Effect of dynamic amplitude on response of single pile embedded in collapsible soil

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Abstract. This paper includes an experiential study of the dynamic response of one pile under the dynamic load that comes from the motor placed on the cover pile called the source of vibration. This study used the effect of the dynamic movement of vibration on a single pile in collapsible soils (gypseous soil) with a gypsum content of 30%. This experiment is performed in the dry and soak state for four slenderness ratios of the pile (12, 17, 22 and 27) and the pile is inserted after preparing the soil layers in a container steel (30*30*60) cm. The results showed that the velocity, acceleration, and displacement amplitude decreased with increasing the slenderness ratio of the pile in the dry and soaking conditions in addition to that the values of velocity, acceleration and displacement amplitude are less than in the case of soaking compared to their values in the dry state.

Keywords: Gypseous soil, Dynamic load, piles, model test, vibration

1. Introduction
Many countries in the world such as South Africa, some parts of Asia, the Midwest and southwest of the U.S.A. covers with unstable soil [1]. Gypseous soils are collapsible soils that are defined as unstable soils with grain rearrangement and mainly decrease in size when soaked with or without additional load [2-3]. The raw materials for collapsible soil are silt, sand, or any other material [4-5]. In Iraq, gypseous soils covered about 31.7% with different gypsum content about 10-70% [6]. Essentially, several problems arise when the soil is saturated with water as a result of the dissolution or submersion of gypsum, resulting in the collapse of the associated structure, cracking and sloping [7]. According to the [8] the collapse and damage that appeared in the soil under the foundation recount in Mosul city, When sedimentation of wet soil or ground water occurs, the main problem is that gypsum begins to dissolve causing loss of bond between soil particles [9].
Pile foundations are used to support various structures in weak soils. Where foundations and structures are subject to dynamic loads in addition to static loads such as vibrations caused by earthquakes, the machine, ocean waves and traffic. With the great progress in construction in last years and with the evolution in the technology of the nuclear energy manufacture, marine structures and other applications, numerous researchers have turned to the study of the dynamic behavior of foundations. Manna and Baidya [10]. Manna and Baidya introduced F.E. analysis using the PLAXIS software, version 8 to see the dynamic response of a single pile under vertical vibration. Where the Mohr-Coulomb model used for soil
modelling, the field test results were for the two complete aggregates to confirm the results obtain from the F.E. analysis of the piles themselves. The F.E. analysis included three stages of calculations. Initially, the plastic measure used to create the pile. In the second stage, the fixed load attached to the top of the pile by inserting the steel plate so that the last phase involved the use of this model, where the vertical vibration amplitude of the vertical harmonic load that was applied measured with different. Capacities (30 K.N. m²) and at different frequencies (10 to 60 Hz), for modeling vibrations patrimonial by the chatterbox. The results of the test showed that the natural frequency and amplitude of displacement were overstated [11].

Puri and Prakash achieved dynamic loading tests on a vast reinforced concrete pile, with dimensions of length (17) and (450) mm in diameter, it was driven into a soil layer of uniform clay sand horizontal and anchored excitation applied to the tip of the pile, the amplitude response observed the pile frequency field and laboratory tests performed to predict soil properties [12]. Elkasabgy et al, studied foundations Supported on helical Piles, Evaluation of Damping. Solidity involves looking at interactive. The forces between the soil and the pile along the pile and at the shaft Spirals thus this work requires, the correct understanding of the analysis. The transmission mechanism, during dynamic loading. Snails have not been fully, investigated for the dynamic behavior of large, capacity helix piles with, one or more [13]. An experimental study by Al-Ezzi, SK, and Zakaria, WA on the dynamic response to a circular foundation, under which an effect on the dynamic load resulting from the placement of an adjacent base as said (a source of vibration), with a square shape and excited by a known vibration source placed above [14].

2. Materials and Methods

2.1. Soil

The gypsum soil used in the this study was taken from Tikrit, Salah Al-Din city center, north of Baghdad, the gypsum content is 30% and soils were used to study the behavior of a single pile exposed to dynamic load. The chemical and physical properties of gypseous soils shown in Table 1 and 2 and the Figures 1 and 2 demonstrated the result of the laboratory test carried out on the grounds. Also, the relative density of the test is not viable for this soil (ASTM.D4254-00), which is the temperature obtained for the initial water content test (40-50) ° C to avoid the loss of the gypsum ground crystal. Gypseous soils are classified as medium to medium hazard (ASTM D 5533-2003).

