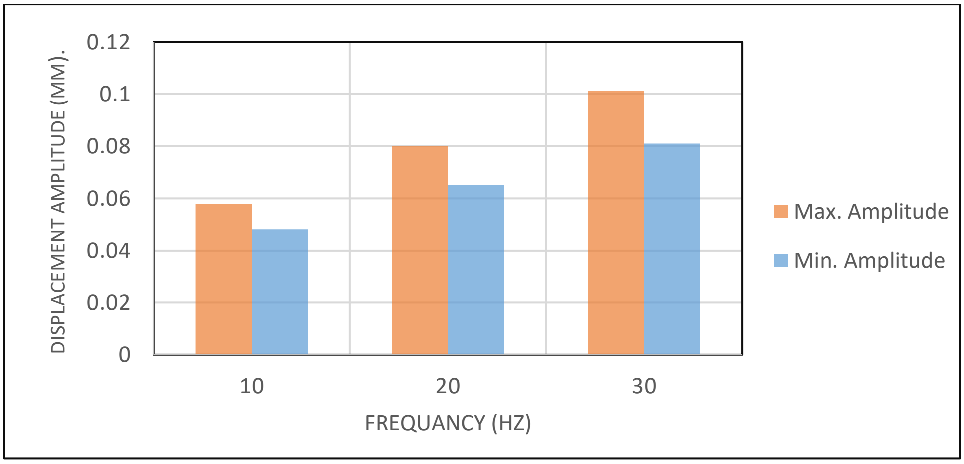

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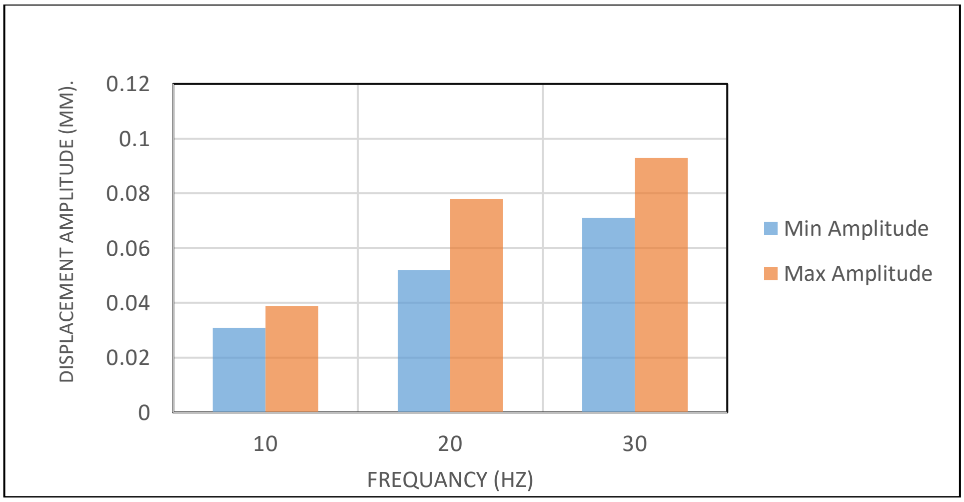
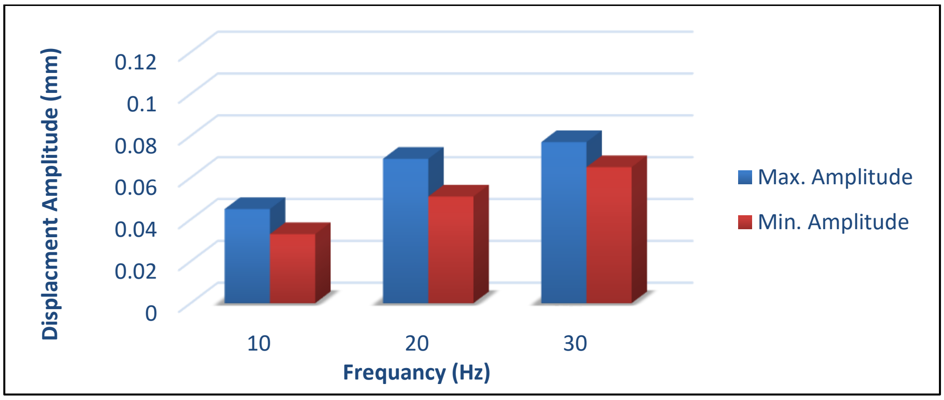


(c)

Fig. 9. The displacement amplitude versus frequency for different spacing (s), (a) at S=B, (b) at S=2B, (c) at S=3B) for dry condition.



