IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

A STUDY ON DETERMINATION OF BEARING CAPACITY OF SHALLOW FOUNDATION BY IS CODE METHOD AND PLAXIS 3D ANALYSIS

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Abstract: Bearing capacity evaluations of shallow foundations in the case of spatially variable soils are currently used primarily for two- dimensional analysis. One of the reasons for this situation is numerical efficiency, which limits the use of three-dimensional finite element formulations for random analyses. However, recent attempts have been made to solve such issues, Moreover, most existing probabilistic methods have been applied tosingle-layered soil. However, from an engineering perspective, two- layered soil is also a highly probable situation. An especially important situation is when the bottom layer is a soft soil and the top layer is a strong soil. This scenario has been extensively examined in the case of deterministic analyses however, there have been very few studies on random analyses of two- layered soil. It is worth mentioning that, it is possible to perform these types of two-dimensional analyses. In the present study soil exploration has been executed in the two fields at two locations. Undisturbed & Disturbed soil samples has been collected up to the maximum depth of 25 m below ground level for each of the two locations. The locations are Hedua (Site - 1) and Canning (Site - 2) which are situated in Kolkata. Engineering Properties of soil samples has been determined by routine testsfrom two above mentioned sites and further evaluation has been made for the types of foundation required for a (G+3) storied building. The ultimate bearing capacity, safe bearing capacity, safe load and corresponding settlement analysis of different shallow foundations has been made. Further model study has been executed by finite element analysis using PLAXIS 3D software for the pre-decided foundation dimension and ultimately a comparative study has been made between those capacities and corresponding settlement for two different locations used in the present study with the values obtained from finite element analysis obtained from PLAXIS 3D.

I. INTRODUCTION:

Bearing capacity is defined as the maximum load per unit area that the soil under the foundation can carry withoutundergoing excessive settlement or failure. Layered soil consists of multiple soil layers of varying properties which highly influences the load carrying capacity of the soil thus affecting the stability and performance of the structure. The Estimation of Bearing Capacity of the soil is governed by the following factors- Cohesion, Angle of internalFriction, Depth of Footing, Size of Footing, Ground water Level and the Bearing capacity factors. Bearing Capacity is estimated as per the guidelines provided by Indian Standard Code (IS 6403:1981). Advanced numerical modeling techniques, such as Finite Element Method (FEM) analysis with software like PLAXIS 3D enable the simulation of complex soil-structure interaction in multi-layered soil conditions. PLAXIS 3D brings Analysis of the soil profile at fingertips, considering the properties of various layers thus predicting much accurate value of bearing capacity. Understanding the bearing capacity of shallow foundations in layered soil is essential for ensuring the safe and economical design of structures in engineering practices.

II. OBJECTIVE AND SCOPE:

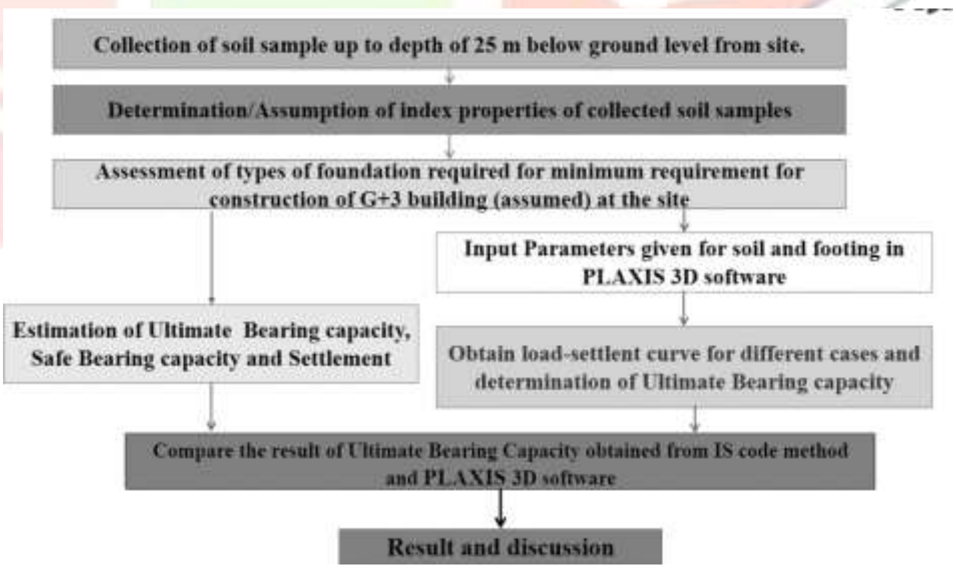
Objectives

- To find out Bearing capacity of Shallow Foundation of different Locations according to the guidelines provided by IndianStandard Code (IS 6403:1981) and by finite element method using PLAXIS 3D software for comparison purpose.
- To Study the variation between the IS Code calculated value and PLAXIS 3D predicted value.

