Comparison of cost and suitability of using raft and pile foundation for building.

PREPARED BY

Md. Labidul Hasan

ID: 171-47-306

Mithun Chandra Barman

ID: 171-47-308

Joy Ghosh

ID: 171-47-311

Md. Shakil Hossen

ID: 171-47-327

This Report Presented in Partial Fulfillment of the Requirements for the Degree of Bachelor of Science in Civil Engineering

SUPERVISED BY

Mr. Rayhan Md. Faysal

Lecturer (Senior Scale)

Department of Civil Engineering

Daffodil International University

DAFFODIL INTERNATIONAL UNIVERSITY

DHAKA, BANGLADESH

JANUARY 2021

CERTIFICATE OF APPROVAL

This thesis titled " **Comparison of Cost and Suitable for using Raft and Pile Foundation for Building** " submitted by Md. Labidul Hassan ID:171-47-306, Mithun Chandra Barman ID: 171-47-308, Joy Ghosh ID: 171-47-311 and Md. Shakil Hossen ID: 171-47-327 to the Department of Civil Engineering of Daffodil International University, has been accepted as satisfactory for the partial fulfillment of the requirements for the degree of B.Sc. in Civil Engineering and approved as to its style and contents. The presentation has been held on Date.

BOARD OF EXAMINERS

____

Dr. Miah M. Hussainuzzaman
Associate Professor and Head
Department of Civil Engineering
Faculty of Engineering
Daffodil International University

Head of the Department

____

(Name)
Designation
Department of Civil Engineering
Faculty of Engineering
Daffodil International University

Internal Examiner

____

(Name)
Designation
Department of -------

External Examiner

DECLARATION

We hereby declare that, this project has been done by us under the supervision of **Mr. Rayhan Md. Faysal, Lecturer, and Department of Civil Engineering** Daffodil International University. We further declare that this work has not been submitted for any other purpose (other than publication).

Supervised by:

Faysal

Mr. Rayhan Md. Faysal
Lecturer (Senior Scale)
Department of Civil Engineering
Daffodil International University

Submitted by:

Md. Labidul Hasan

Md. Labidul Hassan
ID: 171-47-306
Department of Civil Engineering
Daffodil International University

mithun

Mithun Chandra Barman
ID: 171-47-308
Department of Civil Engineering
Daffodil International University

Joy Ghosh
ID: 171-47-311
Department of Civil Engineering
Daffodil International University

Md. Shakil Hossen
ID: 171-47-327
Department of Civil Engineering
Daffodil International University

ACKNOWLEDGEMENT

First of all the author would like to express her deepest sense of faith and gratitude to Almighty God, Who is Gracious to all.

We really grateful and wish our profound our indebtedness to **Mr. Rayhan Md. Faysal** Lecturer Department of Civil Engineering Daffodil International University of Dhaka. Deep knowledge and keen interest our supervisor in the field of "Comparison **of Cost and Suitable for using Raft and Pile Foundation for Building"** to carry out this thesis. His endless patience, scholarly guidance ,continual encouragement, constant and energetic supervision, constructive criticism, valuable advice, reading many inferior draft and correcting them at all stage have made it possible to complete this thesis. His generosity and support will not be forgotten.

We would like to express our heartiest gratitude to **Dr. Miah M. Hussainuzzaman, Head, Department of Civil Engineering**, for his kind help to finish our project and also to other faculty member and the staff of Civil Engineering department of Daffodil International University.

The author expresses her appreciation to DIU authority for allowing her to carry out all the field works and complete the thesis successfully.

Finally, the author expresses profound gratitude to our family for their endless love, unceasing prayers and encouragement. Without them the accomplishment of this thesis would not have been possible.

Dedicated to…..

OUR BELOVED PARENTS

ABSTRACT

The two parts of the building are superstructure and substructure. Carries all types of loads on the building to the foundation carrying superstructure and substructure. Raft and pile foundations are becoming increasingly popular in the construction of multistory buildings, especially when the load bearing capacity of the foundation is low and the column load is very high. This thesis paper discusses the cost of laying the foundation of concrete buildings and which foundation is more affordable.

There are mainly two types of foundation discussed here, where the bearing capacity of the soil and the value of SPT value N are assumed to be the same for the two foundation. These two types of foundations are raft and pile foundations, where raft and pile foundations are relatively heavy and expensive structures. Many types of research papers have come out in the days of raft and pile foundation design but no one has discussed which foundation building is more affordable and long lasting.

Depending on all the circumstances and surroundings, raft foundation cannot be used in some buildings but pile raft foundation can be used where the cost of raft foundation becomes more expensive than pile foundation.

Based on all these circumstances, it can be said that the cost of a foundation will be more or less determined by where the building is being erected. However, in most cases, it is more affordable to set up a raft foundation than a pile foundation.

NOTATIONS

B	Width
D	Depth
C	Undrained Cohesion of Soil
Y	Density of Soil
$N_c N_q N_\gamma$	Bearing Capacity Factors.
Q_u	Ultimate Bearing Capacity
$Q_{net(u)}$	Net Ultimate Bearing Capacity
D_f	Depth of Foundation
L	Length
s_e	Settlement
R	Total Vertical Load on Raft
I_x	Moment of the Inertia about the X-Axis
I_y	Moment of the Inertia about the Y-Axis
e_x, e_y	Co-ordinate of the Resultant Force
U	Factored Column Load
$\emptyset$	Reduction Factor
f'_c	Compressive Strength of Concrete

M_u	Ultimate Moment
A_s	Area of Steel per Unit Width
f_y	Yield Stress of Reinforcement Tension
E_F	Modulus of Elasticity of Mat Foundation
μ_F	Poison's Ratio of Concrete
K	Coefficient of subgrade
M_r	Radial Moment
M_t	Tangential Moment
r	Radial Distance the Column
Q_p	Load-Carrying Capacity
Q_s	Friction Resistance
A_p	Area of the Pile Tip
q_p	Unit Point Resistance
P_A	Atmospheric Pressure
S	Spacing
D	Dia of Bar
P	Pitch
L	Length of Pile & Pile Cap

CONTENT

CHAPTER 1

INTRODUCTION

1.1 GENERAL

All engineering construction has a base that carries all the loads of the installation. There are various types of foundations of a building, the choice of which depends on the building itself and the underlying soil. The two most commonly used installations in large buildings are the Pile Foundation and the Raft Foundation.

A Raft foundation is a large concrete footing that transmits the loadings from several columns in a building or the entire building loads to the ground. Raft foundations become economical when the loads are so large that footings would occupy more than 50% of the projected area of the building. Raft foundations are commonly used for heavy column loads or poor soil conditions those results in conventional footings or piles to occupy most of the site. For many multi-storied buildings a single Raft Foundation is more economical than constructing a multitude of isolated foundation elements. On the foundation of an elastic sub-grade, the soil pressure and the bend Varies from point to point. Raft foundations due to their continuous nature provide resistance to independent differential column movements, thus enhancing the structure's performance. Raft foundations are mainly used in regions where the underlying layer consists of clayey materials with low bearing capacity. It is also used as a load-distributing element to be found on piles or directly high bearing capacity soil or rock. Raft foundation has gained wide popularity among the engineering community of many countries around the world.

Raft foundations are also popular for deep basements both to spread the column loads to a more uniform pressure distribution and to provide the floor slab for the basement. A particular advantage for basements at or below the ground water table is to provide a water barrier. Raft foundations are also advantageous in places where settlements may be a problem as where a site contains erratic deposits or lenses of compressible materials etc.

The various advantages of Raft foundations are:

(1) Use of the raft as a basement floor having considerable commercial values in urban areas.

(2) Use of the flexural stiffness to reduce differential settlements due to swelling and shrinking of active soils.

(3) Use of the flexural stiffness to reduce contact pressures in regions of higher soil compressibility.

(4) Use of its own rigidity and that of the superstructure to activate bridging effect.

(5) Use of the raft in combination with piles to reduce total settlement.

(6) Use of flotation effect due to displaced volume of soil.

A pile foundation is a structure that transports all the loads of the structure through a hard lining of soil through the piles. The major apparatus of a pile foundation are the pile cap and the piles.

Where soil carrying capacity is low and there is higher cost of installation. In this kind of situation, the greatest concern of the geotechnical engineers ought to be the design of a foundation from a number of technically acceptable alternatives based on economy of the whole scheme. In most parts of Bangladesh, the bearing capacity of the soil is low and the cost of installation in those places is subject to cost. As a result, engineers now use wooden piles in most cases to reduce this cost. Recently Public Works Department (PWD) of Bangladesh has started using pre-cast and cast in-situ (bored) piles for their different projects located in different parts of Bangladesh. There are two objectives behind using piles; firstly low cost pre-cast RCC piles of 175 mm by 175 mm with 7 m length have been used as a replacement for the timber piles for low rise structures constructed on soils with low bearing capacity. On the other hand, 300 mm by 300 mm precast square RCC piles with 11000 mm length and bored piles of 400 mm to 500 mm diameter with 12000 mm to 18000 mm length are used for intermediate rise structures. All the tests were static compressive vertical pile load tests and were performed according to the procedure outlined in ASTM D1143 (ASTM 1989). These papers summarize pile load test procedure, criterion for estimation of pile load capacity and typical pile load test results.

1.2 BACKGROUND OF THE STUDY

Foundations Pile are used as load carrying and cargo carrying systems for several years. Within the period of socialism, villages and towns were located near rivers and lakes in terms of communication, defense, or strategy. It had been ergo consequential to invigorate the bearing ground with some style of piling. In 1740 Christoffoer Polhem designed pile-driving apparatus which resembled today's pile-driving instrument. Steel piles have been used since the 1800s and concrete piles since the 1900s. With the appearance of steam and diesel-powered machines in tandem with the jug, significant changes came to the pile driving system. Advances in technology within the current era have led to several changes in pile driving.

A number of methods are available for the analysis of Raft. There are the some approximate methods that are quite unproven and can be used for an extended time. Recently, there are some numerical methods available. However, these methods idealize mat unrealistically. The soil has its own specific limitations which (Liou and Lai, 1996) reveals.

In this case, the method, known as the Conventional method, is like a slab at the underside of a column; the raft foundation is then divided into strips in the middle of the column line, and the force system on each strip is adjusted to balance. This method is expressed by ACI when a load of adjacent span and column does not change capable to or greater than 20%. ACI is one of the most widely used and popular methods of raft foundation analysis Approximate Flexible Method (ACI Committee 336), which is based primarily on Schleicher (1926) analysis. Shukla (1984) provided design support for the use and analysis of this method. Subsequently, this method was further analyzed and modified by Mician (1985).

Baker (1948) projected a method of mat foundation investigation everywhere the mat is separated into column strips inactive on Winkler average and individually strip is analyzed individually. Further Finite Difference Method (Deryck and Severn 1961, Bowles 1974) everywhere the raft is designed as a large flat plate in an elastic medium.

Liou and Lai presented a special structural design for the Raft Foundation in 1996 as a stiffener of grad floor beams. The design becomes grid floor beams on an elastic foundation with loadings applied at the connections of floor beams.

Morshed in 1996 and Sutradhar in 1999 differentiated between the Finite Element Method and Conduct Comparative Analysis, The ACI method and the Conventional method used Ahmed’s dense shell material for the Raft Foundation. Morshed suggested laying the foundation of the Raft Foundation of variable thickness. His research has paved the way for the Raft Foundation to develop a new concept and design and reasoning and analysis. In 1999, Sutradhar published some more acceptable rules for sorting the basis of variable thickness for the Finite Element Method analysis. In 2001, Rahman Finite Element ANSYS analyzed the Raft Foundation with this software. He used the plate elements to study the behavior of the mat. Based on his work, he suggested a more simplified method to design non-uniform mat foundations.

1.3 OBJECTIVE OF THE PRESENT RESEARCH

The main purposes of the exploration are as follows: -

- (i) First of all we need to show the difference between Raft Foundation and Pile Foundation.
- (ii) Learn where to use Pile Foundation and where to use Raft Foundation.
- (iii) The main purpose of using these two types of Foundation is to get an idea about the cost of building after installation, to get an idea about tension and pressure strength of the installation.

1.4 RESEARCH METHODOLOGY

A study of the literature on attempts to compare research strategies has been discussed in depth inside. All the topics discussed here have been studied in detail. Also, the characteristics of the materials required for the study are discussed in depth.

A raft foundation is very good for building foundations. Strong rocky and unexplored natural soil, which is somewhat deeper than the soil layer. The upper surface is much stronger and harder than the loose soil layer. If a raft foundation is laid with a rod cage mesh at the excavated level a few feet below the ground and concrete walls are made around the foundation to prevent breakage, it will be a strong foundation for the building.

Pile foundations are used in most cases where the carrying capacity of the soil is low and the load from the building is high. However, it is the responsibility of the civil engineer to study the piles that have been installed to ensure that the bearing capacity of the soil does not exceed. The pile holes must be placed a certain amount away so that one pile is no longer too close to another. The load coming from the top of the building should be transferred evenly over the pile foundation. The pile foundation consists of two parts and one or more piles are placed as a means of load transfer by boring into the soil where there is a pile cap by RCC on top of all and building columns are built on this pile cap.

This is the main topic of discussion of the thesis literature are presented in chapter 2. Plan & load capacity discuss in chapter 3. Cost analysis of pile & pile cap in chapter 5. Cost compression between pile and raft foundation discuss in chapter 6. Conclusions and recommended in chapter 7.

CHAPTER 2

LITERATURE REVIEW

2.1 Foundation

Foundation is a very important factor for any installation. The longevity of the installation largely depends on the foundation. And at the present time more and more high-rise buildings are being built, so the importance of the foundation is increasing manifold. However, the method of building a house is a little difficult. And with all the calculations, it is always a little difficult to make any predictions or calculations about the foundation of the house.

We know that, there are various kinds of foundations. So let's talk about the cost, before we talk about the foundation of the house. The type of foundation you need for your home depends entirely on the quality of the soil, the type of soil suitable for building the house, and the type of load on the building.

2.2 Bearing Capacity of Foundation

Terzaghi's (1943) bearing capacity theory denotes one of the first efforts to adapt to soil mechanics. The formula proposed by subsequent researchers is generally transcribing into forms corresponding to Terzaghi's. So the most convenient manner of comparing the various theories is to compare the dimensionless factors called Bearing Capacity Factors originally defined therein. It probably may be claimed that despite many complementary works, Terzaghi's (1943) original solutions are still widely used.

According to Terzaghi’s (1943), for a strip foundation of with 'B' and at a shallow depth 'D', the ultimate bearing capacity is determined by the expression-

$$Q_u = \mathrm{c}N_c + \gamma \mathrm{D} N_q + .5\gamma \mathrm{B} N_\gamma \tag{1}$$

Where, c = Undrained Cohesion of Soil

γ = Density of Soil

N_c, N_q and N_γ= Bearing Capacity Factors.

These bearing capacity factors depend on the angle of internal friction "φ"of the soil. Considering the importance of Terzaghi's original solution on most of the subsequent work it is deemed useful repeating the above fundamental information not resisting its appearance in most publications.

The ultimate bearing capacity of shallow foundations according to Terzaghi's equations,

$$q_u = 1.3c'N_c + qN_q + .4\gamma \mathrm{B} N_\gamma \quad \text{(for shallow square foundations)} \tag{1.2}$$

And

$$q_u = 1.3c'N_c + qN_q + .3\gamma \mathrm{B} N_\gamma \quad \text{(for shallow circular foundations)} \tag{1.3}$$

Similarly, the general bearing capacity equation for shallow foundations

$$q_u = c'N_cF_{cs}F_{cd} + qN_qF_{qs}F_{qd} + \frac{1}{2}B\gamma N_\gamma F_{ys}F_{yd} \tag{1.4}$$

Hence, in general, the ultimate load-bearing capacity may be expressed as

$$q_u = c'N_c + qN_q + \gamma \mathrm{B} N_\gamma \tag{1.5}$$

N_c , N_q , $N_\gamma$are the bearing capacity factors that include the necessary shape and depth factors.

2.3 Types of Foundation

There are mainly two types of foundations;

Shallow Foundation

1. Strip Footing
2. Spread or Isolate Footing
3. Combined or Cantilever Footing
4. Raft or Mat Foundation

Deep Foundation

1. Basements
2. Buoyancy Rafts
3. Caissons
4. Cylinders
5. Shaft Foundation
6. Pile Foundation

There are many types of foundations for buildings, but here we will discuss pile and raft foundations in detail. However, the main attention is what are the costs of these two types of foundations from this analysis? Its analysis will show the longevity of a foundation and how much pressure it can take. Chapter may be outlined as;

- Raft or Mat foundation
- Pile foundation

2.4 Raft or Mat Foundation

A raft foundation usually covers the entire area of the building, thereby distributing the total load to a larger area than a footing foundation and reduces the bearing pressure to a minimum. The choice between a raft and a footing foundation depends on the soil properties and the weight of the building. If a preliminary design with footing foundations reveals that the sum of the footing areas required to s upon the structure exceeds 60% of the total building area; a raft foundation covering the entire area of the building should be preferred. The amount of differential settlement may be excessive for a footing foundation moreover, where the soil properties vary largely throughout the site, but with a raft foundation the effect of weak zones scattered at random tend to even out. Therefore, the settlement pattern is Jess erratic and the differential settlement is also reduced considerably. Also the raft foundation superstructure reduces the rigidity load supply.

