Comprehensive Analysis of Soil Characteristics by Using Geo5 Software

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***Abstract*—Geotechnical engineering design requires accurate analysis of soil behaviour and foundation performance to ensure structural safety and serviceability. Traditional manual calculations are time consuming and may not fully capture soil–structure interaction. In this study, GEO5 software is used to analyze important geotechnical engineering problems including spread footing, pile foundation, slope stability, and settlement analysis. The software allows engineers to input soil parameters, load conditions, and geometry of structures to obtain reliable results such as bearing capacity, settlement values, stress distribution, and factor of safety. The results obtained from GEO5 are compared with theoretical concepts to evaluate accuracy and effectiveness. The study demonstrates that GEO5 software simplifies complex calculations and improves efficiency in geotechnical design. The analysis confirms that software-based modelling provides safe, economical, and optimized design solutions for civil engineering projects**

***Index Terms*—GEO5, soil characterization, geotechnical analysis, bearing capacity, settlement, soil-structure interaction, foundation design.**

I. INTRODUCTION

Geotechnical engineering plays a significant role in civil engineering projects because the behaviour of soil directly influences the stability and safety of structures. The safe design of foundations requires a clear understanding of soil parameters such as cohesion, angle of internal friction, unit weight, stress distribution, and bearing capacity characteristics. These parameters control the load transfer mechanism between the structure and the ground, thereby affecting the performance and durability of the foundation system.

In modern engineering practice, software tools are widely used to reduce manual calculation errors and improve the accuracy of design results. GEO5 is one of the most commonly used geotechnical engineering software packages that enables engineers to analyse soil–structure interaction using both analytical and numerical methods. The software provides reliable results for bearing capacity, load distribution, and reinforcement design, which helps engineers make safe and economical decisions.

In this study, spread footing and pile foundation are analysed using GEO5 software. Spread footing represents shallow foundation systems, while pile foundation represents deep foundation systems used when surface soil conditions are weak. The main objective of this work is to evaluate bearing capacity, load distribution behaviour, and structural safety of these foundation systems under different loading conditions.

The results obtained from GEO5 help in understanding the behaviour of soil under structural loads and support the selection of appropriate foundation type. The study demonstrates the importance of software-based analysis in improving design accuracy and ensuring safe and reliable foundation performance in civil engineering projects.

II. IMPORTANCE OF GEO5 SOFTWARE

- The software covers a wide range of geotechnical tasks by using different methods.
- As it contains international standards which includes vast methodologies suitable for global projects.
- It is important that it provides 3-D visualization to better understand the soil behaviour and structural interactions.
- As it provides accurate results, reduces the risk of errors and ensure safety of the project.

III. LITERATURE REVIEW

Several researchers have applied GEO5 software for foundation analysis. Previous studies indicate that software-based analysis improves design accuracy and reduces computational time.

Dudekula Naseer Baba and Nivedita (2025) used GEO5 software to analyze spread footing and pile foundations using soil parameters such as cohesion and unit weight. Their study concluded that GEO5 provides reliable results when compared with IS code calculations.

Prof. R. Y. Kale et al. (2025) explained that GEO5 software improves design efficiency by calculating vertical and horizontal bearing capacity under different load conditions. Their research shows that circular footing provides better bearing capacity compared to strip footing.

Nur Ayu Diana (2024) used GEO5 to analyze slope stability of rock cliffs using Bishop method. The study showed that slope reinforcement increased factor of safety from 1.15 to 2.07, ensuring structural safety.

Harish Kumar and Rama Krishna (2024) analyzed cantilever retaining wall design using Rankine and Coulomb earth pressure theories. Their research showed that GEO5 provides reliable results compared to manual calculations.

Amjeth Basheer and Amit Prashant (2021) used slope stability module to analyze canal failure in lateritic soil. The study concluded that rainfall and pore pressure significantly influence slope stability.

IV. METHODOLOGY

1. Introduction to GEO5

GEO5 is not a single tool but a collection of different modules, where each module is developed for a specific geotechnical problem such as bearing capacity, settlement

All programs or modules use the same basic user interface. The fundamental principle is to work with specific frames from top to bottom, the basic inputs are entered in input frames, then gradually moving on to the analysis frames to perform the various designs and verifications.

