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# FORETELL THE BEARING CAPACITY OF MIXED SOIL MODEL

**Asha G Hiremath[1], Dr. Nagaraja Gupta M S[2]**

M.Tech Student, Department of Geotechnical Engineering, East West institute of Technology,

Bengaluru, Karnataka, India[1]

Professor and Head, Civil Engineering Department, East West institute of Technology, Bengaluru, Karnataka, India[2]

**Abstract:** Lab experiments were carried out to characterize laterite soil in the soil mixture and its properties were evaluated to determine safe bearing capacity. Investigation was carried by changing the proportions of different soil in the soil mixture. The bearing capacity of soil was evaluated by employing standard footing dimensions and method, with regards to how mineralogy affects soil. It has considerable impact on the soils bearing ability.

The findings of Experimental, analytical, numerical evaluations of soil mixture are documented in the literature. The application of the advanced decision making techniques is required for the geotechnical engineering design to produce the optimum outcomes. This work can be a guideline to apply soil mixed design in geotechnical engineering to improve the subsoil quality. Mixed soil technique can be employed for accurate understanding failure mitigation of soil foundation. By understanding all factors, which effected to soil, could be starting way of the improvement of any soil. ANN analysis of the study can be done.

**Keywords:** Bearing capacity, Mixed soil, Mechanical properties, ANN.

## I. INTRODUCTION

The soil bearing capacity of any soil can be defined as the maximum load per unit area that soil can support without yielding. Mixed soil model technology is fairly new. This technique is used to stabilize cohesive and cohesion less soils. In slope stability applications, soil mixing improve the overall shear strength of the soil adequately increases the factor of safety. Soil mixing has also been applied to construction of in-situ gravity structures. Wide ranges of soils have shown improved soil characteristics based on application of the technique of soil mixing.

The bearing capacity of soil changes owing to the mechanical properties of the soil and it influences the structural stability. In most of the geotechnical engineering projects, there are several mechanical experiments that need interpretation before application. The mechanical properties of soil make the prediction of soil bearing capacity complex. However, the enhancement of construction project safely needs the interpretation of soil experiments and design results for proper application in geotechnical engineering.

In this regard, laboratory testing plays a critical role in assessing soil properties. This investigation is invaluable in terms of providing recommendations concerning site improvement. Several laboratory experiments are required for developing the soil bearing capacity should include a logical investigation in laboratory testing method for accurate interpretation of results providing feasible data in field application.

Lab experiments were carried out to characterize laterite soil in the soil mixture and its properties were evaluated to determine safe bearing capacity. Investigation was carried by changing the proportions of different soil in the soil mixture. The bearing capacity of soil was evaluated by employing standard footing dimensions and method, with regards to how mineralogy affects soil. It has considerable impact on the soils bearing ability. The findings of Experimental, analytical, numerical evaluations of soil mixture are documented in the literature. The application of the advanced decision making techniques is required for the geotechnical engineering design to produce the optimum outcomes.

However it is challenging to foretell the soil bearing capacity due to the mechanical characteristics of soil interaction. The objective of the study is to foresee the relationship between each component of the soil's mechanical characteristics and the mixed soils capacity.

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## II. MATERIALS AND METHODOLOGY

### MATERIALS

**Mixed Soil model:**

Soil is an unconsolidated material, composed of solid particles produced by the disintegration of rocks. Classified mainly as sand, silt, and clay.

Mixed soil is the material in which the different types of soils are mixed in different proportions. Mixed soil models are developed by using mixing Plastic soil with sand and other soils. All soils collected for the preparation of mixed soil model were at a depth of 2m from ground level.

**Table 1: Types of soil with depth and place**

| Sl.no | Type of soil | Depth(m) | Place |
|---|---|---|---|
| 1. | Laterite soil | 2 | Bengaluru |
| 2. | Red soil | 2 | Bengaluru |
| 3. | Black soil | 2 | Mahalingapur |
| 4. | Light brown soil | 2 | Mahalingapur |
| 5. | Sand | - | - |

**Table 2: Mixed soil models**

| Mixed soil model number | Percentage of laterite soil | Percentage of red soil | Percentage of black soil | Percentage of light brown soil | Percentage of natural sand |
|---|---|---|---|---|---|
| 1 | 100 | 0 | 0 | 0 | 0 |
| 2 | 55 | 45 | 0 | 0 | 0 |
| 3 | 55 | 0 | 45 | 0 | 0 |
| 4 | 55 | 0 | 0 | 45 | 0 |
| 5 | 55 | 0 | 0 | 0 | 45 |
| 6 | 60 | 10 | 10 | 10 | 10 |
| 7 | 85 | 5 | 5 | 5 | 0 |
| 8 | 70 | 10 | 10 | 10 | 0 |
| 9 | 55 | 15 | 15 | 15 | 0 |
| 10 | 60 | 20 | 20 | 0 | 0 |

