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Design of pile foundation in black cotton soil by using STAAD. foundation

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Abstract:

The selection of foundation depends on many factors like soil condition, bearing capacity of soil, ground water level, climatic conditions, location of site, cost of foundation, purpose of construction, material availability, etc.. .. It is very important for an engineer to save time. as a sequel to this an attempt is made to analyze and design a Multistoried building by using a software package staad pro. For analyzing a multi storied building one has to consider all the possible loadings and see that the structure is safe against all possible loading conditions. The dead load and live loads are applied and the design for beams, columns, footing is obtained STAAD Pro with its new features surpassed its predecessors, and compotators with its data sharing capabilities with other major software like AutoCAD, and MS Excel. We conclude that staad pro is a very powerful tool which can save much time and is very accurate in Designs. Thus it is concluded that staad pro package is suitable for the design of a multistoried building. In this paper foundation is designed based on soil condition, analytical method and the pile cap is designed by STAAD FOUNDATION in a safe conditions and to reduce the time for foundation designing. STAAD.foundation is an advanced technique of STAAD.PRO. STAAD.foundation is a cost saving downstream application that enables engineers to analyze and design a foundation. STAAD.foundation can automatically absorb the geometry, loads and reactions from a STAAD.Pro model and accurately design isolated, pile cap, strip footing, true mat foundations and even perform pile arrangements for a pile cap. For G+2 building in black cotton soil along with a pile foundation.

Key words: Black Cotton Soils, Pile foundation, Staad Pro, Staad.foundation, G+2 building.

Introduction:

Black cotton soil is very troublesome and problematic and hazardous due to its characteristic. Because of its very low bearing capacity and high swelling and shrinking characteristics, the black cotton soil it has been challenge to the engineers. It is very hard when dry but loses its strength completely when in wet condition. Swelling and shrinking of expansive soil cause deferential settlement resulting in severe damage to the foundation, buildings, roads, retaining structure and canal linings. To overcome this types of problems we need to provide very strong foundation for such soil conditions. The under reamed piles developed by the CBRI, Roorkee, are commonly used in India for foundation in expansive soils. Piles are columnar elements in a foundation which have the function of transferring load from the superstructure through weak compressible strata or through water, onto stiffer or more compact and less compressible soils or onto rock. They may be required to carry uplift loads when used to support tall structures subjected to overturning forces from winds or waves. Pile foundations are used when the strata at or just below the ground surface is highly compressible and very weak to support the load transmitted by the structure. In case of expansive soils, such as black cotton soil, which swell or shrink as the water content changes, piles are used to transfer the load below the active zone. Collapsible soils, such as loess, have breakdown of structure accompanied by a sudden decrease in void ratio when there is an increase in water content. Piles are used to transfer the load beyond the zone of possible moisture changes in such soils. STAAD Foundation is software used to design the foundation by analyzing the super structure loads. STAAD.foundation provides a total solution for your foundation needs.- In this paper an attempt has been made to study the following objectives.

1. To study the existing soil condition in the study area by conducting laboratory tests.

2. Design and analysis of G+2 building in staad pro.
3. Design of pile foundation by using analytical approach.
4.Design of pile cap using software.

II. LITERATURE REVIEW:

Chaudhari and Dr K. N. Kadam(2013), Has studied the influence of pile length configurations on behaviour of multi-storied are evaluated under vertical loading. In practice, the foundation loads from structural analysis are obtained without allowance for soil settlements and the foundation settlements are estimated assuming a perfectly flexible structure. Symmetrical four bay G + 11 storey frame having one pile supported under each column and the plan of the building with piles position is 25 piles. Hence, the interaction among structures, their foundations and the soil medium below the foundations alter the actual behaviour of the structure considerably than what is obtained from the consideration of the structure alone.

Dinachandra Thoidingjam, Dr.D S V Prasad, Dr. K.Rambha Devi,(2016). In foundation engineering, generally the most popular types of foundations used for high rise buildings or special structures are raft foundations or pile foundations. These soils are characterized by low bearing capacity and high compressibility. A pile-raft foundation can be used to reduce the settlements caused by concentrated building loads. This study is mainly aimed to study the influence of spacing of piles and raft width on the behaviour of the pile raft foundation in organic clay. These systems when implemented alone will fulfill the design requirements. With different number of piles and also the comparison between different thicknesses for 100 and 200 mm width flexible and rigid piled rafts with 1, 4 and 9 piles respectively. It is observed that the load carrying capacity of the piles increase as the size of the raft increase. However, in most cases they become over safe and economically not efficient. Furthermore, in some cases when being used alone they can cause some important problems. On the other hand, when the conditions are suitable, these systems can be combined and one can have a more efficient, safe and economical design.

