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SETTLEMENT OF SANDY SOIL IMPROVED BY STEEL SLAG UNDER SEISMIC LOAD

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ABSTRACT

*In this study, a circular foundation with dimensions of 100 * 100 mm was used, made of plastic glass material, which was loaded with 4 kg. This foundation is based on sandy soil improved using steel slag, which is an industrial waste resulting from iron and steel factories, with a mixing ratio of (3,6,9,12,15) % using a shaking table influenced by the Halabjah earthquake, Bolunun Earthquake and Ali AL-Gharbi Earthquake, The measured that settlement in sandy soil in the dry and saturated states for each of the three types of earthquakes is measured by the Linear Variable Differential Transformer (LVDT) sensors that are installed on the foundation surface. For unimproved soil, the settling time was four seconds; for soil improved with 15% steel slag, it was fifteen seconds. Additionally, for the three earthquakes, the rate of settlement decline increases with decreasing seismic acceleration. Additionally, the three earthquakes are closely spaced around the initial period of the commencement of settlement. Through the differences in what was done, it was found that increasing the percentage of steel slag led to a decrease in the foundation settlement in the dry and saturated cases by a greater percentage in the dry case than in the saturated case.*

1. INTRODUCTION

Recycled materials with potential for use in geotechnical engineering applications include waste roof shingles and sludge from paper mills. These components can be refined into a more appealing product or utilized as an appropriate building material straight out of the bag. The fact that recycled materials have engineering qualities that are on par with or better than those of traditional building materials is one of the factors propelling study into this area. Reusing these materials eventually prevents them from ending up in landfills, which is the other factor. The need for this is critical since landfill space is running out quickly.

Carreon (2006) concluded the ash was material that showed true potential for stabilizing soils by blending. The result compaction and shear strength testing conducted showed that materials such as scrap roofing shingles had either little to no effect or even detrimental effects on the geotechnical properties the soils being stabilized. However, MSW ash demonstrated that it might improve the properties of shear strength and compaction behavior when mixed with soils. The maximum dry unit weight of the sample increased overall during compaction tests when MSW ash was added to sand. This is closely related to gaining more strength.

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Puri and Prakash (2007) investigated piles and shallow foundations under seismic loads in both liquefied and non-liquefied soils. It was possible to evaluate the loss of bearing capacity in shallow footings and predict settlement increases by an experimental approach that coupled earthquake acceleration, frequency, dynamic bearing capacity parameters (Nc, Nq, N\), and structure aspects ratio.

Azzam (2009) Concluded that, under different stress levels, the presence of steel slag as a reinforced element significantly impacts reducing and mitigating the vertical and horizontal deformation of sandy soil. At higher densities, the degree of horizontal and vertical deformation or dilatation was constrained by the fiber-like slag present; it was shown that the slag content impacted the shear stress deformation response. As seen for 10% and 50% slag contents, increasing the slag content led to a progressive increase in peak strength with decreasing shear displacement. On the other hand, no peak was seen for slag content greater than 50%.

Mohammad *et al.* (2011) investigated shallow foundations based on liquefiable sandy soil under dynamic loads using a shaking table on which the foundations rest. To aid in the examination of the soil structure system, the foundation's size and loading direction were examined, and the procedure was long-term video-monitored in the lab. The tests' settlement values were improved by the foundation's aspect ratio, and the loads parallel to the width increased more than those parallel to the length.

Day (2012) compared the number of structures damaged by earthquake-induced settlement, there are far fewer structures that have earthquake-induced bearing capacity failures. This is result of the following factors: Settlement is in charge, comprehensive research, Factor of safety: (q)ult is split by the safety factor. embedment depths, minimum footing sizes, permissible bearing pressures dimensions of the footing.

El Sawaf and Nazir (2012) investigated the behavior of strip footing supported on a loose sandy slope under both monotonic and cycle loads. According to test results, adding soil reinforcement to the sand that has been replaced not only greatly improves the stability of the sandy slope, but it also dramatically reduces both cumulative and monotonic cyclic settlements, resulting in a footing that is economically designed.

Puri and Prakash (2013) calculated soil shear stress caused by earthquakes. Shear stress and volumetric stress are identical when the volume loading remains constant. They found that total settlement equals the difference in soil volume caused by an earthquake and the building pressure.

Akinwumi (2014) demonstrated that, in the absence of unfavorable swell behavior, crushed steel slag might be employed to improve the lateritic soil's plasticity, uncured strength, and drainage properties. Only when 8% steel slag was added to the soil did the uncured strength of the soil improve. When 8% steel slag was added to the soil, its unconfined compressive strength improved by 66.7 kN/m^2 and its unsoaked CBR increased by 40%.

