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Behavior of Gypseous Soil under Static and Dynamic Loading

S. H. Abid Awn*, H. O. Abbas

Department of Transportation and Airports Engineering, University of Diyala, Iraq

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ABSTRACT

This study is concerned with the soaking and leaching of gypseous soil at both static and dynamic conditions. The soil used was Natural gypseous soil with 50% gypsum. Three parameters were studied (deformation ratio, dissolve gypsum salts, and hydraulic conductivity) in both static and dynamic conditions..20 tests were carried using laboratory model. A platform base connected to the loading frame was designed in a manner that allows free movement provided for dynamic test, as an earthquake. Results of experimental work revealed that the deformation ratio S/B (settlement /footing width) for the sample subjected to 10 seconds vibration was twice that of sample without vibration, while the deformation ratio was 15 times that of the sample without vibration when subjected to 30 seconds. On the other hand, 70% of hydraulic conductivity was achieved at the first 10 minutes of leaching for the model subjected to 30 seconds of vibration. That reflects the effect of earthquakes on structures constructed on such problematic soil.

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1. INTRODUCTION

One of the biggest problems facing humanity is climate change and construction. 58% of the climate change indicators are critical and give evidence of the negative outlook that housing building organizations have in terms of sustainability. This can contribute to designing strategies to promote sustainable building by the local government, and thus achieve more sustainable organizations that contribute to reducing their impact on climate change [1].

The presence of problematic soil like gypseous soils cause structural problems for the buildings built on them especially when exposed to moisture from any water source. When such soil is subjected to sudden earthquakes it becomes more dangerous. Lack of information or studies on some variables such as permeability, rate of dissolved salts, and subsidence with time during exposure of such soil to an earthquake. This study was needed because of its practical and applied importance to study the behavior of these soils which are spread in large areas of the continent of Asia. Structures constructed on gypseous soil including buildings, roads, bridges, harbors, and railways have always been associated with settlement problems [2].

The problem appears when water table or rainfall fluctuates and/or infiltrates into the gypseous soil and dissolution of gypsum occurs, causes loss of cementation between soil particles [3]. Another problem appears for hydraulic structures and irrigation channels which are presented by the leaching problem for gypseous soil below these structures [4]. The presence of water in these structures and the difference in heads between the upper and lower stream of dam structures causes seepage of water, also it causes washing of the dissolved gypsum between soil particles [5]. This washing process led to what we call cavities, inside the soil mass below the heavy hydraulic structure which is filled with water and the dissolved gypsum. At this stage, sudden failure of hydraulic structure constructed on such soil may happen [6]. The problem appears at the first moment of soaking the soil with water [7]. While the other problem presented by leaching the dissolved gypsum inside soil structure, as in the hydraulic structures like dams and irrigation channels [8].

This issue becomes more serious when the soil

*Corresponding Author Email: dr.safaalshamary@gmail.com (S. H. Abid Awn)

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subjects to earth quickly or any dynamic excitation like the offshore or retaining wall structure [9]. The dynamic effect of an earthquake depends on the amplitude and duration time of the wave the acceleration and the velocity of the locomotor system causing the vibration to simulate the earthquake presentation in the laboratory [10]. Shaking table, the rotor-mounted disk with eccentric gravity is one of the means of representing the dynamic effect on the soil model .

Till now there is no obvious evidence about the presentation of the behavior of such soil by a standard laboratory test, as other soils. The common method of measuring failure of gypseous soils is by using the oedometer test device by a single or double oedometer test [9]. This method is unrealistic to the natural behavior for this soil because of the disturbance of soil sample which may happen when placing the sample of soil inside the ring of the oedometer cell and the small size of the ring and using large scale model is more real.

The strongest earthquake that struck the world is in the Chilean region, with a magnitude of 9.5 on the Richter scale, and it occurred in the city of Valdivia in southern Chile on May 22, 1960, and its duration was 10 minutes[2]. The effect of earthquakes on the structures built on collapsing soils is shown in Figure 1.

