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Determination of Safe Bearing Capacity of Soil Using is Code, Terzaghi's Method and Geo5 Software as Per Indian, British and European Standards

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Abstract

This study investigates the bearing capacity of soil, a crucial parameter in foundation design, using the Geo5 software. Accurate bearing capacity determination is essential for ensuring the stability and safety of structures. This research explores various established theoretical approaches for calculating bearing capacity, including IS Code, Terzaghi's method, and compares their results with numerical solutions obtained from Geo5 as per Indian, British, and European Standards. The study analyzes the influence of key soil parameters, such as cohesion, angle of internal friction, and unit weight, and foundation geometry, including shape, size, and depth, on the ultimate bearing capacity. Furthermore, the research evaluates the applicability and accuracy of Geo5 in simulating complex geotechnical scenarios. A real-world case study, involving a specific foundation design and soil profile, is analyzed using Geo5 to demonstrate the practical utility of the software in geotechnical engineering practice. The comparison between theoretical and numerical results provides insights into the strengths and limitations of both approaches, highlighting the importance of considering various factors and methodologies in bearing capacity analysis. The findings of this project contribute to a better understanding of soil behavior under foundation loads and provide valuable guidance for geotechnical engineers in designing safe and economical foundations.

Keywords: GEO5 Software, IS Code, Terzaghi's, Bearing Capacity, Soil Parameters, Etc

1. INTRODUCTION

Soil is a universally available natural material derived mostly from rocks and rocky minerals. As soil is a product of nature possess an inherently variable and complex character. The bearing capacity is the most important soil property which governs the design of foundation. Soft clay strata are often unable to bear the load transferred from the super structure to the foundation Bearing capacity and the settlement are the two important parameters in the field of geotechnical engineering. Civil engineering projects such as buildings, bridges dams and roadways require detailed subsurface information as part of the design process. Bearing capacity is affected by various factors like change in level of water table eccentric loads, inclined loads dimensions of the footing etc. Terzaghi proposed the first comprehensive bearing capacity analysis for the case of strip footing with rough base for a frictional cohesive soil using limit equilibrium method. The initial contributions in this area were also made by Prandtl. Prandtl obtained analytical closed form solutions for ultimate bearing pressure for the case of a strip footing on weightless semi-infinite space. This analysis is applicable to frictional cohesive soil and to a purely cohesive soil. Meyerhoff used limit equilibrium method for the evaluation of ultimate bearing capacity of shallow foundation with rough base for a c-Øsoil. Chen used limit analysis approach and employed Prandtl and Hill mechanism for the evaluation of bearing capacity factors for rough and smooth footings respectively. Finite element analysis has been used by different investigators in conjunction with plasticity theory, to predict bearing capacity of strip footings. Many investigators attributed the beneficial changes in properties of soil and increase in the load carrying capacity of the soil by various methods like compaction, preloading, grouting, densification using vibratory equipment, using in situ reinforcement, using geotextiles, chemical stabilization etc.

2. LITERATURE REVIEW

M.S. Dixit & K.A. Patil (2009) Studied the effects of various parameters on soil bearing capacity, analyzing different foundation depths and footing shapes. Their research found that bearing capacity increases with foundation depth and width, with square and circular footings performing better than strip and rectangular ones. The study also highlighted the significant impact of water table variations, especially on non-cohesive soils. Comparisons between Terzaghi's method and IS code calculations provided insights into soil behavior under different conditions.

M. S. Dixit and Dr. K. A. Patil (2012) The study examined the effect of footing depth and water table on the bearing capacity of clayey soil collected from Aurangabad Airport. Laboratory tests analyzed soil properties such as cohesion, angle of internal friction, and compaction characteristics. Results showed that increasing footing depth increased safe bearing capacity by 11.76% to 34.51%, while a rising water table reduced it by 8.45% to 29.43%. The study concluded that footing depth significantly enhances bearing capacity, while the presence of a highwater table decreases it, requiring correction in foundation design.

Nayan M R (2021) Has performed the analysis of foundations using Geo5.In this analysis, shallow foundation is considered. The analysis is to estimate and calculate the factor of safety using GEO5 student version Software. A vertical and horizontal bearing capacity analysis is performed by the program. Design of foundation includes four types of foundation. Analysis of foundation include different cases like with and without earthquake, with and without surcharge. Main objective of analysis is to design and calculate the dimensions and stability of spread footing foundation and to find the value of factor of safety using GEO5program. In this analysis he observed that how four different types of foundations might increase their bearing capability. In comparison to other types of footing, the results demonstrate that bearing capacity increases greatly in the circular spread footing and decreases in the strip footing.

Umesh N. Waghmare & Dr. K. A. Patil (2012) Conducted a study on soil and bearing capacity at different sites to determine optimal foundation depths. Their research analyzed soil samples from waste disposal and market sites in Aurangabad, evaluating properties like cohesion, density, and moisture content. The study found that increasing foundation depth improves bearing capacity, with general shear failure occurring beyond 1.5m depth. Their findings help in selecting suitable foundation types and applying water table corrections for safer construction practices.