To fulfill the objective following scope has been taken up:

- Soil samples have been collected up to depth of 25 m below ground level from 2 different sites of West Bengal,followed bydetermination of its index properties.
- Further attempt has been made to find out Bearing Capacity in PLAXIS 3D Software.
- To Understand the trend of Load vs Settlement curve obtained from PLAXIS 3D.

III. METHODOLOGY:



The methodology is explained in brief in the form of following Flow Chart.

A. FIELD EXPLORATION

The boring was advanced by a combination of auger and mud circulation method as per IS 1892:1981 and standard penetration test (SPT) have been conducted at suitable intervals, within the borehole, as per IS 2131:1981. A flush Joined collar casing has been used to prevent the caving of the sub-soil during boring work. The undisturbed and disturbed soil samples have been collected from suitable depths and brought to the laboratory for testing purpose.

B. FIELD INVESTIGATIONS

The programmes of field work at the present site are consisted of the following: -

- Sinking of boreholes (2 Nos).
- Collection of undisturbed soil sample from suitable depth below G.L.
- Conduction of standard penetration test at suitable depths below G.L.
- Collection of disturbed soil samples.
- Observed water level and Standing water level after 24 hours.

C. FIELD INVESTIGATIONS

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D. LABORATORY TESTS

The laboratory tests consist of the following:

a) Determination of Natural Moisture Contents (N.M.C.) IS:2720 (Part 2).
b) Determination of Bulk & Dry Unit Weight IS:2720 (Part 2).
c) Mechanical Analysis (Hydrometer & Sieve Analysis) IS:2720 (Part 4).
d) Determination of Atterberg Limits (Liquid Limit and Plastic Limit) IS:2720 (Part 5).
e) Tri-axial Tests (UU & CU) IS:2720 (Part 11, 12).
f) Unconfined Compression Test (UC) IS:2720 (Part 10).
g) Permeability Test IS:2720 (Part 17).
h) Consolidation Tests IS:2720 (Part 15).
i) Direct Shear Test IS:2720 (Part 13)
j) Specific Gravity IS:2720 (Part 3).

IV. ANALYSIS:

All these tests are conducted as per relevant IS codes were such exists and the test results are tabulated in tables. In this section, the results of all laboratory tests from locations of West Bengal namely, Hedua and Canning have been reflected in a form in Bore log and test result sheet. Table 4.1 and Table 4.2 represent detailed soil profile analysis and laboratory test results of site-1 (Hedua) respectively

A. DETAILED SOIL PROFILE ANALYSIS OF SITE AT HEDUA (SITE – 1)

WATER TABLE: 1.

DESCRIPTION	Bore hole no : 01	Depth (m) From	Depth (m) To	Thickness (M)	N-Value	Type & marked	Samples Depth (M)
Top Soil : Filling with dark brownish grey silty clay/clayey silt,rubbish and brick bats		0.00	2.50	2.50	-	DS	1.00
					-	DS	2.00
					4	SPT	2.50
Soft to medium brownish grey silty clay / clayey silt		2.50	4.00	1.50	-	UDS	3.00
Very soft to soft dark grey silty clay with organic materials and decomposed wood		4.00	13.50	9.50	4	SPT	4.50
					4	SPT	6.00
					2	SPT	7.50
					2	SPT	9.00
					2	SPT	10.50
					2	SPT	12.00
					-	UDS	13.50
Medium stiff light bluish grey silty clay with kankars		13.50	16.50	3.00	12	SPT	15.00
					14	SPT	16.50
Stiff to very stiff light yellowish grey clayey silt		16.50	20.50	4.00	-	UDS	18.00
					19	SPT	20.00

UDS-Undisturbed sample, SPT-Standard penetration test DS-Disturbed sample.