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| | | | | | |
|---|---|---|---|---|---|
| 11 | 60 | 20 | 0 | 20 | 0 |
| 12 | 60 | 0 | 20 | 20 | 0 |
| 13 | 60 | 20 | 0 | 0 | 20 |
| 14 | 60 | 0 | 20 | 0 | 20 |
| 15 | 60 | 0 | 0 | 20 | 20 |

**Types of soils used for mixed soil models:**

- Laterite soil
- Red soil
- Black soil
- Light brown soil
- Natural sand

Laterite soil: - It is the type of soil found in areas where there is heavy rainfall and temperature. Water soluble lime and silicates dissolved in rainwater settle down in the lower layers, iron and aluminum, which are non-soluble, remain in the top of layers. The soil becomes soft during rainy season and dries up during summer leading to the formation of laterite rock. This rock is used for construction purposes.

Red soil: - It is the type of soil obtained from the weathering of granite and genesis. It contains iron oxides and hence it is red in color. It is rich in iron, lime and salt, but contains small amounts of humus. It is light, has thin layers and it is not very fertile. Its capacity for moisture retention is less.

Black soil: - This type of soil is formed by the weathering of basalt rocks. It is rich in aluminum, magnesium and oxides of iron. Hence it is black in color. It is also called as black cotton soil. This soil has the ability to retain moisture for many days. Since it is rich in nutrients a variety of crops can be grown in the soil.

Light brown soil: - they are less developed soil of hilly terrains. This soil is rich in humus, so it is acidic in nature. It is not very fertile. They are also very susceptible to soil erosion.

This soil has pH of 4.5 to 6.0 and is poor in phosphorous content due to its precipitation with iron and aluminum. They are rich in humus but lack potash, lime and phosphorous.

Natural sand: - sand is a granular material composed of finely divided mineral particles. Sand has various compositions but is defined by its grain size. Sand grains are smaller than gravel and coarser than silt. Sand is a non-renewable resource over human times scale and sand suitable for making concrete is in high demand. Desert sand although plentiful is not suitable for concrete.

## III. METHODOLOGY

**The methodology adopted for the study is represented in flow chart:**

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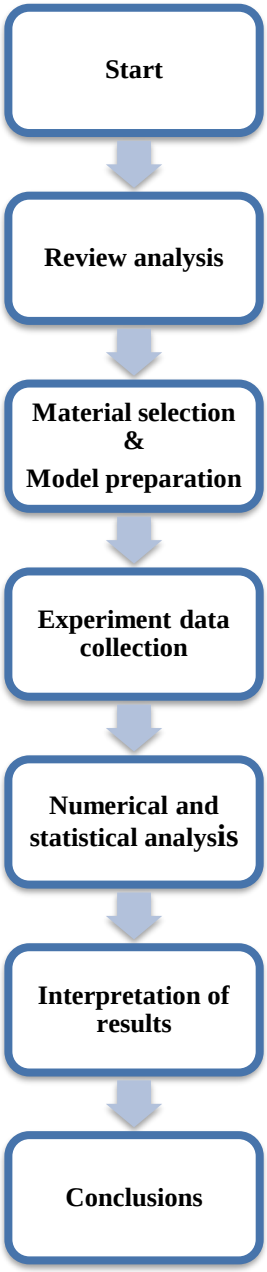


**Fig 2: Flow chart of methodology**

**Review analysis**

The maximum load applied on the soil foundation without the allowable settlement, deformation and shear failure is called safe bearing capacity of soil. The safe construction of the structure depends on the safe bearing capacity of soil foundation. The geotechnical engineering design of a soil foundation decides how soil behaves differently from place to place depending on the variation of mineralogy and morphology of natural soil. As, this creates difficult situation to choose safe bearing capacity in civil engineering project by the geotechnical designer.

**Material selection**

Different types of soil were collected. Using this several models has been developed. For all models, laterite soil was considered in order to assess soil foundation improvement. It has been done by performing laboratory tests through the

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interpreting of the test results. In this investigation liquid limit, plastic limit, Dry sieve analysis, standard compaction test and Direct shear test is been conducted to study the behavior of models in laboratory.

