ADDIS ABABA UNIVERSITY
SCHOOL OF GRADUATE STUDIES

FACULTY OF TECHNOLOGY
DEPARTMENT OF CIVIL ENGINEERING

DEVELOPING SUPPORTING SOFTWARE FOR ANALYSIS. DESIGN AND COST ESTIMATION OF COMMONLY USED REINFORCED CONDRETE FOUNDATIONS

A Thesis Submitted to the School of Graduate Studies, Addis Ababa University in Partial Fulfillment of the Requirement for the Degree of Master of Science in Civil Engineering

Mekonnen Shibru

Advisor: Dr. Mesele Haile

July 2003

ADDIS ABABA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

FACULTY OF TECHNOLOGY

DEPARTEMENT OF CIVIL ENGINEERING

DEVELOPING SUPPORTING SOFTWARE FOR ANALYSIS, DESIGN AND COST ESTIMATION OF COMMONLY USED REINFORCED CONCRETE FOUNDATION

MEKONNEN SHIBRU
JULY, 2003

Declaration

The thesis is my original work, has not been presented for a degree in any other university and that all sources of material used for the thesis have been duly acknowledged

Name :	Mekonnen Shibru
Signature:	________________
Place:	Faculty of Technology, Addis Ababa University Addis Ababa.
Date of submission:	July 2003

ACKNOWLEDGEMENT

This study was conducted under the supervision of my advisor,Dr.Messele Haile of Civil Engineering Departement,Addis Ababa University. I would like to express my deepest gratitude to my advisor to Dr.Messele Haile for his helpful guidance throughout my research work and for providing me with the relevant materials.

The author has no words to express his deepest gratitude for MH engineering PLC for being full sponsor in attending the Graduating Program.

I would also like to express my thanks to my collequies in the firm.

Mekonnen Shibru

LIST OF FIGURES

LIST OF FLOW CHARTS

ABSTRACT

Key words: Supporting analysis and design software, Supporting Cost estimation software, foundation selection.

The choice of the most appropriate type of foundation for structures is one of the challenges a civil design engineer faces. Different structural systems and loads from the super structure, hetrogenous soil conditions and variations of soil strength parameters with change in soil moisture makes determining the most appropriate foundation type a tedious process. Besides engineering consideration ,the variation in cost of construction materials and labour for the different foundation types and for different locations of projects makes the choice of the most appropriate foundation (function and cost) an extremely time consuming process.

This practical difficulty has led most design engineers to opt for one type of foundation based on engineering judgment and experience. This not so rational process is not expected to lead to optimal design , it may even end up with erroneous design.

In this thesis an attempt is made to develop a computer program that requires super structural input as foundation reaction and soil data and does analysis. Once design is completed the quantity of material and labour is calculated and cost comparison is made. Ultimately the functional best and economical foundation type is chosen in a matter of minutes. This

enables design engineers to get an optimal solution in the foundation system at the same time saving design time.

1. Objectives and Organization of the thesis

1.1 Introduction

The component which interfaces the superstructure to the underlying soil or rock is referred to as the foundation. Its function is to transfer the loads above the foundation (superstructure loads) to the underlying soil formation without overstressing the soil.

Usually, in practice,the design of foundation is done by selecting one type of foundation like isolated foundation, mat foundation or pile foundation.The selection of one of or another foundation type is done based on investigation and experience. The tendency of comparing the cost of different types of foundation is not common. Designing and comparing the different types of foundation takes a lot of time and cost of the designer. Moreover in the design of foundations the usual trend is to determine foundation types by selecting large ranges of foundation reactions from superstructure in order to reduce the calculation effort.

Software's for analysis and design of foundation which are commercially available and also developed in most design offices by using spread sheet programs like Microsoft Excel program do not have the capacity to make complete analysis and design of foundation.

1.2 Essential of Foundation

The term foundation is usually restricted to structural members that transmit the superstructure load to the underlying soils, but in a complete sense it includes the soil and rock formation below the foundation. It is the transition of structural connection whose design depends on the characteristics of both the structure and the underlying soil or rock.

A satisfactory foundation design must satisfy three requirements. Foundation must :

- **be placed at an adequate depth to prevent frost damage, or damage from future construction nearby**
- **be safe against breakage into ground**
- **not settle to disfigure or damage the structure.**

It is obvious that the foundation must be adequate to safely carry loads .The planning and design of foundation requires proper engineering skill and good judgment.

1.3 Objectives

The designers of the foundation are faced with problems beset by uncertainties. The designer should obtain all the information possible about the problem confronting him, to determine what course of actions are open to him, to study various alternatives that might be used to support the structure, to visualize the probable action of those alternatives, to estimate their approximate costs, to decide upon the relative feasibility of their construction, to choose the best foundation, and the last but not least ,to justify to his clients the nature of the problems and the reason for his recommendations.

Thus, the major decisions may rest upon his engineering judgment and experiance. These qualities are developed and made reliable through years of study and experience .Yet study and experience are not guaranty of expert ability if they have not been of the right caliber. One of the greatest of an engineer’s asset is the ability to visualize and to think clearly.

There are different super structure analysis and design softwares.In contrast for substructure part of the building there are few analysis and design software.

The normal procedures used by foundation engineers are both laborious and time consuming because trial designs may be repeated a number of times before an acceptable solution is obtained. Developing a computer program reduces this labor and the effect of any change in the value of any parameter can be studied without difficulty.

The objective of the thesis is to develop a computer program that does analysis and design of the different types of foundations and makes automatic cost comparison of the different alternatives. This enables one to choose cost efficient and safe foundation in extremely short time.

1.4 Organization of the Thesis

The purpose of this paper is to produce supporting programs for substructure analysis and design. For this purpose, a theoretical review of general cross section analysis for reinforced concrete foundation is present in chapter two. In chapter 3 some commonly used reinforced concrete foundations analysis and design methods are briefly explained. Of this the current practice of local consultants on commonly used reinforced concrete foundations will be investigated in chapter 4.Chapters 5 and 6 are devoted in producing programs which aid analysis design and cost estimation of common reinforced concrete foundations. Lastly sample analysis design and cost estimation of foundation by using the software's developed in this paper will be shown with conclusion.

1.5 Description of Developed Programs

The program developed in this study is done by using a Fortran-90 programming language. The developed programs help the designer of foundation in analyzing ,designing and cost estimation of commonly used reinforced concrete foundation.The objective of each developed program is described below.

Program 01-IMPSAPI

The program selects data required for foundation design from inputs of Superstructure analysis software

Program 02-IMPSAPO

The program selects data required for foundation design from outputs of Superstructure analysis software

Program 03-FOOTDES

Isolated Footing design program.

Program 04-AVESTR

Program for calculating the average stress in mat foundation.

Program 05-CORNERC

Program for selecting the critical corner foundation reaction.

Program 06-SIDEC

Program for selecting the critical side foundation reaction.

Program 07-MIDDLEC

Program for selecting the critical middle foundation reaction.

Program 08-EFECTMATD

Program for determination of the critical depth of uniform mat foundation.

Program 09-PILE1

Program for determination of the bearing capacity and the skin friction resistance of pile foundation soil profiles.

Program 10-PILE2

Program for determination of the required length of pile.

Program 11-PILEGR

Program for determination of the Capacity of pile group.

Program 12-TAKOFF

Program for performing take-off sheet for specification and bill of quantities of foundation.

Program 13-ISSPBOQ

Program for performing specification and bill of quantities of isolated foundation.

Program 14-MTSPBOQ

Program for performing specification and bill of quantities of mat foundation.

Program 15-PLSPBOQ

Program for performing specification and bill of quantities of pile foundation.

2. Reinforced Concrete Foundations Design Approach

2.1 General

The function of foundation is to transfer the load of the superstructure to the underlying soil formation without overstressing the soil. Hence a safe foundation design provides for a suitable safety factor against (i) shear failure of the soil and (ii) excessive settlement. The soils limiting shear resistance is referred to us ultimate bearing capacity, (qu), of the soil. For design purposes an allowable bearing capacity, (qa) is obtained by dividing the ultimate bearing capacity with a suitable factor of safety. The safe bearing capacity of the soil must not be exceeded otherwise excessive settlement may occur, resulting in damage to the building and its service facilities. Foundation failure can also affect the overall stability of structure .

2.2 Basic Assumptions

Determination of ultimate capacity of reinforced concrete is based up on the following assumptions.

1. Plane section remain plane implying that there is a linear variation of strain across the cross- section and the strain at any point on the cross-section is proportional to the distance from the neutral axis.
2. **There is no bond slip between steel and concrete, that is the strain in the reinforcement steel and concrete at the same location are equal.**
3. **Concrete is weak in tension and its tensile strength can be neglected.**
4. **The idealized stress-strain relation ship for steel and concrete are according to EBCS-2 [1]**
5. The pressure distribution beneath most footings are intermediate because of the interaction of the footing rigidity with the soil type ,state and time response to stress. For this reason EBCS-7 recommends to the use of a linear pressure distribution beneath spread footings.[2]

2.3 Evaluation of Bearing Resistance

Analytical method of determining bearing resistance according to EBCS-7 1995 is shown below:[2]

Approximate equation for the design bearing resistance ,derived from plasticity theory and experimental findings may be used. Allowance should be made for the effect of the following:

i. The strength of the ground ,
ii. Eccentricity and inclination of design loads
iii. The shape depth and inclination of the foundation
iv. Inclination of the ground surface
v. Ground water pressure and hydraulic gradient
vi. The variability of the ground, especially layering.

The design bearing resistance for drained condition is calculated from:

$$R/A=(2+\Pi)C_u S_c I_c+q \qquad [2.1]$$

With the design values of dimensionless factor for:

(i)the shape of foundation:

-for a rectangular shape

$Sc=1+0.2(B'/L')$ [2.2]

-for a square or circular shape

$Sc=1.2$

(ii) the inclination of the load ,caused by a horizontal load H:

$i_c=0.5(1+\surd(1-H/A'C_u))$ [2.3]

For drained condition the design bearing resistance is calculated from:

$R/A=c'N_cS_ci_c+q'N_qS_qI_q+0.5Y'B'N_yS_yI_y$ [2.4]

With the design values of dimensionless factors for the bearing resistance:

$N_q=e^{\Pi\tan\Phi'}\tan^2(45+\Phi'/2)$ [2.5]

$N_c=(N_q-1)\cot\Phi'$ [2.6]

$N_y=2(N_q-1)\tan'$ when $\delta\geq\Phi'/2$ (rough base) [2.7]

The shape of the foundation:

For rectangular shape;

$S_q=1+(B'/L')\sin\Phi'$ [2.8]

$S_y=1-0.3(B'/L')$ [2.9]

For square or circular shape

$S_q=1+\sin\Phi'$ [2.10]

$S_y=0.7$

For rectangular ,square or circular shape

$S_c=(S_qN_q-1)/(N_q-1)$ [2.11]

The inclination of load,caused by a horizontal load H parallel to B':

$i_q=\{1-0.7H/(V+A'c'\cot\Phi')\}^3$ [2.12]

$i_y=\{1-H/(V+A'c'\cot\Phi')\}^3$ [2.13]

$i_c=(i_qN_q-1)/(N_q-1)$ [2.14]

Where

δ =the design base friction angle

q=the design total overburden pressure at the level of the foundation base;

Φ=the angle of shearing resistance

Φ'=the effective angle of shearing resistance

q'=the design effective overburden pressure at the level of the foundation base;

y'=the design effective unit weight of soil below the foundation level

A'=B'L' the design effective foundation area

B'=the design effective foundation width

L'=the design effective foundation length

2.4 Estimation of Settlement and Limiting Values

The total settlement of foundation on cohesive and non-cohesive soil may be estimated by using analytical approach or from field tests like Standard Penetration test. If water table is at shallow depth correction should be applied in settlement computation. [4]
For normal structures with isolated foundations a total settlement of up to 50mm and differential settlements between adjacent columns up to 20mm are often acceptable. Larger total and differential settlements may be acceptable provided that the relative rotations remain with in acceptable limits and the total settlement don't cause problem to service entering the structure or cause tilting etc.[5]

2.5 Ground Property

The soil under the foundations is one of the most variable of all the material that are considered in the design and construction of structures. Under a small building the soil may vary from soft clay to rock. Also the nature and properties of the soil may change with the seasons, and the weather.

Design values of ground properties Xd shall either be drived from characteristic values Xk (such as tanΦ,c',c_u and q_u obtained from table 2.1 of EBCS-7). This could be related as follows:

$$X_d = X_k/\gamma_m \qquad (2.15)$$

Where

X_d = Design values of ground properties

X_k =Characteristic values

γ_m is the safety factor for the ground property

For conventional situations values of γ_m equal to 1.7 may be used.[2]

2.6 Reinforced Concrete Design Strength

Concrete is the most commonly used material for foundation construction. It is strong and durable, is reasonably resistant to ordinary (sometimes even abnormal) acidic or alkaline conditions of soils, and is a convenient and economical construction material, workable and adaptable to field construction and requirements

In basic mechanics it is common practice for structural members subjected to bending to assume that stress is proportional to strain. The triangular stress distribution (e.g Fig 2.1 in compression face) serves for Working Stress Design.

The EBCS code places total emphasis on the ultimate strength design. Thus the guide related to the design and analysis of concrete foundations herein will reflect the EBCS.with virtually total emphasis on and conformity to the allowable strength Design

2.6.1 Load Factor

The EBCS specifies that the service loads be converted to ultimate loads by the following Expressions:.