Sumalatha J (2023) conducted a study on improving the bearing capacity and settlement characteristics of black cotton soil using rubber powder. The research analyzed soil mixed with 1%, 3%, and 5% rubber powder, finding that plasticity index and density decreased while CBR and shear strength increased. Consolidation tests showed that adding 5% rubber powder and 0.5% NaCl reduced compressibility and swelling. Using GEO5 software, the study confirmed that soil modification with rubber powder allows for smaller footing dimensions while maintaining stability.

3. EXPERIMENTAL WORK

3.1 Material

3.1.1 Soil

The soils used in the study were collected from different locations and depth. The details of the soil samples collected are as shown in the table 1. The proposed depths of foundation at these sites were considered based on judicious judgment.

Table 1 : Details of Different Soils Collected

Symbol	Location	Depth of foundation in meter
Soil – 1	Arjun Nagar, Amravati	1.5
Soil – 2	Yashoda Nagar Road, Amravati	1.2
Soil – 3	Arjun Nagar, Amravati	1.5
Soil – 4	Sharda Vihar, Amravati	1.8

4. LABORATORY TESTS

The aim of this work is to study the effect and IS Classification of different parameters on bearing capacity of the soil. Four representative soil samples from proposed depth of foundation were collected. Experimental work was planned to study the properties of different soils collected for determination of ultimate bearing capacity of the soil. For all these soils the Triaxial test and California Bearing Ratio tests (CBR), Standard Compaction Test, Atterberg limits test and Sieve Analysis were conducted to determine maximum dry density, optimum moisture content, cohesion and angle of internal friction (Ø), Coefficient of curvature, Coefficient of Uniformity, Plasticity Index, . The test results of different soils tested for these properties are as shown in table 2.

Table 2 : Properties of different soils collected for bearing capacity analysis.

Properties	Soil - 1	Soil - 2	Soil - 3	Soil - 4
C	24	16	9	9
Ø	8.53	14	14	14
Unit Weight	18.97	21.13	14.34	18.14

MDD	1.544	1.85	1.39	1.58
OMC	25	17	19.01	17.01
Cc	1.01	0.16	1.36	1.11
Cu	3.95	0.40	4.38	3.88
Ip	8.49	5.42	7.18	27.76
CBR (Soaked)	2.77%	2.19%	2.84%	2.62%
CBR (Unsoaked)	3.41%	8.27%	4.25%	4.08%
IS Classification	Poorly Graded Gravel (GP)	Poorly Graded Sand (SP)	Well Graded Gravel (GW)	Well Graded Gravel (GW)

5. RESULTS & DISCUSSION

1. Sieve Analysis Test

A sieve analysis test determines how soil particles are distributed based on size. The uniformity coefficient (Cu) and curvature coefficient (Cc) help classify whether the soil is well-graded or poorly graded. A well-graded soil has a Cu greater than 3, meaning a good mix of different particle sizes. While A poorly graded soil has a Cu less than 3, meaning it lacks a good range of particle sizes. From the table, the Cu values range from 0.40 to 4.38, and the Cc values range from 0.16 to 1.36. These values indicate that some soil samples are well-graded (GW), while others are poorly graded (GP, SP). Based on this, the soil in the tested area consists mainly of poorly graded gravel (GP), poorly graded sand (SP), and well-graded gravel (GW).

