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A Review Paper on Experimental Investigation on Liquefaction Mitigation by Using Rubber Tire Chips and Geotextile

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ABSTRACT: Liquefaction has become a well-known disaster induced by earthquake due to its destructive effects to infrastructure. As liquefaction is one of the major problems that cause settlement, lateral spreading as well as lateral displacement in liquefiable soils during earthquakes. To reduce the effects due to liquefaction, traditional methods have been widely applied in engineering practice. Some relatively novel ideas for mitigating liquefaction have been put forth, such as employing geosynthetics and artificial materialto reinforced the soil. In order to lessen the impact of pore pressure, settlement, acceleration, and cyclic stress ratio on the soil susceptible to liquefaction and to increase the factor of safety of the soil against liquefaction, this dissertation work includes the study of reinforcing materials such as Geotextiles and Rubber Tire Chip.

KEYWORDS: Liquefaction, Geotextile, Rubber Tire chip, 1g shaking table test, Pore water pressure, Acceleration,Differential Settlements Cyclic stress ratio.

I. INTRODUCTION

The phenomenon known as liquefaction occurs when pore water pressures rise in saturated and cohesive soils, causing a loss of strength and a reduction in the effective stresses brought on by dynamic loading. This phenomenon occurs when rapid loading, such as shaking from an earthquake, reduces the strength and stiffness of the soil. Given that one of the main issues causing lateral spreading, lateral displacement, and settlement in liquefiable soils during earthquakes. Geologists and engineers have created a number of strategies to lessen the damaging effects of liquefaction by reinforcing the impacted soils and lowering the risk of liquefaction.

Liquification, a phenomena when saturated soils lose their strength and behave like a liquid and cause structures to sink, tilt, or even collapse, is one of the most destructive effects of earthquakes. To improve liquefiable soil resistance against liquefaction are basically done by densifying the surrounding soil, reducing the generation of excess pore water pressure. Research efforts are focused on how important it is to remediate soil to prevent liquefaction. These actions improve the stability of structures, reduce settlement, and lessen the harmful consequences of liquefaction during seismic events by reinforcing the soil and controlling groundwater levels.Several ground improvement techniques have been developed for liquefaction mitigation.

1.1 Geotextiles

They are used in geotechnical and civil engineering applications, such as infrastructure works, roads, railways, coastal protection, landfills, control erosion. Geotextile products have been improving geotechnical designs for years, providing numerous advantages in comparison to traditional techniques.Geotextiles are thin & strong membrane fabric which is used to reinforce soil & prevent from damage Geotextiles are permeable fabrics which, when used in association with soil, have the ability to separate, filter, reinforce, protect, or drain. It is typically made from polypropylene or polyester and polyetheleneas shown in Fig.1.Geo-textile fabrics come in two basic forms woven and nonwoven.Two or more sets of fibers are woven or interlaced at a right angle to create woven geotextiles. randomly oriented fibers are mechanically bonded or punched with a needle to create non-woven geotextiles. Geotextiles are thin & strong membrane fabric which is used to reinforce soil & prevent from damage.

(a) Woven Geotextile (b) Nonwoven Geotextile
Fig.1.Geotextile

1.2 Rubber Tire chip

In basically, tire chips are products made from tires that are used to replace or substitute reinforcing materials in ground improvement or building construction projects. Because of its special engineering qualities, tire chips have been used in many different applications. The soft soil's different engineering features have been enhanced by its mix with soil material as shown in Fig. 2.

Fig.2.Rubber Tire chip

1.3 Shaking Table Test

A shaking table is a device that can simulate earthquakes and other dynamic loadings that are applied to test models and structures in a realistic manner. Building structure dynamics and input ground motion characteristics. Shaking table tests can be used for dynamic testing. Time histories of displacement, velocity, pore pressure, and acceleration are used to quantify the structure's dynamic response.Normally test model are developed to understand the effects of different parameters and process that leads to failure of prototype at a real time.The dynamic qualities, which are reflected by vibration modes, damping ratios, and natural frequencies, can be approximated by analysis the response. Shake table studies involve preparing a big specimen of saturated sand in a laminar box and setting it on shaking table. The shake table test schematic view is shown in Fig. 3.