2.5 Bearing Capacity of Raft or Mat Foundation

The gross ultimate bearing capacity of a mat foundation can be determined by the same equation of foundation.

$$q_u = CN_cF_{cs}F_{cd}F_{ci} + qN_qF_{qs}F_{qd}F_{qi} + \frac{1}{2}B\gamma N_\gamma F_{ys}F_{yd}F_{yi} \quad (1.6)$$

The term B is the lowest width of the mat.

The net ultimate capacity of a Raft Foundation is

$$q_{net(u)} = q_u - q \quad (1.7)$$

An appropriate factor of safety should be used to calculate the net allowable bearing capacity:

- For Raft on clay, the factor of safety should not be less than 3 under dead load or maximum live load. However, under the most exciting conditions, the factor of safety should be at least 1.75 to 2.
- For raft constructed over sand, a factor of safety of 3 should normally be used. Under most working conditions, the factor of safety against bearing capacity failure of raft on sand is very large.

For saturated clays with φ=0 and a vertical loading condition (β=0),

The ultimate bearing capacity

$$q_u = 5.14c_u\left(1 + \frac{0.195B}{L}\right) + \left(1 + 0.4\frac{D_f}{B}\right) + q \quad (1.8)$$

Hence, the net ultimate bearing capacity

$$q_{net(u)} = q_u - q = 5.14c_u\left(1 + \frac{0.195B}{L}\right) + \left(1 + 0.4\frac{D_f}{B}\right) \quad (1.9)$$

For Factor of Safety = 3,

The net allowable soil bearing capacity

$$q_{net(all)} = \frac{q_{net(u)}}{FS} \quad (1.10)$$

The net allowable bearing capacity for mats constructed over granular soil deposits can be adequately determined from the standard penetration resistance numbers. For Shallow foundation

$$q_{net(all)} = \frac{N_{60}}{0.08}\left(\frac{B+0.3}{B}\right)^2 F_d \frac{S_e}{25} \quad (1.11)$$

Where,

N_{60} = Standard penetration resistance

$$F_d = 1 + 0.33\left({}^{D_f}/_{B}\right) < 1.33 \quad (1.12)$$

Width = B

Settlement = $S_e(mm)$

If width "B" is large, net allowable bearing capacity

$$q_{net(all)} = \frac{N_{60}}{0.08}\left[1 + 0.33 * \frac{D_f}{B}\right]\left[\frac{S_e(mm)}{25}\right] < 16.63N_{60}\left[\frac{S_e(mm)}{25}\right] \quad (1.13)$$

Generally, shallow foundations are designed for a maximum settlement of 25 mm and a differential settlement of about 19 mm. accordingly the customary assumption is that, for a maximum raft settlement of 50 mm, the differential settlement would be 19 mm.

The net pressure applied on a foundation

$$q = \frac{Q}{A} - \gamma D_f \leq q_{(net)all} \quad (1.14)$$

In all cases, q should be less than or equal to allowable$q_{(net)all}$.

2.6 Structural Design of Raft or Mat Foundation

Raft foundations are designed and constructed in different pattern and varying types. There are several types of Raft foundation, namely

1. Conventional rigid Method.

2. Approximate flexible method.

3. Discrete element method.

a. Finite different method

b. Finite grid method (FGM)

c. Finite element method (FEM)

2.6.1 Conventional Rigid Methodof Raft Foundation

In the conventional method of design, the mat is assumed to be infinitely rigid, and therefore, the flexural deflection of the mat does not influence the pressure distribution. The soil pressure is distributed during a line or a plane surface such the centric of the soil pressure coincides with the road of action of the resultant force of all the hundreds working on the inspiration.

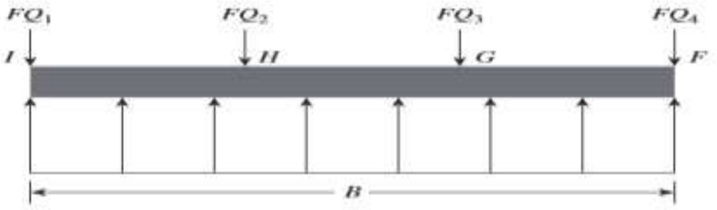


Figure 2.1 Conventional Rigid Method of Raft Foundation

2.6.2 Analysis Procedure

Conventional Analysis Method:

1. Find the total of the incoming loads of each column on the Raft Foundation.
   Q= $Q_1 + Q_2 + Q_3 + \cdots$ (1.15)

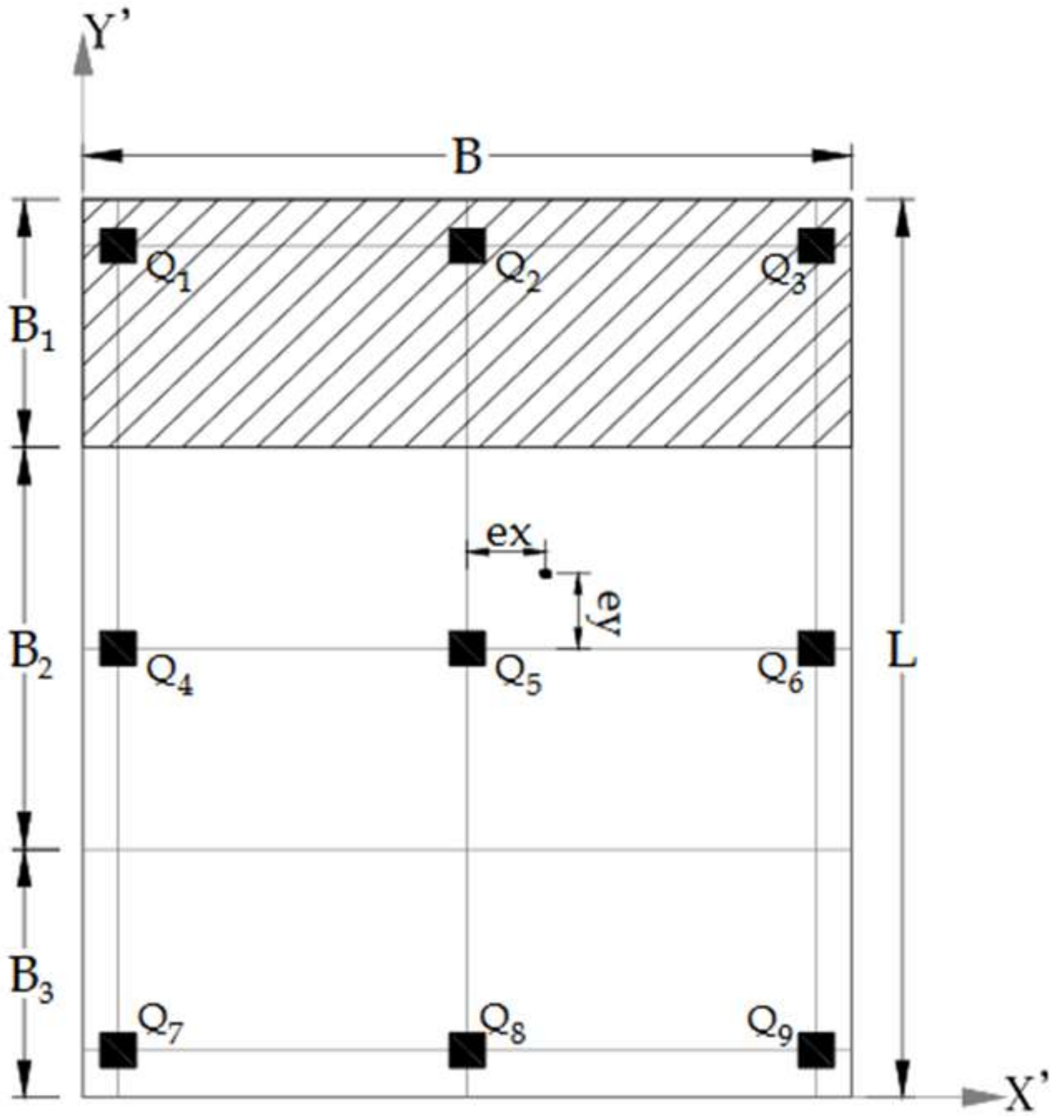


Figure 2.2

2. The contact pressure distribution on the soil is determined using the equation

$$q = R\left(\frac{1}{A} \pm \frac{e_x X}{I_y} \pm \frac{e_y Y}{I_x}\right) \quad (1.16)$$

Where,

R $= \Sigma Q =$ total vertical loads on the mat
$I_x =$ Moment of the inertia about the x-axis
$I_y =$ Moment of the inertia about the y-axis
$e_x, e_y =$Co-ordinate of the resultant force
$A =$Total area of the mat
X, Y =Co-ordinate locations where soil pressures are desired

3. Compare the values of the soil pressures determined in 2 with the net allowable soil pressure to determined whether q $\leq q_{net(all)}$.

4. The slab is separated into strips in x and y directions. Each strip is assumed to act as an independent beam subjected to the contact pressure and the column load. Contact pressure is taken because of the average of two end pressures of the strip.
5. This average contact pressure of the strip and the column loads should be modified since they do not satisfy statics. That is the resultant of column loads and the resultant of contact pressure are not equal and they do not correspond. The reason is that the strips don't act independently as assumed and there's some shear transfer between adjoining strips.

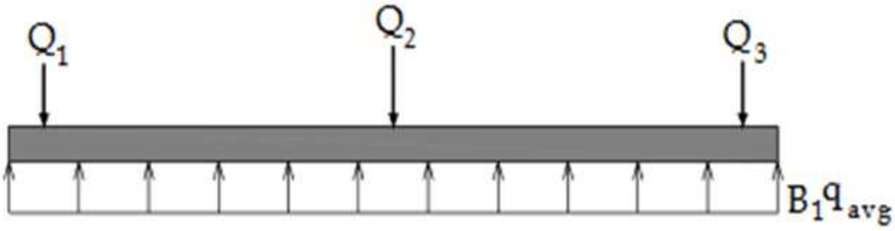


Figure 2.3

a) The average load on the strip is calculated by

$$Q_{av} = \frac{q_{avg} B_1 B + Q_1 + Q_2 + Q_{3+} \dots}{2} \tag{1.17}$$

b) The modified average soil pressure is calculated by

$$q_{av}(modified) = q_{avg}\left(\frac{Q_{av}}{q_{avg} B_1 B}\right) \tag{1.18}$$

c) The modified column load is determined by multiplying each load in strip by a factor,

F= $\frac{Q_{av}}{\Sigma column\ loads}$ (1.19)

Where;

q_{avg} = Average soil pressure on the strip

$\Sigma column\ loads = Q_1 + Q_2 + Q_{3+} \dots$

Q_{av} = Average Load

6. Determined factored column load.

U = $b_0 d\left[\emptyset(0.34)\sqrt{f'_c}\right]$ (1.20)

Where,

U= Factored column load or (column load*factor load)

$\emptyset$ = Reduction Factor = 0.85

f'_c = Compressive Strength of Concrete at 28 days (MN/m^2)

7. Determined the areas of steel per unit width for positive and negative reinforcement,

$$M_u = \emptyset A_s f_y \left(d - \frac{a}{2}\right) \quad (1.21)$$

And $a = \frac{A_s f_y}{0.85 f'_c b}$

Where,

M_u = Ultimate moment

A_s = Area of steel per unit width

f_y = Yield stress of reinforcement tension.

$\emptyset$ = Reduction factor '0.9'

2.6.3 Approximate Flexible Method

ACI Committee 336 (1966) suggested this method for the overall case of flexible mat supporting columns randomly locations with varying intensities of load. Based on these method theories of circular plate on Winkler Medium, Shukla (1984) suggest this method to calculate moment, shear forces and deflections of a raft foundation.

2.6.4 Analysis Procedure

The approximate flexible method required the following steps:

1. Determine the mat thickness supported punching shear at critical column supported column load and shear perimeter.

2. The flexural rigidity "R" of the mat foundation calculated

$$R = \frac{E_F h^3}{12(1-\mu_F{}^2)} \quad (1.22)$$

Where,

E_F = Modulus of elasticity of mat foundation material

μ_F = Poison's ratio of concrete (0.15 to 0.25)

h = Thickness of mat

3. The radius of effective stiffness is then calculated L' as follows

$$L' = \sqrt[4]{\frac{R}{K}} \quad (1.23)$$

Where,

K = Coefficient of subgrade

The zone of influence of any column load will be on the order of $3L'$ to $4L'$.

4. The radial and tangential moments, the shear and deflection at a point are calculated using the following formulas

$$M_r = \text{Radial Moment} = -\frac{Q}{4}\left[A_1 - \frac{(1-\mu_F)A_2}{\frac{r}{L'}}\right] \quad (1.24)$$

And

$$M_t = \text{Tangential Moment} = -\frac{Q}{4}\left[A_1\mu_F - \frac{(1-\mu_F)A_2}{\frac{r}{L'}}\right] \tag{1.25}$$

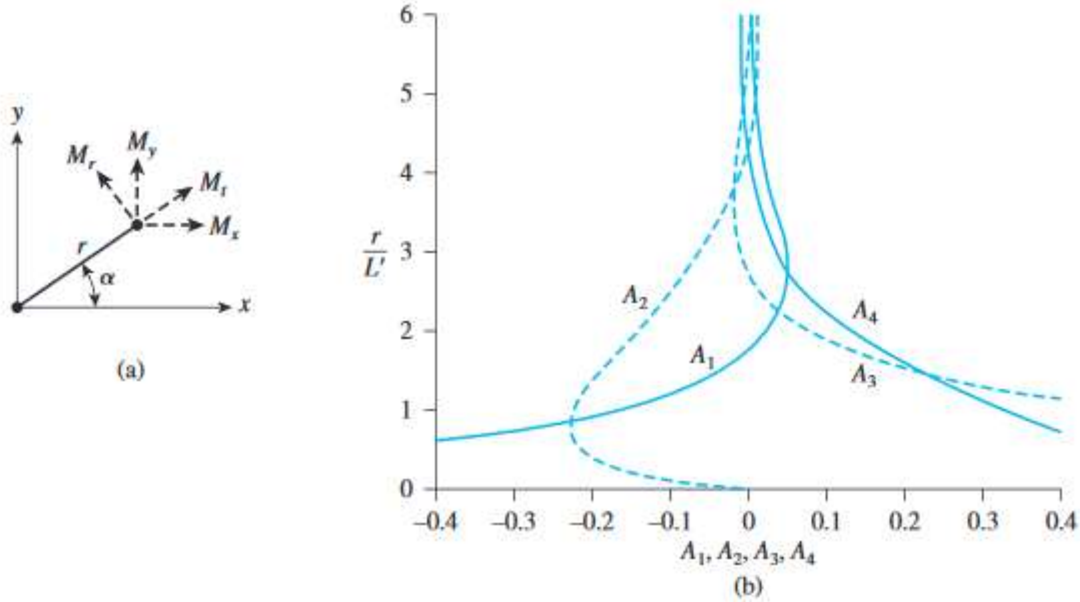


Figure 2.4 Approximate flexible method of mat design

Where,

r = Radial distance the column
Q = Column load
A_1A_2 = Function of $\frac{r}{L'}$

In the Cartesian coordinate system

$$M_x = M_t sin^2\alpha + M_r cos^2\alpha \tag{1.26}$$

And

$$M_y = M_t cos^2\alpha + M_r sin^2\alpha \tag{1.27}$$

5. For the unit width of the raft, calculated the shear force V caused by a column load

$$V = \frac{Q}{4L'}A_3 \tag{1.28}$$

The variation of A_3 with $\frac{r}{L'}$ is shown in figure 2.4

6. If the edge of the mat is located in the zone of influence of a column, calculated the moment and shear along the edge, assuming that the raft is continuous. Moment and shear, opposite in sign to those determined, are applied at the sides to satisfy the known condition.
7. Deflection at any point is given by the following equation

$$\delta = \frac{QL'^2}{4R}A_4 \tag{1.29}$$

2.7 Pile Foundation

Piling is a type of foundation of a building or installation, which provides a solid foundation to the installation by transferring the load deep into the soil beneath the installation. This is usually done in lands where the soil bearing capacity is low but the installation is multi-storey. It can be compared to an installation column, which is placed deep in the ground.

Piles are the main used:

1. To carry vertical compression load from buildings, bridges, and so on.
2. To resist horizontal or inclined loads by retaining wall, bridge pier, waterfront structures and structures subjected to wind or seismic loads.
3. To resist uplift forces in transmission towers and underground structures below the water table.

2.7.1 Types of Pile Foundation

Various kinds of piles are used in construction, depending on the type of load to be carried, the subsoil conditions and the location of the water table.

