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

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ABSTRACT: The content discusses the use of block foundations as a common choice for machine foundations, which are subjected to dynamic loads generated by moving machine elements. The recurrent dynamic stress can lead to soil settling in the foundation. One way to address this issue is by reducing cyclic loads caused by machine vibrations, which can help decrease excessive soil settlement. Increasing soil stiffness through methods like soil reinforcement with geosynthetics is suggested as a solution. The review paper focuses on the effect of dynamic response of a machine foundation on a reinforced soil bed with different infill materials, aiming to lower peak vertical displacement and resonance frequency by using geosynthetic material for soil reinforcement.

KEYWORDS: Machine Foundation, Soil Reinforcement, Geosynthetic Material, Infill Material

I. INTRODUCTION

Machine foundations are continuously subjected to the dynamic loads i.e. vibrations generated due to machine. The repetitive nature of dynamic load leads to excessive settlement of foundation soil. The excessive settlement of the machine foundation system can be reduced by increasing stiffness of soil. Among several techniques, soil reinforcement with geosynthetics material is one of the solutions for improving the stiffness of the soil. Several studies have been conducted to understand the dynamic interaction of foundations in group, which explains the dynamic interaction between two closely spaced square foundations of different sizes, by conducting large scale model experiments.

II. LITERATURE REVIEW

M. V. S. Sreedhar et.al (2016) conducted a study on reinforced soil bed beneath a model machine foundation showed that geosynthetics can alter resonant frequency and decrease peak amplitude, essential for designing machine foundations.



Fig. 1 Experimental setup [M. V. S. Sreedhar et.al (2016)]

Table 1 Summary of results [M. V. S. Sreedhar et.al (2016)]

Test Condition	Peak displacement at Resonance		Magnification Factor at resonance	
	(mm)	% drop	Value	% drop
Soil	0.07	0.00	7.34	0.00
Soil + Woven Geotextile	0.065	7.10	6.58	10.40
Soil + Biaxial Geogrid	0.025	64.30	3.84	47.70

A. Swain et.al (2016) conducted an experimental study on dynamic interaction of closely spaced square foundations under machine vibration. Large-scale model tests involved isolated and interacting footing responses with on footing subjected to dynamic loading and the other to static weight. Results analyzed the displacement amplitude vibration with frequency and determined the transmission ratio for dynamic excitation effects on passive footing.

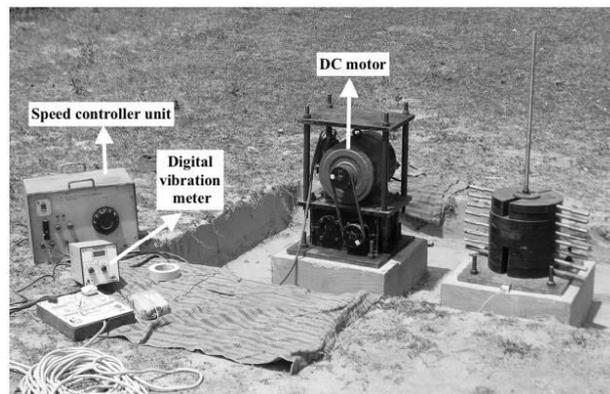


Fig. 2 Experimental setup [A. Swain et.al (2016)]

V. Hasthi et.al (2018) Numerical analyses using PLAXIS 2D studied machine foundations on geocell-reinforced beds, showing significant reductions in displacement and peak particle velocity compared to unreinforced and geogrid-reinforced cases. Geocell reinforcement led to a 163% increase in soil damping ratio, highlighting its potential in supporting machine foundations. Geosynthetics are effective in reducing settlement under static loads, but their performance under dynamic loads is not fully understood.

V. Hasthi et.al (2018) Large-scale field tests and numerical studies were conducted on geosynthetics reinforced soil beds supporting model machine foundation, showing significant reduction in resonant amplitude and peak particle velocity (PPV) with geocell reinforcement. Different conditions were tested, including unreinforced, single layer geogrid reinforced, two-layer geogrid reinforced, and geocell reinforced, with geocell reinforcement showing the most improvement in dynamic properties. Geocell reinforcement reduced resonant amplitude by 61%, increased natural frequency by 1.38 times, reduced PPV by 48%, and improved elastic uniform compression of the foundation bed by 91%. Experimental results were validated with numerical studies using FLAC 3D, showing good agreement in controlling lateral spreading of vibrations with geocell reinforcement.

