Performance of square footing under the axial and eccentric loading on reinforced Non cohesive soil by geotextile : an experimental investigation

Pranoti P. Ghule[1], Pranav P.Ghume[2], Aniket K.Wasnik[3], Pawan D. Dhainje[4], Sunil J. Payghan[5]

[1] BE student (Civil engg) , DYPCOE Akurdi, Pune, Mahashratra, India.
[2] BE student (Civil engg) , DYPCOE Akurdi, Pune, Mahashratra, India.
[3] BE student (Civil engg) , DYPCOE Akurdi, Pune, Mahashratra, India.
[4] BE student (Civil engg) , DYPCOE Akurdi, Pune, Mahashratra, India.
[5] Asst. Prof. In (Civil engg) , DYPCOE Akurdi, Pune, Mahashratra, India.

ABSTRACT

There are several approaches available to enhance the bearing capacity of soil, but soil reinforcement stands out as a well-established and commonly employed method, especially for footings. In this study, we aim to investigate the performance of square footings using non- cohesive soil, deviating from the typical sand-based cohesive soil often used in experimental studies. The experimental setup will consist of a 500X500X450mm tank, equipped with essential instruments including a dial gauge, proving ring, and mechanical jack. Our focus will be on examining the impact of eccentricity in scenarios where axial or central loads are applied to square footings. We will conduct a comparative analysis, looking at cases both with and without the incorporation of GeoFibres, to assess their influence. Ensuring a stable foundation is of utmost importance for structural stability and resistance. However, achieving this stability can be challenging due to varying soil conditions. Therefore, it is essential to evaluate how a foundation settles on different soil types before embarking on actual construction. The proposed model serves as a valuable tool for such assessments. By introducing GeoFibres as a reinforcement measure, we aim to improve the soil's load-bearing capacity. We will conduct tests under varying conditions, with and without GeoFibres, and subsequently, comprehensively analyze and compare the results to gain valuable insights.

Keyword:-*Non cohesive soil, geotextile, MS tank, bearing plate, loading frame, Proving ring, Screw jack etc.*

---

1. Introduction

Foundation is a lower part of the structure. It act as a backbone to the structure. It is a part of substructure of the building. The function of the footing is to distribute the load which is coming from the superstructure into of soil below the footing. The life of the structure depends on the performance of the foundation. It may be subjected to inclined loads or eccentric loads or both. The problems of footings subjected to inclined loads are frequently encountered in the case of the foundations of retaining walls, abutments, columns, stanchions, portal framed buildings etc. Footing located at property line, machine foundation are some examples where the foundations experience eccentric loading. If the load is eccentric, the stress distribution below the footing will be non uniform causing unequal settlement at two edges[1]. The essence of every civil engineering construction is often said to lie in its foundation, which serves as the fundamental support system. Positioned at the base of a building. Due to the delicate nature of the soil beneath, it lacks the capacity to independently sustain the load of the superstructure. The optimum configuration was 4B reinforcement width and 0.375B backfill thickness. Rubber grid provided higher bearing capacity and lower. settlement than geogrid, offering a sustainable reuse of tire waste [2] .The operational efficiency of a structure hinges significantly on the effectiveness of its foundation. Despite its pivotal role, the behavior of this foundational element remains largely unexplored, necessitating careful and meticulous construction. The biaxial prestressing significantly improved the ultimate bearing capacity and settlement response compared to uniaxial prestressing and unreinforced conditions[3].The Failure of shallow foundation Is mainly due to shear and settlement criteria. Also bearing capacity can be found out from Foundation These two criteria i.e. shear and settlement, minimum of two criteria value is taken as ultimate bearing capacity of that foundation[4]. The most important part of any civil engineering construction is often considered to be the foundation, serving as the fundamental support system. Located at the base of a building, the foundation itself cannot support the load of the superstructure due to the delicate nature of the soil underneath. the bearing capacity decreased linearly with increasing eccentricity. The optimum reinforcement depth was 0.2B. The minimum bearing capacity ratio occurred at 0.15B[5].How well a structure operates significantly depends on how effective its foundation is. Despite its crucial role, the behavior of this foundational element is still not fully understood, requiring careful and precise construction. The reduction factor, that relates the ultimate bearing capacity of an eccentrically loaded foundation to that of a centrally loaded foundation[6] .The slope geometry, soil properties, foundation dimensions, loading conditions, and other factors influence the stability and capacity of footings on slopes[7]. Ensuring a structure's stability involves not only dealing with vertical loads but also considering potential tilting moments and shear forces in footings used as foundations for retaining walls, supports, and framed buildings.