Ye and Hu (2018) came to the conclusion that permeability affects the creation of pore pressure, and that settlement is higher in looser sand and declines with density.

Zhuang Haiyang *et al*. (2019) used a shaking table model test for the seismic response of the link between the two-story, the study found the seismic response of the subterranean structure in the inclined liquefied layer law, as well as the three-span subway underground station structure and the interval tunnel in the slightly inclined liquefiable site.

Al-Salakh and Albusoda (2020) used theoretical and experimental methodologies to study establishment footing sinking on liquefied soil on sandy soils at different earthquake stresses. They showed a notable degree of convergence between the amended equation and the observed settlement values.

Hazarika *et al.* (2020) discovered the using the optimum tire and gravel mixture in the reinforcement layer, as well as the optimum thickness and the proper location for the layer, the liquefaction counter measure described herein can lead to the prevention of the liquefaction-induced settlement of buildings. The technique possesses tremendous potential for application in developing and emerging economies, where the alarmingly high rate of car usage as the mode of commuting has already created problems of stockpiling and illegal dumping, which in turn is placing a huge burden on the environment.

Alzabeebee (2020) investigated the efficiency of using skirts as a method to reduce the settlement of a strip footing under machine vibration. He found that the skirt's effect in reducing the dynamic settlement was reduced by increasing the soil stiffness. The reduction in settlement percentages ranged from 2% to 70% for loose sand, 1% to 68% for medium sand, and 0.5% to 67% for tight sand.

Abed, N., & Abbas, J. K. (2020) of gypsum soil and how they improve its behavior. Based on gypsum weight, iron fills were added to the soil at 5%, 7.5%, 10%, 12.5%, and 15%. After that, chemical, physical, and engineering testing were done. As additives increased from 0% to 5%, soil engineering properties improved. It reduced soil collapse from <5.08 to 1.16 and increased cohesiveness from 29.34 to 50.02 KN/m3. Additionally, the soil's internal friction angle increased from 33.19º to 43º.

Katfan and Al-Busoda (2021) researched the bearing capacity, footing depth, and the settlement behavior are representing the major factors that governing the design of shallow foundation. The behavior of the bearing capacity and the ensuing settlement for the square, circular, and rectangular footing foundations are the main topics of this study. The three modes of (Df/B) ratio (0, 1/3, and 2/3) under earthquake loading are used in this work, and the finite element 3D PLAXIS numerical program is used for the simulation. The results of the analysis show a second order relation between the 2D bearing capacity coefficients and the earthquake horizontal acceleration; the magnitude of dynamic bearing capacity is influenced by the footing's shape.

Hasen, N. A., & Abbas, J. K. (2024) studied the reinforcement to prevent foundation settlement damage, research is being done on reinforced sandy soils following the three earthquakes (Halabjah, Bolunun, and Ali Al-Gharbi). Shaking table tests examined 70%-density sand samples with and without geogrid reinforcement—use of five geogrid layers. The dynamic force causes settling. Hence, the 100 * 100 * 30 mm plastic base was chosen. This is 5.294 kN/m2 static load. Increased seismic acceleration settles sandy soil foundations. With more geogrid reinforcing layers, base settlement lowers faster with lower earthquake acceleration. Settlement and start times are identical in all circumstances. Soaked earth settles twice as fast as dry.

2. MAIN HEADING

2.1 Sandy Soil

The sand used in the trials was from a nearby river, which is widely accessible and typically used for most construction projects. It was transported from the Tuz region in the heart of Iraq, which is situated in the Salah-Aldeen Governorate 80 kilometers east of Tikrit. A suitable amount was sieved via sieve No. 4 prior to the testing commencing. Through the use of engineering experiments, including direct shear, and classification tests, the properties of the soil were ascertained. Table 1 presents the results of the tests conducted on the sand based on the ASTM index, while Figure 1 displays the sand's particle size distribution.

Table 1. Properties of Sand Used in the Test

Properties	Specification	Value
"Moisture Content", (ω)%	ASTM D2216-02	1
"Specific Gravity", (G_s)	ASTM D-854	2.656
"Coefficient of Uniformity", Cu	ASTM D-421	2.95
"Coefficient of Curvature", Cc	ASTM D-421	1.087
"Unified Soil Classification System"	Sieve Analysis	SP
"γ_{dmin}" kN/m^3	ASTM D4254-00	15.81
"γ_{dmax}" kN/m^3	ASTM D1557-12	17.50
"γ_{dfield}" kN/m^3	ASTM D1557-00	16.95
C (kN/m^2)	ASTM D-3080	0
Ø	ASTM D-3080	33.46^o

