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# Dynamic Response of the Adjacent Machine Foundations Resting on Reinforced Soil Bed: A Review

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**ABSTRACT:** Machine foundations are critical in almost all industries because they are subjected to dynamic loads caused by rotating equipment mounted on them. The earth-holding device structures experience unique sinusoidal and repetitive movements. The behavior of movements to the earth and structure is very challenging and differs from the familiar and comprehended behavior with no load. Various studies highlight the effectiveness of geosynthetic materials like geogrid and geotextile in enhancing the ability to bear weight, reducing settlement, additionally improving the dynamic properties of the ground under machine foundations. Field tests demonstrate that geosynthetic reinforcements significantly decrease resonant amplitudes, increase natural frequencies, and reduce settlement under dynamic loading conditions.

**KEYWORDS:** Machine Foundation, Geocell, Dynamic Force, Displacement, Frequency

## I. INTRODUCTION

When simulating multiple moving devices supports that are separated in space, the disturbance between both of them has been examined. Up till the critical distance the distance where the interference has no effect on the evolved dynamic settlement many distances have been modeled. The findings have been given in terms of the normalized distance ( $S/B$ ), which has been adjusted for clarity by setting the separation among both grounds ( $S$ ) to the structure width ( $B$ ). The way the ground and foundation behave during these kinds of vibrations is incredibly intricate and distinct from how they behave under a static load. The soil needs to stay elastic under these vibrations; otherwise, deformation would grow repeatedly with every phase and lead to excessive moving. The highest displacement amplitude of the device at its frequency of operation and the natural frequency of the device foundation system must be taken into account while building the machine foundation. Reducing the greatest magnitude of footing vibration to safe limits is the main objective of machine foundation building. One method to improve the strength and stiffness of soil is soil reinforcement. In order to increase soil strength, various tension-resistant elements, such as geogrid and geocell, are included into the soil mass and positioned to minimize or suppress any possible tensile strain brought on by gravity and boundary forces. There are several uses for technologies involving reinforced soil. Unreinforced soil performs very differently from reinforced soil. It is made up of earth fill and reinforcing strips and has a great deal of tensile strength. Soil reinforcement is a widely used technique in numerous projects that stops soil slopes from becoming looser and improves the soil's ability to support loads.

## II. GEOCELL

Geocell: Fig. 1 shows Geocell utilized for a reinforcing compound to enhance the characteristics of the soil. Geocell is a unique polymeric alloy that has been produced. The novel polymeric alloy was primarily made up of polyolefin and a thermoplastic designing polymer. The joining strips serve as the walls for a multidimensional, elastic cellular

framework into which the appropriate filler materials are put and crushed. Longitudinal strengthening generates delivery, results in a free-draining structure that minimizes weight motions and holds the filler material in place. Cell-based confining technology improves the strength and functional characteristics of both soil and aggregate filler components. Fig. 2 shows sand, as filler material for the geocell pocket.



Fig. 1. Geocell used in Experimental Investigation



Fig. 2. Sand used in Experimental Investigation

### III. LITERATURE REVIEW

Several researchers performed the following experimental and computational investigations into machine foundations supported by reinforced soil.

A. Amiri et.al in 2023 performed soil beds are strengthened using multi-layer geocell structures to withstand machines foundation. Longitudinal devices vibration on a square concrete basis were tested in the laboratory ( $0.4 \times 0.4\text{m}$ ) resting on soil that is unreinforced or reinforced and has one, two, or three geocell layers. The examinations use concrete blocks and a mechanical oscillator, with three stages of static load and three degrees of vibrating energy. Shear modulus, damping coefficient, resonant frequency, and amplitude are the variables investigated in vibration responses. The results show that, whereas the damping coefficient, shear modulus, and resonant frequency all improved with geocell reinforcement, the resonant amplitude decreased significantly. The use of strengthening of geocells in three layers resulted in the greatest enhancement (reduction in vibration amplitude) within the boundaries of the given frequencies and vibrations force, as well as the reduced amplitude.

