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A Review Study of the Dynamic Load Effect on the Behavior of Shallow Footing Resting on Geogrid-Reinforced Soil

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Abstract:

The seismic performance of geogrid-reinforced soils in earthquakes was examined using published data from previous cases. The study summarizes the lessons learned from seismic interpretation and potential failure mechanisms and shows the latest physical model testing conducted using the Shaking table. In this specific laboratory test, there is variability between the reinforced soil's seismic response and the foundation's behavior. This research overviews the analytical and numerical techniques for evaluating liquefaction, settlement, and bearing capacity in reinforced soil. The present review was presented to investigate the dynamic load influence on the presence of shallow foundations supported by reinforced soils. Foundation construction costs may drop, and economic sustainability may rise if failures and risks are better managed and reduced. Many kinds of literature were investigated to compile the most comprehensive summary compatible with the research study. Reinforcement Condition is an optimization strategy used when earthquakes occur beneath foundations, increasing bearing capacity and decreasing settlement. Also, this research discusses geogrid reinforcements to increase the resilience of sandy soils against erosion. For decades, researchers have looked into the geogrid impact on the soil during earthquakes, both experimentally and theoretically, and the results of these studies have been analyzed and reviewed. The researchers studied the causes of failure in the soil under the shallow foundations due to earthquakes, increasing settlement, tilt, and the phenomenon of soil liquefaction (Puri and Prakash [35]).

Keywords:

Bearing capacity, Dynamic load, Geogrid, Liquefaction, Settlement.

Highlights:

- Zn–Ce bifunctional catalyst from agro-waste optimizes sustainable biodiesel yield.
- Microwave-assisted synthesis enables rapid conversion in under 5 minutes.
- Hybrid ANN-GA modeling predicts biodiesel production with 99.6% accuracy.
- Optimized parameters achieve a maximum biodiesel yield of 98.57% from waste oil.
- Deep and shallow ANN architectures compared for nonlinear process optimization.

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1.INTRODUCTION

Liquefaction, durability, and settlement are geotechnical earthquake engineering topics considered to be among the most dramatic and complex. At the same time, most damage that occurs during earthquakes is brought on by failure caused by one of the abovementioned causes. A soil mass encounters liquefaction when subjected to monotony, shock, or cyclic loading, as this causes the soil mass to lose a significant portion of its shear resistance. It causes the soil mass to flow like a fluid in regions where the shear stresses acting on the soil mass have been reduced (Sladen et al. [45]). Liquefaction happens when the loose and saturated soil loses strength due to increased pore water pressure. Because of dynamic loading, shear strength is reduced. When rapid convection is combined with the loose disintegration, saturated sand grains, and loosely crowded granular soil particles, the result is a system called liquefaction, which allows transformation to a denser structure. However, in an earthquake, the water in the soil does not have enough time to pressurize. Instead, the water is trapped, attempting to prevent soil particles from contacting each other. As a result, the pressure increases while the contact forces that hold soil-type particles together decrease. Therefore, the soil becomes more flexible and unstable. Increased pore water pressure may cause soil particles to separate and lose contact in extreme conditions. In such cases, the soil's cohesive force is marginal and behaves more like a liquid than a solid. Several studies investigated the bearing capacity actions of reinforced soil foundations (Biswas and Naik [9]). Bathurst et al. [7], Yoo and Kim [53], Selvadurai and Gnanendrn [44], Lee and Manjunth [30], Yoo [54], Alamshahi and Hataf [3] demonstrated scale models. Tests were performed to determine the soil's bearing capacity for slope foundations. Sommers and Viswandham [46] conducted experiments using the centrifuge model. Several authors also investigated the possible relationship between the laboratory model testing results and numerical methods. Furthermore, the researchers have created analysis methods. It can accurately identify the bearing capacity of footings on reinforced soil when used in the field by experts. Jahanandish and Keshavarz [23] used a new approach known as the slip-line method to evaluate the required load-bearing capacity of reinforced soil beneath earthquake-loading conditions. Based on material and reinforced soil slope geometry, a computer program determines the plastic zone geometry and ultimate load. Consider non-uniform reinforcement and seismic coefficient distribution. Non-dimensional graphs show simple case analysis results for preliminary design. This research compares the studies that investigated the liquefaction in saturated sandy soil that occurs during dynamic loads at different conditions, the effect of geogrid reinforcement and the bearing capacity of the soil, the clarification of all the factors that affected it, and the settlement of foundations based on sandy soil reinforced with geogrids under the influence of dynamic loads.