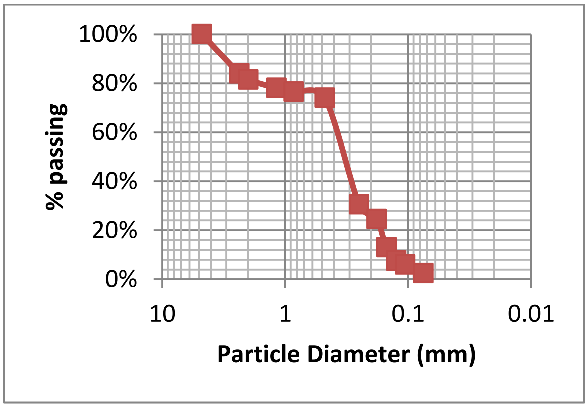


Figure 1. Distribution of Sand Particle Sizes Used

2.2 Steel Slag

The source of this trash was the steel industry located in Sulaymaniyah Governorate's Bazian area. The iron Arc process yields this residue as a byproduct. To check the percentage of silica and lime, a chemical test was run.

After that, the slag was broken up using a jaw crusher and sieved to a 250-micron size (No. 60). Using a hand shovel, the steel slag and sand were combined until the material was homogenized. Chemical experiments were carried out in the Department of Chemical Engineering laboratory at Tikrit University's College of Engineering, and the results for steel slag after grinding and passes through sieve No.60 are shown in Table 2.

Table 2. The present study's steel slag's chemical composition

Chemical Components	Percentages (%)
"Fe_2o3"	42.01
"SiO_2"	14.27
"Al_2O_3"	2.81
"MgO"	2.08
"CaO"	32.96
Other	5.87

3. MODEL BOX AND FOUNDATION PREPARATION

3.1 Shaking Table

A 60*120*10-centimeter steel structure that is screwed into the ground makes up the shaking table. The cart's base, which is 80 by 80 by 8 cm, is supported by this structure and moved by wheels attached to steel tubes that slide. A ball screw shaft with a 40 mm diameter is used to translate the motor's spinning motion into linear displacement, as shown in Figure 2, which shows the mechanical component system of the shaking table, 750 mm overall length, and 620 mm journey length. The frame of the shaking table had two brackets fastened to it that functioned as nut brackets for the ball screw. The other bracket held the driving rod in place while it was fastened to the frame of the rocking table. joins the ball screw to allow for unhindered frame sliding.

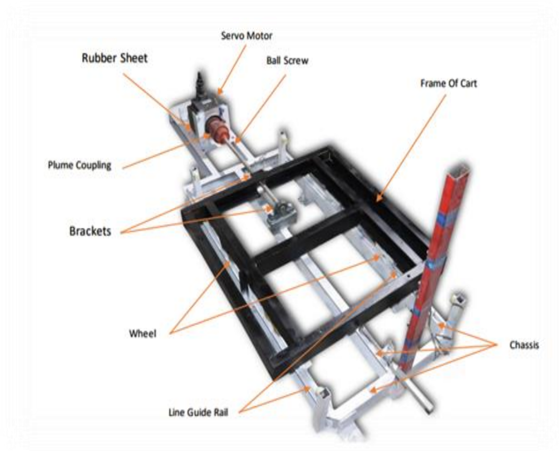


Figure 2. Shaking table system

3.2 Instrumentations (LVDT) Sensor and Flexible Laminar box (FLB)

Direct displacement measured by a linear variable differential inductor (LVDT). The DC LVDT is a great device since it features a standard output signal and a sealed circuit that can operate in wet and dusty environments. A 20-millimeter hydraulic cylinder and a stainless-steel housing encase this computer. Valve control, detection, and position. The study's 100mm LVDTs are displayed in Figure 3. On top of a foundation, an LVDT is mounted to measure settlement. The mechanical behavior of soil-based foundation models under shear stress circumstances is studied using a technological laboratory device called the flexible laminar box (FLB) are displayed in Figure 4. It is intended to replicate the shearing process that occurs when dynamic forces from the outside are applied to soil layers. With a fixed-side box, boundary effects usually arise. This one seeks to lessen those effects. The limits are substantially lower because of the relative horizontal deformation of the plates. FLB is engineered to have end wall shear stiffness that is comparable to the dirt models. The soil layers are represented by the many layers of hard materials that make up the FLB. The primary uses of FLB are in the investigation of interlayer sliding phenomena and soil interface behavior, both of which are crucial for geotechnical engineering applications.