GEO5 programs are available in more than 20 languages. The output protocols can also be in different languages. Of course, local customization also applies to standards and norms.

The programs allow you to verify the design according to Eurocodes EN 1997, including national annexes, US Load and Resistance Factor Design (LRFD), Chinese GB Standards, Theory of Safety Factors (ASD), Theory of Limit States (LSD).

V. EXPREIMENTS

1. Spread Footing:

Spread footing is one of the most commonly used shallow foundation systems in civil engineering, designed to transfer structural loads safely to the soil at relatively shallow depth. It distributes the load over a larger area so that the contact pressure on the soil remains within the allowable bearing capacity, thereby preventing shear failure and excessive settlement.

Spread footing is generally used when the soil near the ground surface has sufficient strength and stiffness to support structural loads. The design of spread footing depends on soil parameters such as cohesion, angle of internal friction, unit weight of soil, and depth of foundation. The analysis of spread footing involves verification of bearing capacity, stress distribution, load eccentricity, and reinforcement requirements.

The bearing capacity of soil depends on cohesion, unit weight of soil, depth of foundation, and width of footing.

$$q_{ult} = cN_c + \gamma D_f N_q + 0.5\gamma B N_\gamma$$

where,

q_{ult} – Ultimate Bearing Capacity(kN/m²)

c– Cohesion of Soil(kN/m²)

N_c– Bearing Capacity Factor

γ– Unit Weight of Soil(kN/m³)

D_f– Depth of Foundation(m)

N_q– Bearing Capacity Factor

B– Width of Footing(m)

N_γ– Bearing Capacity Factor

Procedure:

Step 1: Project and User Management

➢ Click the Project tool in the frame and give details as given below:

Project: Spread Footing

Description: Analysis of Spread Footing

➢ Then click on settings set the verification methodology to Safety Factors (ASD) and Allowable eccentricity to 0.33.

Step 2: Soil Defining & Assigning

➢ Go to Profile and then click add. Now give the interface depth or thickness as per soil investigation report as shown in fig 1, say the thickness of each layer as 1 m.

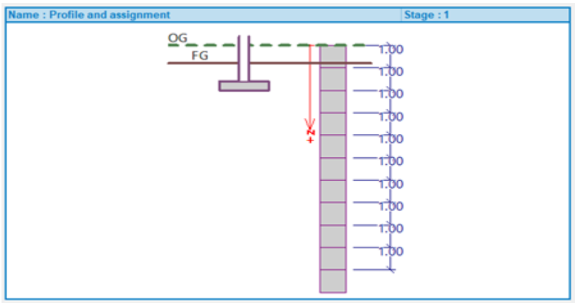


Fig 1: Interface of soil

➢ Now define the soil with the properties given in the soil investigation report and then assign to respective layer.

Step 3: Geometry & Structural Modelling

➢ Click on Foundation and give the type of foundation as centric spread footing with steps and give depth of footing from OG and FG as1.6 m and thickness as 0.45 m and move to SG bed and give thickness as 0.22 m and assign the soil layer as well graded gravel.

➢ Navigate to geometry tool and give the horizontal dimensions as shown in fig 2.

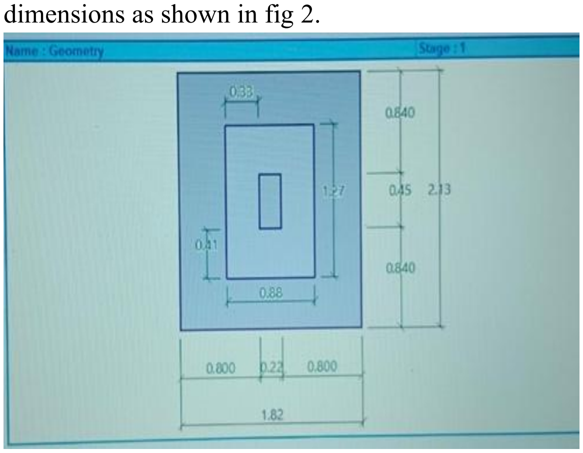


Fig 2: Geometry of Footing

Step 4: Load Assigning

➢ Now add different load combinations as design and service load as required and then assign to the soil.

