DEVELOPMENT OF MICROSOFT EXCEL TEMPLATE TO CALCULATE THE ULTIMATE BEARING CAPACITY AND SETTLEMENT OF A SHALLOW FOUNDATION

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DEDICATION

In our lives, three sets of people matter most.

First and greatest is God Almighty, who daily re-creates us,

Second is our family, the people we love the most,

The next is our friends, the bright side of us.

It is to these, I dedicate this project.

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To start with, I acknowledge the overwhelming help and grace God gave me throughout my years of study. He encouraged me not to give up in my quest of obtaining a degree, and when I was getting to the end of my rope, He hurriedly came to my rescue.

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To everyone at the Civil Engineering Department, I say, “Thank you and God bless you”.

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ABSTRACT

Engineers are often overwhelmed with laborious work while analyzing bearing capacity and settlement behaviour of shallow foundations. This is largely due to the number of iterations required under various empirical design considerations. To mollify this challenge, an effort is made in this research to develop a spreadsheet-based solution that can effectively, accurately and timely resolve bearing capacity and settlement problems of shallow foundations. The Microsoft excel (2010) package was used to develop a user-friendly, accessible, economical and analytical program to evaluate settlement and ultimate bearing capacity problems. It offers user-controlled parameter panels while the analysis and calculations are done automatically. A sample question was adopted, manual calculations were made, and a comprehensive Microsoft excel spreadsheet was developed. The spreadsheet analysis template was based on Terzaghi's method for the ultimate bearing capacity and Gazeta's method for the settlement analysis for different shape of footings under varying water levels with respect to the same sample question. Comparisons were made to see the variation between the manual calculation and the Microsoft Excel spreadsheet that was developed. The difference between the manual calculation and the Microsoft Excel spreadsheet in the bearing capacity analysis is less than 0.50kN/m^2 which is within an acceptable range and in the settlement analysis, there is no significant difference between the Microsoft excel spreadsheet and the manual calculation for all the footing types. The spreadsheet developed produced a more accurate result within a short time compared to a more laborious, lengthy and less accurate output of manual calculation undertaken on the same case study. The output presentation satisfied the requirements of a standard professional submission. Hence, the developed template can be a potent tool in the hands of designers and consultants.

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND OF THE STUDY

Any structure that is not flying or floating rests on the ground and the base of the structure and the soil together make up the foundation. Buildings and embankments must have foundations and so must vehicles and people. All foundations settle because nothing (not even tarmac or rock) is rigid, but obviously, some settle more than others do. When you walk across the beach and leave a footprint, it is simply a mark of the settlement of a foundation and so too is a tyre track.

A foundation is an integral part of a structure. The stability of a structure depends upon the stability of the supporting soil. Two important factors that are to be considered are:

1. The foundation must be stable against a shear failure of the supporting soil.
2. The foundation must not settle beyond a tolerable limit to avoid damage to the structure.

It is the customary practice to regard a foundation as shallow if the depth of the foundation is less than or equal to the width of the foundation. The other factors that require consideration are the location and depth of the foundation. The two key properties required in the design of shallow foundations are the bearing capacity (i.e., qu) and settlement (i.e.,) behaviour of soils.

Design of foundations must satisfy two main requirements, which are a complete failure of the foundation must be avoided with an adequate margin of safety, and the total and relative settlements of the foundation must be kept within limits that can be tolerated by the superstructure. The ultimate bearing capacity of a foundation is defined as the maximum load that the ground can sustain or namely general shear failure where the load settlement curve does not exhibit a peak load, the bearing capacity is taken as the load at which the curve passes into a steep and fairly straight tangent namely local shear failure. A theoretical method for estimating this bearing capacity will be explained later in this study.

Bearing capacity is the ability of soil to safely carry the pressure placed on the soil from any engineered structure without undergoing a shear failure with accompanying large settlements. Applying a bearing pressure that is safe with respect to failure does not ensure that settlement of the foundation will be within acceptable limits. Therefore, settlement analysis should generally be performed since most structures are sensitive to excessive settlement. While ultimate bearing capacity is the generally accepted method of bearing capacity analysis is to assume that the soil below the foundation along a critical plane of failure (slip path) is on the verge of failure and to calculate the bearing pressure applied by the foundation required to cause this failure condition. This is the ultimate bearing capacity qu. Besides, allowable bearing capacity qa is the ultimate bearing capacity qu divided by an appropriate factor of safety, FS.

A settlement is the vertically downward movement of a structure due to the compression of underlying soil because of increased load. Estimation of total and differential settlement is a fundamental aspect of the design of a shallow foundation. Differential settlement and relative rotation between adjacent structural elements should be evaluated. Settlements are considered tolerable if they do not significantly affect the serviceability and stability of the structures under the design load. These performance-based design criteria are best validated with building settlement monitoring. The total settlement of a shallow foundation usually comprises primary and secondary settlement. The primary settlement results from the compression of the soil in response to the application of foundation loads. As the bearing pressure increases the settlements start to accelerate and at some point, the foundation can be said to have failed because the settlements have become large. Foundations do not fail in the sense that they can no longer support a load or the load on them has reached a maximum or starts to decrease. Instead, they continue to settle and the bearing pressure continues to increase slowly as the depth of the foundation increases with further settlement.

By considering all the factors such as the shape of footing, type of soil, water table and bearing capacity factor which are associated with bearing capacity and settlement of a shallow foundation, it is realized that a programmed to calculate bearing capacity and settlement of a shallow foundation should be developed. Excel spreadsheet would be chosen due to its availability in all package of Microsoft programme.

The Microsoft Excel software is accessible and economical and besides, the excel spreadsheet can redo all calculation for different data. Excel is not limited to just summing, the user can automatically tell it to perform most simple to most complex mathematical calculations on the data entered, add automatically generated charts, illustrations, histograms, etc. Besides, user can choose the style of the chart and have complete control over how it looks whether they prefer the most simple one or go for fancy 3-d ones. Furthermore, Excel can store as much data as the user required. By using Excel, the user can easily organize their work into a hierarchy of folders, different files inside folders and different spreadsheets inside files. Moreover, Excel can easily create a backup file. Users also can choose from hundreds of text styles, sizes, colours, even fancy stylized text individually. Another reason for using Excel is it works smarter with copy and paste.

1.2 STATEMENT OF THE PROBLEM

The manual calculation for determining the ultimate bearing capacity and the settlement is quite complicated and demanding. Hence, it will increase human errors and take a longer time to compute and determine the settlement and the load-bearing capacity when we are using many shallow foundations for a project. If only one number changes on a paper-based spreadsheet, that may mean having to do all the calculations that are directly or indirectly associated with the changed number which can be very hectic and tiresome. Due to this matter, it is decided to develop a computer programming by Microsoft Excel that will be able to analyze and design the foundation in four types of shapes, which include strip, square, circular and rectangular.

1.3 PURPOSE OF THE STUDY

1. To analyze the value of the ultimate bearing capacity, the factor of safety, allowable bearing capacity and the settlement by taking the relevant factors using Terzaghi's Method for the ultimate bearing capacity and Gazeta's method for the settlement analysis.
2. To identify the parameters in the calculation of bearing capacity that has many effects on the values of the ultimate bearing capacity and allowable bearing capacity.
3. To develop a user-friendly Microsoft excel template using Terzaghi's bearing capacity factors to analyze the ultimate bearing capacity and Gazeta's method for the settlement analysis.
4. To compare the result between the computer program that was developed and the manual calculation.

1.4 SCOPE OF THE STUDY

This study is to develop a spreadsheet to calculate the ultimate bearing capacity and settlement of a shallow foundation by using Excel spreadsheet considering the type of soil, shape of footing, and the water table. The computation for the settlement will be limited to immediate settlement. The analysis and result would be obtained by using Microsoft Excel and will be compared with the result by manual calculation to make sure the programmed run correctly.

1.5 SIGNIFICANCE OF THE STUDY

The output of this work shall provide a versatile ready to use platform for all geotechnical Engineers faced with the challenge of calculating the bearing capacity and settlement of a shallow foundation. It will place at their disposal a design tool that is user-friendly, quick, easy to use, accurate and less laborious.

CHAPTER TWO

2.0 LITERATURE REVIEW

Over the past decades, there have been findings that deal with the problem of foundations resting on layered soils. At first, researchers based their studies on the results of prototype laboratory model testing in order to develop empirical formulae to predict the ultimate bearing capacity and settlement of these footings. Recently, theories based on finite element and numerical analyses are presented that gave more rational solutions as compared to the previous ones. This chapter presents a review of the literature relevant to the present topic of research in chronological order.

2.1 BEARING CAPACITY IN GENERAL

Bearing capacity is the capacity of soil to support the loads applied to the ground. The bearing capacity of a soil is the maximum average contact pressure between the foundation and the soil which should not produce shear failure in the soil. There are many different methods to calculate the bearing capacity of a foundation. The best-known methods are possibly Terzaghi, Meyerhof, Hansen and Verci.

Terzaghi (1943) was the first to propose a bearing capacity equation on the consideration of general shear failure in the soil below a rough strip footing. Using the principle of superposition, he demonstrated the effects of soil cohesion, its angle of internal friction, surcharge (soil lying above the level of footing base), soil unit weight and footing width on the ultimate bearing pressure. Later on, Brinch Hansen introduced a factor that accounted for footing shape and load inclination, in the bearing capacity equation.

2.2 FORMS OF BEARING CAPACITY FAILURE

Three distinct modes of failure have been identified and they will be described in the subsequent heading below with reference to a strip footing.

2.2.1 GENERAL SHEAR FAILURE

In this mode of failure, continuous failure surfaces develop between the edges of the footing and the ground surface. As the pressure increases towards the value of the ultimate bearing capacity, it reaches a state of plastic equilibrium in the soil around the edges of the footing, and then gradually spreads downwards and outwards. Ultimately, the state of plastic equilibrium is fully developed throughout the soil above the failure surfaces. The heaving of the ground surface occurs on both sides of the footing although the final slip movement would occur only on one side, accompanied by tilting of the footing. This mode of failure is typical of soils of low compressibility (i.e. dense or stiff soils).