B. LABORATORY TEST RESULTS OF SITE AT HEDUA (SITE – 1)

Borehole No.	Depth (m)	Type of sample	Bulk density (t/m^3)	NMC (%)	Sp. Gr.	Atterberg Limits		Shear Strength Parameters				Consolidation
						LL (%)	PL (%)	Type of Test	UCS C(kg/cm^2)	UU C(kg/cm^2)	Ø(°)	m_v (cm^2/kg)
	3.00	UDS	1.82	31.75	2.67	50	22	UCS/UU	0.27	0.23	6	0.052
	13.50	UDS	1.86	31.18	2.67	55	23	UCS	0.56		-	0.029
	18.00	UDS	1.91	29.83	2.67	44	24	UCS	0.92		-	0.017

C. ESTIMATION OF BEARING CAPACITY BY IS CODE METHOD

Site-Hedua, of depth 2.5m

SIZE OF FOUNDATION (m)	ULTIMATE BEARING CAPACITY(t/m^2)	SAFE BEARING CAPACITY (t/m^2)
1.5x1.5x2.5	24.05	9.62
1x1	27.05	10.82
2x2	22.55	9.027
1.5x1	23.575	9.43
1.5x2	21.275	8.51

D..INPUT PARAMETERS OF PLATE ELEMENT IN PLAXIS3D

Identification	Concrete (Pla
Material Type	Elastic
Thickness(d) in m	0.5
Density (KN/m^3)	25

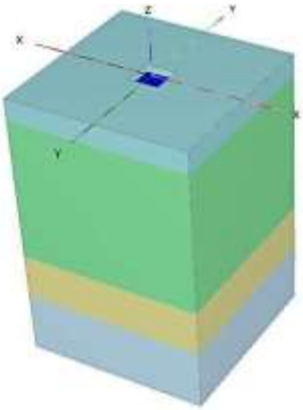
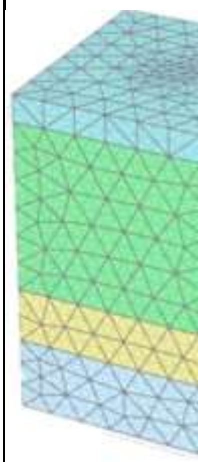
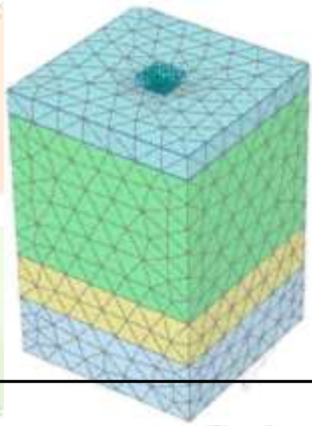
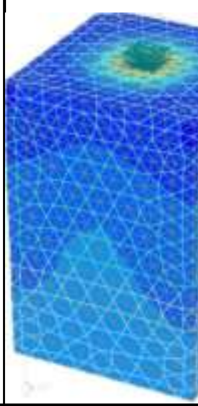
Isotropic	Yes
Elastic Modulus(E) (MPa)	25000
Poisson's Ratio (v)	0.15

E. INPUT PARAMETERS OF SOIL STRATA FOR ANALYSIS IN PLAXIS-3D

Input Data for FEM Analysis of Soil Profile in PLAXIS-3D For Site Hedua

Stratum( ) / Parameter ( )	Stratum 1	Stratum 2
Material model	Mohr coulomb	Mohr coulomb
Thickness (m)	1.5	9.5
Material Behavior	Undrained (B)	Undrained (B)
Unsaturated unit weight, ɣ (KN/m^3)	16.5	16.5
Saturated unit weight, ɣ (KN/m^3)	18.2	17.2
Young's modulus E, (KN/m^2)	13500	11000
Cohesion C, (KN/m^2)	27	22
Poisson's ratio, ν	0.33	0.38
Friction angle, ϕ (degree)	0	0