Depending on their function pile foundation:

1. Sheet Pile
2. Anchor Pile
3. End Bearing Pile
4. Compaction Pile
5. Friction Pile
6. Batter Pile
7. Fender Pile
8. Uplift Pile
9. Dolphin Pile

Materials based on composition pile foundation:

1. Cast Iron Pile
2. Sand Pile
3. Steel Pile
4. Timber Pile
5. Composite Pile
6. Concrete pile

i) Pre-cast Pile
ii) Cast in Situ Pile
iii) Pre-stressed Pile

2.7.2 Estimation of Pile Capacity

Vertical compressive load working on a pile is transferred to the soil. Section of the load on pile is resisted by shear resistance compacted at the pile-soil interface. This part is understood as skin frictional resistance of pile. The rest of the load is transferred through the base or point of the pile. This component is known as point resistance or point load.

The ultimate load-carrying capacity Q_u of a pile is given by the equation

$$Q_u = Q_p + Q_s \tag{1.30}$$

Where

Q_p = Load-carrying capacity of the pile point

Q_s = Friction Resistance

If Q_s is very small, then

$$Q_s = Q_p \tag{1.31}$$

In this case, the specified pile length could also be estimated accurately if proper subsoil exploration records are available.

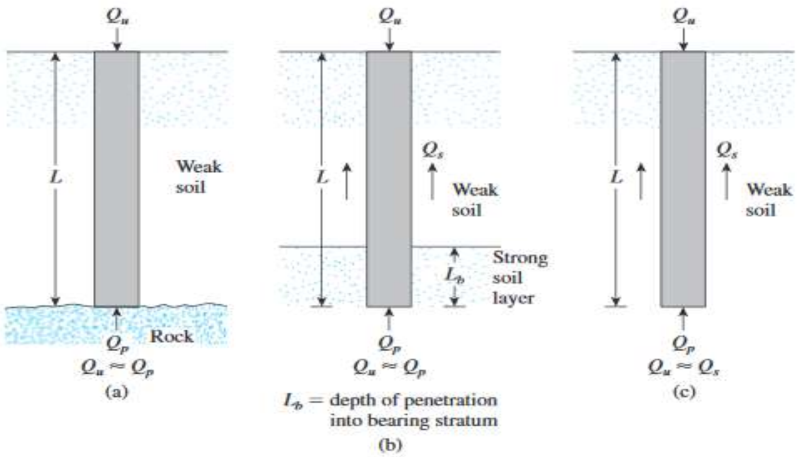


Figure 2.5 (a) and (b) point bearing pile (c) friction pile

2.7.3 Load-carrying Capacity of the Pile Point Q_p

The notation used in this chapter for the width of the pile is D. Where the equation (1.5) substituting D for B. Where width D of a pile is relatively small, the term$\gamma D N_\gamma$ may be droppedfrom the right side of the preceding equation without introducing a serious error

$$q_p = \left(c' N_c + q' N_q\right) \tag{1.32}$$

The load-carrying capacity of the pile point is

$$Q_p = A_p q_p = A_p\left(c' N_c + q' N_q\right) \tag{1.33}$$

Notations

A_p =Area of the pile tip

q_p =Unit point resistance

c' =Cohesion of the soil supporting the pile tip

q' = Effective vertical stress at the extent of the pile tip

N_c , N_q , N_γ = Bearing capacity factor.

2.7.4 Meyerhof's Method

For Sand

The cohesion c'equal to zero, thus equation takes this form

When, cohesion $c' = 0$

$$Q_p = A_p q_p = A_p(q' N_q) \tag{1.34}$$

Q_p Should not exceed the limiting value, or$A_p q_l$, so

$$Q_p = A_p q' N_q \leq A_p q_l \tag{1.35}$$

Soil friction angle, ϕ (deg)	N_q^*
20	12.4
21	13.8
22	15.5
23	17.9
24	21.4
25	26.0
26	29.5
27	34.0
28	39.7
29	46.5
30	56.7
31	68.2
32	81.0
33	96.0
34	115.0
35	143.0
36	168.0
37	194.0
38	231.0
39	276.0
40	346.0
41	420.0
42	525.0
43	650.0
44	780.0
45	930.0

Figure 2.6 Interpolated Values of Based on Meyerhof's Theory

The limiting point resistance is

$$q_l = 0.5 p_a N_q tan\varphi \quad (1.36)$$

Where

$p_a = Atmospheric\ Pressure = 100 kN/m^2$

$\varphi = Effective\ soil\ friction\ angle\ of\ the\ bearing\ stratum.$

For Clay

For piles in saturated clays under undrained conditions cohesion c'equal to zero.

The net ultimate load can be

$$Q_p \cong\ N_c C_u A_p = 9 C_u A_p \quad (1.37)$$

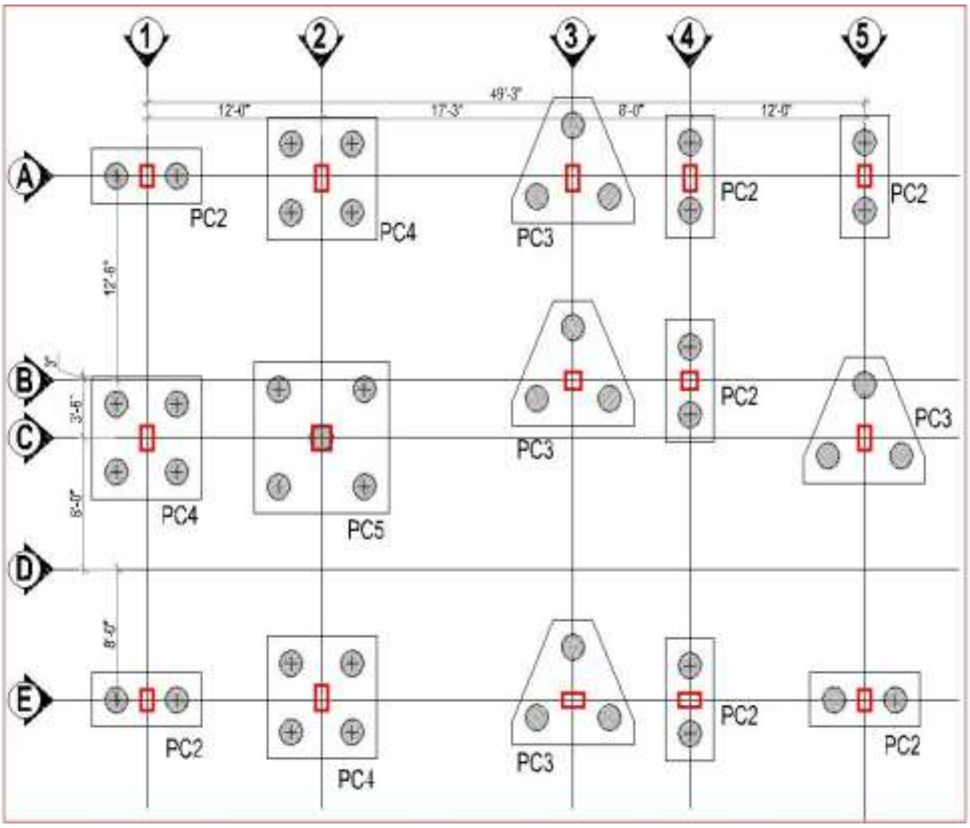
Where

$C_u = Undrained\ Cohesion\ of\ the\ Soil$

CHAPTER 3

PLANS & LOAD CAPACITY

3.1 Architectural Plan

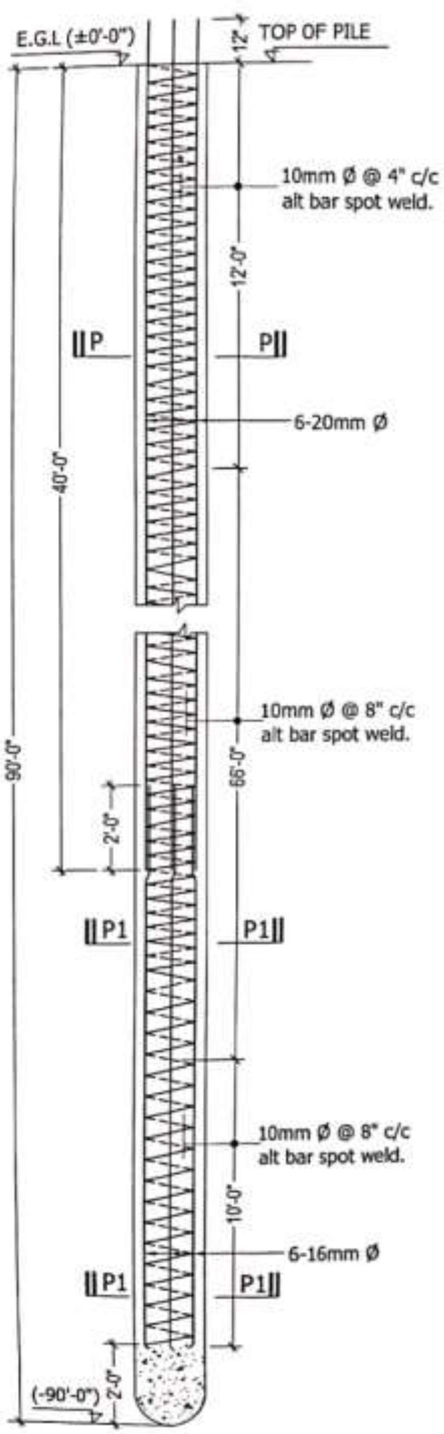


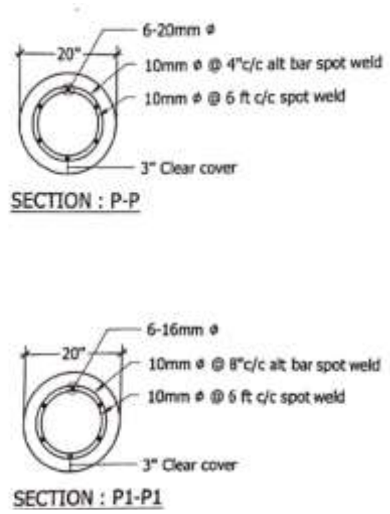
3.2 Column Load

All Column load

Column	Load(kip)	Column	Load(kip)	Column	Load(kip)
Column 1	93	Column 6	149.804	Column 11	82.608
Column 2	183.510	Column 7	250.5	Column 12	170
Column 3	124.915	Column 8	114	Column 13	88
Column 4	95	Column 9	106	Column 14	70
Column 5	85	Column 10	135.749	Column 15	82

3.3 Section of Pile

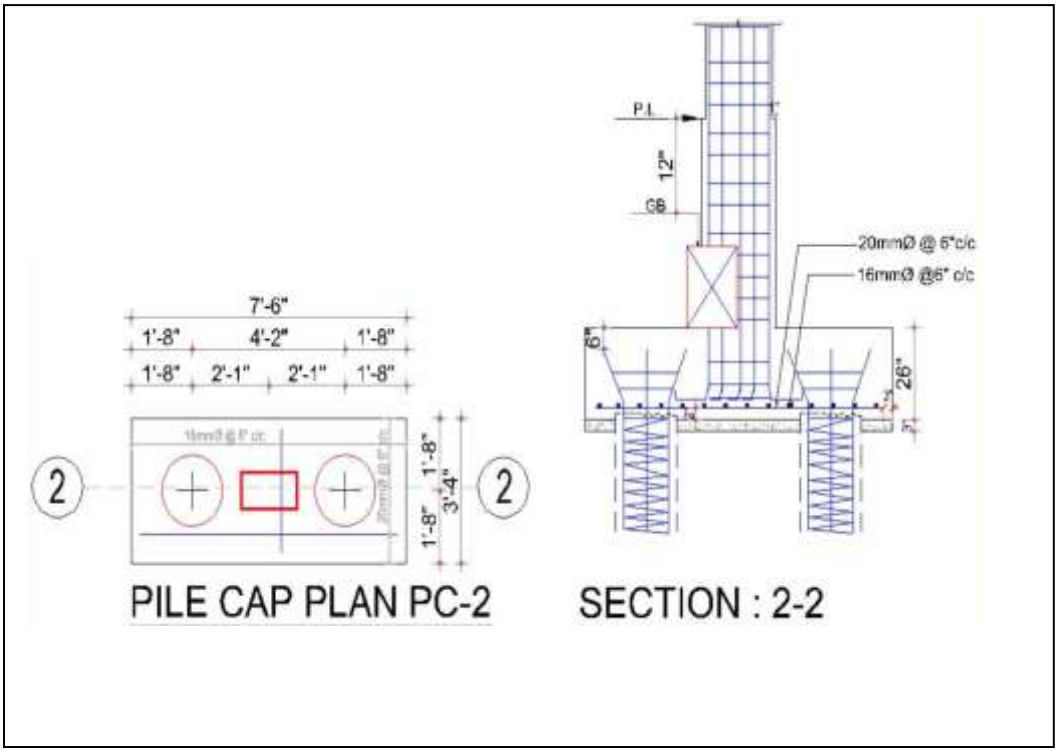


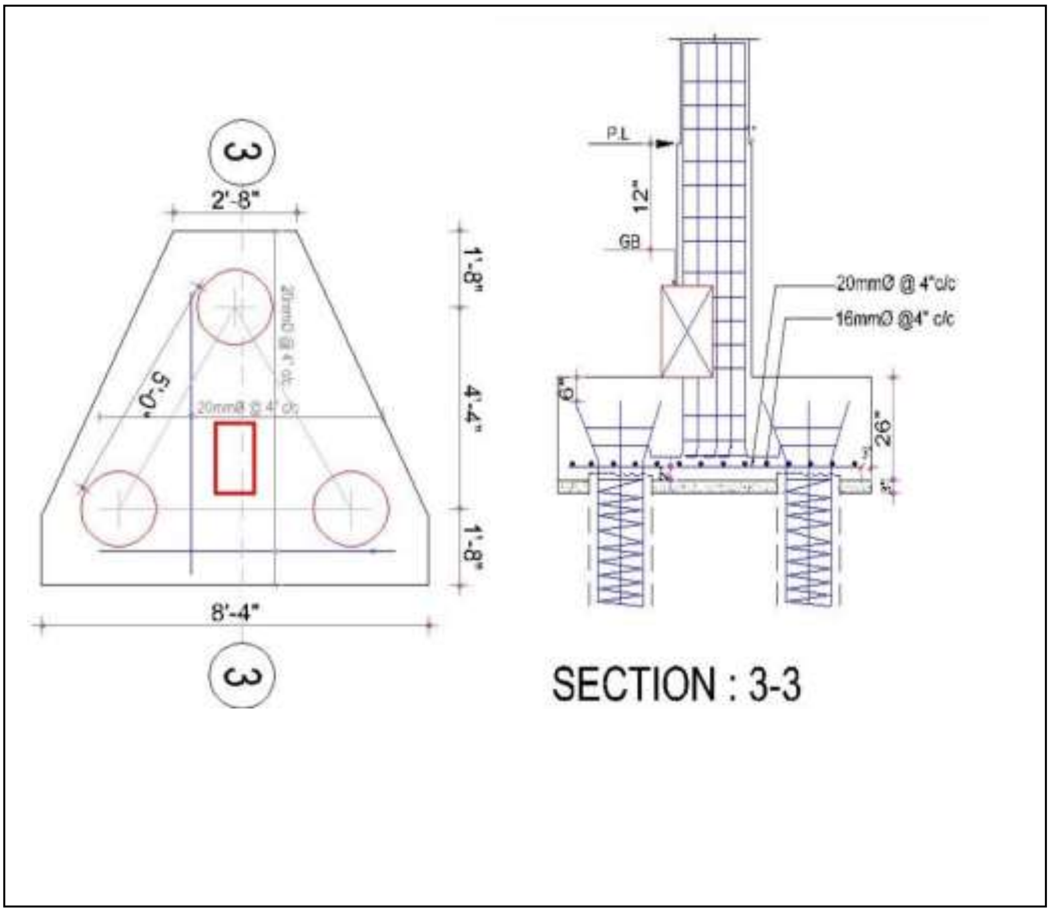


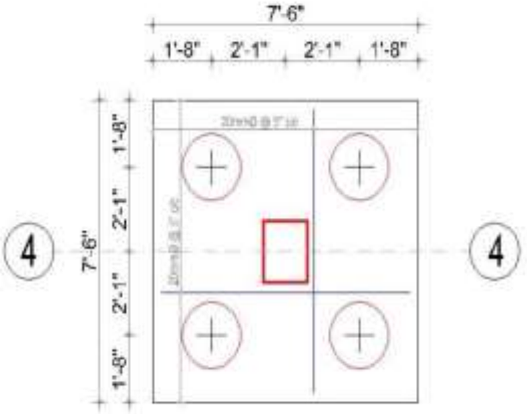
Foundation Notes

1) Foundation for 8 storied.
2) Clear cover:
   a) Pile = 3 in
   b) Pile cap = 2 in
   c) 20 in dia of pile cap
   d) 120 kip load per pile
1) Concrete mix:
   a) For Pile 1:1.5:3 with 20 mm downgraded crushed stone chips 100 % Sylhet sand.
   b) For pile 1:2:3 within 20mm downgrade stone chips&100% Sylhet sand.
   c) Where f'c = 3500 psi minimum
   d) Reinforcing bar should be used fy = 60 ksi(minimum)