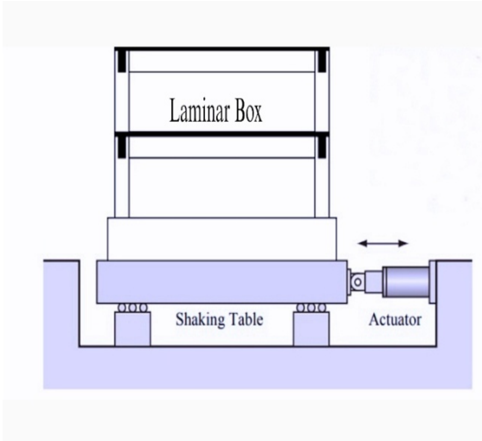

Fig.3.Schematic view of shake table test

II. LITERATURE REVIEW

The investigation into liquefaction mitigation utilizing different geosynthetics, For liquefaction mitigation, a number of ground improvement methods based on various mechanisms have been developed, including the jet grouting method, deep mixing method, sand compaction pile method, and gravel drain method. Numerous scholars have conducted analytical and experimental work on sand compaction columns, deep soil mixing, sheet piles, and other related topics. The gap in the research is determined by the literature evaluation, and this research will be conducted to form the basis of the current work.

H. Setiawan et.al (2018)[1]. performed experiments on shaking table equipment to study the influence of geosynthetics along with gravel usage to reduce the vertical soil displacement caused by liquefaction. shaking table tests were performed using aacrylic tank of dimensions 1500 mm x 750 mm x 750 mm. The sand layer in the sand container was divided into two parts, which not liquefiable and, composed of dense sand with a relative density 90%, liquefiable sand, composed of loose sand with relative density around 50%.

The sand used was silica sand. Crushed stone was used to form a model of a gravel layer of 6 cm thick. Furthermore, a sheet of model geosynthetics made of polyethylene was placed at the bottom of the gravel layer.To determine the impact of friction between geosynthetics and sand on the ground displacement that occurred, two distinct types of geosynthetics Type I and Type II were used. To assess how well the suggested abatement against the settlement problem performed, a series of 1-g shaking table tests were carried out. The 5 Hz input harmonic wave was used, with a goal maximum input acceleration of about 80 cm/sec² and a 15-second shaking duration. To conduct the tests, four cases were observed. To conduct the tests, four cases were observed. Fig.4, and Fig.5, shows average ground vertical displacements and differential settlement for all the four cases.

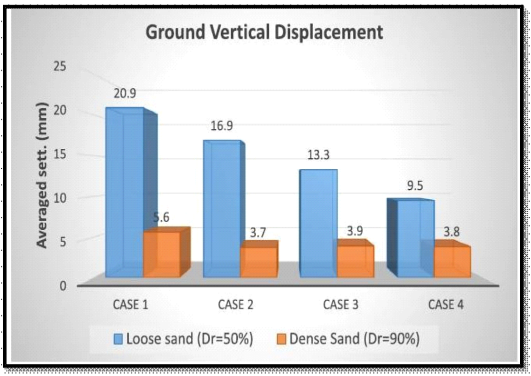

Fig.4: Averaged ground vertical displacement

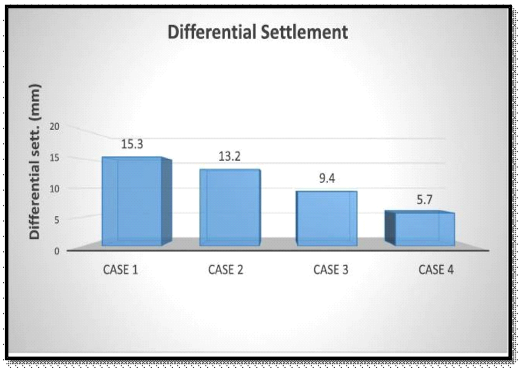

Fig.5: Differential settlement

From the results, it was concluded that the use of gravel and geo-synthetics effectively reduced the vertical ground displacement of liquefiable soil due to the permeability of the gravel and tension strength of the geo-synthetics. The results showed that by using this proposed mitigation, the settlement of the ground surface decreased by around 54% in the liquefiable zone and up to 32% in the non-liquefiable zone.