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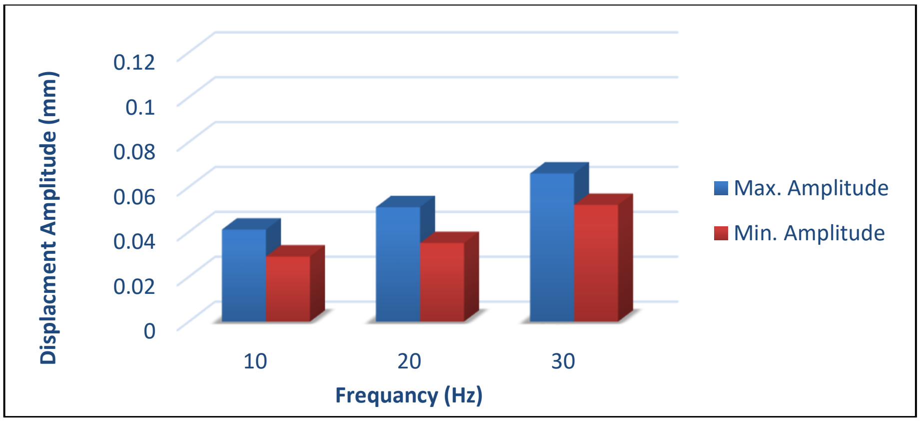

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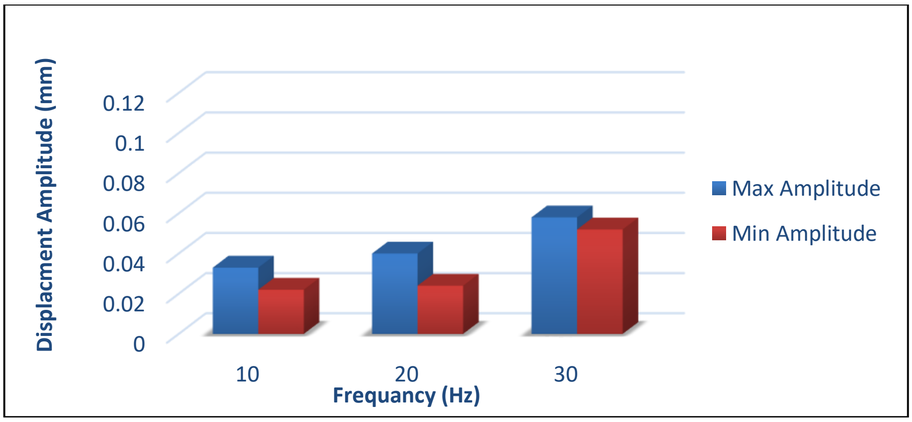

(c)

Fig. 10. The displacement amplitude versus frequency for different spacing (s), (a) at S=2B, (b) at S=4B, (c) at S=6B) for soaking state.