1.1 Need for study.

The cornerstone of any structure lies in its foundation, which represents a critical component for overall functionality. The importance of foundations extends to various aspects, as they serve to bear and convey structural loads to the soil. In addition to minimizing settlements, both total and differential, foundations play a pivotal role in preventing potential structural shifts caused by periodic subsoil shrinkage and swelling. They enable construction over water or waterlogged terrain, resist wind-induced uplift and overturning forces, counter lateral forces resulting from soil movements, and effectively manage water infiltration and dampness. Foundations must demonstrate resilience against overall shear failure in the supporting soil while avoiding excessive settlement to ensure optimal functionality. The considerations of total settlement and its rate are distinct facets of this concern. Notably, in the design of shallow foundations, settlement often takes precedence over bearing capacity. Consequently, predicting settlement remains a significant challenge and a crucial factor in foundation construction. Despite employing various analytical techniques, achieving consistent and accurate settlement predictions remains an ongoing challenge.

1.2 Aim And objective

Aim - To determine the UBC of Square footing under axial and eccentric loading on non cohesive soil.

Objective –

- To enhance structural stability and resistivity of foundations.
- To investigate the characteristics of uniform and differential settlement in foundations.
- comparative analysis of the stability of foundations with and without the incorporation of Geotextile.
- To explore various soil engineering properties through the execution of diverse testing procedures.

1.3 Problem Statement

The tests will be conduct for axial load , the eccentric ratio e/B varying from zero (0) to 0.2and by achieving the engineering properties of sand. A square bearing plate having size 10 cm X 10cm X 1cm will be used for all the test. The details of the test and experimental procedure of the test have been mention in IS code 1888 1982. Geotextile will be used for reinforcing the soil in order to improve the ultimate bearing capacity of soil. Then we will be perform the test on footing as per the guideline of the IS Code 1888-1982 under the axial and eccentric loading, And then we will be analyzed results of the test. Soil will be use for test is Non cohesive i.e. sand, Test model will be prepared.

2. Materials, Equipment's and Method

The experimental model was consisted by mild steel tank, model footing (bearing plate) , dial gauge, proving ring, mechanical screw jack, geotextile. These are mention below in detailed.

Mild steel Tank:- the tank was made of 2 mm thick M. S plate. The Tank having the internal dimensions of 50cm X 50cm X 45cm . As per the Is code the minimum tank size required to be 5 times of width or breath of bearing plate whichever is more. Horizontal and vertical braces are provided for resisting the bulging effect.

Fig -1: MS Tank

Model of footing (bearing plate) – the model of footing is made of mild steel having size of 10 cm X 10 cm X 1 cm thick. Little grooves are provided on plate for the application of eccentric load and one groove is provide at the center for axil load. Two hangs are welded on both sides center of the plate to the measurement of settlement of footing under the action of load.

Fig -2 : Bearing plate

Dial Gauge :- The dial gauges were used to measure the settlement. Least count of dial gauges was 0.01 mm and total run was 25 mm. During testing, the two dial gauges were used for the measurement of vertical deformation of the footing and one dial gauge was used to measure the horizontal deflection. Two Dial gauges are provide on both sides of side to record the settlement of footing under the action of load**.**

Fig -3: Dail Gauge

Proving Ring :- For laboratory plate load test, proving rings of 50 kN capacity was used. The proving ring was fixed to bottom plunger to transfer load from proving ring to footing. Load is applied by using calibration certificate (expire date 18 January 2024)

Fig -4: Proving ring

Screw Jack :- The loads are applied on the model footing with the help of a 25 Ton capacity screw jack. The screw jack was fixed at the center of horizontal member of reaction frame which is called as horizontal girder.

Fig -5: screw jack

Materials :-

Sand :- The soil Is collected for pavana River which is near to our college, soil is must required for conducting the test. Mostly the soil is in Non cohesive in nature. By washing and cleaning the sand, it made free from the roots ad organic matters etc. Then various laboratory tests were perform as per the research papers which we had read to decide the different geotechnical and engineering properties of sand such as specific gravity, grade, density of sand etc.

