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INVESTIGATING THE EFFECT OF GRANULAR PILES ON THE BRHAVIOR of WEAK SOILS

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ABSTRACT

The study explores the challenges associated with constructing structures over weak soil layers. It presents a novel solution involving the utilization of granular piles made from gravel to enhance soil properties and counteract issues such as excessive settlement and pronounced lateral deformation. The investigation is conducted within the framework of the Jawharat Al-Fustat residential project, a development project comprising 45 residential buildings in the Ain Al-Sira area in Cairo governorate, Egypt. The project site consists of three layers of soil (Historical backfill & silt clay with interlayers of sand). The current study presents the effect of soil properties, granular pile dimensions, spacing between piles, and replacement soil thickness on the behavior of structures and the replacement ratio. Plate load tests were carried out within the natural at the foundation level, and over granular piles after one month of installation. The results refer to the significant improvement in the bearing capacity of soil attributed to the use of granular piles, which leads to increased strength and deformation properties of the weak soil. Field investigations confirm the feasibility of using granular piles incorporating gravel, combined with vibratory compaction and vibration replacement techniques, which effectively enhance the performance of buildings constructed on weak soils. The field measured on-site settlement values were compared with those analytically estimated using Terzaghi's approach, and the finite element methods (PLAXIS 3D). The results show an increase in the bearing capacity of the improved soil by approximately (95% to 89%) compared to natural soil and a significant decrease in soil settlement when using granular piles compared to natural soil, On the other hand, the settlement measured on site was much lower than estimated. This is due to attention to the quality of implementation work and the short period of monitoring settlement values.

KEYWORDS: Granular pile, Weak soil, Ground Improvement, Finite Element Analysis (PLAXIS 3D), Settlement.

دراسة تأثير الخوازيق الحبيبية على سلوك التربة الضعيفة

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الملخص

تستكشف الدراسة التحديات المرتبطة باقامة مباني فوق طبقات التربة الضعيفة. تقدم حلاً يتضمن استخدام الخوازيق الحبيبية المكونة من الحصى لتعزيز خصائص التربة ومواجهة المشكلات مثل الهبوط الزائد والتشوه الجانبي الملحوظ. يتم إجراء التحقيق ضمن إطار مشروع "جوهرة الفسطاط" السكني، وهو مشروع تطوير يتكون من 45 مبنى سكنيًا في منطقة عين الصيرة بمحافظة القاهرة، مصر. يتكون موقع المشروع من ثلاث طبقات من التربة (ردم تاريخي وطمي وطين مع تداخلات من الرمل). تستعرض الدراسة الحالية تأثير خصائص التربة، وأبعاد الخوازيق الحبيبية، والمسافات بين الخوازيق ، وسمك تربة الاحلال على سلوك المنشآت ونسبة الاستبدال. تم إجراء اختبارات تحميل الألواح علي التربة الطبيعية عند مستوى الأساس وفوق الأكوام الحبيبية بعد شهر من تنفيذها تشير النتائج إلى التحسن الكبير في قدرة تحمل التربة الناتج عن استخدام الخوازيق الحبيبية، مما يؤدي إلى زيادة في قوة وخصائص تشوه التربة اللينة. تؤكد القياسات الحقلية جدوى استخدام الخوازيق الحبيبية المكونة من الحصى، مع الجمع بين التقنيات الاهتزازية للدمك والاستبدال، التي تعزز بشكل فعال أداء المنشآت المقامة على التربة الضعيفة. تم مقارنة النتائج الحقلية لقيم الهبوط في الموقع مع تلك المستمدة من الطرق التحليلية (Terzaghi) وطرق العناصر المحدودة (PLAXIS 3D). أظهرت النتائج زيادة في قدرة تحمل التربة المحسنة بنسبة تتراوح بين (95% إلى 89%) مقارنة بالتربة الطبيعية وانخفاضًا كبيرًا في هبوط التربة عند استخدام الخوازيق الحبيبية مقارنة بالتربة الطبيعية. من ناحية أخرى، كانت القيم المقاسة للهبوط في الموقع أقل بكثير من المتوقع، ويرجع ذلك إلى الاهتمام بجودة تنفيذ العمل وفترة المراقبة القصيرة لقيم الهبوط.

الكلمات المفتاحية : خوازيق حبيبية، تربة ضعيفة، تحسين الأرض، تحليل العناصر المحدودة (PLAXIS 3D)، الهبوط.

1. INTRODUCTION

According to Egypt's vision for comprehensive sustainable development and balanced regional progress by 2030, engineers are forced to explore innovative ways to improve marginal sites in a world where land values are rising, and suitable building sites are diminishing. Among the various land improvement techniques [1], the construction of granular piles is an environmentally friendly material in multiple fields and one of the most versatile and cost-effective methods, superior to alternatives such as dredging. Using granular substrates was the best choice for improving the weak soils that is the subject of the study. To improve the structural performance of facilities such as dams or buildings [2] located above weak soil layers. The research aims to address pressing soil issues, in particular over-settlement and significant lateral deformation, in line with the overarching goal of fortifying infrastructure to accommodate population growth while at the same time enhancing the urban landscape by eliminating slums. Specifically, the study focuses on a residential area in Cairo Governorate, which includes a complex of 45 reinforced concrete buildings. The study investigates various factors that influence the structural integrity of the granular piles, including the shear resistance of weak soil,geometry of granular piles (length and diameter), horizontal reinforcement using geotextile, and material replacement ratio. The research utilizes experimental results and an analytical approach to comprehensively understand the structural improvements achieved.

The installation techniques for granular piles are designed based on technical expertise, efficiency, and local conditions of granular substrates. The study highlights vibratory compaction and vibration replacement as proven techniques for granular pile construction. Additionally, the research enriches the discourse through comprehensive field research on granular pile construction using impact displacement methods, providing promising insights. The practical culmination of the study appears in the load tests carried out on the constructed granular piles, which confirm a significant increase of 2.00 to 2.50 times in the bearing capacity of the improved soil compared to its natural state. Granular piles have a rich historical background dating back to the 1830s in France and gaining modern appeal in Germany in the 1930s. They have effectively addressed various challenges at foundation sites globally, such as enhancing bearing capacity, reducing settlements, and improving stability [3]. Research has contributed significantly to understanding the performance of granular piles under different loading conditions, revealing stress distribution patterns and settlement behavior within reinforced soil layers [4]. Additionally, experimental exploration of the bearing capacity of reinforced granular piles has provided practical insights into designing effective granular foundations for reinforced piles [5]. These studies collectively contribute to a nuanced understanding of load-bearing capacity, settlement behavior, dynamic response, cyclic loading, and numerical modeling within structures constructed over weak soils. Furthermore, using stone columns encased with suitable geosynthetics has been shown to impart the necessary confinement to improve their strength and stiffness, enhancing the stability of soils under cyclic loading and providing practical solutions for improving soil Historical backfill & silt clay with sand ratio behavior. The literature also introduces the concept of critical length for optimizing bearing capacity, contributing to improving the efficiency of granular pile designs in soft soils. Moreover, insights into the behavior of reinforced stone columns under cyclic loading have been provided, demonstrating the effectiveness of geosynthetic reinforcement in improving the properties of soft soils. experimental and numerical analysis of geosynthetic-reinforced floating granular piles in soft clays, shedding light on the behavior of granular piles in specific soil conditions [6]. Numerical modeling of granular anchor pile systems in loose sandy soil subjected to uplift loading, providing insights into the behavior of granular piles under uplift conditions [7]. Additionally, the uplift behavior of axial granular pile anchors encased with geogrid in cohesionless soil, contributing to understanding the influence of geogrid encasement on the behavior of granular piles [8]. These findings collectively contribute to a comprehensive understanding of the diverse aspects related to the improvement of weak soils using reinforced stone columns, covering various reinforcement methods, soil types, and loading conditions, and contributing to the development of effective geotechnical solutions for challenging soil conditions. [9]