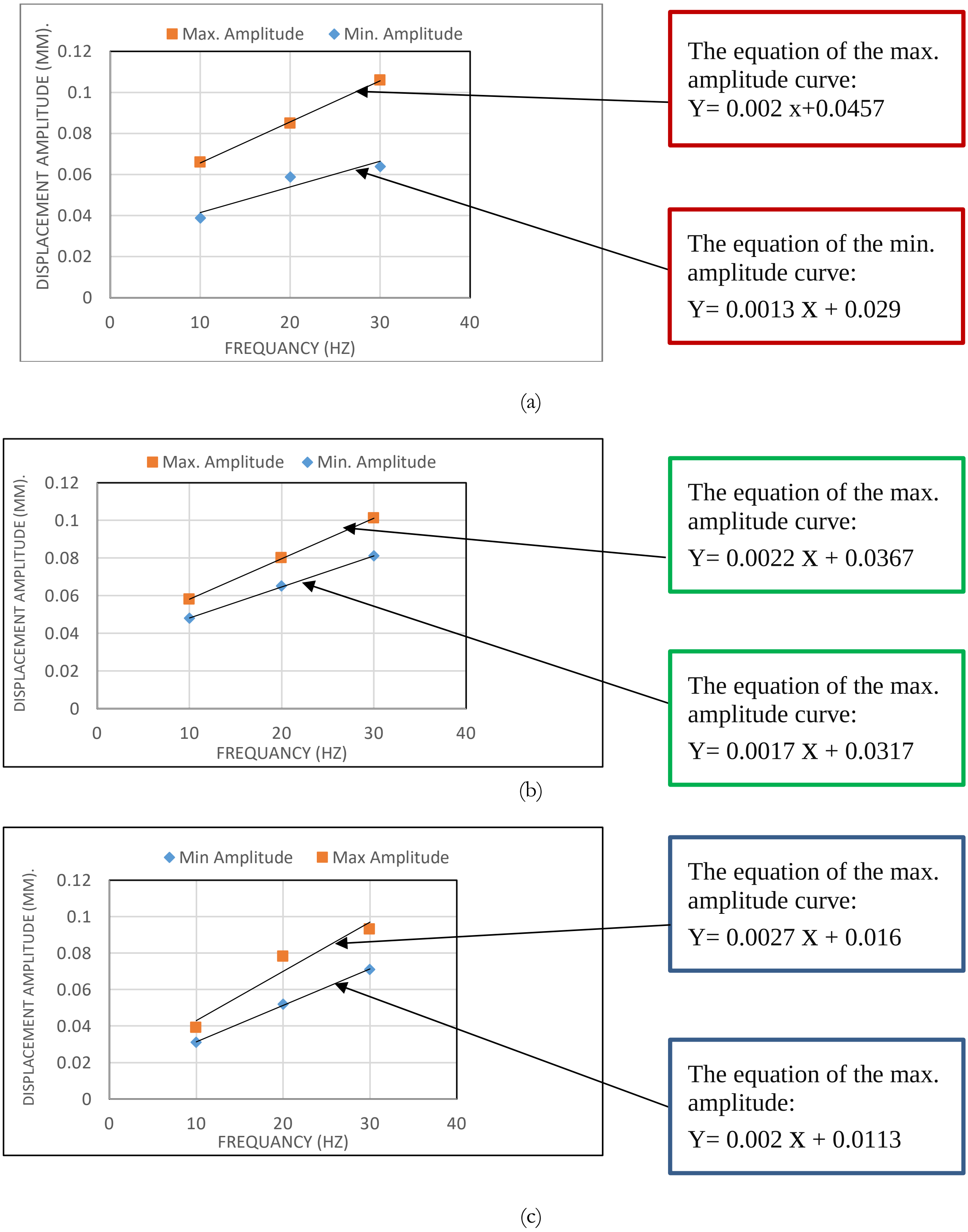

Fig. 11. The equations of displacement amplitude for different spacing (s), (a) at S=2B, (b) at S=4B, (c) at S=6B) for dry state.