For dead load and live load only

$$Pu=1.3Gk+1.6Qk \tag{2.16}$$

For wind load is included

$$Pu=0.75(1.3Gk+1.6Qk+1.6Wk) \tag{2.17}$$

When Dead load and wind load only

$$Pu=0.9D+1.3W \qquad (2.18)$$

2.6.2 Capacity Reduction Factor

The nominal design strength is multiplied by a capacity reduction factor in order to account for uncertainties related to material strengths, variation from drawings, workmanship, accuracy of calculations ,exactness of equation, and other possible deviation from ideal or assumed conditions.

2.6.3 Flexure

Strains in concrete members subjected to bending vary almost linearly with the distance from the neutral axis.Stress on the other hand varies in a linear fashion as shown in Fig 2.1a until f_c equals approximately 0.5fc.As the bending moment is increased,the linearity in the stress distribution is lost.; in the process ,the neutral axis is lowered.[4]

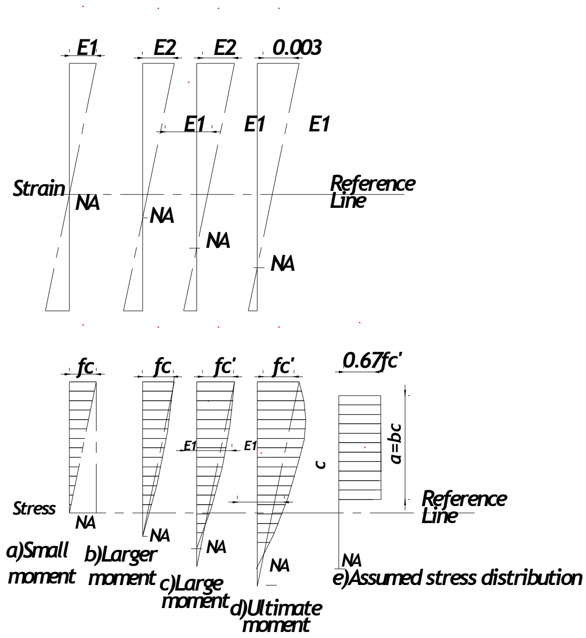


Fig 2.1 Sterss strain relation ship in concrete section.

A simplified rectangular stress block of intensity equals to 0.85 f_c and a depth of $\beta_1 c$ as depicted in fig 2.1 gives acceptable results. The rectangular stress block shown in Fig 2.1 has found virtually universal adoption; it will be the one focused on herein.

Reference is made to Fig 2.2

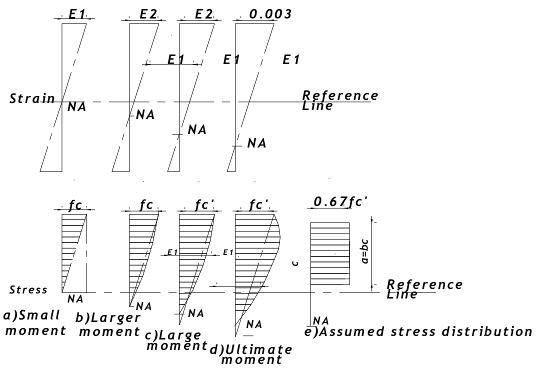


Fig 2.2 Assumption used for the development of the ultimate strength design equation

The ultimate design strength of a concrete section is obtained by dividing its characteristic strength by the appropriate partial safety factor.

Ultimate design strength of concrete

=fcu/Ym =0.67fcu

Ultimate design strength of Reinforcement

=fy/Ys =0.87fy

From $\Sigma F_x=0$, C=T

Thus,

$$0.67f'_c ab=A_sF_y \qquad (2.19)$$

or

$$a=A_sF_y /0.67f_c b \qquad (2\text{-}20)$$

The code limits the tensile reinforcement to a maximum of $0.75\rho_b$.This is designed for the steel to yield prior to sudden concrete failure. Thus the ultimate strength will be governed by the tensile steel.[3]

Hence from $\Sigma M_c = T(d-a/2) = A_s F_y (d-a/2)$ (2-21)

The ultimate moment $Mu=\Phi Mn$ or for $\Phi = 0.9$

$$Mu=\Phi Mn=0.9\ A_s F_y (d-a/2) \qquad (2.22)$$

The expression for a from Eq. 2-1 can be written as:

$$a= A_s F_y / 0.67f'_c b = f_y / 0.67f'_c * (As/bd)*d=(fyd/0.67fc) * (\rho) \qquad (2.23)$$

where ρ=As/bd.Hense substituting for a in equation 2.22

$$Mu=0.9\ A_s f_y\ (d-(d/2)*(fy/0.67fc)*\ \rho)$$

$$=0.9\ A_s f_y\ d\ (1-\ \rho\ f_y/1.7f_c\ )$$

or

$$Mu=0.9\ A_s f_y\ d\ (1-\ 0.59\rho\ f_y/f_c\ ) \qquad (2-24)$$

Also

$$\rho_{max}=0.75\ \rho_b; \qquad \rho_{min}=200/f_y$$

where $\rho_b = A_s/bd$,% at balanced design

The neutral axis may be located by using a linear strain relationship depicted in Fig 2.2b

$$C/d=0.003/(0.003+\ f_y/E_s\ ) \qquad (2.25)$$

From fig 2.2c for balanced design (i.e. $\rho b=A_s/bd$)

$$C=a/\beta_1=\ \rho b\ f_y\ d/0.67\ f_c\ \beta_1 \qquad (2.26)$$

2.6.4 Shear

The code stipulates that Vu=¢Vn and Vn=Vc+Vs.

Vu=ultimate shear;

Vc=shear strength provided by shear reinforcement;

Vs is commonly absent in footings

The code provides the following expression for Vn when evaluating shear forces in footings.

Section evaluated	**Expression**
Wide beam shear	**Vu=(¢/6*Γf_c)bw*d**
Diagonal tension or wide beam shear	**Vu=(¢/3*Γf_c)bw*d**

Where Vu=Shear force

V=allowable shear stress

b_w=width of footing

d=effective depth of footing

¢=0.85

f_c=28 day compressive strength.

3.0 Analaysis and Design of Commonly Used Reinforced Concrete Foundations.

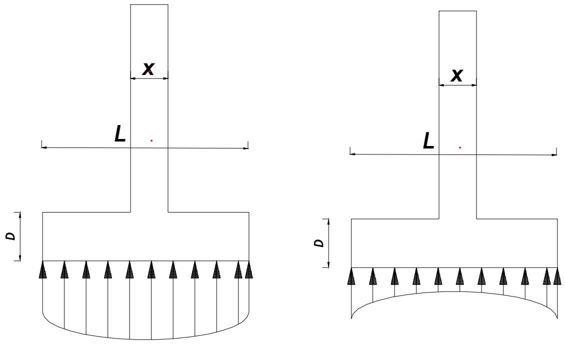
In this chapter an attempt will be made to summaries the background and procedures used for the design of commonly used foundation types. The main types of foundations that are considered here are Isolated footing ,mat foundation and cast in place pile foundation.

3.1 Analysis and Design of Isolated Foundation

A footing carrying a single column is called a spread footing, since its function is to spread the column load to the soil so that the stress intensity is reduced to a value that the soil can safely carry.

3.1.1 Assumptions used in design of Footings.

Analysis and observations using theory of elasticity indicate that the stress distribution beneath symmetrically loaded footing is not uniform. The actual stress distribution depends on both footing rigidity and condition of base soil. For footings on loose sand, the grains near the edge tend to displace laterally, whereas the interior soil is relatively confined. This results in a pressure diagram qualitatively shown in Fig 3.1. Fig 3.2 is the theoretical pressure distribution for the more general case of rigid footings on any material. [8]



a)Footing on Sand *b)Footing on clay*

Fig-3.1 Pressuer distribution under footing

The high pressure may be explained by considering that the edge shear must occur before any settlement can takes place. Since the soil has low rupture strength ,and most footings are of intermediate rigidity ,it is very unlikely that high edge shear stress are not developed.

The pressure distribution beneath most footings will be rather indeterminate because of the interaction of the footing rigidity with the soil type, state and time response to stress. For this reason it is common practice to use a linear pressure distribution beneath spread footing. [9]

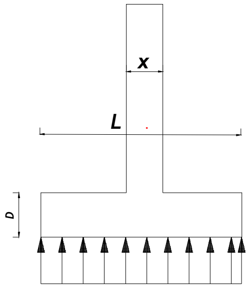


Fig-3.2 Assumed pressure distribution under rigid footings

Assuming a linear distribution under the footings bearing pressure across the base will take one of the three forms shown in figure 3.3 below according to the relative magnitude of the axial load N and the moment M acting on the base.

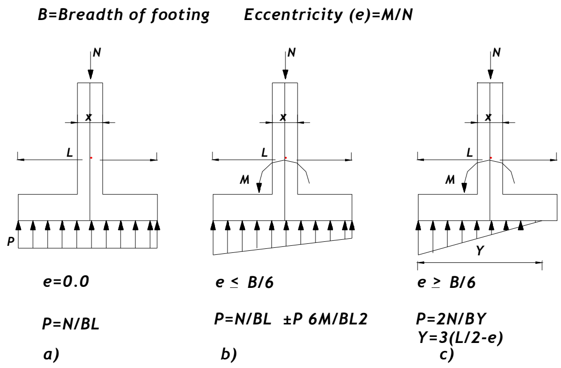


Fig 3.3 Pressure distribution under footings

3.1.2 General Criteria for Spread Footing Design

The name spread or isolated footing encompasses both square and rectangular footings that support column.Shear stress usually governs the thickness of reinforced footings. Diagonal tension stress (or punching shear) always controls the thickness of reinforced square footings subjected to concentric loads; this is true for combined footings as well. Wide beam shear may govern the footing thickness for long footings; generally when the length to width ratio exceeds about 2:1.Thus, if the depth of rectangular footing is calculated based on diagonal shear , a check should be made for wide beam shear stress.

Shear failure never occur on vertical planes. Instead, the diagonal tension cracks develops on planes slopped at approximately 45^0 as shown in Fig 3.4 below. Thus for footings a truncated pyramid is punched out from the footing .It is recommended that diagonal tension shear stress be calculated on planes at a distance of (d/2) from the face of the column. For rectangular footing the shear stress is to be checked across the width of the footing at a distance d from the face of the column.

3.1.3 Design Strength

The design strength for a given material property and limit state is obtained in principle by dividing the characteristic strength f_k by the appropriate partial safety factor for the material property y_m i.e.

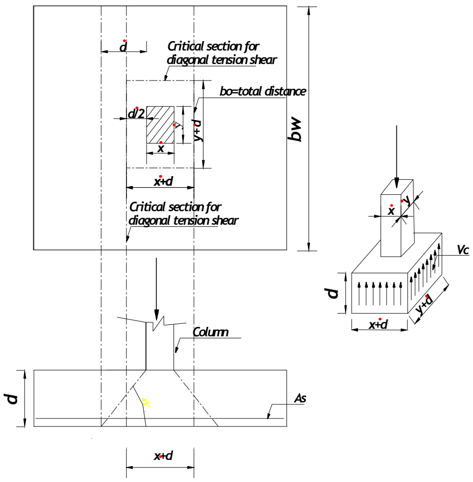


Fig 3.4 Critical section for wide beam shear and diagonal tension shear

Refering to Fig 3.4

$$P_u=2xv_cxd(x+d)+2xv_cxd(y+d)+(x+d)x(y+d)xq \qquad \mathbf{(3.5)}$$

$$P_u=BxLxQ \qquad \mathbf{(3.6)}$$

Thus expanding an rearranging terms eq (a) becomes

$$BxLxQ=d^2x(4v_c+q)+dx(2v_c+q)+(X)x(Y)xq \qquad \mathbf{(3.7)}$$

Or for rectangular columns

$$(BxL-xy)q= d^2x(4v_c+q)+dx(2v_c+q)(x+y) \qquad \mathbf{(3.8)}$$

For square columns x=y.Thus Eq 6-6 becoms

$$(BxL-x^2)q/4= d^2x(v_c+q/4)+(d)x(X)x(v_c+q/2) \qquad \mathbf{(3.9a)}$$

For round columns of diameter 2r Eq 6-6 becoms

$$(BL-Acol)q/\prod= d^2(v_c+q/4)+2dr(v_c+q/2) \qquad \mathbf{(3.9b)}$$

In the above equations q represents the ultimate soil pressure. The allowable soil pressure q_a is part of the given data; so are column dimensions X,Y(or r), and fc'.. Hence one proceeds to solve for d, then to check for wide beam shear stress, hence subsequently to complete the design.[4]

The general procedure for design of isolated footing subjected to concentric load is as follows:

Given: column dimensions and reinforcement; column load; fc' for footing and column, fy for footing and column; q_a

Solution

1. Find P_u
2. Compute the plan dimensions B and L; using the allowable soil pressure $B=(D+L)/q_a$

3. Determine V_c for diagonal tension
4. Determine d via applicable Eqs 6-6,6.6a,or 6-6b.For rectangular footing ,check wide beam shear; the larger d governs
5. Compute the required flexure steel, development length,etc, in each direction .The moment is computed at the critical sections as specified by Code.
6. Compute column bearing stress and select the appropriate dowels
7. Compute a design drawing showing all details(footing dimensions, reinforcement size , spacing cover etc.)

3.2 Mat Foundation

Mat or raft foundations are thickened concrete slabs that support a number of columns or walls; hence, one may view mats as large combined footings. Mats may be preferred over spread footings on strata that are erratic or have low bearing capacities, or large differential settlement is likely if one were to use spread footings. A mat is more economical than footing when the total base area required for individual footing exceeds about one-half of the area covered by the structure.