K. N. Ujjawal, et. al in 2018 The efficiency of a geocell strengthening in isolating vibrations was investigated using a numerical simulation technique. The dynamic simulations were carried out with FLAC3D, a detailed finite-difference program. The longitudinal type blocks resonant examination outcomes were first used to verify the computer models. The Mohr-Co and elastic linear models were used to represent the soil substrate and the concrete foundation, respectively. Either the Equivalent Composite Approach (ECA) and the Honeycomb Shape Approach were used to model the geocell. In comparison to an unreinforced bed, the results demonstrated that the use of geocells decreased the resonance movement magnitude by 56% while increasing the soil-foundation system's natural frequency by 42%. Figure 3: a three-dimensional framework of finite differences under various circumstances.

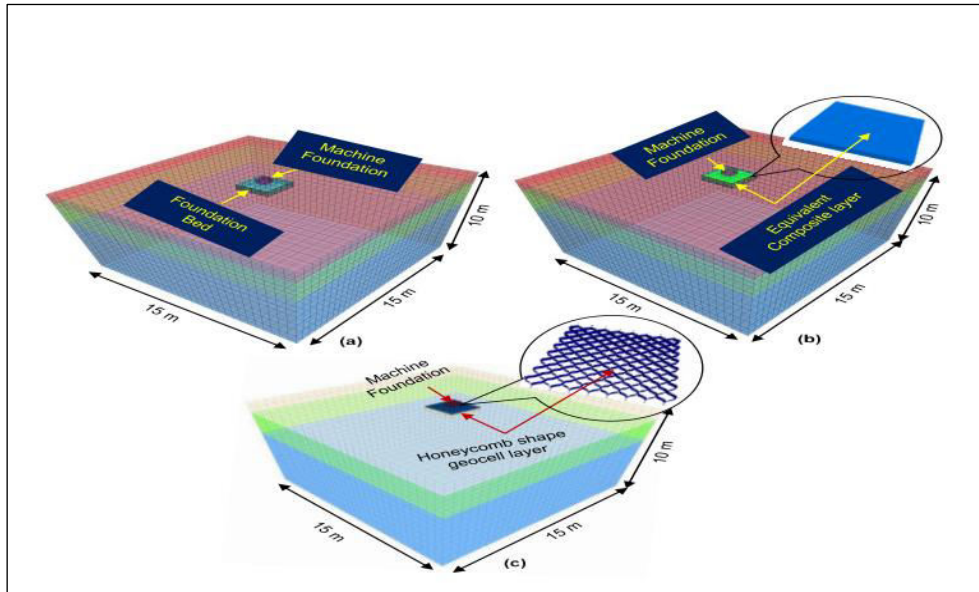


Fig. 3. A three-dimensional framework of finite differences under various circumstances.: (a) unreinforced; (b) geocell reinforced ECA; (c) geocell reinforced

Fig. 4 shows use of the geocell reinforcement greatly enhanced the foundation bed's performance.

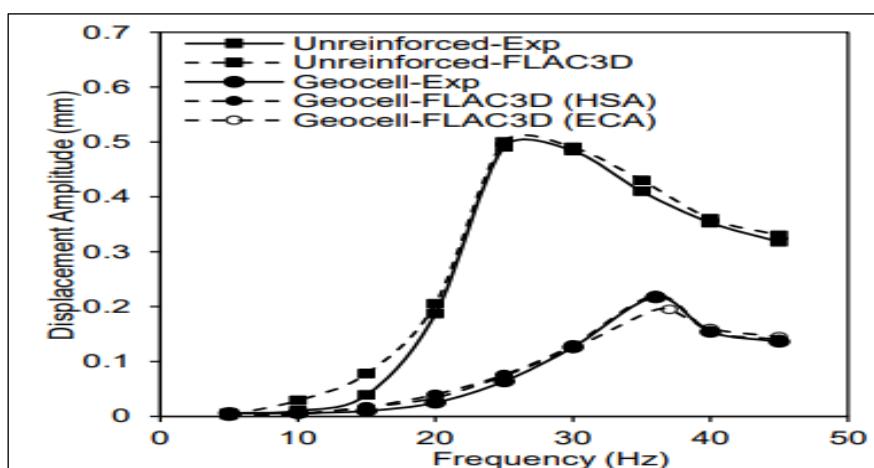


Fig. 4. Validation of numerical model using displacement amplitude-frequency data