Fig -6: sand

Table No. 1- Properties of soil

Sr. No.	Properties	Result
1	Specific gravity	2.65
2	Angle of internal friction: ø	35.94
3	Average grain size: D60	2.3
4	Effective grain size: D10	0.35
5	Coefficient of uniformity: Cu	6.57
6	Coefficient of curvature: Cc	2.43
7	I. S. Classification	Medium sand

Geotextile :- The geotextile is a permeable fabric placed beneath the loading plate that allows uniform settlement and reduces friction, thus lowering the bearing capacity.

Fig -7: geotextile

2.2 Method

The objective of the study is to determine the basic properties of soil through plate load testing using a mild steel tank and model footing. The tank's dimensions are 50×50×45cm Its exterior is made of 2mm thick mild steel sheets to provide stability during testing. The four sides are adequately supported to prevent bulging. The model footing, simulating a foundation, has a square shape of 100×100×10mm . Constructed from mild steel plates, the footing is secured by applying adhesive and rolling it over a sand layer, although this process may cause unevenness at the bottom. To achieve the desired average unit weight for compaction, sand is poured into the tank in layers of 25mm and the compaction is done by using a rainy approach from a predetermined height to ensure uniform distribution[8]. This step establishes the required compaction conditions. The height of fall for the sand is adjusted through test runs to obtain the desired unit weight before the actual test. Once the optimum height is determined, the model foundation is positioned in the tank's center, following the specified depth/breadth ratio. A mechanical jack applies load on the model footing, while dial gauges positioned along the breadth side measure the vertical settlement accurately, The load is applied at rate of 5 kN with increment until the soil fails and also measure the corresponding vertical displacement for each load. After that empty the tank and again fill with as per above procedure, then place the tank below the loading frame having eccentricity of 0.1,0.15 and 0.2 and aslo measure the corresponding vertical displacement. Then form that result plot the load settlement curve for each eccentricity[9].

Fig -8: Setup

3. Result

The experimental plate load tests were carried out on square footings having size 10 cm x 10 cm. The data from all the plate load tests, including the vertical settlement corresponding to the applied load, is provided in Table No. 2,3,4 & 5. Load-settlement curves were plotted for each of the tests. The ultimate bearing capacity was determined from these load intensity-settlement curves. The results of the reinforced soil under axial and eccentric loading were compared in terms of the Bearing Capacity Ratio, which is the ratio of the ultimate bearing capacity (UBC) of the soil with geotextile reinforcement.

Table -2: load and settlement e/B=0

Sr. No.	e/B=0	
	Load intensity (KN/m²)	Vertical Displacement (mm)
1	0	0.00
2	5	0.06
3	10	0.12
4	15	0.17
5	20	0.24
6	25	0.30
7	30	0.36
8	35	0.41
9	40	0.49
10	45	0.72
11	50	0.96
12	55	1.20
13	60	1.43
14	65	1.52
15	70	1.58
16	75	1.66
17	80	1.74
18	85	1.86
19	90	1.97
20	95	2.10
21	100	2.21
22	94	2.72