The aim of this study to simulate the effect of an earthquake on a big scale gypseous soil sample and study the variation of total dissolved salts, permeability and deformation with time in both static and dynamic cases using a big scale laboratory model.

2. EXPERIMENTAL WORK

2. 1. Soil Used The soil used in the study was brought from Tikrit City (North of Iraq), with 50% gypsum. The testing program is shown in Figure 2. The engineering properties including chemical and physical properties of soil used are shown in Tables 1 and 2. All laboratory tests were carried out on such soil; also

Figure 1. The earthquakes on the structures built on collapsing soils

[2] https://www.arabiaweather.com/content

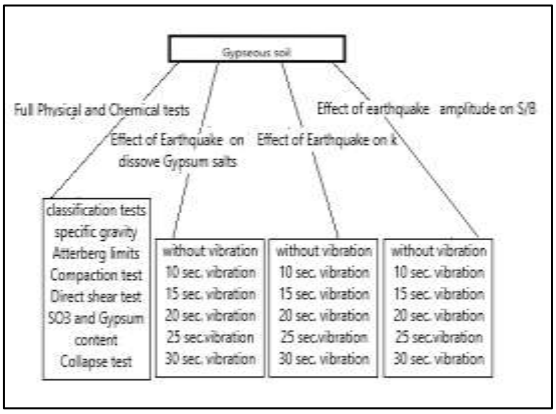


Figure 2. Experimental work program flow chart

TABLE 1. Chemical test for soil used

Soil composition	Value (%)
Dissolve salts	45.6
Sulphate content	20.5
Organic material	0.23
Gypsum content	50
Chloride content	0.08
pH	6.9

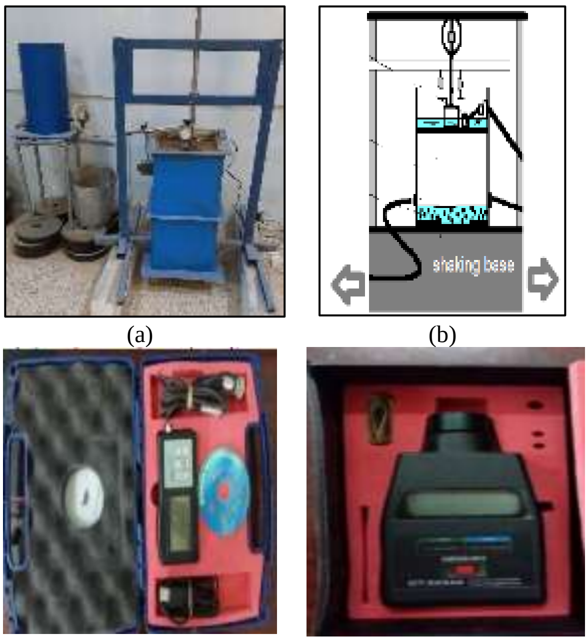
TABLE 2. Physical properties of gypseous soil used in the study brought from Salah-Alden governorate in Iraq

Test type	Property	Value
	D10 mm	0.06
	D30 mm	0.07
	D60 mm	0.19
Grain size	Coefficient of Uniformity, Cu	3.02
	Coefficient of Curvature, Cc	0.4
	Passing sieve no. 200	38
	Soil Type	SM
Specific gravity		2.42
	Liquid limit (L.L) %	24
Atterberg limits	Plastic Limit (P.L) %	none
	friction angle (Ø) (dry soil)	34
Shear test	cohesion (c) (kN/m²) (dry soil)	5
	Friction angle (Ø) (soaked soil)	30
	cohesion for soaked soil (kN/m²)	8
Void ratio		0.63
Water content		7.3
Compaction test	Dry unit weight (kN/m³)	17.1
	Optimum moisture content%	14
Field density kN/m^3		15.1

relative density was carried according to (ASTM D4254), the temperature for the initial water content determination test is (40 - 50°C) to obviate losing crystal of gypseous soil. The gypseous soil is classified as moderate and moderately severe according to (ASTM D 5533-2003).