H. Venkateswarlu et.al in 2018. performed a field and numerical investigation into geosynthetic-strengthened soil layers that hold up the model machine foundations. A strong solid foundation sustained by various strengthened soil types undergoes a series of vertical model block resonance tests. The testing takes place in a test pit that is 2 m x 2 m x 0.5 m in size, and it has a concrete base that is 0.6 m x 0.6 m x 0.5 m in size. Unreinforced, single-layer geogrid

reinforced, two-layer geogrid reinforced, and geocell reinforced were the four choices to take into account. Peak particle velocity (PPV), decreased resonant amplitude, and improved soil dynamic characteristics are the main metrics used to study the dynamic response. The outcomes of the experiment showed that geosynthetics significantly reduced vibration displacement amplitude. In comparison to the other conditions, the presence of reinforcement using geocells results in the greatest reduction. When geocell reinforcement is present resonant amplitude is reduced by 61%, while the soil system's normal frequency increases in comparison to the unreinforced state, by 1.38 times. Furthermore, When geocell reinforcements is placed 0.5 meters away from the foundation face, it was shown to lower PPV by 48%.

M. V. S. Sreedhar *et al* in 2016 study conducted to better understand that the ground layer is strengthened with geosynthetic material situated underneath a model machine base. Several Vibration Tests for Laboratory Model Blocks were conducted on a test bed, both with and without geosynthetic reinforcement. The test bed was reinforced with a non-woven geotextile and a biaxial geogrid. These reinforcing components' effects on the test bed's dynamic properties, peak amplitude, and resonant frequency were investigated. The resonant frequency was altered, and the peak amplitude decreased significantly. consequently, the concluded that the uses of geosynthetics under machine foundations in tuning the frequency ratio while also controlling peak amplitude.

S. Haldar, *et al.* in 2020 Limiting the greatest amplitude of motion to a safe level is the main objective of machine foundation design. To reduce foundation motion in machine foundations with poor underlying soil, typically, pile foundations are utilized. The article provides analysis results from a field example where a generator's foundation response was improved through the use of reinforced soil techniques. The efficiency of the approach is validated by computer models of the response of the foundation on reinforced soil. According to the study, improved foundation performance under dynamic loads may be achieved using reinforced soil foundations.

A. Swain *et al* in 2016 investigated the mechanical vibration-induced dynamic interaction impact of closely spaced square foundations. under Kanpur, India, several field investigations were conducted under dynamic settings to examine the solitary and interacting footing responses sitting on the native soil. RCC M 20 square footings were produced for two model footings: 0.55 x 0.55 x 0.2 m for F1 and 0.65 x 0.65 x 0.2 m for F2. Both footings were subjected to varying degrees of dynamic stress (S), and their locations at distinct clear-space intervals were noted. After combining the observations, displacement amplitude frequency variations were shown. The gearbox ratios that were computed showed how the active footing's dynamic excitation would affect the passive footing. The 3 HP DC motor with variable speed was used to power the mechanical oscillator. As seen in Fig. 5, the DC motor was positioned and fastened above the oscillator, and a belt was used to link their shafts.