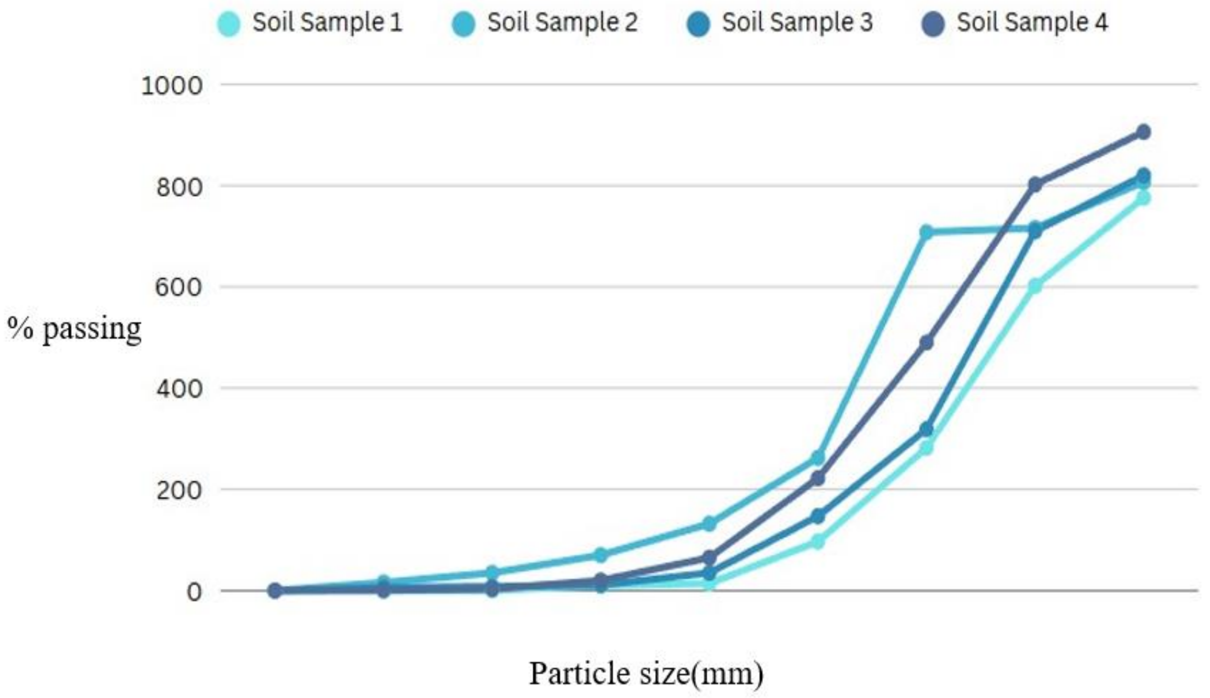

Fig 1. Graph of sieve Analysis test of all soil samples

2. Atterberg Limits Test

The Atterberg Limits Test is used to determine the consistency and plasticity of fine-grained soils, which helps in soil classification and behavior analysis. The Plasticity Index (PI), calculated as the difference between the Liquid Limit (LL) and Plastic Limit (PL), is a key parameter in evaluating soil plasticity. From the test results, the Plasticity Index (PI) values range from 5.42 to 27.76, indicating variations in soil plasticity. Soil Sample 4 has the highest PI value (27.76), suggesting a higher clay content and increased plasticity, whereas Soil Sample 2 has the lowest PI value (5.42), indicating lower clay content and reduced plasticity. These values are crucial for assessing soil behavior under different moisture conditions, impacting the soil's engineering applications.

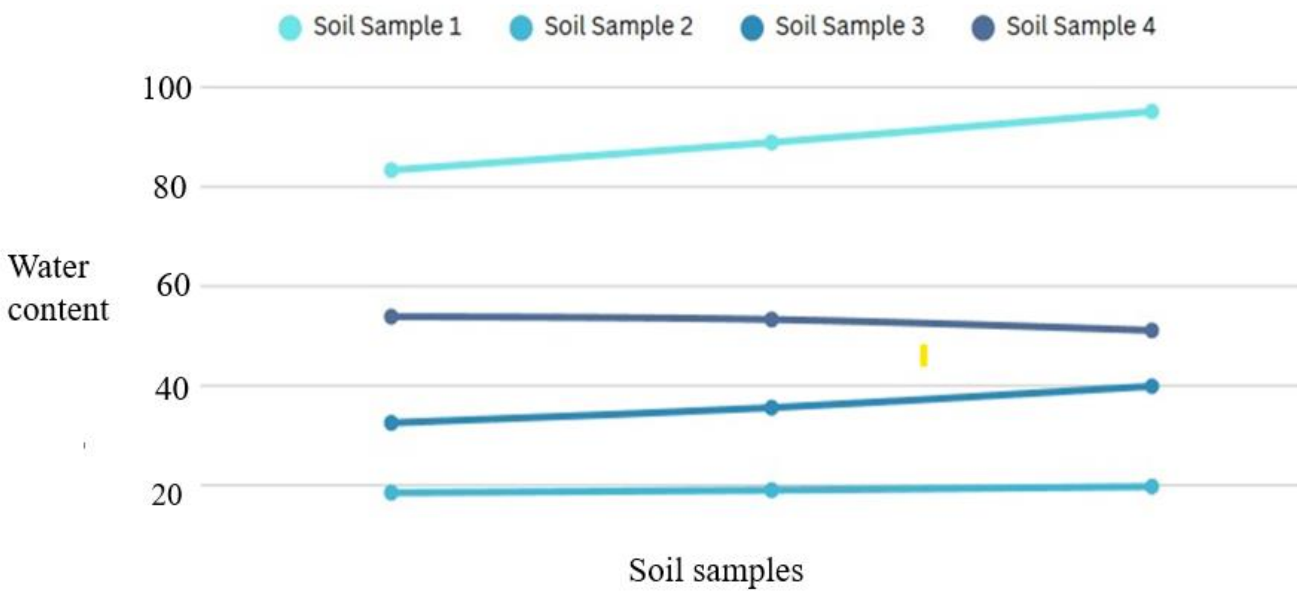

Fig 2. Graph of Liquid limit test of all soil samples

3. Standard Compaction Test

The Standard Compaction Test determines the Maximum Dry Density (MDD) and Optimum Moisture Content (OMC), which are crucial for understanding soil compaction characteristics. The MDD values range from 1.39 g/cc to 1.85 g/cc, while the OMC values range from 17.01% to 25%. Soil Sample 2 has the highest MDD (1.85 g/cc), indicating a denser and more compact soil, whereas Soil Sample 3 has the lowest MDD (1.39 g/cc), suggesting a relatively loose soil structure. The OMC values indicate that Soil Sample 1 requires the highest moisture content (25%) for compaction, whereas Soil Sample 3 requires the least (19.01%).