The use of mat foundation may be also advantageous where the foundation is below water table and there is need to eliminate water infiltration into basement type construction.

As rafts are at some depth below the ground surface, a large volume of soil is excavated and therefore the net pressure on the soil is considerably reduced. An advantage of this reduction in the pressure can be taken while designing the raft.

Mats are reinforced with both positive and negative steel, adequately reinforced to resist moments in both the x and y directions. Generally, this makes a rather large volume of steel reinforcements. In addition, the effort related to the detailing and placing of such reinforcement is significant. Frequently , one is confronted with other concern related to large single pour: special technique and machinery (e.g.,cranes and special buckets for pouring of the concrete, concrete pumps),intense labor preparations and high concrete-volume delivery arrangements [7]

3.2.1 Allowable bearing pressure for mat foundations.

The ultimate bearing capacity of the soil under a mat may be computed using Eq. 3.10,repeated here.

$$Q_u = cN_c d_c s_c i_c + \gamma L N_q d_q s_q i_q + \gamma/2 B N_\gamma s_y i_y \qquad \textbf{(3.10)}$$

The allowable bearing capacity ,q_a is obtained by dividing q_u by a reasonable safety factor. Since mat foundations typically provide a bridging effect over intermittent soft or erratic spots in the soil , mats are usually nonprone to the magnitude of settlement, particular differential settlement, associated with spread footings. Hence the allowable bearing value to be used for design of mat foundation may be somewhat higher than that for spread (isolated)footings.

Based on standard penetration test (SPT), the allowable bearing capacity for an allowable settlement of 50mm may be estimated from:[5]

$$q_a = \frac{N_{55}\ Kd}{F2} \qquad \textbf{(3.11)}$$

Take $F2=0.08$,$Kd=1+0.33D/B \leq 1.33$

With cone penetration data the bearing capacity can be estimated as

$$q_a = \frac{q_c\ Kd}{20} \qquad \textbf{(3.11)}$$

while the above equations are applicable to cohesionless soil,for cohesive soil it may be necessary to supplement unconfined compression data with some what better soil parameter estimate.

Mat foundations are commonly used where settlements may be a problem as where a site contains erratic deposits or lenses of compressible materials, suspended boulders, etc. The settlement tends to be controlled via:

1. Lower point contact pressure.
2. Displaced volume of soil (floatation effect); theoretically if the weight of excavation equals the combined weight of the structure and mat, the system “floats” in the soil mass and no settlement occurs.
3. Bridging effects due to mat rigidity
4. Superstructure-rigidity contribution to the mat
5. Allowing somewhat larger settlements, say 50 instead of 25mm.

3.2.2 Analysis and Design of mat Foundation

Mat may be designed as either rigid or as flexible slabs supported by an elastic stratum, or as a combination of both .The combination approach is common in current practice.
The design of mat foundation presents problems of highly statically indeterminate nature. The method of design depends on the assumption one uses. Basically there are two methods of design, namely the Rigid Method and the Elastic method.

In the rigid method ,it is assumed that the mat is infinitely rigid compared to the sub-soil. The contact pressure under the mat is assumed to be linearly distributed and the centeroid of the bearing pressure coincides with the line of action of the resultant force of all loads acting on the mat.

The method of analysis of elastic method may be divided into two groups.The first group is known as the simplified elastic method or Winkler method,it is based on the assumption that the soil behaves like individual separate elastic springs.The spring constant is usually taken to be the modulus of subgrade reaction of the soil.The second group is known as the true elastic method. This is based on the assumption that the soil is an elastic continuum with a constant or variable modulus of compressibility.[7]

<u>3.2.2.1 Rigid method</u>

A mat foundation is considered to be rigid if it supports a rigid superstructure or when the column spacing is less than 1.75/λ.[7]

. $$\lambda.=[ks.b/4Ec.I]^{1/4} \qquad \textbf{(3.12)}$$

where

Ks=cooeficient of subgrade reaction

b=width of strip of mat between centers of adjacent bays.

Ec =modulus of elasticity of concrete

I=Moment of inertia of the strip of width b

λ =characteristic cooeficient

The above equation is valid for relatively uniform column loads (loads not varying more than 20% between adjacent columns)and relatively uniform column spacing.

A large number of computer programs are commercially available for mat analysis.

Using the ultimate limit strength design method (LSD), the following procedure is summarized for the design of mat foundations:

Proportion the mat using unfactored loads and overturning moments. Thus the pressure distribution will be based on :

$$q=R/A+ M_xY/I_x + M_yX/I_y; \tag{3.13}$$

$$Mx=Re_x \tag{3.14}$$

$$My=Re_y \tag{3.15}$$

where R=resultant=$\sum$P=sum of all loads on mat

A= area of mat

X,Y=coordinate of any point on the mat where q is to be determined

e_x ,e_y =eccentricity of the resultant, R, with respect to X- and Y-axes

I_x and I_y =moment of inertia of mat area with respect to the X- and Y-axes

Determine the mat thickness (minimum) based on punching shear at critical columns based on column load and shear parameter.Avoid the use of shear reinforcement; the thickness of the mat will be determined based on the punching shear strength of unreinforced concrete.

Design the reinforcing steel for bending by treating the mat as a rigid body and isolated strips in perpendicular directions, provided the following criteria are met:

a)Column spacing is less than 1.75/λ, or the mat is very thick, and

b)Variation in column loads and spacing is not over 20%.

These strips are analyzed as independent continuous , or combined footings with multiple column loads , supported by soil pressure on the strip, and column reactions equal the factored loads obtained from the superstructure analysis. Consideration of the shear strength transfer between strips may be necessary to satisfy the summation of forces in the vertical directions

3.2.2 The elastic method

In analyzing raft foundation according to the elastic method one bases its calculation on the well known deflection equation of the plate.

The general equation for the deflection of the plate acted upon by external loads p(x,y) and contact pressure Ơ(x,y) is given by

$$\Delta\Delta w=1/Nx\ [P(x,y)- Ơ(x,y)] \tag{3.16}$$

Where w=deflection of the plate

N=stiffness of the plate=E’xI/b

$E'=E/(1-\mu^2)$

E=modulus of elasticity of the plate

μ =Poissons ratio of the plate

I=moment of inertia of the plate having a width of

P(x,y) = External load on the plate

Ơ(x,y) = contact pressure acting on the plate

The solution of equation *for variable external loading in both direction is complicated. One normally takes the variation of loading in one direction only. The equation would then be simplified to

$\Delta\Delta w=1/Nx\ [P(x)-\sigma(x)]$ ** (3.17)

It is in the analysis of this equation that different matimatical models are used for representing the foundation soil in elastic method.[7]

3.3 Pile Foundations

3.3.1 Introduction

A pile is a slender structural member installed in the ground to transfer the structural loads to the soil at some significant depth below the base of the structure. Structural loads include axial loads, lateral loads and moments. In this part bored and cast in place piles will be discussed.

Pile foundations are used when:

- **The soil near the surface does not have sufficient bearing capacity to support the structural loads.**
- **The estimated settlement of the soil exceeds tolerable limits (i.e. settlement greater than the serviceability limit state)**
- **Differential settlement due to soil variability or no uniform structural loads is excessive**
- **The structural loads consist of lateral loads and/or uplift forces**
- **Excavation to construct a shallow foundation on a firm soil layer are difficult or expensive.**

3.3.2 Types of piles and installation

Piles are made from concrete or steel or timber. The selection of the type of pile required for a project depends on what type of pile is readily available, the magnitude of the loading , the soil type and the environment in which the pile will be installed.

Commonly in Ethiopia ,the cast in site piles are used. This attribute to lack of pile driving equipment required for pre cast piles.

Advantages of using Boared and Cast in situ piles.

1. Length can be varied to suit variation in the level of bearing stratum
2. Soil or rock removed during boaring can be inspected for comparison with site investigation data.
3. In situ loading tests can be made in large diameter pile boreholes ,or penetration test made in small boreholes.
4. Very large bases can be formed in favorable ground.
5. Drilling tools can break up very large boulders or other obstruction which can not be penetrated by any form of displacement pile.
6. material forming pile is not governed by handling or driving stress
7. Drilling can be done in very long lengths
8. Installation can be done without appreciable noise or vibration
9. Ground heave is not significant.
10. Installation could be done in conditions of low headroom.

Disadvantage

1. Concrete in shaft is liable to squeezing or necking in soft soils where conventional types are used.
2. Special techniques are used for concreting in water bearing soils.
3. Concrete can not be inspected after installation
4. Enlarged bases cannot be formed in cohesionless soils
5. drilling a number of piles in group can cause loss of ground and settlement of adjacent structures.

3.3.2.1 Concrete Piles

There are different types of concrete piles that are commonly used. These includes cast-in-place concrete piles, and drilled shafts. Cast in place concrete piles are formed by driving a cylindrical steel shell into the ground to the desired depth and then filling the cavity of the shell with fluid concrete.

Precast concrete piles usually have square or circular or octagonal cross-sections and are fabricated in a construction yard from reinforced concrete or prestressed concrete. They are preferred when the pile length is known in advance. The disadvantaged of concrete precast piles are problems in transporting long piles, cutting and lightening.

3.3.3 Ultimate Capacity of a pile

The pile support is realized from two sources:

1)end-bearing

and 2) side friction.

Although the percentage of the pile load assumed by the friction or the end bearing will generally vary widely with different situations, static equilibrium dictates that

$$Q_u=Q_p+Q_s \qquad (3.18)$$

where Q_u**=total pile load**

Q_p**=point resistance (end-bearing)**

Q_s**=side friction resistance**

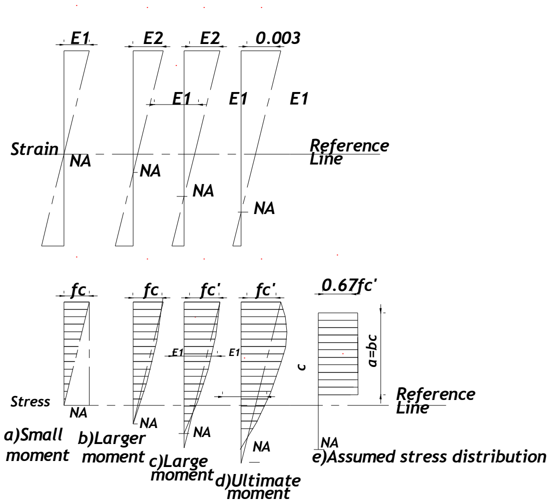


Figure 4.1 shows the forces acting on a pile as described by Eq.11.1.The magnitude of Qp can be estimated with acceptable accuracy by using a form of the general bearing capacity formula. The shapes and depth factors are replaced with compensating terms more representative of the conditions associated with different types of soil, types and length of piles, methods of installation, and other factors. However in general Q_p may be estimated as [6]

$$Q_p = A_p\,(cN_c + \gamma L N_q + 0.5(\gamma) B N_\gamma) \qquad \textbf{(3.19)}$$

The total support provided by friction Qs could be estimated as the product of the surface area (product of perimeter p and length) of the pile in contact with the soil times the average shear resistance per unit area S_s developed between the soil and the pile, that is , $Q_s = pL\ S_s$ .However the unit shear resistance S_s vary over the length of the pile, an average unit resistance is difficult to ascertain with any degree of accuracy. It would be more logical to express the total resistance derived from friction as the sum of unit resistances These are expressed by Eq 3.20, where ΔL is the increment of pile length. For a layered system and/or varied sections,

$$Q_s = \Sigma\ (\Delta L)\ p_i\ S_{si} \qquad \textbf{(3.20)}$$

For uniform soil characteristics (S_s =constant) and constant section (p=constant),

$$Q_s=pL\ S_s \qquad \textbf{(3.21)}$$

Substituting the equivalent quantities from Eqs.3.20 and 3.21 into Eq.13.18 one obtains a general ultimate load bearing capacity for piles as given by Eq.3.22.That is for layered system and /or varied pile sections the ultimate load becomes

$$Q_p= A_p\,(cN_c+\gamma LN_q+\gamma/2BN_\gamma)+ \Sigma\ (\Delta L)\ p_i\ S_{si} \qquad \textbf{(3.22)}$$

As a special case ,for uniform soil strength (S_s =constant) or constant pile section (p=constant) and round piles of radius R, we have

$$Q_u= \Pi r^2\,(cN_c+\gamma LN_q+\gamma/2BN_\gamma)+ 2\Pi rL\ S_s \qquad \textbf{(3.23)}$$

Q_u =ultimate bearing capacity of a single pile

S_{si} =shaft resistance per unit area at any point along pile

B=general dimension for pile width

A_p =cross sectional area of pile at point(bearing end)

R=radius of pile at given increment of length

p_i =perimeter of pile in contact with soil at any point

L=total length of embedment of pile

γ =unit weight of soil

c=effective cohesion of soil

N_c,N_q,N_γ =bearing capacity factors

3.3.4 Friction pile in cohesionless soils

When a pile is driven into a cohessionless soil , the density of the stratum is increased due to (1) the volume displacement (volume equal to the volume of the embedded portion of the pile):and (2) the densification resulting from the driving vibratos.