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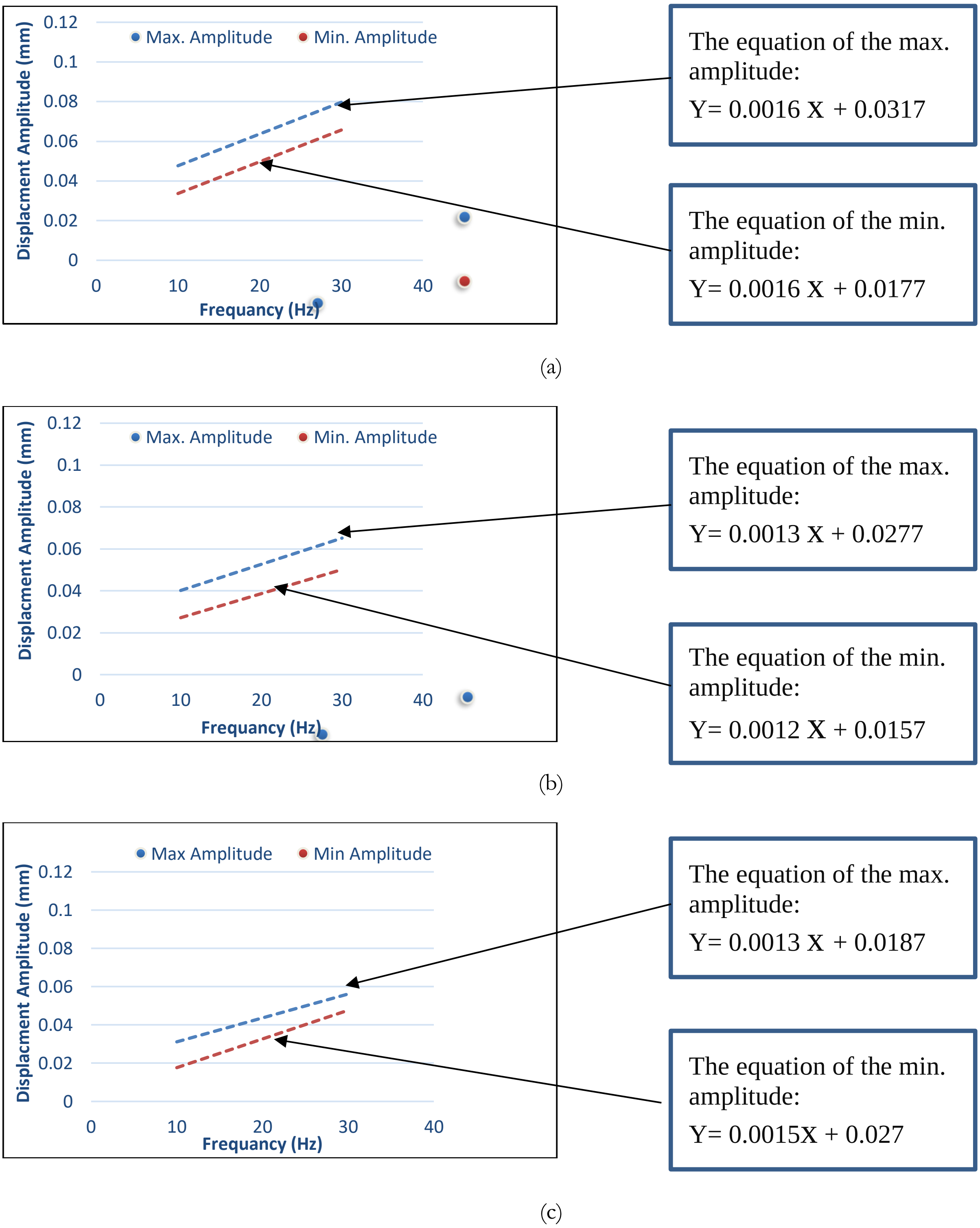
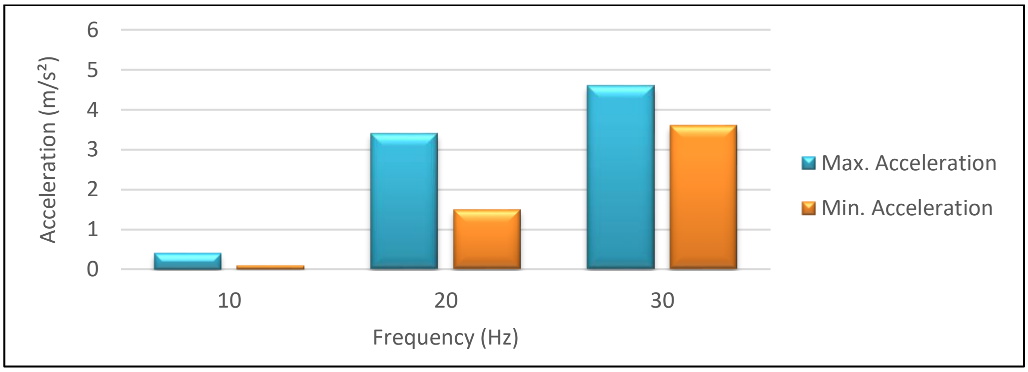
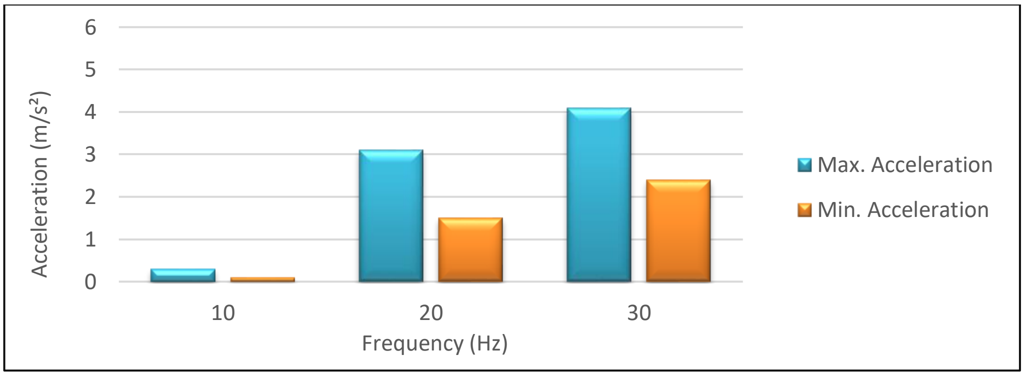


Fig. 12. The equations of displacement amplitude for different spacing (s), (a) at S=2B, (b) at S=4B, (c) at S=6B) for soaking state.



