Experimental Study to Relate the Bearing Capacity with Density Index of Cohesionless Soil Using Empirical Relationship

Premranjan Kumar 1 (P.G Scholar)
Dept. of Civil Engineering
RNTU Bhopal, INDIA

Reetesh Khare 2 (Asst. Prof.)
Dept. of Civil Engineering
RNTU Bhopal, INDIA

Abstract

This research presents an experimental investigation into the relationship between bearing capacity and density index of cohesionless soil. The primary aim of this study was to develop an empirical relationship that could reliably predict the bearing capacity of such soils based on their density index. To achieve this, a comprehensive set of laboratory tests and field measurements were conducted on different samples of cohesionless soil.

The research involved the preparation of soil samples with varying density indices, followed by load tests to determine their bearing capacities. These tests were carried out under a range of conditions, including varying moisture content and compaction methods, to capture the real-world variability of soil properties.

The results of the study revealed a strong correlation between the density index and bearing capacity of cohesionless soils. An empirical relationship was developed, which can serve as a valuable tool for geotechnical engineers and construction professionals to estimate the bearing capacity of such soils without the need for extensive and costly testing.

This research not only enhances our understanding of the behavior of cohesionless soil but also provides a practical and cost-effective approach for assessing soil stability in construction projects. The findings of this study have the potential to contribute to safer and more efficient geotechnical engineering practices.

Keywords : Cohesionless soil, Soil stability, Geotechnical engineering, Bearing capacity, Density index.

1.0 INTRODUCTION

The gradation of sand, the distribution of particle sizes within a sand sample, plays a pivotal role in determining the relative density of the material. Relative density, also known as density index or degree of compaction, is a critical parameter in geotechnical engineering, as it directly influences the soil's mechanical properties, permeability, and overall stability. The relationship between sand gradation and relative density is of significant importance in various engineering applications such as construction, foundation design, and soil mechanics. Sand, composed of granular particles ranging in size, exhibits different behaviors and characteristics based on the distribution of these particles. The arrangement and distribution of particle sizes, including fine, medium, and coarse grains, influence how closely these grains pack together within a given volume. Consequently, this arrangement directly impacts the relative density of the sand mass.

The relative density of sand, a measure of how densely packed the soil particles are compared to the maximum possible packing, significantly affects the soil's load-bearing capacity, shear strength, and porosity. This, in turn, has implications for the stability of structures built upon or within sand formations. Understanding the relationship between sand gradation and relative density involves assessing how variations in particle sizes and their distribution affect the void spaces between particles. A uniform distribution of particle sizes might result in more efficient packing, leading to higher relative density, while uneven gradation could lead to increased voids and reduced relative density.

2.0 Literature Review

Burmister (1948) Proposed an analogy regarding the limit densities of sands. Limit density (or void ratio) values of cohesion less soils should be considered as significant as the properties like the coefficient of uniformity (Cu), coefficient of curvature (Cc), and mean particle size (D50), and particle shape, among others, when providing a comprehensive description of sand. Density (or void ratio) limits help to describe the material under consideration in a more precise manner and are essential when evaluating the relative density of in-place soils.

Meyerhof (1956) Suggested relationship between angle of internal friction (φ) and relative density. [26] Ø 0 = 25 + 0.15Dr (Granular soils or sands with more than 5 % silt) Ø 0 = 30 + 0.15Dr (Granular soils or sands with less than 5 % silt).

Lee and Suedkamp (1972) Studied on the compaction of granular soils and found compaction curve can be irregular if compaction tests are carried out using a larger number of test points. The compaction curves were found to be more dependent on material's nature. They found four types of compaction curve for different liquid limit (LL), such as bell shaped (30 <LL< 70), one & one-half peak (LL < 30), double peak (LL < 30 or LL < 70) and odd shaped (LL > 70).

Selig and Ladd (1973) Did research on relative density measurements process and its applications. They summarized the factors influencing relative density and correlate the relative density to blow count and strength of cohesionless. Finally, a series of recommendations are given for modifications to the ASTM test procedures based on all of the information gathered.

3.0 Methodology

Being an experimental study, it follows a methodology that involves gathering samples, analyzing them, running various tests, and drawing conclusions based on the findings. The following components make up the project.

3.1 Acquisition of Samples: Sand samples were obtained from four distinct locations, namely the banks of the Tapi and Betwa rivers in Bhopal. The samples were purchased for the building project. They are appropriate for use in building for uses at the university location.