Figure 3. LVDT Sensors

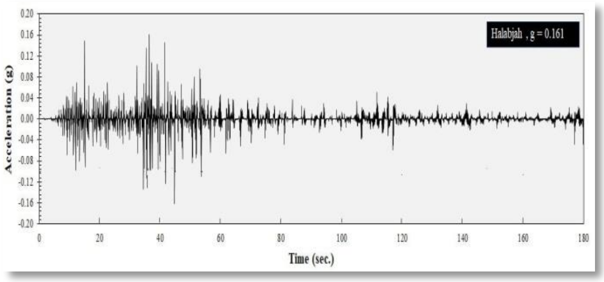
Figure 4. System format FLB

4. ADOPTED EARTHQUAKE DATA

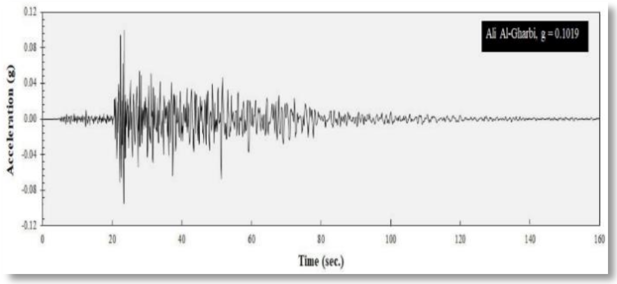
Various real earthquake acceleration history data will be used, including Bolunun in Turkey (2000), Halabjah in Iraq (2017), and Ali AL-Gharbi (2015). The information regarding the used earthquake data is displayed in the table below. Information on earthquake data is included in Table 3. The acceleration histories of the employed earthquakes and the device-verified acceleration history are displayed in Figure 5.

Table 3. Displays info on earthquakes

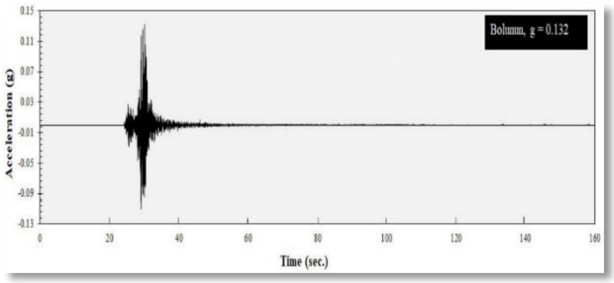
Earthquake	**Halabjah**	**Ali Al-Gharbi**	**Bolunun**
Area	Iraq-Iran border	Iraq	Turkey
"Date (UTC*)"	2017-11-12 18:18:17	2015-09-25 06:10:24	2000-02-14 06:56:36
"Magnitude", mw	7.3 M_w	4.9 M_w	7.4 M_w
"Modified mercalliintensity", MMI	VIII- Moderated heavy	N/A	VIII
"Epicenter depth", km	19.0	10.0	15.7
"Shake duration", sec	300	160	354
"Station distance toepicenter", km	218.8	106.9	168.7



(a) The earthquake in Halabajah



(b) The earthquake in Ali Al-Gharbi



(c) The earthquake in Bolunun

Figure 5. History of acceleration for the employed earthquakes

5. FOOTING MODEL

An additional mass was added to the foundation model of the solid plastic glass block, bringing its total weight to 4.16 kN/m^2. It is positioned next to the foundation and measuring 100 mm in diameter and a depth of 30 mm. Load is fastened with a screw and nut. A variety of glass paper types were used to guarantee the strength of the contact between the granules and the foundation, and "AA240" glass paper was used to cover the bottom face of the foundation in order to replicate the friction of the foundation with thick, dry, and saturated sand. The soil used in both the prototype and the model shared similar mechanical characteristics, such as strength values and the stress-strain relationship. In addition to the acceleration and tilt sensors on the foundation's surface, displacement sensors are also placed on the structure's two sides. Figure 6 shows the foundation and the application of loads to it.

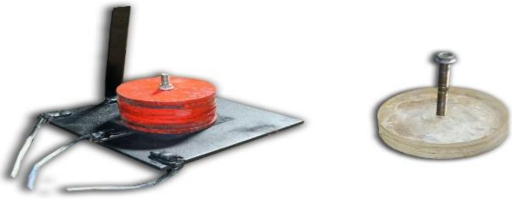


Figure 6. Fixing technique for the load above the foundation

6. EFFECT OF STEEL SLAG ON SETTLEMENT UNDER DYNAMIC LOAD

Earthquakes affect foundation settlement in different ways. The vibrating pressures that an earthquake applies to the foundations cause the sand grains to move and rearrange themselves. Analysis of the data and numbers revealed that the foundation started to settle as soon as the earthquake happened. For unimproved soil, the settling time was four seconds; for soil improved with 15% steel slag, it was fifteen seconds. It was noted that the foundation settlement's stabilization phase changed and stabilized at various times to continue until the earthquake's conclusion. But in general, it tends to deteriorate. It was found that the unimproved soil has a starting settlement value of 14.26 mm. From that point on, it progressively declines at various rates that are affected by the steel slag; these rates diminish until they arrive at a settlement rate of 15% of the steel slag, with a value of 10 mm representing the maximum percentage of settlement reduction. Table 4 and Figure 7 present the results for sandy, dry soils.

