Study of Stress Distribution in Foundation for an Eccentrically Loaded Footing: A Literature Review

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Abstract— The paper approaches to investigate the present status of studies and researches conducted in the field of footing design. This paper tried to examine existing application and scope of the application of foundations capacity design methods. Various papers and results concluded by different researchers on foundation rocking are reviewed. Footing design is one of the critical design parameter, and is selected as a research filed by the author. Load bearing capacity of the footing is one of the most important and critical parameter which is needed to understood in better way critically.

Key words: Footing Design, Eccentricity, Load Bearing Capacity, Displacement, Stresses Involved, Foundation Base

I. LITERATURE STUDY

Mohammed Basheer Uddin and Adi Narayan, (2016)Researches from various researchers are involved with study of load bearing capacities and limitations of foundations. Few researches were conducted to test bearing capacity of shallow foundations on geogrid-reinforced sand subjected to eccentric load. It is due to test strip or square foundation.This paper tests some models utilizing square type foundation with reinforced sand base. The size of the model footing is of size 10cm x 10cm. Relative density maintained is 69%. Material selected for study is SS 20 in 2, 3 and 4 number of layers. The load eccentricity is selected in the range from 0 to 0.15B with an increment of 0.05B. Constants are vertical distance from base, geogrid layers distance from each other, and geogrid width. Results were obtained for all load intensities in terms of load.Ultimate load bearing capacity is determined. Parametric studies is conducted to test influence of load eccentricity on load bearing capacity. Maximum bearing capacity can be found by considering the ultimate bearing capacity of square footing subjected to central load and a reduction factor(RkR) for reinforced condition.

Dry sand bed or base was used to conduct tests there is scope of other aspects related to shallow foundations. The cope was concluded as:

- Foundations with cohesive soil can be tested.
- Equation developed can be validated in future for various cases.
- Eccentrically inclined loaded reinforced soil Condition can be studies using present study.
- Different density of sand can be studied and tested in future

P.W. Taylor * and R.L. Williams, (1979) Capacity foundation design method is studied in this research paper, results for rocky foundation and implications involved with design procedure are studied in detail. The research tried to develop a standard procedure to design foundations for earthquake-resisting structures. The presented study is unique because the research area stands somewhere between structure and foundation engineering which is not attended or rarely attended or selected by researchers. Fresh concepts and study are also included which are capacity design, uplift and rocking of foundations.

J.E. Turnbull, H.A. Jackson, and D. Lowe, (1979)Foundation design is critical when the sol is weak in nature, it is difficult to design load spread of tall buildings and structures over the area of soil with required factor of safety. Eccentricity included with wall loads and soil reaction pressures results in the failure, rotation and break of footing rings. The design involved the flat and continuous spiral of steel reinforced with annular ring. It resists rotation and improves ultimate bearing capacity of footing on soft soil. Canadian Farm Building Code (1977) is used to conduct the study and solutions were calculated for soils ranging from 72 to 288 kN/m2 (1500 to 6000 lb/ft2) safe bearing pressures.

D.M.Dewaikar, K.G.Guptha, H.S.Chore, (2009) Experimental research is conducted to study behavior of square footings on reinforced soil subjected to deformation under load. Set up includes two-layered system consisting of clay as sub-grade and mine waste as backfill material. Study is conducted considering footing s subjected to eccentric loads. Geotextiles, Kolon Geo-grid (KGR-40) and Rubber grids derived out of waste tyresare selected and reinforcing material to proceed with the study.it is observed that the there is improvement in performance of an eccentrically loaded model square footing when applied with reinforcing element in the soil system. The values of BCR, SRF and tilt of footing shows the fact that is written prior. The advantages with reinforcement are noted at higher load eccentricities.It is also noted that rubber grid performed better than the geo-grid and geotextiles in respect of BCR, SRF and tilt of footings. The paper highlighted specialty and significance of application of solid waste materials in the field of civil engineering.

It is concluded that the performance of square footing subjected to eccentric loading improves using reinforcing element in the soil system. It is cost optimized and is an better alternative to use rubber grid for effective ground improvement.

Nidhi Gupta, (2015)The technique in which eccentric loading with vertical or inclined wall surrounds one or more sides of the soil mass beneath the footing, is well identified bearing capacity improvement techniques. If footing projection is provided as an integrated part at the footing base, it is known as angle shape footing. It provides positive limit to base soil and provides resistance to soil against footing sliding. In this type of cases the soil is protected from lateral movement and so, footing tilt can be reduced to nil which is possible by facilitating downward inclined footing projection of required depth toward the loading side. In the result displacement values were listed and by comparing them design conditions were suggested. The research involved experiments and numerical analysis to investigate the study in detail.