2.THE LIQUEFACTION OF SOIL

2.1.Factor Affecting Liquefaction

The liquefaction phenomena are impacted by a wide range of elements, all of which can be described as follows (Day [13]):

1) **Earthquake duration and intensity:** The duration and acceleration of shaking impact, shear strains, constricting soil particles, and generating excess pore pressures cause liquefaction. Liquefaction increases with earthquake strength and shaking duration. The strongest earthquakes are associated with the most significant ground acceleration and longest ground shaking. Nevertheless, liquefaction requires a peak ground acceleration of 0.1g and a local magnitude 5 (Ishihara [22]).
2) **Groundwater table**: Saturated soil is the most impacted by liquefaction. In contrast, liquefaction affects unsaturated soil, whereas unsaturated soil placed above the groundwater table does not liquefy.
3) **Soil type:** Non-plastic (cohesionless) soil types are soils subjected to liquefaction. Clean sands, non-plastic silty sands, non-plastic silt, and gravels are the slightest resistance to the liquefaction of cohesionless soil types.
4) **Relative density:** Liquefied cohesionless soils have a low relative density. Non-plastic loose soils compress in earthquakes, making additional pore pressures. Dense sands dilate upon cyclic shear stress reverse, so the initial liquefaction state causes less deformations.
5) **Particle size gradation and uniformity:** Soils that are uniformly graded and non-plastic tend to form more unstable particle agreements that are more prone to liquefaction than well-graded soils. Fine particles in well-graded soils fill the hollow space between the large particles. Reducing the soil's potential compression culminates in less creation of excess pore pressures during earthquakes.
6) **Drainage conditions:** As the excess pore pressure can quickly dissipate, the soil may not liquefy. Hence, highly permeable gravel drains or gravel layers decrease the liquefaction potential of the adjacent soil.
7) **Confining pressures:** The sensitivity of soil to liquefaction reduces as confining pressure increases. Situations that cause a more significant confining pressure can be discovered at different depths below the

floor surface, and surcharge stress can be implemented on the floor.

8) **Particle shape:** The interaction among soil with rounded forms is less than that among sand grains with angular shapes. Consequently, the soil of rounded particles is more susceptible to liquefaction than just angular soil particles.

2.2.Theory of Liquefaction

The well-known Mohr-Coulomb criteria are a valuable tool to calculate the shear strength of sandy soil. The following is an explanation of how the Mohr-Coulomb standards work:

$$\tau = \sigma' \tan \varphi \quad \textbf{(1)}$$

where (τ) denotes the shear strength, (σ') represents the effective stress, and (φ) represents the angle of internal friction. The shear strength of the soil is fully decreased in the event of total liquefaction, which is also known as initial liquefaction, as there is an associated increase in the pore pressure (Δu);

$$0 = (\sigma' - \Delta u) \tan \varphi \quad \textbf{(2)}$$

($\tan \varphi$) is a constant value and does not equal zero;

$$\sigma' = \Delta u \quad \textbf{(3)}$$

For initial liquefaction ($\Delta u/ \sigma'$=1), the term ($\Delta u/ \sigma'$) is called excess pore water pressure ratio (r_u). The earthquake cyclic stress ratio equation is also known as (CSR). When a flat earth surface and a soil column of unit length and width are assumed, it is assumed that the soil section will keep moving horizontally as a solid body due to the maximum horizontal acceleration (a_{max}) caused by the earthquake at the earth's surface because of the assumption that the soil column will move horizontally due to the earthquake (Seed and Idriss [42]).

$$F = ma = (W/g).a_e = (\gamma_t h/g) = \sigma\ (a_{max}/g) \quad \textbf{(4)}$$

where the weight of the soil column, signified by the symbol (W), equals the soil unit weight, represented by the symbol (γ_t), multiplied by the depth of the soil, signified by the symbol (h), the total stress of the soil, represented by the symbol (σ). The horizontal force of the earthquake acting on the soil column is represented by (F), the earthquake's acceleration is indicated by (a_e), and the ground's acceleration is signified by (g). When all horizontal forces are tallied up, the outcome is the maximum shear force at the soil's base, and it equals force (F) affected on the solid soil element. Assuming that the soil component's base length and width are the same, it can be concluded that the maximum shear force (F) equals the maximum shear stress (τ_{max}). The solution to this equation is (5), whose value can be calculated by dividing both of the equation's sides by the effective vertical stress (σ');

$$(\tau_{max}/\sigma') = (\sigma/ \sigma')^*(a_{max}/g) \quad \textbf{(5)}$$

The result could be simplified by converting the typical randomized stress distribution measured in earthquakes into a series of constant cyclic stress (Seed et al. [43]), allowing the technique to be used more quickly, that were successful able to achieve their objectives by thinking of the following:

$$\tau_{cyc} = 0.65\ \tau_{max} \quad \textbf{(6)}$$

The magnitude of the earthquake's constant periodic shear stress is indicated here by the symbol (τ_{cyc}), which is part of this equation. The irregular motion caused by the earthquake transformed into a comparable series of a continuous period of shear stress. The proportion of available periodic stresses in a rigid soil profile to general periodic stresses in an elastic soil profile is the stress reduction factor (r_d) ([42]). In this study, the authors proposed a mean curve as a depth function and provided (r_d) values for ground motions from earthquakes and soil features containing sand. This curve was designed as an extension of Golesorkhi's [16] and Idriss's [21] study for all earthquake magnitudes and feature depths. After conducting hundreds of parametric site response studies, the researchers concluded that the factor (r_d) could correctly describe a relationship between the earthquake and depth in the most practical conditions. Figure 1 depicts the available sizes and shapes (M). It is possible to compute the seismically cyclic stress ratios (commonly known as CSR) by solving equation 7;

$$CSR = (\tau_{cyc}/\sigma') = 0.65 r_d\ (\sigma/\sigma')^*(a_{max}/g) \quad \textbf{(7)}$$

The cyclic stress ratios (CSR) are calculated by dividing the cyclic shear stress (τ_{cyc}), trying to act only on horizontal planes by the effective vertical stress. This definition applies to the shaking table and the simple shear test. It is critical to be aware of this at all times.

$$CSR = (\tau_{cyc}/\sigma') \quad \textbf{(8)}$$

During a cyclic triaxial test that is only isotopically consolidated, the greatest cyclic deviator stress ($\sigma_d/2$) calculates the CSR. This stress is then divided by the isotropic consolidation stress (σ'_c).

$$CSR = (\sigma_d/2\sigma'_c) \quad \textbf{(9)}$$

The cyclic shear test or the simple shear test can measure liquefaction stresses over a defined number of cycles ([42]). The earthquake magnitude influences the approach considered. The appropriate number of periodic stresses, indicated by N, is determined by the earthquake's magnitude in addition to the length of time the ground was shaking, according to Seed and Idriss [41]. Figure 2 depicts the findings of [21], who studied the difference in this relationship. Figure 3 shows a relation between the mean grain size (D_{50}) and the cyclic stresses ratios (CSR) of the cyclic triaxial test ($\sigma_d/2\sigma'_c$) [42]. When the relative density (Dr) is 50%, this ratio is estimated to cause liquefaction in 10 to 30 cycles.

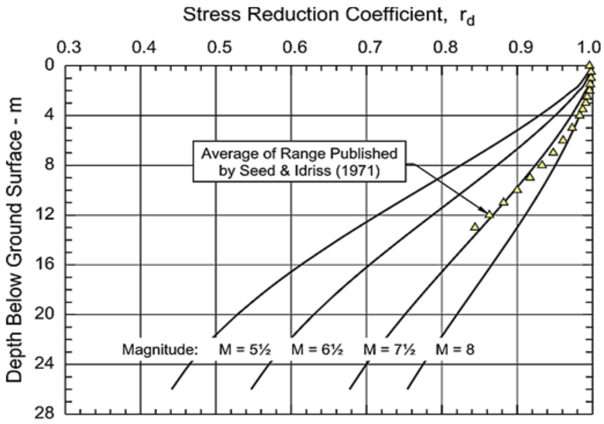

Fig. 1 The Variation in the Stress Reduction Factor between Earthquake and Depth Magnitude is Attributed to Idriss [21].

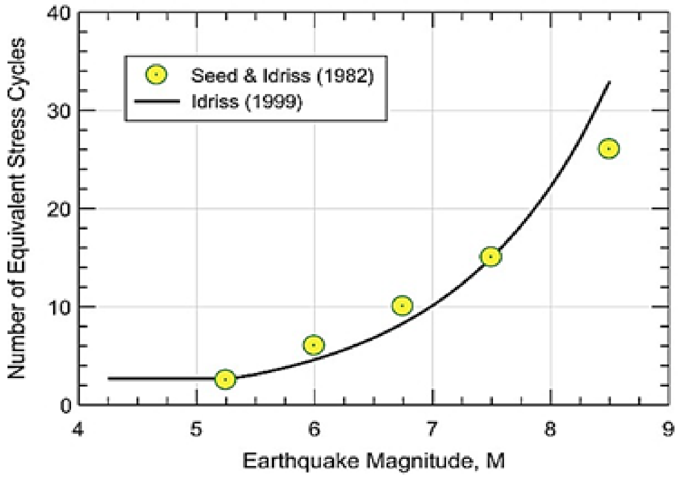

Fig. 2 Number of Equivalent Cyclic Stresses (N) vs the Magnitude of an Earthquake [21].

