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# Design of Foundation for 220 kV Electrical Substation on Black Cotton Soil

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**Abstract**: *The design on black cotton soil has always been a difficult task for the engineers because the structure resting on black cotton soil cracks with none warning. Black cotton soil is found in M.P., Karnataka, Maharashtra and Andhra Pradesh in our country. Soil proportion changes depending upon their constituents, i.e. water content, density, bulk density, angle of friction, shear strength etc. With the rapid development in Soil improvement, construction technique and social need various constructions of structure are happening. the likelihood of excellent construction sites to create structures on Black Cotton Soils is difficult because of their poor strength and deformation characteristics. The failures of structure are mostly because of the failure of foundations. Foundation is that the most vital a part of the structure. The strength and sturdiness of any structure depends upon the strength of its foundation. The most objective of this study is to style an appropriate and feasible foundation for the black cotton soil for 220KN electrical substation structure using software analysis. This study discussed during which sort of foundation is suitable for 220KN electrical substation in black cotton soil.*

**Keywords**: Pile Foundation, Reinforcement, Combined Footing, Strength, Design, High Compressible Clay, STAAD Pro.

## I. INTRODUCTION

In India, the percent of the black cotton soil found in total soil deposition is almost 15%. This type of land is found in many other countries of the world. Previously most of the Indian farmers grew cotton in black soil. Black soil is very much favorable (good fertility) for producing the plant of cotton and hence this soil is known as black cotton soil in India and south Asia particularly.

Basically the black cotton soil has fine-grained clay particles which cause a massive change in volume with change in moisture conditions, i.e. it swells excessively when wet and shrinks during dry period. Hence black cotton soil is also known as expansive soil. Please note all black cotton soil is not expansive and all expansive soil is not black. It is the expansive nature of soil which is challenging and creates problems and not color.

Building a foundation in black cotton soil is a risk and to avoid the risk, read here which will reveal the mystery of foundation in black cotton soil.

**Figure 1.Electrical substation**.

An electrical Network comprises of the following systems

1. Generating Stations
2. Transmission Systems
3. Receiving Stations
4. Distribution Systems
5. Load Points

In all these systems, the power flow of electrical energy takes place through Electrical Substations. An Electrical Substation is an assemblage of electrical components including bus bars, switchgear, power transformers, auxiliaries, etc. Basically an electrical substation consists of a number of incoming circuits and outgoing circuits connected to common bus bar system. Bus bars are conducting bars to which a number of incoming or outgoing circuits are connected. Each circuit has certain electrical components such as circuit-breakers, isolators, earthling switches, current transformers, voltage transformers, etc. These components are connected in a definite sequence such that a circuit can be switched off/on during normal operation by manual/remote command and also automatically during abnormal conditions such as short-circuits. A substation receives electrical power from generating station via incoming transmission lines and delivers electrical power via the outgoing transmission lines. Substations are integral parts of a power system and form important links between the generating stations, transmission and distribution systems and the load points.

## II. LITERATURE REVIEW

Rashmi.S. Unone (2020) Analyzed the time of analysis and designing the load transfer part and load dispersion member plays an important role normally the structure and design for gravity loads which is considered to be vertically downward does the total load of superstructure is transmitted through the substructure putting the stability of the footing depend upon the perfect analysis and design considering the soil underneath it the behavior of the soil it changes with the change in season and thus its behavior with the contact structures is the properties of black cotton soil show large variation the study in this dissertation is done to analyses the effect of seasonal variation of black cotton soil on footing.

Parth Akbari and Hardik Patel (2020) concluded urbanization increases worldwide, the available land for building is becoming scarier and scarier, and the cost of land is becoming higher and higher. Thus the popularity of tall structure is increasing day by day to withstand the load of these structures proper stiff foundation is to be used such as pile foundation which includes the study of static analysis of pile foundation.