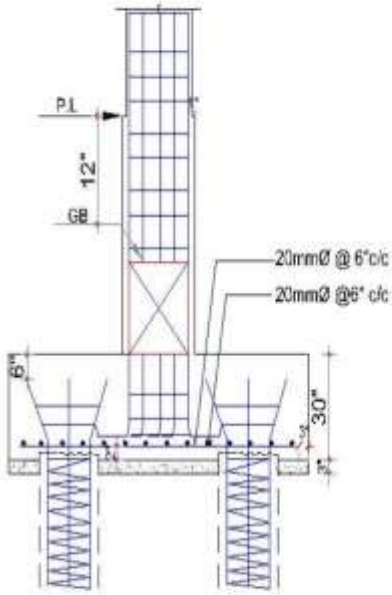
3.4 Section of Pile Cap



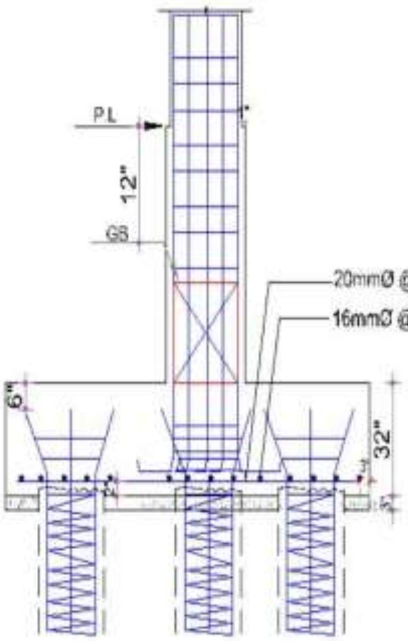




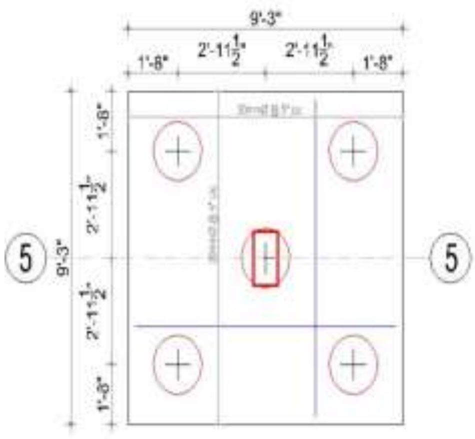
PILE CAP PLAN PC-4



SECTION : 4-4



SECTION : 5-5



PILE CAP PLAN PC-5

CHAPTER 4

COST ANALYSIS OF PILE & PILE CAP

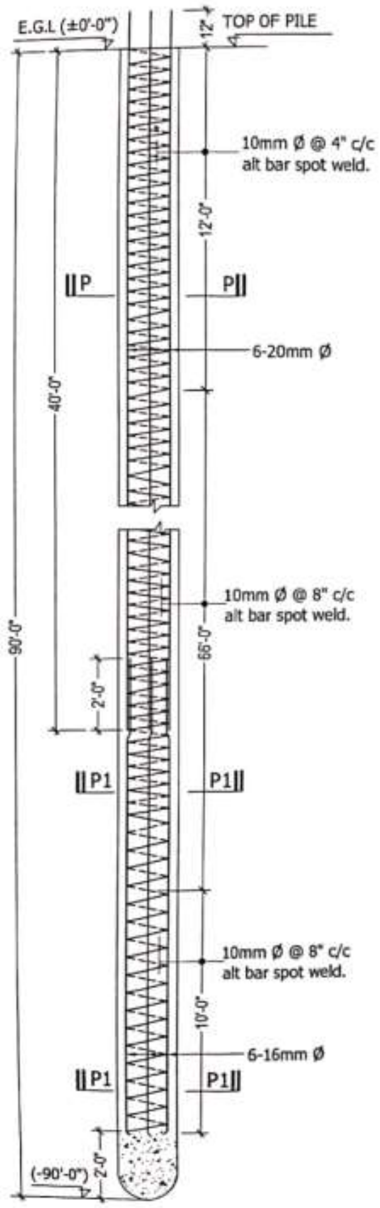
4.1 Pile Bar Bending Schedule

VERTICAL BAR

Development length = 50 d

Steel

0 to -12 ft.	6-20 ф
-12 to -78 ft.	6-16 ф
-21 to -88 ft.	6-16 ф



Length of 1 bar 20 ф

= 50 d + 3657.6 + 50 d

= (50 x 220) + 12000 + (50 x 20)

= 5657.6 mm

= 5.67 m

There for,

Length for 6 no. bar = 6 x 5.67 = 33.95 m

Length of 1 bar 16 ф

= 20116.8 + 50 d

= 20116.8 + (50 x 16)

= 20916.8 mm

= 20.916 m

There for,

Length for 6 no. bar = 20.916 x 6 = 125 m

Length of 1 bar 16 ф

= 3048 + 300 – (bend)

= 3048 + 300 – (1 x 2 x d)

= 3048 + 300 – (1 x 2 x 16)

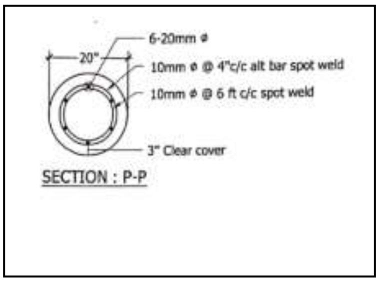
= 3316 mm

= 3.316 m

There for,

Length for 6 no. bar = 3.316 x 6 = 19.896 m

MASTER RING



Given:

Dia. of master ring = 10 mm @ 1828.8 mm c/c

Size of pile = 27.432 m or 27432 mm

r = Radius of pile – two side cover – spiral ring dia. – vertical bar dia. – 0.5 master ring dia.

r = 254 – 75 – 10 – 20 – (10/2)

r = 144 mm

r = 0.144 m

Length of one master ring = Perimeter of circle = 2 π r

= 2 x 3.14 x 0.144

= .904 m

Total number of master ring = (Length of pile ÷ Spacing) + 1

= (27432 / 1828.8) + 1

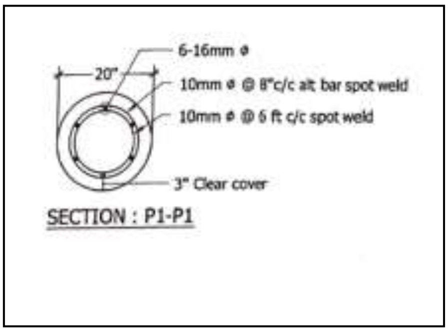
= 16 no.

For 16 nos. of master ring

= 0.904 x 16

= 14.475 m

SPIRAL RING



Given:

Spacing = 150 mm

Clear cover = 75 mm

Dia. of pile = 508 mm or .508 m

Size of pile = 27.432 m or 27432 mm

Dia. of spiral bar = 10 mm ϕ

Net radius of spiral in caging = radius of pile –cover – 0.5 x Spiral bar dia.

= 254 – 75 – (10/2)

= 254 – 75 – 5

r = 174 mm

Length of one spiral ring = perimeter of one spiral ring

= 2 πr

= 2 x 3.14 x 174

= 1093.2 mm

= 1.1 m

Number of spirals = (Length of pile ÷ spacing of pile) + 1

= (27432 / 150) + 1

= 184 no.

Total length of spiral ring = 1.1 x 184 = 202.4 m

We know one length of full bar is 12 ft. or 3.66 m.

Lap considered 50 d

= 50 x 10

= 500 mm

= 0.5 m

Total number of lap = [length of spiral ring ÷ length] – 1

= [202.4 / 3.66] – 1

= 55 nos.

Total length = 0.5 x 55 = 27.5 m

Total length of spiral ring = 202.4 + 27.5 = 229.9 m

Total weight of steel required for pile

Dia. of bar in mm	Total length in m	Unit weight of steel in kg/m	Total weight in kg
Vertical Bar 20 mm1st	33.9 m	2.466 kg/m	84 kg
Vertical Bar 16 mm2nd	125.5 m	1.58 kg/m	198 kg
Vertical Bar 16 mm3rd	19.896 m	1.58 kg/m	32
Master Ring 10 mm	14.475 m	0.62 kg/m	9 kg
Spiral Ring 10 mm	229.9 m	0.62 kg/m	141 kg
Total Weight of Rod			464 kg

4.2 Pile Cost Analysis

Volume of pile = $\frac{\pi D^2}{4} = \frac{\pi\ x\ 1.67^2}{4}\ x\ 90 = 197.14$ cft

Dry volume = 197.14 x 1.5 = 295.7 cft.

Sum of ratio = 1+1.5+3 = 5.5

Cement = $\frac{1\ x\ 295.7}{5.5}\ x\ @0.8\ bag\ per\ ft\ x\ 460\ tk\ per\ bag$ = 19,785 tk.

Sand = $\frac{1.5\ x\ 295.7}{5.5}\ x\ @34\ tk\ per\ cft$ = 2,742 tk.

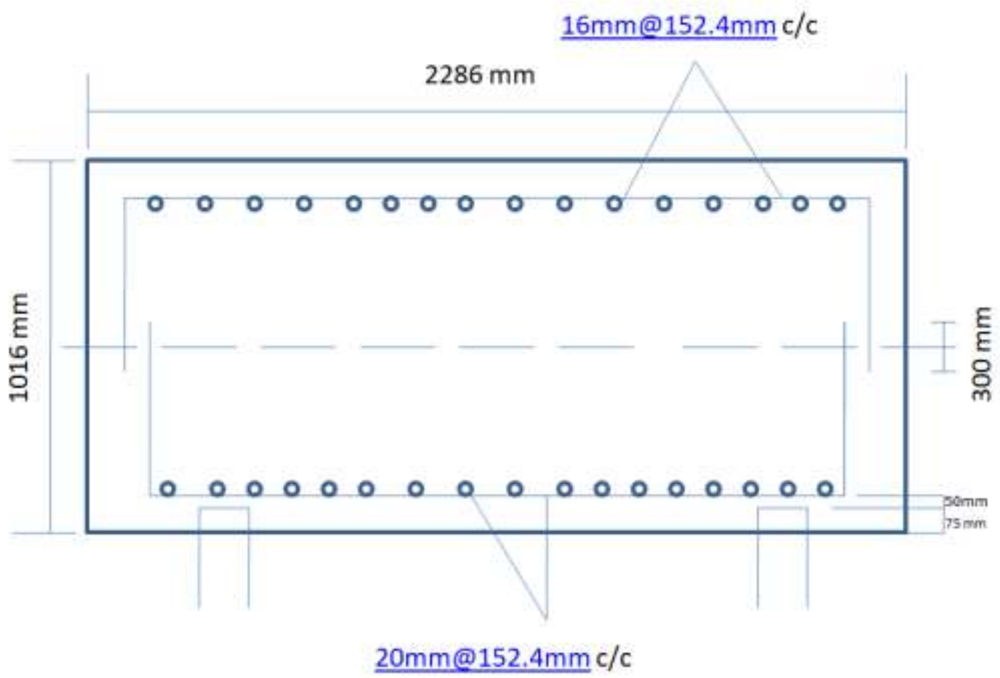
Stone Chips = $\frac{3\ x\ 295.7}{5.5}\ x\ @180\ tk\ per\ cft$ = 29,033 tk.

Rod = 464 x @58 $tk\ per\ cft$ = 26,890 tk.

Materials	Taka	Total taka
Cement	19,785 tk.	78,450 tk.
Sand	2742 tk.	
Stone Chips	29,033 tk.	
Rod	26,890 tk.	

4.3 Two Pile Cap Bar Bending Schedule

2 Pile Cap Size (2286 mm x 1016 mm)



Clear cover = 50 mm

a = Extra bar

a = 1016/2 – 75 – 50 – 10 + 150

=523 mm

Bottom reinforcement 1st layer

20 ф = Length of pile cap – (two side cover) – (2 x half of bar) + (2 x extra bar) – (2 x 2d)

$20\ \phi = 2286 – (2 \times 50) – (2 \times 20/2) + (2 \times 523) – (2 \times 2 \times 20)$

= 3132 mm

= 3.132 m

Number of bar = [(Length of bar – clear cover)/ Pitch] + 1

= [(2286 – 100)/ 152.4] + 1

= 16 nos.

For 16 nos

Total length = 16 x 3.132 = 50.112 m

Top reinforcement 1st layer

b = extra bar

b = 508 – 50 – 8 + 150

b = 600 mm

$16\ \phi$ = Length of pile cap – (two side cover) – (2xhalf of bar) + (2 x extra bar) – (2x2d)

$16\ \phi = 2286 – (2 \times 50) – (2 \times 8) + (2 \times 600) – (2 \times 2 \times 16)$

= 3.306 m

Total number of bar = [(Length of bar – clear cover) / pitch] + 1

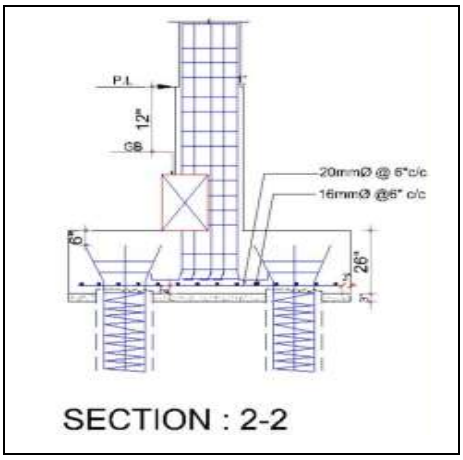
= [(2286 – 2 x 50) / 152.4] + 1

= 16 nos.

For 16 nos

Total length = 16 x 3.306 = 52.896 m

Pile Cap (2286 x 1016)



Clear cover = 50 mm

Bottom reinforcement 2st layer

a^1 = Extra bar

a^1 = 508 – 75 – 50 – 20 – 10 + 150

a^1 = 503 mm

20 ф = Length of pile cap – (two side cover) – (2 x half of bar) + (2 x extra bar) – (2 x 2d)

20 ф = 2286 – (2 x 50) – (2 x 10) + (2 x 503) – (2 x 2 x 20)

= 3.092 m

Total number of bar = [(Length of bar – clear cover) / pitch] + 1

= [(2286 – 2 x 50) / 152.4] + 1

= 16 nos.

For 16 nos,

Total length =16 x 3.092= 49.472 m

Top reinforcement 2st layer

b^1 = Extra bar

b^1 = 1508 – 50 – 16 – 8 + 150

b^1 = 584 mm

16 ф = Length of pile cap – (two side cover) – (2 x half of bar) + (2 x extra bar) – (2 x 2d)

16 ϕ = 2286 – (2 x 50) – (2 x 8) + (2 x 584) – (2 x 2 x 16)

= 3.274 m

Total number of bar = [(Length of bar – clear cover) / pitch] + 1

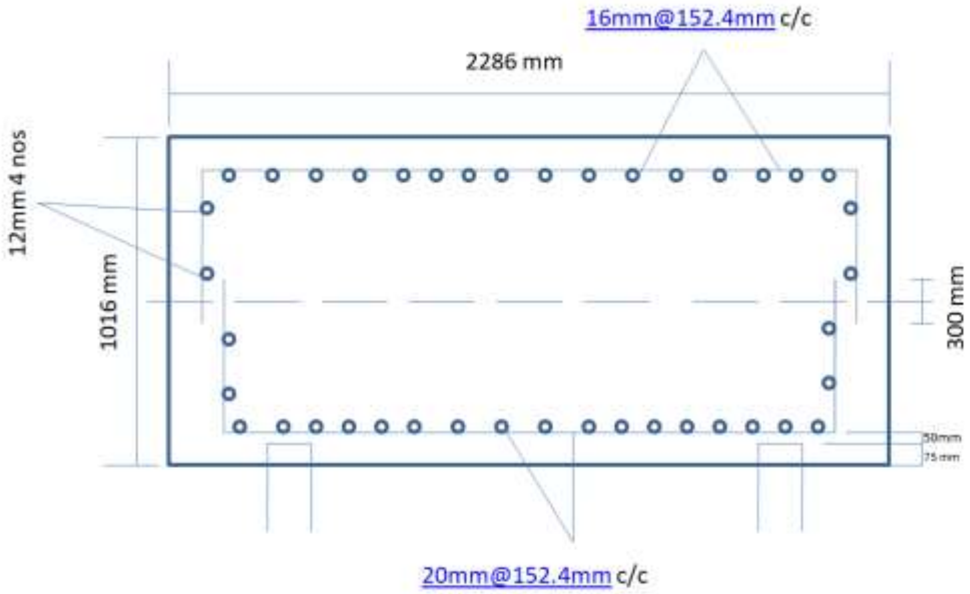
= [(2286 – 50 x 2) / 152.4] + 1

= 16 nos.