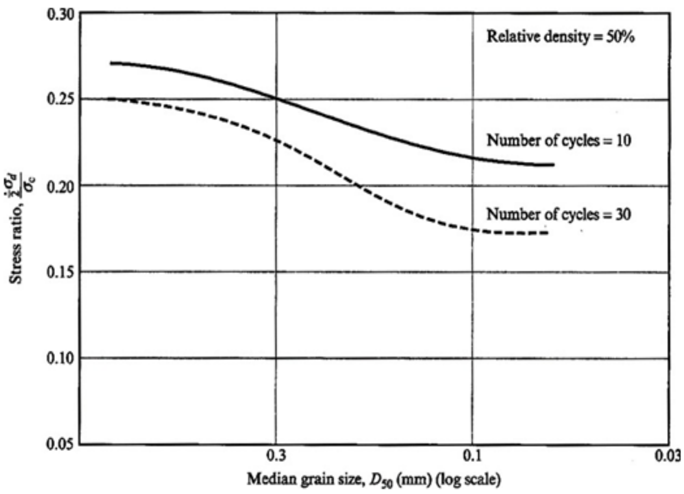

Fig. 3 The Stress Ratios, according to [44], Cause the Sand to Become Liquefied Anywhere between 10 and 30 Cycles.

The cyclic stress ratio ($CSR = \tau_{cyc}/\sigma'$) required for liquefaction under field conditions is less than the corresponding value of the triaxial test. The triaxial test correction factor (C_r) determination based on relative density is depicted in Fig. 4. The cyclic stress ratio (CSR) should be maintained if initial liquefaction occurs, and this value must be approximately proportional to the relative density. When all of these elements are combined, the cyclic stress ratio, or CSR, can be computed using Eq. (10);

$$CRR = (r/\sigma_0')_{\%\,D_r} \cong (\sigma_d/2\sigma_c') * C_r\,(D_r/50) \quad \textbf{(10)}$$

Various types of research on multiple types of soil and their relative densities were conducted to define a relationship, as shown in Fig. 3 for (CSR) and (N), which initially stood for the cyclic stresses ratios of liquefaction and is also made reference to as the cyclic resistance ratio (CRR). Yoshimi et al. [55] provided one such result, shown in logarithmic and logarithmic scales, as shown in Fig. 5.

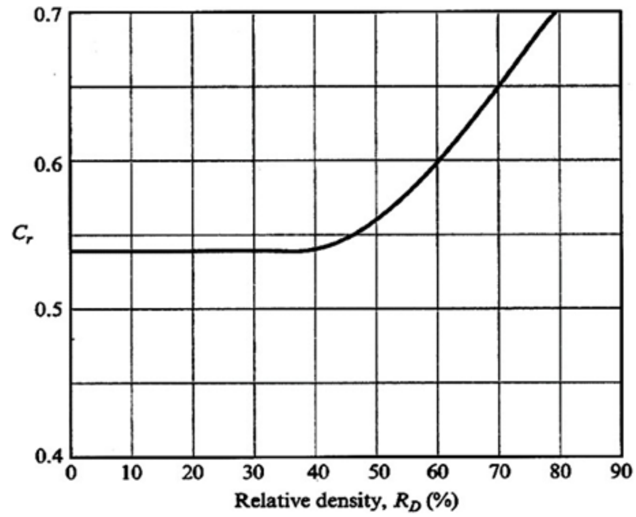

Fig. 4 Changes in (C_r) in Response to Changes in Relative Density (Adapted from [42]).

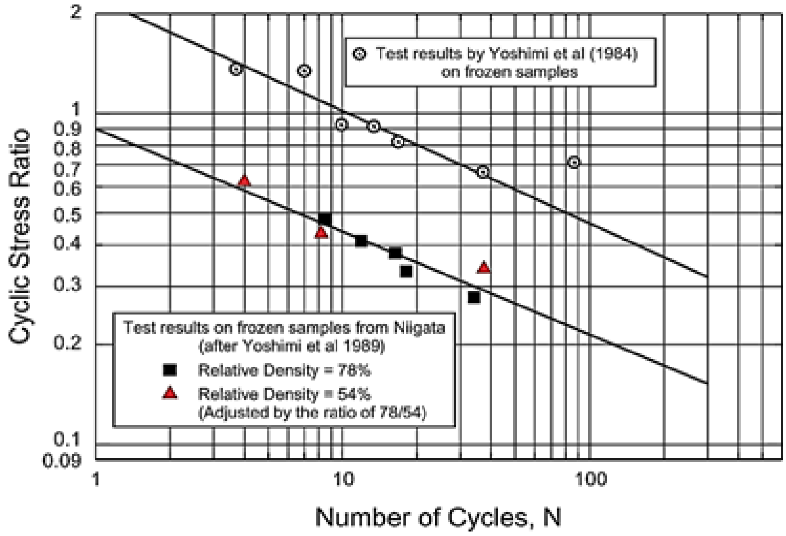

Fig. 5 CSR, i.e., CRR, Causes Liquefaction Compared to Several Uniform Loading Cycles for Frozen Samples [55].