Sruthi Obulreddy (2019) studied the percent of the black cotton soil found in total soil deposition is almost 15%. This type of land is found in many other countries of the world. Black cotton soil is very troublesome and problematic and hazardous due to its characteristics. Because of its high swelling and shrinkage characteristics, the black cotton soil has been a challenge to the Engineers. The black cotton soil is very hard when dry but loses its strength completely when in wet condition. Soil deposits in nature exist in an extremely erratic manner producing there by an infinite variety of possible combination which will affect the strength of the soil and the procedure to make it purposeful.

Roochira R. Bobde (2019) studied Civil Engineering Aspects in Black Cotton Soil is giving hazardous problems to engineers. With the rapid development in Soil improvement, construction technique and social need various constructions of structure are taking place. The possibility of good construction sites to build structures on Black Cotton Soils is difficult due to their poor strength and deformation characteristics.

Vijay Rajoria and Suneet Kaur (2015) studied the soil stabilization has become a vital term in the field of geotechnical engineering due to the construction of heavy structures such as high rise buildings, large dams, underground structures etc. These structures impose immense pressure on soil. Most of the time engineers are not lucky enough to get the soil strata having sufficient strength to sustain this pressure, especially in case of highly cohesive soil which undergo huge variation in strength in dry and wet conditions.

## III. METHODOLOGY

### 3.1 Design Considerations

Pile foundations shall be designed in such a way that the load from the structure can be transmitted to the sub-surface with adequate factor of safety against shear failure of sub-surface and without causing such settlement (differential or total), which may result in structural damage and/or functional distress under permanent/transient loading. The pile shaft

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should have adequate structural capacity to withstand all loads (vertical, axial or otherwise) and moments which are to be transmitted to the subsoil and shall be designed according to IS 456.

Diameter of Piles — Piles of 600 mm or less in diameter are commonly known as small diameter piles while piles greater than 600 m diameter are called large diameter piles. Minimum pile diameter shall be 450 mm. and Minimum grade of concrete to be used in pile foundations has been revised to M 25.

- Safe Load — It is the load derived by applying a factor of safety on the ultimate load capacity of the pile or as determined from load test.
- Ultimate Load Capacity — The maximum load which a pile can carry before failure, that is, when the founding strata fails by shear as evidenced from the load settlement curve or the pile fails as a structural member.
- Working Load — The load assigned to a pile as per design.
- Spacing of Piles -The minimum center-to-center spacing of piles is considered from three aspects, namely,

a) Practical aspects of installing the piles,
b) Diameter of the pile, and
c) Nature of the load transfers to the soil and possible reduction in the load capacity of piles group.

**3.2 Pile Foundation Design**

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b) Diameter of the pile, and
c) Nature of the load transfers to the soil and possible reduction in the load capacity of piles group.

**B. Pile Groups**

- In order to determine the load-carrying capacity of a group of piles a number of efficiency equations are in use. However, it is difficult to establish the accuracy of these efficiency equations as the behavior of pile group is dependent on many complex factors. It is desirable to consider each case separately on its own merits.
- The load-carrying capacity of a pile group may be equal to or less than the load-carrying capacity of individual piles multiplied by the number of piles in the group. The former holds true in case of friction piles, cast into progressively stiffer materials or in end-bearing piles.

**2.1 Pile Capacity**

- The load-carrying capacity of a pile depends on the properties of the soil in which it is embedded. Axial load from a pile is normally transmitted to the soil through skin friction along the shaft and end-bearing at its tip. A horizontal load on a vertical pile is transmitted to the soil primarily by horizontal subgrade reaction generated in the upper part of the shaft. Lateral load capacity of a single pile depends on the soil reaction developed and the structural capacity of the shaft under bending. It would be essential to investigate the lateral load capacity of the pile using appropriate values of horizontal subgrade modulus of the soil. The ultimate load capacity of a pile should be estimated by means of static formula based on soil test results. Pile capacity should preferably be confirmed by initial load tests [see IS 2911 (Part 4)]. The settlement of pile obtained at safe load/working load from load-test results on a single pile shall not be directly used for estimating the settlement of a structure. The settlement may be determined on the basis of subsoil data and loading details of the structure as a whole using the principles of soil mechanics.