(a)



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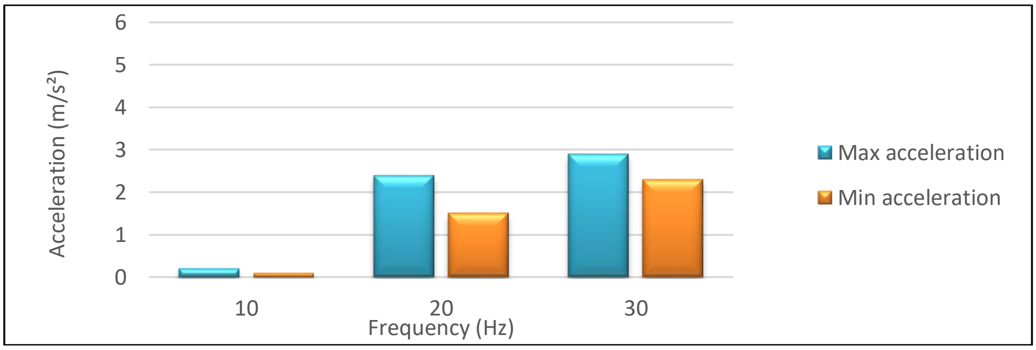

(c)

Fig. 13. The Acceleration versus frequency for different spacing (s), (a) at S=2B, (b) at S=4B, (c) at S=6B) for dry condition.

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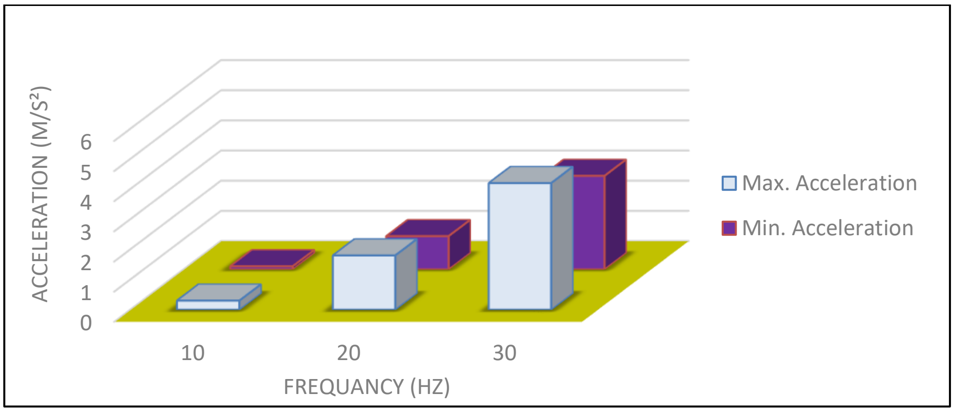

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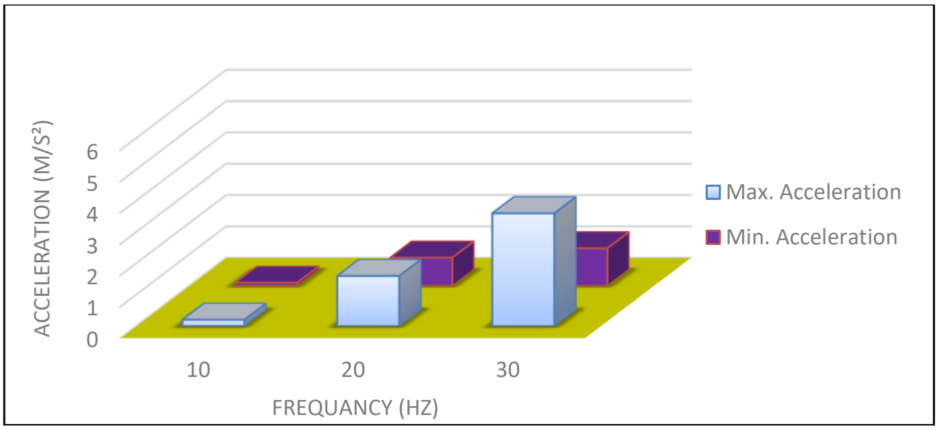