2.2.2 LOCAL SHEAR FAILURE

In this type of failure, there is significant compression of the soil under the footing and only partial development of the state of plastic equilibrium. The failure surfaces, therefore, do not reach the ground surface and only slight heaving occurs. There is no tilting of the foundation. Local shear failure is associated with soils of high compressibility, it is characterized by the occurrence of relatively large settlements (which would be unacceptable in practice) and the fact that the ultimate bearing capacity is not clearly defined.

2.2.3 PUNCHING SHEAR FAILURE

Punching shear failure occurs when there is relatively high compression of the soil under the footing, accompanied by shearing in the vertical direction around the edges of the footing. There is no heaving of the ground surface away from the edges and no tilting of the footing.

Relatively large settlements are also a characteristic of this mode and again the ultimate bearing capacity is not well defined.

2.3 AN OVERVIEW OF BEARING CAPACITY THEORIES

The methods of calculating the ultimate bearing capacity of shallow strip footings by the plastic theory developed considerably over the years. No exact analytical solution for computing bearing capacity of footings is available at present because the basic system of equations describing the yield problems is nonlinear.

From the work of Terzaghi, many researchers became interested in this problem and presented their own solutions. However, the form of the equation presented by all these researchers remained the same as that of Terzaghi, but their methods of determining the bearing capacity factors were different.

2.3.1 TERZAGHI'S BEARING CAPACITY THEORY

Terzaghi's method of analysis of the bearing capacity of cohesive soil is independent of the width of the footing. The settlement, however, of cohesive soil is inversely proportional to the width 'b' of the footing.

A strip footing of width "B" gradually compresses the foundation soil underneath due to the vertical load from the superstructure. Let q_f be the final load at which the foundation soil experiences failure due to the mobilization of plastic equilibrium. According to Terzaghi, the soil mass above the failure surface consists of three zones:

Zone I: Because of friction and adhesion between the soil and the base of the footing, this zone cannot spread laterally. It moves downward as an elastic wedge and the soil in this zone behaves as if it is a part of the footing

Zone II: This zone is called zones of radial shear. The soil in this zone is pushed into zone III.

Zone III: These are the two passive Rankine zones, boundaries of which make angles (45°−ϕ/2) with the horizontal.

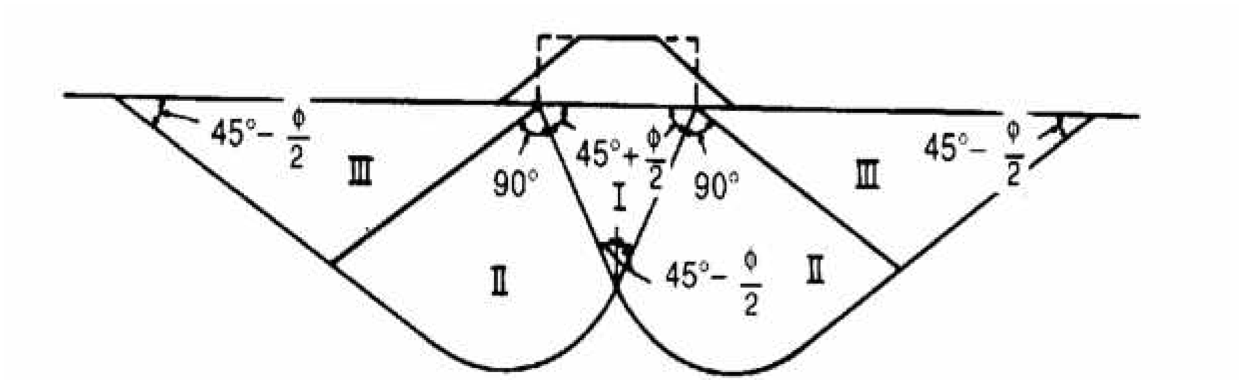

Figure 2.1: Terzaghi's system for ideal soil, rough base and surcharge.

(Element of soil mechanics by GN Smith and IAN GN Smith, 7th edition)

2.3.2 MAYERHOF'S BEARING CAPACITY THEORY

Meyerhof (1963) extended Terzaghi's analysis of the plastic equilibrium of the surface footing to shallow and deep foundations, considering the shear strength of overburden. Figure2.2 shows the failure mechanism for shallow and deep foundations according to both Terzaghi and Meyerhof's analysis.

In the Meyerhof's analysis, ABD is the elastic zone, BDE is the radial shear zone and BEFG is the zone of mixed shear in which shear varies between radial and plane shear, which depend upon the depth and roughness of the foundation. The plastic equilibrium in all these zones is established from the boundary conditions starting from the foundation shaft. To make the analysis simpler, Meyerhof introduced a parameter β, the angle to define the line bf, joining point B to F where the boundary failure slip line intersects the soil surface.

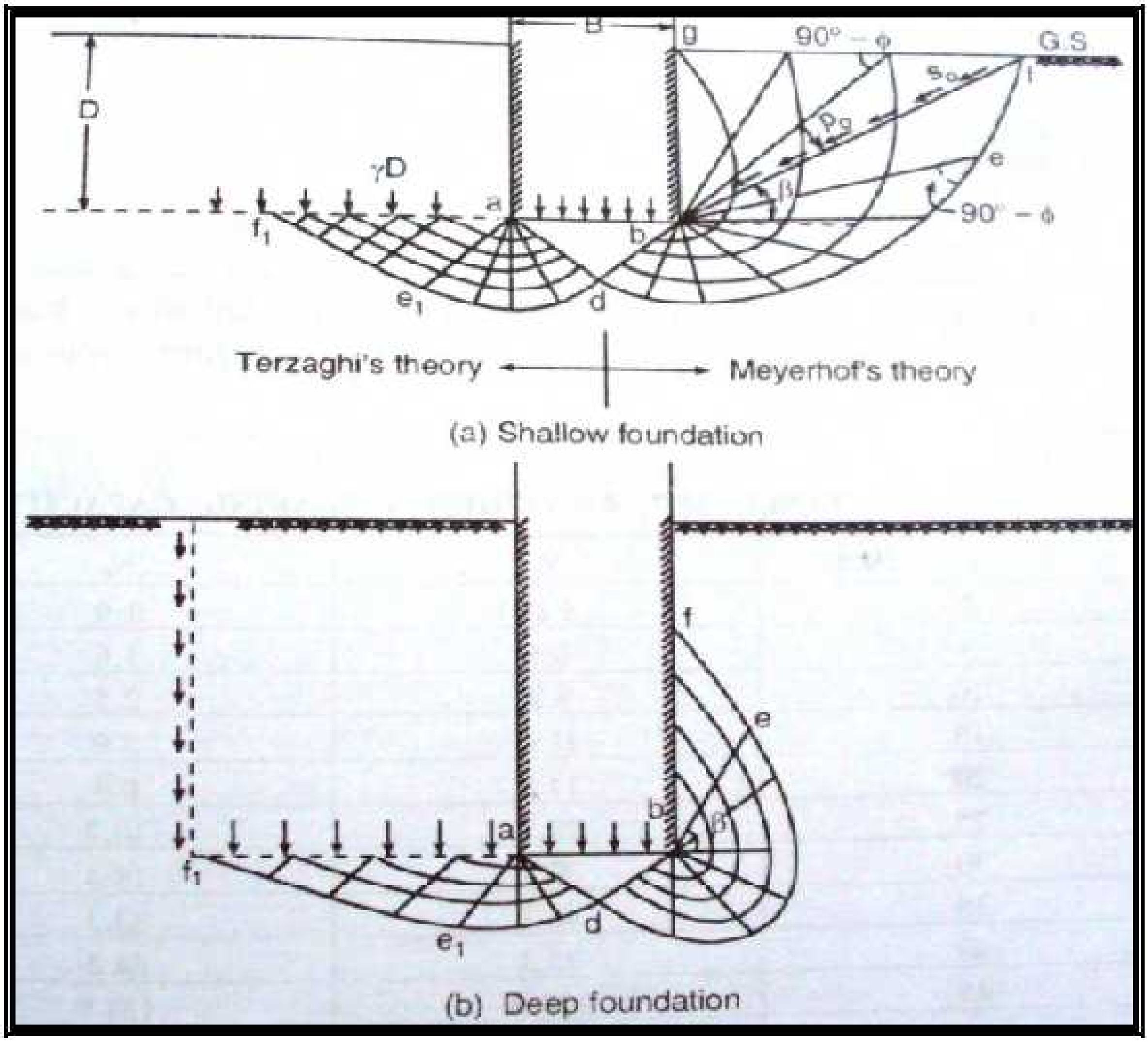

Figure 2.2: Meyerhof's Analysis (After Meyerhof, 1963)

The resultant effects of the wedge BFG are represented by normal stress and tangential stress, p_0 and s_0 on bf. The plane bf is termed as the equivalent free surface, and p_0 and s_0 are termed as the equivalent free surface stresses. The value of β increases with depth and becomes 90° for deep foundations. The equation for ultimate bearing capacity (taking into account the shape, depth and inclination factors) can be expressed as,

$$q_u = c.N_C.s_c.d_c.i_c + q.N_q.s_q.d_q.i_q. + 0.5\gamma.B.N_\gamma.s_\gamma.d_\gamma.i_\gamma$$

$$N_q = \tan^2\left(4 \quad + \frac{\phi}{2}\right).e^{\pi} \quad ,$$

$$N_C = (N_q - 1)\cot\phi'$$

$$N_\gamma = (N_q - 1)\tan(1.4\,\phi')$$

Where S_c, S_q, S_γ = shape factor

d_c, d_q, d_γ= depth factor

i_c, i_q, i_γ= inclination factors

N_q, N_C, and N_γ = bearing capacity factors.