2. 2. Laboratory Model Preparation and Test Methodology A steel model consists of a steel tank with dimensions 300*300*600mm and stiffened at sides and the entire face painted to reduce friction with the soil. A graded fine aggregate was placed at the lower 150mm of the steel model to allow for the leaching water infiltration out of the gypseous soil specimen in the leaching test. Natural gypseous soil with 50% gypsum was used in this study. The density of soil was controlled using the raining technique. A steel footing with 100mm diameter was placed at the center of the soil specimen. Fix weights were fitted over the circular footing with the aid of a vertical shaft connected to the loading frame from its tip to prevent overturning. The soaking process was controlled by feeding water from a water tank as shown in Figure 3.

The leaching process was controlled by making two openings at the bottom of the plastic container opened at the beginning of the leaching test. The head at both upstream and downstream sides was fixed all over the leaching process.



(a) (b) (c) (d)

Figure 3. (a) Loading frame and water control system (b) Set up of laboratory model and preparation of soaking (c) Vibration measuring device (d) Digital Tachometer

The platform base of the loading frame was designed in a manner that allows free movement using slotting spindles and holes provided for dynamic excitation simulating the earthquake as shown in Figure 3.

A mechanical Oscillator fixed to the platform base. It is composed of steel weel with a small mass placed on its edge. A digital tachometer (DT-2234At) was used to control and fix the Oscillator speed at a frequency of 10Hz which was obtained by rotating the weel 600 revolution per minute with 2.63 mm/s velocities and 1.72 m/s^2 acceleration which kept constant during the dynamic test.

To ensure the fixity of these values, a device called Piezoelectric Accelerometer connected to digital wave velocity model (HG-6360) use to measure velocity and acceleration and can connect to a computer. All accessories used in the study are shown in Figure 2. The valves in the lower part of the models have opened the dissolved salt liquid collected after a limited period to measure the cumulative water and hydraulic conductivity k and dissolve salts.

3. RESULTS AND DISCUSSION

3. 1. Dynamic Response of Gypseous Soil

3. 1. 1. Deformation of Gypseous Soil The relationship between stress and strain was studied for models of gypsum soils subjected to a static dynamic vibration of 10 Hz and at different vibration times (10, 15, 20, 25, 30 seconds) and they were compared with a static model as shown in Figure 4. It can be seen that the footing deformation for gypseous soil sample exposed to 30-second vibration increased about 18 times compared with the static model. While the increase was twice for the model exposed to the same vibration frequency for 10 seconds, especially after the immersion of gypsum from the soil model compared with the static model. This may be due to the effect of gypsum melting inside the soil and restructuring the grains, and this condition increases with an increase in the vibration time; which leads to large deformation of the foundation, while the deformation was less for the foundation based on the gypsum soil model subjected to less vibration. It can recognize that the problem of leaching is not less dangerous than the problem of soaking and it is more serious for models subjected to dynamic excitation. This behavior is more pronounced as with vibration time. With continuous feeding of water, the excitation of saturated gypseous soil model rearrange soil particles and increase footing settlement for soaking and leaching tests in addition that the pores between soil particles increase with continuous flooding of water because gypsum dissolution causes sudden collapse of gypseous soil.

3. 1. 2. Permeability and Solubility of Gypseous Soil Figure 5 shows the hydraulic conductivity (k) relation with leaching time for the gypseous soil model subjected to different vibration time amplitudes (5, 10, 15, 20, 25, and 25 s). At the beginning of the leaching test, high values of coefficient of permeability were recorded this may be due to the pressure release of collected water from the previous soaking stage and not from chemical changes .An increase in shaking time for the laboratory model subjected to a dynamic vibration reduces permeability due to an increase in the pore water pressure for saturated gypseous soil due to the disturbance movement of particles inside soil specimen so the permeability decreases.