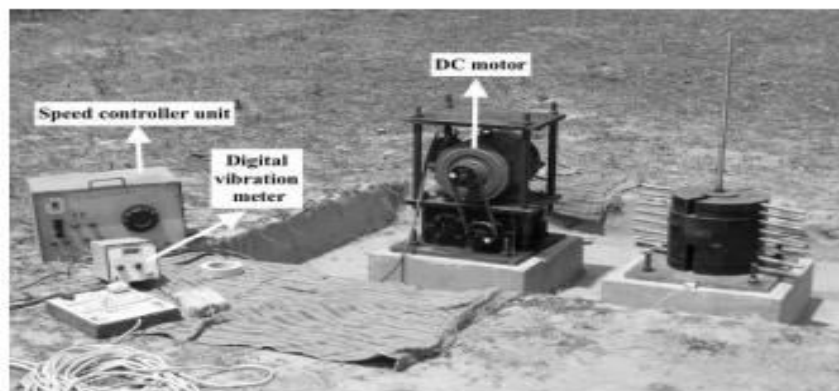


Fig. 5. Photographic view of the experimental setup

H. Venkateswarlu *et al* in 2018 conducted a study in which numerical analyses were used to get a deeper comprehension of how machine foundations supported by geocell-reinforced beds work. The PLAXIS <sup>2D</sup> finite element program was utilized to conduct the studies. A fictitious 1 m diameter circular machine base sitting on wet silty sand was examined. Unreinforced, a geogrid strengthened, and geocell reinforced were the three options that were taken into consideration. In every instance, the response was examined by altering the dynamic excitation frequency while maintaining a constant force amplitude. The ideal geocell position decreased displacement amplitude by 61% as compared to the unreinforced foundation bed. In a similar vein, geocell cut displacement in half when compared to

geogrid. Furthermore, peak particle velocity was reduced by 40% in the occurrence of a geocell at the footing's core. Figure 6 displays the schematic diagram for each of the three scenarios that were examined in the research.

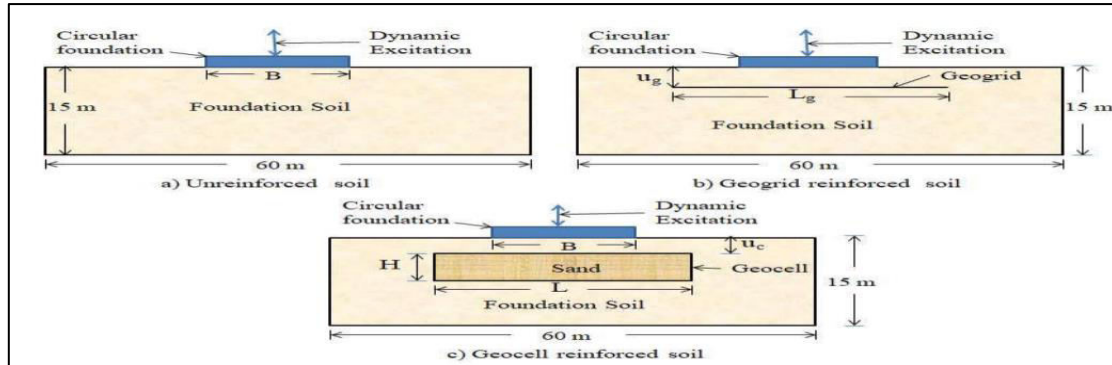


Fig. 6. Schematic representation of the different reinforced soil bases

H. Venkateswarlu *et.al* in 2020 field research was done to assess the screening effectiveness of reinforced foundation beds. with vibration produced by a mechanical oscillator. There were four cases to consider: unreinforced, single-layer geogrid, two-layer geogrid, and geocell-reinforced. The isolation efficacy was assessed using peak particle velocity and amplitude reduction ratio. By contrasting the reinforced soil system's performances with that of the unreinforced system, the efficacy of the former was determined. Field according to test findings, geosynthetics considerably decreased ground vibration. The geocell-reinforced condition showed the greatest reduction when compared to the other cases. When geocells were present, when compared to the unreinforced state, peak particle velocity and resonant amplitude dropped by 48% and 61%, respectively. In a similar vein, geocells produced a 98% increase in the foundation bed's rigidity. The schematic representation of the field test setup is shown in Fig. 7.