A single conversion was finally finished by creating a solid connection between (CRR) and (N), forming a straight line on the log-log (Boulanger and Idriss [10]). The following configuration could appear in a configuration or arrangement that can be observed in the graph:

$$CRR = a \times (N)^{-b} \quad (11)$$

where a is a constant parameter of the *CRR-N* line, and *b* is the line's angle with the logarithmic scale. Parameter (*b*) is considered the main (*CRR*) relation factor. According to the design figures, liquefaction at any research site would also require earthquakes, with the highest ground acceleration of 0.15 g (Abdullah et al. [1]). The procedure developed by [42], through studying the soil characteristics at two locations in Karbala, was used to draw the design figures. When the underlying material is sand with a relative density between 25% and 40%, soils with a plasticity index greater than 15 becomes liquid. As a result, increasing the plasticity index (PI) reduces the likelihood of liquefaction in the soil. Figure 6 shows the correlation between a_{max}/g and relative density. Figure 6 depicts this connection, which can be used to predict the likelihood of liquefaction.

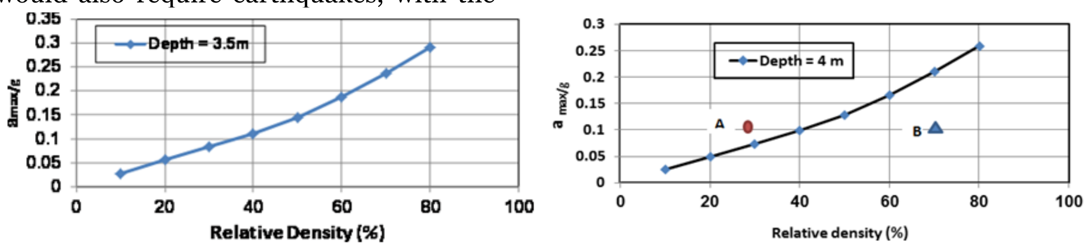

Fig. 6 Determine the Liquefaction Potential, a Plot of the a_{max}/g Value vs the Relative Density (Adapted from [1]).