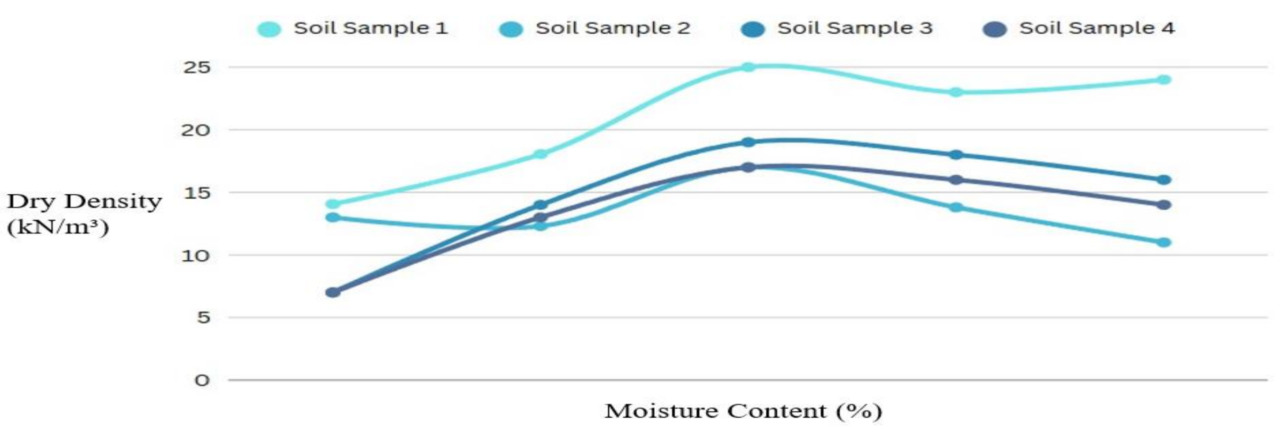

Fig 3. Graph of Standard compaction test of all soil samples

4. California bearing ratio test (CBR)

The CBR test is a penetration test used to evaluate the strength of subgrade soil and its suitability for road and pavement design. The results of the CBR (Soaked) test range from 2.77% to 8.27%, while the CBR (Unsoaked) test values range from 2.19% to 4.25%. The highest CBR (Soaked) value of 8.27% (Soil Sample 2) indicates relatively stronger soil, while the lowest value of 2.77% (Soil Sample 1) suggests weaker subgrade conditions. Similarly, the CBR (Unsoaked) values follow a similar trend, with Soil Sample 4 having the highest value of 4.25%. These values indicate that some soil samples may require stabilization for better load-bearing capacity, especially in pavement construction.

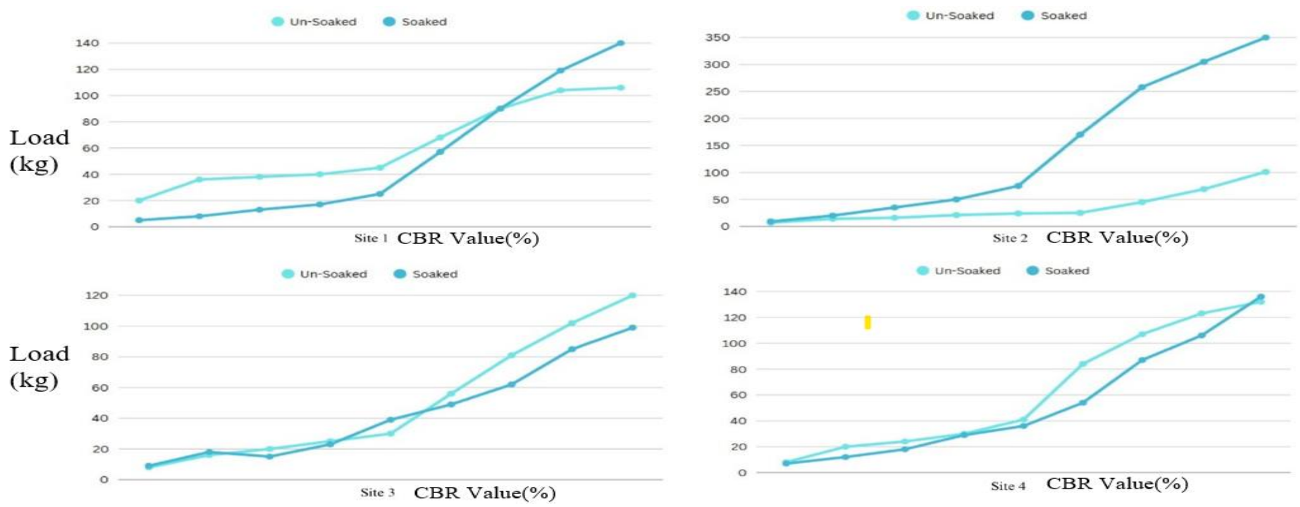

Fig 4. Graph of CBR test of all soil samples

5. Triaxial test

The Triaxial Shear Test evaluates the shear strength parameters of soil, including cohesion (C) and the angle of internal friction (ϕ), which are critical for foundation design. The cohesion values range from 9 kPa to 24 kPa, with Soil Sample 1 exhibiting the highest cohesion (24 kPa), suggesting greater soil binding strength. The angle of internal friction (ϕ) values range from 9° to 14°, with Soil Sample 2 showing the highest value (14°), indicating better resistance against shear failure. These parameters are essential in geotechnical engineering applications such as retaining wall design, slope stability analysis, and foundation performance evaluation.