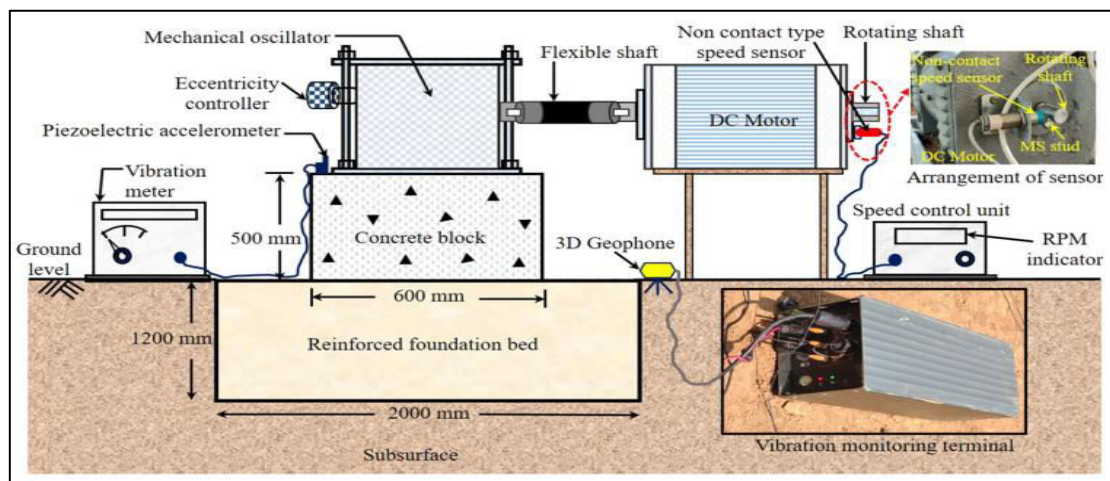


Fig. 7. Schematic representation of the field vibration test setup

K.S. Sherin *et al.* (2017) conducted field vibration testing on a square footing supported by geocell-reinforced sand to ascertain the impact of cell geometry and multi-layer systems. To find the pressure-settlement response of reinforced soil for different geometric parameters including diameter, height, placement depth, and geocell shape, laboratory plate load experiments were performed. This paper also discusses how the strength of the geocell material affects load-carrying capacity. This paper also includes Performance evaluations of geocell-reinforced sand, both single and multi-layer with varying spacing. The test results confirm that the reinforced sand layer significantly improves bearing capacity when compared to unreinforced sand. Experiments were also conducted to determine the ideal distance apart in a geocell system with two layers.

S. Banerjee *et al* in 2024 performed a study to thoroughly examine the performance of geocell-reinforced pavement using a combination of computational and experimental analysis methods. The process begins with full-scale model testing of both reinforced and unreinforced sections. Then, numerical analysis is performed using PLAXIS 3D, a three-dimensional finite element tool. The experimental research's findings were used to calibrate the numerical models. The computational research focuses on the effects of several factors on the performance of pavement sections reinforced with geocells. These parameters include base material, wheel contact area diameter, and subgrade conditions. Across all pavement sections, the base layer's incorporation of geocells led to a notable decrease in the concentration of subgrade pressure and permanent deformation as in comparison with unreinforced parts. The wheel contact area diameter and subgrade strength have an impact on the pit depth reduction value. However, pit length and subgrade vertical stress were found to be significantly reduced in reinforced pavement portions with fly ash bases as opposed to those with bases composed of wet mix macadam (WMM) and sand, according to the study. Fly ash is highlighted in the study as the best option for infill material since it shows less rut depth and lower pressure values at the subgrade level. Fly ash is highlighted in the study as the ideal filler material since it has lower pressure values at the foundation level and pit depth.

