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# STRUCTURAL DESIGN FOR ECCENTRIC LOADING OF FOOTING

**Nidhi Gupta***
*Assistant Professor, Department of Civil Engineering, RKDF Bhopal

## ABSTRACT

Eccentric loading, in which vertical or inclined wall surrounds one or more sides of the soil mass beneath the footing, is one of the recognized bearing capacity improvement techniques. The footing when provided with footing projection on one side such that it is an integral part of the footing it is called angle shape footing. Construction of footing projection at the base of the footing, confining the underlying soil, generates a soil resistance on projection side that helps the footing to resist sliding. In such a footing the soil particles near the footing projection are prevented from moving laterally thus footing projection to tilt in direction opposite the one in which the footing has tendency to tilt thus tilt of the footing can be reduced to zero by providing a downward inclined footing projection of required depth toward the loading side. The idea of angle as well as suitable length of projection has been used here by giving the footing an angle shape of variable projection angle. Various load inclination angles, load eccentricities, various angles as well as lengths of footing projection were investigated. Load displacement values for all cases were compared, and favourable design conditions were suggested. Laboratory work and numerical analysis were performed to study the behaviour of eccentric loading subjected to eccentric inclined load.

**KEYWORDS: Eccentric loading, Bearing Capacity of Soil**

## INTRODUCTION

In every building the load is transferred to soil by foundation. It is necessary to design &Check it properly for probable failures. The foundation may fail due to excessive settlement, shear, tilting etc. A foundation is the lower part of a structure that transmit the load to the soil orrock. It includes the soil or rock. Thus, the word foundation refers to the soil under structure as well as any intervening load carrying member. In the design of any foundation system the aim is to provide adequate foundation to support load margin of safety against bearing capacity failure i.e. against a soil shear failure and to keep the settlements within tolerable limits. Thus, there arises a necessity of consideration of two different criteria, viz, the stability criterion and the settlement criterion in the design of foundation system.

Foundation is classified as shallow and deep foundation depending on the depth of the load transfer member below the superstructure. Thus a deep foundation as the one in which the depth to the bottom of the footing is less than or equal to the least dimension of footing. In modem usage, the term shallow foundation is used to describe of an arrangement where structural load are carried by the soil directly under the structure, such as footing and raft and deep foundation is used to carry the load to firm soil or rock at some depth.

It is known from the observation of the behavior of foundation subjected to a load that bearing capacity failure usually occurs as the shear failure of the soil supporting the footing. The minimum gross pressure intensity at the base of foundation at which the soil fails in shear is called the ultimate bearing capacity, qu. The ultimate bearing capacity diviedeby the desired factor of safe bearing capacity. For the design capacity of foundation it is not only safety against shear failure which is considered but also likely settlement. A pressure intensity which is considered safe both with respect to shear failure and called the allowable bearing pressure, qu or the design unit load. Thus the allowable bearing pressure is excessive settlement detrimental to the structure.

Factors that affected on foundation design are:-
(i) Safe Bearing Capacity
(ii) Swelling Shrinkage Behavior
(iii) Minimum depth of foundation - Lever Arm
(iv) Settlement Criteria
The bearing capacity is affected by the many parameters like
(a) water table
(b) eccentricity
(c) hape of foundation
(d) roughness of foundation base mpressibility of soil
(e) loading
(f) adjacent footing near the foundation

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The bearing capacity may be determined by any of the following methods:-
(i) Calculation by using shear parameter based upon equations proposed by many researches.
(ii) By conducting the field test like plate load test, penetration test etc.
(iii) By using the guidelines given in the National building code which is based upon the classification of soil.

The evaluation of safe bearing capacity by using theory does not indicate the true safe bearing capacity as the field conditions may varying and the equations may not stimulate feild conditions.

## BEARING CAPACITY THEORIES

There are two approaches for the analysis of stability foundations. The first these is convectional approach which generates from work of coulomb (1977). This is based on the assumption of a certain shape for the rupture surface. The other approach which stands from the works of Rankine (1857) and Kotter (1903) is based on the assumption of simultaneous failure at every point in certain zone of the soil mass. This is referred here as plasticity approach.