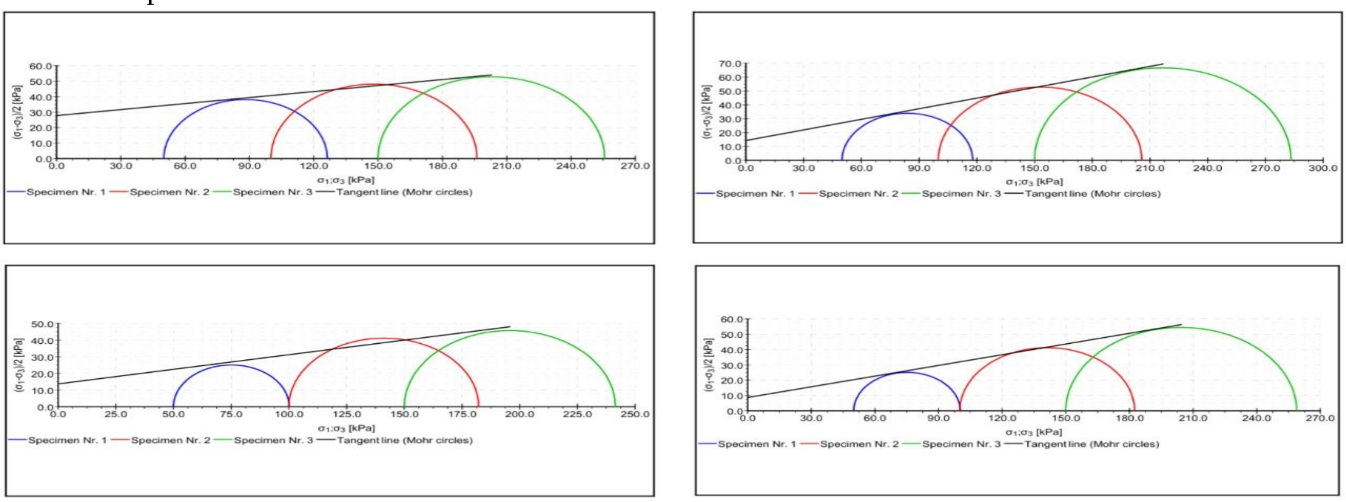

Fig 5. Graph of triaxial test of all soil samples

6. Bearing Capacity Analysis Using Manual Calculation

The bearing capacity analysis was conducted using IS Code Method and Terzaghi's Method. These methods provided different results compared to the GEO5 software-based analysis. For Soil Sample 1, the IS Code Method estimated a bearing capacity of 473.25 kN/m², while Terzaghi's Method calculated it as 362.55 kN/m². Similarly, for Soil Sample 3, the values were 258.61 kN/m² (IS Code) and 296.41 kN/m² (Terzaghi's Method). The variations between these methods highlight the differences in empirical assumptions and theoretical approaches. Manual calculations remain a fundamental technique in geotechnical engineering, but software-based analysis like GEO5 provides greater precision and efficiency in assessing soil strength.