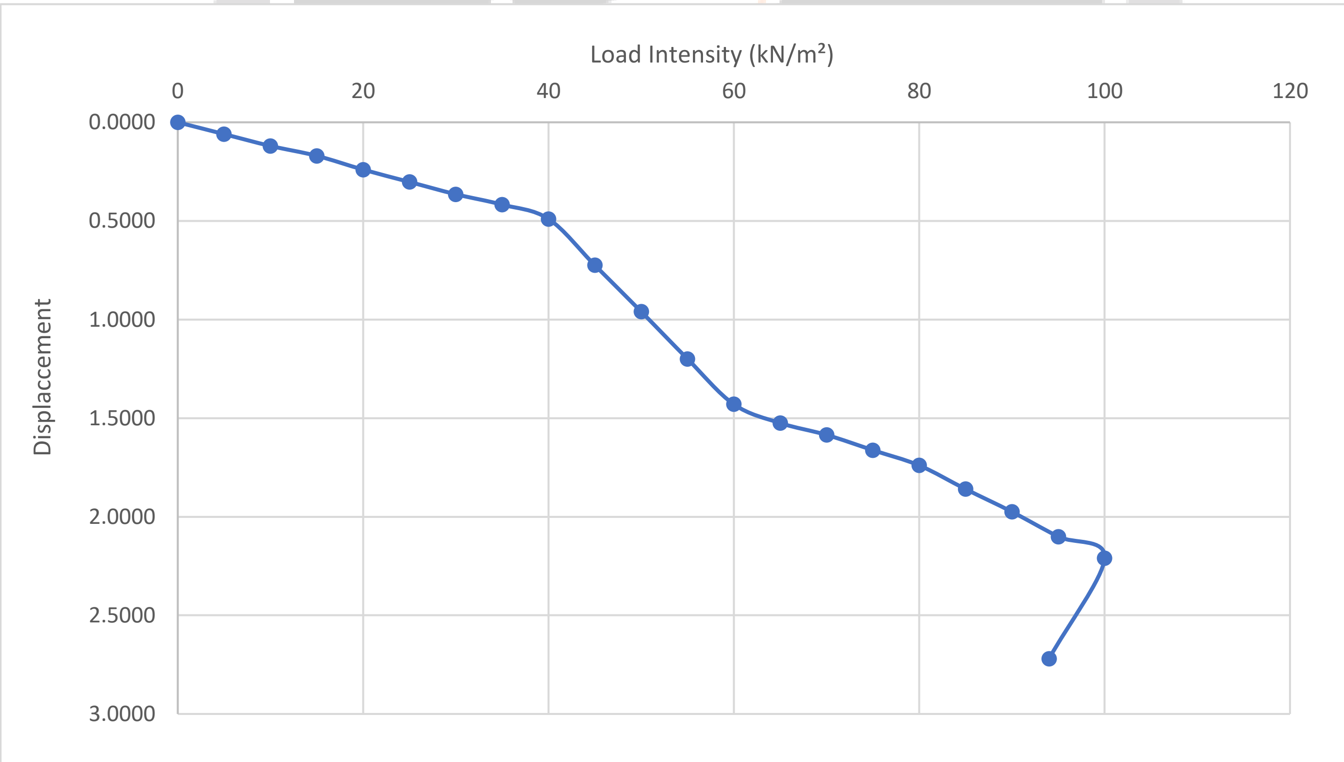

Chart -1 -load settlement curve for axial loading (e/B=0)

Result analysis for axial loading :-

- The ultimate bearing capacity was reached at a load intensity of around 100 kN/m^2 and the corresponding vertical displacement of 2.21mm.
- The load-settlement curve shows a gradual increase in settlement as the load intensity increases, which is typical behavior for axial loading on a square footing
- It achieve maximum UBC as comparative to eccentric loading.
- In this case footing is more safe than other because it does not create major impact on the model of footing.

Table -3: load and settlement for e/B=0.1

Sr. No.	e/B=0.1	
	Load intensity (KN/m²)	Vertical Displacement (mm)
1	0	0.00
2	5	0.07
3	10	0.15
4	15	0.23
5	20	0.32
6	25	0.51
7	30	0.70
8	35	0.89
9	40	1.10
10	45	1.29
11	50	1.43
12	55	1.68
13	60	1.89
14	65	1.97
15	70	2.08
16	75	2.20
17	80	2.31
18	85	2.48
19	90	2.71
20	95	2.93
21	100	3.13
22	93	3.68