Research carried out by V.Suneetha, Dr.D.S.V.Prasad (2017),the failures of structure are mostly due to the failure of foundations. Foundation is the most important part of the structure. The strength and durability of any structure depends upon the strength of its foundation. With the total load on piles of 1000KN and the safe load carrying capacity of 4 piles is 1502.8KN for G+2 building. Based on research carried out to develop an effective foundation system, it is found that under-reamed piles provide an ideal solution to foundation in black cotton soil or other similar types of expansive soils.

Falah Rahil, Mohanned Waheed(2018), Piles are structural members made of steel, concrete or timber that are used to build the pile foundation, which is used when the bearing capacity of the shallow top soil is not capable of supporting the structure via using any of the shallow foundation types. The load carrying capacity of piles resulting from the base resistance and the shaft resistance, the load transfer mechanism of piles is complicated since the mode of failure of these components is different in addition to the effect of pile installation on the soil surrounding of piles. The different pile lengths (L) are selected (300mm and 450mm) so that the centre to centre spacing between the piles (Sp) used are (3D) and (5D). However, according to the maximum point resistance will not be mobilized until the tip of pile has moved about (10 to 25 %) of pile width Based on the available literature, it can be reported that there was a lack observed regarding an experimental study of the behaviour of the base and the shaft pile resistance in clayey soil deposits due to the limited research in these types of soils which make the behaviour is difficult to understand.

3.STUDY AREA:

Kurnool developments comprise the most part shales, quartzites, limestones/dolomites. Ground water happens in submerged table conditions in weathered segment of the arrangement and the thickness of the weathered portion is around 10 m bgl. Iron ore is present in Ramallakota with hard rock and we designed end bearing pile foundation, district survey report(2018).

Soil is collected from Ramallakota, village at a depth of four feet at Veldurthy Mandal, Kurnool District, Andhra Pradesh. Ramallakota is a village panchayat located in the Kurnool district of Andhra-Pradesh state, India. The latitude 15.571906 and longitude 78.001986 are the geocoordinate of the Ramallakota. It belongs to

Rayalaseema region . It is located 32 KM towards South from District head quarters Kurnool. 4 KM from Veldurthi. 243 KM from State capital Hyderabad.

4.METHODOLOGY:

The various laboratory tests conducted to determine the index and engineering properties of the clays selected for study are briefly described. Methods followed by the objectives of our project have been discussed here.

4.1. To study the existing soil condition in the study area by conducting laboratory tests.:

We are going to analyze the characterization of materials used in this study, details of the experimental investigations such as index properties and engineering properties of the collected soil as per the IS standards. Soil tests are conducted in laboratory IS code 2720 of different parts and the results obtained should be within the limits of IS code.

4.2. Design and analysis of G+2 building in staad pro.

The various structural elements of the multi-storey building need to be designed taking the strength and stability factors into consideration, the building needs to be designed to follow the framed-structure type i.e. the beams, columns and slabs will be connected to each other rigidly and the beams and columns will form a grid-like pattern. In designing a foundation many types of loads may be acting on a building which we have to take into consideration, like dead load, live load, wind load, earthquakeloads,etc..as per IS 456 2000.

First we are going to design rectangular columns of 0.25x0.30m. Beams of rectangular size of 0.25x0.25m, with the slab thickness of 125mm, Concrete of M30 and HYSD steel bars, and applying different types of load conditions of dead load, live load and slab load according to IS 456 2000. Considering these dimensions building is designed and then run analysis to complete the designing procedure.

4.3. Design of Pile foundation:

Piles in closely spaced groups behave differently than single isolated piles because of pile-soil-pile interactions that take place in the group. It is generally recognized that deflection of a pile in a closely spaced group are greater than the deflections of an individual pile at the same time load because of these interaction effects. The maximum bending moment in a group will also be larger than that for a single pile, because the soil behaves as if it has less resistance, allowing the group to deflect more for the same load per pile[17]. For the design of pile foundation we should know about the load carrying capacity of a pile foundation. Here we are using static formula method to determine load carrying of pile foundation[13].

Static Formulae Piles in cohesive soils

The ultimate bearing Qu of piles in cohesive soils is given by the following formula

Qu = End bearing resistance Qp + Skin resistance QS

$Q\text{u} = A\text{p}\ N\text{c}C\text{p} + \Sigma\alpha\ A\text{si}\ C\text{si}$

where

NC = Bearing capacity factor in clays which is taken as 9

cP = Average cohesion at pile toe.