K.S. Beena et al. (2021) [2].performed experiments using shaking table with laminar box to study the liquefaction potential of coastal sand. To understand the effect of gradation of soil and amplitude of base shaking on the generation of excess pore water pressure at varying relative density of soil (30%, 40% and 50%) but at a constant frequency of shaking (1 Hz). The laminar box developed, has an overall internal dimension of 1 m x 0.6 m x 0.75 m. During the sand model preparation, six pore water pressure sensors and two accelerometers were installed at the proper locations to study the excess pore water pressure buildup, dissipation, and soil acceleration at each point. After forming the model, it was saturated from the bottom very slowly without disturbing the layers. All experiments were conducted in a controlled manner keeping the relative density constant. Two tests were conducted to investigate the influence of the box boundaries, with sensors positioned as shown in Fig.6, and the readings from sensors P5, P1, and P4 were examined for soil 1 and soil 3 at 30% relative density.

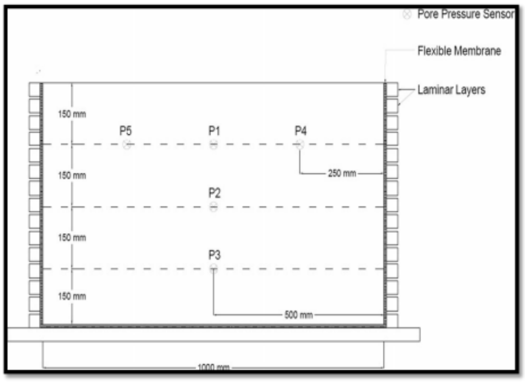

Fig.6: Location of pore pressure sensors to study the effect of boundary

The maximum EPWP value obtained at P5, P1, and P4 was 1.48, 1.464, and 1.475, respectively; thus, the end sensors at 0.25 L showed an average deviation of just 0.92% of the middle sensor value. The result showed that the difference between the responses was negligible where there was maximum EPWP, which was the primary concern of the study, demonstrating that the laminar box functioned effectively without much boundary effect. Fig. 7, shows the development of excess pore water pressure of soil 1 at three different positions at 150 mm depth from the top. Fig.8, shows variation of EPWP at the bottom sensor at different accelerations of Shaking.

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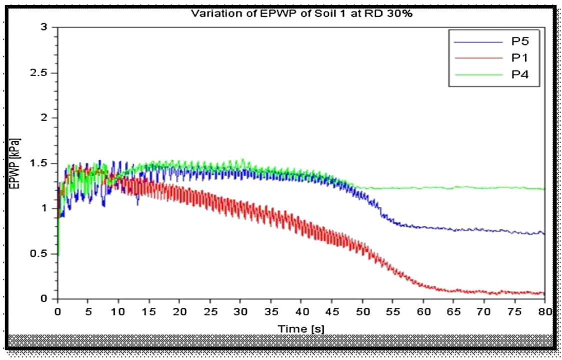

Fig.7: Variation of EPWP at three positions of top layer

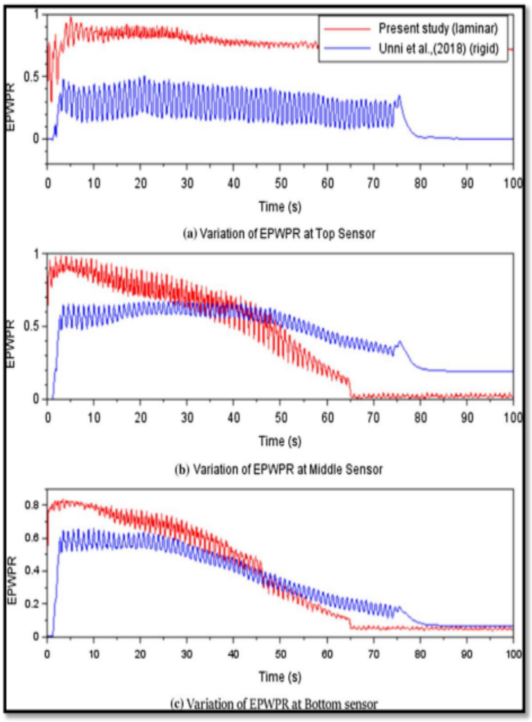

Fig.8:Variation of EPWP at the bottom sensor at different accelerations of Shaking