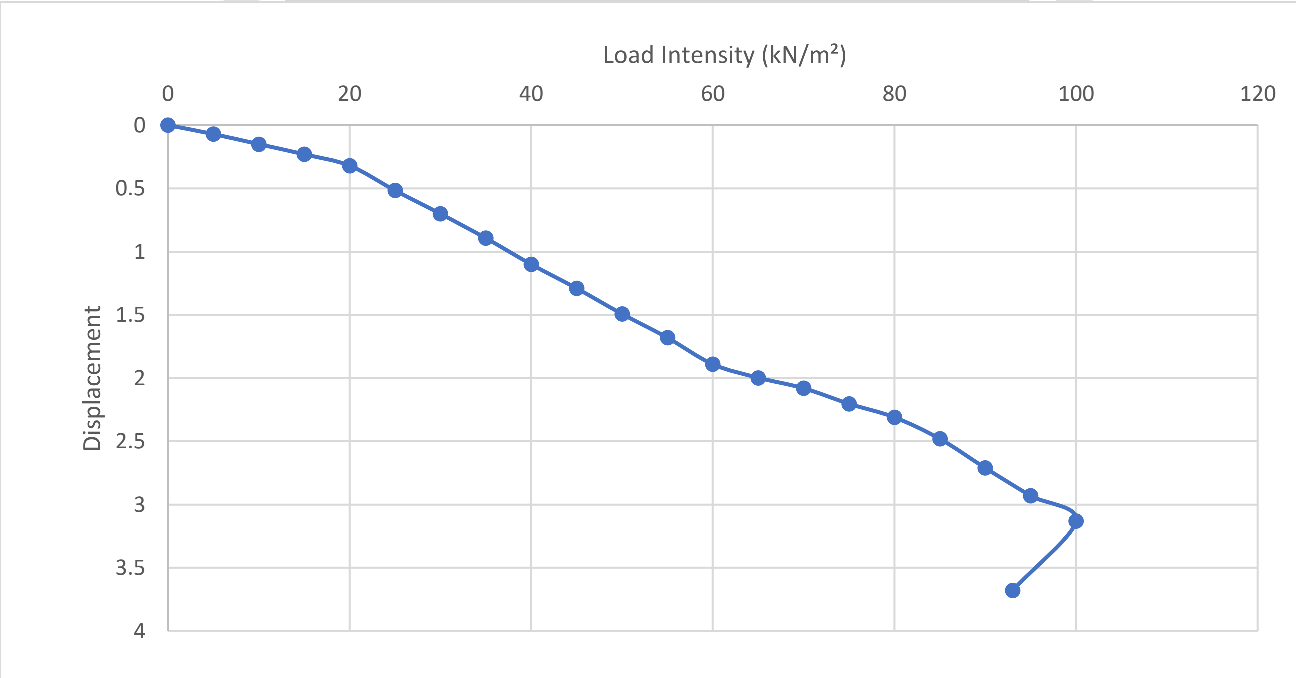

Chart -2: load settlement curve for eccentric loading (e/B=0.1)

.

Result analysis for eccentric loading (e/B=0.1):-

- The ultimate bearing capacity was reached at a load intensity of around 100 kN/m^2 and a vertical displacement of 3.13 mm.
- The load-settlement curve shows a gradual increase in settlement as the load intensity increases, which is typical behavior for eccentric loading on a square footing
- The Bearing capacity ratio for eccentricity of 0.1 is 1
- As per result comparison with axial, the eccentric load is unsafe for the structure because it create a major impact on the model of footing.

Table -4: load and settlement for e/B=0.15.

Sr. No.	e/B=0.15	
	Load intensity (KN/m²)	Vertical Displacement (mm)
1	0	0.00
2	5	0.14
3	10	0.34
4	15	0.48
5	20	0.68
6	25	0.88
7	30	1.12
8	35	1.27
9	40	1.45
10	45	1.57
11	50	1.68
12	55	1.95
13	60	2.24
14	65	2.33
15	70	2.43
16	75	2.58
17	80	2.78
18	76	3.09