2. The Study Area

2.1. General Location of the Study Area

The investigation site for this research work is located at the Jawharat Al-Fustat residential project in the Ain Al-Sira area, Cairo Governorate, Egypt. The site is accessible from Al-Fustat Street, in front of the Museum of Civilizations in Cairo, Egypt (Fig. 1), and the site will be prepared for the project comprises 45 residential buildings concrete skeleton type, including a basement, ground floor, mezzanine, and eight upper floors, the proposed builsings are supported on a raft foundations. The design load of the building is estimated to be approximately 125 kPa, which exceeds the primary soil's permissible bearing capacity due to the soil profile as weak soil layer. The geotechnical analysis reveals a significant challenge where near-surface soil layers lack adequate bearing capacity, necessitating the transfer of building loads to lower more stable soil layers at reasonable depth. To address this, the designers proposed using a stone pile system to enhance the bearing capacity while reducing settlement to permissible values, improving lateral pressure, enhancing the coefficient of stiffness, and facilitating drainage in the cohesive layers, allowing, at the same time, supporting the foundation on the raft.

Fig. 1. Location of the area under study and site plan.

2.2. Geologic Setting of the Study Area

Egypt's geological structure is currently experiencing subsidence issues due to its geological composition. A significant part of the country consists of a solid basement complex dating back to the Kenyan ages, occasionally emerging at the surface[10] .During the Cretaceous period, there was a land subsidence in northern Egypt, allowing the advance of the sea and the deposition of thick calcareous layers up to 200 meters [11]. Subsequent uplifts and subsidence occurred until the Pliocene era. Following this, the Nile River carved its path from the south to the north, forming lakes and a delta [12]. The project area, is located east of the Nile River and 5.0 km from downtown Cairo, reflects historical influences of Cretaceous sedimentation from the Mediterranean Sea. It exhibits top Quaternary formations and Upper Eocene. The upper layer is a weathered alluvial deposit primarily composed of loose sands and slits. These formations include diverse deposits formed from abundant calcium sea deposits .Exposed surfaces reveal light brown to yellow fractured limestone layered with tough clay and sandstone . The underlying sediments include blown sands from surface erosion, silt and clay deposits, beach deposits during the presence of the sea, and calcium marine sediments forming layer is a historical backfill below the foundation level; this layer is a weak soil and contains the wide voids inside it, which causes the drilling fluid to leak horizontally, carrying with it part of the soil, [14] in addition to its weakness in bearing the pressure of pouring concrete during implementation, with the concrete leaking into the existing voids. In addition to the silty clay formations that appear below the historic backfill layer, the soil characteristics are explained in Section 4.4 in detail. Therefore, using granular piles is considered a suitable, safe, and economical alternative to transfer stresses to the appropriate foundation layer [15] [16]. Its importance in using environmentally friendly materials and reducing dependence on cement aligns with the sustainable development goals of Egypt’s Vision 2030 [15].

2.3. Soil and Granular Pile Properties

A thorough investigation into the soil profile at the Jawharat Al-Fustat residential project site was conducted through a combination of field and laboratory tests, using borehole tests and standard penetration tests (SPTs) [17], the “Egyptian Code of Practice for Foundation Design and Construction”, The study aimes to conduct a comprehensive analysis of soil factors at the site, by analyzing soil samples from 14 different Soil Boring, each 20 m deep. Fig.2 shows a plan for the location of the soil boring and how it was carried out from the site. After analysis and laboratory tests, the soil was classified into three layers. As in the survey report shown in **Error! Reference**

source not found., It was found that the first layer, with an average thickness of 11.75 m, consists of historical backfill consisting of limestone, fine gravel, sand, and silt, This layer is not suitable for foundation purposes. The second layer, with an average thickness of 3 meters, was identified as silty clay, with differences in the proportions of clay and silt across the different wells, indicating spatial heterogeneity .The third layer, below the level of approximately 20 m, was characterized as a layer of medium-strength limestone. Details of the underlying soil condition and soil characteristics are shown in Table 1. All sensors monitor the groundwater level.revealed that, the average groundwater level at the site is about (+30.5) with an average depth of about 6 m below the natural ground level. These results are crucial to understanding the site's hydrological conditions and potential water-related issues. The proposed foundation level was considered, which is proportional to the road level of about (+31.85), and the basement level should be (+34.60) to allow the construction of a basement and the installation of utilities. This level is located in the backfill layer, and the next suitable layer for the foundation is the limestone layer that follows the consolidated clay layer. Based on geotechnical data and analysis of soil properties, the type of proposed foundation was determined, and the structures and their effective loads on the soil were studied ,as shown in **Error! Reference source not found.** .

Fig.2. Plan of boring locations and implementation of borings in the site .