**Theories based on conventional approach**

Fellenius Method: - Fellenius (1929) presented a method for determination of ultimate bearing capacity of footing on highly cohesive soils. He assumed failure surface to be of circular cylindrical shape. The expression for the ultimate bearing capacity of long surface footing on highly cohesive soils is given by

Qu =5.5c

Qu = ultimate soil bearing pressure

C = cohesion of the soil

Study the effect of shear parameters on load carrying capacity of angle shaped fitting and concluded that load carrying capacity increases with increases in angle of internal friction and tilt was zero at all values.

Wilsons (194 1) extended this method to footing founded below ground surface and the ultimate bearing capacity for footing below the surface of highly cohesive soils is obtained as

qu = (1+0.38D/B)

D = Depth of foundation

B =Width of foundation

The circular are method has the advantage of being simople and it gives reasonable result for surface footing and footing at shallow depth in highly cohesive soils (=0)

**Terzaghi's Bearing Capacity Theory**

Assumption:

Based on Pranti 'S theory (1920) for plastic failure of metal under rigid punches Terzaghi derived a general bearing capacity equation. All soils are covered in this method by two cases which are designated as general shear and local shear failures. General shear is the case wherein the loading test curve for the soil under consideration comes to a perfectly vertical ultimate at relatively small settlement. Local shear is the case wherein settlement are relatively large and there is not a definite vertical ultimate to the curve. The following assumption was made in the analysis.

•The footing is continuous.

•The weight of soil above the base level of footing is replace by equivalent surcharge q = yD,

•The shear resistance of the soil above the base level of footing is neglected.

•The base of footing of rough.

•The principal of superposition is valid.

Terzaghi presented the following bearing capacity expression for general shear failure:

qu=cNc+qNq +ViBN

q=yD

B = Least lateral dimension of footing

N, Nq, NT = Dimensionless bearing capacity factors.

Limitations:

•The shear strength of soil above the base level of footing is neglected. Hence for deep footing, errors become large.

•This theory gives conservative value for footing whose depths are greater than 0.

•Subdivision of the bearing capacity problems in two types of shear is an arbitary one, since two cases can not cover the wide range of conditions.

**Meyerhof's Bearing Capacity Theory**

Assumption:

The bearing capacity of shallow and deep foundation has been derived by Meyerhof (195 1) taking in to account the shear strength of the soil above the base level of the footing. For the shallow foundation, he assumed a failure mechanism similar to Terzaghi's but extending up to ground surface.

The following assumption is made in the analysis:

•The footing is continuous.

•The failure surface is composed of straight line and logarithmic spiral.

•The principle of superposition is valid.

The ultimate bearing capacity qu is expressed in terms of (YO, the normal stress along the equivalent free surface, as

q=cN +oNpq+'/2yBNpy

Where, NpclNpq, and Np bearing capacity factors.

Limitations:

Bearing capacity computed from Meyerhof's theory are found to be higher then observed bearing capacities in sands at greater depths.

### 2.4 Skempton's (1951) bearing capacity for clays

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Skempton (1951) recommended the following shape and depth factors, and values of Nc for surface footing on clays.

•Surface footing (D=0)

Nc z5 for strip footing

Nc = 6 for square or circular footing

•At Depth D

dc= (1+0.2 x D/B) forD/B <2.5

dc-- 1.5 for D/B>2.5

•At any depth, for rectangular footing,B X L

Sc = (1+ 0.2 x B/L)

•The ultimate bearing capacity is given by

qu= c Nc dc Sc

**Brinch Hansen's Bearing Capacity Theory**

A theory, somewhat similar to the Terzaghi's has been proposed by Hansen (1961). The ultimate bearing capacity according to this theory is given by

qu = c Nc de Sci + q Nq Sqdqiq + '/27 B N.yS.yd.yi.y

Where,

S= shape of factor

d= depth of factor

i= inclination of load factor

N= (Nq 1) coW

Nq= tna2 (45 + 0/2) e"

N.y= 1. 80( Nq - 1) tan (approx.)