3.3 HANSEN BEARING CAPACITY THEORY

Brinch Hansen (1960) modified the equation of Terzaghi by including five new variables, namely, the (i) shape factor ‘s’, (ii) depth factor ‘d’, (iii) inclination factor ‘i’, (iv) ground factor ‘g’ and (v) base factor ‘b’ and expressed the bearing capacity equation as follows:

$$q_u = c.N_C.s_c.d_c.i_c.g_c.b_c + q.N_q.s_q.d_q.i_q.g_c.b_c + 0.5\gamma.B.N_\gamma.s_\gamma.d_\gamma.i_\gamma.g_c.b_c$$

where;

g_c= ground factor

b_c= base factor

Hansen’s recommendation for the bearing capacity factors N_c and N_q are the same as those recommended by Meyerhof but $N_\gamma$holds a different equation as follows:

$N_\gamma = 1.5(N_q - 1)\tan(\phi')$. **(Hansen, 1970)**

2.3.4 VESIC’S BEARING CAPACITY THEORY

Vesic (1973) assumed failures surfaces which were identical to Terzaghi’s but the angle which the inclined surface make with the horizontal was taken as (45 + φ/2) instead of φ. Bearing capacity factors Nc and Nq are identical to those of Meyerhof’s and Hansen. Nγas given by Vesic is a simplified form of the recommendations of Caquot and Kerisel (1948).

$N_q = \tan^2\left(4 \quad + \frac{\phi}{2}\right).e^{\pi}$,

$N_C = (N_q - 1) \cot\phi'$

$N_\gamma = 2(N_q + 1) \tan(\phi')$

2.4 SETTLEMENT IN GENERAL

It is practically impossible to prevent settlement of shallow foundations. At least, an elastic settlement will occur. The estimation of the settlement of shallow foundations is an important topic in the design and construction of buildings and other related structures. In general, settlement of a foundation consists of two major components—elastic settlement (*Se*) and consolidation settlement (*Sc*). In turn, the consolidation settlement of a submerged clay layer has two parts; that is, the contribution of primary consolidation settlement (*Sp*) and that due to secondary consolidation (*Ss*). For a foundation supported by granular soil within the zone of influence of stress distribution, the elastic settlement is the only component that needs consideration. This project gives a general overview of various aspects of the elastic settlement of shallow foundations supported by granular soil deposits.

2.5 REVIEW OF RELATED WORKS ON SETTLEMENT

2.5.1 TERZAGHI AND PECK'S METHOD OF SETTLEMENT ANALYSIS

Terzaghi and Peck (1948) proposed the following empirical relationship between the settlement (*Se*) of a prototype foundation measuring *B*×*B* in plan and the settlement of a test plate [*Se*(1)] measuring *B*1×*B*1 loaded to the same intensity.

$$\frac{S}{S\ (1)} = \frac{4}{\left[1+\left(\frac{B}{B}\right)\right]^2} \text{------------------------------------} \quad (1)$$

Although a full-sized footing can be used for a load test, the normal practice is to employ a plate of the order of 0.3 m to 1 m. Bjerrum and Eggestad (1963) provided the results of 14 sets of load settlement tests. This is shown in Figure (2.3) along with the plot of Eq. (1). For these tests, *B*1 was 0.35 m for circular plates and 0.32 m for square plates. It is obvious from Figure (2.3) that, although the general trend is correct, Eq. (1) represents approximately the lower limit of the field test results. Bazaraa (1967) also provided several field test results. Figure (2.4) shows the plot of *Se*/*Se*(1) versus *B*/*B*1 for all tests results provide by Bjerrum and Eggestad (1963) and Bazaraa (1967) as compiled by D'Appolonia et al. (1970). The overall results with the expanded database are similar to those in Figure (2.3) as they relate to Eq. (1). Terzaghi and Peck (1948, 1967) proposed a correlation for the allowable bearing capacity, standard penetration number (*N*60), and the width of the foundation (*B*) corresponding to a 25 –mm settlement based on the observation given by Eq. (1). This correlation is shown in Figure (2.4). The curves in Figure (2.3) can be approximated by the relation;

$$S_e\ (\text{mm}) = \frac{3}{N_6}\left(\frac{B}{B+0.3}\right)^2 \text{------------------------------------} \ (2)$$

Where q = bearing pressure in kN/m^2

B = width of foundation (m)

If corrections for groundwater table location and depth of embedment are included, then Eq. (2) takes the form;

$$S_e = C_W C_D \frac{3}{N_6}\left(\frac{B}{B+0.3}\right)^2 \text{------------------------------------} \ (3)$$

Where

C_W= groundwater table correction

C_D= correction for depth of embedment = 1 – (D_f/4B)

D_f= depth of embedment

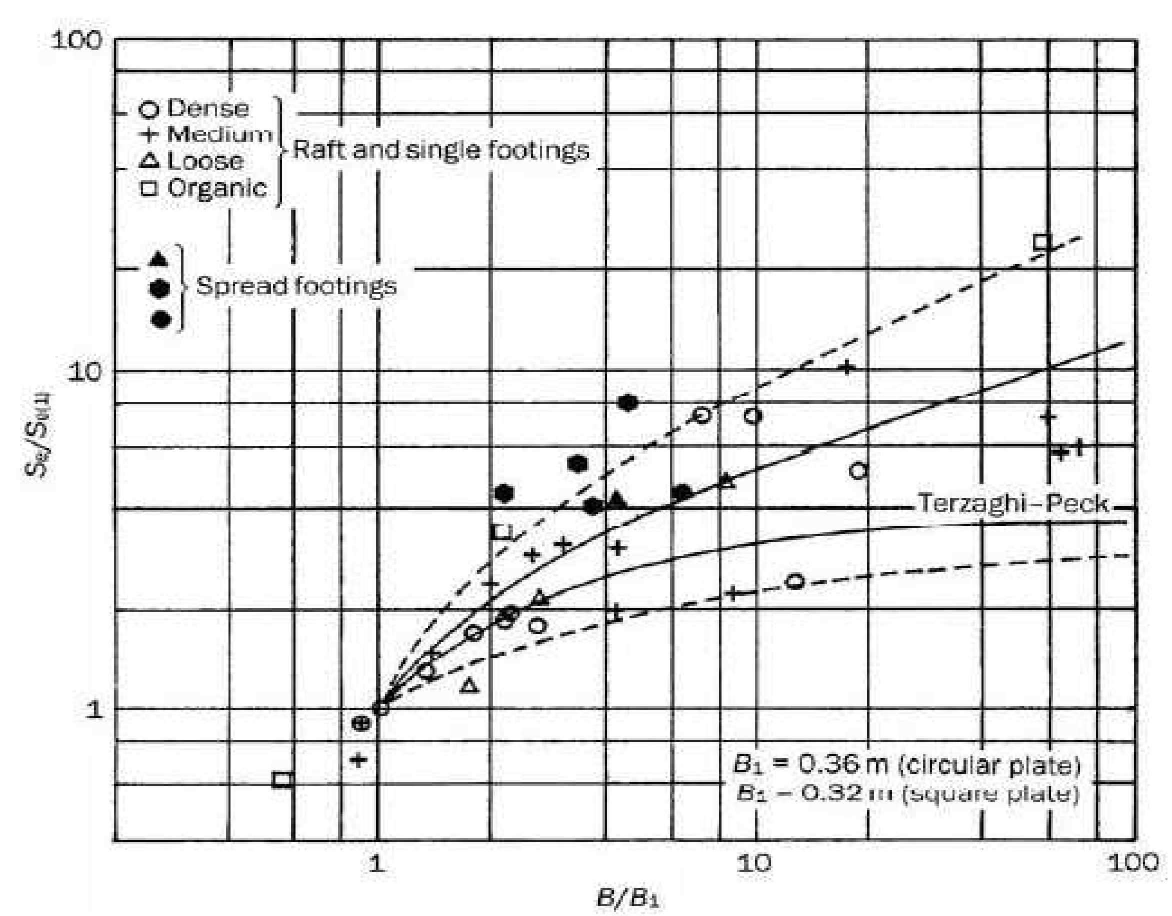

Figure 2.3: Variation of *Se*/*Se*(1) versus *B*/*B*1 from the load settlement results of Bjerrum and Eggestad (1963)

(Note: B1 = 0.36 m for circular plates and 0.32 m for square plates).

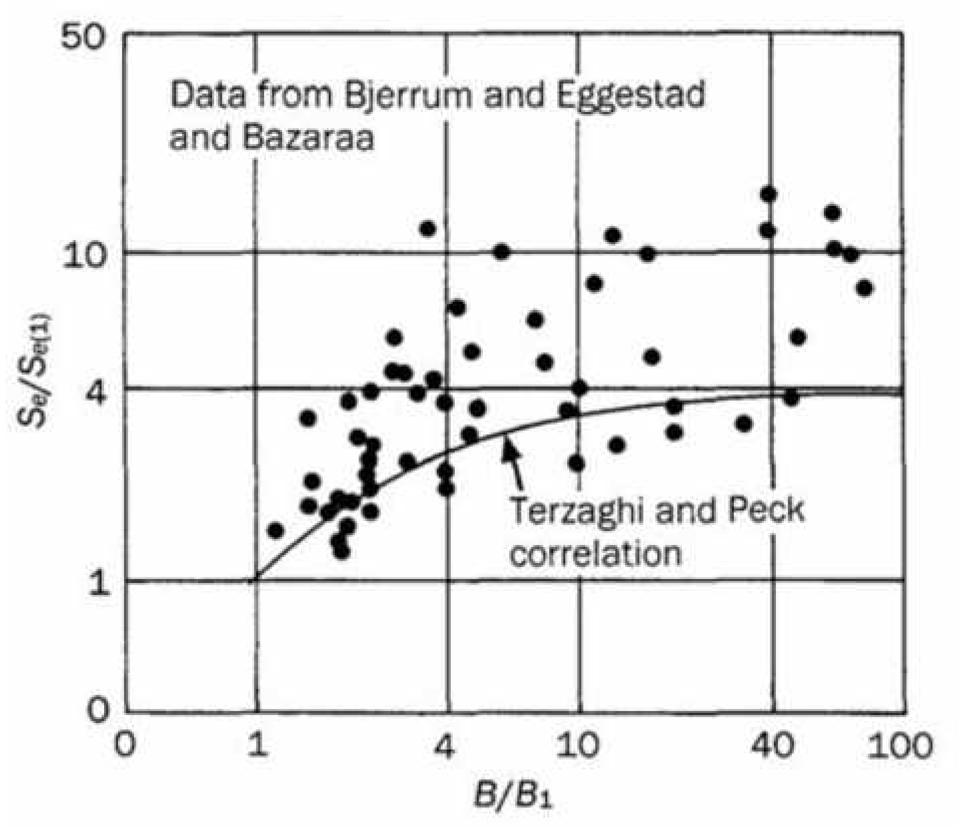

Figure 2.4: Variation of *Se*/*Se* (1) versus *B*/*B*1 based on the data of Bjerrum and Eggestad (1963) and Bazara (1967) (adapted from D'Appolonia et al., 1970).