**Experiment data collection**

The properties of mixed soil and the calculated SBC are reported in the literature. The distribution of the optimum moisture content, density, angle of friction and cohesive of the mixed soil is analyzed. This procedure is repeated for 15 soil mixture models and significant factors impacting on the safe bearing capacity are explained. This helps in accuracy of analysis in prediction and assessment.

**Laboratory experiments carried out are:-**

- Dry sieve analysis
- Atterberg's limit :- Liquid limit and plastic limit
- Standard compaction test
- Direct shear test

**Sieve analysis**: - It is the average representation of the sizes of particles in soils drawn in semi logarithm plot if diameter size on logarithmic scale and percent finer on arithmetic scale represents the grain size distribution of a soil. Dry sieving is used for clean sandy soils and gravels. The soil is placed on the top sieve of the sieve rack and sieved.

**Atterberg's limit**: only liquid limit and plastic limit

This test is carried to determine the range of moisture content which exhibits certain consistency of a given sample. In 1911 Swedish scientist Atterberg's reported an extensive study on the plasticity of soil. In the progressive transition from liquid state to solid state, the soil undergoes dramatic change in consistency. All limits are expressed as W/C.

**Plastic limit**: - It is the moisture content at which a thread of soil just begins to crack and crumble when rolled to a diameter of 3mm.

**Light compaction test**: to find the relationship between maximum density to which soil is compacted and the moisture content of the soil during compaction. R.R.proctor (1930) devised a test by which it is possible to determine in laboratory the moisture content that will give maximum density, with the selected expenditure of energy.

**Direct shear test**: Test used to determine shear strength properties of soil. It is performed by deforming a specimen at controlled rate on or near single shear plane.

**Numerical and statistical analysis**

Mechanical properties of soil behave differently in group and the interaction between the soil elements requires a suitable technique for selecting the range of safe bearing capacity of mixed soil.

## IV. INTERPRETATION OF RESULTS

The morphology of mixed soil from the internal angle of friction, the mineralogy of mixed soil from soil cohesive, the moisture content and density of mixed soil have been interpreted to identify the best occurrence of safe bearing capacity. The method performed in the present work can be a guideline to be applied to soil mixed design in geotechnical engineering to improve subsoil strength and stiffness at acceptable quality.

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| Mixed soil model number | Plastic limit | Liquid limit | $D_{10}$ | $D_{30}$ | $D_{60}$ | $C_U$ | $C_C$ | % of Gravel | % of Sand | % of Silt And Clay |
|---|---|---|---|---|---|---|---|---|---|---|
| **1** | 15.30 | 40.5 | 0.10 | 0.52 | 1.3 | 13 | 2.08 | 0.39 | 73.2 | 26.42 |
| **2** | 23.00 | 35.0 | 0.15 | 0.34 | 0.96 | 6.4 | 0.8 | 11.33 | 85.71 | 2.96 |
| **3** | 29.06 | 49.8 | 0.14 | 0.46 | 1.19 | 8.5 | 1.27 | 10.97 | 85.08 | 3.95 |
| **4** | 15.02 | 23.8 | 0.13 | 0.52 | 1.5 | 11.54 | 1.387 | 14.77 | 79.575 | 5.65 |
| **5** | NON PLASTIC | 20.2 | 0.16 | 0.56 | 1.3 | 8.125 | 1.51 | 12.12 | 85.09 | 2.79 |
| **6** | 18.9 | 33 | 0.24 | 0.69 | 2.6 | 10.83 | 0.76 | 23.717 | 73.96 | 2.32 |
| **7** | 19.5 | 31 | 0.26 | 0.72 | 1.6 | 6.15 | 1.25 | 12.485 | 85.245 | 2.27 |
| **8** | 21.55 | 22 | 0.06 | 0.45 | 1.3 | 21.67 | 2.59 | 12.90 | 83.42 | 3.68 |
| **9** | 20.43 | 18.8 | 0.15 | 0.5 | 1.4 | 9.03 | 1.15 | 14.9 | 81.46 | 3.64 |
| **10** | 21.39 | 30 | 0.12 | 0.47 | 1.13 | 9.42 | 1.63 | 13.49 | 82.86 | 3.65 |
| **11** | 18.67 | 26.08 | 0.12 | 0.45 | 1.5 | 12.5 | 1.125 | 14.74 | 80.99 | 4.27 |
| **12** | 26.58 | 30 | 0.15 | 0.53 | 1.6 | 10.67 | 1.17 | 17.42 | 79.16 | 3.42 |
| **13** | NON PLASTIC | 19.5 | 0.17 | 0.69 | 3.7 | 21.76 | 0.76 | 20.1 | 77.36 | 2.54 |
| **14** | 18.57 | 29.9 | 0.18 | 0.6 | 2.2 | 12.22 | 0.91 | 22.31 | 74.42 | 3.27 |
| **15** | NON PLASTIC | 13 | 0.14 | 0.5 | 2.6 | 18.6 | 0.69 | 4.1 | 91.8 | 4.1 |