Table 4. Settlement of Footing with the Halabja Earthquake's Impact on Sandy, Dry soil

Case of soil	Sandy soil settlement (mm)	The proportion of soil settlement that decreased between	The percentage decrease in cumulative settlement rate per slag addition	The timing of settlement commencement	The stability of settlement time
Unimproved soil		each addition of slag		(sec.)	(sec.)
3% of steel slag	14.26	-	-	4	81
6% of steel slag	13.29	7.3%	7.3%	4	76
9% of steel slag	13.56	-1.99%	5.31%	4	74
12% of steel slag	12.36	9.7%	15.01%	7	72
15% of steel slag	11.43	8.13%	23.14%	13	71

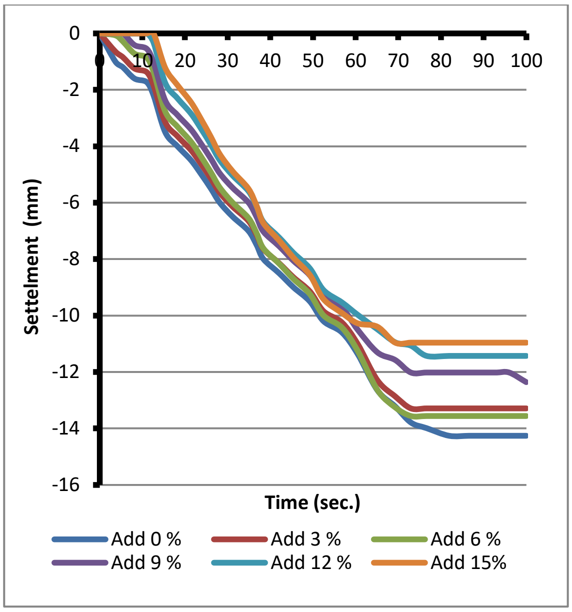


Figure 7. Halabjah Earthquake and Foundation Settlement in dry Sand

The settlement in the flooded sandy soil that happened during the Halabjah earthquake is depicted in Table 5 and Figure 8. When discussing saturated sandy soil foundations, the term "settlement" describes the vertical settling brought on by sand compaction and buildup brought on by earthquakes. An earthquake impacts the water in the pores in the sand particles when there is water between them, which leads to the buildup of pressure. The foundation sinks as a result of the rising water pressure, falling water-holding capacity of the sandy soil, and sliding and gathering of the sand grains. The accumulation occurs gradually over time, with settling being considered the result of this accumulation. In saturated sandy soils, the force of vibrations that an earthquake sends down to the soil increases the point collapse rate and stability, which affects soil settlement. Thus, there is a chance that earthquakes will increase the risk of settling and occasionally cause foundation flooding. It was revealed through data analysis and numerical examination that the foundation begins to settle at the beginning of an earthquake. The unimproved soil settles in three seconds, while the soil improved with 15% steel slag settles in fourteen seconds. There are some obvious differences between this soil and dry sandy soil, but overall, they are comparable. The settling time of the foundation was found to vary, and these phenomena will continue after the earthquake. However, it still tends to be downward in general. Due to the influence of steel slag, the value of settlement for unimproved soil begins at 26.88 mm and progressively declines at varying rates. When they reach 15% of steel slag, the deterioration rates accelerate, and their value drops to 23.97 mm.

Table 5. Settlement of Footing with the Halabja Earthquake's Impact on Sandy, Saturated Soil

Case of soil	Sandy soil settlement (mm)	The proportion of soil settlement that decreased between each addition of slag	The percentage decrease in cumulative settlement rate per slag addition	The timing of settlement commencement (sec.)	The stability of settlement time (sec.)
Unimproved soil	26.88		-	3	77
3% of steel slag	26.9	0.07%	0.07%	3	81
6% of steel slag	27.36	-1.68%	-1.61%	6	82
9% of steel slag	25.75	6.25%	4.64%	11	86
12% of steel slag	25.06	2.75%	7.39%	11	87
15% of steel slag	23.97	4.54%	11.93%	14	87