H. Sarkar, *et al* in 2022 the traditional geocell reinforcement single layer is commonly used to strengthen weak soil for foundation purposes. However, it is noted that a significant portion of the reinforcement volume remains unused in single-layer systems, leading to difficulties in soil compaction and buckling issues. To address these challenges and optimize material usage, a multilayered stepped configuration is proposed. To investigate the performance of a multilayered geocell system by use of numerical simulation in Plaxis<sup>2D</sup>, building on previous research by Biswas (2019). The study compares the performance of single-layer and multilayered configurations to demonstrate the benefits of the proposed concept.

M. Allahbakhshi *et al.* (2015) examined the use of the technique using finite elements to analyze foundations on embankments over spongy ground. Model tests were conducted using a 1m diameter model footing and geogrids to examine the behavior of industrial machinery foundations on embankments. The Plaxis computer code was used to perform finite element analyses, with a non-linear hardening soil model representing the soil and elastic elements serving as reinforcement. The study discovered that incorporating geogrid layers into sand improved footing performance and reduced the necessary depth of the reinforced sand layer, with greater effectiveness observed with more geogrid layers and longer lengths. The superior effect of pre-stressed geotextile compared to unreinforced and non-pre-stressed reinforced embankments.

H. Sarkar, *et al* in 2023 interconnected honeycombing geosynthetics called geocells are used to reinforce weak soil, embankments, pavement bases, and subgrades, among other structures. Because of its geometry and the way that the reinforcement and soil interact, modeling geocell-reinforced soil numerically is challenging; that being said, current FEM software can produce remarkably accurate estimates. The behavior of single- and multi-layered embankments reinforced with geocell systems is numerically compared in this study. When a divided (layered) geocell system is found to perform better when compared to a single-layer geocell-soil combination of the same height. In this study, PLAXIS2D is used to simulate the work.

K. S. Sherin, *et al* in 2017 the impacts of cell geometry and multi-layer systems are investigated by an examination of the behavior of a square foundation lying on geocell-reinforced sand. Testing was done on three distinct PVC polymer geocells with variable strengths and thicknesses. The pressure-settlement response of reinforced soil was measured for a range of geometric parameters, such as diameter, height, placement depth, and geocell form, using laboratory plate load testing. The impact of geocell material strength on load-carrying capacity is also covered in this work. A performance comparison of single-layer and multi-layer geocell-reinforced sand with different spacing is also included in this article. The test results confirm that the reinforced sand layer shows a significant increase in bearing capacity in comparison to the unreinforced sand.

S.N. M. Tafreshi, *et al* in 2015 Lower loads and deformations can be achieved by section performance enhancement through several methods when numerous layers of geosynthetic reinforcement are positioned beneath foundations or in the supporting layers of road pavements. This work aims to provide a new analytical approach for predicting the pressure-settlement response of a circular footing supported by such foundations, in particular those with geocell layers, based on multi-layered soil system theory. To forecast strain and confining pressure that propagates across an existing multi-layer system, the research proposes an analytical model that takes into account the elastic characteristics of soil and reinforcement. The materials data from triaxial tests on unreinforced and geocell-reinforced soils were utilized to compute the elastic modulus in terms of strain and confining pressure using a modified elastic technique.

S. Jeyanthi, *et.al* in 2024 the research presents a technique to compute the pressure-settlement in soil layers reinforced by geocells using the mayfly optimization algorithm (MOA). The geocell pocket form, soil and geocell reinforcing stiffness impacts, compaction-induced stresses, and soil strength and strain compatibility are all accurately and successfully estimated by the proposed MOA technique. Even though it might not be the fastest, the mayfly optimization technique has a higher chance than the others of finding a global ideal. The convergence behavior of the mayfly optimization method is distinct since it often finds the best general solution in the first few rounds. To comprehend structures reinforced with geocells, parametric sensitivity was examined. According to this study, bearing pressure rose and settlement reduced when soil modulus number, secant modulus, and geocell layers increased.