➢ Click on material and select the concrete as M20 and longitudinal and traverse reinforcement as Fe 415.

➢ Now we have to assign the Ground Water Table as 2.55 m which is mentioned in soil investigation report.

➢ Now click on analysis tool to check the bearing capacities and settlements of the footing

Table 1: Load Combinations

No.	Load new	Load edit	Name	N [kN]	M_x [kNm]	M_y [kNm]	H_x [kN]	H_y [kN]	Type
1	Yes		Load No. 1	1208.00	0.00	0.00	0.00	0.00	Design
2	Yes		Load No. 2	805.00	0.00	0.00	0.00	0.00	Service
3	Yes		Load No. 3	635.00	0.00	0.00	0.00	0.00	Design
4	Yes		Load No. 4	423.00	0.00	0.00	0.00	0.00	Service
5	Yes		Load No. 5	348.00	0.00	0.00	0.00	0.00	Design
6	Yes		Load No. 6	232.00	0.00	0.00	0.00	0.00	Service

2. Pile Footing

A pile footing is a type of deep foundation used when the surface soil is too weak to support the weight of a heavy structure. It consists of long, slender columns called piles made of concrete, steel, or timber, which are driven or bored deep into the ground. These piles bypass the unstable upper soil layers to reach more competent, stiffer soil or solid bedrock below. By anchoring the building to these deeper strata, the foundation prevents excessive settlement and ensures the stability of high-rise buildings, bridges, and industrial facilities.

Structurally, the system is organized into two primary components: the individual piles and the pile cap. The pile cap is a thick slab of reinforced concrete that sits on top of a group of piles, acting as a platform to receive the load from the building's columns. This cap ensures that the massive vertical and horizontal forces from the superstructure are distributed evenly across all the piles in the group. Depending on the soil conditions, the piles work through end-bearing or friction to hold the weight.

The ultimate load carrying capacity of a pile is determined by the combined resistance developed at the base of the pile and along the surface of the pile shaft. The load transfer mechanism mainly depends on end bearing resistance and skin friction resistance offered by the surrounding soil.

$$Q_u = Q_b + Q_s$$

Where:

Q_u– Ultimate Load Carrying Capacity of Pile

Q_b– End Bearing Resistance

Q_s– Skin Friction Resistance

In the GEO5 software suite, pile footing design is primarily handled through three specialized modules Pile, Pile Group, and Pile CPT. The Pile module focuses on the vertical and horizontal bearing capacity and settlement of single piles, accounting for various technologies like bored, driven, or CFA piles, while the Pile Group module analyses a cluster of piles connected by a rigid cap (raft) to determine the

distribution of internal forces, settlement, and rotation. For sites where field data is available, the Pile CPT module utilizes results from Cone Penetration Tests to verify capacity directly from soil resistance data.
Procedure:

Step 1: Project and User Management

➢ Click the Project tool in the frame and give details as given below:
Project: Pile Foundation
Description: Analysis of Pile foundation

➢ Then click on settings set the verification methodology to Safety Factors (ASD) and Allowable eccentricity to 0.33.

Step 2: Soil Defining & Assigning

➢ Go to Profile and then click add. Now give the interface depth or thickness as per soil investigation report say the depth of the layer is taken as 20 m.

➢ Click on soil tool and then add now define the soil with the data given in soil investigation report

➢ Now assign the soil with the respective layer which had the parameters defined in soil investigation report.

Step 3: Geometry & Structural Modelling

➢ Click on Structure and give width of the pile cap along x, y directions, number of piles along x, y direction, diameter of the pile and the spacing between the piles in both the directions.