## SOIL MECHANICAL PROPERTIES AND SAFE BEARING CAPACITY

The morphology of mixed soil from the internal angle of friction, the mineralogy of mixed soil from soil cohesive, the moisture content and density of the mixed soil are interpreted to identify the best occurrence of safe bearing capacity. This method performed in present work can be a guideline to be applied to soil mixed design in geotechnical engineering to improve subsoil strength and stiffness at acceptable quality.

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| Sl.N0. | MODEL NO | OPTIMUM MOISTURE CONTENT | γ [kN/m$^3$] | Φ [º] | C [kN/m$^2$] | S B C [kN/m$^2$] |
|---|---|---|---|---|---|---|
| **1** | 1 | 13.5 | 17.9 | 27 | 0 | 342.6 |
| **2** | 2 | 13 | 17.66 | 30 | 0 | 466.28 |
| **3** | 3 | 15 | 16.3 | 20 | 0.03 | 129.3 |
| **4** | 4 | 17 | 18.44 | 25 | 0.022 | 261.3 |
| **5** | 5 | 13.5 | 18.5 | 37 | 0 | 1370.5 |
| **6** | 6 | 10 | 18.6 | 22 | 0.02 | 192.97 |
| **7** | 7 | 10.7 | 18.15 | 15 | 0.05 | 83.32 |
| **8** | 8 | 16 | 17.66 | 25 | 0.022 | 250.21 |
| **9** | 9 | 14.2 | 17.17 | 22 | 0 | 178.15 |
| **10** | 10 | 16.7 | 16.87 | 18 | 0.03 | 166.89 |
| **11** | 11 | 12 | 17.95 | 30 | 0.005 | 471.81 |
| **12** | 12 | 16 | 17.17 | 20 | 0.03 | 136.17 |
| **13** | 13 | 11 | 18.64 | 30 | 0 | 492.16 |
| **14** | 14 | 11 | 18.05 | 20 | 0.042 | 143.15 |
| **15** | 15 | 10 | 18.14 | 18 | 0.08 | 119.63 |