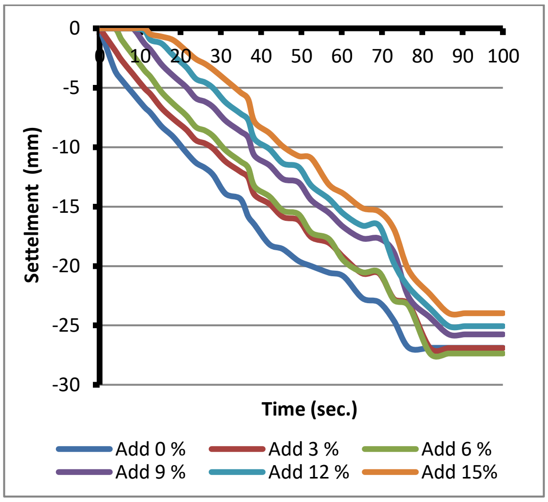


Figure 8. Halabjah Earthquake and Foundation Settlement in Saturated Sand

Table 6 and Figure 9 depict how the Bolunun earthquake affected the arid, sandy soil. When dry sandy soil is compressed and subjected to pressure, the effect of settlement on the foundations causes compaction and accumulation because of the gravitational forces created by the acceleration of the earthquake at the site of the failure. This failure is what causes the sand particles to gradually disintegrate due to movement and improper arrangement. Settlement may happen in a difference or consistently throughout the foundation. Soil settlement is impacted by earthquakes in several ways. Sand grains migrate and organize themselves as a result of the vibrating energy that the earth experiences during an earthquake.

After examining the data and figures, it was discovered that the foundation began to settle as soon as the earthquake happened. Specifically, the unimproved soil experienced a settling time of three seconds, while the improved soil experienced an eleven-second time span. It was also observed that the foundation's settling stabilized at different points during the earthquake and continued until the end, with a change in the duration of settlement, however, it tends to be downhill. It was discovered that the settlement begins at a value of 13.81 mm for unimproved soils and then steadily decreases at different speeds.

Table 6. Settlement of Footing with the Bolunun Earthquake's Impact on Sandy, Dry Soil

Case of soil	Sandy soil settlement (mm)	The proportion of soil settlement that decreased between each addition of slag	The percentage decrease in cumulative settlement rate per slag addition	The timing of settlement commencement (sec.)	The stability of settlement time (sec.)
Unimproved soil	13.81	-	-	3	90
3% of steel slag	13.65	1.17%	1.17%	3	84
6% of steel slag	13.76	-0.79%	0.38%	4	88
9% of steel slag	11.23	22.52%	22.9%	8	89
12% of steel slag	10.82	3.78%	26.68%	10	89
15% of steel slag	9.46	14.37%	41.05%	11	90

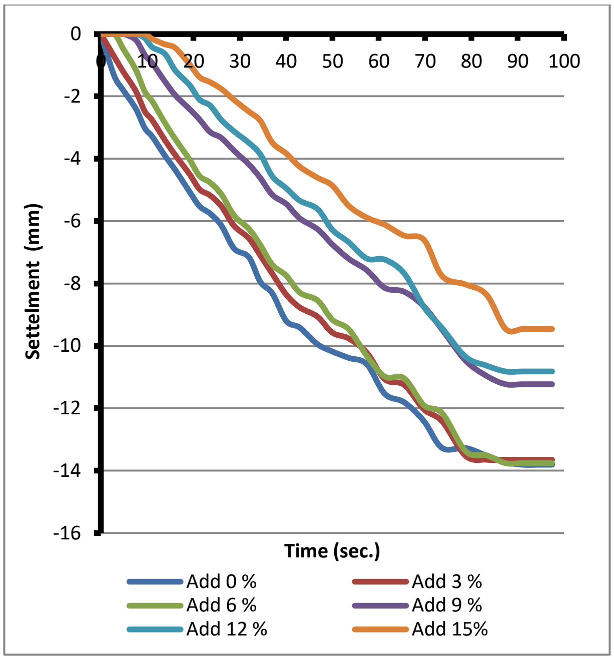


Figure 9. Bolunun Earthquake and Foundation Settlement in Dry Sand

Table 7 and Figure 10 present the effects of the earthquake in Bolunun on the saturated sandy soil. Settlement on the foundations based on the saturated sandy soil, when compressed, causes its buildup and compaction because of the gravitational forces brought on by the earthquake's acceleration. Through data and numerical analysis, it was discovered that settlement occurred primarily in the early phases of the earthquake. The settling period begins in the fourth second for unimproved soil. Only slight differences were observed in the findings for the saturated soil. On the other hand, the fifteen percent steel slag enhancement of the soil occurs in fourteen seconds.

Subsequently, it gradually diminishes at varying rates due to the influence of the steel slag. These reduction rates gradually increase until reaching the 15% of steel slag, where the value reaches 18.56 mm. It was clear that the Bolunun earthquake caused more foundation settlement than the Halabjah earthquake, even with saturated sandy soil. Furthermore, Bolunun earthquake-related settlement decline is occurring at a faster rate than Halabjah earthquake-related settlement decline.