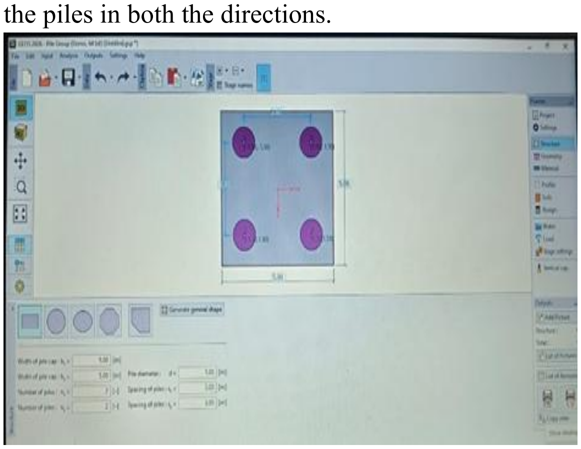


Fig 3: Structure of the Pile Group

➢ Navigate to geometry and give the necessary details like thickness of the pile cap, length of the pile, pile offset and depth from ground surface. Now click on material tool and assign the material properties like grade of concrete as M 20, reinforcement both in longitudinal and traverse as Fe 415.

Fig 4: Geometry and Material of the Pile Group

Step 4: Load Assigning

➢ Now add different load combinations as design and service load

➢ Now click on analysis tool to check the bearing capacities and settlements

Table 2: Load Combinations

Number	Load		Name	N	Mx	My	Hx	Hy	Mz	TYPE
	New	Edit		[kN]	[kNm]	[kNm]	[kN]	[kN]	[kNm]	
1	Yes		Load No.	2500	0	480	310	0	0	Design
2	Yes		Load No.	2000	0	320	240	0	0	Service

VI. RESULTS

I. SPREAD FOOTING

1. Bearing Capacity

As a result, the vertical and horizontal bearing capacity of the spread footing was checked using GEO5. From the figure 5, the maximum contact pressure is 264.72 Kpa which is less than the design bearing capacity of soil 408.32 Kpa, resulting in a factor of safety of 1.54, which satisfies the minimum requirement. Hence, the footing is safe against bearing capacity failure. Also, from the figure 6, the horizontal bearing capacity is satisfactory due to 0 kN Horizontal load as shown in figure 6. Hence, the footing is safe in both the directions.

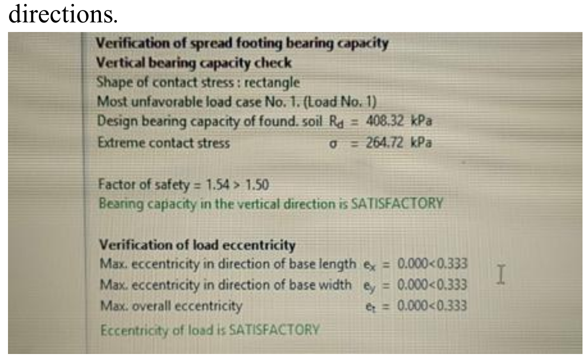


Fig 5: Bearing Capacity along Vertical Direction and Eccentricity

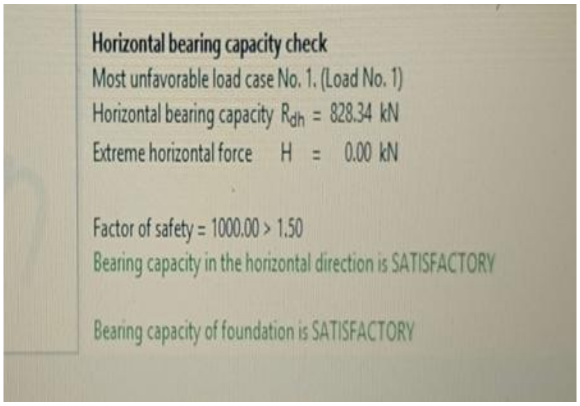


Fig 6: Bearing Capacity along Horizontal Direction

2. Eccentricity Check

From the figure 5, the eccentricities in both directions (ex, ey) and overall eccentricity (et) are zero and well within the permissible limit (B/6). This confirms that the load is applied centrally and the soil pressure remains compressive over the entire footing area.