F. TYPICAL SOIL-PROFILE MODEL IN PLAXIS

	
Modelling of footing	Fine mesh gene
	
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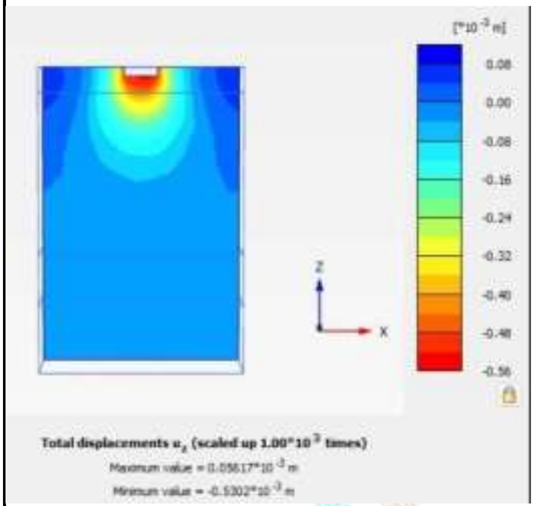
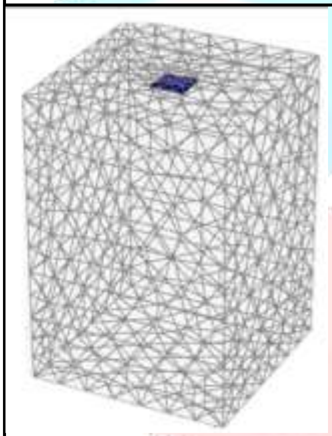
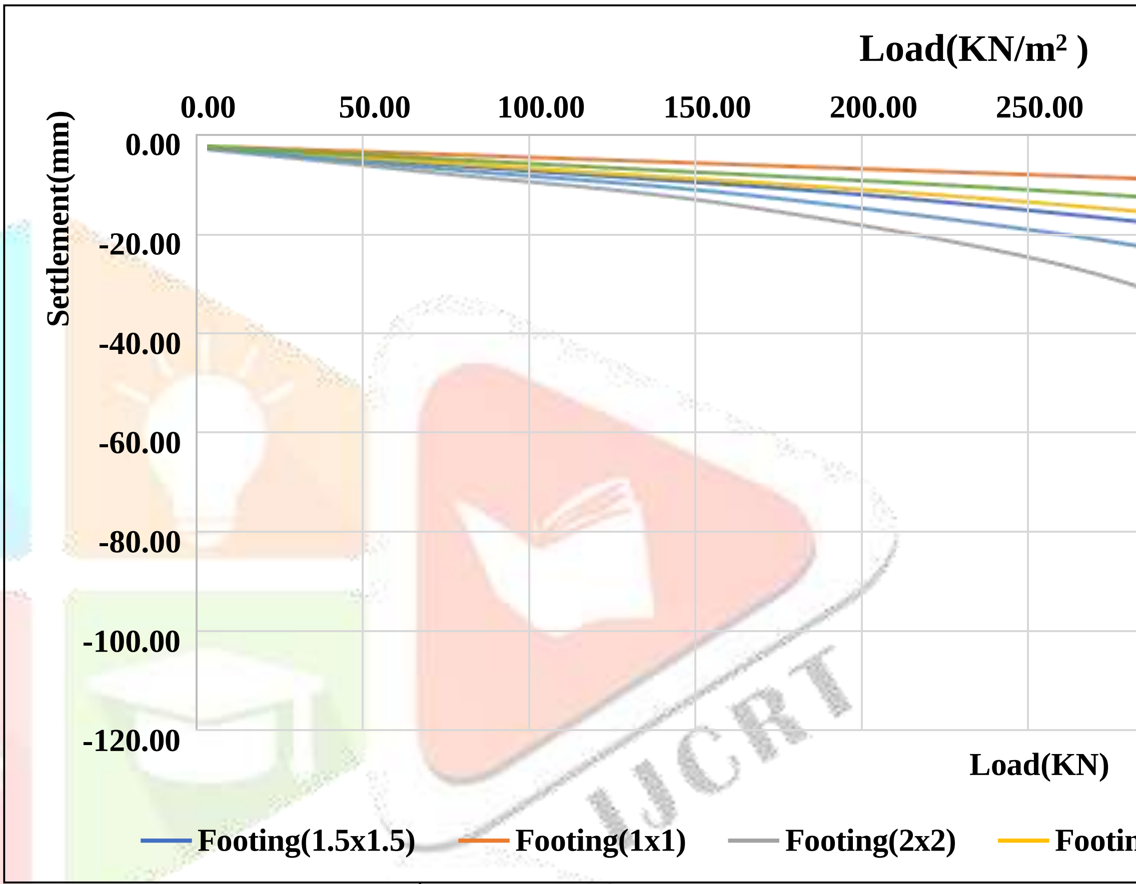
G.TYPICAL SOIL-PROFILE MODEL IN PLAXIS

	
Deformed mesh showing the extreme total displacement in terms of shadings	Typical nodal st
	
reme total displacement interms of arrows	Load vs settleme

H.LOAD- SETTLEMENT CURVE FROM PLAXIS



Load vs settlement Graph(For Dep

I. Bearing capacity obtained from PLAXIS

Site - Hedua

SIZE OF FOUNDATION (m)	DEPTH (m)
1x1	2.5
1.5x1.5	2.5
2x2	2.5
1.5x1	2.5
1.5x2	2.5
1x2	2.5
1x1	3
1.5x1.5	3
2x2	3
1.5x1	3
1.5x2	3
1x2	3