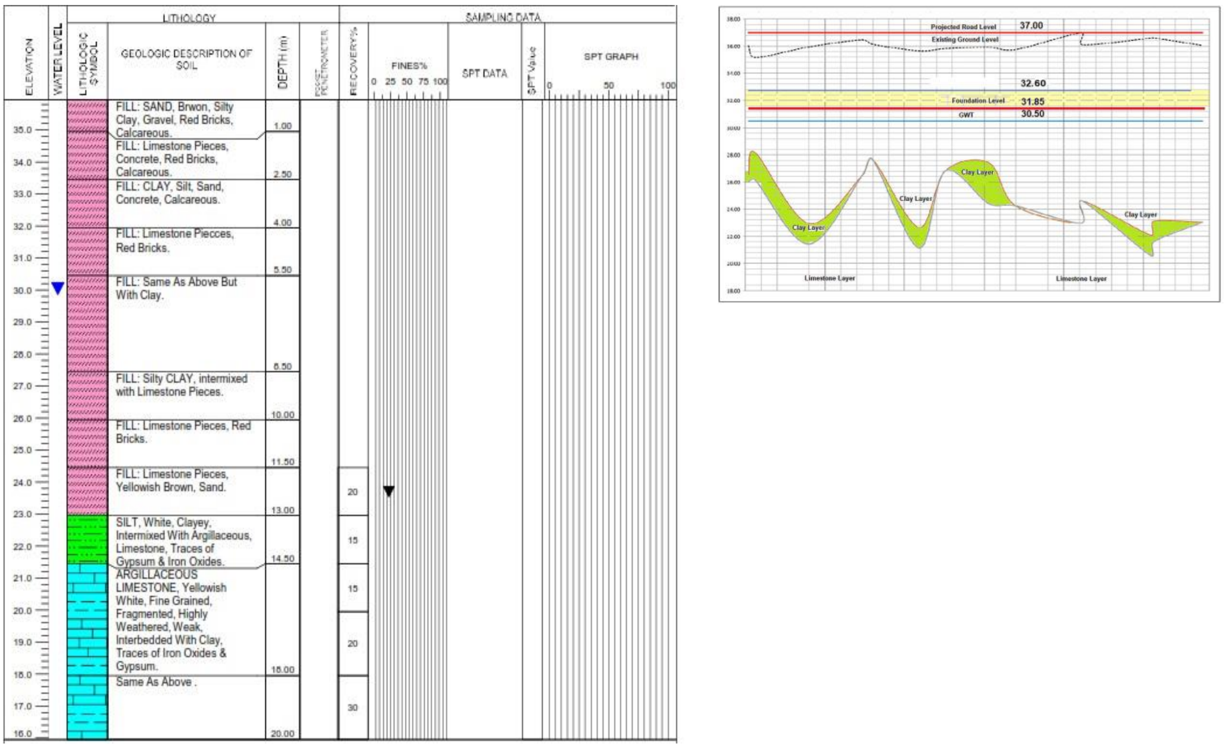


Fig.3. Sample of borehole logging record.

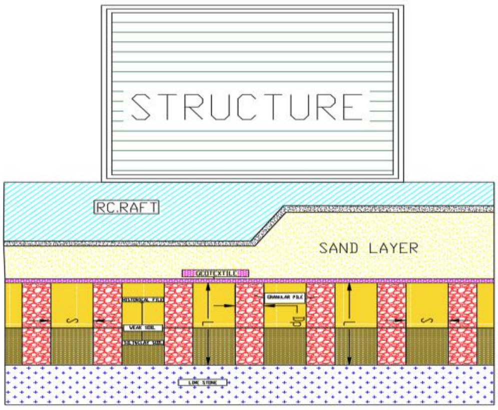


Fig.4. Layers of soils in site and simulation of sample building.

Table 1 Parameters soil and granular pile

Parameter	Symbol	Units		Soil Layers		
			Granular pile	Backfill	Silty &clay	Limestone
Material model	Type		Mohr-Coulomb			
Condition	Condition		Drained	Drained	Drained	Un drained
Wet soil unit weight	γ wet,	kN/m3	23	11	12	21
Sat soil unit weight	γ sat	kN/m3	24	12	13	22
Poisson's ratio	υ (-)	-	0.3	0.3	0.35	0.3
Liquid limit	L.L	(%)	-	-	23.68	-
Plastic limit	PL	(%)	-	-	3.11	-
Plasticity index	Ip	(%)	-	-	20.57	-
Water content	wc	(%)	-	-	16.41	-
Cohesion	C	(kPa)	0	3	2	.5
Friction angle	φ °	(Deg)	45	26	25	30
Dilatancy angle	ψ°	(Deg)	10	0	0.25	6
Young's modulus	E50	(kPa)	190000	20000	15000	75000

2.4. Granular pile construction

Granular piles were positioned beneath the structure's foundations in an equilateral triangular arrangement,and Installed using the Vibro-Replacement (wet top feed method) with pressurized water injection is a widely employed technique for installing granular piles. Figure 5 illustrates the distribution method of granular piles, indicating their diameters and the distances between them; the stone columns with an average depth of H =10.0 m, a diameter of 1.0 m, and a spacing of 2.0 m. These parameters were determined based on the permissible stress and the induced settlement. The unit cell concept associates tributary soil surrounding each granular pile with the column. This results in replacement ratios estimated at approximately 35.5% of the weak soil **Fig.5**. recommended sand layer with a thickness of 0.75 meters and 1.20 meters is placed under the raft foundation to distribute the stresses. The stone columns begin directly below this cushion layer. The piles must extend to the bottom layer of stone. The piles should extend down to the lower limestone layer, considered a bearing layer, until refusal is determined by the type of equipment used, such as pneumatic vibrators.

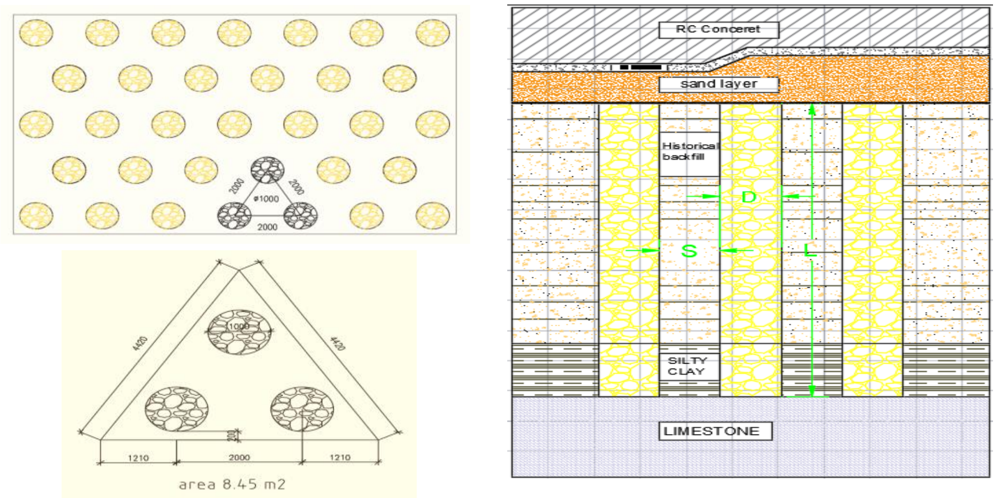


Fig.5. Granule pile distribution map and the triangular distribution pattern.

2.4.1. Stages of constructing replacement Granule pile wet method of feeding from above:

I. The first step : is preparing the site for installing the stone columns, excavating the site, and preparing materials.

II. The second step : The vibrator penetrates the weak soil to the design depth under the action of vibrations of compressed air, and drop lever facility at the required depth; the stone is released and compressed by small up and down movement of the vibrator, the downward pull is used in the downward compaction process. With stone added to the system where necessary at any stage of the construction procedure, a granular pile of very high integrity is constructed tightly interwoven with the surrounding soil up to ground level.