3. Settlement Analysis

From the figure 7, the computed settlement of the footing is 22.6 mm, which lies within allowable limits for isolated footings. No rotation was observed in either direction, indicating uniform settlement and stable foundation behaviour as shown in figure 7.

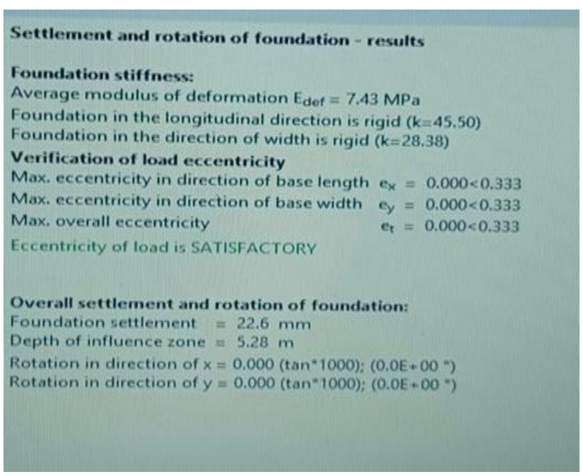


Fig 7: Settlement and Rotation of Spread Footing

4. Structural Design of Footing

The footing reinforcement was designed and verified for flexure. In the x-direction, the provided reinforcement in figure 8, satisfies both minimum reinforcement and moment capacity requirements. In the y-direction, reinforcement is not required as the offset is smaller than the footing thickness.

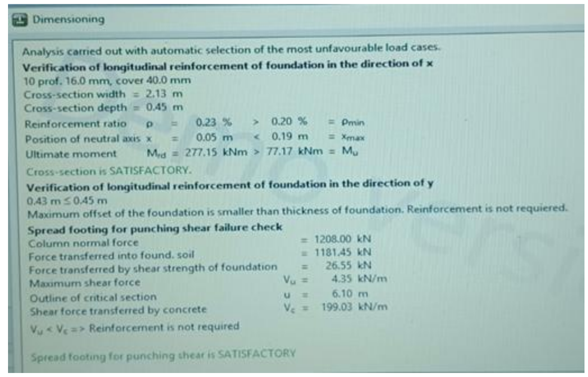


Fig 8: Dimensioning of Spread Footing

5. Punching shear check

Punching shear was verified at the critical section. The applied shear force as shown in figure 9 is 4.35 kN/m is much lower than the concrete shear resistance 199.03kN/m. Hence no punching shear reinforcement is required for the footing.

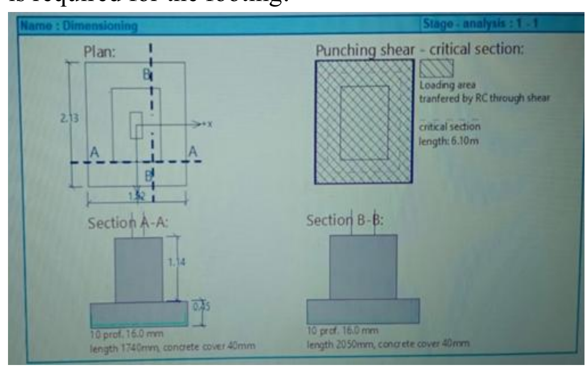


Fig 9: Reinforcement Details of Spread Footing

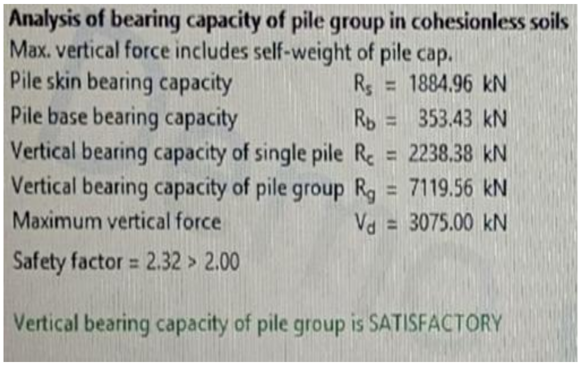
II. PILE GROUP

1. Bearing Capacity

The bearing capacity analysis of a pile group foundation carried out using GEO5 software. The calculated skin friction resistance (Rs) is 1884.96 kN, while the base bearing resistance (Rb) is 353.43 kN which is shown in figure 10. The combined ultimate vertical bearing capacity of a single pile (Rc) is obtained as 2238.38 kN. For the pile group given in figure 10, the total vertical bearing capacity (Rg) is calculated as 7119.56 kN.