The results it was concluded that, The laminar box's development has significantly reduced the effect of boundary conditions caused while using a rigid box. The experimental results show that as the relative density increases, the excess pore water pressure ratio decreases. Fine sand was more suitable to liquefaction than coarse sand.

H. Hazarika et.al. (2019)[2]. performed a shaking table tests to prevent vibration-induced and liquefaction-induced damage to residential buildings during earthquake. They used a mixture of tire chips and gravel as the horizontal reinforcing inclusion under the foundation of residential houses. The Fig.9. shake table test model the box was 600 mm in length, 300 mm in width, and 500 mm in height. To youra sand was used for the foundation soil of a model house. Pure tire chips (2 mm in size) or tire chips mixed with gravel (almost similar to tire chips in size) were used in preparing the horizontal inclusion. Keeping the height of the ground in the soil box at 300 mm, the relative density of both the base layer and the layer containing the horizontal inclusion was adjusted to be around 50%.To achieve the desired relative density, the dry pluviation technique was used to prepare uniform and consistent layers of sand. The gravel-tire chip layers were prepared using the usual compaction method. The layer immediately below the foundation was made of gravel, which replicates the top layer of the building foundation normally improved by some sorts of ground-improvement techniques. The sample was saturated by introducing water from the bottom of the soil box at a very slow flow rate. A total of seven test cases were examined under three different conditions of horizontal inclusion.

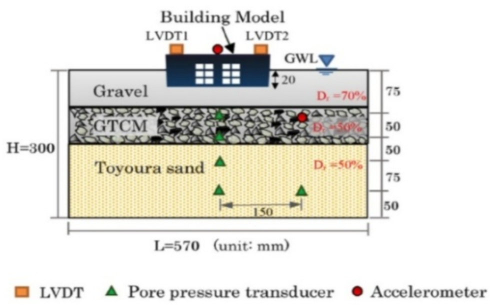

Fig.9: Shake table model test setup

Pure tire chips (2 mm in size) or tire chips mixed with gravel (almost similar to tire chips in size) were used in preparing the horizontal inclusion. Keeping the height of the ground in the soil box at 300 mm, the relative density of both the base layer and the layer containing the horizontal inclusion was adjusted to be around 50%.Fig.10. shows influence of various factor in model test, Case 0 represents conventional foundation soil. Case 1, Case 2-1, and Case 2-2 represent the cases in which the thickness of the horizontal inclusion was 10 cm. Case 3-1 and Case 3-2 represent the conditions in which the thickness of the horizontal inclusion was reduced to 5 cm.

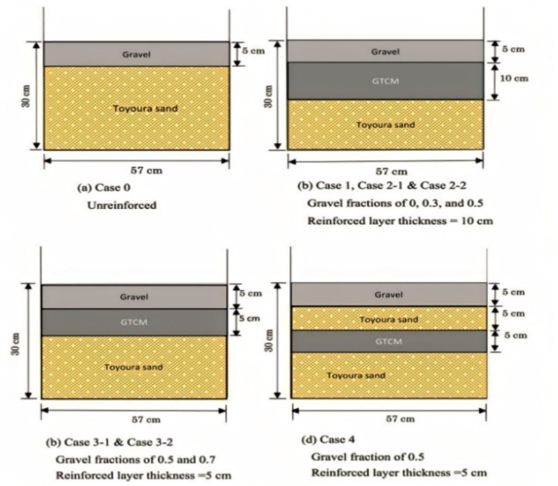

Fig.10: Influence of various factors in model tests.

The average final settlements (LVDT1 + LVDT2/2) of the model house due to the cyclic loading for each case are shown in Fig11.