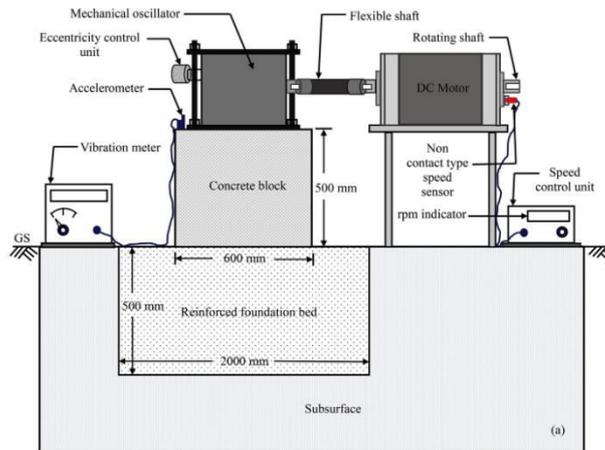


Fig. 3 Block vibration test setup [V. Hasthi et.al (2018)]

K. N. Ujjawal et.al (2018) investigates the vibration isolation effectiveness of geocell reinforced through numerical simulations, showing a reduction in resonant displacement amplitude by 56% and an increase in natural frequency by 42% compared to unreinforced conditions.

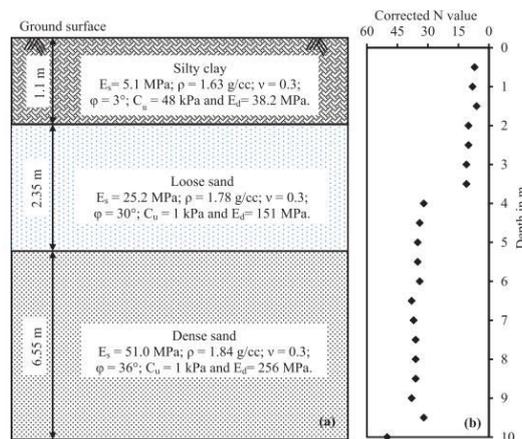


Fig. 4 Details of the subsurface profile: (a) soil profile; (b) variation in corrected SPT-N value with the depth [K. N. Ujjawal et.al (2019)]

K. N. Ujjawal et.al (2019) Numerical analysis using FLAC 3D validated cellular confinement systems for isolating machine-induced vibrations. Two techniques, ECA and HSA, were used to simulate 3D geocell confinement, showing significant reductions in displacement amplitude, resonant frequency changes, and improved elasticity of the foundation bed. Geocell reinforcement led to a 56% reduction in displacement amplitude, 42% change in resonant frequency, and 102% improvement in foundation bed elasticity. The HSA approach accurately predicted experimental results, investigating the impact of geocell properties on reducing vibration amplitudes under dynamic loading conditions. Parametric studies showed that geocell modulus and interface friction angle directly influenced the performance of geocell-reinforced beds under dynamic loading conditions, emphasizing the importance of these properties in enhancing the dynamic behaviour of the foundation bed.

V. Hasthi et.al (2019) explores the effectiveness of geocell reinforced foundation beds filled with various materials using block resonance tests. The geocell, made from a novel polymeric alloy (NPA), was tested in five different scenarios: unreinforced, geocell reinforced silty sand, geocell reinforced sand, geocell reinforced slag, and geocell reinforced aggregate. The presence of geocell improved the screening efficacy of the foundation bed across all infill materials, with significant reductions in displacement amplitudes. The highest isolation efficiency was observed with aggregate infill, showing a 150% improvement in shear modulus and reductions of 57% in peak particle velocity and 48%

in peak acceleration. The study also analysed the efficacy of the mass spring dashpot (MSD) analogy in predicting the frequency-displacement response of different reinforced cases, revealing a notable enhancement in damping ratio with geocell reinforcement.