The ultimate bearing capacity Q_u is the sum of the forces realized from skin-frictions and end bearing as expressed by equation 3.18.The expansion of this equation given by Eq 3.19 can be used to determine the capacity of pile in granular formation with some modifications. That is it is readily apparent that for cohesionless case (c=o) the first term of equation Eq.3.19 drops out. Further more , the third term (N_γ term) is relatively small when compared with the middle term.Hense ,a reasonable approximation for the ultimate bearing capacity of piles in cohesionless materials could be given by Eq 3.24

$$Q_p= A_p\,\gamma LN_q+ \Sigma\ (\Delta L)\ p_i\ S_{si} \qquad (3.24)$$

The above equation simply that both end bearing and total skin resistance would increase with increasing depth for a homogeneous stratum. However experimental evidence and field observation indicate that the end-bearing capacity reaches some upper limits and does not increase infinitely with depth. It appears that crushing,compressibility,and general failure in the zone near the pile tip , as well as other factors, impose an upper limit on the ultimate bearing capacity of a given pile. Letting Ơ represents the effective overburden pressure at the pile tip ,the tip resistance could be represented by

$$Q_p= A_p\ \text{Ơ}\ N_q \le\ A_p\ \text{Ơ}_e \qquad \textbf{(3.25)}$$

Where σ_e represents some limiting value for end bearing for which the depth D equals or greater than the critical depth (that is, $D \leq D_c$).

$$S_s = K_s \sigma_e \tan\delta \qquad \textbf{(3.26)}$$

And therefore the value for Q_s is given by eq (c)

$$Q_p = \Sigma\, p_i\, (\Delta L)\, K_s\, \sigma_e \tan\delta \qquad \textbf{(3.27)}$$

Where K_s =average coefficient of earth pressure on the pile shaft

σ_e =average effective overburden pressure along the pile shaft

δ= angle of skin friction

$\tan\delta$=coefficient of friction between soil and pile surface

3.3.5 Pile group

In most practical situation, piles are used in groups. They are arranged in geometric pattern (squares,rectangles,circles, and octagons)at spacing center to center distance),not less than 2D (where D is the diameter or width of the pile).The piles are connected at their heads by a pile cap which may or may not be in contact with the ground. If the pile cap is in contact with the ground ,part of the load will be transferred directly to the soil.

The load capacity of a pile group is not necessarily the load capacity of a single pile multiplied by the number of piles.In fine grained soil the outer piles tend to carry more loads than the piles in the center of the group.In coarse grained soils the piles in the center take more loads than the outer piles.[7]

The ratio of the load capacity of a pile group,$(Q_{ult})_g$ to the total load capacity of the piles acting as individual piles (nQ_{ult}) is called efficiency factor,η_e;that is

$$\eta_e = \frac{(Q_{ult})_g}{(nQ_{ult})} \qquad (3.28)$$

where n is the number of pile in the group and $\underline{Q_{ult}}$ is the ultimate load capacity of a single pile.

Two modes of soil failure are normally investigated to determine the load capacity of a pile group. One mode called block failure may occur when the spacing of the piles is small enough to cause the pile group to fail as a unit. The group load capacity for block filure mode is based on a perimeter defined by the exterior piles. The other mode is determined by the sum of the capacity of the individual piles.

3.3.6 Pile caps

A pile cap has the function of spreeding the load from one compassion or tension member to the other in a group of piles so that as far as possible ,the load is shared equally between the piles.The pile cap also accommodates deviation from the intended position of piles ,and by rigidily connecting all the piles in one group by a massive block of concrete the ill effect of one or more defective piles are overcomed by redistributing the loads.

A single pile is seldom used except when th top portion of the pile extends above the ground level to act as a column. Even piles under walls are placed in row and are provided with a reinforced concrete cap on the top.These caps act as a rigid footing that rest on the pile and are subjected to concentrated reaction from the piles.The load on the pile caps includes the superstructures load and the moment at the foundation level,the weight of the soil above the cap and the weight of the cap.

In the design of pile cap the following assumptions are usually made:

- the pile cap is perfectly rigid
- the pile heads are perfectly hinged to the pile cap,.as a result no bending moment is transmitted from the pile cap to the piles.
- The deformations and stress distributions are considered planar.

The structural design of pile cap is similar to the design of reinforced concrete footings. The critical sections ,for moment punching shear and bond stress (development length of reinforcement) are taken to be at the same location as defined for isolated footing.

- **The pile cap should be deep enough to allow for the necessary overlap of the columns and the pile reinforcement.**

- **The reaction from piles is calculated from:**

$$R_p = Q/n \pm M_y x/\Sigma x^2 \pm M_x y/\Sigma y^2$$

Where M_x and M_y = moments with respect to x and y axis.

Q= total vertical load at the centeroid of the cap

N= number of piles in the group under the cap

X,y,=distance from x-axis to y-axis

4. Current practice on Analysis and Design of foundation.

This chapter deals with the current practice on design of foundations which are widely used in many consulting firms. Enough data was collected from different consulting firms to investigate the different methods of foundation design.

4.1 Current practice on Analysis and Design of Isolated foundation.

The trend in the design of isolated foundation is to collect the whole foundation reaction and to form a group according to their magnitude. The group formation depends on the range of reaction magnitude and the experience of the foundation designer.

After forming groups the footing is designed by taking the maximum reaction from each group. All other footings in the group will have the section and reinforcement for the largest footing in the group.

4.1.1 Hand Calculation for design of Isolated Foundation

In most design offices footings are designed manually. In this part the design of isolated foundation will be explained by solving one practical example.

Design of isolated Footing

Iterative calculations in determining adequate depth and size of foundation are initially solved

Footing load varies from 100kN to 311kN and footings are grouped in to two as follows.

Footing Group F1=311kN

Footng Group F2=150kN

Foundation depth=1.25m

Assume a footing size of 2x2.0m and thickness D=25cm.

Own weight of footing=1.3x0.25x2x2x25=32.5

Soil weight =1.3x2x2x1.25x17=$\underline{110.5}$

143kN

Allowable soil pressure σ_{all}=100kpa

Material

Concrete C-30

Fcd=0.67x30/1.5=13.4Mpa

$Fctd=\frac{0.35\sqrt{30}}{1.5}=1.28Mpa$

Steel strength S=300

$Fyd=\frac{300}{1.5}=261Mpa$

Allowable punching resistance of concrete

Vup=0.5fctd(1+50ρ) , use ρ= ρmin=0.002

0.5x1.28x1000(1+50x0.002)=704kpa

Vup=231/4(0.4+0.15)0.15=700<704 ok

$M=\frac{250x(l^2)}{2x2}$, l'=0.8m

$=(250/4) X(0.8^2)/2=20Knm/m$

$kd=0.15/\underline{\sqrt{20/1}}$ =0.034 ks=4.01

$As=4.01x20/0.15=531mm^2/m$

Using dia 12mm reinforced

Spacing , S=113000/535=211mm

Use diameter12mm with c/c 200mm

Iterative calculations in determining adequate depth and size of foundation are initially solved

4.1.2 Design of Isolated Foundation using Microsoft Excel

- **In some consulting offices some programs are developed using Microsoft excel for the design of footing foundation.**

Such programs will not make the design completely, rather they aid the designer by giving results immediately for each iteration in the design process.
As an example design of isolated foundation will be considered here.

FOOTING DESIGN PROGRAMME			
Take rho = ρ_{min} = 0.002			
S =	*300*		***260.87***
C =	*25*	*fct=0.67*fyk/1.5*	**11.17**
f_{ctd} = 0.35*(f_c)^0.5/1.5=	*1.17*		
Allowable punching resistance of concrete, Vup(Kpa)	***= 0.5fctd(1+50*rho)***	=	**816.67**
Allowable bearing pressure, σ (Kpa)	**370**		
Allowable wide beam shear resistance of concrete, v_{ud} (Kn/m^2)		=	**700.00**
Foundation depth, f_d (m)	***3.00***		
Unit weight of soil, γ_s (Kn/m^3)	***18.00***		
Column width, a (m)	***0.40***		
Footing Group	***1***		
Super-structural load, P_s (Kn)	***3515.00***		
1	***3.50***	***3.50***	4
Footing Area, A(m^2)	***12.25***		
Depth, D (m)	***0.85***		
Effective depth, d (m)	***= D - 0.05***		***0.80***
Own Weight of Footing, Wc (Kn)	***=1.3*A_f*d*g_s***	=	***338.41***

Soil Weight , Ws(Kn)	$= 1.3*A_f*(f_d-d)*g_s$	=	616.30
Total load on footing, P_T (Kn)	= Ps+Wc+Ws	=	4469.70
Checking Bearing Capacity	$= P_T/A$	=	364.87
Punching Shear, Vp (kn)	$= P_s*(1-((a+d)/L)$^2 =	=	3101.81
Punching Shear Stress, Vup (Mpa)	$= V_p/(4(a+d)*d)$	=	807.76
Wide beam Shear, V_{up} (Kn)	= Ps/Af(L/2-d-a/2)	=	215.20
Wide beam Shear stress (Kn/m^2)	= Vup/(b*d)	=	269.01
Design Moment, M_d (Kn-m/m)	= (Ps/Af)*((L-a)/2)^2*0.5	=	344.69
N	= (Mu*10E+6/fcd*b*d^2)	=	0.048
B	1 -(1 - 2*N)^0.5		0.049
As	B*fcd*b*d/fyd		1693.49
Asmin	0.5/fyk*b*d		1336.00
Asing (3.14*d^2/4)	16.00		201.14
Spacing *for As*	Asig*1000/As		118.77
Spacing *for Asmin*	Asig*1000/Asmin		150.56
Final		*use dia. 16 c/c 110*	

In the design shown above data like foundation depth, column size, concrete and steel strengths and allowable bearing capacity will be adjusted according to the proposed site conditions.

Footing sizes and depth will be determined by trial and error. Finally the program will determine the required amount of reinforcement and the spacing of reinforcement for the selected diameter of reinforcement bar.

4.1.3 Design of Isolated Foundation using Commercially available software SAFE

The software is developed by using Finite Element Method.The program also

Shows the whole foundation part graphically.It has also options for flat slabs ,mat slabs,and combined footings.

In the design text box data like column size, concrete and steel strengths and allowable bearing capacity will be adjusted in the inquiry text box.

Footing sizes and depth will be determined by trial and error.Finally the program will determine the stresses and amount of reinforcement. Required.

4.2 Current practice on Analysis and Design of Mat foundation.

The trend in selection of foundation for high-rise buildings is almost always tends to the use mat foundation.The design of mat foundation presents problems of highly statically indeterminate nature. The method of design depends on the assumption one uses. Basically there are two methods of design, namely the Rigid Method and the Elastic method.

In the rigid method ,it is assumed that the mat is infinitely rigid compared to the sub soil.The contact pressure under the mat is assumed to be linearilly distributed and the centeroid of the bearing pressure coincides with the line of action of the resultant force of all loads acting on the mat.

The method of analysis of elastic method may be divided into two groups. The first group is known as the simplified elastic method or Winkler method, it is based on the assumption that the soil behaves like individual separate elastic springs. The spring constant is usually taken to be the modulus of sub grade reaction of the soil. The second group is known as the true elastic method assumes that the soil is as elastic continuum with a constant or variable modulus of compressibility.

4.2.1 Procedures on analysis and Design of Mat Foundation

.

The procedure for conventional design of Mat foundation consist of the following steps.

1. Determine the line of action of all loads acting on the raft .The self weight of the raft is not considered, as it is taken directly by the soil.
2. Determine the contact pressure distribution as under
    a. If the resultant passes through the center of the raft, the contact pressure is given by
        i. $Q=P/A$
    b. b) If the resultant has an eccentricity of ex and ey in X and Y directions.
        i. $Q=\frac{P}{A} + \frac{P.ex.X}{Iyy} + \frac{P.ey.Y}{Ixx}$
    c. The maximum contact pressure should be less than the allowable soil pressure
3. Divide the slab into strips (bands) in the X and Y directions. Each strip is assumed to act as independent beams subject to the contact pressure and the column loads
4. Design the individual strips for the bending moment and shear force. The raft is designed as an inverted floors supported at columns
5. In the case of ribbed slab, the slab between the stiff beams will be analyzed initially and the load from the slab to the mat beams will be transferred.
6. Finally the mat beam will be designed for the load transferred from the slab

4.3 Current practice on Analysis and Design of Cast-in place Reinforced Concrete Pile foundation.

Cast in place piles are made by pouring concrete in a prepared bore hole. Generally such piles are divided into three categories.

Advantage of Using cast in place piles

- Relatively large bearing capacity can be developed
- They can be treated for sea water installation.

- They are easier to alter pile lengths
- Damage due to handling and driving can be eliminated.
- They can be installed by pre-excavation thus eliminating vibrations due to driving.

But it takes longer construction time .The quality control and construction below ground water level is difficult.

4.3.1 Procedure on analysis and design of Board and cast in place pile foundation.

The following procedure is usually followed on Analysis and design of cast in place piles

i) The foundation strata engineering properties (bearing capacity and skin friction resistance of each layer) will be determined
ii) pile arrangement will be determined
iii) the maximum pile reaction due to the superstructure load and self weight of pile cap will be calculated according to the selected arrangement.
iv) The pile length for the maximum pile reaction will be calculated by trial and error.
v) The strength of the pile for the maximum reaction will be checked
vi) the group pile capacity will be compared with the applied load
vii) finally pile cap will be designed

5. Developing a Software for Analysis and Design of foundation.

5. 0 General

The usual trend in the analysis and design of commonly used reinforced concrete foundation is by using manual calculation. However for superstructure part of buildings adequate softwares are easily available for analysis and design of foundation. In design of foundation manually commonly there are a lot of iteration. Due to these the designers are faced with problems to arrive at proper solution immediately. As a result foundations are designed conservatively so as to avoid a no of iteration steps in foundation design.

In this chapter an attempt will be made to develope programs which aid analysis design and cost estimation of foundation by using Fortran-90 programming language. Moreover the developed programs are arranged to be compatible with the output data of commonly used superstructure analysis software's like SAP2000.