It is also pointed that need of software is there to analyze seismic response and to analyze foundation of various structures with IS codes. There is difficulty with numerical approach at large scale for Indian analysis professionals.

Adel Belal, Nabil Nagy, Ahmed Elshesheny, (2015) Research works on the fact that due to low bearing capacity weak soil cannot withstand against load. Techniques used t improve performance are difficult and soil reinforcing is one of the used technique. Present paper presents numerical model to solve and analyze square footing strength, also ANSYS is used to test performance of footing with finite element analysis. Various parameters are considered and research is made to study effects of parameters. Numerical model of dimensions 900mm x 900mm x 600mm and 150mm x 150mm x 25mm is considered to model and analyze soil and the square footing. Reinforcing layers used footing capacity and non-reinforcing model is studies to compare experimental results. There are six types of Geosynthetic reinforcing layers were used to conduct study.

A. I. Dhatrak, PoonamGawande, (2016) To develop resistance against lateral loading and to avail overturning stability ring foundations are used specially for big high-rise structures. These were used all around the world for telecommunication towers, liquid storage tanks, bridges and offshore structures. Performance directly depends on the foundation, but the foundation response is not well analyzed. It should be designed critically, analytical or experimental approach can be followed to evaluate performance for load bearing capacity. The paper discussed ring footing behavior under eccentric loading on sand. The effects of ring radii ratio and load eccentricity have been investigated by means of experimental investigation.

It is concluded that at ring ratio (Di/Do) of 0.4 bearing capacity is maximum and eccentricity is inversely proportional to bearing capacity.

Bijay Sarkar, (2014) A rigid isolated foundation of square or rectangular shape is considered and analyzed subjected to vertical load and high biaxial moments at centre in this paper. Pressure intensity for any set of load on footing resists on elastic soils can be calculated with general method of analysis or numerical procedure. In this paper common assumption of linear contact pressure in footing-soil interface is adopted for the solutions. Special attention has been given where there are inactive parts of foundation, without contact with soil and necessary equations on case to case basis are deduced. Flow Chart for computer procedure is also provided at end. The solution for these cases is not yet given in any Indian Standards.

Günay ÖZMEN, (2011) The buildings and their footings in seismic areas are designed according to biaxial bending moments. Main objective and aim of present paper is to introduce a general method which can be used to calculate the base pressures of rectangular footings under biaxial bending. The footing with heavy eccentricity may be classified on the basis of shape of the pressure region. Then the formulation given by Löser for the design of rectangular columns subjected to biaxial bending are generalized and applied to the calculation of base stresses. Since the position of the neutral axis is not known initially, a process of successive approximations is developed. The application of the computation procedure is demonstrated on a numerical example.

Nihat Kaya and Murat Ornek, (2013) Vertical axial load and eccentric loads due to earth pressure, seismic action, water or wind are applied to the structure footings. Eccentric load causes tilt to footing results in ununiformed pressure below footing. Paper suggested T-shape footing to resist action of eccentric loads. The vertical insertionin T-shaped in the soil avails great resistance to sliding and overturning. This paper presents experimental and numerical results for T-shaped footings are reported. 48 models were analyzed with variable parameters which are geometry and soil density.

Pritam Dhar, Soumya Roy and Bikash Chandra Chattapadhyay, (2013)Paper discussed the results and outcomes from model tests for the behavior of footing on Ganga sand subjected to eccentric and inclined load. Square and rectangular footing load carrying capacity with rest on surface dense sand bed is selected as a problem in this paper. Footing behavior under axial load is analyzed to compare results for shape variations. Results were listed for various shapes of footings as shape affects load carrying capacity. The load settlement characteristics of footings of different shapes resting on the surface of sand of same area are also studied through the load settlement curves. To study the effect of eccentricity on ultimate load carrying capacity of footings, model footings are subjected to both one way and two eccentricities. Lastly effect of load inclination with vertical on surface footing is presented in this paper.

Nasser M. Saleh, Ahmed E. Alsaied,(2008) Foundations which are with vertical or inclined wall surrounds one or more sides of the soil mass beneath the footing is identified technique of improving bearing capacity.Again base of the footing is tested and resistance of the footing against sliding is analyzed. Experimentaland analytical study was conducted to elaborate the response of one sided skirted strip footingundereccentric or inclined load.As a result optimized design parameters and solutions were suggested.it is finally concluded that length of skirt is directly proportional to performance related to load response, skirt improves footing sliding resistance.

Dayanand P. Joshi and Hemant Kumar Mahiyar, (2010) This paper discussed an fresh type of foundation concept which is applicable to eccentric loading conditions. The concept of Angle Shaped Footing comes into action from year 2000, the researcher in present study describes the effectiveness with different angle of projectionsand the results were observed for all the cases. Earth pressure increases due to footing is inclined and it improves the tilting resistance. Number of experiments are conducted and the results are validated with 'ANSYS', a Finite Element based software.Concluded that footing with angle are more effective in the range of 15° - 30°. The horizontal displacements due to vertical eccentric loading is almost zero.