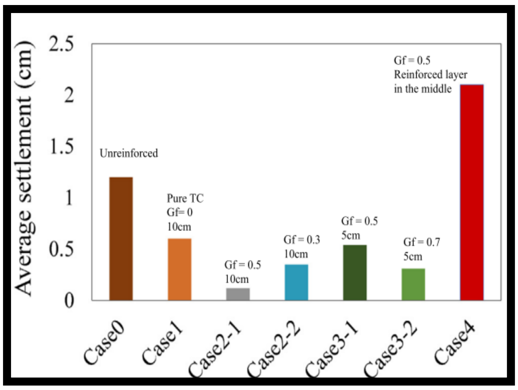

Fig.11: Comparison of settlements of model house in each case

From this figure, it is clear that the settlement of the house reinforced by pure tire chips (10- cm-thick inclusion) was reduced to half that of the non-reinforced foundation. However, when compared with the foundation reinforced with gravel mixed with tire chips (10-cm-thick inclusion), it is seen that the settlement of the house was reduced to half that of the foundation reinforced with pure tire chips.

Salem et al. (2017) [4]. presented results of investigation of the effectiveness of stone column as liquefaction remediation. Twenty-four case studies, in which SPT and CPT tests were performed before and after stone column reinforcement, which were used as a basis of the research. Densification and stiffening mechanisms were investigated and their individual and combined effects were analyzed. In order to study the liquefaction potential of reinforced soil with stone columns, 24 case studies using project data located in seven countries were considered. For each project, different design parameters of stone columns were adopted viz. triangular or square grid pattern, spacing, diameter, area replacement ratio, and treatment depth. In situ tests, 31 SPTs and 33 CPTs, were performed before and after stone column reinforcement, to establish the effectiveness of stone column reinforcement. The densification improvement was evaluated using SPTs and CPTs performed before and after stone column installation to analysis the liquefaction potential of reinforced soil. The SPT and CPT results were corrected. Fig.12. (a and b) shows comparative results of initial and final penetration resistance N-corrected and q-corrected values, respectively, recorded before and after stone columns installation. Penetration resistance greatly increased after stone column installation. The increase in the penetration resistances N-corrected and q-corrected ranged from 31.13 to 69.29% and from 57.10 to 318.28%, respectively.

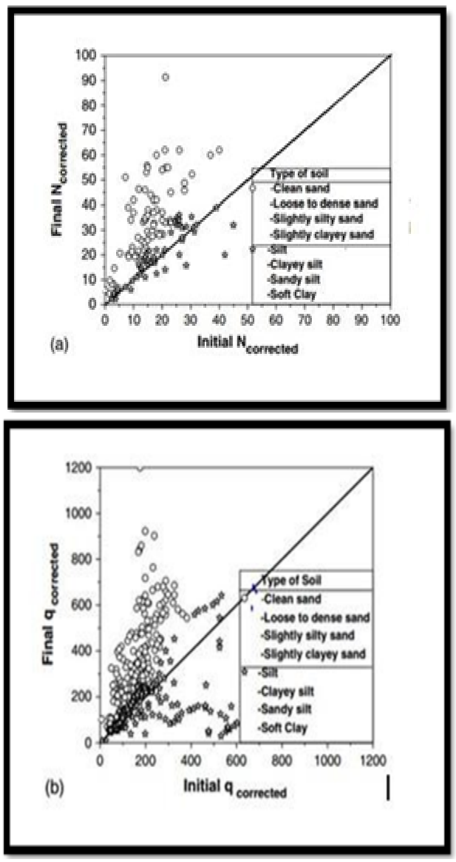

Fig.12: Variation of initial and final values of (a) N-corrected(b) q-corrected

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Thus, stone columns provided shear reinforcement and decreased the cyclic shear stress ratio (CSR) to which the treated soils was subjected during an earthquake. This stiffening mechanism was considered to be more effective for silt and clayey layers in which densification and drainage were difficult to achieve. This was based on the assumption that stiff columns deform compatibly in shear with the surrounding soil. Fig.13 shows reduced CSR after reinforcement by stone columns