5.1. Importing Inputs and Outputs of Super Structure for Analysis and Design.

Most structural analysis software commercially available produces thousand pages of input and output text data. Most of the data produced by the software's are not required for analysis and design of foundation. The main objective of this chapter is to develop a program which selects data which are required for analysis and design of foundation from superstructure analysis software.

5.1.1 Inputs of Super structure Analysis

Inputs of super structure analysis which are important for analysis and design of the foundation include:

Foundation identification (Joint identification of each foundation)

Relative location of the foundation (Coordinates in the three directions)

Foundation Column size and its reinforcement

As a sample input data of SAP-2000 structural analysis software is shown below.

```
 SAP2000 v6.11 File: BUILDINB  KN-m Units  PAGE 1
 January 31, 2002 16:37


 Private co.
```

```
S T A T I C   L O A D   C A S E S

   STATIC     CASE    SELF WT
    CASE      TYPE    FACTOR

    LOAD1     DEAD    1.0000

SAP2000 v6.11 File: BUILDINB  KN-m Units  PAGE 2
January 31, 2002 16:37

Private co.

 J O I N T   D A T A

  JOINT     GLOBAL-X     GLOBAL-Y     GLOBAL-Z    RESTRAINTS   ANGLE-A
ANGLE-B   ANGLE-C

     21    -7.50000    -6.00000     0.00000   1 1 1 1 1 1    0.000    0.000    0.000
     26    -7.50000    -2.00000     0.00000   1 1 1 1 1 1    0.000    0.000    0.000
     31    -7.50000     2.00000     0.00000   1 1 1 1 1 1    0.000    0.000    0.000
     36    -7.50000     6.00000     0.00000   1 1 1 1 1 1    0.000    0.000    0.000
     41    -2.50000    -6.00000     0.00000   1 1 1 1 1 1    0.000    0.000    0.000
     46    -2.50000    -2.00000     0.00000   1 1 1 1 1 1    0.000    0.000    0.000
     51    -2.50000     2.00000     0.00000   1 1 1 1 1 1    0.000    0.000    0.000
     56    -2.50000     6.00000     0.00000   1 1 1 1 1 1    0.000    0.000    0.000
     61     2.50000    -6.00000     0.00000   1 1 1 1 1 1    0.000    0.000    0.000
     66     2.50000    -2.00000     0.00000   1 1 1 1 1 1    0.000    0.000    0.000
     71     2.50000     2.00000     0.00000   1 1 1 1 1 1    0.000    0.000    0.000
     76     2.50000     6.00000     0.00000   1 1 1 1 1 1    0.000    0.000    0.000
     81     7.50000    -6.00000     0.00000   1 1 1 1 1 1    0.000    0.000    0.000
     86     7.50000    -2.00000     0.00000   1 1 1 1 1 1    0.000    0.000    0.000
     91     7.50000     2.00000     0.00000   1 1 1 1 1 1    0.000    0.000    0.000
```

```
 96     7.50000      6.00000      0.00000   1 1 1 1 1 1    0.000    0.000    0.000
101    12.50000     -6.00000      0.00000   1 1 1 1 1 1    0.000    0.000    0.000
106    12.50000     -2.00000      0.00000   1 1 1 1 1 1    0.000    0.000    0.000
111    12.50000      2.00000      0.00000   1 1 1 1 1 1    0.000    0.000    0.000
116    12.50000      6.00000      0.00000   1 1 1 1 1 1    0.000    0.000    0.000
```

The above input data are taken from Superstructure analysis software by selecting joints which are at foundation levels.If all the foundation level is the same, it is possible to select the whole foundation id and coordinate by selecting a plane with with a window plane which is at foundation level.

Text data which describe the structural analysis model file name,load cases and joint data are different for different load cases and load combinations .This affects the space taken by these texts.To avoid these variations all descriptions out of joint id and coordinates will be erased and saved in different file with the required format of the program for importing inputs of superstructure analysis software.

In this paper the proper input data is saved by ‘AA1.txt’

From the above data the program to selects joint identifcation and coordinates of each foundation.

5.1.2 Program for importing Inputs of Super structure Analysis

The program shown below import inputs of superstructure data which are required for analysis and design of foundation and prints in suitable format for design of foundation

```
PROGRAM IMPORTING INPUTS OF SAP  [PROGRAM-01]
IMPLICIT NONE
INTEGER I,N
REAL ,DIMENSION(:),ALLOCATABLE::X,Y,Z
!X,y,z =coordinates of foundations
INTEGER ,DIMENSION(:),ALLOCATABLE::JID
PRINT*,"HOW MANY FOOTINGS DO YOU HAVE?"
READ*,N
ALLOCATE(JID(N))
ALLOCATE(X(N))
ALLOCATE(Y(N))
ALLOCATE(Z(N))
OPEN(11,FILE='AA1.TXT',STATUS='OLD')
DO I=1,N
READ(11,10)JID(I),X(I),Y(I),Z(I)
!READ(11,*)
10 FORMAT(I9,F15.5,F15.5,F15.5)
END DO
```

```
PRINT*,"THE OUT PUT FILE LOOKS LIKE THIS"
DO I=1,N
PRINT*,JID(I),X(I),Y(I),Z(I)
END DO
OPEN(21,FILE='DATA5.TXT',STATUS='OLD')
WRITE(21,40)
40 FORMAT(" THIS IS THE OUT PUT FILE OF THE JOINT IDENTIFICATION NUMBER& COORDINATES FOR EVERY JOINT")
WRITE(21,30)
30 FORMAT("  JOINT ID          X              Y              Z")
DO I=1,N
WRITE(21,20)jid(I),x(I),y(I),z(I)
20 FORMAT(i9,F15.5,F15.5,F15.5)
END DO
END PROGRAM
```

```
THIS IS THE OUT PUT FILE OF THE JOINT IDENTIFICATION NUMBER& COORDINATES
FOR EVERY JOINT
  JOINT ID          X              Y              Z
       21       -7.50000       -6.00000        0.00000
       26       -7.50000       -2.00000        0.00000
       31       -7.50000        2.00000        0.00000
       36       -7.50000        6.00000        0.00000
       41       -2.50000       -6.00000        0.00000
       46       -2.50000       -2.00000        0.00000
       51       -2.50000        2.00000        0.00000
       56       -2.50000        6.00000        0.00000
       61        2.50000       -6.00000        0.00000
       66        2.50000       -2.00000        0.00000
       71        2.50000        2.00000        0.00000
       76        2.50000        6.00000        0.00000
       81        7.50000       -6.00000        0.00000
       86        7.50000       -2.00000        0.00000
       91        7.50000        2.00000        0.00000
       96        7.50000        6.00000        0.00000
      101       12.50000       -6.00000        0.00000
      106       12.50000       -2.00000        0.00000
      111       12.50000        2.00000        0.00000
      116       12.50000        6.00000        0.00000
```

5.1.3 Outputs of Super structure Analysis

These include foundation reactions mainly forces and moments.

```
 SAP2000 v6.11 File: BUILDINB  KN-m Units  PAGE 1
 January 31, 2002 16:37

 Private co.


 L O A D   C O M B I N A T I O N   M U L T I P L I E R S

  COMBO    TYPE    CASE    FACTOR  TYPE        TITLE

  COMB1     ADD                          COMB1
           LOAD1    1.3000  STATIC(DEAD)


 SAP2000 v6.11 File: BUILDINB  KN-m Units  PAGE 2
 January 31, 2002 16:37

 Private co.


 J O I N T   R E A C T I O N S

    JOINT  LOAD          F1        F2        F3        M1        M2        M3

     21  COMB1       17.9746   11.1690   922.6594  -11.0919   17.9971    0.0000

     26  COMB1       17.9746   -0.2918  1333.5327    0.2139   17.9971    0.0000

     31  COMB1       17.9746    0.2918  1333.5327   -0.2139   17.9971    0.0000
```

36	COMB1	17.9746	-11.1690	922.6594	11.0919	17.9971	0.0000
41	COMB1	-0.5078	11.1690	1447.9595	-11.0919	-0.2627	0.0000
46	COMB1	-0.5078	-0.2918	1858.8329	0.2139	-0.2627	0.0000
51	COMB1	-0.5078	0.2918	1858.8329	-0.2139	-0.2627	0.0000
56	COMB1	-0.5078	-11.1690	1447.9595	11.0919	-0.2627	0.0000
61	COMB1	0.0000	11.1690	1431.6542	-11.0919	0.0000	0.0000
66	COMB1	0.0000	-0.2918	1842.5275	0.2139	0.0000	0.0000
71	COMB1	0.0000	0.2918	1842.5275	-0.2139	0.0000	0.0000
76	COMB1	0.0000	-11.1690	1431.6542	11.0919	0.0000	0.0000
81	COMB1	0.5078	11.1690	1447.9595	-11.0919	0.2627	0.0000
86	COMB1	0.5078	-0.2918	1858.8329	0.2139	0.2627	0.0000
91	COMB1	0.5078	0.2918	1858.8329	-0.2139	0.2627	0.0000
96	COMB1	0.5078	-11.1690	1447.9595	11.0919	0.2627	0.0000
101	COMB1	-17.9746	11.1690	922.6594	-11.0919	-17.9971	0.0000
106	COMB1	-17.9746	-0.2918	1333.5327	0.2139	-17.9971	0.0000
111	COMB1	-17.9746	0.2918	1333.5327	-0.2139	-17.9971	0.0000
116	COMB1	-17.9746	-11.1690	922.6594	11.0919	-17.9971	0.0000

5.1.4 Program for importing Outputs of Super structure Analysis

[PROGRAM-02]

The program shown below imports outputs of superstructure data and prints in suitable format for design of foundation

`From this file the program imports foundation reactions.`

```
PROGRAM IMPORTING SAP OUTPUTS.

IMPLICIT NONE

INTEGER I,N

REAL ,DIMENSION(:),ALLOCATABLE::FR3,M1,M2

PRINT*,"HOW MANY FOOTINGS DO YOU HAVE?"

READ*,N

ALLOCATE(FR3(N))

ALLOCATE(M1(N))

ALLOCATE(M2(N))

OPEN(11,FILE='AA.TXT',STATUS='OLD')

DO  I=1,N

READ(11,10)FR3(I),M1(I),M2(I)

READ(11,*)

10 FORMAT(51X,F10.5,5x,F10.3,F10.3)

END DO

PRINT*,"THE OUT PUT FILE LOOKS LIKE THIS"
```

```
DO I=1,N
PRINT*,FR3(I),M1(I),M2(I)
END DO
OPEN(21,FILE='DATA4.TXT',STATUS='OLD')
WRITE(21,30)
30 FORMAT(" THIS IS THE OUTPUT FILE OF THE AXIAL LOAD AND THE MOMENTS IN THE 3 DIRECTIONS")
WRITE(21,40)
40 FORMAT("      F3        M1         M2")
DO I=1,N
WRITE(21,20)FR3(I),M1(I),M2(I)
20 FORMAT(F10.3,F10.3,F10.3)
END DO
END PROGRAM
```

The file containing superstructure analysis software output are saved with the required format by the name ‘data4.txt’.

```
THIS IS THE OUTPUT FILE OF THE AXIAL LOAD AND THE MOMENTS IN THE 3
DIRECTIONS
      F3        M1         M2
   922.659    11.092    17.997
  1333.533     0.214    17.997
  1333.533    -0.214    17.997
   922.659    11.092    17.997
  1447.959    11.092    -0.263
  1858.833     0.214    -0.263
```

```
 1858.833    -0.214    -0.263
 1447.959    11.092    -0.263
 1431.654    11.092     0.000
 1842.527     0.214     0.000
 1842.527    -0.214     0.000
 1431.654    11.092     0.000
 1447.959    11.092     0.263
 1858.833     0.214     0.263
 1858.833    -0.214     0.263
 1447.959    11.092     0.263
  922.659    11.092   -17.997
 1333.533     0.214   -17.997
 1333.533    -0.214   -17.997
  922.659    11.092   -17.997
```

5.2 Program for Analysis and design of Foundation.

[PROGRAM-03]