The maximum applied vertical load (Vd**)** acting on the pile group is 3075.00 kN, which is significantly lower than the available pile group capacity. The resulting factor of safety is 2.32, which exceeds the minimum recommended value of 2.0.

Hence, the vertical bearing capacity of the pile group is satisfactory


Analysis of bearing capacity of pile group in cohesionless soils
Max. vertical force includes self-weight of pile cap.

Pile skin bearing capacity	R_s = 1884.96 kN
Pile base bearing capacity	R_b = 353.43 kN
Vertical bearing capacity of single pile	R_c = 2238.38 kN
Vertical bearing capacity of pile group	R_g = 7119.56 kN
Maximum vertical force	V_d = 3075.00 kN

Safety factor = 2.32 > 2.00

Vertical bearing capacity of pile group is SATISFACTORY

Fig 10: Analysis of Bearing Capacity of Pile Foundation

2. Load–Settlement Curve of Pile Group

The load–settlement curve is shown in figure 11, obtained from GEO5 illustrates the relationship between applied vertical load and corresponding settlement of the pile group foundation. The horizontal axis represents the applied load in kN while the vertical axis represents settlement in mm.

Initially, the curve shows a gradual increase in settlement with increasing load, indicating elastic behaviour of the soil. As the load increases further, the settlement rate becomes higher, representing nonlinear soil behaviour due to mobilization of skin friction and base resistance.

At the design load level, the observed settlement is approximately 25.4 mm which is shown in figure 32, is less than the maximum permissible settlement of 30 mm. The total resistance mobilized by the pile group is 8033.52 kN, indicating adequate reserve capacity beyond the applied load.

Thus, the load–settlement curve in figure 11, confirms that the pile group foundation satisfies serviceability limit state requirements and that soil deformability is within acceptable limits.

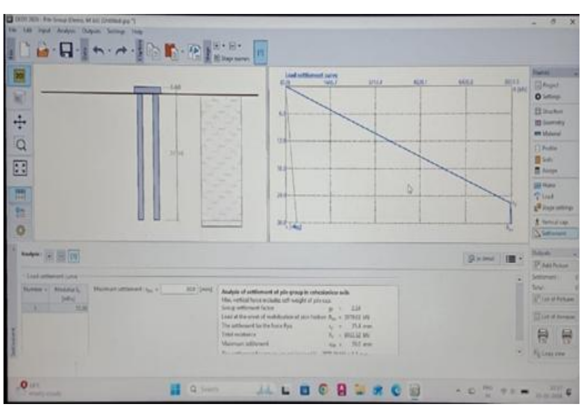


Fig 11: Load – Settlement Curve

V. CONCLUSION

- The geotechnical analysis is carried out using GEO5 software, helped to evaluate the performance of spread footing, pile foundation, slope stability, and settlement behaviour under the given soil conditions.
- The spread footing analysis confirmed that the design vertical bearing capacity i.e., 408.32 kPa developed which is less than the allowable soil bearing capacity and the factor of safety 1.54 satisfies the design factor of safety 1.5.
- Settlement and eccentricity checks are done which gives the overall settlements of 22.6 mm indicates uniform load distribution without excessive deformation or rotation of the spread footing.
- The pile group analysis shows that the available pile group capacity i.e., 7119.6 kN is significantly greater than the applied structural load (3075 kN), which ensuring safe load transformation.
- The load–settlement behaviour of the pile group indicates settlement 25.4 mm which is within the permissible limits and stable soil response Overall, the analysis confirms that the soil conditions and designed foundation systems are safe, stable, and suitable for supporting the applied structural loads.

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