## FOUNDATIONS SUBJECTED TO EARTHQUAKE

Many Indian earthquakes in historical times clearly demonstrated the important role that Geotechnical conditions play under strong earthquake shaking. Every year world is facing so many earthquakes in various parts of the world and due to earth quake numerous R.C. framed building collapsed during recent earthquakes emphasized the need for the risk assessment. According to seismic design philosophy foundation must not fail even during the devastating earthquakes because the failure of foundation leads to the collapse of whole structure. If it happens then in that case loss of the human being and other things will be huge. Hence it is important to design foundations which can sustain the earthquake without failure.

Once earthquake risk and site effects have been evaluated the foundation designer needs to proceed with the proportioning of the foundation. To date there is little in the way of code recommendations to cover this, especially along the emerging trends of performance based design. Eurocode is an exception and contains an extensive section on the design of foundations to resist earthquake loading. This has been developed using the results of a number of special investigations, both laboratory and theoretical.

Normally the failure of structures during earthquakes is the result of structural inadequacies, foundation failure, or a combination of both. The failure of a building may predominantly due to structural inadequacies such as poor ductility and improper beam - column joint. On the other hand, the failure may due to any structural adequacies but due to foundation failure. In such failures the soil supporting the foundation plays an important role. The behavior of foundations during earthquakes is often dictated by the response of its supporting soil due to ground motion or shaking. So it is necessary to quantify seismic hazards while designing a structure to withstand earthquakes. In general, there are two major seismic hazards associated with the design of structures and foundations, such as: (i) ground shaking and (ii) ground deformation Seismic hazards can be established either deterministically or probabilistically. Sometimes a detailed seismic hazard study has to be established using both deterministic and probabilistic methods incorporating the recently gained knowledge on the definition of seismic sources, seismic models, attenuation of strong ground motion parameters and soil conditions.

Design of foundations still remains a challenging task for the earthquake geotechnical engineer. Leaving aside the seismic retrofit of existing foundations, which is an even more difficult issue, the design of new foundations raises issues which are far from being totally resolved. One of the main reasons stems from the complexity of the problem which requires skills in soil mechanics, foundation engineering, and soil-structure interaction along with, at least, some knowledge of structural dynamics.

## ECCENTRIC LOADING

When a footing is to resist a moment, the problem of eccentricity of the load has to be considered. Merehof's (1953) presented chart for the determination of ultimate bearing) capacity of an eccentrically loaded footing by introducing the concept of useful width. This is based on the assumption that the edge of foundation further from the point of load application no longer contributes to the bearing capacity.

**Behavior of Eccentric Loading**

When footing is subjected to an axial point load and its centroid matches with the centroid of footing area then pressure distribution below the footing is uniform. However when the footing subjected to an axial load with moment or eccentric point load the distribution below the footing is not uniform and depending upon eccentricity it may be trapezoidal or

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triangular. In order to have uniform pressure under the footing area and centroid of column load should coincide.

However due to higher eccentricity it become very difficult to match the centroid of the column and footing area, because it may demand a very high footing size, which is uneconomical.

In angle shaped footing subjected to eccentric load, when the eccentric width ratio (e/B) and depth of footing projected (D/B) are in accordance with third degree polynomial equation, the footing subjected to uniform settlement and uniform pressure.

## CONCLUSION

There is need to develop indigenous software in the area of seismic analysis and design of foundations of structures using IS codes and put it for use by the Indian academicians, researchers and practicing engineers. Currently the technology to handle large scale numerical simulations with IS codes and practices is not available for Indian users. The code published by Bureau of Indian standards, which specify minimum design requirements for earthquake - resistance design of foundation. These requirements take into consideration the characteristics and probability of occurrence of earthquake, the characteristics of the structure and the foundation, and the amount of damage that is considered tolerable. Modern codes provide for reduction for seismic forces through provision of special ductility requirements. Detail for achieving the safety, economy in reinforced concrete structures under earthquake forces is given in IS 13920.

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