Figure 6 shows the relation between leaching time and coefficient of permeability k for laboratory model tested at different vibration amplitudes. The undissolved gypsum from the first stage (immersion stage) begins to dissolve during the washing process due to the low concentration of solvent water inside the model and to allow the dissolved gypsum to exit outside the model, so gaps are formed which filled with water and begins to form gaps between the soil grains of the laboratory model which made the soil becomes more permeable.

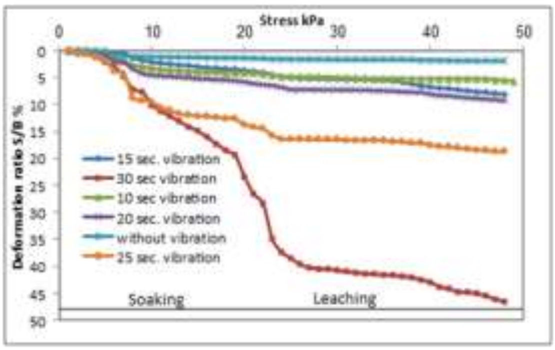


Figure 4. Effect of soaking and leaching on the deformation of footing constructed on gypseous soil of big-scale laboratory model subjected to 10Hz vibration with different vibration times (gypsum content=50%)

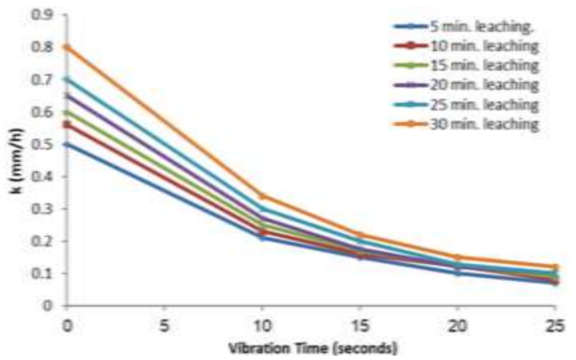


Figure 5. Relation between hydraulic conductivity and vibration time amplitude for different leaching periods

Figure 7 shows the dissolve salt-leaching time relation for gypseous soil models tested at different vibration periods. The dissolve salts vary with leaching time and fluctuate in a randomly descending order until reaching the steady-state condition after 10 days of leaching, this may attribute to the rearrangement of soil particles with vibration time which led to the reduction in pores between soil particles. It was also observed that after 12 days of continuous washing of the gypseous soil model with water after conducting a dynamic examination, the percentage of dissolved salts decreases with an increase in the shaking time. Therefore, the dissolved salts of the model subjected to 25 seconds of vibration reduced 16% from the static model.

4. CONCLUSION AND SUMMARY

In this study, a sample of gypseous soil was exposed to the same conditions and frequency as in the highest earthquake that struck the world in Valencia, southern Chile on 22 May 1960. different vibration periods were investigated (0, 10, 15, 20, 25, 30 seconds). The longest time for earthquakes that hit the world was 10 seconds. The effect of earthquakes on the deformation of a foundation constructed on high contaminated gypseous

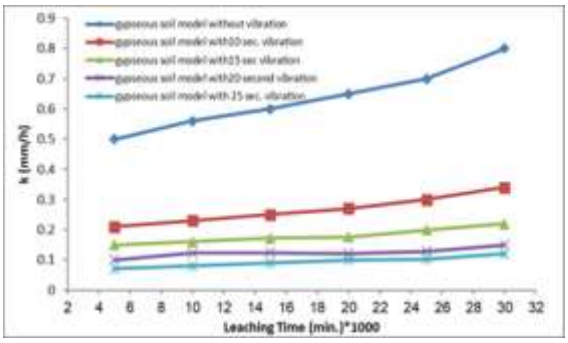


Figure 6. Leaching time and permeability relationship

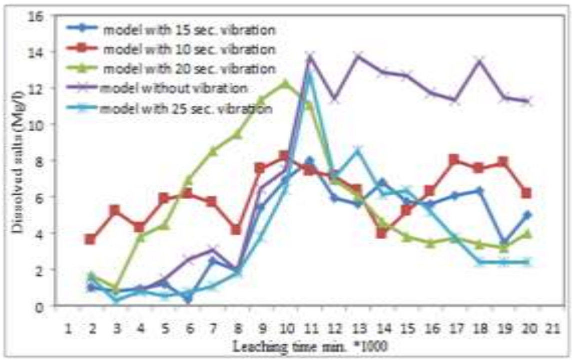


Figure 7. Effect of leaching time on the dissolve salts of gypseous soil mode tested at different vibration time, 10, 15, 20, 25 s and sample without vibration