άi = Adhesion factor.

ci = Average cohesion of the ith layer on the side of the pile.

Asi = Surface area of pile stem in the ith layer.

άi ci = Adhesion between shaft of pile and clay.

4.4.Design of pile cap using software:

A reinforced concrete slab or block which interconnects a group of piles and acts as a medium to transmit the load from wall or column to the Piles is called a **Pile Cap**. STAAD.foundation is an exhaustive analysis, design, and drafting solution for a variety of foundations that include general foundation types such as isolated, combined footings, mat foundations, pile caps and slab on grade and plant foundation such as vertical vessel foundation and heat exchanger foundation. We are using this software which if from the family of STAAD Pro to design our foundation pile cap, it gives us the output as limit state method and it also facilitate us to export the output design into auto cad from where we can get a printout of it. It gives efficient foundation design and documentation using plant-specific design tools, multiple design codes including Indian codes and metric bar sizes, design optimization, and automatic drawing generation. STAAD Foundation provides you with a streamlined workflow through its integration with STAAD.Pro or as a stand-alone application. You can design virtually any type of foundation, from basic to the most complex. After the design and analysis of structure in staad pro go to staad

foundation and pile cap is designed with a geometrical data and analysis is done to get output.

5.RESULTS AND DISCUSSIONS

5.1. *Properties of soil:*

Table 1: Results of Properties of soil

S.N0	PROPERTIES	RESULTS
1	Specific Gravity	2.1
2	Liquid Limit	65%
3	Plastic Limit	27.71%
4	Plasticity Index	37.28%
5	Free Swell	62%
6	Optimum Mositure Content(OMC)	19.5%
7	Maximum Dry Density(MDD)	1.5g/cc
8	CBR Unsoaked	15.59%
9	CBR Soaked	9.90%
10	Unconfined Compressive Strength(UCC)	2.04Kg/cm2
11	Cohesion	98Kpa

Results obtained by the black cotton soil are within the limits as per IS code plasticity index of 37.28% the soil is classified as high compressible soil(black cotton soil). specific gravity, free swell, omc, mdd, cbr, ucc, cohesion all the results mentioned in table 1 are within limits of IS code as given in table 1.

5.2. Design and analysis of G+2 building in staad pro.

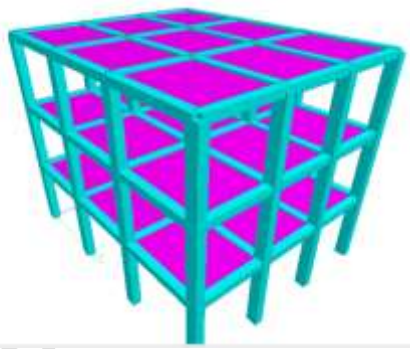

Fig 1: 3D Rendering view

Here g+2 building is designed in staad pro with input as mentioned in methodology and by running analysis we get the output of the design. The fig1 shows the plan of a case study, with the design parameters of columns, beams and slabs we get 3D rendering view of the building as shown in fig 1. After the application of loads acting on the structure it get shear forces, bending moment, deflection. the final output of total loads acting along with steel and concrete acting in 26,189 KN. The results of staad pro allows as to get the printout.

5.3. Design of Pile foundation:

Ultimate load capacity of pile group according static formula

Qu=Qp+Qs

Diameter of pile is 0.6m

Length of pile 8m

Ap=0.282m2

As=15.07m2

Qp=98x9x0.282

=248.724KN

Qs=0.6x98x15.07

=886.116KN

Qu=248.72+886.116

=1134.84KN

Load bearing capacity of individual pile is

Qu=Nx(Qp+Qs)

Qu=4x4x1134.84

=18157.44KN

Pile groups in clay

Qgu=qpAg+ αCPgD

qp= Unit point resistance =CNc

Ag=Base area of block

Pg=Perimeter of block

D =Depth of block

For square pile Lg=Bg

Lg=((n-1)s)+D

n=Number of piles

S=Spacing of piles

=3.5D =2.1m

Lg=32.1

qpAg=9x98x32.1x2
=56624.4KN
αCPgD=1x98x32.1x4x8
=100665.6KN
Qgu=56624.4+100665.6
=157290KN
Efficiency
η=Qgu/NQu x100
=157290/16x18157.44 x100
=54.14%
Ulimate load =18157.44/2.5
Safe load=Ulimate load/Factor of safety
=72629.76/2.5
=29051.904KN
29051.904KN > 26189KN, Hence Safe.