3.BEARING CAPACITY OF FOOTING

3.1.Dynamic Bearing Capacity of Footing Resting on Geo-grid Reinforced Sand

Accurately estimating the seismic bearing capacity of the underlying soil in seismic areas is important. California, Alaska, and the Pacific Northwest are examples of these places. It is essential to carry out the relevant calculations to ascertain the seismic carrying capability of the underlying soil shallow footings in seismic parts of the world. Further, the steps necessary to address the varying seismic pressures with both time and depth should be considered. The likelihood of seismic activity was considered by the researchers, who examined the structure-bearing capacity to determine how it might be affected if seismicity occurred [12]. Budhu and Al Karni [12] explored the consequences of the horizontal and vertical earthquake accelerating coefficient. Their findings offered estimations of the earthquake-bearing capacity for (c-ϕ) soils. R. Richards Jr.et al. [36] found that the foundation capacity can be declined due to several variables, such as the loss of seismic stability and strength inertia loads communicated by shear through the construction to the footing and any additional costs. In addition, this method results in a foundation construction procedure that limits the amount of seismic settlement that can occur, which is an advantage of using this method. The limit analysis upstairs tied theory was the preferred approach for estimating the bearing capacity factors in seismic situations (Dormeux and Pecker [15], and Soubra [47, 48]) because it provides the most reliable data. The characteristics technique was used to collect the data required to study the seismically bearing capacity of shallow footings Kumar and Rao [28, 29]. Nonetheless, the gravitational acceleration of seismic acceleration should be regarded during this study. A study investigated whether earthquakes impact the load-bearing capacity of the underlying soil shallow footing (Deepankar and Rao [14]). Pseudo-seismic endurance factors N_{cd}, N_{qd}, and N_{cd} indicate the components of coherence, cohesion, and need, respectively, throughout a numerical-band repetition. Those variables are involved while computing the unit weight. The efficacy of the results obtained through the current analysis in the event of earthquakes is determined by comparing it with the results that are presently available. The earthquake-bearing capacity parameters of shallow strip foundations were demonstrated (Rao and Deepankar [37]). Even though the pseudo-static method considers the dynamic and time-dependent character of earthquake loads, it still demands a higher level of accuracy and careful consideration of the soil dynamic characteristics. Several studies' findings can be reached through the use of probabilistic analysis; however, neither of these methods considers the dynamic nature of the seismic activity (Massih et al., [31]; Joharia et al., [25] and Hamrouni et al., [20]). According to the greatest of the authors' knowledge, there has never been an investigation assessing how the occurrence of an active seismic event affects the seismic bearing capacity of homogeneous soil. The study's purpose was to establish the earthquake-bearing capacity of strip foundations about dynamic earthquake forces over a range of soil types; as a result, the appropriate preventative measures can be considered at the appropriate time. Keshavarz A. et al. [26] used stress characteristics to investigate reinforced soil strip foundations' seismic ultimate bearing capacity to determine seismic forces and vertical and horizontal pseudo-static seismic coefficients, such as K_h and K_v. However, increasing the design confidence to compare the results with any future experiments is essential. Agarwal et al. [2] proposed a mathematical approach to assess the seismic bearing capacity of reinforced soil strip foundations. As a result, the earthquake-bearing capacity of the strip foundations can be calculated. The study conducted by Binquet and Lee [8] for a static load strip foundation provided the basis for the methodology. The data are provided in non-dimensional graphs, out of which correct seismic bearing capacity calculations could be made. When creating these charts, the frictional resistance and rupture strength parameters were carefully considered. To ensure that the concept is fully understood, an example that can be used as an illustration was provided. Xie and Leshchinsky [52] investigated the shallow footing load-bearing capacity utilized in MSE constructions and various factors that impact the foundations' load-bearing capacity to determine the footings' maximum bearing capacity. The Geosphere Reinforced the Soil Integrated Bridge Simulation was used to perform a (3D) finite element (FE) analysis of (GRS-IBS) (M. Abu-Farsakh et al. [34]**)**. Following the bridge's construction, the software program 3DFE PLAXIS 3D 2016 was used to simulate the GRS conduct of TIR beneath various loading situations and then compare the model results to field data. Furthermore, the (3D-FE) analysis and the (2D-FE) study were contrasted. According to the study results, the FHWA analytical method may be up to 2.5 times more accurate than the (FE) analysis. This difference was determined by the loading condition and the reinforcement location. Halder and Chakraborty [19] determined the tape base's seismic bearing capacity on a slope of reinforced non-cohesive soil. They discovered that the bearing capacity doubled when the soil was armed twice. In seismic areas, adding geo-grid reinforcement layers to the soil category with a more robust soil layer beneath the footing could increase the bearing capacity of a rough strip footing (Kumar and Chakraborty [27]). Concurrent seismic was suggested along a soil mass's and foundation's x and y axes. Problems involving (a) geometry parameters, (b) sandy soil characteristics, and (c) seismic loadings can be solved. The authors discussed the optimal reinforcement width and critical reinforcement depth for various soil types and earthquake forces. When seismic loads were applied, it was discovered that reinforcements should be placed at a shallow depth to the entire value. In a few cases, failure patterns were also demonstrated. Jaiswal and Bhusan Chauchan [24] aimed to increase the maximum load capacity of the ground with geosynthetic ground reinforcements, reduce the amount of settlement encountered by shallow foundations, and enhance the overall performance of shallow foundations that can be done by placing one or more synthetic overlay layers underneath the foundation. The authors proved that the entire rolling technique effectively trapped soil mass and reduced the foundation settlement.