soil, in addition, to change in the solubility of salts and permeability with time in cases of immersion and washing of gypsum, was also investigated.

1. It is recommended to use large model tests rather than the conventional oedometer tests for both soaking and leaching on gypseous soil at dynamic tests.

2. The danger caused by the exposure of saturated gypseous soil to dynamic vibration increases with an increase in time of the vibration. The deformation of foundation constructing on these soils increases to more than 200% if it is subjected to 10 minutes of vibration. compared to the static model.

3. It may be dangerous to construct heavy structures with a high-stress level on such kind of problematic soil without suitable treatment. In addition to that, the problem of the collapse was more pronounced for the gypseous soil model subjected to 30 seconds excitation, the deformation ratio increased 25 times compared with that for the static model.

4. An increase in shaking time reduces the permeability of the soil, which leads to the retention of water inside the soil as a result of the dynamic activity because of the earthquake, which leads to an increase in pore water pressure and thus has a significant impact on soil behavior.

5 . From the results of the dynamic leaching test, 70% of the hydraulic conductivity was achieved at the first 10 min leaching for the model subjected to 30 seconds vibration. On the other hand, the deformation ratio at the leaching process was continued especially for the model subjected to 30 seconds vibration.

6. It can be recognized that the percentage of dissolved salts in leaching of the gypsum soil decreases with the increase in the time of vibration, which delays the dissolution of the gypsum salts inside the soil. The dissolve salts vary with time and fluctuate in a randomly descending order until reaching the steady-state condition after 12 days of continuous leaching.

7. It is recommended to take caution when constructing buildings beside any dynamic soars, especially in gypseous soil.

8. It is recommended to study the possibility of using a laboratory model and its realistic representation and to identify the dynamic behavior of gypsum soils with different gypsum ratios and the possibility of treating them using chemical additives such as cement or lime or physical treatments such as aggregate columns or soil reinforcement to ward off construction hazards.

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Persian Abstract

چکیده

این مطالعه مربوط به خیساندن و شسته شدن خاک گچ در هر دو شرایط استاتیک و دینامیکی است. خاک مورد استفاده خاک گچی طبیعی با گچ ۵۰٪ بود. سه پارامتر (نسبت تغییر شکل ، حل نمک های گچ و هدایت هیدرولیکی) در هر دو حالت استاتیک و دینامیکی مورد بررسی قرار گرفت. ۲۰ آزمون با استفاده از مدل آزمایشگاهی انجام شد. یک پایه سکو متصل به قاب بارگیری به شکلی طراحی شده است که امکان حرکت آزاد را برای آزمایش پویا فراهم می کند ، به عنوان یک زلزله. نتایج کار آزمایشی نشان داد که نسبت تغییر شکل (S / Bته نشینی / عرض پایه) برای نمونه مورد آزمایش ۱۰ ثانیه لرزش دو برابر نمونه بدون لرزش بود ، در حالی که نسبت تغییر شکل ۱۵ برابر نمونه بدون لرزش هنگام قرار گرفتن در معرض بود ۳۰ ثانیه. از طرف دیگر ، ۷۰ درصد هدایت هیدرولیکی در ۱۰ دقیقه اول شستشو برای مدل تحت ۳۰ ثانیه لرزش به دست آمد. این نتایج نشان دهنده تأثیر زلزله بر روی سازه های ساخته شده در چنین خاک مشکل دار است.