### C. Negative Skin Friction or Drag down Force

- When a soil stratum, through which a pile shaft has penetrated into an underlying hard stratum, compresses as a result of either it being unconsolidated or it being under a newly placed fill or as a result of remolding during installation of the pile, a drag down
- Force is generated along the pile shaft up to a point in depth where the surrounding soil does not move downward relative to the pile shaft. Existence of such a phenomenon shall be assessed and suitable correction shall be made to the allowable load where appropriate.

## IV. OVERLOADING

When a pile in a group, designed for a certain safe load is found, during or after execution, to fall just short of the load required to be carried by it, an overload up to 10 percent of the pile capacity may be allowed on each pile. The total overloading on the group should not, however, be more than 10 percent of the capacity of the group subject to the increase of the load on any pile being not more than 25 percent of the allowable load on a single pile.

### 4.1 Reinforcement

The design of the reinforcing cage varies depending upon the installation conditions, the nature of the subsoil and the nature of load to be transmitted by the shaft-axial, or otherwise. The minimum area of longitudinal reinforcement of any type or grade within the pile shaft shall be 0.4 percent of the cross-sectional area of the pile shaft. The minimum reinforcement shall be provided throughout the length of the shaft.

## V. LOAD CALCULATIONS DETAILS

### 5.1 Current Transformer

Almost all AC protective relays in various protection systems are actuated by the current supplied by the current transformers. It is not an easy way to measure the high magnitude alternating current with low range ammeters. And also relays must be rated at high currents to actuate under these high alternating currents. Therefore, the current transformer does the current conversion from high currents to a measurable range of currents. The specific application of current transformers involves in various considerations such as type of mechanical construction, ratio of primary to secondary currents, type of insulation (oil or dry type), thermal conditions, accuracy, service type, etc.

### 5.2 Electrical Isolator

The isolator can be defined as; it is one type of mechanical switch used to isolate a fraction of the electrical circuit when it is required. Isolator switches are used for opening an electrical circuit in the no-load condition. It is not proposed to be opened while current flows through the line. Generally, these are employed on circuit breaker both the ends thus the circuit breaker repair can be done easily without any risk.

Fig2. Electrical Isolator

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### 5.3 Circuit Breaker

A circuit breaker is a switching device that interrupts the abnormal or fault current. It is a mechanical device that disturbs the flow of high magnitude (fault) current and in additions performs the function of a switch. The circuit breaker is mainly designed for closing or opening of an electrical circuit, thus protects the electrical system from damage.

### 5.4 Lightning Arresters

Lightning Arresters are a device used to protect from lightning strikes. These are known as Lightning Arresters. An electric shock is nothing but a temporary increase in voltage, arc, spark, and surge current caused by electricity.

### 5.5 Wave trap

Line trap also is known as Wave trap. What it does is trapping the high frequency communication signals sent on the line from the remote substation and diverting them to the telecom/teleportation panel in the substation control room (through coupling capacitor and (LMU). This is relevant in Power Line Carrier Communication (PLCC) systems for communication among various substations without dependence on the telecom company network. The signals are primarily teleportation signals and in addition, voice and data communication signals. Line trap also is known as Wave trap.

## VI. RESULT AND DISCUSSION

### 6.1 Discussion

In the present study, comparative analysis of RCC foundation, almost all different component of load considers for analysis and design. The foundation are analyses for dead load and live load and also factored load should be considering for Design foundation. Comparison has been made on structural parameters pile foundation reinforcement and rectangular or mat foundation reinforcement.