4.EFFECT OF DYNAMIC LOAD ON THE SETTLEMENT OF RECTANGULAR FOOTINGS ON GEO-GRID REINFORCED SAND

The present study compares and contrasts a collection of studies on the effect of the geo-grid-strengthened land on the transfer of dynamic loads under the foundations. The evaluation was conducted with a key focus on surface settlement behavior. In addition, the impacts of various variables, including relative density, frequency, geographical depth and width, and load capacity, will be studied. Das et al. [11] empirically determined the maximum loading. The maximum variance was found in a foundation created on saturated clay reinforced with geogrid and loaded with a cyclic low-frequency way. The surface sector of the foundation's permanent settlement strip footing was first exposed to an acceptable constant load before the cyclic loads were applied. Additionally, some changes may be made to the loading condition's frequency and the amplitude strength that the cycle loading possesses. They discovered that geogrid reinforcement reduced permanent settlement by 20%-30% compared to an unarmed operation. On impregnated Greek sands of various strengths, Stamatpolous et Al. [49] conducted laboratory tests with an OCR and a direct cyclic shear device. The fundamental parameters measured during the experiments were volume constant with volumetric stress and controlled shear stress. Moreover, the situation was comparable to an earthquake. They discovered that, depending on the condition and loading history in various soil conditions, their findings were accurate compared to other studies (dry and saturated). Seismically loaded shallow foundations and piles in liquefied and non-liquefied soils were studied in detail (Vijay K. Puri and S. Parakash [50]). They investigated and discussed the decline in bearing capacity of the shallow footing and the beginning of an expected rise in the level of the expected settlement, using an experimental approach that correlates the potential identification, such as earthquake acceleration, frequency, dynamic bearing capacity factors (N_c, N_q, N_γ), and aspects ratio of structures. Geocell-based strip footings and planar-reinforced sand beds with geotextile qualities performed well in laboratory model tests (S. N. Moghaddas Tafreshi and A. R. Dawson [40]). Reinforcement width, geotextile planar layers, and geocell height below the footing foundation were tested. Similar to previous studies, geocell and planar reinforcement performance were assessed at low to medium settlement levels. Planar reinforcement layers, geocell reinforcement height, and reinforcement breadth decreased reinforcement efficiency. Geocell improved bearing capacity (IF) and footing settlement (PRS) to 2.73 and 63% at 4% settlement, respectively, compared to 1.88 and 47% for planar reinforcement. Geocell reinforcement methods are stronger and have higher load capacity, with lower settlement than planar reinforcement systems for the same geotextile material. Thus, less geocell material than planar geotextile reduces bearing pressure and footing settlement. A variety of laboratory tests were conducted on strip foundations supported by flat, three-dimensional reinforced sand layers (S. N. Moghaddas Tafreshi and A. R. Dawson [39]). Repetition and continuous loads were also applied to the foundations until they failed because of high settlement or stability loss. Repeated loading results in a maximum settlement at baseline significantly better than unreinforced sand and on par with planar or three-dimensionally reinforced sandy soil. Adding more reinforcement to the sand minimized the reinforcement effectiveness in minimizing the majority of foundation settlement. After modifying a fraction of the concentrated sandy soil layer and installing reinforcement for the structural floor, the type of contact of a strip foundation built on a slope of loose sand while subjected to periodic and cyclical pressures was investigated (El Sawwaf and Nazir [33]), which was elaborated so that the results could be used to guide future design decisions. The cumulative periodic settlement of substituted and reinforced sand deposits covered a slope of loose sand-reinforced model foundations was studied. The advantages of soil reinforcement were evident, as it increased slope stability, significantly reduced foundation settlement, and provided more reinforcement in static and dynamic loading situations. To determine volumetric stress, Vijay K. Puri and S. Prakash [51] investigated the induced shear stress determination in soil induced by seismic loading. They assumed in their study that the shear stress equaled volumetric stress if constant volume loading was maintained. According to what they found, the overall settlement was equal to the sum of the volume variation in the soil that the earthquake induced, plus the added pressure from the buildings that were already present. It was found that this was indeed the situation. When the shear modulus of the soil was low, so much protection was required. The authors developed various equations, graphs, and empirical connections for the given soil condition, changes in PWP when in a seismic event, and discrepancies in the quantity of acceleration. The researchers excellently provided a close-up look at several soil settlement approaches. The results of a specific standard lab experiment on square footings resting on layers of sand reinforced by geo-grid were examined (Basavaraj Hotti at el. [6]). Additional loading and unloading conditions, varying sand layer densities, and varying depth ratios for the geogrid were included in these tests. The accumulative values of load intensity, including both loading and reloading, were used to calculate the elastic rebound amount of the base for all load cycles, which evaluated the square foundation's response. The results showed that using the geogrid network improved by decreasing the settlement amount. Despite increased load and reload cycles, foundation settlement remained on the decline. A. H. Boushehrian and Afzali [17] proved that increasing dynamic load, static load, and shallow foundations response are supported by reinforced sand with embedded pipes. The grid anchor technology reduced soil settlement by 54% when the dynamic load was introduced. The researchers utilized soil-stabilizing reinforcements to change the soil's behavior in shallow foundations. They provided formulae for dynamically loaded reinforced or unreinforced soils to simplify deformation analysis. These equations allow permanent settling for each foundation of a certain size built on mesh-reinforced sand, with or without an integrated tube. Riccardo Conti [38] proposed a complete method to assess a shallow footing's earthquake-bearing capacity on cohesive friction and pure cohesive soils. Decreased vertical bearing capacity coefficients in the Terzaghi equations and inertial forces in soil bearing capacity estimations were necessitate assumptions. Comparatively, the proposed equation was stable enough for design practice. Liquefaction alters soil structure. All computations, from strength, bearing capacity, and hardness, were used to understand and predict soil characteristics depending on exposed soils. Formulae and soil mechanics problems considered the above consequences while evaluating the settlement and bearing capacity of the suggested method changed soil formula. Al-Salakh and Albusoda [5] experimentally and theoretically studied the footings sinking maintained on liquefied soil. Experiments with check tables were repeated several times for relatively shallow locations with sandy soils. A variety of earthquake loads were applied. The research explored theoretical equations to predict base settlement caused by seismic loading and their calibration and verification. Throughout the experiment, various fillers were also used. The seismic settlement equations were also modified with the statistical analysis software SPSS. Using SPSS, the liquefaction condition was identified, and the adjusted equation demonstrated a significant level of convergence with the measured settlement values. H. H. Karim et al. [18] examined the demonstrated settlement and internal displacement of shallow foundations on liquefaction-reinforced or unreinforced wet multi-layered sand (medium-dense). Twenty models were accurately tested. They tested variable-frequency loading conditions under geogrid construction despite maintaining other parameters constant, reinforcing material, layer structure, and number of layers prevented settlement. A. H. Boushehrian [4] proved that under periodic stress, geogrid soil reinforcement affected strip foundation settlement on sandy slopes. Vehicle traffic, machine foundation, and oil tank filling/discharging represent such loading conditions. The number of loads and unloading cycles, reinforcing layers, reinforcement type, and cyclic load magnitude to static loading influence strip foundation permanent settlement. Permanent settlement increased with more loading and unloading cycles and cyclic loading amplitude while reinforcing layers had the opposite effect. Permanent settling and needed loading cycles were examined. M. Y. Fattah et al. [32] experimentally studied ring footing models, observing their periodic behavior and constructing a circular foundation on sandy soil reinforced with geocell. Various models were used to test shallow foundations when exposed to cyclic loads at different loading rates. Cyclic loads decreased the soil settlement as footing depth increased. When maintaining other factors, the bearing capacity of the footing was improved if the depth to which it was pushed out increased.