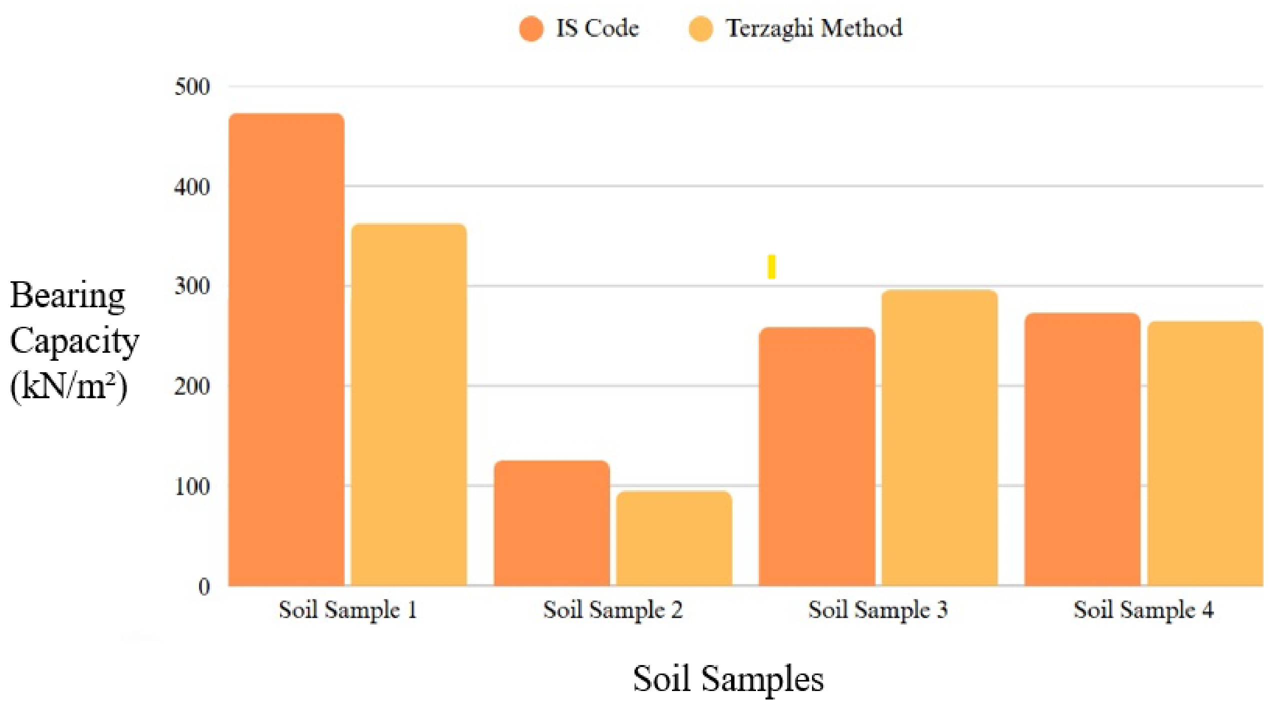

Fig 6. Bearing capacity evaluation using manual calculation

7. Bearing Capacity Analysis Using GEO5 Software

The bearing capacity of soil was analyzed using GEO5 software, which provides an advanced computational approach based on multiple international standards, including Indian, European, and British guidelines. The results showed significant variations among different standards. For instance, Soil Sample 1 had the highest bearing capacity of 480.71 kN/m² according to the Indian Standard, while the European and British Standards provided comparatively lower values of 162.71 kN/m². Similarly, Soil Sample 2 exhibited a bearing capacity of 144.53 kN/m² (Indian Standard) and 132.61 kN/m² (European Standard). The Indian Standard in GEO5 consistently provided the highest bearing capacity values, indicating a relatively conservative approach to soil strength evaluation. This method allows for an accurate and efficient assessment of soil bearing capacity, reducing the risk of errors in manual calculations and improving engineering reliability.

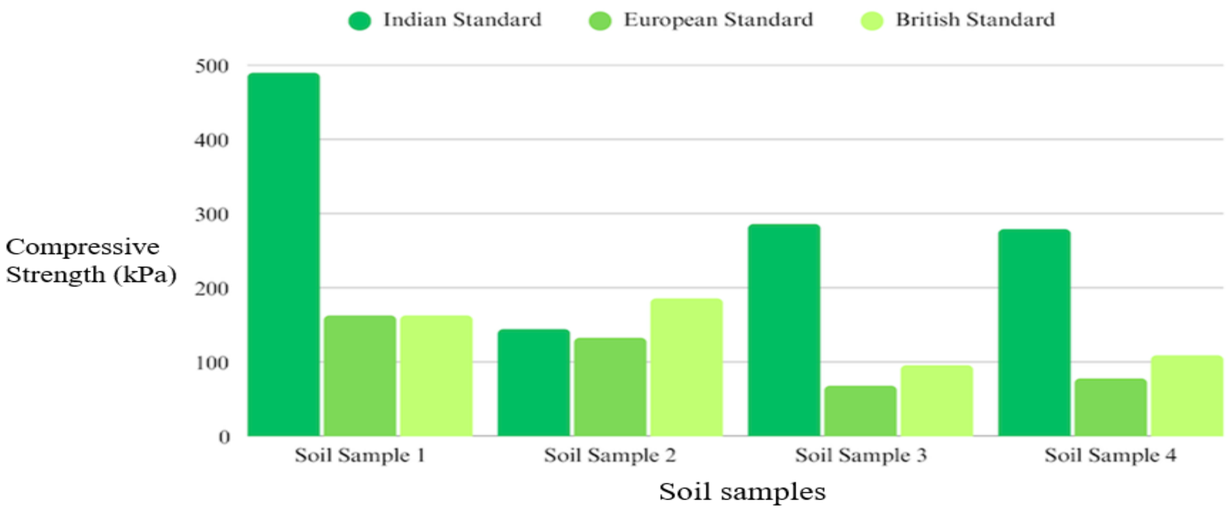

Fig 7. Bearing capacity evaluation using Geo5 software

8. Analysis of bearing capacity using GEO5 software tool

The experimental values of soil properties were given as input in the GEO5 software tool and the analysis was carried out with the assumed footing dimensions and loads. The footing dimensions were assumed as 1.8 m x 3 m located at a depth of 1.5 m below the finished ground level. The footing location and input soil properties are shown in Fig. The bearing capacity of the soil without amendments was estimated and found that the factor of safety is less than 1.5.