Table 7. Settlement of Footing with the Bolunun Earthquake's Impact on Sandy, Dry Soi

Case of soil	Sandy soil settlement (mm)	The proportion of soil settlement that decreased between each addition of slag	The percentage decrease in cumulative settlement rate per slag addition	The timing of settlement commencement (sec.)	The stability of settlement time (sec.)
Unimproved soil	22.44	-	-	4	78
3% of steel slag	22.14	1.355%	1.355%	4	82
6% of steel slag	22.64	-2.21%	-0.85%	4	82
9% of steel slag	21.91	3.33%	2.45%	8	81
12% of steel slag	21.12	3.74%	6.19%	12	77
15% of steel slag	18.56	13.79%	19.98%	13	72

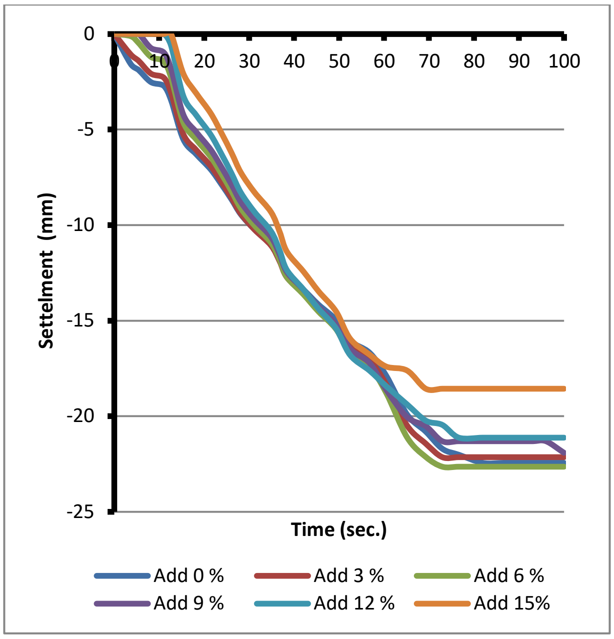


Figure 10. Bolunun Earthquake and Foundation Settlement in Saturated Sand

Table 8 and Figure 11 show the effects of the Ali Al-Gharbi earthquake on sandy, dry soil, it was established through data analysis and numerical investigation that the foundation has been settled ever since the earthquake. This period starts the third second after the earthquake occurs for unimproved soils and concludes in the eleventh second for soil improved with 15% steel slag. However, in general, it tends to deteriorate. It has been discovered that in terms of settlement of unimproved soils, it starts at a value of 12.66 mm and then gradually decreases at different rates due to the effect of steel slag. The statistics show that the rate of decline is considerable since the rates of decrement continuously increase until they reach 15% of steel slag, at which time their value is 8.51 mm. It was determined that the largest earthquake to ever hit Halabjah, Bolunun earthquake, which was smaller than it, and that the Ali Al-Gharbi earthquake had less settlement by comparing the settlement with the foundation. The Bolunun earthquake had the largest rate of settlement decline, followed by the earthquakes in Ali Al-Gharbi and Halabjah, which had the least amount of settlement decline.

Table 8. Settlement of Footing with the Ali Al-Gharbi Earthquake's Impact on Sandy, Dry Soil

Case of soil	Sandy soil settlement (mm)	The proportion of soil settlement that decreased between each addition of slag	The percentage decrease in cumulative settlement rate per slag addition	The timing of settlement commencement (sec.)	The stability of settlement time (sec.)
Unimproved soil	12.66	-	-	3	88
3% of steel slag	12.07	4.88%	4.88%	3	88
6% of steel slag	11.55	4.5%	9.38%	3	88
9% of steel slag	10.1	14.35%	23.73%	7	82
12% of steel slag	8.96	12.72%	36.45%	7	81
15% of steel slag	8.51	5.28%	41.73%	11	81