III. The third step : is to carry out the plate load test , placing the geotextile layer, making the sand layer and compaction process, regular Casting concrete, and the rest of the construction work.

a b c d

Fig.6. I. The first step The Granule pile construction steps(a) (Google Earth) for the project, (b) The general location of the project, (c) Preparing the site for the level of installation stone columns, (d) Excavation of the site and preparation of materials.

e f g h

Fig.7. The second step:(e) Establishing the equipment and beginning construction work, (f) The resistance stage and reaching the foundation layer, (g) Filling stone materials inside the pits, (h) Compacting stone materials and leveling the surface.

i j k

Fig.8. The third step : (i) Making the geotextile layer, (j) Sand layer and compaction process, (k) Regular concrete and the rest of the construction work began.

3. Assessment of Settlement Before and After using the Granular Pile Foundations System:

General

This paper presents settlement forecasts for the granular pile technique used to improve weak soils The comparison between settlement expectations was made using the analytical method [20] and field testing. In contrast, the finite element model method (praxis 3D) was used in addition to the rate of soil improvement after using stone columns.

3.2 The Experimental Program and Calculation.

Loading is executed on a complete triangle array using two jacks to ensure even stress distribution [18]. The load is applied incrementally, with each increment maintained for 15 minutes before adding the new load. The load is maintained for 12 hours at the working load, ensuring the settlement rate does not exceed 0.05 mm per hour. Subsequently, loading continues up to 200% of the working load at the same rate load. Upon reaching the final load, it is maintained for 12 hours, and the settlement rate should not exceed 0.05 mm per hour. Unloading is conducted in five equal increments, with each load maintained for at least five minutes. The contractor must present details about the loading devices, dead weight arrangement, and accuracy of readings based on their available readings of the dial gauge, as shown in Fig.9 . This illustrates the variation in settlement values over time under different loading conditions, as shown in Fig.10. It demonstrates how different loading cases impact the settlement behavior of the soil before and after soil improvement.Fig.11 depicts the relationship between settlement values and the applied load during loading. It showcases how changes in the magnitude of the applied load influence the corresponding settlement, highlighting the load-settlement relationship during the loading and unloading process.

Fig.9. Details about the loading devices and sample of readings of the dial gauge .

3.1. Analytical method

The settlement of soil layers was calculated using the Terzaghi method. "Terzaghi's one-dimensional consolidation theory as the presented equation “ [19] is employed for calculating soil settlement utilizing the theory of time-dependent loading.

$$S=Mv*\Delta\sigma*H \qquad \text{Equation 1}$$

This equation enables the computation of settlement (S) when the soil undergoes external pressure ($\Delta\sigma'$) at a specific depth (H), modulus of volume change (mv). By utilizing this equation, the anticipated settlement of the soil under the influence of external loads can be estimated. To calculate the total settlement (S total) for a foundation on multiple soil layers, you would typically sum up the settlements of each layer. The settlement underneath the raft of the unreinforced soil under stresses 125 kPa is estimated to be about 57.84 mm. The settlement obtained from this run represents the settlement of the upper layers. The disparity between these values indicates the settlement of the upper layers. It has been observed that the settlement of the upper layers constitutes roughly 90% of the total settlement, rendering the settlement of the lower layers negligible.

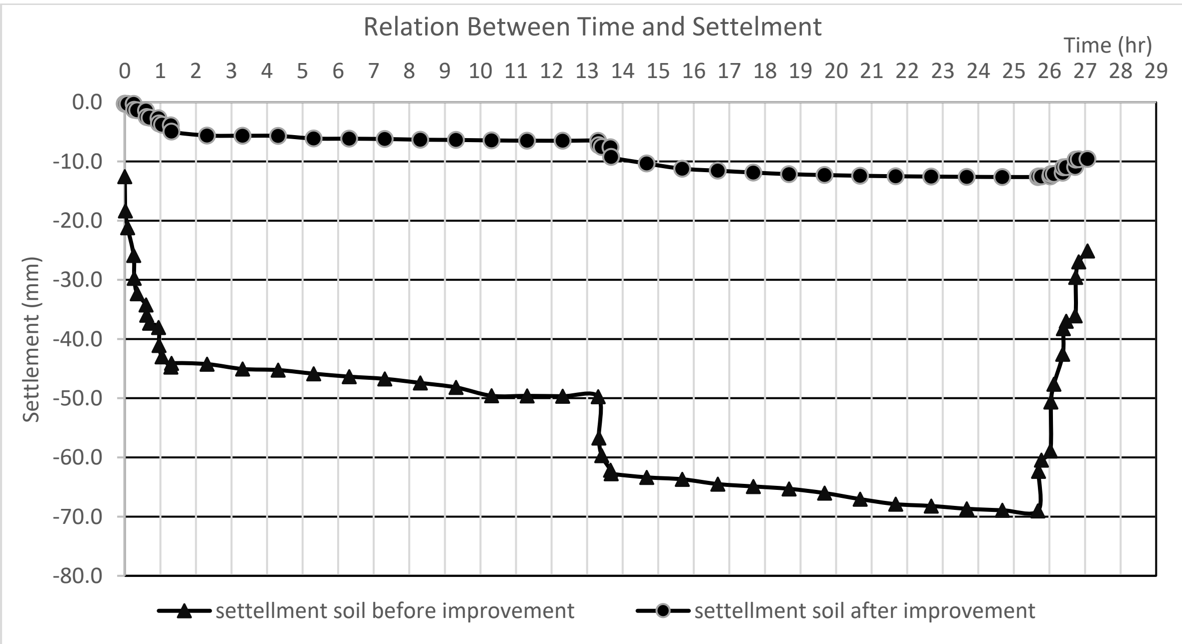


Fig.10. Time & Settlement relationship for soil and granular pile from the field test.