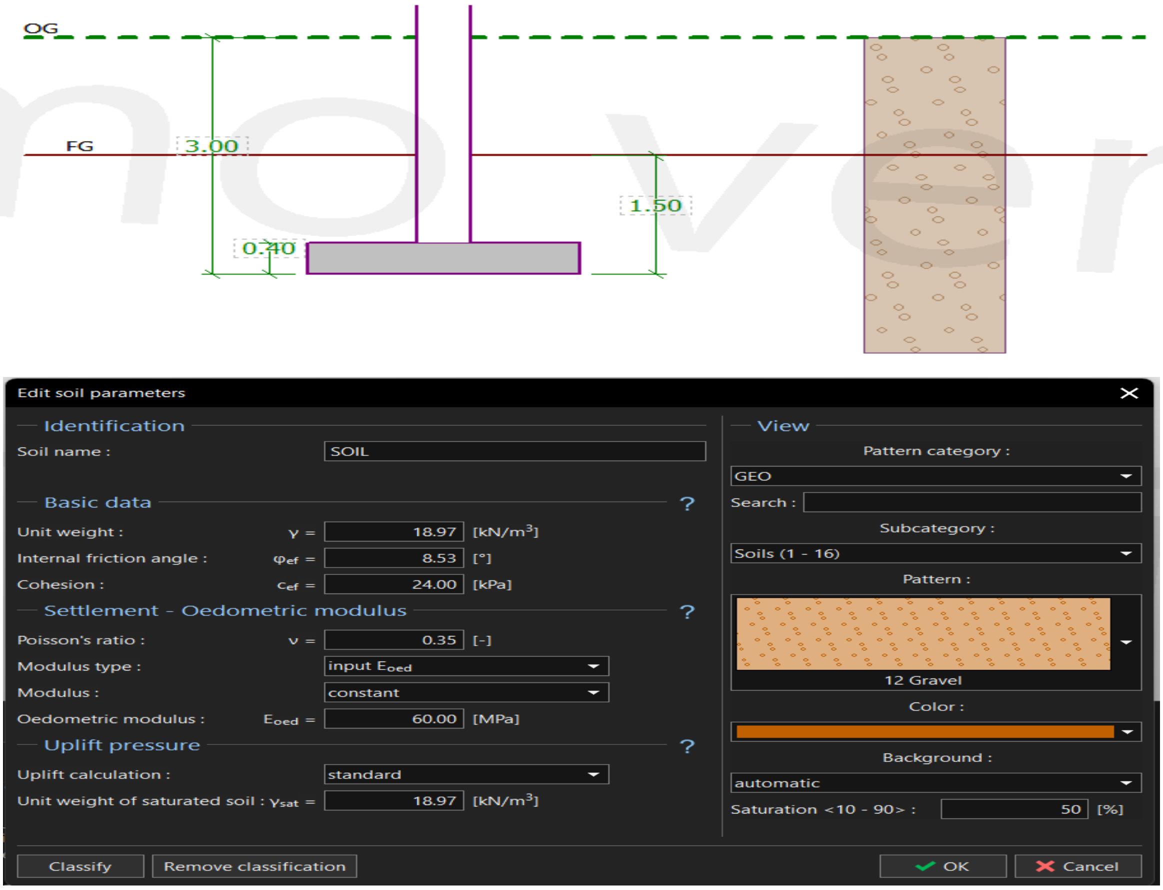

Fig 8. Model prepared using GEO5 software with the soil properties

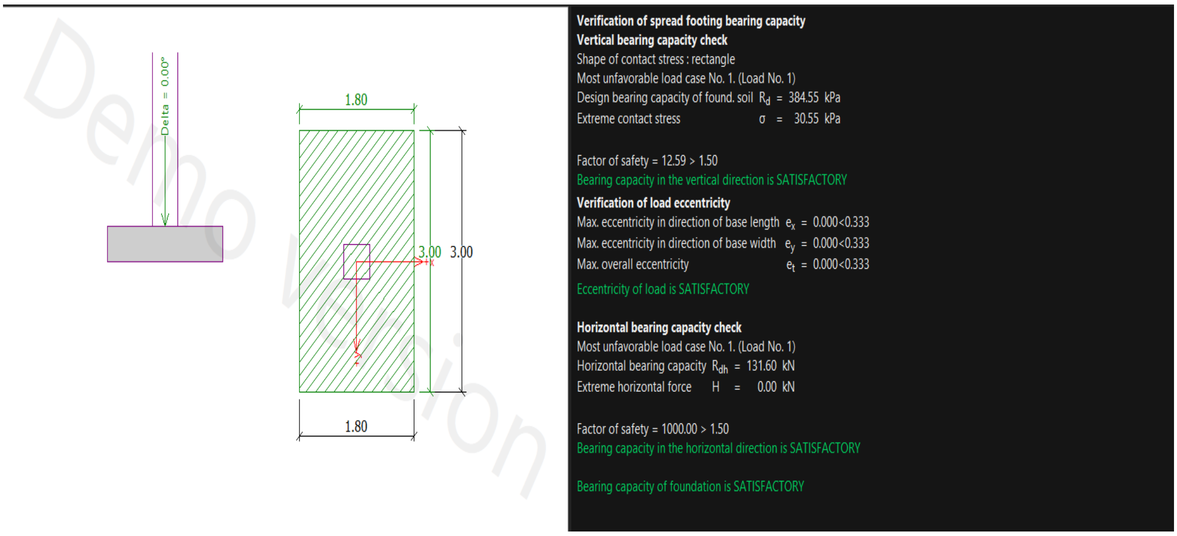

Fig 9. Bearing capacity and factor of safety with the soil using GEO5 software

9. Analysis of settlement using GEO5 software tool

The settlement analysis was also carried out using the GEO5 software tool to check the effect of rubber addition on the value of settlement. The settlement analysis carried out on the untreated soil (Fig.) shown that a settlement of 7.53 mm occurs with the footing dimensions of 1.8 x 3 m.