Fig. 4 Preparation of different reinforced conditions [V. Hasthi et.al (2019)]

V. Hasthi et.al (2020) geosynthetics were studied for isolating ground vibrations from vertical dynamic excitation. Field tests compared unreinforced beds with geogrid and geocell reinforced beds, showing significant reduction in vibration with geocells. Geocells improved peak particle velocity resonant amplitude, and foundation bed stiffness with analytical predictions aligning well with field results.

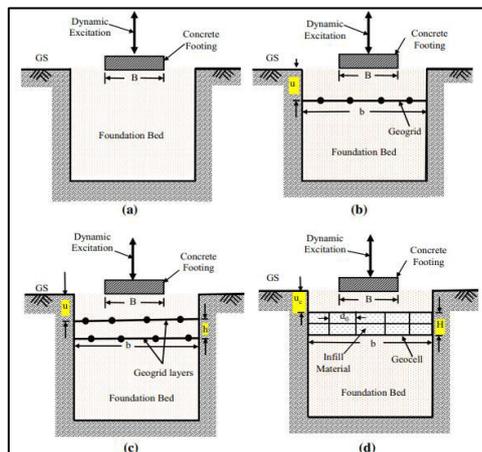


Fig. 5 Schematic representation of various reinforced conditions: a UR; b BGR-1; c BGR-2; and d GCE condition [V. Hasthi et.al (2020)]

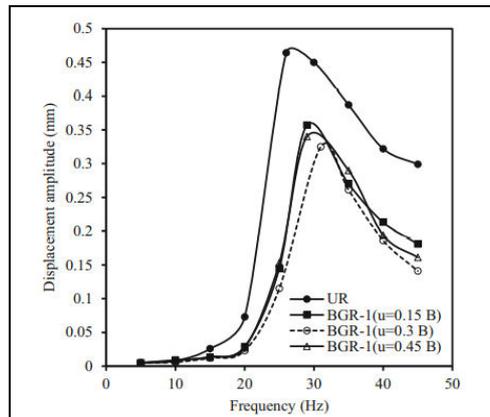


Fig.12 Variation in dynamic response of the foundation bed with the change of placement of geogrid
[V. Hasthi et.al (2020)]

R. S. Sharma et.al (2023) investigates the behaviour of a square footing on a geocell-reinforced base layer with different infill materials over soft clay subgrade. Three infill materials - sand, aggregates, and construction demolition (C&D) waste - were compacted at different density indexes. Geocell reinforcement increased the load-bearing capacity of the foundation bed, reducing settlement by approximately 71-81.3%. C&D waste was found to be the most effective infill material for reducing surface heaving. Numerical analyses using ABAQUS software validated the experimental findings. Parametric studies were conducted to analyse the performance of the geocell in improving the bearing capacity of the foundation bed.

S. N. Moghaddas et.al (2022) presents the results of static and cyclic plate loading tests conducted on a weak unreinforced sand bed covered by a 160 mm thick layer of compacted soil, either unreinforced or geocell-reinforced. The study aimed to examine the impact of soil density and grain size as filler materials for the covering layer. Three types of granular soils with different average particle sizes were used. The findings showed that the bearing pressure increased by 23% on average when the grain size of the upper soil layer changed from 2.20 mm to 8.47 mm under static loading. The use of a geocell-reinforced layer improved bearing pressure by about 37%, with no significant further improvement observed when larger soil grains were used in the geocell pockets. Cyclic loading tests indicated a maximum settlement reduction of about 50% for Soil 1 with a geocell layer. The study suggests that increasing soil density may be more effective in enhancing geocell performance than using larger particle sizes.

S. Kolathayar et.al (2022) discusses model footing tests conducted on sand bed reinforced with HDPE and coir geocells. The study evaluates the use of sand tire crumb (STC) mixture as infill material compared to pure sand, analysing shear and density properties through direct shear and density tests. The mix with the highest shear strength and density properties is selected, and plate load tests are performed to assess the effectiveness of tire crumb as infill material in geocell pockets. The results indicate that the sand tire crumb mix is effective, particularly for coir geocells, leading to a significant reduction in surface heave.

C. Doley et.al (2020) experimental program focused on geocell-reinforced granular bases made from Brahmaputra River sand, using different geocell heights and infill densities. The study found that increasing geocell height and infill density positively impacted the bearing capacity of the geocell-reinforced sand bed. Compared to unreinforced beds, the bearing capacity increased by 1.8–4.3 times for certain conditions and 4.3–8.6 times for others. The research also highlighted a significant reduction in settlement when using geocell reinforcement.