**DISTRIBUTION OF MECHANICAL PROPERTIES OF SOIL**

- OPTIMUM MOISTURE CONTENT Vs. MIXED SOIL MODEL NUMBER

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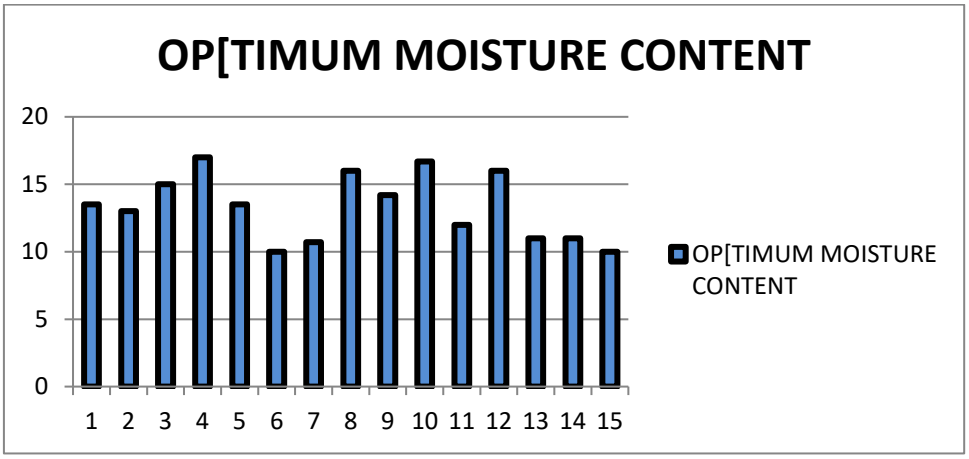
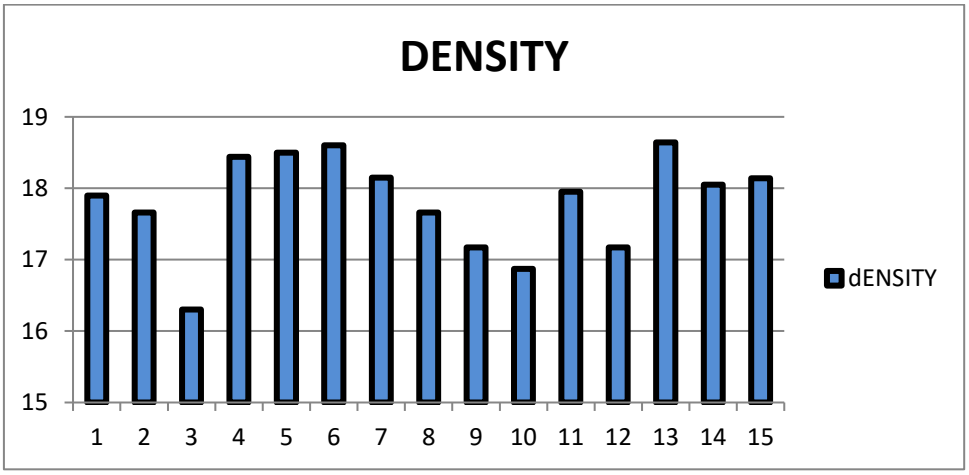
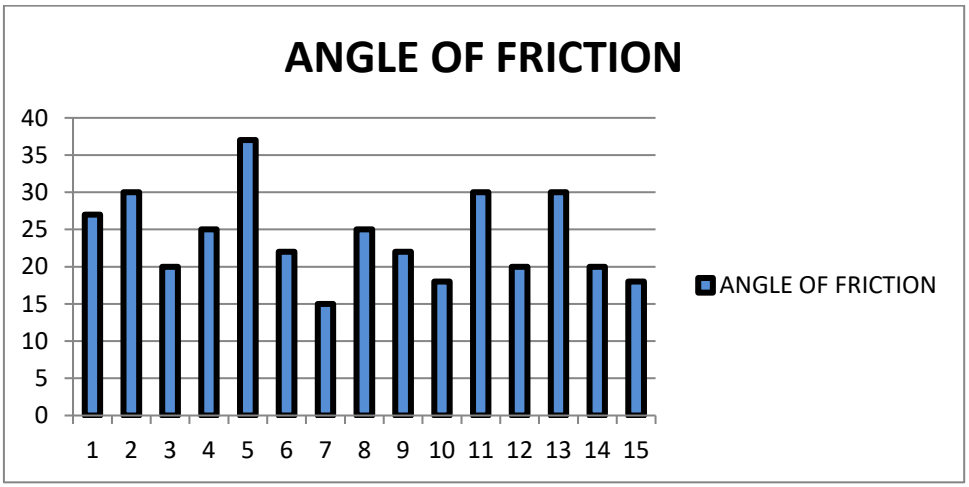