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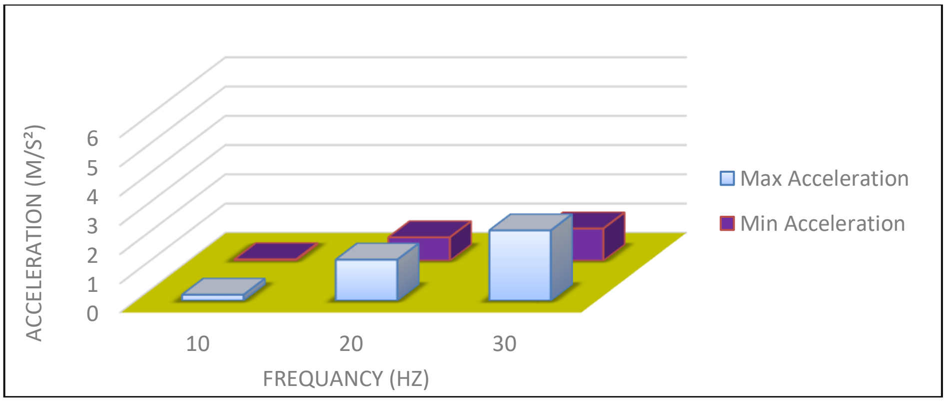
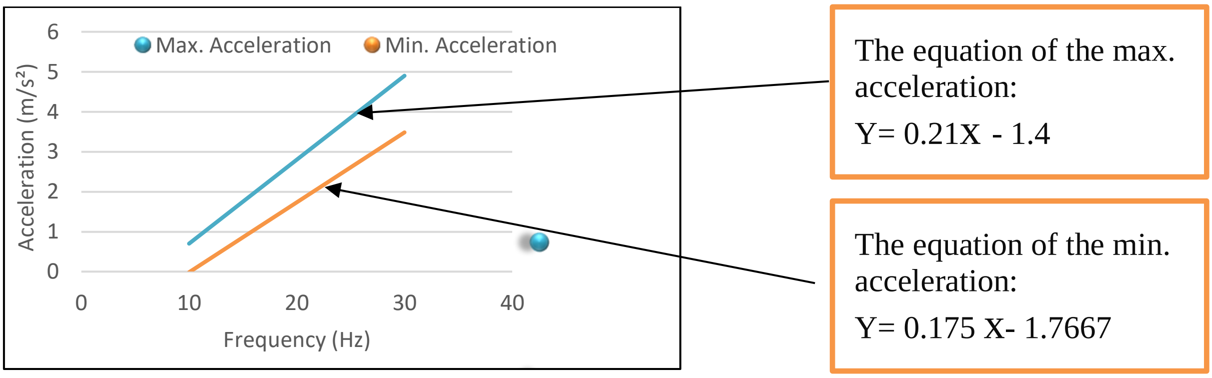
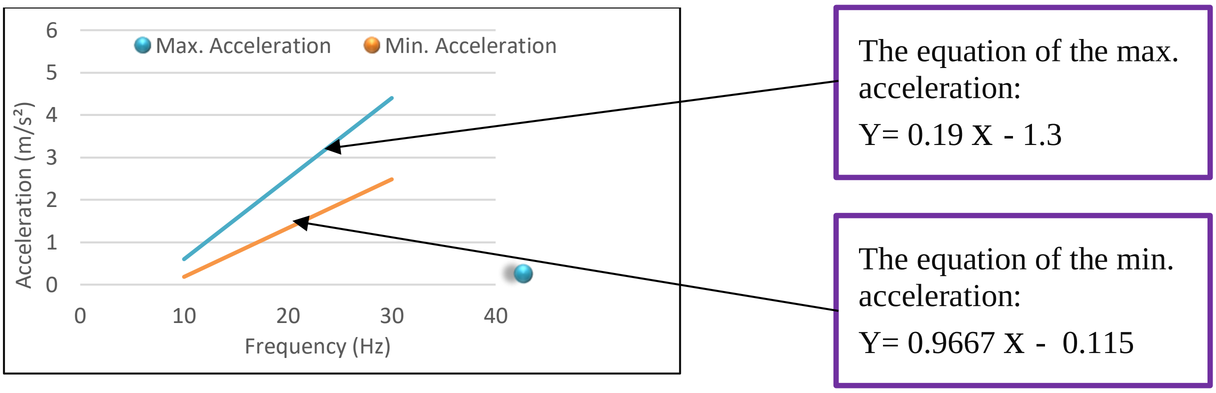


(c)

