ISSN: 0975-833X

Available online at http://www.journalcra.com

International Journal of Current Research
Vol. 12, Issue, 05, pp.11744-11747, May, 2020

DOI: https://doi.org/10.24941/ijcr.38514.05.2020

INTERNATIONAL JOURNAL OF CURRENT RESEARCH

RESEARCH ARTICLE

DETERMINATION OF AVERAGE BEARING CAPACITY FOR BLACK COTTON SOIL (IN NUMAN FEDERATION) AND, SELECTION OF SUITABLE FOUNDATION STRUCTURE

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ARTICLE INFO

Article History:
Received 09th February, 2020
Received in revised form
14th March, 2020
Accepted 08th April, 2020
Published online 31st May, 2020

Key Words:
Bearing Capacity, Foundation,
Black Cotton soil,
Numan Federation.

ABSTRACT

This research work determined the average bearing capacity for black cotton soil in Numan Federation and selection of suitable foundation for simple structures using Adamawa State Polytechnic, Yola Numan Campus as case study. Series of laboratory soil tests were carried out to analyse the soils sampled collected from the campus. The results for test analyses showed that the bearing capacity of soil is poor in terms of meeting engineering requirement. The consolidation test show that the soil settles deeper than the allowable and the permeability rates of the soil is very low. Hence the soil became densely saturated very soft in the wet season. The study recommended that engineering practices to determine bearing capacity of soils should be conducted before embarking on construction. Also, various practices that can stabilize the black cotton soil can be adopted to improve the bearing capacity of the soil in Numan federation.

Citation: ***Engr. KabiruSalihu and Chinda Zaria.*** **2020.** "Determination of average bearing capacity for black cotton soil (in numan federation) and, selection of suitable foundation structure", *International Journal of Current Research*, 12, (05), 11744-11747.

INTRODUCTION

Black cotton soil is an expensive soil that typically occurs in arid and semi-arid region of the tropical temperate zones marked with dry and wet seasons with low rainfall, poor drainage and exceeding great heat. Black cotton soil form a major soil group found in the north eastern part of Nigeria. In Numan Local Government Area of Adamawa state, foundation failure is no longer news in the area, because almost all houses or buildings have so many cracks appearing on them. The simple is that Numan area is characterized by deposit of black cotton soil that is very poor for engineering purpose. Black cotton soil is characterized by high shrinkage and swelling properties due to changing of moisture content. Montmorillonite is the predominant mineral of black cotton soil, because of it high swelling and shrinkage characteristics, black cotton soil has been serious problem to high way and other civil engineering works. It is strong hard when dry but weak in wet condition in addition black cotton soil have poor bearing capacity raring from ST/M2 to Dt/M2.These properties result crack in soil without any warning. These crack have sometime extent severe limit like ½ to 12 depths.

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In view of the above use of such soil for construction purpose have to be treated with great care as it poist great danger to lives of in habitat using the structure cotton such soil it also results in the waste of resources as such the need to know the bearing capacity of the soil and suitable foundation design that can suit the area is paramount.

Objectives: The objective of this research is to determine the average bearing capacity of the soil and recommend the suitable foundation that can suit the place.

LITERATURE REVIEW

Engineering definition of soil: For engineering purpose soil is considered to be any loose sedimentary deposit, such as gravel sand silt, clay or a mixture of their material it should not be confused with the geological definition of soil which is the weathered organic material on the surface or topsoil, top soil is generally removed before any engineering project are carried out (Amit, Jitendra, and Ajay, 2018).

Soil Classification: According to Brajesh(2015) more classification system divide soil into their main group; cohesion less, cohesive and organic the main characteristics displayed by their group and shown in the table

Bearing capacity of soil: The bearing capacity of a soil simply refer to the value of loading intervarsity of a soil can carry before it fails. This bearing capacity has been classified into two, which are ultimate bearing capacity and allowable bearing capacity. According to whitlow R et al (Brajesh,2015); British standard code of practice (CP 200:1972) the bearing capacity of a soil isdefining. Ultimate bearing capacity (qu) the value of net loading intensity at which the grown fails in shear

- Net loading intensity the value of the additional loading intensity imposed by the new structure or other work.
- Presumed bearing value the value of loading intensity appropriate to a particular type of ground for preliminary resign purpose

For a given foundation in a given soil a value many be determined for ultimate bearing capacity which will yield a working or safe value as follows: Safe bearing capacity 9

General property of black cotton soil

- The swelling and shrinkage behavior of a soil would largely depend upon clay minerals (like montmorillonite) present in soil
- Montmorillonite is predominant mineral of black cotton soil
- It swells excessively when wet and shrink excessively when dry
- It hasgreat activity to water

Safety Precaution in Designing Footing on the Black Cotton Soil

- In absence of test the bearing capacity of these soils may be limited to 5-10 tone/m^2
- Foundation to be placed where the crack cease to extend. The minimum depth of the foundation should be at least 1.5m
- If the thickness of black cotton soil layer is not more than 1 to 1.5m the entire soil should be removed and the foundation should be laid.
- If the depth is more the content between foundation and soil should be prevented by wider and deeper excavation for foundation trench below the footing till reach un weather rock formation.
- It is necessary to prevent the direct contact of black cotton soil with masonry work below ground level. This cube achieved by making wide trenches for foundations and filling spaces on either side of the foundation masonry with sand and
- If the soil is very soft and having poor bearing capacity the bed of foundation trench should be made firm hard by ramming it well
- In ordinary building the foundation should be taken at least 30cm dipper than the depth where the crack stop
- In important structure raft foundation should be under provided.
- Construction in black cotton soil should be under taken running dry season.