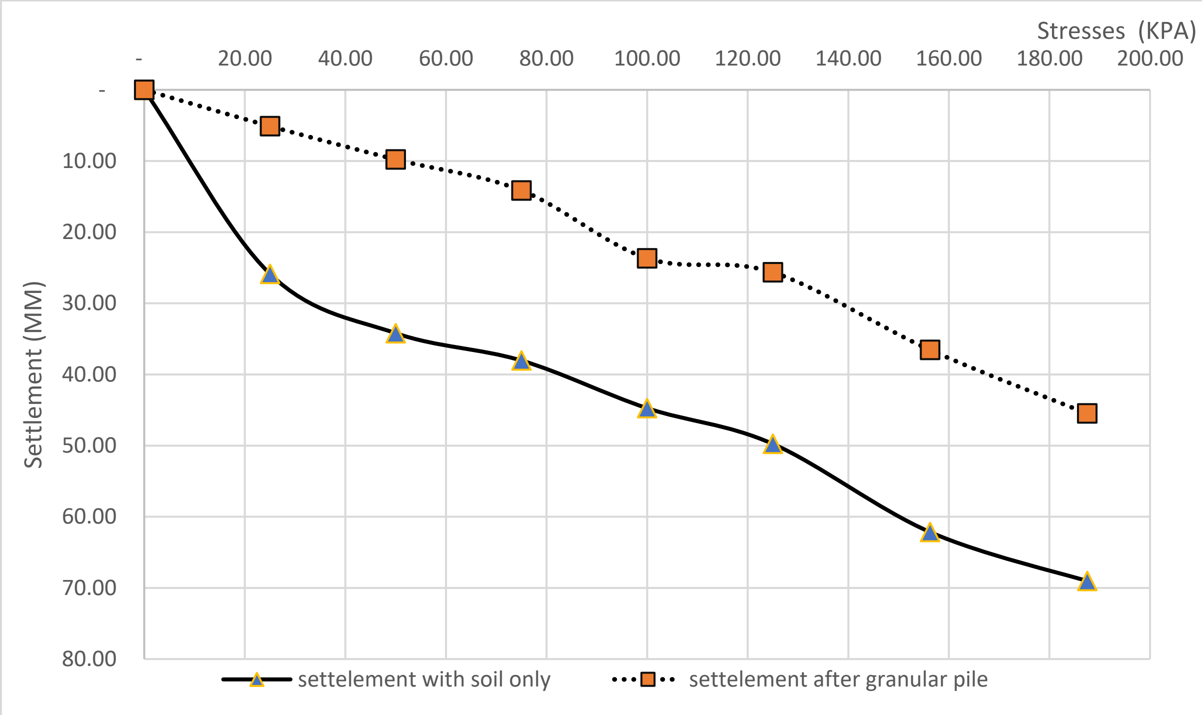


Fig.11. Stresses & Settlement relationship for soil from field test before and after construction of granular pile.

$$n0 = 1 + \frac{Ac}{A}\left[\frac{5-\frac{Ac}{A}}{4Kac\left(1-\frac{Ac}{A}\right)} - \right] \qquad \text{Equation 1}$$

where n0 =improvement factor, Ac = granular pile area, A = grid area, Kac = coefficient of active earth pressure for column material, ϕC = friction angle of the granular material.

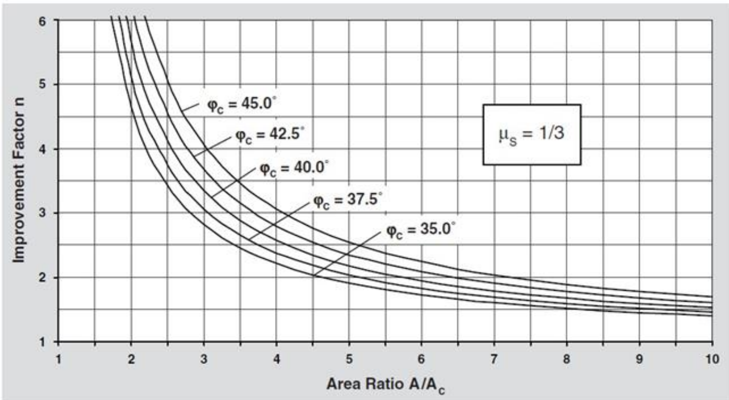


Fig.12. chart (Priebe, 1995)

The adjusted settlement for the upper layers, reinforced by stone columns, is determined using design charts Fig.12, developed by the US Department of Transportation – Federal Highway Administratio In using the method proposed by Priebe method (1995) [20]. the settlement of the layer reinforced by stone columns (as computed from elastic theory) undergoes reduction through the improvement factor from treated (Streated) to untreated (Suntreated) about n0 ≈ 1.89. This value is calculated according to the relationship between the improvement factor n0, the reciprocal area ratio A/AC = 7.76 and the friction angle of the granular pile material ϕC=45.0 .

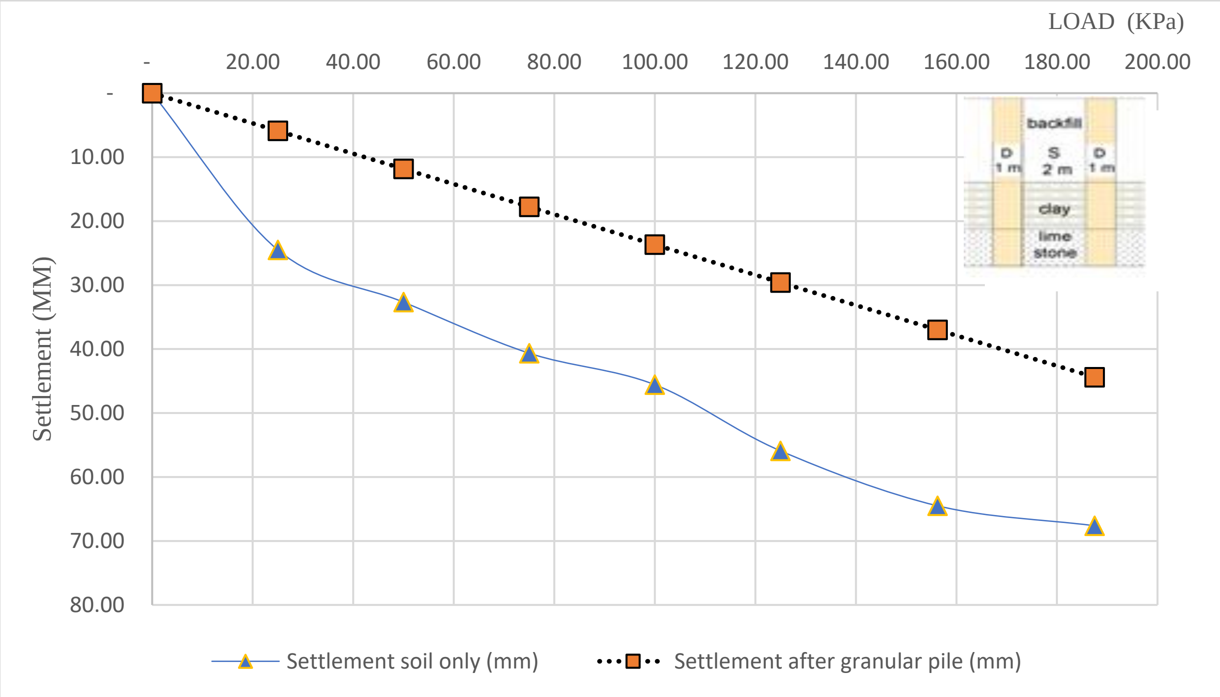


Fig.13. Stresses & Settlement relationship for soil from Analytical calculation before and after construction of granular pile.