For 16 nos

Total length = 16 x 3.274 = 252.384 m

Side Face Reinforcement



a= 508 – 50 – 6 + 150

a= 602 mm

12 ϕ = {Length of pile cap – (two side cover) – (2 x half of bar) + (2 x extra bar) – (2 x 2d)} x 2

= {2286 – (2x50) – (2 x 6) + (2 x 602) – (2 x 2 x 12)} x 2

= 6.660

For 4 no. of bars

= 4 x 6.660

= 26.64 m

Pile Cap Steel Quantity

Dia. in mm	Total length in m	Unit weight m-kg	Total weight in kg
12 mm	26.64 m	0.89	23.71 kg
16 mm	105.27 m	1.58	166.33 kg
20 mm	99.582m	2.47	245.97 kg
Total Weight kg			436 kg

4.4 Pile Cap Cost Analysis

Wet volume = 7.5 x 3.3 x 2.17 = 54.42 cft

Dry volume = 54.42 x 1.5 = 81.64 cft

Sum of ratio = 1 + 2 + 3 = 6

Cement = $\frac{81.64\ x\ 1}{6}\ x\ @\ 0.8\ bag\ x\ 460\ tk\ per\ bag = 5008\ tk$

Sand = $\frac{81.64\ x\ 2}{6}\ x\ @34\ tk\ per\ cft = 926\ tk$

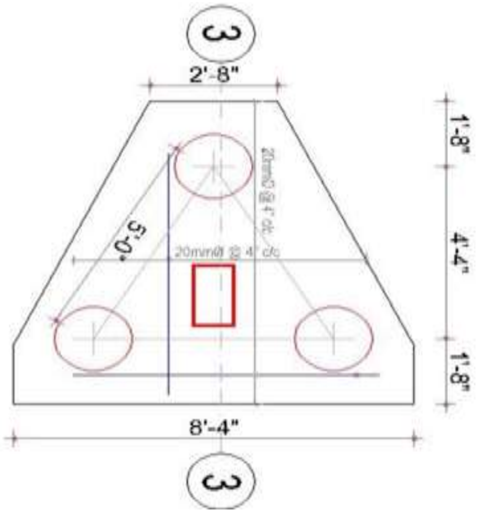
Stone Chips = $\frac{81.64\ x\ 3}{6}\ x\ @\ 180\ tk\ per\ cft = 7350\ tk$

Rod = 436 x 58 tk per kg = 25288 tk

Materials	Tk	Total Tk
Cement	5008 Tk	38572 Tk
Sand	926 Tk	
Stone Chips	7350 Tk	
Rod	25288 Tk	

4.5 Three Pile Cap Bars Bending Schedule

3 Pile Cap Size (9.33 ft x 8.33 ft)



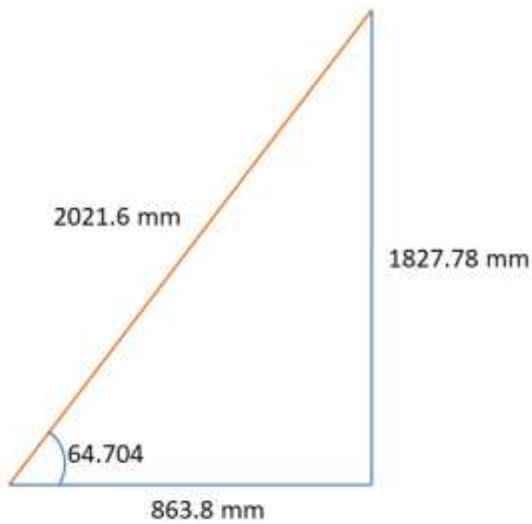
Calculate Main Bars.

No of bars = (1777.78/101.6) + 1

=18

Hyperbolic = $\sqrt{(863.8^2 + 1827.78^2)}$

= 2021.61 mm



Angle $\alpha = \tan^{-1}(\frac{Vertical\ Length}{Horizontal\ length})$

$= \tan^{-1}\left(\frac{1827.78}{863.8}\right)$

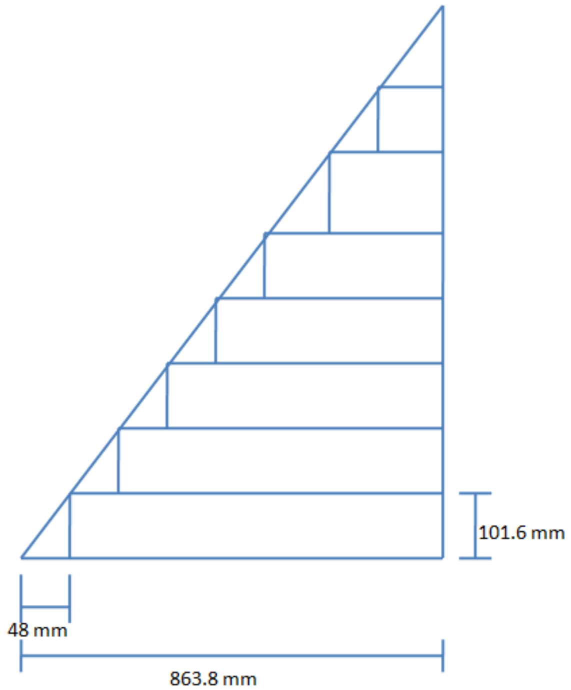
= 64.704

$$\tan\alpha = \frac{Vertical\ length}{Horizontal\ length}$$

$$\tan 64.704 = \frac{101.6}{x}$$

= 48 mm

Triangle one side length (mm)



B1= 863.8 – 48= 815.8

B2= 815.8 – 48 = 767.8

B3= 767.8 – 48 = 719.8

B4= 719.8 – 48 = 671.8

B5= 671.8– 48 = 623.8

B6= 623.8– 48 = 575.8

B7= 575.8– 48 = 527.8
B8= 527.8– 48 = 479.8

B9= 479.8– 48 = 431.8

B10= 431.8– 48 = 383.8

B11= 383.8– 48 = 335.8

B12= 335.8– 48 = 287.8

B13= 287.8– 48 = 239.8

B14= 239.8– 48 = 191.8

B15= 191.8– 48 = 143.8

B16= 143.8– 48 = 95.8

B17= 95.8– 48 = 47.8

Total cutting length main bar (mm) Figure 1.1

Calculate top to down

Length – (2*dia. of face bar + side cover)

1. = 815.8 x 2 + 812.4 – (2 x 12 + 50 x 2) = 2300
2. = 767.8 x 2 + 812.4 – 124 = 2224
3. = 719.8 x 2 + 812.4 – 124 = 2128

4. = 671.8 x 2 + 812.4 – 124 = 2032
5. = 623.8 x 2 +812.4 – 124 = 1936
6. = 575.8 x 2 +812.4 – 124 =1840
7. = 527.8 x 2 +812.4 – 124 = 1744
8. = 479.8 x 2 +812.4 – 124 = 1648
9. = 431.8 x 2 + 812.4 – 124 = 1552
10. = 383.8 x 2 +812.4 – 124 = 1456
11. = 335.8 x 2 + 812.4 – 124 = 1360
12. = 287.8 x 2 + 812.4 – 124 = 1264
13. = 239.8 x 2 +812.4 – 124 = 1168
14. = 191.8 x 2 + 812.4 – 124 = 1072
15. = 143.8 x 2 +812.4 – 124 = 976
16. = 95.8 x 2 + 812.4 – 124 = 880
17. = 47.8 x 2 + 812.4 – 124 = 784
18. = 2540 – 124 = 2416

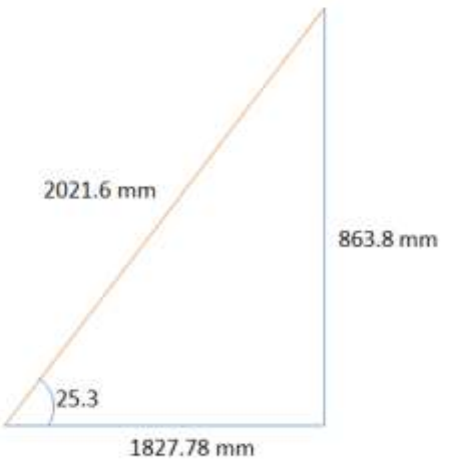
Distribution Bar

Number of bars = (2540-100)/101.6+1

= 25 nos.

Two side use 9 number bar

= 9 + 7 + 9



Angle $\alpha = \tan^{-1}(\frac{Vertical\ Length}{Horizontal\ length})$

$= \tan^{-1} \frac{863.8}{1827.78}$

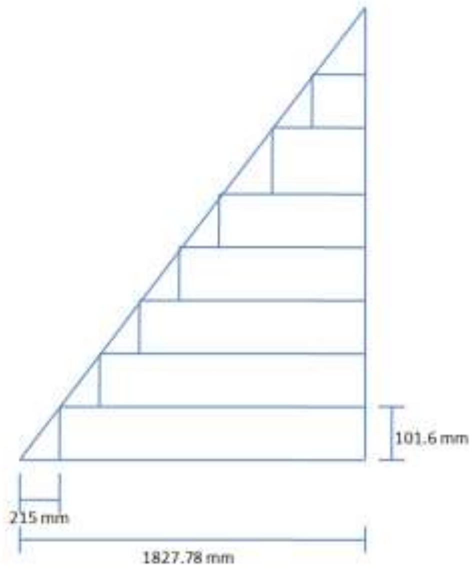
$Since, \alpha = 25.3$

$$\tan \alpha = \frac{Vertical\ length}{Horizontal\ length}$$

$$\tan 25.3 = \frac{101.6}{x}$$

Since, x = 215 mm

Triangle one side length (mm)



1. = 1827.78 – 215 = 1812.78
2. = 1812.78 – 215 = 1597.78
3. = 1597.78 – 215 = 1382.78
4. = 1382.78 – 215 = 1167.78
5. = 1167.78 – 215 = 952.78
6. = 952.78 – 215 = 737.78
7. = 737.78 – 215 = 522.78
8. = 522.78 – 215 = 307.78
9. = 307.78 – 215 = 92.78

Total Cut Length of Pile Cap (mm)

Length – (2 x dia. of face bar + side cover)

1. = 1812.78+ 508 – (2 x 12 + 2 x 50) = 2196.78
2. = 1597.78+ 508 – 124 = 1981.78
3. = 1382.78+ 508 – 124 = 1770.78
4. = 1167.78+ 508– 124 = 1551.78
5. = 952.78+ 508 – 124 = 1336.78
6. = 737.78 + 508 – 124 = 1121.78
7. = 522.78 + 508 – 124 = 906.78
8. = 307.78+ 508 – 124 = 691.78
9. = 92.78 + 508 – 124 = 476.78

Total distribution bar 25 nos,

Total weight of rod

Top main and bottom main

SR	Details	Dia of Bar mm	Shape of Bar	Spacing mm	No	Cutting Length m	Total Length m	Weight of Bar	Total Weight kg
1	Bottom Main(1)	20	2300 + 662 x 2		1	3.62	3.62		8.94
2	Bottom Main(2)		2224+ 662 x 2		1	3.55	3.55		8.76
3	Bottom Main(3)		2128 + 662 x 2		1	3.45	3.45		8.5
4	Bottom Main(4)		2032 +662 x 2		1	3.35	3.35		8.2
5	Bottom Main(5)		1936 + 662 x 2		1	3.26	3.26		8.05
6	Bottom Main(6)		1840 + 662 x 2		1	3.16	3.16		7.8

7	Bottom Main(7)	20	1744 +662 x 2	101.6	1	3.06	3.06	2.47	7.5
8	Bottom Main(8)		1648 + 662 x 2		1	2.97	2.97		7.3
9	Bottom Main(9)		1552 +662 x 2		1	2.87	2.87		7.08
10	Bottom Main(10)		1456 + 662 x 2		1	2.78	2.78		6.8
11	Bottom Main(11)		1360 +662 x 2		1	2.68	2.68		6.6
12	Bottom Main(12)		1264+ 662 x 2		1	2.58	2.58		6.3
13	Bottom Main(13)	20	1168 + 662 x 2		1	2.49	2.49		6.1
14	Bottom Main(14)		1072+662 x 2		1	2.39	2.39		5.9
15	Bottom Main(15)		976 +662 x 2		1	2.3	2.3		5.6
16	Bottom Main(16)		880 + 662 x 2		1	2.2	2.2		5.4
17	Bottom Main(17)		784 + 662 x 2		1	2.1	2.1		5.1
18	Bottom Main(18)		2416 +662 x 2		5	3.7	18.5		44.4
Total weight of main bar top								=	164.33

Total weight of main bar bottom = 164.33 kg

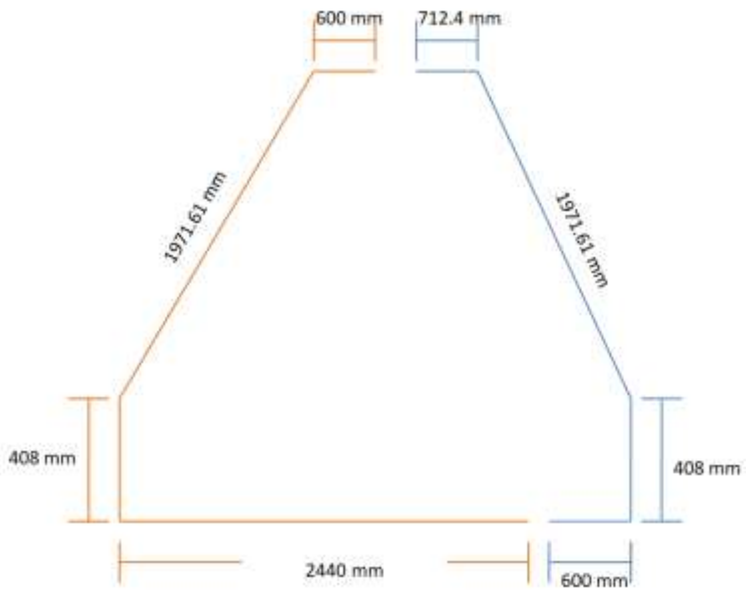
Total Weight of Distribution Bar

Distribution bar top and bottom

SR	Details	Dia of Bar mm	Shape of Bar	Spacing mm	No	Cutting Length m	Total Length m	Weight of Bar	Total Weight kg
1	Dist(1)	20	2196.78 + 662 + 662	101.6	2	3.5	7	2.47	17.29
2	Dist(2)		1981.78 + 662 +662		2	3.3	6.6		16.3
3	Dist(3)		1770.78 +662 +662		2	3.1	6.2		15.3
4	Dist(4)		1551.78+662+662		2	2.8	5.6		13.8
5	Dist(5)		1336.78+662+662		2	2.6	5.2		12.8
6	Dist(6)		1121.78+662+662		2	2.4	4.8		11.9
7	Dist(7)		906.78+662+662		2	2.2	4.4		10.8
8	Dist(8)		691.78+662+662		2	2.01	4.02		9.9
9	Dist(9)		476.78+662+662		2	1.8	3.6		8.8
10	Dist(10)		2211.78+662+662		7	3.5	24.5		60.5
Total weight of distribution top bar(kg)									177.39

Total weight of distribution bottom bar = 177.39 kg

Face Side Reinforcement



12 mm dia 150 mm c/c

So, nos = (762-100)/150 +1=5

Face Bar (left) = 600 + 1971.61 + 408 + 2440 = 5.41 m

Total length = 5 x 5.41 =27.09 m

Total Weight = $\frac{12^2}{162.2}\ x\ 27.09 = 24.05\ kg$

Face Bar (right) = 600 + 1971.61 + 408 + 712.4 = 3.58 m

Total length = 5 x 3.58 = 17.9 m

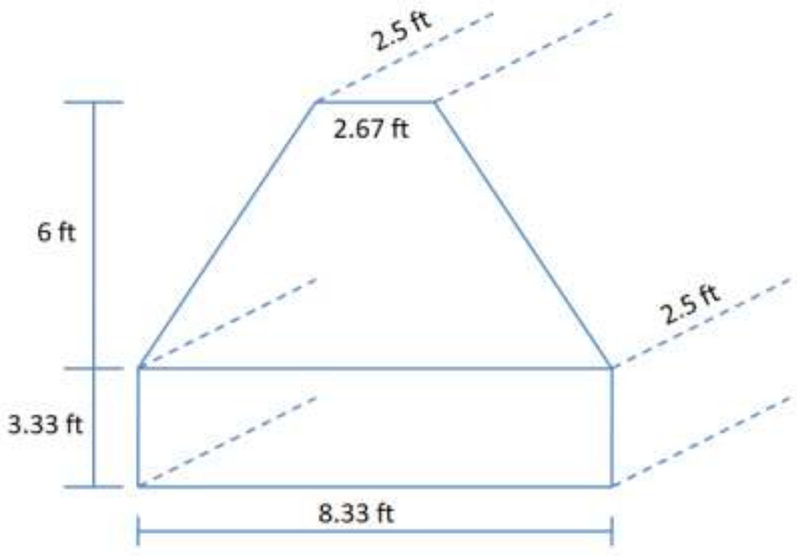
Total Weight = $\frac{12^2}{162.2}\ x\ 17.9 = 15.89\ kg$