The program below reads outputs of SAPINPINPUTS.F90 and SAPOUTPUT.F90 and other engineering properties of soil and determines the depth, size and reinforcement of all footings. More over it will print in suitable format for quantifying.

```
PROGRAM footing design
IMPLICIT NONE
INTEGER ,DIMENSION(:),ALLOCATABLE::JID,dia12,dia14,dia10
INTEGER I,N,J
REAL RHO,FYK,FCK,CW,FD,QALL,FCD,FCTD,FYD,COEFA,COEFB, VCP,VCWB
REAL ,DIMENSION(:),ALLOCATABLE:: AF,FSIZE,PT,FR3,MD,NU,QACT,EFFD,M1,M2,EX,EY
REAL ,DIMENSION(:),ALLOCATABLE::WC,WS,DT
REAL ,DIMENSION(:),ALLOCATABLE:: COEFC,DESCRM,DEFFP,DEFFWB,BA,AS,ASMIN
PRINT*,"HOW MANY FOOTINGS DO YOU HAVE?"
READ*,N
ALLOCATE(AF(N))
ALLOCATE(FSIZE(N))
ALLOCATE(FR3(N))
ALLOCATE(MD(N))
```

```
ALLOCATE(PT(N))
ALLOCATE(NU(N))
ALLOCATE(BA(N))
ALLOCATE(COEFC(N))
ALLOCATE(DESCRM (N))
ALLOCATE(DEFFWB(N))
ALLOCATE(AS(N))
ALLOCATE(QACT(N))
ALLOCATE(ASMIN(N))
ALLOCATE(DT(N))
ALLOCATE(JID(N))
ALLOCATE(DEFFP(N))
ALLOCATE(WS(N))
ALLOCATE(WC(N))
ALLOCATE(EFFD(N))
ALLOCATE(M1(N))
ALLOCATE(M2(N))
ALLOCATE(dia10(N))
ALLOCATE(dia12(N))
ALLOCATE(dia14(N))
OPEN(11,FILE='DATA1.TXT',STATUS='OLD')
READ(11,*)
READ(11,10)RHO
10 FORMAT(4x,f4.3)
READ(11,20)FYK
20 FORMAT(4x,f3.0)
READ(11,40)FCK
40 FORMAT(4x,f4.1)
READ(11,50)CW
50 FORMAT(3x,f3.2)
READ(11,60)FD
60 FORMAT(3x,f3.1)
READ(11,30)QALL
30 FORMAT(12x,f5.0)
OPEN(21,FILE='DATA4.TXT',STATUS='OLD')
```

```
READ(21,*)
READ(21,*)
DO I=1,N
READ(21,70)FR3(I),M1(I),M2(I)
70 FORMAT(F10.3,F10.3,F10.3)
END DO
OPEN(31,FILE='DATA5.TXT',STATUS='OLD')
READ(31,*)
READ(31,*)
DO I=1,N
READ(31,80)JID(I)
80 FORMAT(I9)
END DO
DO I=1,N
FCD=0.444*FCK
FCTD=(0.35*SQRT(FCK))/1.5
FYD=FYK/1.15
END DO
OPEN(11,FILE='DATA2.TXT',STATUS='OLD')
WRITE(11,90)
90 FORMAT("THE OUT PUT FOR THE FOOTING DESIGN IS AS FOLLOWS")
WRITE(11,100)FCD
100 FORMAT("THE COMPRESIVE RESISTANCE OF CONCRETE (fcd) IS=",F10.3)
WRITE(11,110)FCTD
110 FORMAT(" THE TENSILE RESISTANCE OF CONCRETE (fctd) IS=",F10.3)
WRITE(11,120)FYD
120 FORMAT("                                        FYD=",F10.3)
    VCP=500*FCTD*(1+50*RHO)
     VCWB=300*FCTD*(1+50*RHO)
WRITE(11,130)VCP
130 FORMAT ("THE ALLOWABLE PUNCHING RESISTANCE OF CONCRETE (Vup)IS=",F10.3)
WRITE(11,140)VCWB
140 FORMAT("THE ALLOWABLE WIDE BEAM SHEAR RESISTANCE OF CONCRETE(Vud)IS=",F10.3)
```

```
    DT=0.15
  DO I=1,N
    AF(I)=FR3(I)/QALL
    WC(I)=1.3*AF(I)*DT(I)*25
    WS(I)=1.3*AF(I)*(FD-DT(I))*17
    PT(I)=WC(I)+WS(I)+FR3(I)
    FSIZE(I)=SQRT(PT(I)/QALL)
    EX(I)=M2(I)/FR3(I)
    EY(I)=M1(I)/FR3(I)
!      CHECKING FOR BEARING CAPACITY
   DO J=1,10
    QACT(I)=(PT(I)/(FSIZE(I)**2))*(1+6*EX(I)/FSIZE(I)+6*EY(I)/FSIZE(I))
   IF (QACT(I).GT.QALL)THEN
    FSIZE(I)=FSIZE(I)+.1
   ELSEIF (QACT(I).LT.QALL)THEN
    EXIT
   END IF
  END DO
  END DO

!        EFFECTIVE DEPTH CALCULATION



DO I=1,N


     COEFA=VCP+QALL/4
     COEFB=CW*(VCP+QALL/2)
     COEFC(I)=(CW**2-FSIZE(I)**2)*QALL*0.25
     DESCRM(I)=COEFB**2-4*COEFA*COEFC(I)
IF(DESCRM(I).EQ.0.0) THEN
     DEFFP(I)=(-COEFB + SQRT(DESCRM(I)))/(2*COEFA)
    ELSEIF(DESCRM(I).GT.0.0) THEN
     DEFFP(I)=(-COEFB + SQRT(DESCRM(I)))/(2*COEFA)
   ENDIF
   END DO
```

```
!  CHECKING FOR WIDE BEAM SHEAR RESISTANCE
   EFFD=0.1
    DO I=1,N
DEFFWB(I)=0.5*(FSIZE(I)-CW)*(QALL)/(VCWB+QALL)
    IF (EFFD(I).LT.DEFFWB(I))THEN
DT(I)=DEFFWB(I)+0.05
      ELSEIF(EFFD(I).GT.DEFFWB(I))THEN
      DT(I)=EFFD(I)+0.05
     ELSE IF (DEFFWB(I).LT.DEFFP(I))THEN
    DT(I)=DEFFP(I)+0.05
     ELSEIF(EFFD(I).LT.DEFFP(I))THEN
       DT(I)=DEFFWB(I)+0.05
   END IF
      EFFD(I)=DT(I)-.05
   END DO

!     CALCULATION OF REINFORCEMENT

      DO I=1,N
!          DESIGN MOMENT
      MD(I)=0.5*FR3(I)*(((FSIZE(I)-CW)/2)**2)/(FSIZE(I)**2)

      NU(I)=MD(I)/(FCD*10000*EFFD(I)**2)
      IF (NU(I).GT.0.5) THEN
      PRINT*,"USE DOUBLE REINFORCEMENT"



      ELSEIF(NU(I).LT.0.5)THEN
      BA(I)=1-SQRT(1-2*NU(I))

      AS(I)=BA(I)*10000000*EFFD(I)*FCD/FYD

      ASMIN(I)=0.5*1000000*EFFD(I)/FYK
      dia10(i)=1000*78.54/as(i)
      dia12(i)=1000*113.1/as(i)
```

```
 dia14(i)=1000*153.94/as(i)
! PRINT*,"DESIGN MOMENT=",MD
! PRINT*,"NU=",NU
! PRINT*,"BA=",BA
 !PRINT*,"ASmin=",ASMIN
 !PRINT*,"please input diameter of your bar:"
 !READ*,dia
  !ASING=0.25*3.14*DIA**2
  !SPACIN=(1000*ASING)/(AS)
 !PRINT*,"AREA OF SINGLE BAR=",ASING
! PRINT*,"SPACING OF REINFORCEMENT BARS=",SPACIN
 END IF
   END DO
   WRITE(11,150)
150 FORMAT(" JOINT ID      FSIZE        DT       AS       ASMIN      dia10      dia12      dia14")
DO I=1,N
 WRITE(11,160)JID(I),FSIZE(I),DT(I),AS(I),ASMIN(I),dia10(i),dia12(i),dia14(i)
160 FORMAT(I9,F10.1,F10.2,F10.3,F10.3,7x,i3,7x,i3,7x,i3)
 END DO
 PRINT*,"THIS IS THE END OF PROGRAM"
 PRINT*,"YOU CAN GET THE OUT PUT DATA IN DATA2.TXT FILE."
  END PROGRAM
```

PROGRAM OUTPUT

```
THE OUT PUT FOR THE FOOTING DESIGN IS AS FOLLOWS
THE COMPRESIVE RESISTANCE OF CONCRETE (fcd) IS=    11.100
 THE TENSILE RESISTANCE OF CONCRETE (fctd) IS=     1.167
                                          FYD=   260.870
THE ALLOWABLE PUNCHING RESISTANCE OF CONCRETE (Vup)IS=   641.667
THE ALLOWABLE WIDE BEAM SHEAR RESISTANCE OF CONCRETE(Vud)IS=   385.000
 JOINT ID     FSIZE        DT       AS      ASMIN      dia10      dia12   dia14
       21       1.5      0.42   850.201   610.958        92       133       181
       26       1.8      0.50  1065.079   748.782        73       106       144
       31       1.7      0.47  1116.475   701.701        70       101       137
       36       1.5      0.42   850.201   610.958        92       133       181
       41       1.9      0.52  1118.978   783.214        70       101       137
       46       2.2      0.59  1297.172   896.801        60        87       118
       51       2.1      0.56  1351.987   849.720        58        83       113
       56       1.9      0.52  1118.978   783.214        70       101       137
```

```
  61     1.9    0.52  1111.427   778.393        70      101      138
  66     2.1    0.59  1290.491   892.549        60       87      119
  71     2.0    0.56  1345.221   845.468        58       84      114
  76     1.9    0.52  1111.427   778.393        70      101      138
  81     1.9    0.52  1118.978   783.214        70      101      137
  86     2.2    0.59  1297.172   896.801        60       87      118
  91     2.1    0.56  1351.987   849.720        58       83      113
  96     1.9    0.52  1118.978   783.214        70      101      137
 101     1.5    0.42   850.201   610.958        92      133      181
 106     1.8    0.50  1065.079   748.782        73      106      144
 111     1.7    0.47  1116.475   701.701        70      101      137
 116     1.5    0.42   850.201   610.958        92      133      181
```

5.3 Program for Analysis and Design of Mat Foundation

5.3.1 Program for calculating the average stress in mat foundation

The program below reads superstructure reaction data and determines the average pressure distribution below the foundation.

The thickness of the mat slab is determined by checking the shear resistance of the whole mat slab. This is done by grouping column reactions which have the same boundary condition and checking the concrete depth for the maximum slab reaction for each boundary conditions. Finally the program selects the maximum depth from each boundary condition.

```
PROGRAM average pressure
IMPLICIT NONE
INTEGER I,N
REAL ,DIMENSION(:),ALLOCATABLE::FR3,M1,M2,M3,X,Y,Z,FR3X,FR3Y
REAL
SFR3,SM1,SM2,SFR3X,SFR3Y,XBAR,YBAR,GEOX,GEOY,EX,EY,SIGMAMAX,SIGMA
MIN,AREA,LX,LY,SIGMAAVG
INTEGER ,DIMENSION(:),ALLOCATABLE::JID
PRINT*,"HOW MANY FOOTINGS DO YOU HAVE?"
READ*,N
ALLOCATE(FR3(N))
ALLOCATE(M1(N))
ALLOCATE(M2(N))
ALLOCATE(M3(N))
ALLOCATE(JID(N))
```

```
ALLOCATE(X(N))
ALLOCATE(Y(N))
ALLOCATE(Z(N))
ALLOCATE(FR3X(N))
ALLOCATE(FR3Y(N))
OPEN(11,FILE='data4.TXT',STATUS='OLD')
! Data4.txt is the file written by the the SAP Output importing program.
READ(11,*)
READ(11,*)
DO I=1,N
READ(11,10)FR3(I),M1(I),M2(I),M3(I)
10 FORMAT(F10.3,F10.3,F10.3,F10.3)
END DO
OPEN(21,FILE='DATA5.TXT',STATUS='OLD')
! Data5.txt is the file written by the the SAP input importing program.
READ(21,*)
READ(21,*)
DO I=1,N
READ(21,20)JID(I),X(I),Y(I),Z(I)
20 FORMAT(I9,F15.5,F15.5,F15.5)
END DO
DO I=1,N
FR3X(I)=X(I)*FR3(I)
FR3Y(I)=Y(I)*FR3(I)
END DO
DO I=1,N
SFR3=SFR3+FR3(I)
SM1=SM1+M1(I)
SM2=SM2+M2(I)
SFR3X=SFR3X+FR3X(I)
SFR3Y=SFR3Y+FR3Y(I)
END DO
OPEN(31,FILE='DATA6.TXT',STATUS='OLD')
WRITE(31,30)
30 FORMAT(" THIS IS THE OUT PUT FILE OF THE JOINT ID,COORDINATES,F3,M1,M2&M3 FOR EVERY JOINT")
```

```
WRITE(31,40)
40 FORMAT("  JOINT ID          X            Y            Z      F3        M1          M2        M3
FR3X    FR3Y")
DO I=1,N
WRITE(31,50)jid(I),x(I),y(I),z(I),FR3(I),M1(I),M2(I),M3(I),FR3X(I),FR3Y(I)
50 FORMAT(i9,F15.5,F15.5,F15.5,F10.3,F10.3,F10.3,F10.3,F10.3,F10.3)
END DO
WRITE(31,60)SFR3,SM1,SM2,SFR3X,SFR3Y
60 FORMAT("THE SUMATION IS
",F10.3,F10.3,F10.3,3X,F10.3,F10.3)
DO I=1,N
PRINT*,JID(I),X(I),Y(I),Z(I),FR3(I),M1(I),M2(I),M3(I)
END DO
XBAR=(SM2+SFR3Y)/SFR3
YBAR=(SM1+SFR3X)/SFR3
PRINT*,"ENTER THE GEOMETRIC CENTER THE BUILDING ALONG X&Y
DIRECTIONS RESPECTIVELY:"
READ*,GEOX,GEOY
PRINT*,"ENTER THE AREA OF THE BUILDING:"
READ*,AREA
PRINT*,"ENTER THE LENGTH OF THE BUILDING ALONG X&Y DIRECTION
RESPECTIVELY:"
READ*,LX,LY
EX=GEOX-XBAR
EY=GEOY-YBAR
SIGMAMAX=(SFR3/AREA)*(1+6*(EX/LX)+6*(EY/LY))
SIGMAMIN=(SFR3/AREA)*(1-6*(EX/LX)-6*(EY/LY))
SIGMAAVG=(SIGMAMAX+SIGMAMIN)/2
PRINT*,"THE AVERAGE STRSS BECOMES=",SIGMAAVG
WRITE(31,34) SIGMAAVG
 34 FORMAT("THE AVERAGE STRSS BECOMES=  ",F10.3)
END PROGRAM
```