3.2 Preliminary Analysis: For the purpose of grading the sand, sieve examination of the samples gathered from various sources was carried out. The ratios of fine, medium, and coarse sand were determined for the sample, which helped us estimate the ratios along the riverbanks. preliminary examinations for determining fundamental characteristics such as specific gravity, dry unit weight, and so on.

3.3 Standard Lab Tests-

From the procured sand samples, 17 sets were prepared with different proportions to find out the relative density of the sand sample were carried out by the vibratory table test method. Obtaining the maximum and minimum void ratios, the relative densities were found out. After relative density, direct shear tests were conducted to find out the angle of internal friction and calculate the bearing capacities for the different samples with the help of IS 6403:2002-Code of Practice for determination of Bearing Capacity of Shallow Foundations.

4.0 Experimental Result and Analysis

Table.4.1 Sieve Analysis data of the samples procured

Sample	Coarse Sand (%)	Medium Sand (%)	Fine Sand (%)
1	10	62	28
2	5	69	26
3	0	88	12
4	14	76	10

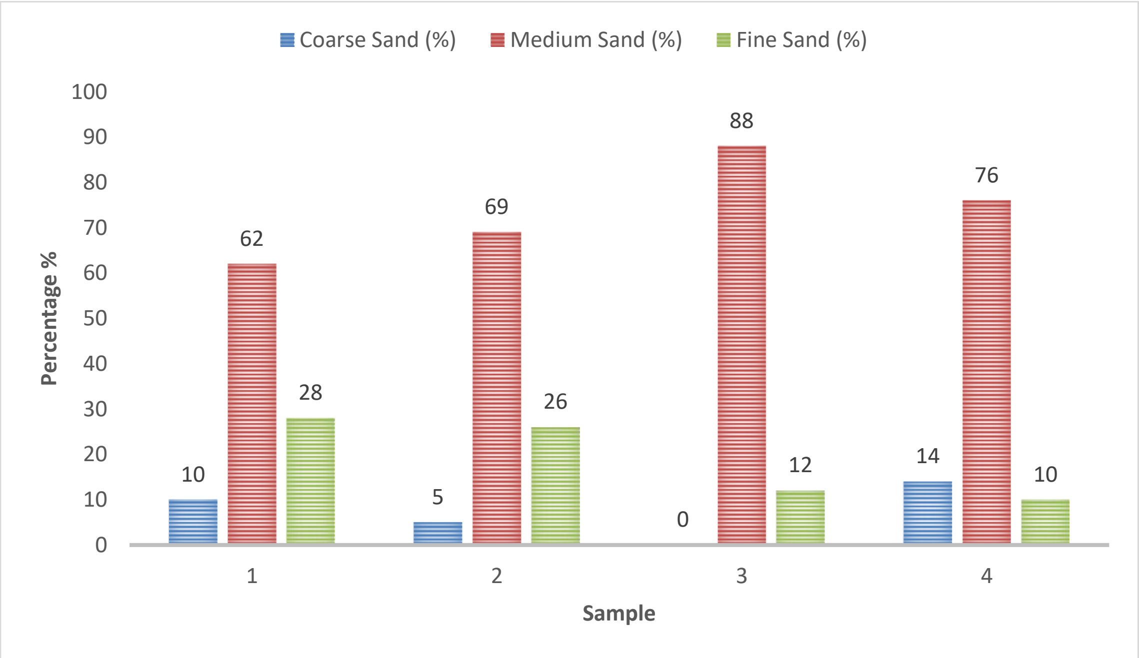
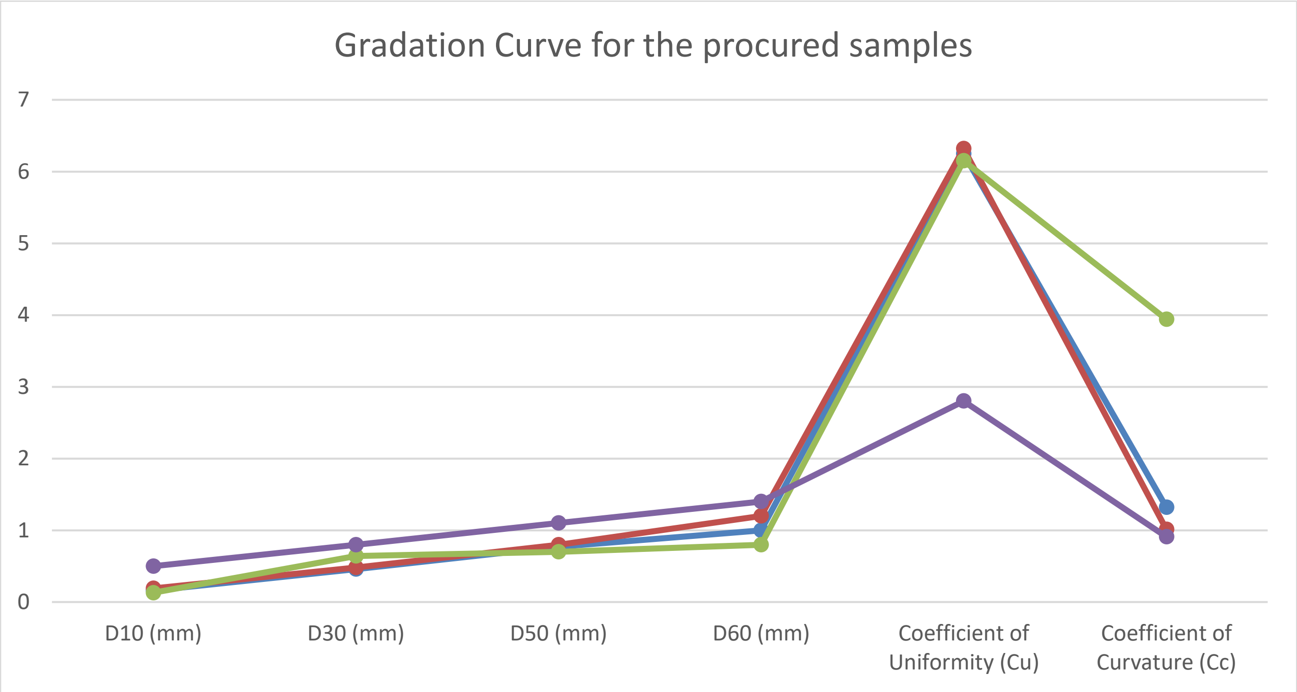