Total weight of 12 mm bar = 46.89 kg

Again Total Weight of 20 mm bar = 683.44 kg

So, total weight of rod = 730.33 kg

4.6 Pile Cap Cost Analysis



Pile cap volume = trapezium volume + rectangle volume

= $\frac{2.67+8.33}{2} x\ 6\ x\ 2.5 + 8.33\ x\ 3.33\ x\ 2.5$

= 151.84 cft

Dry volume = 151.84 x 1.5 = 227.77 cft

Sum of ratio = 1 + 2 + 3 = 6

Cement = $\frac{227.77}{6}\ x\ @.8\ bag\ x\ 460\ tk\ per\ bag = 13970\ tk$

Sand = $\frac{227.77\ x\ 2}{6}\ x\ @\ 34\ tk\ per\ cft = 2582\ tk$

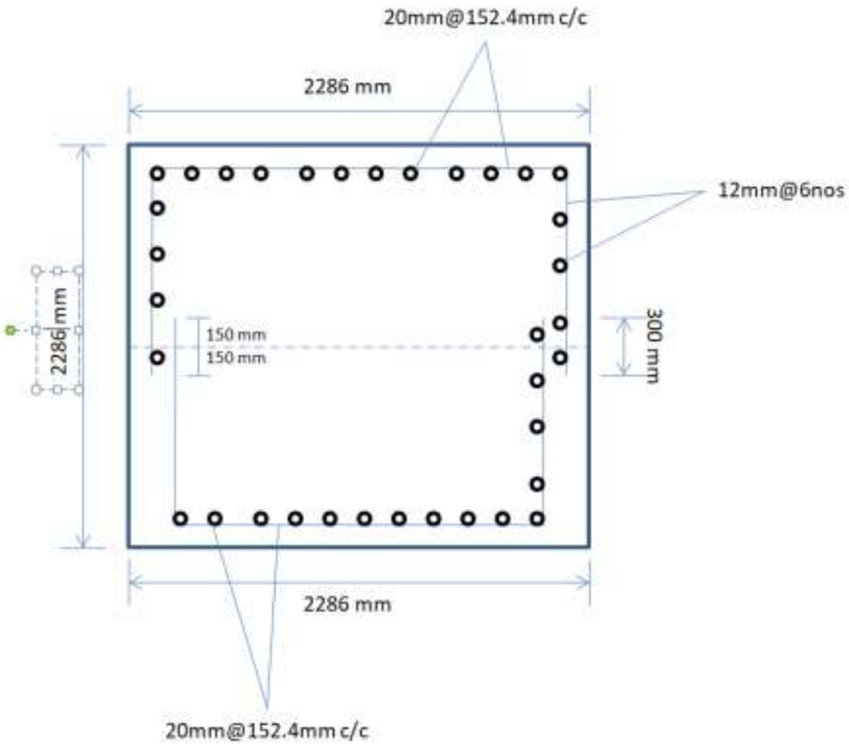
Stone Chips = $\frac{227.77\ x\ 3}{6}\ x\ @\ 180\ tk\ per\ cft = 20500\ tk$

Rod = 730.33 x 58 tk per kg = 42360 tk

Materials	Tk	Total Tk
Cement	13970 Tk	79412 Tk
Sand	2582 Tk	
Stone Chips	20500 Tk	
Rod	42360 Tk	

4.7 Four Pile Cap Bar Bending Schedule

4 Pile Cap (2286 mm x 2286 mm)



Clear cover = 50 mm

a = 1143/2 – 75 – 50 – 10 + 150

=1158 mm

Bottom reinforcement 1st layer

20 ф = Length of pile cap – (two side cover) – (2 x half of bar) + (2 x extra bar) – (2 x 2d)

20 ф = 2286 – (2 x 50) – (2 x 20/2) + (2 x 1158) – (2 x 2 x 20)

= 4402 mm

= 4.402 m

Total number of bar = [(Length of bar – clear cover)/ pitch] + 1

= [(2286 – 100)/ 152.4] + 1

= 16 nos.

For 16 nos

Total length = 16 x 4.402 = 70.432 m

Top reinforcement 1st layer

b = 1143 – 50 – 10 + 150

b = 1233 mm

20 ф = Length of pile cap – (two side cover) – (2 x half of bar) + (2 x extra bar) – (2 x 2d)

20 ф = 2286 – (2 x 50) – (2 x 10) + (2 x 1233) – (2 x 2 x 20)

= 4.552m

Total number of bar = [(Length of bar – clear cover) / pitch] + 1

= [(2286 – 2 x 50) / 152.4] + 1

= 16 nos.

For 16 nos

Total length = 16 x 4.552 = 72.83 m

Pile Cap (2286 x 2286)

Clear cover = 50 mm

Bottom reinforcement 2st layer

a^1 = 1143 – 75 – 50 – 20 - 10 + 150

a^1 = 1138 mm

20 ф = Length of pile cap – (two side cover) – (2 x half of bar) + (2 x extra bar) – (2 x 2d)

20 ф = 2286 – (2 x 50) – (2 x 10) + (2 x 1138) – (2 x 2 x 20)

= 4362 mm

= 4.362 m

Total number of bar = [(Length of bar – clear cover) / pitch] + 1

= [(2286 – 2 x 50) / 152.4] + 1

= 16 nos.

For 16 nos

Total length =16 x 4.362= 69.79 m

Top reinforcement 2st layer

b^1 = 1143 – 50 – 20 – 10 + 150

$b^1 = 1213$ mm

20 ϕ = Length of pile cap – (two side cover) – (2 x half of bar) + (2 x extra bar) – (2 x 2d)

20 ϕ = 2286 – (2 x 50) – (2 x 10) + (2 x 1213) – (2 x 2 x 20)

= 4.512 m

Total number of bar = [(Length of bar – clear cover) / pitch] + 1

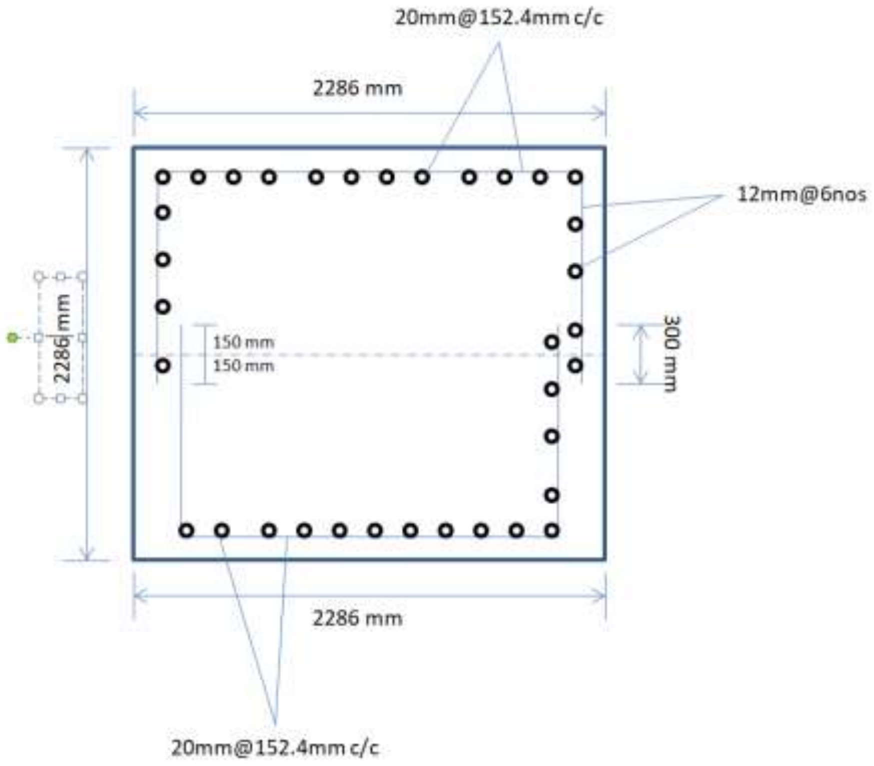
= [(2286 – 50 x 2) / 152.4] + 1

= 16 nos.

For 16 nos.

Total length = 16 x 4.512 = 72.192 m

Side Face Reinforcement



a= 1143 – 50 – 10 + 150

a= 1233 mm

12 ϕ = {Length of pile cap – (two side cover) – (2 x half of bar) + (2 x extra bar) – (2 x 2d)} x 2

= {2286 – (2x50) – (2 x 6) + (2 x 1233) – (2 x 2 x 12)} x 2

= 9.184 m

For 6 no. of bars

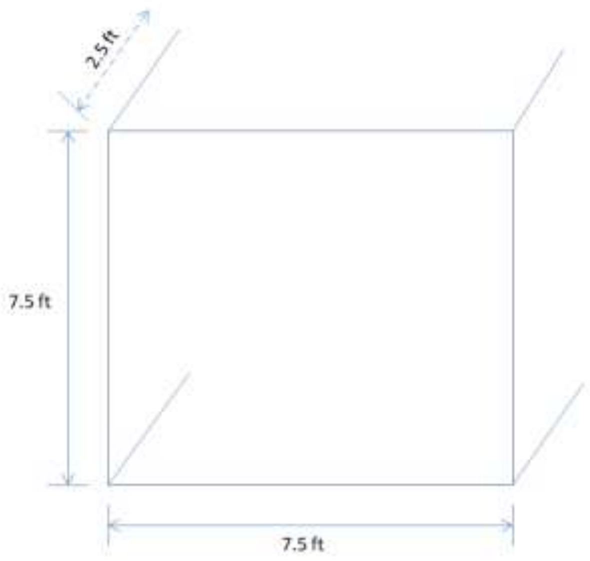
= 6 x 9.184

= 55.104m

Pile Cap Steel Quantity

Dia. in mm	Total length in m	Unit weight m-kg	Total weight in kg
12 mm	55.104 m	0.89	49.043 kg
20mm(Bottom)	140.222 m	2.47	346.348 kg
20 mm(Top)	145.022 m	2.47	358.204 kg
Total Weight kg			753.595 kg

4.8 Pile Cap Cost Analysis



Wet volume = 7.5 x 7.5 x 2.5 = 140.625 cft

Dry volume = 140.625 x 1.5 = 210.94 cft

Sum of ratio = 1 + 2 + 3 = 6

Cement = $\frac{210.94\ x\ 1}{6}\ x\ @\ 0.8\ bag\ x\ 460\ tk\ per\ bag = 12938\ tk$

Sand = $\frac{210.94\ x\ 2}{6}\ x\ @34\ tk\ per\ cft = 2391\ tk$

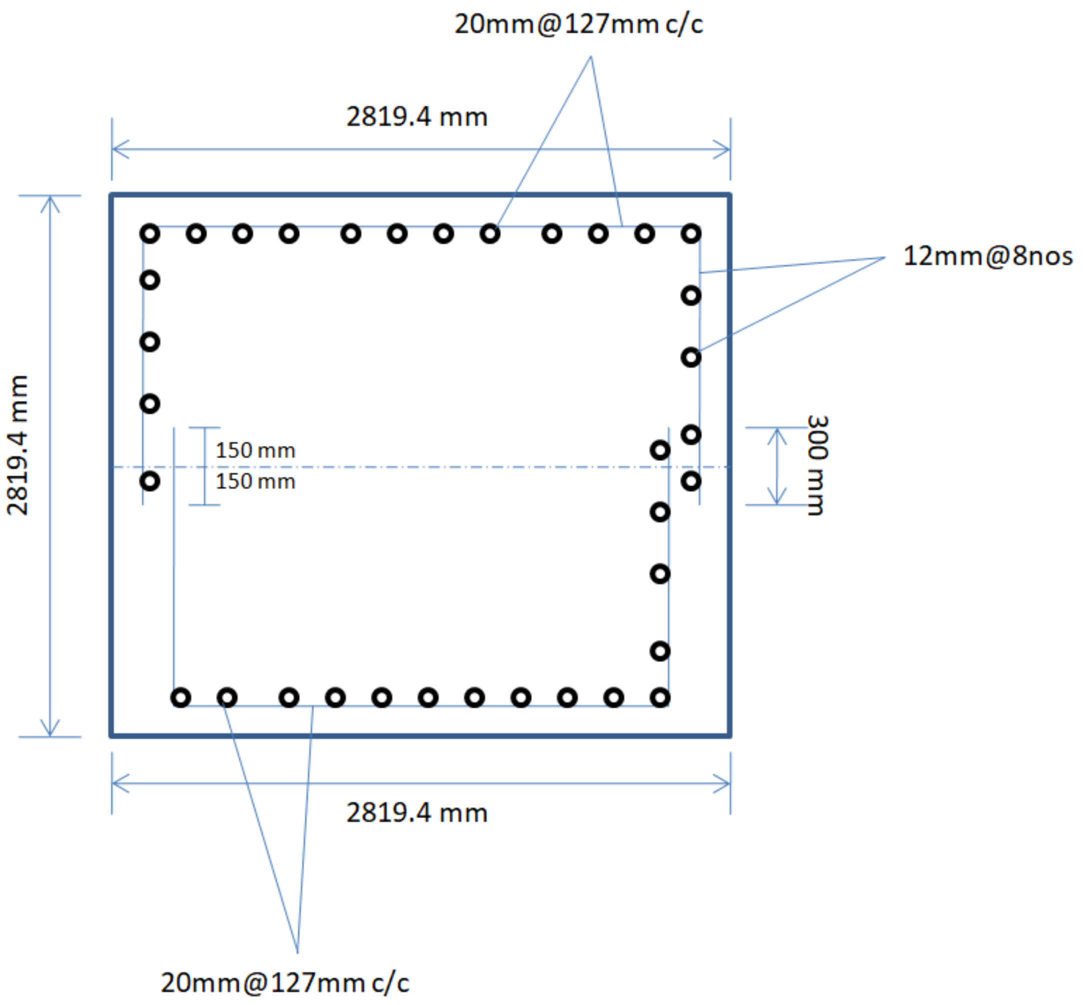
Stone Chips = $\frac{210.94\ \ x\ 3}{6}\ x\ @\ 180\ tk\ per\ cft = 18983\ tk$

Rod = 753.595 x 58 tk per kg = 43709 tk

Materials	Tk	Total Tk
Cement	12938 Tk	78021 Tk
Sand	2391 Tk	
Stone Chips	18983 Tk	
Rod	43709 Tk	

4.9 Five Pile Cap Bar Bending Schedule

5 Pile Cap Size (2819.4 mm x 2819.4 mm)



Clear cover = 50 mm

a = 2819.4/2 – 75 – 50 – 10 + 150

=1424.7 mm

Bottom reinforcement 1st layer

20 ϕ = Length of pile cap – (two side cover) – (2 x half of bar) + (2 x extra bar) – (2 x 2d)

20 ϕ = 2819.4 – (2 x 50) – (2 x 20/2) + (2 x 1424.7) – (2 x 2 x 20)

= 5468.8 mm

= 5.468 m

Total number of bar = [(Length of bar – clear cover)/ pitch] + 1

= [(2819.4 – 100)/ 127] + 1

= 23 nos.

For 23 nos

Total length = 23 x 5.468 = 125.764 m

Top reinforcement 1st layer

b = 2819.4/2 – 50 – 10 + 150

b = 1499.7 mm

20 ϕ = Length of pile cap – (two side cover) – (2 x half of bar) + (2 x extra bar) – (2 x 2d)

20 ϕ = 2819.4 – (2 x 50) – (2 x 10) + (2 x 1499.7) – (2 x 2 x 20)

= 5.618

Total number of bar = [(Length of bar – clear cover) / pitch] + 1

= [(2819.4 – 2 x 50) / 127] + 1

= 23 nos.

For 23 nos

Total length = 23 x 5.618 = 129.214 m

Pile Cap (2286 x 2286)

Clear cover = 50 mm

Bottom reinforcement 2^{st} layer

a^1 = 2819.4/2 – 75 – 50 – 20 - 10 + 150

a^1 = 1404.7 mm

20 ϕ = Length of pile cap – (two side cover) – (2 x half of bar) + (2 x extra bar) – (2 x 2d)

20 ϕ = 2819.4 – (2 x 50) – (2 x 10) + (2 x 1404.7) – (2 x 2 x 20)

= 5428.8 mm

= 5.428 m

Total number of bar = [(Length of bar – clear cover) / pitch] + 1

= [(2819.4 – 2 x 50) / 127] + 1

= 23 nos.

For 23 nos.