2.5.2 MAYERHOF'S METHOD OF SETTLEMENT ANALYSIS

In 1956, Meyerhof proposed relationships for the elastic settlement of foundations on granular soil similar to Eq. (2) as illustrated above. In 1965, he compared the predicted (by the relationships proposed in 1956) and observed settlements of eight structures and suggested that the allowable pressure (q) for a desired magnitude of Se can be increased by 50% compared to what he recommended in 1956. The revised relationships including the correction factors for water table location (C_W) and depth of embedment (C_D) can be expressed as:

$$\mathbf{S_e = C_w C_D}\frac{1.2}{N_6} \text{(for B} \leq \text{1.22m)}$$

and;

$$S_e = C_w C_D \frac{2}{N_6}\left(\frac{B}{B+0.3}\right)^2 \text{(for B > 1.22m)}$$

Where;

$$C_w = 1.0 \quad \text{and} \quad C_D = 1.0 - \frac{D_f}{4}$$

2.5.3 PECK AND BAZARAA METHOD OF SETTLEMENT ANALYSIS

Peck and Bazaraa (1969) recognized that the original Terzaghi and Peck method was overly conservative and revised Eq. (3) as illustrated above to the following form:

$$S_e = C_w C_D \frac{2}{(N\ \ )_6}\left(\frac{B}{B+0.3}\right)^2$$

Where; S_e is in mm, q is in kN/m^2, and B is in m.

$(N1)_6$ = corrected standard penetration number

$$C_w = \frac{\sigma_O\ a\ \ 0.5B\ b \quad the\ b \quad o\ \ the\ f}{\sigma'_O\ a\ \ 0.5B\ b \quad the\ b \quad o\ \ the\ f}$$

σ_o = total overburden pressure

σ'_o = effective overburden ratio

$$C_D = 1.0 - 0.4\left(\frac{\gamma\ \ f}{q}\right)^{0.5}$$

γ = unit weight of soil

The relationships for $(N1)_{60}$ are as follows:

$$(N1)_{60} = \frac{4\ \ \ 6}{1+0.0\ \ \ '_o}\text{(for } \sigma'_O \leq 75\text{kN/m}^2\text{)}$$

and;

$$(N1)_{60} = \frac{4\ \ \ 6}{3.2\ \ +0.0\ \ \ '_o}\text{(for } \sigma'_O > 75\text{kN/m}^2\text{)}$$

D'Appolonia et al. (1970) compared the observed settlement of several shallow foundations from several structures in Indiana (USA) with those estimated using the Peck and Bazaraa method. It can be seen that the calculated settlement from the theory greatly overestimates the observed settlement. It appears that this solution will provide nearly the level of settlement that was obtained from Meyerhof's revised relationships.

2.5.4 BERARDI AND LANCELLOTTA'S METHOD OF SETTLEMENT ANALYSIS

Berardi and Lancellotta (1991) proposed a method to estimate the elastic settlement that takes into account the variation of the modulus of elasticity of soil with the strain level. Berardi et al. (1991) also describe this method. According to this procedure,

$$S_e = I_s\left(\frac{q}{E_s}\right)$$

Where; I_s = influence factor for a rigid foundation (Tsytovich)

E_s = modulus of elasticity of soil

The variation of *Is*(Tsytovich, 1951) with Poisson's ratio= 0.15 is given in Table 2.1.

Table2.1: Variation of I_s (Tsytovich, 1951)

	Depth of influence H_I/B			
L/B	**0.5**	**1.0**	**1.5**	**2.0**
1	**0.35**	**0.56**	**0.63**	**0.69**
2	**0.39**	**0.65**	**0.76**	**0.88**
3	**0.40**	**0.67**	**0.81**	**0.96**
5	**0.41**	**0.68**	**0.84**	**0.99**
10	**0.42**	**0.71**	**0.89**	**1.06**

Using analytical and numerical evaluations, Berardi and Lancellotta (1991) have shown that, for a circular foundation,

$$\mathbf{H_{25} = (0.8 \text{ to } 1.3)\, B}$$

For plane strain condition (that is, $L/B \geq 10$)

$$\mathbf{H_{25} = (1.5 \text{ to } 1.7) H_{25(circle)}}$$

Where; H_{25} = depth from the bottom of the foundation below which the residual settlement is 25% of the total settlement

2.5.5 GAZETAS ET AL METHOD OF SETTLEMENT ANALYSIS

According to Gazetas et al (1985), an embedded footing has the following effects in comparison with a surface:

1. Soil stiffness generally increases with depth, so the footing loads will be transmitted to a stiffer soil. This will result in a smaller settlement.
2. Normal stresses from the soil above the footing level have been shown to reduce the settlement by providing increased confinement on the deforming half-space. This is called the trench effect.
3. Part of the load on the footing may also be transmitted through the sidewall depending on the amount of shear resistance mobilized at the soil-wall interface. The accommodation of part of the load by side resistance reduces the vertical settlement. This has been called the side-wall contact effect.

CHAPTER THREE

MATERIALS AND METHOD

3.1 MICROSOFT EXCEL 2010

Microsoft Excel 2010 is a commonly used spreadsheet program. It is used by engineers for creating tables for use in technical documents as well as for manipulation, charting data and simple mathematical modelling. Microsoft Excel is a tool that can be used in virtually all careers and is valuable in both professional and personal settings.

3.2 THE GRAPHIC INTERFACE

3.2.1 MENU BAR

It is a portion of the interface that provides the user with one way to access the Microsoft excel commands. Commands are actions you perform on your worksheet. Examples are: saving the data to a file, printing a worksheet, changing the appearance of some text etc.

3.2.2 TOOL BARS

Toolbars are another more intuitive and quicker method of accessing commands. Each tool on a toolbar is depicted by an icon. For example, “clicking on the copy tool” or the copy button.

3.2.3 WORKSPACE

The workspace is the central part of your work. Data are being typed here and calculations are also made. The main part of the space is divided by gridlines into rows and columns. The smallest unit of space where the rows and columns intersect is called a cell.

3.2.4 STATUS BAR

The status bar is a part of the graphic interface which provides information and we have the message area located at the left side of the status bar.

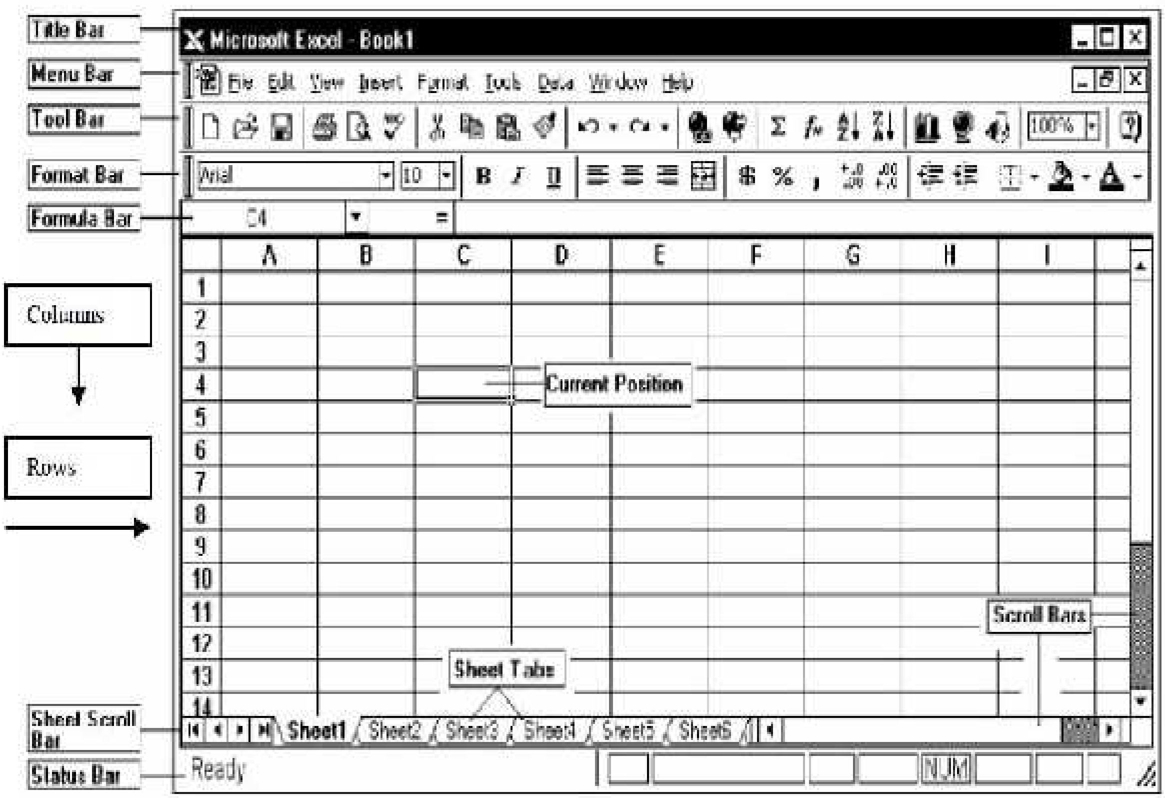

Figure 3.1: A typical graphic interface of Microsoft excel.

3.3 APPLICATION OF MICROSOFT EXCEL SPREADSHEET.

A spreadsheet is the computerized equivalent of a general ledger. It has taken the place of the pencil, paper, and calculator. Spreadsheet programs were first developed for accountants but have now been adopted by anyone wanting to prepare a budget, forecast sales data, create profit and loss statements, and compare financial alternatives and any other mathematical applications requiring calculations. A spreadsheet is essentially a matrix of rows and columns. Consider a sheet of paper on which horizontal and vertical lines are drawn to yield a rectangular grid. The grid namely a cell is the result of the intersection of a row with a column. Such a structure is called a Spreadsheet.

The electronic spreadsheet is laid out similar to the paper ledger sheet in that it is divided into columns and rows. Any task that can be done on paper can be performed on an electronic spreadsheet faster and more accurately. The problem with manual sheets is that if any error is found within the data, all answers must be erased and recalculated manually. With the computerized spreadsheet, formulas can be written that is automatically updated whenever the data are changed.