![Figure 1. Collapse test (odometer test) in G.C 30%](image1)

![Figure 2. Grain size distribution of soil 30% G.C](image2)
Table 1. Results of chemical properties of gypseous soil (BS 1377:1990, Part 3).

| Composition                  | Magnitude |
|------------------------------|-----------|
| Total soluble salt (T.S.S) %  | 32.7      |
| Sulphate content (So₃)%      | 13.8      |
| Gypsum content %             | 30        |
| organic matters (O.M)%       | 0.25      |
| Chloride content (C.L)%      | 0.06      |
| PH value                     | 7         |

Table 2. Physical properties of gypseous soil.

| Property                           | Sample (G.C 30%) | specification       |
|------------------------------------|------------------|---------------------|
| Grain size analysis                |                  |                     |
| D30 (mm)                           | 0.22             |                     |
| D60 (mm)                           | 0.14             |                     |
| Coefficient of uniformity, Cu      | 3.02             | ASTMD22-02          |
| Coefficient of curvature, Cc       | 0.4              |                     |
| passing sieve No. 200% (kerosene)  | 38               |                     |
| Specific gravity, Gs               | 2.48             | ASTM854(2006)       |
| Atterberg limits                   |                  |                     |
| Plastic limit (P.L) %              | N.P.             | ASTM 316-84         |
| Liquid limit (L.L)%                | 23               |                     |
| Plasticity index (P.I)             |                  |                     |

The angle of Internal Friction (Ø) is dry for the γ test 34
The angle of Internal Friction (Ø) is soak for γ test 30 ASTMD3080-98
Soil Cohesion (C) (K.N/m²) in dry 8
Soil Cohesion (C) (K.N/m²) is soak 5

Dry unit weight
Maximum, yd (max) KN/m3 16.9
Minimum, yd (min) K.N./m3 12.8
Relative density, Dr% 75
Test unit weight (kN/m3), γd test 15.12
Field density ((kN/m3), γfield by (Tikrit university) 15 ASTM D1556-07
Initial void ratio, test 0.63

Initial water content % 0.72 ASTMD2216-02

Compaction characteristics
Max. Dry unit weight (KN/m³) 17.4 STM689-00
Optimum Moisture content (%) 14.8
Collapse Potential % 4.9 ASTM D5533-2003

2.2 Experimental program
The tests are conducted in the Civil Engineering Laboratory at the College of Engineering at the University of Diyala using the laboratory model, the steel tank used in this method with dimensions (600 * 300 * 300) mm. The inner face of the steel tank is painted to reduce the friction of the axial loading test, and the equipment is designed so that pressure is applied in a pile by a hydraulic jack.
3. Apparatuses of Model
   1. Steel tank with dimension (600*300*300) mm.
   2. Water tank.
   3. Steel frame.
   4. Circular weight.
   5. Mechanical - oscillator.
   6. Single pile.
   7. Dial gage.
   8. Cap pile.
   9. Ac automatic voltage regulator
   10. Computer device.
   11. Digital tachometer.
   12. Variable frequency drive.
   13. Vibration meter.

Figures explain the model with equipment’s

Piles that used in the study are solid steel piles which slenderness ratio 12, 17, 22 and 27 explain in Figure 4. The cap pile put on the pile, the cap pile dimension (3 mm in thickness, 60 mm in width and 120 mm in length), it contained the mechanical oscillator put in the centre of the cap.

The mechanical oscillator is composed of disc made of steel with dimension 35 mm and thickness 2 mm. A small mass placed on a rotating disk at deflection, the weight of the block is 50 g. The value of cap and the mechanical oscillator is 300 gm. Circular weight (0.5 Kg) used for constant loading, worse case in soak state taken and It is important in this test that a digital tachometer model (DT-2234At) is used to verify if there is no difference in the speed of mechanical oscillator. The dynamic response of the pile is measured by experiment with a device called a piezoelectric accelerometer, which is connected to a
digital wave scale model (HG-6360) that has a single channel. Its accuracy (0.001 to 4.0) mm is used to measure velocity, acceleration, capacitance and displacement, and it can also connect to a computer to display the dynamic response depending on the pre-set function.

4. Test procedure
4.1 Soil Bed preparation
Gypseous soil is used to fill the test box with a size (600 * 300 * 300) mm divided into six layers. Each layer has dimensions (100 * 300 * 300) mm. Soil volume weight was calculated based on the dry soil weight unit in place (15.12 KN / m³) for (30% GC) Soil layer was compacted by steel plate (square shape) to avoid soil particles shattering Each layer was planned after compaction before adding the layer next. Pressure probability and time are constant in all prepared soil layers to obtain uniform density for all layers.