Fig.4.1 Natural Gradation of the procured samples

Table.4.2 Specific Gravity results for procured samples

D10 (mm)	D30 (mm)	D50 (mm)	D60 (mm)	Coefficient of Uniformity (Cu)	Coefficient of Curvature (Cc)
0.16	0.46	0.77	1	6.25	1.32
0.19	0.48	0.8	1.2	6.32	1.01
0.13	0.64	0.7	0.8	6.15	3.94
0.5	0.8	1.1	1.4	2.8	0.91

Fig.4.2 Specific Gravity results for samples procured



5.0 Discussion

The Discussion chapter provides a comprehensive interpretation and analysis of the experimental findings presented in Chapter 3, aiming to derive meaningful insights and implications. It involves critical examination, comparison with existing models, and an exploration of the broader significance of the results within the field of geotechnical engineering.

Interpretation of Findings

Correlation Analysis Recap: Summarize the identified relationships between the density index and bearing capacity as observed from the experimental data.

- **Discussion of Patterns and Trends**: Delve into the observed trends, variations, or anomalies in the relationships, explaining the implications of different density indices on the bearing capacity of cohesionless soils.
- **Factors Influencing Bearing Capacity**: Analyze and discuss the factors contributing to the variations in bearing capacity concerning different density index values.

Comparison with Existing Models

Evaluation of Empirical Relationships: Compare and contrast the newly developed empirical relationships with established models or theories available in literature.

Advantages and Limitations: Discuss the strengths and weaknesses of the newly derived models compared to existing ones, addressing where the novel models excel and where they may have limitations.

Implications for Geotechnical Engineering

Engineering Applications: Discuss the practical implications of the study's findings in the field of geotechnical engineering and construction practices.

Design Considerations: Elaborate on how the relationship between density index and bearing capacity can influence the design of foundations, embankments, or other geotechnical structures.

6.0 Conclusion

On the basis of present experimental study, the following conclusions are drawn:

- Sand samples that are well-graded, meaning they have a relative density of greater than 70% and are classified as "dense sand" because they have a higher density than the other samples ($1< Cc <3$ and $Cu >6$) (McCarthy, 2007).
- The relative density and internal friction angle are within the +/- 5% error range specified by Meyerhof's (1956) empirical relation

- It is discovered that the most important factor influencing the index property, or relative density for cohesion-less soils taken, is the mean particle size. The current experimental work so suggests an empirical relationship as $Dr = (73\ D50)^{(-0.07)}$
- The relationship between Ultimate Bearing Capacity (qd) and Relative Density (Dr) was determined to be directly proportional. The composition of the soil or the sample's history of stress can be used to explain why the two samples' empirical relations differed.

7.0 Referances

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