A spreadsheet looks a lot like a table you might see in any word processing package, but it has some very important features that most tables do not. The first is that it is designed to make repetitive and/or complicated calculations very easy to carry out. Secondly, most spreadsheet programs have advanced graphing capabilities that make producing graphs from the data on the spreadsheet relatively simple.

3.4 TERZAGHI'S METHOD

Terzaghi considered the case of rough foundation bases resting on a soil mass that possesses weight. He developed a general bearing capacity equation for a uniformly loaded strip footing. Terzaghi's theory is based on the following **assumptions**:

1. Soil is homogeneous and Isotropic.
2. Mohr Coulombs Criteria represent the shear strength of the soil.
3. The footing is of strip footing type with rough base. It is essentially a two-dimensional plane strain problem.
4. The failure mode is General shear failure.

5. Failure zone is not extended above, beyond the base of the footing. Shear resistance of soil above the base of footing is neglected. The soil above the base of the footing is substituted by an equivalent surcharge (**$q = \gamma * D_f$**), where γ = unit weight of soil above the base of the footing.
6. Method of superposition is valid.
7. Passive pressure force has three components (P_{pc} produced by cohesion, P_{pq} produced by surcharge and $P_{p\gamma}$ produced by weight of shear zone).
8. Effect of the water table is neglected.
9. Footing and ground are horizontal.
10. Limit equilibrium is reached simultaneously at all points. Complete shear failure is mobilized at all points at the same time.
11. The properties of foundation soil do not change during shear failure.

Terzaghi's theory has the following **limitations**:

1. The theory is applicable to shallow foundations.
2. As the soil compresses, ϕ increases which are not considered. Hence fully plastic zone may not develop at the assumed ϕ.
3. All points need not experience limit equilibrium condition at different loads. Method of superstition is not acceptable in plastic conditions as the ground is near failure zone.

NOTATIONS

q_{ult}: ultimate bearing capacity

C: cohesion for the soil beneath the foundation

q: surcharge ($q = \gamma * D_f$)

γ: the effective unit weight of the soil

B: width (or diameter) of foundation

L: length of foundation

N_c, N_q and N_γ: Terzaghi's bearing capacity factors (See Table 3.1)

The shape of the footing influences the bearing capacity. Terzaghi suggested the correction to the bearing capacity equation for shapes other than strip footing based on his experimental findings. The following are the corrections for circular, square and rectangular footings.

For Strip Footing:

$q_{ult} = cN_c + \gamma^* D_f N_q + 0.5\gamma B N_\gamma$

For Circular Footing:

$q_{ult} = 1.3cN_c + \gamma^* D_f N_q + 0.3\gamma B N_\gamma$

For Square Footing:

$q_{ult} = 1.3cN_c + \gamma^* D_f N_q + 0.4\gamma B N_\gamma$

For Rectangular footing:

$q_{ult} = (1+0.3\ B/L)cN_c + \gamma^* D_f N_q + (1 - 0.2B/L)0.5\gamma B N_\gamma$

Where:

$$N_q = \tan^2\left(4 \quad + \frac{\phi}{2}\right).e^{\pi} \quad '$$

$$N_C = (N_q - 1)\cot\phi'$$

$N_\gamma = 2(N_q + 1)\tan(\phi') / 1 + 0.4\sin(4\ \phi')$ (adopted from foundation design D. Coduto)

Table 3.1: Terzaghi bearing capacity factors.foundation design (Coduto, 2001)

ϕ^o	N_c	N_q	N_γ	ϕ^o	N_c	N_q	N_γ
0	**5.7**	**1**	**0**	**16**	**13.68**	**4.92**	**2.5**
2	**6.3**	**1.22**	**0.1**	**18**	**15.12**	**6.04**	**3.3**
4	**6.97**	**1.49**	**0.3**	**20**	**17.69**	**7.44**	**4.4**
6	**7.73**	**1.81**	**0.5**	**25**	**25.13**	**12.72**	**9.2**
8	**8.6**	**2.21**	**0.7**	**30**	**37.16**	**22.46**	**20.1**
10	**9.61**	**2.69**	**1.0**	**40**	**95.66**	**81.27**	**121.5**
12	**10.76**	**3.29**	**1.4**	**45**	**172.28**	**173.28**	**348.75**
14	**12.11**	**4.02**	**1.9**	**50**	**347.5**	**415.14**	**1149.77**

3.4 WATER TABLE CONDITIONS

CONDITION 1: WATER TABLE RISING TO THE GROUND LEVEL

If the water table rises to the ground level, changes are made in the ultimate bearing capacity equation for all the footing types as follows:

For Strip Footing:

$q_{ult} = cN_c + \gamma_b{*}D_fN_q + 0.5\gamma_bBN_\gamma$

For Circular Footing:

$q_{ult} = 1.3cN_c + \gamma_b{*}D_fN_q + 0.3\gamma_bBN_\gamma$

For Square Footing:

$q_{ult} = 1.3cN_c + \gamma_b{*}D_fN_q + 0.4\gamma_bBN_\gamma$

For Rectangular footing:

$q_{ult} = (1+0.3\ B/L)cN_c + \gamma_b{*}D_fN_q + (1 - 0.2B/L)0.5\gamma_bBN_\gamma$

where: $\gamma_b = \gamma_{sat} - \gamma_w$

$\gamma_w = 9.8KN/m^3$

CONDITION 2: WATER TABLE AT DEPTH Z = B

If the water table is at a depth below the base of the footing such that z = b, changes would not be made in any of the bearing capacity equation in any of the footing types.

For Strip Footing:

$q_{ult} = cN_c + \gamma{*}D_fN_q + 0.5\gamma BN_\gamma$

For Circular Footing:

$q_{ult} = 1.3cN_c + \gamma{*}D_fN_q + 0.3\gamma BN_\gamma$

For Square Footing:

$q_{ult} = 1.3cN_c + \gamma{*}D_fN_q + 0.4\gamma BN_\gamma$

For Rectangular footing:

$q_{ult} = (1+0.3\ B/L)cN_c + \gamma{*}D_fN_q + (1 - 0.2B/L)0.5\gamma BN_\gamma$

CONDITION 3: WATER TABLE AT A DEPTH Z < B

If the water table is at a depth below the base of the foundation such that z < b, the expression "γB" in the bearing capacity equation for all footing types is replaced by the expression:

"$(\gamma_{sat}{*}Z + (B – Z))$". Hence,

For Strip Footing:

$q_{ult} = cN_c + \gamma^*D_fN_q + 0.5(\gamma_{sat}^*Z + (B - Z))N_\gamma$

For Circular Footing:

$q_{ult} = 1.3cN_c + \gamma^*D_fN_q + 0.3(\gamma_{sat}^*Z + (B - Z))N_\gamma$

For Square Footing:

$q_{ult} = 1.3cN_c + \gamma^*D_fN_q + 0.4(\gamma_{sat}^*Z + (B - Z))N_\gamma$

For Rectangular footing:

$q_{ult} = (1+0.3\ B/L)cN_c + \gamma^*D_fN_q + (1 - 0.2B/L)0.5(\gamma_{sat}^*Z + (B - Z))N_\gamma$

CONDITION 4: WATER TABLE AT DEPTH Z BELOW GROUND LEVEL

If the water table is at a depth z below the ground level, the expression "γ^*D_f"in the bearing capacity equation for all footing types is replaced by the expression:

"$(\gamma_{sat}^*Z + \gamma' (D_f - Z))$". Hence,

For Strip Footing:

$q_{ult} = cN_c + (\gamma_{sat}^*Z + \gamma' (D_f - Z))N_q + 0.5\gamma BN_\gamma$

For Circular Footing:

$q_{ult} = 1.3cN_c + (\gamma_{sat}^*Z + \gamma' (D_f - Z))N_q + 0.3\gamma BN_\gamma$

For Square Footing:

$q_{ult} = 1.3cN_c + (\gamma_{sat}^*Z + \gamma' (D_f - Z))N_q + 0.4\gamma BN_\gamma$

For Rectangular footing:

$q_{ult} = (1+0.3\ B/L)cN_c + (\gamma_{sat}^*Z + \gamma' (D_f - Z))N_q + (1 - 0.2B/L)0.5\gamma BN_\gamma$

3.5 GAZETAS ET AL METHOD

Gazetas et al. (1985) considered an arbitrary shaped rigid footing embedded in a deep homogenous soil and proposed the following equation for the elastic settlement.

$$\rho_e = \frac{P}{E_u}(1 - V_u^2)\ \mu_s\mu_{emb}\mu_{wall}$$

Where;

P = Total vertical load

$\mathbf{E_u}$ = Un-drained elastic modulus of the soil

L = One- half of the length of a circumscribed rectangle

$\mathbf{V_u}$= Poisson ratio for the un-drained condition

μ_{s}, μ_{emb} and μ_{wall} = shape, embedment (trench) and sidewall friction given as:

$$\mu_s = 0.45\left(\frac{A_b}{4\ {}^{2}}\right)^{-0.3}$$

$$\mu_{emb} = 1 - 0.04\frac{D_f}{B}\left[1 + \frac{4}{3}\left(\frac{A_b}{4\ {}^{2}}\right)\right]$$

$$\mu_{wall} = 1 - 0.16\left(\frac{A_w}{A_b}\right)^{0.5}$$

Where;

$\mathbf{A_b}$ = Actual area of the base of the foundation

$\mathbf{A_w}$ = Actual area of the wall in contact with the embedded portion of the footing

$\frac{A_b}{4\ {}^{2}}$ = Dimensionless shape parameter. See Table 3.2.

Table 3.2: Values of $\frac{A_b}{4\ {}^{2}}$ for common footing shapes

FOOTING SHAPE	$\frac{A_b}{4\ {}^{2}}$
Square	1
Rectangle	B/L
Circle	0.785
Strip	0

Soil Mechanics and Foundation (Budhu, 2000)

The full wall resistance is mobilized if sufficient settlement occurs. It is difficult to ascertain wall resistance in the quality of the soil-wall adhesion. If wall friction and embedment are neglected, then μ_{wall}= 1and μ_{emb}=1

CHAPTER FOUR

PROGRAM DEVELOPMENT AND RESULT DISCUSSION

The sample question used for the testing of the Microsoft Excel template was adopted and formulated from "principles and practices of soil mechanics and foundation Engineering" by V.N.S. Murthy and "soil mechanics and foundation" by Muni Budhu.