4.2 Instillation of model pile and test
After the process of preparing the soil, the pile is inserted through the mechanical jacking device, since the steel tank is placed inside the frame of the device, as the pile forms in the space below the cell and then the pile is pushed through a mechanical piston and as the force is determined to be pushed if it should not exceed the depth of the pile entering the soil 2 - 2.5 mm / min. After completing the insertion of the pile, the steel tank is placed in the inspection frame and a static load is attached to it. The dynamic response (displacement amplitude, velocity, and acceleration) of the recorded pile is measured at the same time using a piezoelectric accelerometer and a daily scale previously placed on the cover pile to obtain the pile adjustment, and the operating frequency is (600) revolution per minute equivalent to (10) Hz and different slenderness ratio 12, 17, 22 and 27 In this study, response coefficients were recorded every 5 minutes for 30 minutes.

5. Result
In this study, the dynamic response of a single pile was examined under the influence of a dynamic force produced by a motor placed over the cap pile after the pile was pushed into the soil and the static load was applied , the dynamic pile was analyzed with the vertical load generated by the machine to obtain the
velocity, acceleration and displacement amplitude at a frequency of 10 Hz and various slenderness ratios 12, 17, 22 and 27 and the process is carried out in the dry and soaked state.

5.1 Velocity
Figure 7 shows the relationship between the velocity and time during operation machine on dry and soaked state at 10 HZ and G.C = 30 for L/D 12, 17, 22 and 27. The magnitude of velocity decrease when increase (L/D) because it gives more strength to the soil and leads to a reduction in the energy of vibration and decrease the velocity of the pile. At dry state, the value of velocity is larger than it is value at soak state because the energy of vibration was decreased due to gypsum content behaviour with the presence of water in soil (acting as a wave retarder)) and that led to reduce in velocity of vibration for all test.

5.2 Acceleration
Figure 8 shown that the relationship between acceleration and time, which recorded for different (L/D) at the dry and soak condition. The magnitude of the acceleration decreases when increasing (L/D) because this gives force to the soil and the propagation of the vibrations through the ground leads to a decrease in the energy of the vibrations and a decrease in the acceleration. In the dry state, the magnitude of the acceleration increases compared to the volume in the soaking condition in all tests because the water in the soil resulted in damping as a wave suppressor (it was mentioned earlier).

Figure 7. Time –velocity in all L/D of the pile at (a) dry state and (b) soaked state.

Figure 8. Time –acceleration in all L/D of the pile in the (a) dry state and (b) at soaked state.
5.3 Displacement amplitude

In Figure 9 shown the relationship between the magnitude of the displacement amplitude in dry and soak state with time in different L/D (12, 17, 22, 27). The magnitude of the displacement amplitude decreased when increased the slenderness ratio L/D. So, the value of displacement amplitude at L/D (12) is more extensive than magnitude at L/D (17, 22, 27) and gives more change than another because the increase in L/D provides more strength to the soil. In the dry state, the magnitude of displacement amplitude increases than magnitude in soak state because the present water leads to acting the energy of vibration.

Figures 9. Time – displacement amplitude in all L/D of the pile at (a) dry state and (b) soaked state.

6. Conclusion

- The values of velocity in the dry state are greater compared to their values in the soak state.
- The velocity vibration of single solid steel L/D 27 pile decrease with increase the slenderness ratio of pile. The value of vibration velocity decreases in the soak state as compared with the dry state at L/D 12, 17, 22 and 27 is 14.8, 28, 17.8 and 16.7% respectively. When the slenderness ratio increases from 12 to 27 at dry and soak state the value of velocity decreases by 77.8 and 78.2% respectively.
- The acceleration values are lower in the soak state than in the dry state.
- The value of acceleration vibration of single solid steel pile decreases when the slenderness ratio increased. The acceleration value decreases in the soak state as compared with the dry state at L/D 12, 17, 22 and 27 is 38%, 20%, 17.8% and 23% respectively. The acceleration value decreases when the slenderness ratio increases from 12 to 27 in the dry and soak states by 84 and 80% respectively.
- The displacement amplitude values in the dry state are greater than its values at soak state.
- The value of amplitude of single solid steel L/D 27 pile decrease with increase the slenderness ratio of pile. The acceleration value decreases in the soak state as compared with the dry state at L/D 12, 17, 22 and 27 is 41.67, 23, 15 and 22.8 respectively. When the slenderness ratio increases from 12 to 27 in the dry and soak states, the amplitude value decreases by 66.67 and 61.4% respectively.
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