J. Comparison of Ultimate Bearing Capacity for site -Hedua

Site	)epth offooting	otingSize	imate bearing capacity by IS COD (t/m2)
Hedua	2.5	1x1	27.05
		1.5x1.5	24.05
		2x2	22.55
		1x2	22.90
		1.5x2	21.275
		1x1.5	23.575
	3	1x1	28.85
		1.5x1.5	25.25
		2x2	23.45
		1x2	24.425
		1.5x2	22.325
		1x1.5	25.075

K. Effect of Footing Size for Site- Hedua

Variation of The Ultimate Bearing Capacity due to change in footing Size (Depth of Footing: 2.5 m)

Footing Size (m)	Ultimate Bearing Capacity (PLAXIS 3D) (t/m²)
1x1	34.2
1.5x1.5	30.5
2x2	29
1x2	31
1.5x2	29.6
1x1.5	31.5

Variation of The Ultimate Bearing Capacity due to change in footing Size (Depth of Footing: 3 m)

Footing Size (m)	Ultimate Bearing Capacity (PLAXIS 3D) (t/m²)
1x1	35.1
1.5x1.5	31
2x2	30.5
1x2	32
1.5x2	30.8
1x1.5	33

L.Effect of Footing Size

It has been observed that the ultimate bearing capacity generally decreases as the footing size increases, with the 1x1 m footing size serving as the baseline for comparison The percentage decrease is more pronounced for larger footing sizes, particularly the 2x2 m footings. Forboth Hedua and Canning sites, the trend of decreasing bearing capacity with increasing footing size is consistent across different depths. For instance, For Site 1 (Hedua), at both depths of 2.5 m and 3 m, the 2x2 m footing size exhibits the highest percentage reduction in ultimate bearing capacity, with 15.20% and 13.11% decreases respectively. Whereas in the Canning site 2x2 m footing size experiences the highest percentage decrease in ultimate bearing capacity, with a reduction of 34.20%.and 20.27% for depth of foundation 1.5m and 2.5 m respectivelyLarger footings (i.e. 2x2 m) show a significant reduction in bearing capacity, suggesting that the larger area reduces the stress per unit area transferred to the soil. The percentage decrease in ultimate bearing capacity is generally more significant for the Canning site compared to the Hedua site, indicating that soil conditions andcharacteristics play a crucial role in the bearing capacity results.

M. Effect of Depth of Foundation

Variation of Ultimate Bearing Capacity Due to Change in Depth of Foundation

Site - Hedua

Footing Size (m)	mate Bearing Capacity (t/m²) at Depth 2.5 m	mate Bearing C
1x1	34.2	35.1
1.5x1.5	30.5	31.0
2x2	29.0	30.5
1x2	31.0	32.0
1.5x2	29.6	30.8
1x1.5	31.5	33.0

N. Effect of Depth of Foundation

The 2x2 footing size shows the maximum percentage increase in ultimate bearing capacity due to the increase in depth, with a 5.17% rise from 29.0 t/m² at 2.5 m depth to 30.5 t/m² at3 m depth. All footing sizes exhibit an increase in ultimate bearing capacity with an increasein foundation depth. The variation in ultimate bearing capacity due to depth is less pronounced for smaller footings (e.g., 1x1 m and 1.5x1.5 m) compared to larger footings (e.g., 2x2 m)

V. SUMMARY, CONCLUSION, LIMITATIONS:

A. SUMMARY

In the present study an attempt has been made to estimate the ultimate Bearing Capacity of isolated footing in multilayered soil using IS code method and numerical method using PLAXIS 3D. Soil samples have been collected from one location in Kolkata, specifically Hedua. and the properties of these soils have been utilized for this analysis.

B. CONCLUSION

For Hedua Site, at a depth of 2.5 meters, the ultimate bearing capacities obtained from PLAXIS 3D are consistently higher than those from the IS Code method, with percentage variations ranging from 26% to 39%. A This is due to the fact PLAXIS 3D performs a three-dimensional analysis, capturing the effects of out-of-plane forces and deformations, which can lead to a more realistic assessment of the bearing capacity. In contrast, the IS Code method typically relies on simplified, two-dimensional approaches. The 2x2 meter footing at the Hedua site shows a maximum decrease of 15.20% in ultimate bearing capacity at a depth of 2.5 meters. As for Hedua site, 2x2 footing size shows the maximum percentage increase in ultimate bearing capacity due to the increase in depth, with a 5.17% rise from 29.0 t/m² at 2.5 m depth to 30.5 t/m² at 3 m depth.

C.LIMITATIONS

Only IS code method has been used for ultimate bearing capacity calculation analytically. Only one location have been considered

VI. References:

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