Consolidation

In saturated cohesive soil, the effect of increasing load is to squeeze out some of the pore water, this process is called consolidation.

A gradual reduction in volume takes place until internal pressure equilibrium is reached: a reduction in loading may cause swelling, provided that the soil can remain saturated. It is essential to understand that a change in loading is required to start the process and that it take several years for the final settlement to be achieved. The most susceptible soil are normally consolidated clays and silts and certain types of saturated fill peat and peaty soil can be highly compressible, resulting in change in stratum thickness of soil as much as 20 per cent under quite modest loading (Dhananjay et al., 2016). When saturated clay is subjected to an increment of total pressure (Δ_p) a corresponding excess pore-water pressure (Δ_u) is set up within the void space of the soil. The magnitude of Δ_u is numerically equal to Δ_p initially assuming that the pore water relatively incompressible (Fulzele et al., 2016).The long term consolidation of clay soils, however may take many years to compete with consequent damage to the structure appearing long after completion of the contract. In coarse grain soil consolidation occurs rapidly and is therefore a different problem. There may also be further settlement when consolidation nears completion due to “creep” in the soil mass. This is known as secondary settlement. The long term consolidation of clay soil is probably the most troublesome type of settlement and is the consolidation (Kavishet al., 2014).

Foundation Design: Foundation design is the process of selecting a suitable foundation type to be used in a particular type of a soil. The selection of foundation type includes the choice of the shape and size of the foundation in selecting the foundation type there are some factors to be considered. According to (Paland Ghosh,20113) a foundation (or footing) provides a critical interface between a surface and the ground beneath it; its function being to transfer the loads transmitted through the structure the supporting rock or soil. It is essential for the designer to consider the component on both sides of the interface. The structural unit above and the soil/rock unit below. The overall performance and the viability of a foundation depend on the shape and size of the footing thussoil should not be seen to have intrinsic bearing capacities assuch, for the designer should think in term of the bearing capacity of specific foundation arrangement the parameters of which describe both soil and footing. The parameters of the design process must include provision for safety, functional reliability and economy leaving aside the structural design of the footing itself, three main design criteria may be defined in the context of soil mechanics.

- adequate depth
- tolerable settlement and
- factor of safety against shear failure

The most common failure of foundation is excessive is excessive or differential settlement when the three factor above are not properly applied (Rajakumar, 2014).

MATERIALS AND METHODS

Physical characteristics of soil around the campus: Samples were collected from trial pit across the campus. Trial Pit 1 (TP1) was located behind class room at the eastern side of the campus, TP2 at the volley ball court, while TP3 at the northern side of the staff quarters. All TPs were located on the campus. Soil sample were taken at different levels from each TP. The first sample was taken at 1m while the second one at 2 m deep.

It was observed that the soil has similar physical characteristic across the campus. In all the TPs the predominantly silt-clay soil terminates at the depth of 1m. The grain size of the soil increases the deeper the pit. The color of the soil in all the pits changes from top to the depth of 1m. The soil in TPs1 and 2 are black color from top to 1m and changes from black color to greenish grey down to 2m. in TP2 it was observed that cracks in the soil going downward (vertically) terminate at the depth of 1m. The color of soil in TP2 is brownish from top down to 1m and changes to yellowish color down to 2m.

Method of sampling: Two methods were used in collecting the soil sample disturbed and undisturbed method of sampling were used. Disturbed method of sampling digger was used to dig loose the soil and a shovel was used to collect it from the pit. The sample was kept in a polythene bag and air tight to avoid loss moisture from the soil. Undisturbed method of sampling secondly, undisturbed samples were taken 150mm diameter cylindrical core, cutter, collar, s hammer and chisel. The core cutter was driven into the ground until it completely sinks down. Having done that, the chisel and hammer were used to dig round the core cutter until it was completely exposed. Then the cutter was carefully removed and trimmed with knife or any sharp edge blade. The core cutter containing the undisturbed soil was kept in an air tight polythene bag and taken to laboratory for analysis.