4.2 SAMPLE QUESTION (BEARING CAPACITY) FOR TESTING THE PROGRAM

A footing of width 3m is founded at a depth of 2m below the ground surface with a length of 5m in a ($c - \phi$) soil having a cohesion of 25kN/m^2 and angle of shearing resistance, ($\phi = 30^0$). Determine the ultimate bearing capacity and allowable bearing capacity and calculate the same if the water table:

a) rises to the ground level. (condition 1)
b) is at a position of the same distance as that of the footing width below the base of the foundation. (condition 2)
c) Is at the position of 2m below the base level of the foundation. (condition 3)
d) Is at the position of 2m below the ground level. (condition 4)

Assume saturated unit weight to be 19 kN/m^3, unit weight of water to be 9.8 kN/m^3 and factor of safety to be 3.

4.3 COMPARISON BETWEEN MANUAL CALCULATION AND EXCEL TEMPLATE USING THE SAMPLE QUESTION ABOVE.

After the Microsoft excel template for the bearing capacity was developed, a comparison was made between the manual calculation (Appendix 1) and the spreadsheet (excel template) that was developed for all the footing types. The difference between the manual calculation and the Microsoft Excel spreadsheet for all the footing types including the water table condition is less than 0.50, which is within an acceptable range.

4.4 SAMPLE QUESTION (SETTLEMENT)

Neglecting side friction, determine the immediate settlement of a footing of 4m x 6m embedded in a deep deposit of homogenous clay with an un-drained elastic modulus of 15Mpa, Poisson's ratio of 0.45 and a total vertical load of 4000kN.

4.5 COMPARISON BETWEEN MANUAL CALCULATION AND EXCEL TEMPLATE USING THE SAMPLE QUESTION ABOVE.

After the Microsoft excel template for the settlement was developed, a comparison was made between the manual calculation (Appendix 2) and the spreadsheet (excel template) that was developed for all the footing types. There is no significant difference between the manual calculation and the Microsoft Excel spreadsheet for all the footing types.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

The following are the conclusion that has emanated from the research and implementation of this project.

- A user-friendly Microsoft excel template for the calculation of the ultimate bearing capacity and settlement of a shallow foundation using Terzaghi's and Gazeta's method respectively has been successfully developed and tested.
- The program developed was used to undertake a sample calculation that was adopted and formulated from (principles and practices of soil mechanics by V.N.S Murthy and soil mechanics and foundation by Muni Budhu).
- The parameter identified to have much effect on the ultimate and allowable bearing capacity is the frictional angle.
- The difference between the manual calculation and the Microsoft Excel spreadsheet in the bearing capacity aspect is less than 0.50, which is within an acceptable range. In addition, in the aspect of the settlement analysis, there is no significant difference between the manual calculation and the Microsoft Excel spreadsheet for all the footing types.

5.2 RECOMMENDATION

The recommendations directly affiliated to this Microsoft excel template are given as follows;

- Future attempts on similar topics should endeavour to develop this template for the ultimate bearing capacity and settlement of shallow foundation using other methods (i.e. Mayerhof's and Hansen's method). This will be an enhancement to the program's flexibility and for comparison between all the methods.
- During the use of this Microsoft Excel template, Engineers should stick to the expression for the bearing capacity factors as adopted (especially for $N\gamma$).

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APPENDICES

APPENDIX 1

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DATE: DECEMBER, 2015

MANUAL CALCULATION

BEARING CAPACITY FOR SHALLOW FOUNDATION USING TERZAGHI'S METHOD

STRIP FOOTING

PARAMETERS

Length, $L = 5m$
Width, $B = 3m$
Depth, $D_f = 2m$
Angle, $\phi = 30^\circ$
Cohesion, $c = 25 KN/m^2$

Factor of Safety $F.O.S = 3$
Saturated unit weight, $\gamma_{sat} = 19 KN/m^3$
Unit weight of water $= 9.81 KN/m^3$
γ' and $\gamma_b = \langle 19 - 9.81 \rangle = 9.19 KN/m^3$

SOLUTION

BEARING CAPACITY FACTORS

$$N_q = \frac{e^{\frac{270-30}{180} \times 3.142 \times \tan 30}}{2 \cos^2 \langle 45 + 30/2 \rangle} = 22.46$$

$$N_c = \frac{22.46 - 1}{\tan 30} = 37.17$$

$$N_\gamma = \frac{2 \langle 22.46 + 1 \rangle \tan 30}{1 + 0.4 \sin \langle 4 * 30 \rangle} = 20.12$$

Ultimate Bearing Capacity, $q_{ult} = \langle 25 * 37.17 \rangle + (19 * 2 * 22.46) + (0.5 * 19 * 3 * 20.12)$

$$q_{ult} = 2356.15 KN/m^2$$

Allowable Bearing Capacity $q_a = \frac{2356.15}{3} = 785.38 KN/m^2$

WATER TABLE CONDITION

Condition 1: It is assumed that the water table rises to the ground level.

Ultimate Bearing Capacity, q_{ult}

$$q_{ult} = cN_c + \gamma_b' D_f N_q + 0.5 \gamma_b' B N_\gamma$$

$$= (25*37.17) + (9.19*2*22.46) + (0.5*9.19*3*20.12)$$

$$q_{ult} = 1619.42 \ kN/m^2$$

Allowable Bearing Capacity, $q_a = \frac{1619.42}{3} = 539.81 \ kN/m^2$

Condition 2: It is assumed that the position of the water table is at a depth below the base of the footing such that $Z = B$

In such a case, no changes would be made in the bearing capacity equation which implies that the position of the water table has no effect.

Hence, $q_{ult} = 2356.15 \ kN/m^2$

$q_a = 785.38 \ kN/m^2$

Condition 3: If the water table is at a depth (z) below the base of the foundation such that $Z < B$

$Z = 2m \quad B = 3m$

$\therefore \gamma_{sat} Z + \gamma'(B-Z) = 19*2 + 9.19\langle 3-2 \rangle = 47.19$

Hence, Ultimate Bearing Capacity q_{ult};

$$q_{ult} = (25*37.17) + (19*2*22.46) + (0.5*47.19*20.12)$$

$$q_{ult} = 2257.46 \ kN/m^2$$

$$q_a = \frac{2257.46}{3} = 752.49 \ kN/m^2$$

CONDITION 4: It is assumed that the water table lies within the embedment depth (ie at a depth (z) below the ground surface).

$Z = 2m$, $B = 3m$, $D_f = 2m$

$\therefore \gamma_{sat} Z + \gamma' (D_f - Z) = 19*2 + 9.19(2-2) = 38$

Hence,

Ultimate Bearing Capacity, q_{ult}

$q_{ult} = (25*37.17) + (38*22.46) + (0.5*19*3*20.12)$

$q_{ult} = 2356.15 \ KN/m^2$

Allowable Bearing Capacity, $q_a = \frac{2356.15}{3} = 785.38 \ KN/m^2$

CIRCULAR FOOTING

Using the Same Parameters as that of the strip footing calculation

$N_c = 37.17$, $N_q = 22.46$, $N_\gamma = 20.12$

Ultimate Bearing Capacity, q_{ult} =

$q_{ult} = (1.3*25*37.17) + (19*2*22.46) + (0.3*19*3*20.12)$

$q_{ult} = 2405.56 \ KN/m^2$

Allowable Bearing Capacity: $q_a = \frac{2405.56}{3} = 801.85 \ KN/m^2$

WATER TABLE CONDITION

Condition 1

Ultimate Bearing Capacity, q_{ult}

$q_{ult} = (1.3*25*37.17) + (9.19*2*22.46) + (0.3*9.19*3*20.12)$

$q_{ult} = 1787.25 \ KN/m^2$.

Allowable Bearing Capacity; $q_{a} = \frac{1787.25}{3} = 595.75 \, KN/m^2$

Condition 2: No Changes made.

$q_{ult} = 2405.56 \, KN/m^2$

$q_{a} = 801.85 \, KN/m^2$

Condition 3: $Z = 2m$, $B = 3m$

$\therefore \gamma_{sat} Z + \gamma' \langle B - Z \rangle = 47.19$

$q_{ult} = (1.3 * 25 * 37.17) + (19 * 2 * 22.46) + (0.3 * 47.19 * 20.12)$

$q_{ult} = 2346.34 \, KN/m^2$

$q_{a} = \frac{2346.34}{3} = 782.11 \, KN/m^2.$

Condition 4: $Z = 2m$, $B = 3m$, $D_f = 2m$

$\gamma_{sat} Z + \gamma' \langle D_f - Z \rangle = 19 * 2 + 9.19 \langle 2 - 2 \rangle = 38.$

Ultimate Bearing Capacity, q_{ult};

$q_{ult} = (1.3 * 25 * 37.17) + (38 * 22.46) + (0.3 * 19 * 3 * 20.12)$

$q_{ult} = 2405.56 \, KN/m^2$

Allowable Bearing Capacity; $q_{a} = \frac{2405.56}{3} = 801.85 \, KN/m^2$

RECTANGULAR FOOTING

Using the Same Parameters as that of Strip footing

$N_c = 37.17$, $N_q = 22.46$, $N_\gamma = 20.12$

Ultimate Bearing Capacity, q_{ult}:

$$q_{ult} = \left(1 + 0.3 * \tfrac{3}{5}\right) * (25 * 37.17) + (19 * 2 * 22.46) + \left(1 - 0.2 * \tfrac{3}{5}\right) * (0.5 * 19 * 3 * 20.12)$$

$$q_{ult} = 2454.72 \text{ kN/m}^2$$

Allowable Bearing Capacity, $q_a = \dfrac{2454.60}{3} = 818.20 \text{ kN/m}^2$.