H. K. Fahliani, *et.al* in 2021 investigated the effects of three main contributing elements on the behavior of footings lying on unreinforced and geocell-reinforced sand slopes using mall-scale model testing. The footing setback, slope inclination angle, and back length of the geocell layer are some of these factors. The findings demonstrate that the geocell inclusion considerably enhances the behavior of the slope-overlying foundations even in the absence of a back length. Additionally, it was discovered that for settlement ratios of less than 20% and more than 20%, respectively, the optimal geocell back length ratios were 0 and 2. Moreover, both the reinforced and unreinforced model slopes' carrying capacities were markedly increased by raising the footing setback.

G. Juneja, *et.al* in 2023 investigated the behavior of a square footing placed on a geocell-reinforced base layer with various infill materials that sit on top of a soft clay subgrade using experimental and numerical modeling techniques. When compared to unreinforced situations, the geocell reinforcement raises the foundation bed's load-bearing capability. Using trash, aggregates, and sand materials in the base layer, respectively, reduces settlement ( $s$ ) by around 81.3%, 79.8%, and 71% with the application of geocell reinforcement. When it came to lowering surface heave, waste materials made for superior filler material. Numerical calculations were carried out using the finite-element software ABAQUS 3D to verify the experimental results. To examine the effectiveness of the geocell in enhancing the foundation bed's bearing capacity, further parametric tests were conducted, including measurements of the base layer's thickness ( $H$ ), the geocell's stiffness ( $K_s$ ), its pocket size, and the width of the footing plate ( $B$ ).

S. Davarifard, *et.al* in 2015 the impact of embedment depth on a foundation that supports a geocell-reinforced bed's bearing capacity utilizing a 300 mm-diameter plate load test. The footing's embedment depth ratio was adjusted from 0 to 0.75. The outdoor test pit, which was 2000 x 2000 mm in plan and 1000 mm in depth, was excavated in natural ground to conduct plate load testing. The nonwoven geotextile utilized in the testing was a non-perforated geocell with a height of 100 mm and a pocket dimension of 110 x 110 mm<sup>2</sup>. It was made of continuous polypropylene filaments. Geocell-reinforced bed sand that was previously compressed to 85 percent relative density was used for the testing. Fig. 8 shows a schematic cross-section of the test setup.

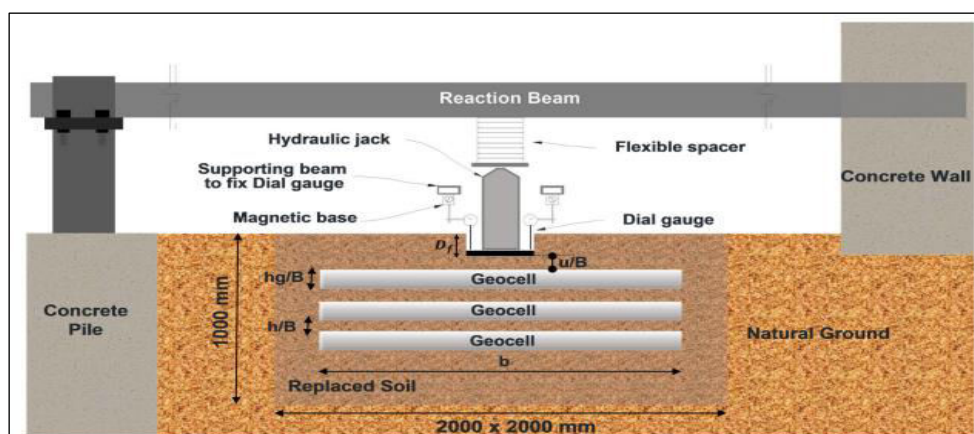


Fig. 8 shows a schematic cross-section of the test setup.

#### IV. CONCLUSION

Numerous studies and analyses have been carried out to look into the impact of dynamic stress on reinforced soil beds, based to the little review of the literature. The majority of the research was done on a single dynamically loaded footing. Future studies on neighboring footings and their dynamic interplay are therefore necessary.



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