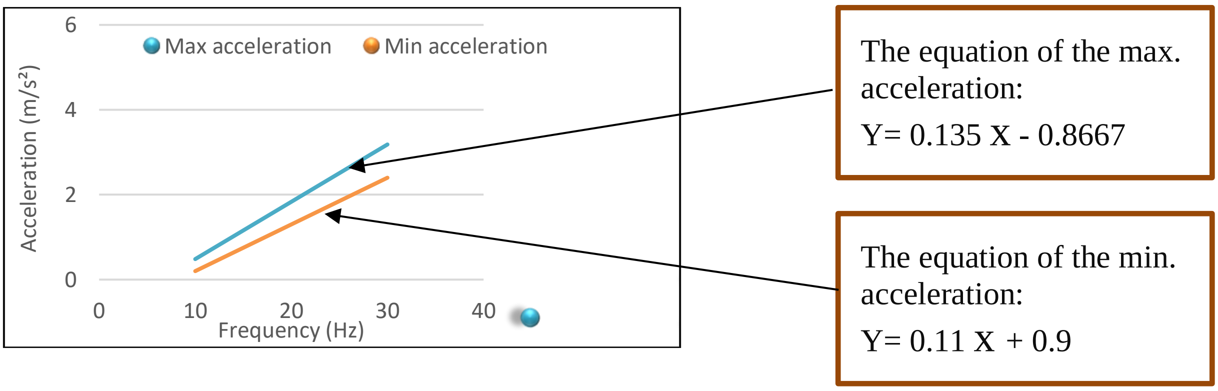
Fig. 14. The Acceleration versus frequency for different spacing (s), (a) at S=2B, (b) at S=4B, (c) at S=6B) for soaked condition.



(a)



(b)



(c)

Fig. 15. The equations of the results of Acceleration for different spacing (s), (a) at S=2B, (b) at S=4B, (c) at S=6B) for dry condition.

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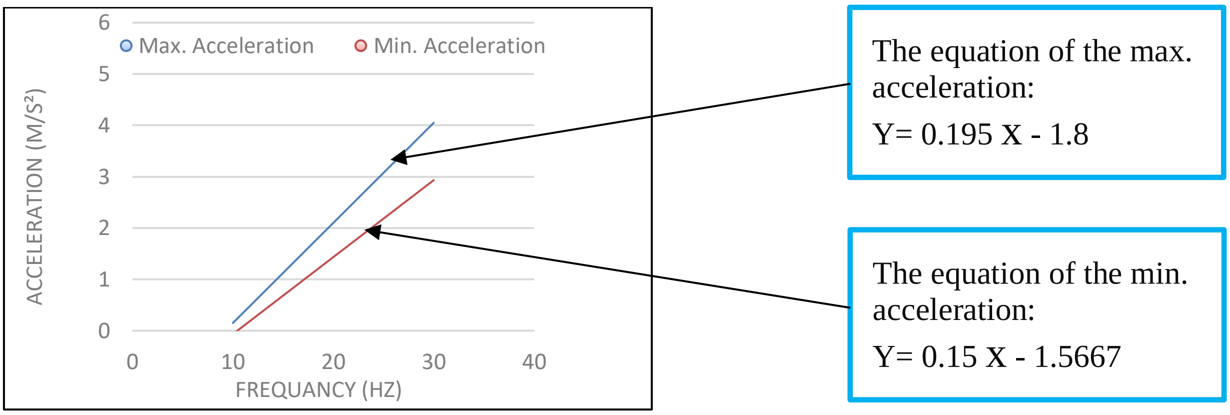
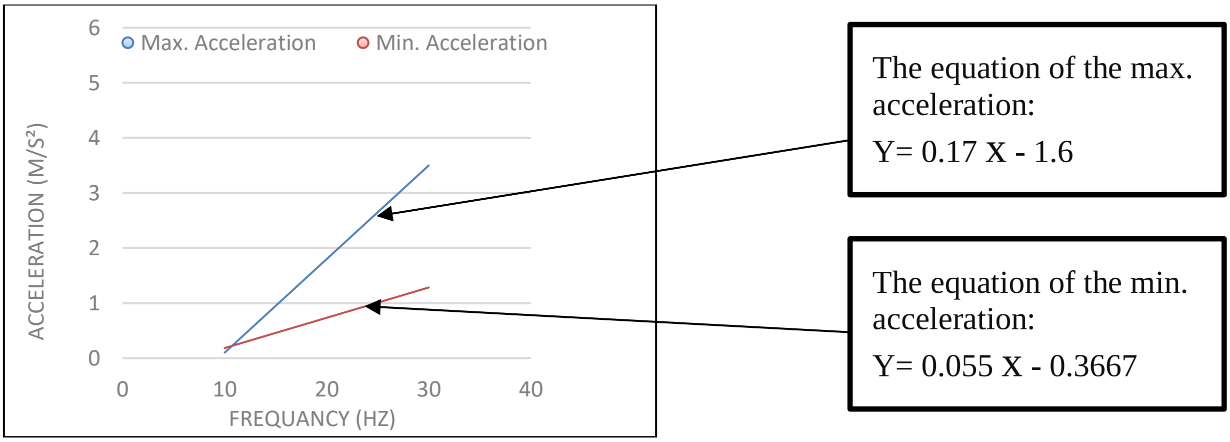
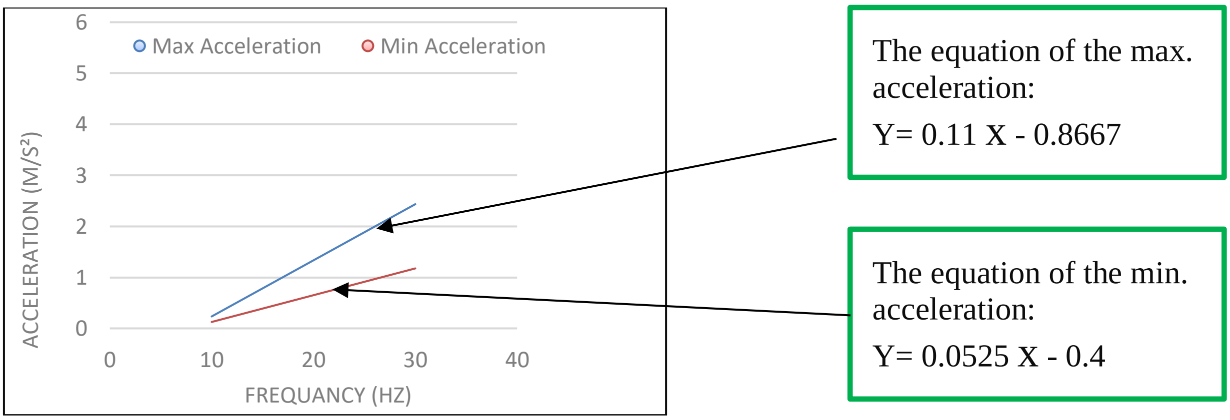