T. G. Sitharam, et.al (2020) discusses the interference effect of footings placed close to each other on soil behaviour, particularly in clay beds. The authors conducted model test experiments on geocell-reinforced clay beds and used numerical simulations to study the parametric effects. Different models were employed to simulate the behaviour of the clay bed and infill material. The study found that the optimum spacing between footings for maximum bearing capacity is 0.5 times the width of the footing. The interference effect was more pronounced in geocell-reinforced clay beds compared to geogrid-reinforced ones. Additionally, when clay was reinforced with geocell and basal geogrid, there was a significant reduction in stress distribution depth, with stress being concentrated in the geocell membrane.

J. Jayamohan et.al (2019) examines the impact of infill material properties on the load-settlement behaviour of geocell mattresses through laboratory tests on clay reinforced with confined geocells. The study varies parameters such as geocell aperture aspect ratio, infill materials (sand, 6 mm aggregates, 12 mm aggregates), and infill material relative density. Experimental results are compared with Finite Element Analyses using Plaxis 2D software, revealing that infill material properties significantly affect load-settlement behaviour. Increasing grain size improves geocell response, while increasing geocell aperture aspect ratio reduces bearing capacity. Sand with 88% relative density shows better improvement than 6 mm aggregate.

S. Kolathayar et.al (2019) compared the bearing capacity and settlement characteristics of sand beds reinforced with coir geocells, HDPE-geocells, and unreinforced sand beds. Model plate load tests showed that coir geocell-reinforced sand had double the bearing capacity of HDPE-geocell-reinforced sand. The study also evaluated the performance of HDPE and coir geocells with seashell infill material, finding that a mix of 20% seashell and 80% sand in coir geocell provided the maximum bearing capacity. The study suggests that reinforcing soil with coir geocell and seashell is both economical and environmentally sustainable.

A. Hegde et.al (2015) conducted plate load tests on geocell reinforced soft clay beds using different infill materials to assess their impact on geocell performance. Neoweb geocells were utilized with aggregate, sand, and local red soil infills. The load carrying capacity of the geocell beds increased significantly with all infill materials, with the aggregate infill providing the highest increase. Settlement reduction was also observed with all infill materials. The study concluded that infill materials did not heavily influence geocell performance. Numerical simulations using FLAC2D supported the experimental findings, showing good agreement between the two.

K. Balan et.al (2016) focused on the effectiveness of different fill materials with geocell reinforcement on soft clay beds through laboratory model tests. Various configurations were tested, including fill material alone, fill material reinforced with planar coir geotextile layer, coir geocell, and geocell with planar geotextile. Results showed improved load carrying capacity and reduced settlement and heaving when fine to medium sand fill material was reinforced with coir geocells. Adding a planar geotextile layer further enhanced performance. However, reinforcing fill material with a grain size larger than 4.75 mm showed only marginal improvement in bearing capacity. Providing geocell reinforcement with a basal planar geotextile layer in coarse aggregate beds under soft clay significantly increased bearing capacity. Stiffening the outer layer of coir geocell with stiffeners decreased carrying capacity and increased settlement but did not cause heaving.

S. Biswas et.al (2021) evaluated jute and bamboo geocell performance with an additional basal mat on unpaved roads using different infill materials. Results showed that RAP had the highest load-bearing capacity, while sand had the lowest. The improvement factor ranged from 4–14.6 for jute geocell and 5.1–16.9 for bamboo geocell, enhanced by using basal mats. The performance of bamboo geocell was superior, with RAP and specific crushed aggregate mixes preferred as infill materials for maximum bearing capacity.

III. CONCLUSIONS

From the brief literature review it can be concluded that many studies have been carried out to investigate the dynamic effect of machine foundation on reinforced soil bed. Based on the available literature, it is observed that limited studies are available on the topic of dynamic response of adjacent machine foundations on geocell reinforced soil bed. Hence the study investigates the dynamic response of adjacent machine foundation on geocell-reinforced soil beds through a series of field vibrations tests. To study their effect towards dynamic response of the adjacent machine foundations on geocell reinforced soil bed.

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