Total length =23 x 5.428= 124.844 m

Top reinforcement 2^{st} layer

b^1 = 2819.4/2 – 50 – 20 – 10 + 150

b^1 = 1479.7 mm

20 ϕ = Length of pile cap – (two side cover) – (2 x half of bar) + (2 x extra bar) – (2 x 2d)

20 ϕ = 2819.4 – (2 x 50) – (2 x 10) + (2 x 1479.7) – (2 x 2 x 20)

= 5.578 m

Total number of bar = [(Length of bar – clear cover) / pitch] + 1

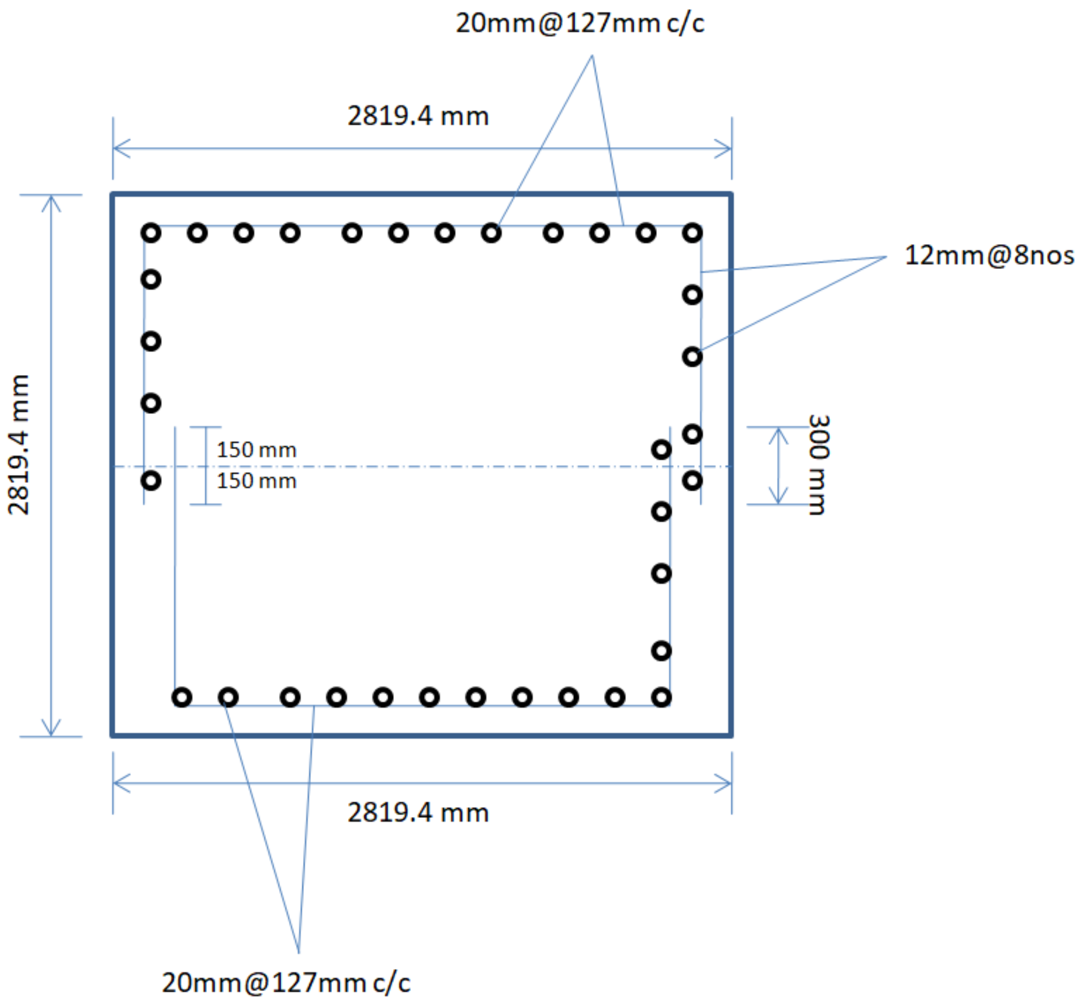
= [(2819.4 – 50 x 2) / 127] + 1

= 23 nos.

For 23 nos

Total length = 23 x 5.578 = 128.294 m

Side Face Reinforcement



a= 2819.4/2 – 50 – 6 + 150

a= 1503.7 mm

12 ϕ = {Length of pile cap – (two side cover) – (2 x half of bar) + (2 x extra bar) – (2 x 2d)} x 2

= {2819.4 – (2x50) – (2 x 6) + (2 x 1503.7) – (2 x 2 x 12)} x 2

= 11.33 m

For 8 no. of bars

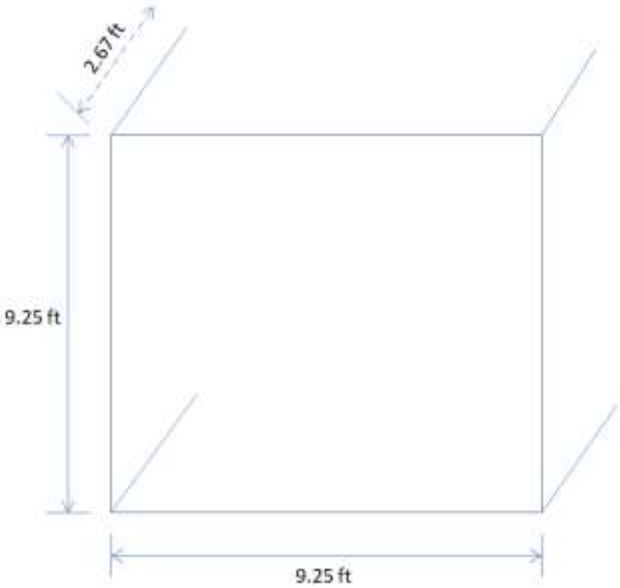
= 8 x 11.33

= 90.64 m

Pile Cap Steel Quantity

Dia. in mm	Total length in m	Unit weight m-kg	Total weight in kg
12 mm	90.64 m	0.89	80.67 kg
20mm(Bottom)	250.61 m	2.47	619 kg
20 mm(Top)	257.51 m	2.47	636.05 kg
Total Weight kg			1335.72 kg

4.9 Pile Cap Cost Analysis



Wet volume = 9.25 x 9.25 x 2.67 = 228.46 cft

Dry volume = 228.46 x 1.5 = 342.68 cft

Sum of ratio = 1 + 2 + 3 = 6

Cement = $\frac{342.68\ x\ 1}{6}\ x\ @\ 0.8\ bag\ x\ 460\ tk\ per\ bag = 21018\ tk$

Sand = $\frac{342.68\ x\ 2}{6}\ x\ @34\ tk\ per\ cft = 3884\ tk$

Stone Chips = $\frac{342.68\ \ x\ 3}{6}\ x\ @\ 180\ tk\ per\ cft = 30842\ tk$

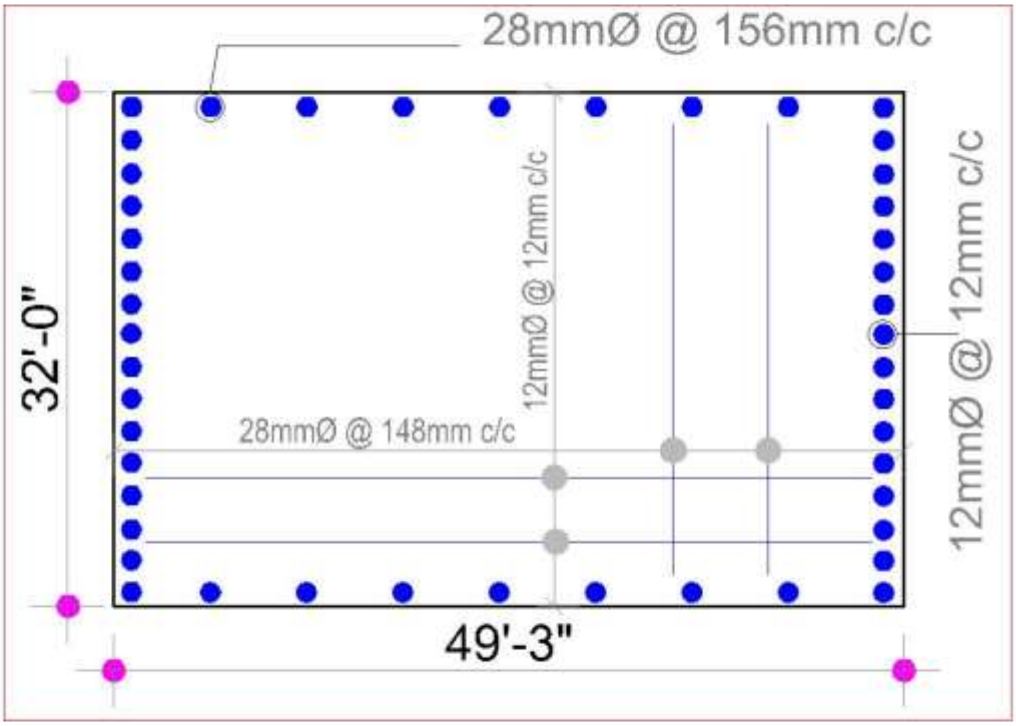
Rod = 1335.72 x 58 tk per kg = 77472 tk

Materials	Tk	Total Tk
Cement	21018 Tk	133216 Tk
Sand	3884 Tk	
Stone Chips	30842 Tk	
Rod	77472 Tk	

CHAPTER 5

RAFT FOUNDATION COST ANALYSIS

5.1 Raft Foundation Section (49.25 x 32 ft)



Where

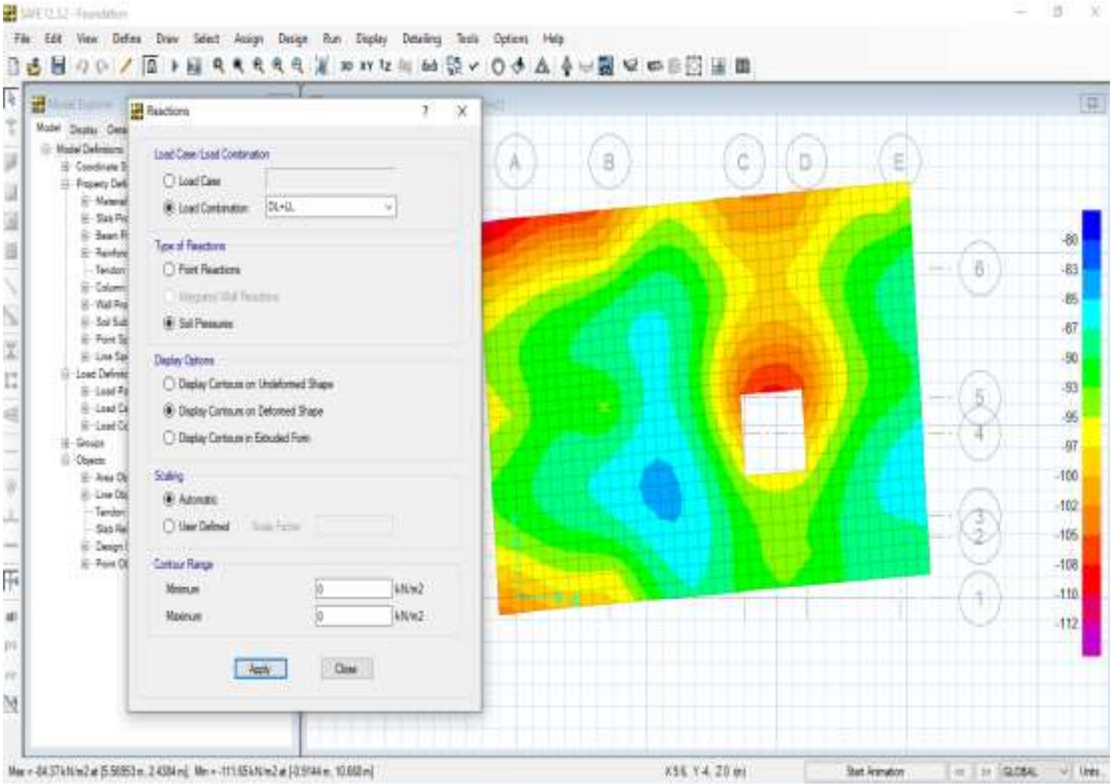
Concrete strength f'c = 4 ksi

Steel strength fy = 60 ksi

Main bar and distribution bar dia 28 mm

5.2 Raft Foundation Allowable Bearing Capacity Check

Soil average allowable bearing capacity = 143 kn/m^3

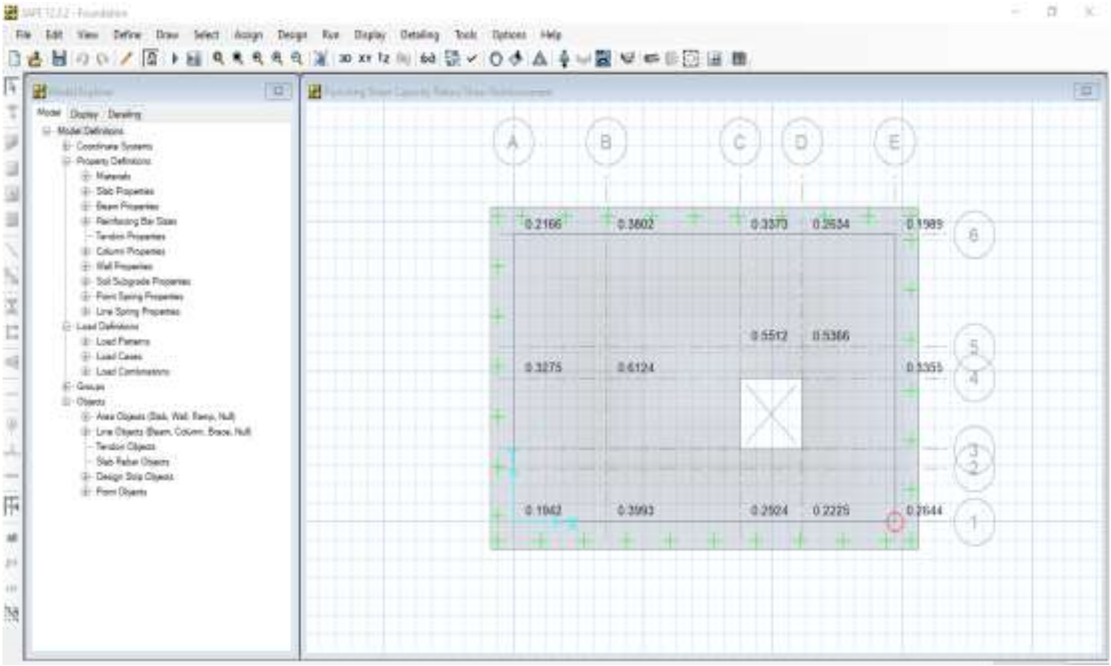


Show allowable bearing capacity 112 kn/m^3

So we can say that the foundation design of the building is right.

5.3 Raft Foundation Punching Shear Check

I was holding punching shear ‘1’ during the design of the foundation.



The value in each column of the building is below 1 so we can say that the design of the foundation is right.