Pile foundation is designed using analytical approach by static method with end bearing piles of pile diameter of 0.6m, length of pile 8m, with 16 piles. The piles considered are safe to bear the load acting on the foundation by the super structure of building and it is proved to be safe.

5.4.Design of pile cap using software:

Pile Cap Length PCL and Width PCW = 7.300 m
Initial Pile Cap Thickness ti = 0.300 m
Pile spacing Ps = 2.100 m
Pile Edge distance e = 0.500 m
Pile Diameter dp= 0.600 m

Concrete Cover:

Bottom Clear Cover CCB and Side Clear Cover CCS = 0.060 m

Pile Cap size = 7.300 mx7.300m

Reinforcement Calculation:

Maximum bar size allowed along length and width # 40

Bending Moment At Critical Section = -747.517 kNm (Along Length)

Bending Moment At Critical Section = -738.670 kNm (Along Width)

Calculated Thickness (t) = 0.400 m

Check for Moment (Along Length):

Effective Depth(def) = = 0.259 m

Depth of neutral axis for balanced section(xu) = 0.115 m

As Per IS 456 2000 ANNEX G,G- 1.1 C

Ultimate moment of resistance(Mulim) = = 1912.612 kNm

We observed Mu<= Mulim

Hence singly reinforced and under reinforced section can be used.

Check for Moment (Along Width):

Governing moment (Mu) = - 738.670 kNm

We assume singly reinforced and under reinforcement section

Effective Depth(def) = 0.259 m

Depth of neutral axis for balanced section(xu) = 0.115 m

As Per IS 456 2000 ANNEX G,G- 1.1 C

Ultimate moment of resistance(Mulim) = 1912.612 kNm

We observed Mu <= Mulim, hence singly reinforced and under reinforced section can be used.

Check for One Way Shear (Along Length):

Design Shear Force for One-Way Action Vu = - 307.007 kN

As Per IS 456 2000 ANNEX B,B- 5.1 and Clause No 34.2.4.2

Design Shear Stress (Tv) = - 162.377 kN/m^2

Allowable Shear Stress (Tc) = 383.077 kN/m^2

Here Tv <= Tc Hence safe.

Check for Two Way Shear (Along Length):

Design Two-Way Shear force = - 613.838 kN

As Per IS 456 2000 Clause 31.6.2.1

Two Way Shear Stress(Tv) = - 1109.565 kN/m^2

As Per IS 456 2000 Clause 31.6.3.1

Allowable shear stress= 1369.307 kN/m^2

Tv < KsTc Hence Safe.

Pile cap is designed using staad foundation detail and schedule drawing is

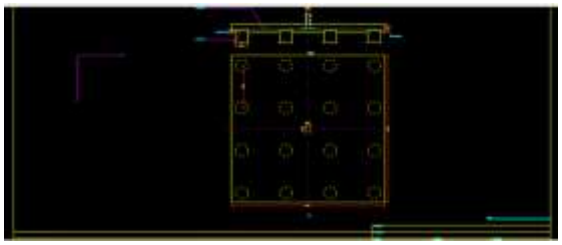

Fig 2:Output of pile foundation

Pile cap is should be designed for pile foundation, pile foundation is designed by using analytical method for that piles, pile cap is designed with required data as mentioned in methodolgy in staad foundation with the loads acting on the pile got safe value design. Check for moment, check for one way shear along length, width, check for two way shear along length, width have been checked like limit state method. Fig 2 is an output of pile foundation with number of piles which can be exported to autocad.

6. CONCLUSIONS

1. Laboratory tests conducted on collected black cotton soil all the values obtained are within limits of IS code, It is observed from the plasticity characteristics PI is 37.28% that soil is classified as high compressible soil(good black cotton soil).

2.To design a foundation we need to know amount of load acting on foundation from the structure design and analysis of G+2 building is done as per IS code using staad pro, the load acting from super structure is 26189KN.

3.Pile foundation is designed using static method and with required number of piles it can bear the load more than the loads acting on super structure with safe load conditions. With 16 piles of dia 600mm and length 8m, as the load acting is 26189KN but our piles bears load of 29051.90KN, Hence it is safe.

4.Pile cap is designed with pile cap of 7.3x7.3m using staad foundation and it is possible to analyze and design the pile cap with the help of software and time can be saved by avoiding lengthy calculations required for analysis and design, it gives us the output as limit state method and it also facilitate us to export the output design into auto cad from where we can get a printout of it.

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