OUTPUT OF PROGRAM

```
THIS IS THE OUT PUT FILE OF THE JOINT ID,COORDINATES,F3,M1,M2&M3 FOR EVERY JOINT
  JOINT ID          X               Y              Z       F3         M1          M2        M3     FR3X    FR3Y
         1      -12.50000      -12.00000        0.00000   922.659    11.092    17.997     0.000-11533.237-11071.908
         2      -12.50000      -12.00000        3.00000  1333.533     0.214    17.997     0.000-16669.162-16002.396
         3      -12.50000      -12.00000        6.00000  1333.533    -0.214    17.997     0.000-16669.162-16002.396
         4      -12.50000      -12.00000        9.00000   922.659    11.092    17.997     0.000-11533.237-11071.908
         5      -12.50000      -12.00000       12.00000  1447.959    11.092    -0.263     0.000-18099.488-17375.508
         6      -12.50000      -12.00000       15.00000  1858.833     0.214    -0.263     0.000-23235.412-22305.996
         7      -12.50000      -12.00000       18.00000  1858.833    -0.214    -0.263     0.000-23235.412-22305.996
         8      -12.50000       -6.00000        0.00000  1447.959    11.092    -0.263     0.000-18099.488 -8687.754
         9      -12.50000       -6.00000        3.00000  1431.654    11.092     0.000     0.000-17895.676 -8589.924
        10      -12.50000       -6.00000        6.00000  1842.527     0.214     0.000     0.000-23031.588-11055.162
        11      -12.50000       -6.00000        9.00000  1842.527    -0.214     0.000     0.000-23031.588-11055.162
        12      -12.50000       -6.00000       12.00000  1431.654    11.092     0.000     0.000-17895.676 -8589.924
        13      -12.50000       -6.00000       15.00000  1447.959    11.092     0.263     0.000-18099.488 -8687.754
        14      -12.50000       -6.00000       18.00000  1858.833     0.214     0.263     0.000-23235.412-11152.998
        15      -12.50000        0.00000        0.00000  1858.833    -0.214     0.263     0.000-23235.412     0.000
        16      -12.50000        0.00000        3.00000  1447.959    11.092     0.263     0.000-18099.488     0.000
        17      -12.50000        0.00000        6.00000   922.659    11.092   -17.997     0.000-11533.237     0.000
        18      -12.50000        0.00000        9.00000  1333.533     0.214   -17.997     0.000-16669.162     0.000
        19      -12.50000        0.00000       12.00000  1333.533    -0.214   -17.997     0.000-16669.162     0.000
        20      -12.50000        0.00000       15.00000   922.659    11.092   -17.997     0.000-11533.237     0.000
THE SUMATION IS                                          28800.295   110.920     0.000        -360003.75     -183954.77
THE                 AVERAGE                 STRSS                 BECOMES=                                                                    53.832
```

5.3.2 Program for Determination of effective depth of mat foundation.

First foundation reactions will be grouped in to three according to their position for accurate determination of effective depth.

These are :

- Corner reactions-columns located at the corner of the bulding (two side free edge)
- Side reaction-Columns located at the side of the building (only one free edge side)
- Middle Columns-Columns at the interior with no free edge)

For this purpose the foundation reaction from the superstructure analysis are saved according to the above grouping.

5.3.2.1 Selecting the critical corner foundation reaction

i) Corner foundation reaction from the superstructure analysis.

```
 21  COMB1       17.9746    11.1690   922.6594   -11.0919    17.9971     0.0000

 36  COMB1       17.9746   -11.1690   922.6594    11.0919    17.9971     0.0000

101  COMB1      -17.9746    11.1690   922.6594   -11.0919   -17.9971     0.0000

116  COMB1      -17.9746   -11.1690   922.6594    11.0919   -17.9971     0.0000
```

From the above data the program below selects the critical data which is required for effective depth calculation

ii) Sub-Program for selecting the maximum corner foundation reaction

[PROGRAM-04]

```
!    Last change:  MS   31 Jan 102    4:00 am

!THIS PROGRAM IMPORTS FOUNDATION REACTION OF CORNER COLUMNS AND SELECT THE MAXIMUM

!COLUMN REACTION FOR MAT EFFECTIVE DEPTH DETERMINATION

!The output of this program are in file named CORNER.txt

PROGRAM TEST6

IMPLICIT NONE

INTEGER I,N

REAL ,DIMENSION(:),ALLOCATABLE::FR3,M1,M2
```

```
REAL BIG
PRINT*,"HOW MANY FOOTINGS DO YOU HAVE?"
READ*,N
ALLOCATE(FR3(N))
ALLOCATE(M1(N))
ALLOCATE(M2(N))
OPEN(11,FILE='CORNERC.TXT',STATUS='OLD')
DO  I=1,N
READ(11,10)FR3(I),M1(I),M2(I)
READ(11,*)
10 FORMAT(51X,F10.5,4x,F10.3,F10.3)
END DO
PRINT*,"THE OUT PUT FILE LOOKS LIKE THIS"
DO I=1,N
PRINT*,FR3(I),M1(I),M2(I)
END DO
!EACH FOUNDATION REACTIONS AND THE MAXIMUM FOUNDATION REACTIONS WILL BE WRITTEN IN FILE CORNR.TXT
OPEN(21,FILE='CORNER.TXT',STATUS='OLD')
WRITE(21,30)
30 FORMAT(" THIS IS THE OUTPUT FILE OF THE AXIAL LOAD AND THE MOMENTS IN THE 3 DIRECTIONS")

!FUNCTION BIG(FR3)
!DIMENSION FR3(N)
BIG=FR3(1)
DO I=1,N
IF(BIG.LT.FR3(I))BIG=FR3(I)
END DO
WRITE(21,31)BIG
31 FORMAT(" THE MAXIMUM CORNER REACTION=",F7.2)
WRITE(21,40)
40 FORMAT("      F3        M1         M2")
DO I=1,N
```

```
WRITE(21,20)FR3(I),M1(I),M2(I)
20 FORMAT(F10.3,F10.3,F10.3)
END DO
END PROGRAM
```

iii)Program output

```
THIS IS THE OUTPUT FILE OF THE AXIAL LOAD AND THE MOMENTS IN THE 3
DIRECTIONS
 THE MAXIMUM CORNER REACTION= 922.66
      F3         M1          M2
   922.659     1.092    17.997
   922.659     1.092    17.997
   922.659     1.092   -17.997
   922.659     1.092   -17.997
```

5.3.2.2 Selecting the critical Side foundation reaction

i) Side foundation reaction from the superstructure analysis.

```
   26  COMB1      17.9746   -0.2918  1333.5327    0.2139   17.9971    0.0000
   31  COMB1      17.9746    0.2918  1333.5327   -0.2139   17.9971    0.0000
   41  COMB1      -0.5078   11.1690  1447.9595  -11.0919   -0.2627    0.0000
   56  COMB1      -0.5078  -11.1690  1447.9595   11.0919   -0.2627    0.0000
   61  COMB1       0.0000   11.1690  1431.6542  -11.0919    0.0000    0.0000
   76  COMB1       0.0000  -11.1690  1431.6542   11.0919    0.0000    0.0000
   81  COMB1       0.5078   11.1690  1447.9595  -11.0919    0.2627    0.0000
   96  COMB1       0.5078  -11.1690  1447.9595   11.0919    0.2627    0.0000
  106  COMB1     -17.9746   -0.2918  1333.5327    0.2139  -17.9971    0.0000
  111  COMB1     -17.9746    0.2918  1333.5327   -0.2139  -17.9971    0.0000
```

From the above data the program below selects the critical data which is required for effective depth calculation

ii) Sub-Program for selecting the maximum Side foundation reaction

[SUBPROGRAM-05]

```
!    Last change:  MS   31 Jan 102    4:07 am
!THIS PROGRAM IMPORTS FOUNDATION REACTION OF SIDE COLUMNS AND SELECT THE MAXIMUM
!COLUMN REACTION FOR MAT EFFECTIVE DEPTH DETERMINATION
!The output of this program are in file named SIDER.txt
PROGRAM TEST6
IMPLICIT NONE
INTEGER I,N
REAL ,DIMENSION(:),ALLOCATABLE::FR3,M1,M2
REAL BIG
PRINT*,"HOW MANY FOOTINGS DO YOU HAVE?"
READ*,N
ALLOCATE(FR3(N))
ALLOCATE(M1(N))
ALLOCATE(M2(N))
OPEN(11,FILE='SIDEC.TXT',STATUS='OLD')
DO  I=1,N
READ(11,10)FR3(I),M1(I),M2(I)
READ(11,*)
10 FORMAT(50X,F10.5,5x,F10.3,F10.3)
END DO
PRINT*,"THE OUT PUT FILE LOOKS LIKE THIS"
DO I=1,N
PRINT*,FR3(I),M1(I),M2(I)
END DO
!EACH FOUNDATION REACTIONS AND THE MAXIMUM FOUNDATION REACTIONS WILL BE WRITTEN IN FILE CORNR.TXT
OPEN(23,FILE='SIDER.TXT',STATUS='OLD')
WRITE(23,30)
30 FORMAT(" THIS IS THE OUTPUT FILE OF THE AXIAL LOAD AND THE MOMENTS IN THE 3 DIRECTIONS")

!FUNCTION BIG(FR3)
!DIMENSION FR3(N)
BIG=FR3(1)
```

```
DO I=1,N
IF(BIG.LT.FR3(I))BIG=FR3(I)
END DO
WRITE(23,31)BIG
31 FORMAT(" THE MAXIMUM AXIAL LOAD ON THE SIDE OF THE BUILDING=",F7.2)
WRITE(23,40)
40 FORMAT("      F3       M1        M2")
DO I=1,N
WRITE(23,20)FR3(I),M1(I),M2(I)
20 FORMAT(F10.3,F10.3,F10.3)
END DO
END PROGRAM
```

iii) Program output

```
THIS IS THE OUTPUT FILE OF THE AXIAL LOAD AND THE MOMENTS IN THE 3
DIRECTIONS
 THE MAXIMUM AXIAL LOAD ON THE SIDE OF THE BUILDING=1447.96
      F3         M1          M2
  1333.533     0.214    17.997
  1333.533     0.214    17.997
  1447.959     1.092    -0.263
  1447.959     1.092    -0.263
  1431.654     1.092     0.000
  1431.654     1.092     0.000
  1447.959     1.092     0.263
  1447.959     1.092     0.263
  1333.533     0.214   -17.997
  1333.533     0.214   -17.997
```

5.3.2.3 Selecting the critical middle foundation reaction

i) Middle foundation reaction from the superstructure analysis.

```
46  COMB1          -0.5078    -0.2918   1858.8329     0.2139    -0.2627     0.0000
```

```
51  COMB1        -0.5078    0.2918   1858.8329    -0.2139    -0.2627     0.0000

66  COMB1         0.0000   -0.2918   1842.5275     0.2139     0.0000     0.0000

71  COMB1         0.0000    0.2918   1842.5275    -0.2139     0.0000     0.0000

86  COMB1         0.5078   -0.2918   1858.8329     0.2139     0.2627     0.0000

91  COMB1         0.5078    0.2918   1858.8329    -0.2139     0.2627     0.0000
```

From the above data the program below selects the critical data which is required for effective depth calculation

ii) Sub-Program for selecting the maximum middle foundation reaction

[PROGRAM-07]

```
!    Last change:  MS   31 Jan 102    3:34 am
!THIS PROGRAM IMPORTS FOUNDATION REACTION OF MIDDLE COLUMNS AND SELECTE THE MAXIMUM
!COLUMN REACTION FOR MAT EFFECTIVE DEPTH DETERMINATION
!The output of this program are in file named MIDLER.txt
PROGRAM TEST6
IMPLICIT NONE
INTEGER I,N
REAL ,DIMENSION(:),ALLOCATABLE::FR3,M1,M2
REAL BIG
PRINT*,"HOW MANY FOOTINGS DO YOU HAVE?"
READ*,N
ALLOCATE(FR3(N))
ALLOCATE(M1(N))
ALLOCATE(M2(N))
OPEN(11,FILE='MIDLEC.TXT',STATUS='OLD')
DO  I=1,N
READ(11,10)FR3(I),M1(I),M2(I)
READ(11,*)
10 FORMAT(51X,F10.5,5x,F10.3,F10.3)
END DO
PRINT*,"THE OUT PUT FILE LOOKS LIKE THIS"
DO I=1,N
PRINT*,FR3(I),M1(I),M2(I)
```

```
END DO
!EACH FOUNDATION REACTIONS AND THE MAXIMUM FOUNDATION REACTIONS WILL BE WRITTEN IN FILE CORNR.TXT
OPEN(22,FILE='MIDLER.TXT',STATUS='OLD')
WRITE(22,30)
30 FORMAT(" THIS IS THE OUTPUT FILE OF THE AXIAL LOAD AND THE MOMENTS IN THE 3 DIRECTIONS")

!FUNCTION BIG(FR3)
!DIMENSION FR3(N)
BIG=FR3(1)
DO I=1,N
IF(BIG.LT.FR3(I))BIG=FR3(I)
END DO
WRITE(22,31)BIG
31 FORMAT(" THE MAXIMUM  AXIAL LOAD ON THE MIDDLE OF THE BUILDING=",F7.2)
WRITE(22,40)
40 FORMAT("      F3        M1         M2")
DO I=1,N
WRITE(22,20)FR3(I),M1(I),M2(I)
20 FORMAT(F10.3,F10.3,F10.3)
END DO
END PROGRAM
```