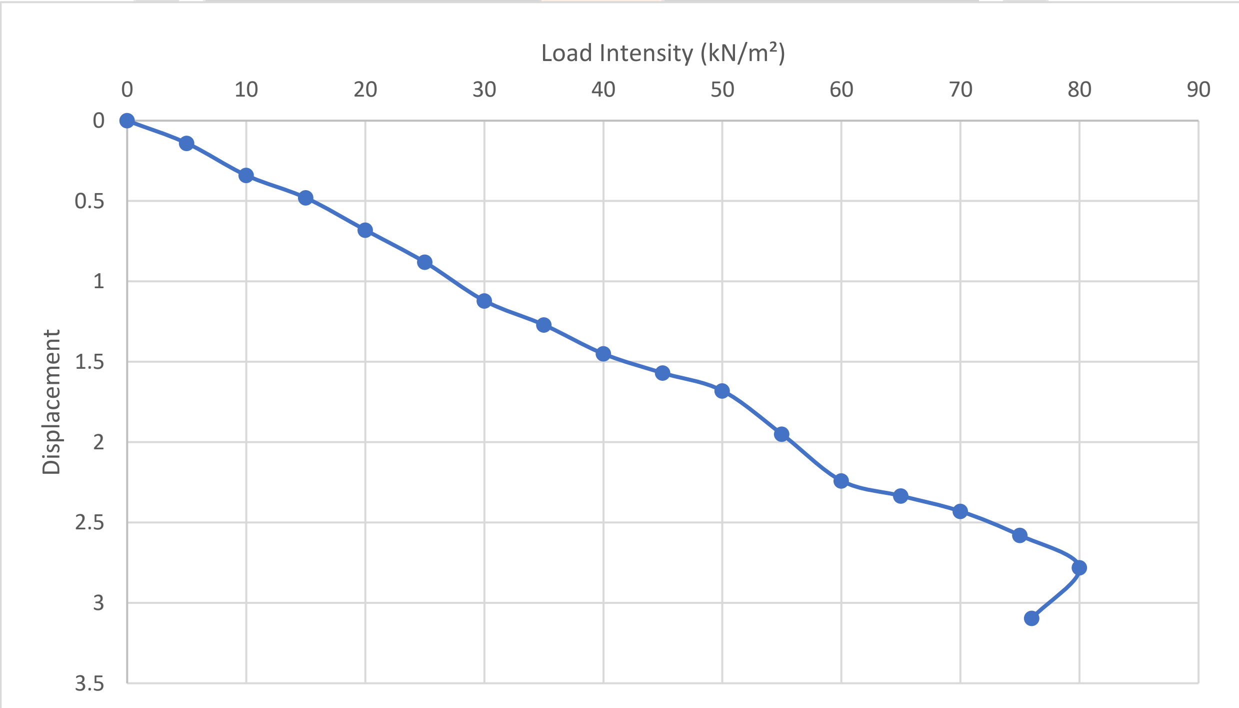

Chart -3: load settlement curve for eccentric loading (e/B=0.15)

.

Result analysis for eccentric loading (e/B=0.15):-

- In this case, The ultimate bearing capacity is reached upto the 80 kN/m^2 and the corresponding vertical displacement is 2.78 mm.
- The load-settlement curve shows a gradual increase in settlement as the load intensity increases, which is typical behavior for eccentric loading on a square footing
- The Bearing capacity ratio for eccentricity of 0.15 is 0.8
- As per result comparison with axial, the eccentric load is unsafe for the structure because the UBC decrease with increasing eccentricity.

Table -5: load and settlement for e/B=0.2

Sr. No.	e/B=0.2	
	Load intensity (KN/m²)	Vertical Displacement (mm)
1	0	0.00
2	5	0.20
3	10	0.45
4	15	0.67
5	20	0.80
6	25	0.94
7	30	1.27
8	35	1.39
9	40	1.47
10	45	1.70
11	50	1.89
12	46	2.23