3.2. Numerical Analysis

This research employed a three-dimensional nonlinear finite element (FE) model to investigate soil behavior, utilizing the properties outlined in Table 1. The study aimed to assess the impact of incorporating granular piles on soil behavior. The FE model was meticulously designed to accurately represent the available data and simulate the complex interactions within the soil-pile system. The various construction phases were simulated through the phased analysis option. Finite element analyses were performed using the general-purpose finite element software PLAXIS 3D. As shown in Fig.14, the soil layers were modeled using the Mohr-Coulomb elastic plasticity model, while the foundation was designed to be linear elastic. Solid elements were used to model the soil layers and their foundations (granular pile and raft of structure) .

The complete 3D finite element model of the vertical loading soil settlement problem before the soil improvement with stone columns, and Fig.15 after the improvement process with stone columns under a uniform load of 125 kPa in and the results are shown in table 2 providing insight into the effects of the improvement process on the behavior of soil and model structure. The finite element software PLAXIS 3D is a well-established tool for performing geotechnical analyses, and its use in this study ensures the reliability and accuracy of the numerical simulations. Settlement patterns were compared before and after the improvement, which contributes to a better understanding of the general impact of the improvement process on soil structure.

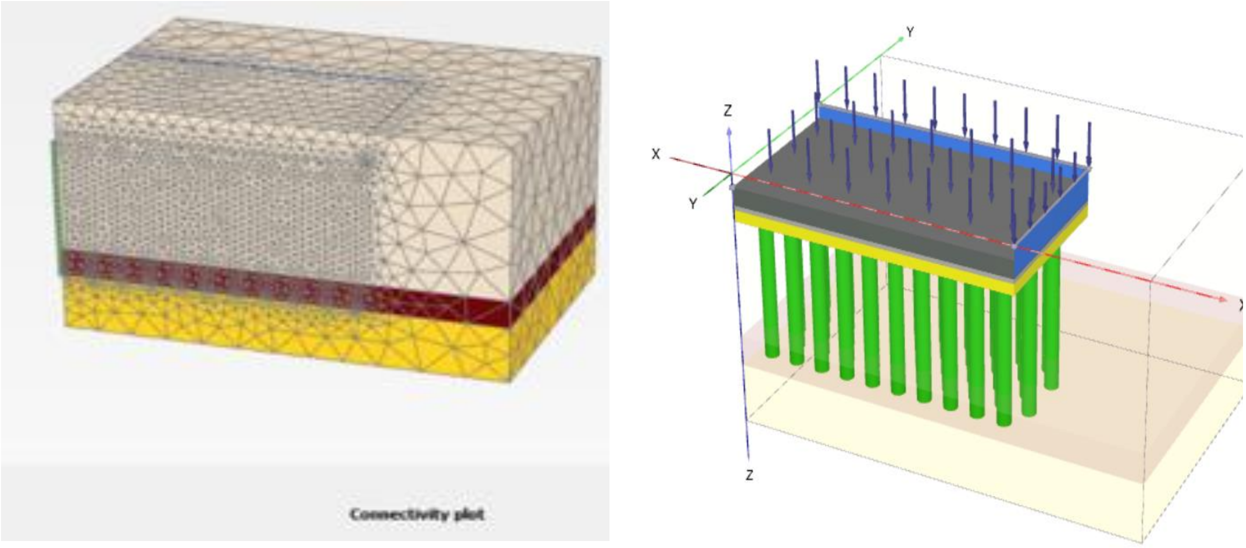
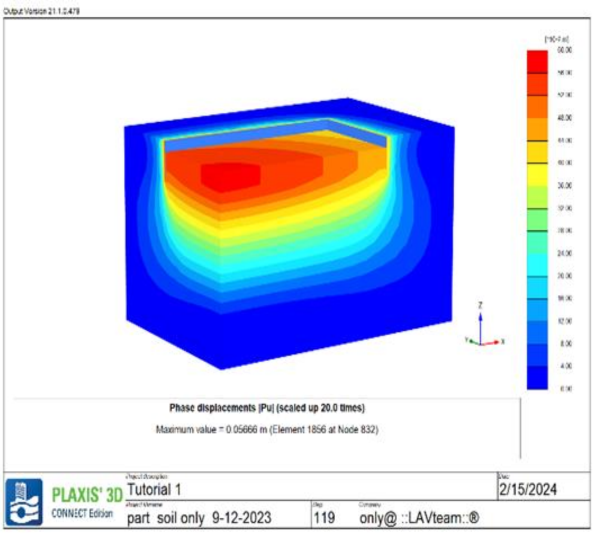


Fig.14 .Model and structure in Plaxis 3D.

3.2.1. Results and discussion.

After conducting a simulation to assess the soil conditions at the site both before and after implementing soil improvement measures, the PLAXIS 3D software was employed. The simulation utilized the parameters and dimensions outlined in Table 1, ensuring accuracy and consistency in the analysis. Various loading conditions corresponding to the specific loading values of the site were applied during the simulation. The simulation results revealed distinct settlement values for each loading case outlined in Table 2 These settlement values serve as indicators of the soil's improvement measures in mitigating settlement issues. Figure 17 represents these settlement values, highlighting the variations across different loading conditions. The comprehensive analysis provides valuable insights into the behavior of the site's soil under various loading scenarios and demonstrates the impact of soil improvement techniques on reducing settlement.