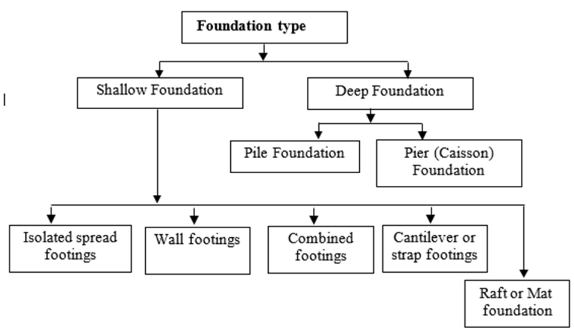



**Figure:** Flow Chart

### 6.1 Shallow Foundations

Are usually located no more than 6 ft. below the lowest finished floor. A shallow foundation system generally used when

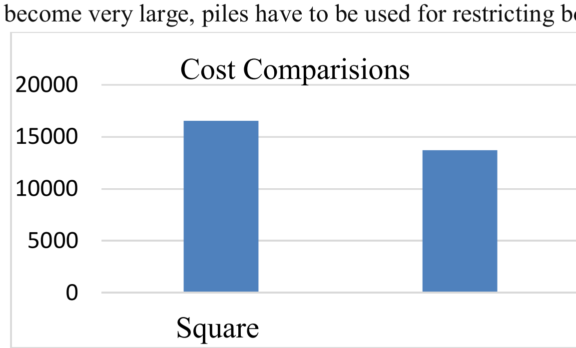
A. The soil close the ground surface has sufficient bearing capacity, and
B. Underlying weaker strata do not result in undue settlement. The shallow foundations are commonly used most economical foundation systems.

### 6.2 Deep Foundation

A deep foundation is a foundation which transfers the loads to deep strata and is placed at a greater depth, and provides lateral support and resists uplift effective. This foundation carries building loads to more competent strata that are down too far below the ground level and from affecting their base bearing capacity deep foundation prevents the surface conditions.

## VII. CONCLUSION

- Based on the analysis and design results following conclusions have been drawn.
- general, the pile require foundation is likely to be more expansive than square footings or mat.In
- Weak soils with heavy column loads require either rafts or piles. Rafts, in general are more economical than piles. But, when rafts become very large, piles have to be used for restricting both cost and settlement.
- When piles and rafts are both equal in cost, then piles are preferable to rafts, as the settlement for piles is considerably less than that of rafts. Thus, pile foundations have to be used when raft foundations are not suitable on grounds of economy or settlement considerations.
- Provision of Rectangular or raft foundation works out to be economical when a medium bearing/moderate bearing soil is available up to a depth of 2 to 3m. However, for structure having more than 4 stores and a hard stratum is available only 10m depth below ground level, then adoption of pile foundation is the best in addition to be economical.
- The key to economy in the pile foundations is to keep the area of pile cap in plan to the Capacity of a pile is increased by increasing either the diameter or depth of a pile, pile spacing (equal to three times the diameter) will increase and this will lead to a large pile cap, which will result in increased cost. So, pile depth should be increased to get high capacity piles. Thus, economy requires the use of a few high capacity deep piles under a column rather than a large number of low capacity shallow piles.
- This also one type of shallow foundation. This types of shallow foundation, filling RCC slab over the entire construction area or some part of it. Many columns, walls are supported on this slab. Mat foundation is more suitable for black cotton soil. Load is very low in this case also use in rectangular footing.
- Weak soils with heavy column loads require either rafts or piles. Rafts, in general are more economical than piles. But, when rafts become very large, piles have to be used for restricting both cost and settlement.




**Graph 1.** Square Vs. Pile Foundations

- Raft foundations are not suitable on grounds of economy or settlement considerations.
- Pile and square foundation both are almost equal cost, but in case rectangular foundation is need for filling gravels, boulders, murum etc. but as compare to pile foundation no need for Filling material. in Raft Foundation Reinforcement percentage is increased 1.2075 % as compare to pile foundation.

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