(a)



(b)



(c)

Fig. 16. The equations of the results of Acceleration for different spacing (s), (a) at S=2B, (b) at S=4B, (c) at S=6B) for soaking condition.

5. Conclusions

5.1. Displacement Amplitude

- The value of the displacement amplitude of the footing under effect of dynamic load comes from nearby foundation (both footings rest on gypseous soil) decreases with decrease the operation frequency.
- The magnitude of displacement amplitude at soaked state is lower than its value at dry state.
- The displacement amplitude increases with decreasing the distance between the two footings. The reduction in magnitude of displacement amplitude when the distance between the two foundations increased from 2B to 4B at frequency of 10Hz is 12.12 % at dry state, and 8.88% at soaking state. And when the distance increased from 2B to 6B, the reduction is 40.9% and 26.6% at dry and soaking state consecutively. At frequency of 20 Hz, the displacement amplitude decreased by (5.9% and 26.8%) at dry and soaked conditions, respectively when distance increased from 2B to 4B and decreased by (8.28% and 42.2%) at dry and soaking state, respectively when distance increased from 2B to 6B. For frequency of 30 Hz, the reduction is 4.71% at dry condition and 14.28% at soaking condition when the distance increased from 2B to 4B. And when the distance increased from 2B to 6B, the displacement amplitude decreased by (12.26% and 24.67%) at dry and soaked state consecutively.
- The reduction in magnitude of displacement amplitude at dry state when increasing the spacing from 2B to 4B or 6B lower than the reduction in magnitude of displacement amplitude at soaking state for the same spacing.

5.2. Acceleration

- The magnitude of acceleration of the foundation under effect of dynamic load resulting from nearby foundation (on gypseous soil) increase with increase the operation frequency.
- The magnitude of acceleration at dry state is greater than its value at soaking state.
- The magnitude of acceleration increases with the decrease of distance between the two footings. The reduction in value of acceleration when the distance between the two footings increased from 2B to 4B, at frequency of 10 Hz is 25 % at dry condition, and 33.3% at soaking condition. And when the distance increased from 2B to 6B, the reduction is 50% and 66.6% at dry and soaking conditions consecutively. At frequency of 20 Hz, the acceleration value decreased by (8.88% and 11.11%) at dry and soaking conditions consecutively when distance increased from 2B to 4B, and decreased by (29.4% and 22.2%) at dry and soaking state respectively when distance increased from 2B to 6B. For 30 Hz frequency, the reduction is 10.86% at dry condition and 14.24% at soaking condition when the spacing increased from 2B to 4B, and when the distance increased from 2B to 6B, the acceleration magnitude decreased by (36.9% and 42.85%) at dry and soaking state consecutively.
- The reduction in value of acceleration at soaking state when increasing the spacing from 2B to 4B or 6B greater than the reduction in magnitude of acceleration at dry state for the same spacing.

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