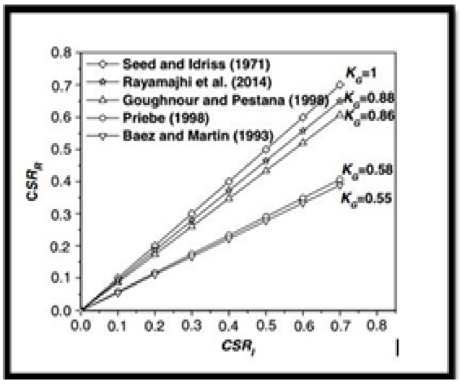

Fig.13: Reduced after reinforcement by stone column

Tang et al. (2015) [5].conducted study on Geo-synthetic-encased stone column (ESC) using three-dimensional finite element (FE) analysis approach to explore the mitigation of sloped saturated sand strata.They investigated the encasement effect in ESC as remediation and the effect of the important design parameters in reducing lateral ground deformation.A total of 20 nodes were used to describe the solid translation degrees of freedom, and 8 corner nodes were used to represent the fluid pressure.The Geo-synthetic encasement around the SC was modeled as a linear elastic material for simplicity.Typical stone columns were constructed in a grid pattern to improve the sand stratum covering the entire building footprint
Fig.14 shows FE mesh for ground modification by Geo-synthetic reinforced SC: (a) Schematic plan view of column layout; (b) FE model elevation.

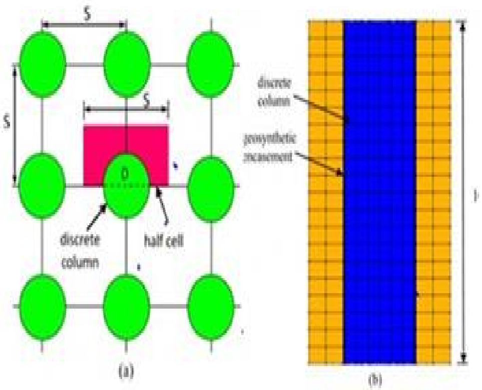

Fig.14: FE mesh for ground modification by Geo-synthetic reinforced SC Tang

Fig.15show the influence of the J and t values respectively, of the geo-synthetic on the maximum lateral ground surface displacements at the SC center.

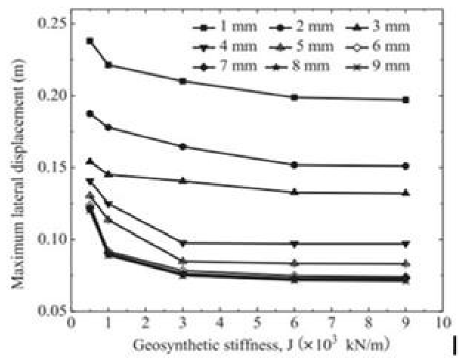

Fig.15: Effect of geo-synthetic stiffness on maximum lateral surface displacement

It was concluded that, both SC and ESC remediation were found to be effective in reducing the sand stratum lateral deformation.

Darshan D. et al. (2022) [5]. studied Liquefaction mitigation by using pumice aggregate and geo-synthetics.Shaking table wasdimension 1m x 1m was used during experimental investigation 3D view of shaking table as shown in Fig.16.