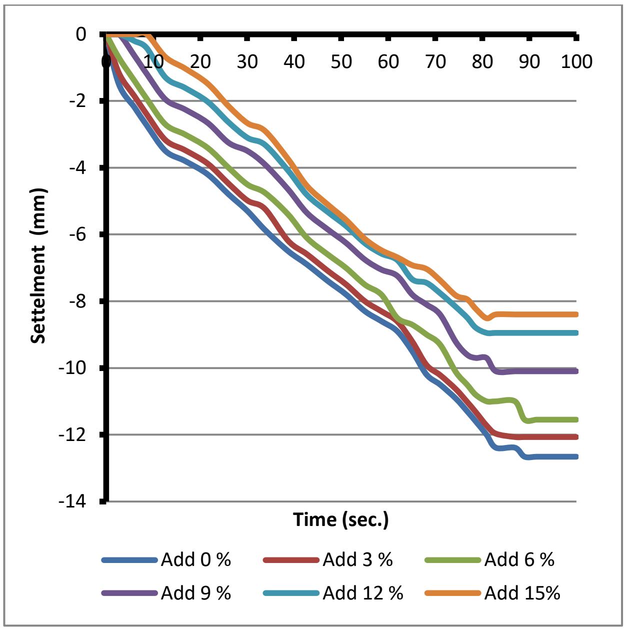


Figure 11. Ali Al-GarbiEarthquake and Foundation Settlement in Dry Sand

Based on data analysis and numerical studies, settlement was more common at the beginning of the earthquake when Table 9 and Figure 12 depict the flooded sandy soil following the Ali Al-Gharbi earthquake. The unimproved soil's settling period is one second, whereas the soil improved with 15% steel slag takes thirteen seconds. The results of the saturated soil were similar, with a few noticeable variations. It was observed that the foundation's settlement period varies, thus it settles at various times to last until the earthquake ends. That being said, generally, it tends to go down. Regarding settlement, it was found that, in the case of unimproved soils, it starts at 20.41 mm and subsequently starts to progressively decline at various rates as a result of the influence of steel slag. The Bolunun foundation settlement is decreasing faster than the Halabjah and Ali Al-Gharbi foundation settlements, additionally, compared to the earthquakes in Bolunun and Halabjah, the foundation settlements for the Ali Al-Gharbi earthquake are smaller. Until they hit the biggest percentage decline in the foundation—15% of steel slag, or 17.42 mm—the percentage rates of settlement values increased. It was discovered that, as a result of the Ali Al-Gharbi earthquake, the foundation's pattern of declining settlement based on dry and saturated sandy soil is non-linear, overlaps for the two tested cases, and grows with an increase in improvement with steel.

Table 9. Settlement of Footing with the Ali Al-Gharbi Earthquake's Impact on Sandy, Saturated Soil

Case of soil	Sandy soil settlement (mm)	The proportion of soil settlement that decreased between each addition of slag	The percentage decrease in cumulative settlement rate per slag addition	The timing of settlement commencement (sec.)	The stability of settlement time (sec.)
Unimproved soil	20.41	-	-	2	93
3% of steel slag	20.55	-0.68%	-0.68%	2	93
6% of steel slag	19.2	7.03%	6.35%	5	90
9% of steel slag	19.01	0.99%	7.34%	8	90
12% of steel slag	18.73	1.49%	8.83%	11	90
15% of steel slag	17.42	7.52%	16.35%	13	89

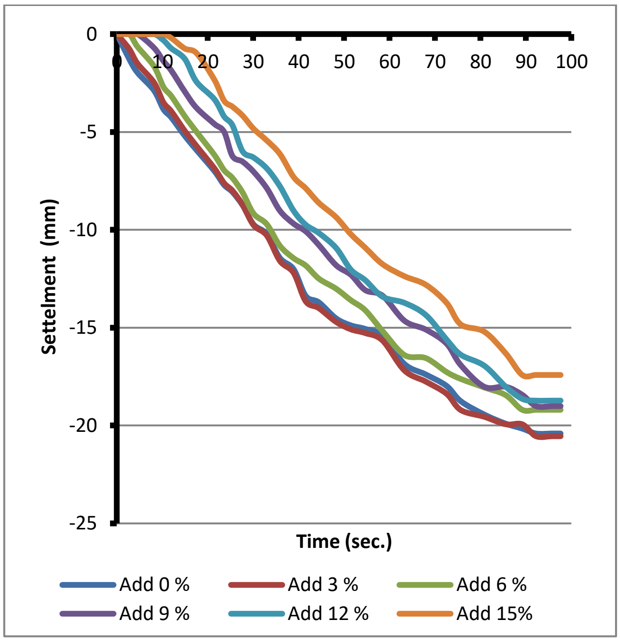


Figure 12. Ali Al-Gharbi Earthquake and Foundation Settlement in Saturated Sand

7. CONCLUSION

The experimental methodology used in this work, with the intention of both their unimproved and improved states, simulation, depiction, and evaluation of the decline of shallow foundations under the effect of earthquakes in dry, sand-filled soil conditions, is appropriate and produces reliable, consistent results under seismic load circumstances. The steel slag upgrading method has been discovered to work well in lessening the effects of foundation settlement. The following outcomes were attained:

1. Settlement grows as earthquake acceleration rises in sandy, dry, and saturated sandy soils.
2. The foundation's settling decreases when the percentage of steel slag rises above 6% in a dry state.
3. The higher the percent of steel slag above 9% for soaked state, the less the foundation's settlement
4. The time for settlement in soked sandy soil begins before settlement in dry sandy soil begins.
5. In dry and wet states, the settlement rate decreases with a decrease in earthquake acceleration.
6. Saturated soil settles faster than dry soil, and after being improved with steel slag, the settlement rate in saturated soil decreases more slowly than in dry soil.

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