- DENSITY Vs. MIXED SOIL MODEL NUMBER




- ANGLE OF FRICTION Vs. MIXED SOIL MODEL NUMBER



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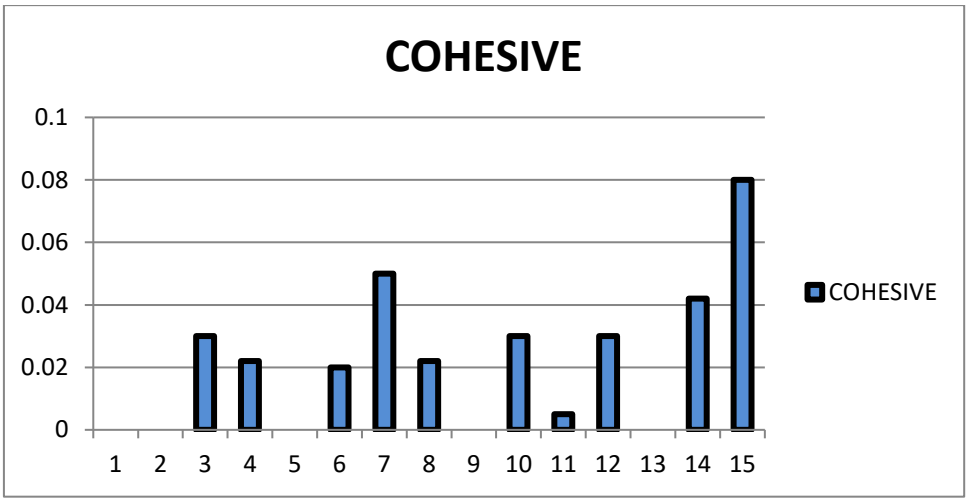
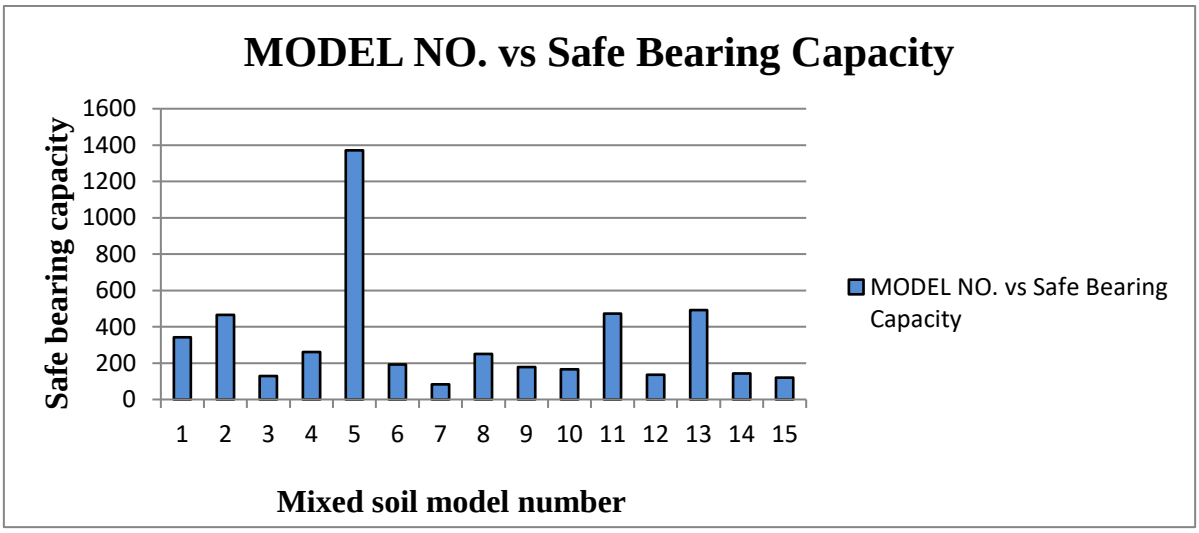
- COHESIVE Vs. MIXED SOIL MODEL NUMBER




**Interpretation of SBC with mixed soil model**

Laterite soil (55%) mixed with sand (45%) with highest angle of friction (37º) has high safe bearing capacity. These characteristics could increase soil foundation stability. Plasticity, morphology, compatibility, and optimum moisture content are the main factors involved in the safe bearing capacity.




## V. CONCLUSION

From the present study of characterizing the behavior of laterite soil when amended with different types of soils, it is concluded that:

- Safe bearing capacity calculation of all models identifies the best and worst mixed soil models. As in this study mixed soil model 5 exhibits highest SBC (**1370.5Kn/m$^2$**) and mixed soil model 7 exhibits lowest SBC(**83.32Kn/m$^2$**) among all 15 soil models
- Plasticity, morphology, compatibility and optimum moisture content are the main factors involved in the soils safe bearing capacity.
- Proper morphology, plasticity, optimum moisture content in any mixed soil model could support stability of the soil foundation and disable forces applied to the mixed soil model.
- The internal angle of friction of soil has more influence on the safe bearing capacity prediction, because mixed soil model 5 with internal angle of friction 37º exhibits highest SBC.
- Increasing density, cohesive and internal angle of friction of mixed soil results in increasing safe bearing capacity of the soil foundation, but moisture has negative influence on the SBC of soil.

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- Most SBC occurs below 1000Kn/$m^2$, implies for high bearing capacity good interaction of mechanical properties of the mixed soil is necessary.

## SCOPE OF FUTURE STUDY

- This work can be a guideline to apply soil mixed design in geotechnical engineering to improve the subsoil quality.
- Safe bearing capacity of all models calculated identifies best and worst soil mixed model for further research work in future.
- Mixed soil technique can be employed for accurate understanding failure mitigation of soil foundation.
- By understanding all factors, which effected to soil, could be starting way of the improvement of any soil.
- **ANN** analysis of the study can be done.

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