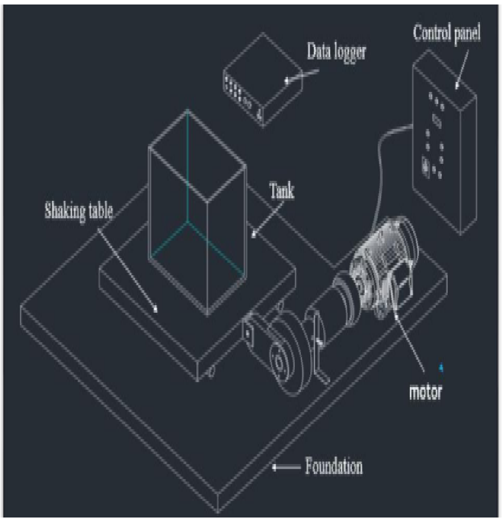

Fig.16: 3D view of shaking table

Case I-Only soilmodel without any inclusion reinforcement.Case II- The soil model reinforced with geotextile only.Case III- To determine the effect of pumice aggregate usage, the soil modelReinforcedwith pumice aggregate only.Case IV- To determine the effectiveness of pumice aggregate and geosynthetics.The sand was filled in the tank with a relative density (Dr) 30 %, using gravity raining technique by maintaining the height of fall of 13 cm. Initially, the sand bed was prepared from bottom of tank up to height corresponding to different cases. The surface of bed was levelled using a plane wooden plate and a spirit level. The Piezometer (P2) and the Accelerometer (A2) were then placed on the sand bed .Total water content required to fully saturate the soil was 23 %. Half the corresponding amount of water was added to the sand bed after placement of sensors. The settlement occured through four different point at the surface was measured. For more clarity, settlement values were averaged and the result are Shown Variation of settlement with frequency For ± 5 mm and ± 7.5 mm base amplitude show in Fig.17 (a)and (b). It was shown that, based on the settlement measured, the presence of the proposed mitigation resulted in a reduced settlement.

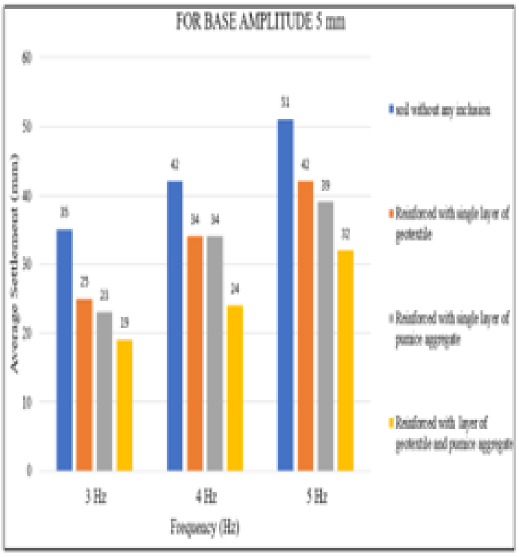

Fig.17 (a):Variationofsettlement with frequency For ± 5 mm baseamplitude

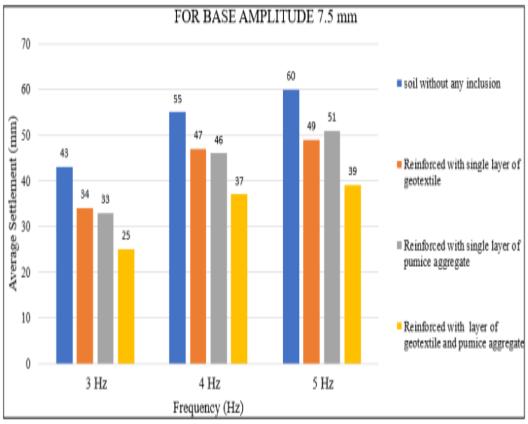

Fig.17 (b):Variationofsettlement with frequency For ± 5 mm baseamplitude

The percentage reduction in the values of settlements developed in soil when providing the geotextile layer with pumice aggregate was higher as compared to other cases i.e. soil without any inclusion (case 1), soil with single geotextile layer andsoil with pumice aggregate. By providing the geotextile layer with pumice aggregate, the value of settlements decreased upto 84%, 72%, for the amplitude ± 5 mm, ± 7.5 mm

The excess pore water pressure can be effectively reduced up to with geo-textile and rubber tire chip inclusion in soil. Tire chip was found to be an excellent material for the prevention of liquefaction. However, due to their compressible nature, their direct use might result in the unwanted settlement of structures resting on such materials.

III. CONCLUSIONS

As the frequency and the amplitude of dynamic loading increases, the pore pressure and settlement also increase. As the frequency and the amplitude of dynamic loading increases, the pore pressure and settlement also increases. Thus, geo-textile with rubber tire chip is most effective inclusion for the improvement.Fine sand was more suitable to liquefaction than coarse sand.

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