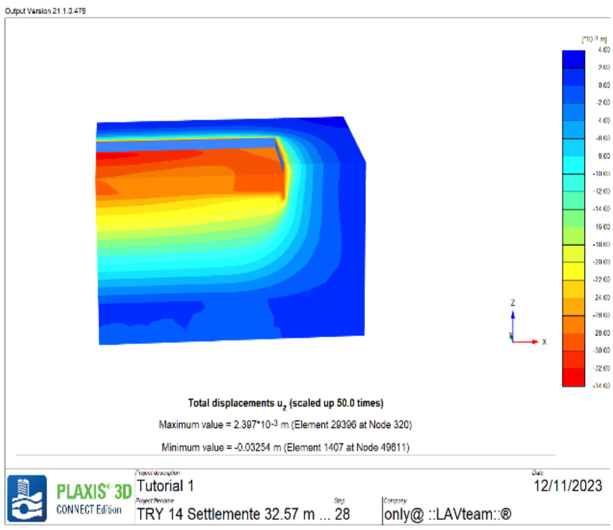


Fig.15. Settlement (mm)Soil before Improvement

Fig.16. Settlement (mm)Soil after improvement

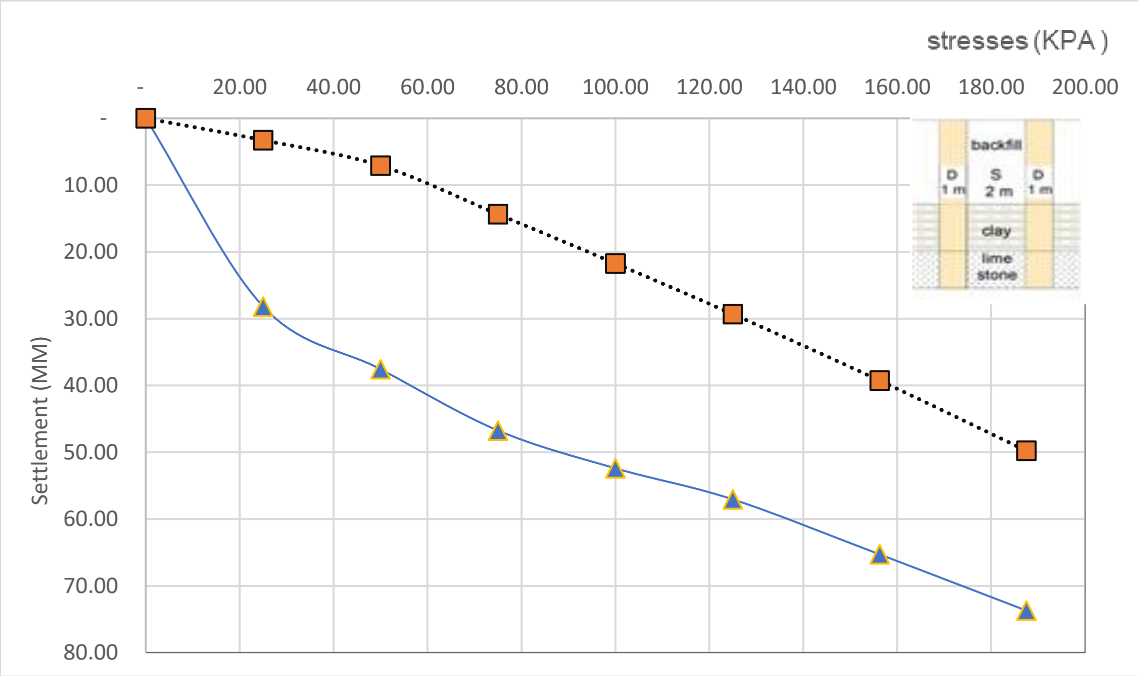


Fig.17. Relation between load and settlement Plaxis 3D before & after improvement soil.

Table 2 values of settlement for soil only and soil with granular pile length:

Method	Settlement (mm)Soil before improvement	Settlement (mm)Soil after improvement	RELATIONSHIP		Ratio of Improvement
ANALYTICAL	61.43	32.5	Sf= .8 SA		%89
Field	49.76	25.65		Sf= .87 SP	%94
PLAXIS 3D	57.05	29.32			%95

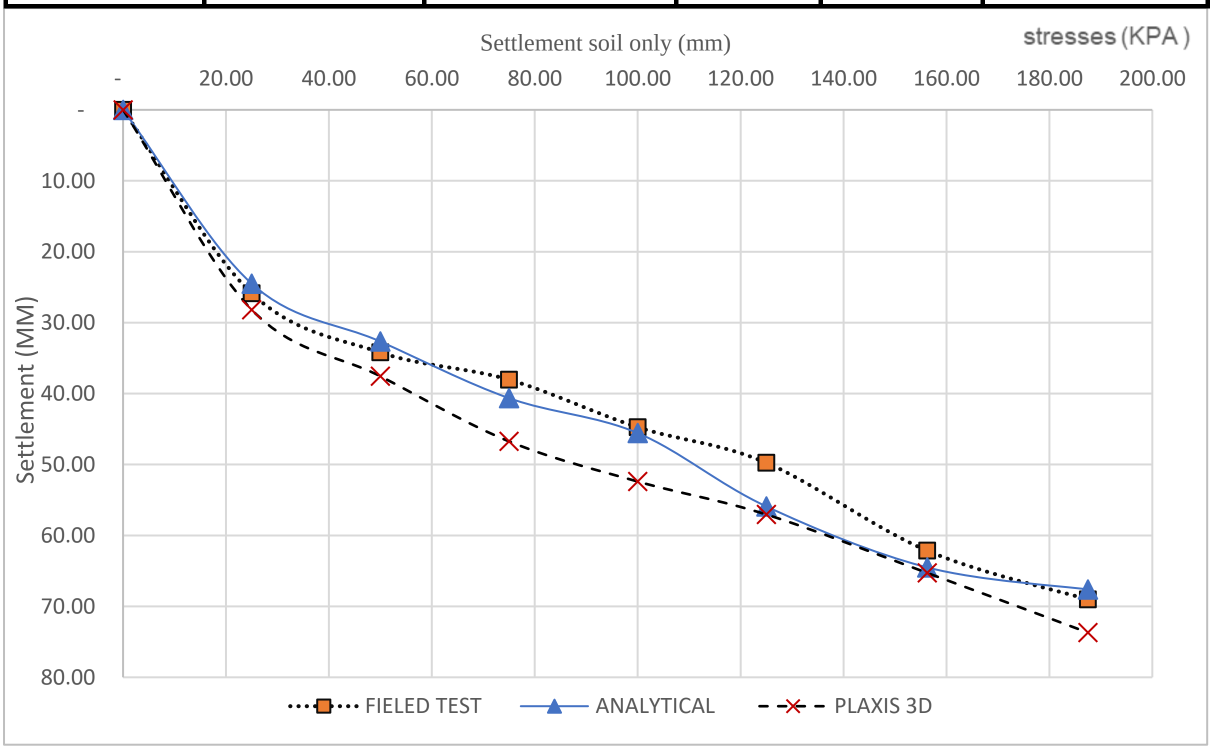


Fig.18. Vertical displacement results for natural soil from Field tests, analytical calculation, and numerical analysis