Radoslaw L. Michalowski *, Liangzhi You, (1998)To improve bearing capacity of footing the symmetrically loaded shallow strip footings are reported. Paper uses loadingeccentricity, where footing width is reduced by twice-the-eccentricity to its `effective' size. Present research examines Meyerhof's suggestion and shows that the bearing capacity of eccentrically loaded footings can

be calculated using the kinematic approach of limit analysis. It was concluded that the rule is applicable to realistic footing models and for cohesive soils. It improves bearing capacity and for cohesion less soils, how- ever, the effective width rule may overestimate the best upper bound. This overestimation increases with an increase in eccentricity.

Dayanand P. Joshi, Hemant K. Mahiyar, (2009) To design foundations which are under seismic forces, using values of horizontal and vertical seismic coefficients, equivalent seismic forces can be conveniently evaluated. The forces with static forces together results in foundations subjected to eccentric inclined loads. To study soil is one of the important factor to design footings subjected to eccentric and inclined loads. Footings tends to tilt with eccentric inclined loads. Also there is uniformity in pressure below footing. If eccentricity increases there is increase in tile and reduction in bearing capacity is noted. This results in increase in footing size which is always uneconomical.

This paper presents some of the experimental results and shows a comparison between the experimental results and the Finite Element Analysis results. It has been observed that eccentrically inclined loaded footing can be designed for no or very small negligible tilt by using angle shaped footing with different angle and length of footing projection Thus Model of angle shaped footing can make reasonable predictions of the inclined loading responses.

II. Conclusion

Mohammed Basheer Uddin and Adi Narayan, (2016) Concluded that square footing can be tested with presented setup and generalized equation has been developed to predict square footing load bearing capacity. An ANN model is also developed to test strip footing similarly. Future study will be focused around stress analysis of footing.

P.W. Taylor * and R.L. Williams, (1979) The paper is different as it discussed issues for both structure and foundation engineering which is ignored by researchers. Further research may include design, uplift and rocking of foundations.

J.E. Turnbull, H.A. Jackson, and D. Lowe, (1979) Canadian Farm Building Code (1977) is used to conduct the study, in India one may use this approach with Indian standard codes to test foundation in Indian context.

D.M.Dewaikar, K.G.Guptha, H.S.Chore, (2009) Researcher in this paper discussed specialty and significance of application of solid waste materials in the field of civil engineering. These materials can be tested against stress distribution.\

Nidhi Gupta, (2015) Displacement were tested and comparison is made to improve design of footing, experimental and numerical approach is followed. There is absence of software application, which is needed to analyze problem easily in less time.

Adel Belal, Nabil Nagy, Ahmed Elshesheny, (2015), uses software application effectively with ANSYS and can be taken as an major reference while performing software analysis for eccentric footing stress distribution analysis.

A. I. Dhatrak, PoonamGawande, (2016) Research discussed ring footing behavior under eccentric loading on sand. It can be extended for variety of cases considering various types of soils and regions.

Günay ÖZMEN, (2011) This paper develops method for base stress computation for rectangular footings under the effect of biaxial loading is developed. Results obtained are developed method is valid to all compression zone all shapes, the developed step is short and procedure can be adopted using any programming language.

Nihat Kaya and Murat Ornek, (2013) Results proves that this investigation is considered to have provided a useful basis for further research, leading to an increased understanding of the T-shaped footing design. In future one may approach to test various footings with different shapes.

Pritam Dhar, Soumya Roy and Bikash Chandra Chattapadhyay, (2013) It was concluded that in case of centrally applied load the bearing capacity of square footing are found better and higher than rectangular footings. This can be considered while performing future researches.

Nasser M. Saleh, Ahmed E. Alsaied,(2008) PLAXIS, Version 7.1, is used as an FEM software which is used to analyses and find the sliding effects and response of footing, it is noted that software results are always higher than experimental result values. Other software like ANSYS or SAP can be adopted to test the conclusion of the paper.

Dayanand P. Joshi, Hemant K. Mahiyar, (2009) This paper compares experimental results and the Finite Element Analysis results. It has been observed that model of angle shaped footing can make reasonable predictions of the inclined loading responses. This is required to retest the conclusion with software application as strong conclusion is unavailable with paper.

Overall It is seen that researchers have not concentrated and not elaborated the complete experimental and numerical analysis in the field of footing design. As eccentricity is important factor, there is need to understand eccentricity and the resultant performance of the footing. It is tried to investigate methods, techniques, approaches, principles and software's to be used while designing the footings for building columns situated on boundaries of plots, especially in row houses.

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