WATER TABLE CONDITION

Condition 1:

Ultimate Bearing Capacity

$$q_{ult} = \left(1 + (0.3 * 3/5)\right) * (25 * 37.17) + (9.19 * 2 * 22.46) + \left(1 - (0.2 * 3/5)\right) * 0.5 * 9.19 * 3 * 20.12$$

$$q_{ult} = 1753.40 \text{ kN/m}^2,$$

Allowable bearing Capacity, $q_a = \dfrac{1753.40}{3} = 584.47 \text{ kN/m}^2$

Condition 2: No changes to be made.

$$q_{ult} = 2454.60 \text{ kN/m}^2$$

$$q_a = 818.20 \text{ kN/m}^2.$$

Condition 3: $Z = 3m$, $B = 3m$, $L = 5m$

$$q_{ult} = \left(1 + 0.3 * 3/5\right) * (25 * 37.17) + (19 * 2 * 22.46) + \left(1 - 0.2 * 3/5\right) * (0.5 * 47.19 * 20.12)$$

$$q_{ult} = 2367.76 \text{ kN/m}^2$$

Allowable bearing Capacity, $q_a = \dfrac{2367.76}{3} = 789.25 \text{ kN/m}^2$

Condition 4:

$$q_{ult} = \left(1+0.3*\tfrac{3}{5}\right)*\left(25*37.17\right)+\left(38*22.46\right)+\left(1-0.2*\tfrac{3}{5}\right)*\left(0.5*19*3*20.12\right)$$

$q_{ult} = 2454.60\ KN/m^2$

Allowable bearing Capacity, $q_a = \frac{2454.60}{3} = 818.20\ KN/m^2$.

SQUARE FOOTING

Using the same Parameters as that of strip footing

$N_c = 37.17$, $N_q = 22.46$, $N_\gamma = 20.12$

Ultimate Bearing Capacity q_{ult}

$$q_{ult} = \left(1.3*25*37.17\right)+\left(19*2*22.46\right)+\left(0.4*19*3*20.12\right)$$

$q_{ult} = 2520\ KN/m^2$.

Allowable bearing Capacity, $q_a = \frac{2520.24}{3} = 840.08\ KN/m^2$

WATER TABLE CONDITION

Condition 1:

Ultimate Bearing Capacity, q_{ult}

$$q_{ult} = \left(1.3*25*37.17\right)+\left(9.19*2*22.46\right)+\left(0.4*9.19*3*20.12\right)$$

$q_{ult} = 1842.72\ KN/m^2$

Allowable bearing Capacity, $q_a = \frac{1842.72}{3} = 614.24\ KN/m^2$

Condition 2: No changes to be made

$q_{ult} = 2520.24\ KN/m^2$

$q_a = 840.08\ KN/m^2$.

Condition 3: $Z = 3m$, $B = 3m$, $L = 5m$

$q_{ult} = (1.3 * 25 * 37.17) + (19 * 2 * 22.46) + (0.4 * 47.19 * 20.12)$

$q_{ult} = 2441.29\ kN/m^2$.

Allowable bearing capacity, $q_a = \frac{2441.29}{3} = 813.76\ kN/m^2$.

Condition 4: $Z = 3m$, $B = 3m$, $L = 5m$

$q_{ult} = (1.3 * 25 * 37.17) + (38 * 22.46) + (0.4 * 19 * 3 * 20.12)$

$q_{ult} = 2520.24\ kN/m^2$

Allowable bearing Capacity, $q_a = \frac{2520.24}{3} = 840.08\ kN/m^2$.

APPENDIX2

IMMEDIATE / ELASTIC SETTLEMENT USING GAZETA'S METHOD

PARAMETERS

Length, $L = 6m$ Width, $B = 4m$

Depth, $D = \frac{6}{2} = 3m$

Undrained Elastic Modulus = 15 MPa

Poisson's Ratio, $V_u = 0.45$

Total Vertical Load, $P = 4000kN$

CONSIDERING RECTANGULAR FOOTING

Actual area of base, $A_b = (4 \times 6)m^2 = 24m^2$

Since it is a rectangle:

$$\frac{A_b}{4L^2} = \frac{B}{L} = \frac{4}{6} = 0.667$$

SHAPE, EMBEDMENT AND WALL FACTOR

Shape Factor, $\mu_s = 0.45\left(\frac{A_b}{4L^2}\right)^{-0.38} = 0.45(0.667)^{-0.38} = 0.525.$

Embedment factor, $\mu_{emb} = 1 - 0.04\frac{D_f}{B}\left[1 + \frac{4}{3}\left(\frac{A_b}{4L^2}\right)\right] = 1 - 0.04 * \frac{3}{4}\left[1 + \frac{4}{3}\langle 0.667\rangle\right]$

$$\mu_{emb} = 0.943.$$

Wall factor, μ_w

Since the wall friction is neglected $\mu_w = 1$

Immediate Settlement, ρ_e

$$\rho_e = \frac{P}{E_u L}\langle 1 - V_u^2\rangle \mu_s \mu_{emb} \mu_w$$

$$= \frac{4000}{15000 * 6} * \langle 1 - 0.45^2\rangle * 0.525 * 0.943 * 1$$

$$\rho_e = 0.017547mm = 17.55mm.$$

CONSIDERING CIRCULAR FOOTING

All other Parameters remains the Same.

For a Circular footing; $\frac{A_b}{4L^2} = 0.785$

SHAPE, EMBEDMENT AND WALL FACTOR

Shape factor, $\mu_s = 0.45 \langle 0.785 \rangle^{-0.38} = 0.493.$

Embedment factor, $\mu_{emb} = 1 - 0.04 * \frac{3}{4}\left[1 + \frac{4}{3} * \langle 0.785 \rangle\right] = 0.939$

Wall factor, $\mu_w = 1$

Immediate Settlement

$$\rho_e = \frac{4000}{15000 * 6} * \langle 1 - 0.45^2 \rangle * 0.493 * 0.939 * 1 = 16.41mm.$$

$$\rho_e = 16.41mm.$$

CONSIDERING SQUARE FOOTING

For a square footing; $\frac{A_b}{4L^2} = 1$

SHAPE, EMBEDMENT AND WALL FACTOR

Shape factor; $\mu_s = 0.45 \langle 1 \rangle^{-0.38} = 0.450$

Embedment factor; $\mu_{emb} = 1 - 0.04 * \frac{3}{4}\left[1 + \frac{4}{3} * \langle 1 \rangle\right] = 0.930$

Wall factor; $\mu_w = 1$

Immediate Settlement

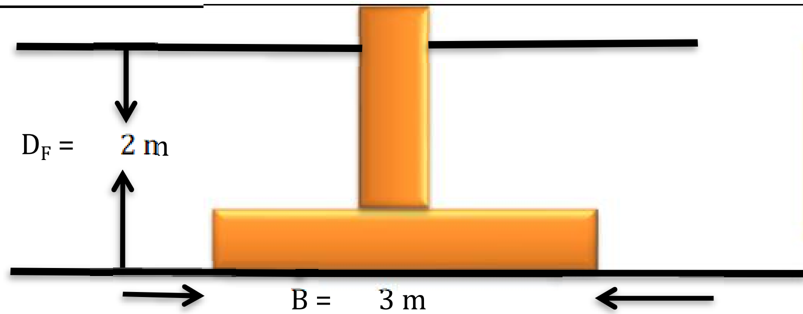
$$\rho_e = \frac{4000}{15000 * 6} * \langle 1 - 0.45^2 \rangle * 0.450 * 0.930 * 1$$

$$\rho_e = 14.83mm.$$

Clients	University of Uyo	***Designed by***	Moses Okon Nseabasi
Title		***Checked by***	ENGR. Ndifreke Udo
Reg. No	010/EG/CV/343	***Date***	January, 2016

BEARING CAPACITY FOR SHALLOW FOUNDATION

USING TERZAGHI'S METHOD



FOOTING TYPE

1 = STRIP
2 = CIRCULAR
3 = RECTANGULAR
4 = SQUARE

General Note: ***Enter values on the green cells only***

Indicate Footing Type : **1** **STRIP FOOTING**

PARAMETERS FOR CALCULATION			
Length, L (m) =	5	Width, B (m) =	3
Depth, D_F (m) =	2	Cohesion, C (kN/m^2) =	25
Factor of Safety, (F.O.S)		=	**3**
Angle of Shearing Resistance, (Φ)		=	30
Saturated Unit Weight, Υ_{sat} (kN/m^3)		=	19
Unit Weight of Water, Υ_w (kN/m^3)		=	9.81
Υ' & Υ_b = Υ_{sat} - Υ_w (kN/m^3)		=	9.19

BEARING CAPACITY FACTORS		
N_C = 37.17	N_q = 22.46	N_Υ = 20.12
Ultimate Bearing Capacity, q_{ult} =		**2356.43 *kN/m²***
Allowable Bearing Capacity, q_a =		**785.48 *kN/m²***

	WATER TABLE CONDITION		
	Condition 1		***Condition 2***
Ultimate Bearing Capacity, q_{ult} =	**1619.61 *kN/m²***		**2356.43 *kN/m²***
Allowable Bearing Capacity, q_a =	**539.87 *kN/m²***		**785.48 *kN/m²***
	Condition 3		***Condition 4***
Depth of Water Table (W.T), z =	**2** m	z =	**2** m
Ultimate Bearing Capacity, q_{ult} =	**2257.73 *kN/m²***		**2356.43 *kN/m²***
Allowable Bearing Capacity, q_a =	**752.58 *kN/m²***		**785.48 *kN/m²***

NOTE:	*In condition1, it is assumed that water table rises to the ground level.*
	In condition 2, it is assumed that the water table is at a depth below the base of the footing such that the depth of the water table (z) = width of the footing (B)
	In condition 3, it is assumed that the water table is at a depth below the base of the footing such that the depth of the water table (z) is less than the width of the footing (B)
	In condition 4, it is assumed that the water table is at a depth below the base of the footing such that the depth of the water table (z) below the ground level.