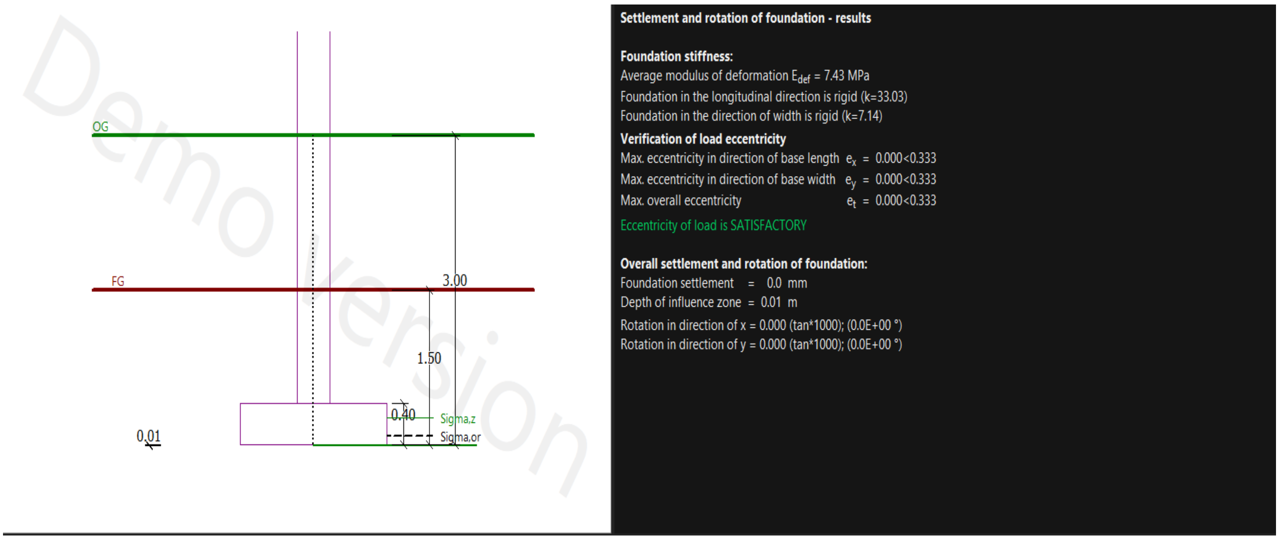

Fig 10. Estimated value of settlement using GEO5 software

7. CONCLUSION

- Properties of Soil Samples: Soil Sample 1 is cohesive and plastic, indicating clayey characteristics with high water retention. Sample 2 is gravelly-sandy with good dry strength and compaction. Sample 3 is silty-clayey with low strength and density. Sample 4 is a moderately plastic clay-sand mix with stable gradation.
- Comparison of Bearing Capacity: Sample 1 demonstrated the best bearing performance due to high cohesion. Sample 2, though strong in dry conditions, is moisture-sensitive. Sample 3 showed weak capacity and requires improvement. Sample 4 performed moderately but needs careful consideration in wet conditions.

- Classification of Soil Samples:

Sample 1: High-plasticity clay (CH)
Sample 2: Well-graded gravelly sand (GW-SW)
Sample 3: Low-plasticity silty clay (CL-ML)
Sample 4: Clayey sand (SC)

- Comparison of Methods Used to Calculate Bearing Capacity: GEO5 (Indian Standard) yielded the highest values. The European Standard offered more conservative results, while the British Standard lay in between. Manual methods such as IS Code and Terzaghi closely aligned with software results, highlighting GEO5's analytical precision.
- Comparison of Foundation Design with All Soil Samples: Shallow foundations are ideal for Samples 1 and 4. Due to lower strength, deep foundations or soil stabilization are recommended for Samples 2 and 3. Proper foundation choice is crucial to ensure safety and serviceability.
- Influence of Moisture Content on Soil Behavior: Higher moisture content significantly reduced the strength of all soil samples, especially in cohesive soils. This highlights the importance of assessing seasonal groundwater variations during foundation planning.
- Effectiveness of GEO5 Software: GEO5 provided reliable and fast analysis for both shallow and deep foundations. Its integration of laboratory data enabled accurate simulation, enhancing design confidence compared to manual calculations.
- Impact of Soil Type on Compaction and Stability: Granular soils like Sample 2 compact more efficiently and achieve higher densities, making them suitable for high-load applications. In contrast, fine-grained soils like Sample 1 require careful moisture control during compaction.
- CBR Results and Pavement Suitability: Sample 2 had the best soaked CBR value, making it most suitable for pavement layers. Samples 3 and 4, though moderate in unsoaked CBR, may be used with stabilization techniques for subgrade applications.
- Importance of Site-Specific Design: Soil behavior varies widely even within the same region. Therefore, site-specific investigation and tailored foundation design are essential to ensure safety, economy, and long-term performance.
- The study compared different methods (Indian, European, British standards, IS Code, and Terzaghi's method) for calculating bearing capacity, revealing that the Indian standard consistently provided higher values, while the European standard was more conservative.
- The laboratory tests confirmed that increasing moisture content reduces soil strength, emphasizing the importance of accurate field moisture assessments.

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