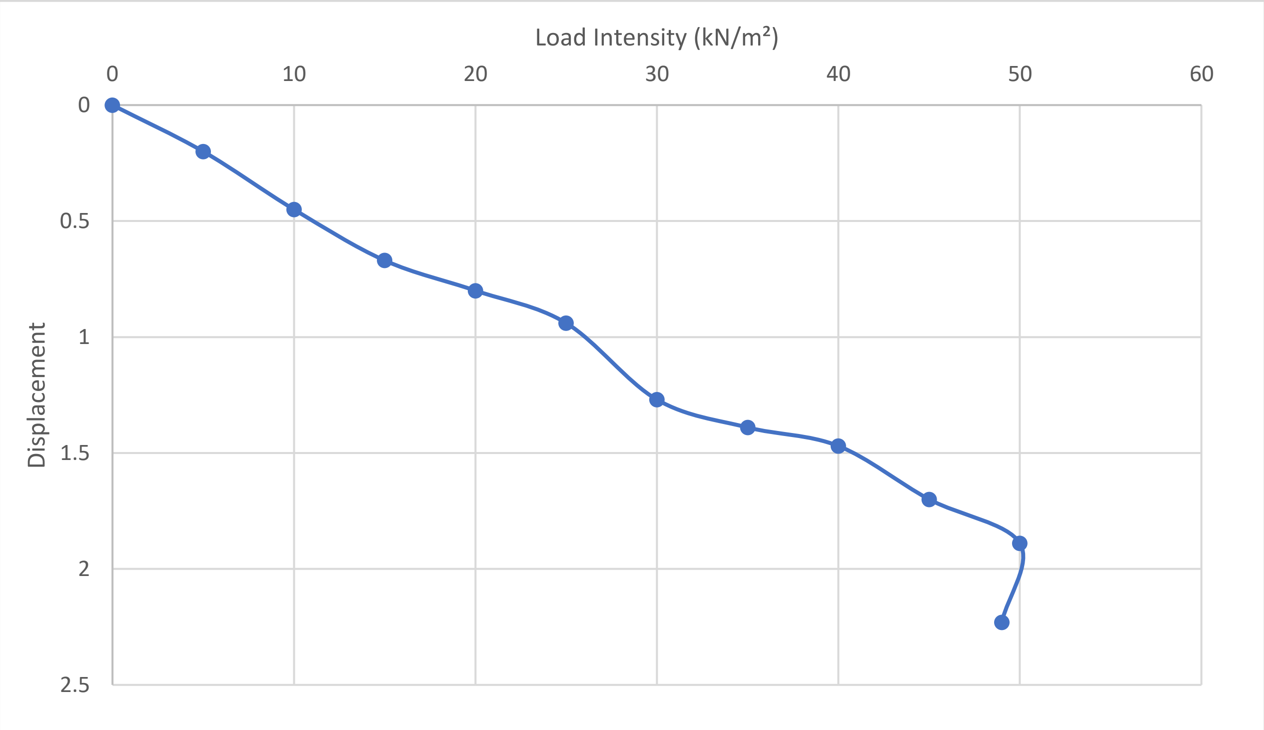

Chart -4: load settlement curve for axial loading (e/B=0.2)

Result analysis for eccentric loading (e/B=0.2):-

- In this case, The ultimate bearing capacity is reached upto the 51 kN/m^2 and the corresponding vertical displacement is 1.89 mm.
- The load-settlement curve shows a gradual increase in settlement as the load intensity increases, which is typical behavior for eccentric loading on a square footing
- The Bearing capacity ratio for eccentricity of 0.2 is 0.51
- As per result, the eccentric load is unsafe for the structure because the UBC decrease with increasing eccentricity.

Table No.6 :UBC and BCR

Sr No.	Loading condition	UBC (kN/m²)	BCR
1	e/ B = 0 (axial)	100	1
2	e/ B = 0.1	100	1
3	e/ B = 0.15	80	0.8
4	e/ B = 0.2	51	0.51

4. CONCLUSIONS

The present work studied the performance of square footing under the axial and eccentric loading on Non cohesive soil. The geotextile was used as the reinforced material, which is used to reinforce the Non cohesive soil. These geotextile was placed in three layer having thickness of soil in each layer is 150mm. The plate load test were conducted on the footing model to understand the performance. Performance of footing presented in terms of Ultimate bearing capacity, vertical displacement. The following conclusion draw from the result Of experiment.

a) The ultimate bearing capacity Of square footing decreased as eccentric loading increases
b) The axial loading does not create a major impact on the ultimate bearing capacity of the square footing as compare to the eccentric loading.
c) Eccentric loading shows major impact on the footing model.
d) The vertical displacement is reduced by using geotextile as reinforcing material.

5. REFERENCES

1. Prof. S. S. Pusadkar, Prof . Y. S. Navkar 2016 -"Performance of square footing subjected to eccentric –inclined Load".
2. Dr. Prof. M. Dewaikar, K. G. Guptha, H. S. Chore 2009 – " Behavior of eccentrically loaded model square footing on Reinforced soil."
3. Dr. A.I. Dhatrak, Prof. Poonam Gawande 2016 – "Behavior of eccentric loaded ring footing on sand".
4. Gaurav Bharti , Bishnu Kant Shukla , Varadharajan Srinivasan, Vaishnavi Bansal 2022 – "Experimental study on eccentrically loaded rectangular footing on sand for embedded condition to enhance serviceability of structures"
5. Mr. Sunil J. Payghan, Mr. Akash G. Charbhe 2019 – "Behavior of square footing under eccentric loading on reinforced sand"
6. Hussam Aldeen J. Hassan and Ressol R. Shakir -2019- "Ultimate bearing capacity of eccentrically loaded Square footing over geogrid-reinforced Cohesive soil"
7. Dhar P., Roy S. and Chattapadhyay B. C. (2013), "Behavior of Rigid Footing under Inclined and Eccentric Loading"
8. Monika R. Gurav, Sumit P. Gawali, Rahul G. Bramhane, Sunil J. Payghan –" Performance of square footing under axial and eccentric loading on non-cohesive soil"
9. I.S. 1888:1982, "Indian Standard Methods of Load Teats on Soils", Second Revision, March- 1982.