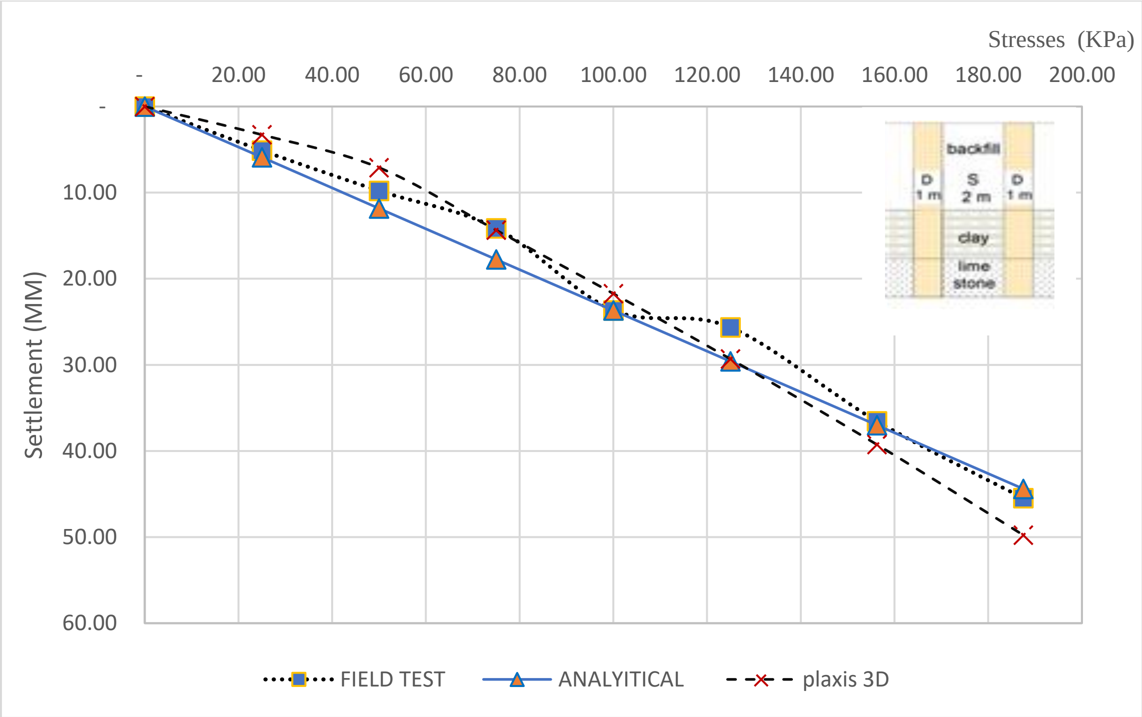


Fig.19. Vertical displacement results for soil improved by granular pile from Field test, analytical calculation, and numerical analysis

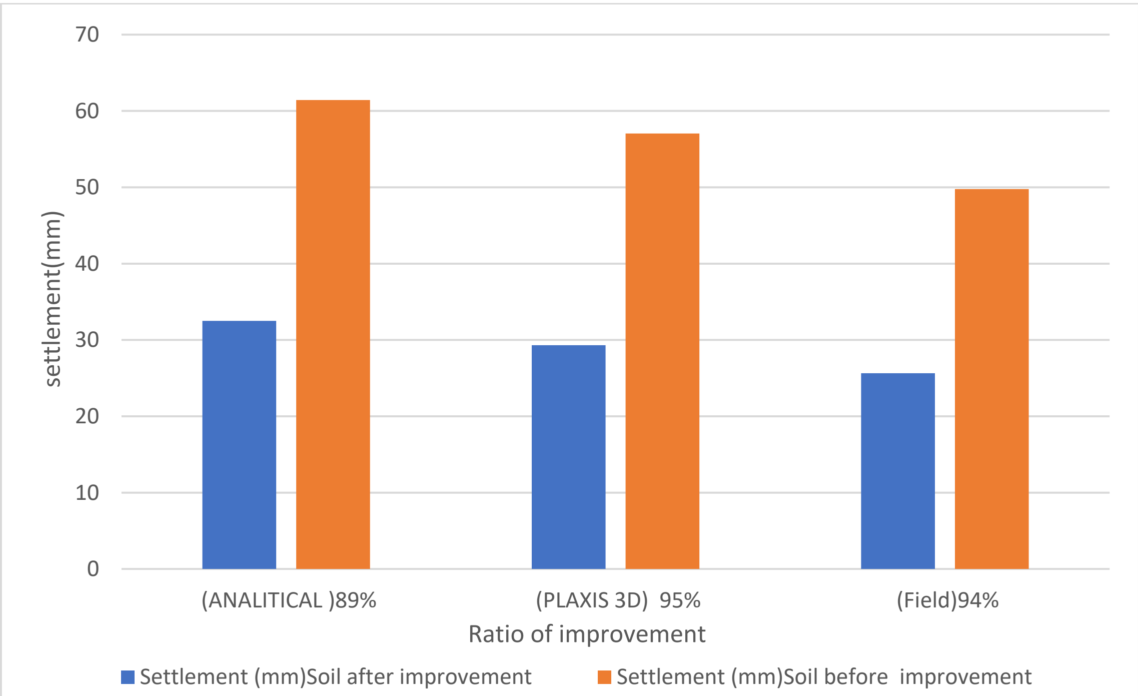


Fig.20. Ratio of Improvement difference in settlement values before and after soil improvement at load 125 kpa

4. Discussion the Results

The settlement analysis for the foundation of the 11-story residential building, considering various methods and conditions, provides significant insights into the effectiveness of soil improvement using granular piles. As illustrated in Fig. (16) analytical results indicate that, the settlement for soil only is 61.43 mm, reduces to 32.54 mm after the incorporation of granular piles, yielding an improvement ratio of 89%. Field measurements show a settlement of 49.76 mm for soil only, which decreases to 25.65 mm with granular piles, resulting in an improvement ratio of 94%. These field results show that the settlement is approximately 0.8 times the analytical settlement, likely due to field conditions and measurement accuracy. The PLAXIS 3D simulation results show a settlement of 57.05 mm for soil only and 29.32 mm with granular piles, achieving an improvement ratio of 95%. The field settlement is about 0.87 times the settlement predicted by PLAXIS, indicating that the simulation results are slightly more conservative. This consistency across analytical, field, and simulation results highlights the reliability of the granular pile method in reducing settlement.

5. Conclusions

The results indicate a consistent trend across different analysis methods: using a granular pile with a length 10 m diameter 1 m leads to a significant reduction in settlement compared to soil-only conditions. This suggests that adding granular piles enhances the load-bearing capacity or stability of the soil system, resulting in less settlement under applied loads.

Granular pile technology proved to be a swift, cost-effective, and efficient method for improving soft ground, owing to the soil conditions at the site.

Adherence to high-quality construction practices during stone pile installation, coupled with the utilization of appropriate equipment, ensured a high level of efficacy in soil improvement.

Comparative Analysis:

- Improvement rates are 89% (analytical), 94% (field), and 95% (PLAXIS 3D).
- Field results show slightly lower initial settlements but consistent improvement rates.
- PLAXIS 3D simulations align well with analytical and field results, confirming model reliability.

Pile Diameter and Spacing:

Piles with a larger diameter (1 meter) are more effective in reducing settlement than piles with a diameter of 0.8 meters. Reducing the spacing between the piles decreases settlement; however, piles with a 1-meter diameter show a decrease of 10.98% when the spacing is reduced from 2 meters to 1.75 meters. Nevertheless, choosing a spacing of 2 meters between the piles is the best solution from an economic standpoint.

The consistency of the results across different analysis methods, including mathematical methods and the finite element method (PLAXIS 3D), particularly when compared to field measurements, adds validity to the findings. This suggests that the benefits of using granular.

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