5.4 Raft Foundation Bar Bending Schedule

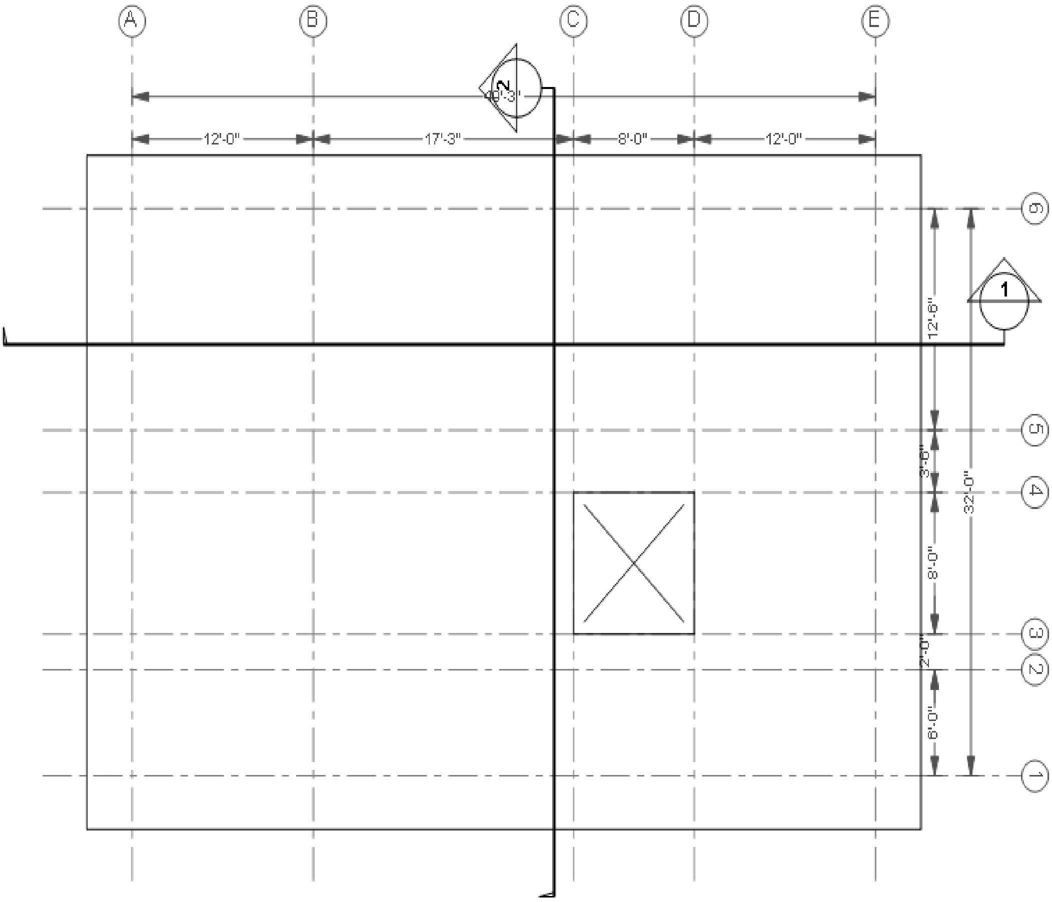
Slab and cover

Concrete Strength = 4 kip / in^2

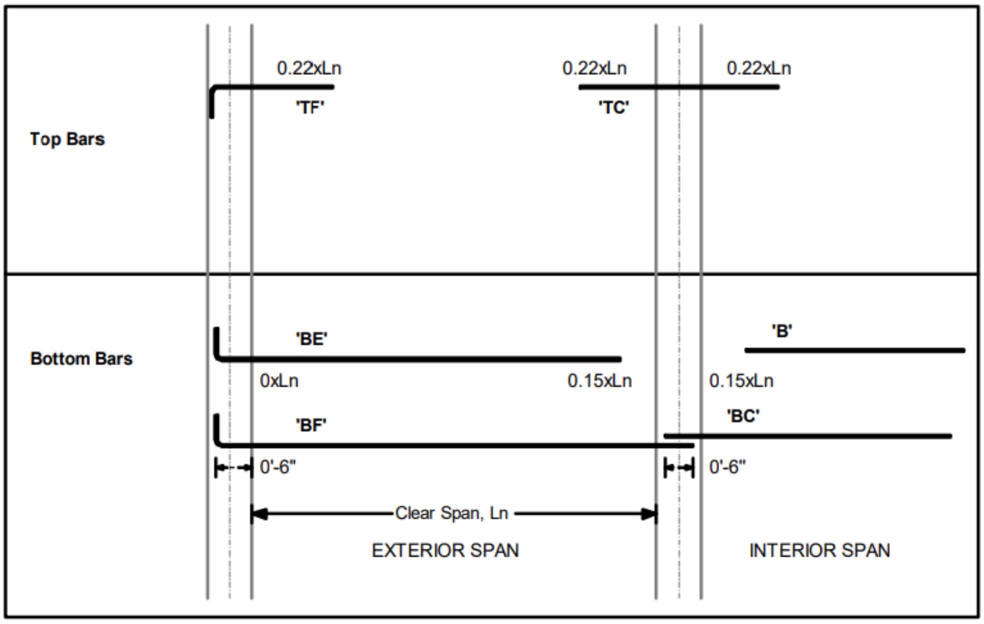
Reinforcement Strength = 60 kip/in^2

Cover = 1.5 inch

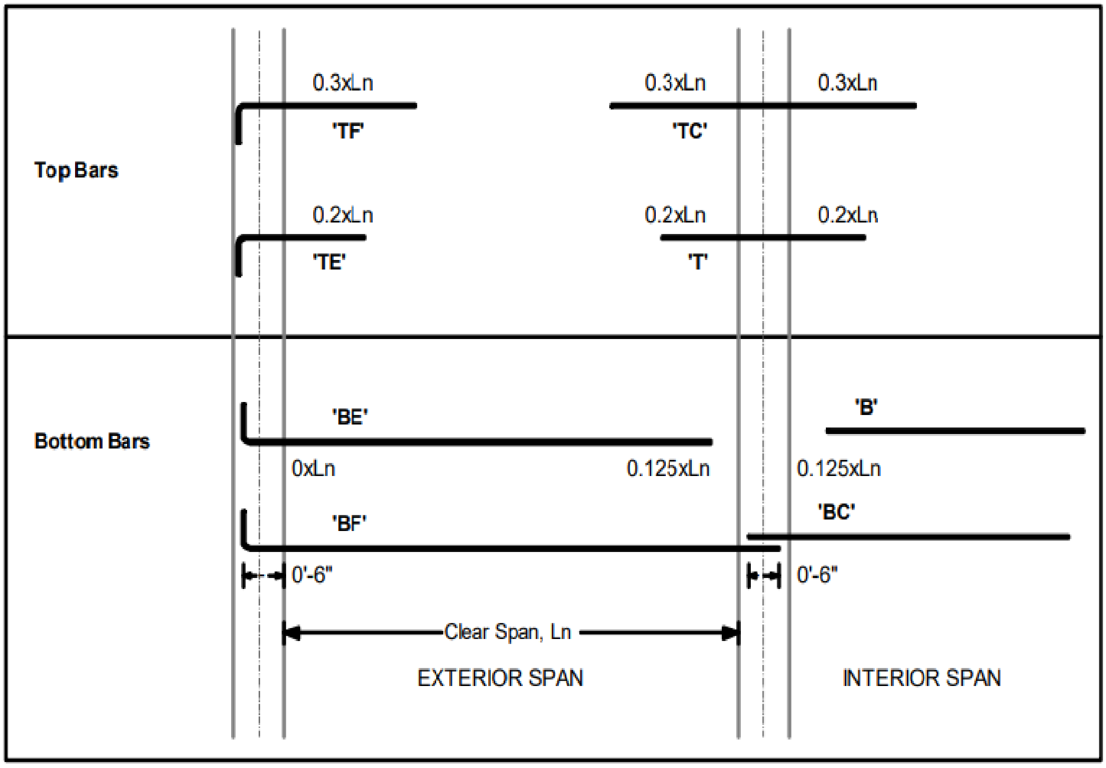
Framing Plan



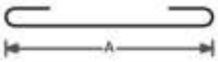
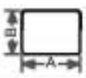
Slab Rebar: Middle Strip



Slab Rebar: Column Strip



Rebar Shape Code

CODE	SHAPE
00	
11	
12	
13	
14	
51	
52	
62	
63	

REBAR TABLE

SR. NO.	BAR MARK	DIA.	SHAPE CODE	CUT LENGTH (FT)	NUMBERS	TOTAL LENGTH (FT)
1	MK-1	#5	11	15'-2"	42	638'-9"
2	MK-2	#5	00	9'-7"	5	48'-0"
3	MK-3	#5	00	27'-7"	7	192'-11"
4	MK-4	#5	11	16'-9"	17	285'-1"
5	MK-5	#4	00	24'-3"	39	947'-4"
6	MK-6	#4	00	24'-5"	13	317'-11"
7	MK-7	#4	00	9'-2"	11	100'-5"
8	MK-8	#5	00	24'-4"	9	218'-10"
9	MK-9	#5	11	18'-5"	28	515'-1"
10	MK-10	#4	11	25'-3"	5	126'-4"
11	MK-11	#4	00	22'-0"	14	308'-3"
12	MK-12	#4	00	9'-11"	13	129'-2"
13	MK-13	#5	11	34'-8"	9	311'-10"
14	MK-14	#5	11	24'-11"	9	224'-1"
15	MK-15	#9	00	31'-1"	4	124'-4"
16	MK-16	#9	11	36'-6"	5	182'-8"
17	MK-17	#9	11	26'-9"	5	133'-11"
18	MK-18	#9	00	31'-6"	6	189'-1"
19	MK-19	#4	11	7'-4"	3	22'-1"
20	MK-20	#9	11	36'-3"	6	217'-8"
21	MK-21	#9	00	5'-8"	6	33'-10"
22	MK-22	#9	00	13'-8"	47	641'-1"
23	MK-23	#9	11	19'-0"	6	114'-2"
24	MK-24	#9	00	19'-1"	7	133'-7"
25	MK-25	#9	11	18'-2"	19	345'-4"
26	MK-26	#9	00	0'-0"	0	0'-0"
27	MK-27	#5	11	17'-0"	9	153'-0"
28	MK-28	#5	11	3'-5"	0	0'-0"

29	MK-29	#4	00	15'-11"	14	223'-2"
30	MK-30	#4	00	0'-0"	0	0'-0"
31	MK-31	#4	11	33'-11"	15	508'-6"
32	MK-32	#9	00	20'-7"	7	143'-11"
33	MK-33	#4	00	24'-1"	11	265'-2"
34	MK-34	#9	00	11'-10"	8	94'-8"
35	MK-35	#9	00	28'-5"	7	198'-9"
36	MK-36	#4	11	24'-5"	10	244'-5"
37	MK-37	#9	00	23'-9"	10	237'-9"
38	MK-38	#5	00	29'-2"	14	407'-9"

SR. NO.	BAR MARK	DIA.	SHAPE CODE	CUT LENGTH (FT)	NUMBERS	TOTAL LENGTH (FT)
39	MK-39	#3	11	5'-8"	2	11'-3"
40	MK-40	#9	00	30'-8"	6	184'-3"
41	MK-41	#4	11	19'-7"	25	489'-2"
42	MK-42	#5	00	22'-8"	4	90'-6"
43	MK-43	#5	00	16'-6"	4	66'-1"
44	MK-44	#5	11	23'-3"	2	46'-6"
45	MK-45	#5	11	21'-8"	3	64'-11"
46	MK-46	#3	11	4'-0"	1	4'-0"
47	MK-47	#3	00	18'-0"	3	54'-0"
48	MK-48	#4	00	31'-1"	9	279'-9"
49	MK-49	#5	00	30'-10"	6	184'-11"
50	MK-50	#5	00	20'-9"	3	62'-3"
51	MK-51	#5	00	17'-5"	11	191'-10"
52	MK-52	#5	11	19'-6"	38	741'-9"
53	MK-53	#5	00	13'-5"	18	241'-11"
54	MK-54	#5	00	11'-1"	6	66'-6"
55	MK-55	#4	00	27'-7"	138	3806'-5"
56	MK-56	#4	00	11'-3"	50	560'-6"
57	MK-57	#5	11	21'-1"	162	3415'-5"

58	MK-58	#5	11	17'-11"	8	143'-4"
59	MK-59	#3	00	11'-3"	6	67'-7"
60	MK-60	#5	00	12'-8"	24	303'-0"
61	MK-61	#5	11	22'-8"	38	861'-4"
62	MK-62	#4	11	27'-9"	46	1276'-7"
63	MK-63	#3	00	12'-1"	10	120'-7"
64	MK-64	#9	11	15'-0"	30	449'-0"
65	MK-65	#9	11	23'-0"	142	3261'-3"
66	MK-66	#4	11	6'-2"	52	322'-1"
67	MK-67	#9	00	29'-6"	60	1771'-8"
68	MK-68	#5	11	13'-1"	22	287'-10"
69	MK-69	#5	00	8'-3"	22	181'-4"
70	MK-70	#4	00	12'-5"	62	769'-9"
71	MK-71	#9	00	21'-5"	20	428'-11"
72	MK-72	#9	00	9'-6"	10	95'-0"
73	MK-73	#4	11	29'-4"	46	1349'-5"
74	MK-74	#3	11	7'-0"	6	42'-0"
75	MK-75	#5	00	11'-10"	10	118'-7"

Total Weight of Foundation Rod:

SR. NO	BAR SIZE	LENGTH(FT)	WEIGHT(TON)
1	#3	299'-6"	0.06
2	#4	12046'-6"	4.10
3	#5	10063'-2"	5.31
4	#9	8980'-11"	15.28
5	TOTAL		24.74

5.5 Raft Foundation Cost Analysis

Wet volume of raft = 49.25 x 32 x 2 = 3152 cft

Dry volume = 3152 x 1.5 = 4728 cft

Sum of ratio = 1 + 2 +4 = 7

Cement = $\frac{4728}{7}\ x\ 0.8\ bag\ x\ 460\ tk\ per\ bag = 2{,}48{,}557\ tk$

Sand = $\frac{4728\ x\ 2}{7}\ x\ 34\ tk\ per\ cft = 45{,}929\ tk$

Stone Chips = $\frac{4728\ x\ 4}{7}\ x\ 180\ tk\ per\ cft = 4{,}86{,}308\ tk$

Rod = 24.74 ton or 24740 kg x 58 = 1,434,920 tk.

Materials	Amount	Total Amount
Cement	2,48,557 tk.	2,215,714 tk.
Sand	45,929 tk.	
Stone Chips	4,86,308 tk.	
Rod	1,434,920 tk.	

CHAPTER 6

COST COMPARISONS BETWEEN PILE AND RAFT FOUNDATION

6.1 Pile Foundation Total Cost

Total Pile Cost

Number of Pile	Single Pile Cost	Total Pile Cost
40 Pile	78450 tk.	31,38000 tk.

Total Pile Cap Cost

Total Number of Pile Cap = 15

Number of Pile for each Pile Cap	Size of Pile Cap	Number of Pile Cap	Single Pile Cap Cost	Total Cost
2 nos	3’-4” x 7’-6”	7	38572 tk.	270004 tk.
3 nos	9’-4” x 8’-4”	4	79412 tk.	317648 tk.
4 nos	7’-6” x 7’-6”	3	78021 tk.	234063 tk.
5 nos	9’-4” x 9’-4”	1	133216 tk.	133216 tk.
			Total Pile Cap Cost =	9,54931 tk.

Pile Foundation total cost

Total pile cost	31,38,000 tk.
Total pile cap cost	9,54931 tk.
Total Cost =	**40,92,931 tk.**

6.2 Raft Foundation Total Cost

Total cost of raft foundation

<table>
<tr><th>Materials</th><th>Amount</th><th>Total Amount</th></tr>
<tr><td>Cement</td><td>2,48,557 tk.</td><td rowspan="4">2,215,714 tk.</td></tr>
<tr><td>Sand</td><td>45,929 tk.</td></tr>
<tr><td>Stone Chips</td><td>4,86,308 tk.</td></tr>
<tr><td>Rod</td><td>1,434,920 tk.</td></tr>
</table>

6.3 Discussion Most Suitable for the Foundation

The foundation size of this building is 49.25 * 32 feet with soil bearing capacity of 3 ksf and soil settlement of 25 mm. Where the base size is 1576 square feet and this foundation requires 40 piles and 15 pile caps, on the other hand a raft foundation with a thickness of 2 feet is laid in the same place. Where a pile base consists of a pile cap and one or more piles.

Where the cost for pile foundation is 4,092,931 tk. and the public cost for raft foundation is 2,215,714 tk. This cost difference is less than 54.13%.

However, even if the cost of raft foundation is low, raft foundation cannot be laid everywhere, some rules have to be followed to lay raft foundation.

So it can be said that if the building is small or multi-story, the foundation will not be based on the load of the superstructure alone. The foundation depends on the soil of the place and where the installation is being set up.

CHAPTER 7

CONCLUSONS

7 Conclusions

Bangladesh is a developing country in the world. The standard of living of the people of this country has increased and so has their daily needs. A few years ago there were no big installations in this country. Nowadays, with the development of technology, it is possible to tell before setting up an installation whether the installation is suitable or not.

Most installations in Bangladesh have two types of foundations, a raft and a pile foundation. The first thing to choose before building an installation is what the foundation will be. This basis depends on the soil layer settlement and bearing capacity of the area. If the soil bearing capacity is high but the distance from one footing to the other of the building is very short, then the raft foundation is more economical than other foundations.

There are many multi-story buildings where raft foundations are laid without pile foundations. Civil engineers have to follow a lot of code behind laying the raft foundation. If the bearing capacity of the soil is low and the water level is low, the building is located away from rivers, seawater or hills, then raft foundation is cheaper without pile foundation.

Based on this study, it can be said that which foundation is more suitable depends not on the load of the installation on the bearing capacity of the soil.

Reference

Bangladesh National Building Code (2015), Chapter 3, Foundation.

Braja M. Das Principles of Geotechnical Engineering 7th Edition

J. A. Hemsley Design Applications of Raft Foundations

Joseph E. Bowles Foundation Design and Analysis (5th Edition)

Braja M. Das Shallow Foundations Bearing Capacity and Settlement

M.J. Tomlinso Pile Design and Construction Practice (4th Edition)

H.G. PoulosE. H. Devis Pile Foundation Analysis and Design

Teng W.e Foundation Design, 13th Ed

Singh. A. Modern Geotechnical Engineering, 3rd Ed

W.G.Curtin,G.Shaw G.I.Parkinson Structural Foundation Designer's Manual

The Chartered Institute of Building New Code of Estimating Practice 1st Edition

B.N Dutta Estimation and Costing

British Standards Institution (1986) Code of Practice for Foundations

Winter, G., and Nilson, AH. (1981), Design of Concrete Structures Mc-Graw Hill Book