5.CONCLUSION

In this review, the following conclusions can be drawn:

1) A variety of experimental and mathematical techniques were explored and analyzed to simulate, represent, and evaluate the liquefaction phenomenon for sandy soils,

bearing capacity calculations for sandy soils, and settlement calculations for shallow foundations under the influence of seismic loads in average soil conditions. The formula was modified to be suitable for earthquake loading and provided accurate and consistent results. A modified formula was developed to estimate and calculate shallow foundation settlement for liquefiable soils and simplify soil improvement.

2) Several experimental and mathematical methods were investigated and evaluated to model, identify, and analyze the liquefaction phenomenon of sandy soil. Some researchers studied the liquefaction phenomenon for specific acceleration values at different relative densities, and some researchers studied the effect of reinforcing layers with different polymeric materials on the liquefaction phenomenon. Some studies considered the in-situ acceleration amplitude level, soil properties, and pore water pressure. At the same time, the researchers' data and results were compared with laboratory results, which were similar and consistent with the conclusions of the analysis. It was much easier to select the appropriate measurement and test, reduce adverse effects, and address the specific site when one had a basic knowledge of the basics of the earthquake and dynamic loading and the expected behavior of soils when subjected to loading of this type.

3) According to the results observed in the researchers' studies, earthquakes create an abnormally significant and rapid decrease in the bearing capacity of the soil mass. Some researchers studied the effect of geogrid reinforcing layers under static and dynamic loads on the bearing capacity of the soil for dry and saturated conditions. They studied experimental methods individually. Some studies determined the number of geogrid layers' effects on the final bearing capacity, affected by the dynamic loading of the soil layers below the foundation, to see how the overall persistence might be affected. These studies also revealed that the number of geogrid layers increased with the soil-bearing capacity. The ideal number of layers was determined based on the results of some investigations, at which point the bearing capacity value increased slightly.

4) In regions where earthquakes generate shear failure and settlement, complete and partial foundation failure and building damage may occur if the sandy soil liquefies during the earthquake, which can happen when earthquakes cause shear failure, which may also be the case in regions where the shear loss occurs due to earthquakes. A vast overall settlement or variance in buildings. In addition to the apparent tilt observed in structures, this tilt can also be observed. Because the lower soil layers reach a boiling state, shallower foundations tend to sink further. Some researchers have studied the settlement of foundations under cyclic load, periodic load, and individual seismic load for dry and saturated soil conditions. Other researchers used the soil reinforcement with a polymeric network and studied its effect on the settlement into the soil, as the settlement was affected.

5) The researchers used originally developed studies and research on various approaches, theories, and hypotheses to mimic the failure mechanism. All of this depends on soil characteristics, soil weakness, and earth movement variables, which they worked on while analyzing the soil and its properties. Furthermore, the behavior of a controlling factor during the earthquake was studied. Although some researchers believed that the ground motion parameters were handled as components of the governing factor, others relied on a mixture of both elements as a controlling factor, which was believed to be more reliable. Those who began to suspect the ground motion parameters were considered components of the governing factor.

6) When all research that explained the phenomenon of liquefaction in saturated sandy soils that occurs during dynamic loads and ways to reduce their risks was examined, it was discovered that a few researchers studied the liquefaction that occurs during earthquakes with different acceleration values at a constant relative density, and reinforcing sandy soils using geogrid layers during earthquake conditions. Drought and saturation, and their effect on the state of sandy soil and increase the bearing capacity of the soil, and clarify all the factors that affected the bearing capacity, and studied these conditions and their impact on the bearing capacity of the soil, and the settlement that occurs for sandy soil foundations on a large scale.

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