RESULTS FROM ANALYSIS

Consolidation Soil

Settlement

TP1 @ 1.0mΔH ranges from 122mm – 1680mm
TP1 @ 2.0mΔH ranges from 114mm – 2000mm
TP2 @ 1.0mΔH ranges from 262mm –4992mm
TP2 @ 2.0mΔH ranges from 262mm ---4992mm
TP3 @ 1.0mΔH ranges from 684mm --- 8192mm
TP3 @ 2.0mΔH ranges from 488mm--- 6720mm

Consolidation rate

TP1 @ 1.0mCv ranges from 3.4m^2/year – 014m^2/year
TP1 @ 2.0mCv ranges from 0.32m^2/year – 089m^2/year
TP2 @ 1.0mCv ranges from 0.411m^2/year – 0.05m^2/year
TP2 @ 2.0mCv ranges from 0.416m^2/year – 0.05m^2/year
TP3 @ 1.0mCv ranges from 0.44m^2/year – 0.04m^2/year
TP3 @ 1.0m Cv ranges from 0.39m^2/year – 0.04m^2/year

Coefficient of permeability

TP1 @ 1.0mK. ranges from 0.193×10^{-3} – 0.923×10^{-3} m/sec
TP1 @ 2.0mK. ranges from 0.528×10^{-3} -- 0.153×10^{-3} m/sec
TP2 @ 1.0m K. ranges from 1.90×10^{-3}– 0.172×10^{-3} m/sec
TP2 @ 2.0m K. ranges from 0.535×10^{-3}– 0.216×10^{-3} m/sec
TP3 @ 2.0m K. ranges from 1.473×10^{-3} – 0.216×10^{-3} m/sec
TP3 @ 2.0m K. ranges from 0.934×10^{-3}– 0.177×10^{-3} m/sec

The result of the consolidation test shown above indicates that the settlement computed is much higher than the allowable settlement. According to Rameshet al. (2014),the allowable settlement for linear foundation (wall) is 25mm and 50mm for raft. Hence from the finding shown above, the settlements for all the load increments are much higher than the allowable.

Major classification of engineering soil

	Cohessionless	Cohesive	Organic
Inclusive soil type	Stone	Silt	Peats
Particle shape	Gravel	Clay	
Particle or size grain	Sand		
Porosity or void	Rounded to angular	Flaky	Fibrous
Permeability	Low	High	High
Inter-particle	High	Low to impermeable	Variable
Cohesion	Non to very high	High	Low
Plasticity	Very low		
Compressibility		High	
Rate of compaction		Moderate to low	Moderate to rapid

(Brajesh, 2015)

The volume of compressibility, of the carried out also shows that it is very low. The rate of consolidation for the load increment shows that the soil is poor. The square root method was used as the one been most preferred. "though the fitting method have been developed to provide the best possible estimate for the Cv. The two methods give different results, but square root method usually gives larger value and more preferred. In addition to the problem involved in the evaluation of Cv from a given load increment, Cv varies from increment to increment and is different for loading and unloading (Kaushaland Guleria, 2015). From the result shown above it also shows that the soil sample have very low permeability.

Tri-Axial Test: Tri-axial test was done to determine the bearing capacity of soil samples. Careful analysis of the soil sampleswas carried out and all necessary data were obtained to plot Mohr's circles. The results from the Mohr's circle were given as follows:

	TP_1@1m	TP_1@2m	TP_2@1m	TP_2@2m	TP_3@1m	TP_3@2m
C	80KN/M^2	48KN/M^2	50KN/M^2	15KN/M^2	60KN/M^2	28KN/M^2
Φ	7^0	9^0	3.5^0	15^0	4^0	12^0

From the result above it Is clear that the soil is cohesive and have some angle of internal friction. The Terzaghi's equation for bearing capacity of soil was used to estimate the average bearing capacity of the soil. According to the equation (q_{uilt}= CNc + γDfNq + 0.5γBNγ), the average bearing capacity of the soil in study q_{uilt}. = 161.91KN/m^2. An estimate of a bearing pressure of sample strip foundation of a building carrying superimposed load of about 80KN gives that the q_{ult} = 417.337KN/M^2. from this analysis it clearly shows that the average bearing capacity of the soil is less than the bearing pressure of a simple foundation. Consequently, for a stable foundation around this area, the spread of the foundation must to wider than the usual three times the thickness of the wall. The depth of the foundation also should be deeper than 1.0m no matter how small the building may be.With the result of the soil analysis presented above which were obtained from soil samples collected from there trial pits on the campus the objective of research was achieved.

CONCLUSION

The consolidation and tri-axial test show that the bearing capacity of soil is poor in terms of meeting engineering requirement. The result of the consolidation test show that the soil settles deeper than the allowable. According to literatures, it states that the allowable settlement for wall foundation is 25mm for walls and 50mm for raft. But the settlement of the soil under review ranges from 100mm up to 8000mm, which is much higher than the allowable. The permeability rate of the soil is very low. Hence the soil became densely saturated very soft in the wet season. The tri-axial test shows that the average allowable bearing capacity of the soil is 161.91KN/N while the average bearing pressure of a simple building is about 400KN/M. Consequently, the result shows that the bearing pressure is higher than the average bearing capacity of the soil in the area. Therefore, for a stable foundation, it has to be deep to about 1.5m and below. The spread of the foundation also has to be wider than 0.7m.

Recommendations

- There should be consistent efforts to determine the bearing capacity of soils before embarking on construction.
- Also, various practices that can stabilize the black cotton soil can be adopted to improve the bearing capacity of the soil in Numan federation.

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