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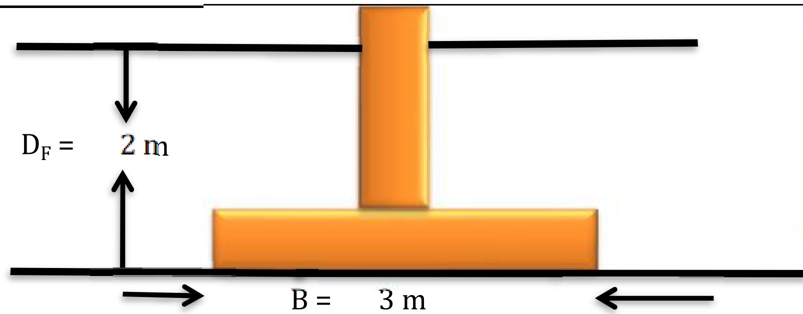
Reg. No	010/EG/CV/343	***Date***	January, 2016

BEARING CAPACITY FOR SHALLOW FOUNDATION

USING TERZAGHI'S METHOD



FOOTING TYPE

1 = STRIP
2 = CIRCULAR
3 = RECTANGULAR
4 = SQUARE

General Note: *Enter values on the green cells only*

Indicate Footing Type :	**2**	**CIRCULAR FOOTING**

PARAMETERS FOR CALCULATION

Length, L (m) =	5	Width, B (m) =	3
Depth, D_F (m) =	2	Cohesion, C (kN/m^2) =	25
Factor of Safety, (F.O.S)		=	**3**
Angle of Shearing Resistance, (Φ)		=	30
Saturated Unit Weight, Υ_{sat} (kN/m^3)		=	19
Unit Weight of Water, Υ_w (kN/m^3)		=	9.81
Υ' & $\Upsilon_b = \Upsilon_{sat} - \Upsilon_w$ (kN/m^3)		=	9.19

BEARING CAPACITY FACTORS

N_C = 37.17	N_q = 22.46	N_Υ = 20.12
Ultimate Bearing Capacity, q_{ult} =		**2405.85** kN/m^2
Allowable Bearing Capacity, q_a =		**801.95** kN/m^2

WATER TABLE CONDITION

	Condition 1		***Condition 2***
Ultimate Bearing Capacity, q_{ult} =	**1787.47** kN/m^2		**2405.85** kN/m^2
Allowable Bearing Capacity, q_a =	**595.82** kN/m^2		**801.95** kN/m^2
	Condition 3		***Condition 4***
Depth of Water Table (W.T), z =	**2** m	z =	**2** m
Ultimate Bearing Capacity, q_{ult} =	**2346.63** kN/m^2		**2405.85** kN/m^2
Allowable Bearing Capacity, q_a =	**782.21** kN/m^2		**801.95** kN/m^2

NOTE:	*In condition1, it is assumed that water table rises to the ground level.*
	In condition 2, it is assumed that the water table is at a depth below the base of the footing such that the depth of the water table (z) = width of the footing (B)
	In condition 3, it is assumed that the water table is at a depth below the base of the footing such that the depth of the water table (z) is less than the width of the footing (B)
	In condition 4, it is assumed that the water table is at a depth below the base of the footing such that the depth of the water table (z) below the ground level.

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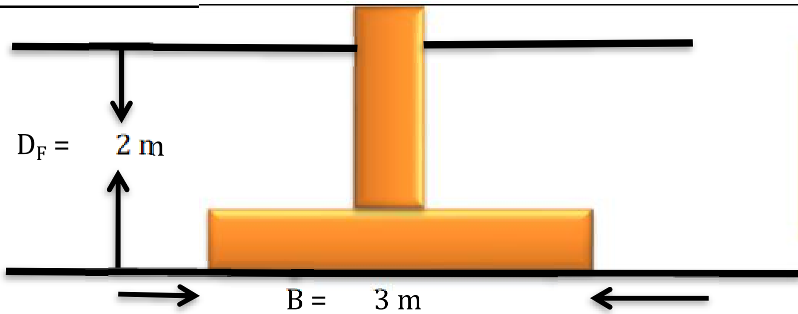
BEARING CAPACITY FOR SHALLOW FOUNDATION

USING TERZAGHI'S METHOD



FOOTING TYPE

1 = STRIP
2 = CIRCULAR
3 = RECTANGULAR
4 = SQUARE

General Note: *Enter values on the green cells only*

Indicate Footing Type :	**3**	**RECTANGULAR FOOTING**

PARAMETERS FOR CALCULATION

Length, L (m) =	5	Width, B (m) =	3
Depth, D_F (m) =	2	Cohesion, C (kN/m^2) =	25
Factor of Safety, (F.O.S)		=	**3**
Angle of Shearing Resistance, (Φ)		=	30
Saturated Unit Weight, Υ_{sat} (kN/m^3)		=	19
Unit Weight of Water, Υ_w (kN/m^3)		=	9.81
Υ' & $\Upsilon_b = \Upsilon_{sat} - \Upsilon_w$ (kN/m^3)		=	9.19

BEARING CAPACITY FACTORS

N_C = 37.17	N_q = 22.46	N_Υ = 20.12
Ultimate Bearing Capacity, q_{ult} =	**2454.90** kN/m^2	
Allowable Bearing Capacity, q_a =	**818.30** kN/m^2	

WATER TABLE CONDITION

	Condition 1		***Condition 2***
Ultimate Bearing Capacity, q_{ult} =	**1753.61** kN/m^2		**2454.90** kN/m^2
Allowable Bearing Capacity, q_a =	**584.54** kN/m^2		**818.30** kN/m^2
	Condition 3		***Condition 4***
Depth of Water Table (W.T), z =	**2** m	z =	**2** m
Ultimate Bearing Capacity, q_{ult} =	**2368.04** kN/m^2		**2454.90** kN/m^2
Allowable Bearing Capacity, q_a =	**789.35** kN/m^2		**818.30** kN/m^2

NOTE:

In condition1, it is assumed that water table rises to the ground level.

In condition 2, it is assumed that the water table is at a depth below the base of the footing such that the depth of the water table (z) = width of the footing (B)

In condition 3, it is assumed that the water table is at a depth below the base of the footing such that the depth of the water table (z) is less than the width of the footing (B)

In condition 4, it is assumed that the water table is at a depth below the base of the footing such that the depth of the water table (z) below the ground level.

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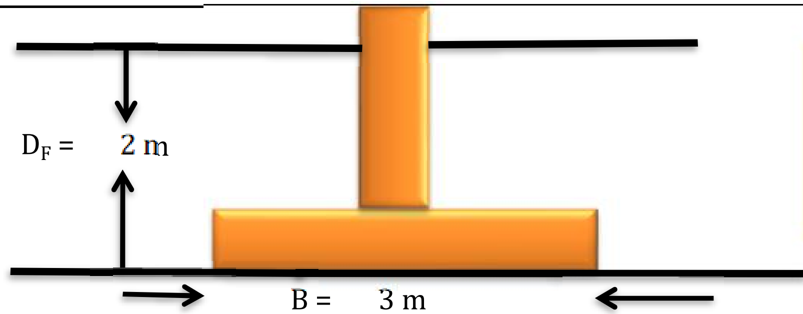
BEARING CAPACITY FOR SHALLOW FOUNDATION

USING TERZAGHI'S METHOD



FOOTING TYPE

1 =	**STRIP**
2 =	**CIRCULAR**
3 =	**RECTANGULAR**
4 =	**SQUARE**

General Note: *Enter values on the green cells only*

Indicate Footing Type : **4** **SQUARE FOOTING**

PARAMETERS FOR CALCULATION

Length, L (m) =	5	Width, B (m) =	3
Depth, D_F (m) =	2	Cohesion, C (kN/m^2) =	25
Factor of Safety, (F.O.S)		=	**3**
Angle of Shearing Resistance, (Φ)		=	30
Saturated Unit Weight, γ_{sat} (kN/m^3)		=	19
Unit Weight of Water, γ_w (kN/m^3)		=	9.81
γ' & $\gamma_b = \gamma_{sat} - \gamma_w$ (kN/m^3)		=	9.19

BEARING CAPACITY FACTORS

N_C = 37.17	N_q = 22.46	N_γ = 20.12

Ultimate Bearing Capacity, q_{ult} =	**2520.54** kN/m^2
Allowable Bearing Capacity, q_a =	**840.18** kN/m^2

WATER TABLE CONDITION

	Condition 1		*Condition 2*
Ultimate Bearing Capacity, q_{ult} =	**1842.95** kN/m^2		**2520.54** kN/m^2
Allowable Bearing Capacity, q_a =	**614.32** kN/m^2		**840.18** kN/m^2
	Condition 3		*Condition 4*
Depth of Water Table (W.T), z =	**2** m	z =	**2** m
Ultimate Bearing Capacity, q_{ult} =	**2441.58** kN/m^2		**2520.54** kN/m^2
Allowable Bearing Capacity, q_a =	**813.86** kN/m^2		**840.18** kN/m^2

NOTE:

In condition1, it is assumed that water table rises to the ground level.

In condition 2, it is assumed that the water table is at a depth below the base of the footing such that the depth of the water table (z) = width of the footing (B)

In condition 3, it is assumed that the water table is at a depth below the base of the footing such that the depth of the water table (z) is less than the width of the footing (B)

In condition 4, it is assumed that the water table is at a depth below the base of the footing such that the depth of the water table (z) below the ground level.

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IMMEDIATE / ELASTIC SETTLEMENT

USING GAZETA'S METHOD

DETERMINING THE GEOMETRIC PARAMETERS

Length, L (m) =	6	
Width, B (m) =	4	
Depth, D (m) =	3	
Undrained Elastic Modulus, E_u =	15	MP_a
Poisson's Ratio, V_u =	0.45	
Total Vertical Load, =	4000	kN
Actual area of the base of the foundation, A_b =	24.00	m^2

Footing Shape	$A_b/4L^2$
Circular	0.785
Rectangular	0.667
Square	1

SHAPE, EMBEDMENT AND WALL FACTOR

FOR CIRCULAR		
Shape Factor, μ_s =	0.493	
Embedment Factor, μ_{emb} =	0.939	
Assumed Wall Factor =	1	
Immediate Settlement, ρ_e =	16.41	mm

FOR RECTANGULAR		
Shape Factor, μ_s =	0.525	
Embedment Factor, μ_{emb} =	0.943	
Assumed Wall Factor =	1	
Immediate Settlement, ρ_e =	17.55	mm

FOR SQUARE		
Shape Factor, μ_s =	0.450	
Embedment Factor, μ_{emb} =	0.930	
Assumed Wall Factor =	1	
Immediate Settlement, ρ_e =	14.83	mm