Iii) Program output

```
THIS IS THE OUTPUT FILE OF THE AXIAL LOAD AND THE MOMENTS IN THE 3 DIRECTIONS
 THE MAXIMUM  AXIAL LOAD ON THE MIDDLE OF THE BUILDING=1858.83
      F3        M1         M2
  1858.833     0.214    -0.263
   858.833     0.214    -0.263
   842.528     0.214     0.000
   842.528     0.214     0.000
   858.833     0.214     0.263
   858.833     0.214     0.263
```

5.3.3 Program Determining Effective Depth of Mat Slab.

[PROGRAM-08]

The program in this section calculates the depth required for each column positions and selects the critical for design of mat foundation.

```
PROGRAM MATEFFDEPTH
IMPLICIT NONE
INTEGER I,N
REAL ,DIMENSION(:),ALLOCATABLE::FR3,M1,M2,M3,X,Y,Z,FR3X,FR3Y
REAL SFR3,SM1,SM2,SFR3X,SFR3Y
INTEGER ,DIMENSION(:),ALLOCATABLE::JID
PRINT*,"HOW MANY FOOTINGS DO YOU HAVE?"
READ*,N
ALLOCATE(FR3(N))
ALLOCATE(M1(N))
ALLOCATE(M2(N))
ALLOCATE(M3(N))
ALLOCATE(JID(N))
ALLOCATE(X(N))
ALLOCATE(Y(N))
ALLOCATE(Z(N))
ALLOCATE(FR3X(N))
ALLOCATE(FR3Y(N))
OPEN(11,FILE='data4.TXT',STATUS='OLD')
READ(11,*)
READ(11,*)
DO I=1,N
READ(11,10)FR3(I),M1(I),M2(I),M3(I)
10 FORMAT(F10.3,F10.3,F10.3,F10.3)
END DO
OPEN(21,FILE='DATA5.TXT',STATUS='OLD')
READ(21,*)
READ(21,*)
DO I=1,N
```

```
READ(21,20)JID(I),X(I),Y(I),Z(I)
20 FORMAT(I9,F15.5,F15.5,F15.5)
END DO
DO I=1,N
FR3X(I)=X(I)*FR3(I)
FR3Y(I)=Y(I)*FR3(I)
END DO
DO I=1,N
SFR3=SFR3+FR3(I)
SM1=SM1+M1(I)
SM2=SM2+M2(I)
SFR3X=SFR3X+FR3X(I)
SFR3Y=SFR3Y+FR3Y(I)
END DO
OPEN(31,FILE='DATA6.TXT',STATUS='OLD')
WRITE(31,30)
30 FORMAT(" THIS IS THE OUT PUT FILE OF THE JOINT
ID,COORDINATES,F3,M1,M2&M3 FOR EVERY JOINT")
WRITE(31,40)
40 FORMAT("  JOINT ID         X            Y            Z       F3        M1         M2        M3
FR3X    FR3Y")
DO I=1,N
WRITE(31,50)jid(I),x(I),y(I),z(I),FR3(I),M1(I),M2(I),M3(I),FR3X(I),FR3Y(I)
50 FORMAT(i9,F15.5,F15.5,F15.5,F10.3,F10.3,F10.3,F10.3,F10.3,F10.3)
END DO
WRITE(31,60)SFR3,SM1,SM2,SFR3X,SFR3Y
60 FORMAT("THE SUMATION IS
",F10.3,F10.3,F10.3,10X,F10.3,F10.3)

DO I=1,N
PRINT*,JID(I),X(I),Y(I),Z(I),FR3(I),M1(I),M2(I),M3(I)
END DO
END PROGRAM
```

```
!     Last change:  MS   19 Aug 102    2:30 pm
PROGRAM   EFFECTIVED
REAL RHO,FYK,FCK,CW,ED,FR3MAX,FCD,FCTD,FYD,VCP,VCWB,DESCRM,DEFFP
!REAL DT
!The coefficients below are used for calculating the effective depth of mat
!required for  columns at the sides of the mat foundation
REAL COEFAS,COEFBS,COEFCS,DEEFPS
!The coefficients below are used for calculating the effective depth of mat
!required for  columns at the corners of the mat foundation
REAL COEFAC,COEFBC,COEFCC,DEEFPC
!The coefficients below are used for calculating the effective depth of mat
!required for  columns at the middle of the mat foundation
REAL COEFAM,COEFBM,COEFCM,DEFFPM
REAL DTS,DTM,DTC
!PRINT*,"HOW MANY FOOTINGS DO YOU HAVE?"
OPEN(12,FILE='DATA11.TXT',STATUS='OLD')
READ(12,*)
READ(12,10)RHO
10 FORMAT(4x,f4.3)
READ(12,20)FYK
20 FORMAT(4x,f3.0)
READ(12,40)FCK
40 FORMAT(4x,f4.1)
READ(12,50)CW
50 FORMAT(3x,f3.2)
READ(12,60)ED
60 FORMAT(3x,f3.1)
OPEN(21,FILE='SIDER.TXT',STATUS='OLD')

READ(21,*)
READ(21,70)FR3MAXS
70 FORMAT(42X,F10.3)
FCD=0.444*FCK
FCTD=(0.35*SQRT(FCK))/1.5
```

```
FYD=FYK/1.15
OPEN(11,FILE='DATA22.TXT',STATUS='OLD')
WRITE(11,90)
90 FORMAT(8X,"THE OUT PUT FOR CALCULATING DEPTH OF MAT
FOUNDATION",//)
WRITE(11,100)FCD
100 FORMAT(5X,"THE COMPRESIVE RESISTANCE OF CONCRETE (fcd) IS=",F10.3,/)
WRITE(11,110)FCTD
110 FORMAT(5X," THE TENSILE RESISTANCE OF CONCRETE (fctd) IS=",F10.3,/)
WRITE(11,120)FYD
120 FORMAT("                              FYD=",F10.3)
      VCP=500*FCTD*(1+50*RHO)
       VCWB=300*FCTD*(1+50*RHO)
WRITE(11,130)VCP
130 FORMAT (5X,"THE ALLOWABLE PUNCHING RESISTANCE OF CONCRETE
(Vup)IS=",F10.3,/)
WRITE(11,140)VCWB
140 FORMAT(5X,"THE ALLOWABLE WIDE BEAM SHEAR RESISTANCE OF
CONCRETE(Vud)IS=",F10.3,///)


! EFFECTIVE DEPTH CALCULATION FOR COLUMNS AT THE SIDE OF MAT
FOUNDATION


!2d**2xVc + 2x(ED+CW)xVcxd-FR3=0.0
      COEFAS=2*VCP
      COEFBS=2*(ED+CW)*VCP
      COEFCS=-1.0*FR3MAXS
      DESCRM=COEFBS**2-4*COEFAS*COEFCS
!IF(DESCRM.EQ.0.0) THEN
 !      DEFFP=(-COEFB + SQRT(DESCRM))/(2*COEFA)
  !   ELSEIF(DESCRM.GT.0.0) THEN
   DEFFPS=(-COEFBS + SQRT(DESCRM))/(2*COEFAS)
    !ENDIF
    !END DO
```

```
!    CALCULATION OF EFFECTIVE DEPTH
   DTS=DEFFP+.05

    WRITE(11,160)DTS
    160 FORMAT(7X,'FOUNDATION DEPTH REQUIRED FOR SIDE COLUMNS=',F10.2,/)

! EFFECTIVE DEPTH CALCULATION FOR COLUMNS AT THE CORNERS OF MAT FOUNDATION

OPEN(22,FILE='CORNER.TXT',STATUS='OLD')

READ(22,*)
READ(22,71)FR3MAXC
71 FORMAT(42X,F10.3)
!d**2xVc + (2*ED+CW)xVcxd-FR3=0.0
     COEFAC=VCP
     COEFBC=(2*ED+CW)*VCP
     COEFCC=-1.0*FR3MAXC
     DESCRM=COEFBC**2-4*COEFAC*COEFCC
!IF(DESCRM.EQ.0.0) THEN
 !     DEFFP=(-COEFB + SQRT(DESCRM))/(2*COEFA)
  !  ELSEIF(DESCRM.GT.0.0) THEN
  DEFFPC=(-COEFBC + SQRT(DESCRM))/(2*COEFAC)
   !ENDIF
   !END DO


!    CALCULATION OF EFFECTIVE DEPTH
   DTC=DEFFPC+.05

    WRITE(11,161)DTC
```

```
    161 FORMAT(7X,'FOUNDATION DEPTH REQUIRED FOR CORNER
COLUMNS=',F10.2,/)

! EFFECTIVE DEPTH CALCULATION FOR COLUMNS AT THE MIDDLE OF MAT
FOUNDATION

OPEN(23,FILE='MIDLER.TXT',STATUS='OLD')

READ(23,*)
READ(23,72)FR3MAXM
72 FORMAT(42X,F10.3)
!d**2xVc + (2*ED+CW)xVcxd-FR3=0.0
     COEFAM=VCP
     COEFBM=(2*ED+CW)*VCP
     COEFCM=-1.0*FR3MAXM
     DESCRM=COEFBM**2-4*COEFAM*COEFCM
!IF(DESCRM.EQ.0.0) THEN
 !     DEFFP=(-COEFB + SQRT(DESCRM))/(2*COEFA)
  !   ELSEIF(DESCRM.GT.0.0) THEN
  DEFFPM=(-COEFBM + SQRT(DESCRM))/(2*COEFAM)
   !ENDIF
   !END DO


!    CALCULATION OF EFFECTIVE DEPTH
    DTM=DEFFPM+.05


    WRITE(11,162)DTM
    162 FORMAT(7X,'FOUNDATION DEPTH REQUIRED FOR MIDDLE
COLUMNS=',F10.2,///)

  WRITE(11,163)MAX(DTS,DTC,DTM)
    163 FORMAT(7X,'FOUNDATION DEPTH REQUIRED FOR MAT
FOUNDATION=',F10.2)
         PRINT*,"THIS IS THE END OF PROGRAM"
```

```
PRINT*,"YOU CAN GET THE OUT PUT DATA IN DATA22.TXT FILE."
 END PROGRAM
```

5.4 Program Supporting analysis and Design of Pile Foundations

The first step on analysis and design of pile foundation is determination of the bearing capacity and the frictional resistance of each layer. The program below reads data describing number of layers,thickness,cohesion and friction angle of each layers and determines the bearing capacity and friction resistance of each layer.

```
These are the input file for the isolated pile length calculation.
Number of soil layers=  3
angle of internal friction&cohesion are given as follows
LAYER THICKNESS   ANGLE OF INTERNAL FRICTION   COHESION   SOIL UNIT WEIGHT
    3.0                        12.0                 10.0              18.0
    5.0                        20.0                 12.0              18.0
    7.0                        14.0                 10.0              19.0
```

5.4.1 Program for determining the bearing capacity and the frictional resistance of each layer

[PROGRAM-10]

```
program pile2
implicit none
REAL,DIMENSION (:),ALLOCATABLE:: P,C,Nc,Nq,Ny,qall,y,l,k,fs,su
integer i,n
REAL dia
print*,"enter the diameter of the pile:"
READ*,dia
OPEN(11,FILE='pile2.txt',STATUS='old')
READ(11,*)
READ(11,10)n
10 FORMAT(23x,i2)
ALLOCATE(p(n))
ALLOCATE(c(n))
ALLOCATE(Nq(n))
ALLOCATE(Nc(n))
```

```
ALLOCATE(NY(n))
ALLOCATE(qall(n))
ALLOCATE(y(n))
ALLOCATE(l(n))
ALLOCATE(k(n))
ALLOCATE(fs(n))
ALLOCATE(su(n))
READ(11,*)
READ(11,*)
do i=1,n
READ(11,20)l(i),p(i),c(i),y(i)
20 FORMAT(3x,f3.1,23x,f5.1,18x,f5.1,12x,f5.1)
end do
PRINT*,l
PRINT*,p
PRINT*,c
PRINT*,y
su(i-1)=0.0
DO I=1,N
p(i)=(22.0*p(i))/(7.0*180.0)
Nq(i)=EXP(3.14*TAN(P(i)))*(TAN(22.0/28.0+P(i)/2)**2)
PRINT*,nq(i)
Nc(i)=(Nq(i)-1)*(1/(TAN(P(i))))
PRINT*,nc(i)
Ny(i)=2*(Nq(i)-1)*TAN(P(i))
PRINT*,ny(i)
su(i)=su(i-1)+y(i)*l(i)
PRINT*,su(i)
qall(i)=C(i)*Nc(i)+su(i)*Nq(i)+0.5*y(i)*dia*Ny(i)
PRINT*,qall(i)
k(i)=(1-SIN(p(i)))/(1+SIN(p(i)))
PRINT*,k(i)
fs(i)=su(i)*k(i)*TAN(2.0/3.0*p(i))
PRINT*,fs(i)
END DO
OPEN(21,FILE='pile1.txt',STATUS='old')
READ(21,*)
READ(21,*)
READ(21,*)
READ(21,*)
READ(21,*)
READ(21,*)
do i=1,n
WRITE(21,30)fs(i),qall(i)
```

```
30 FORMAT(8x,f7.2,22x,f7.2)
end do
PRINT*,qall
PRINT*,fs
end program
```

Result of Program

```
THESE ARE THE OUT PUT FILE FOR THE PILE LENGTH PROGRAM
THE NUMBER OF LAYERS OF THE SOIL=3
THE DIAMETER OF THE PILE=0.3
THE AXIAL LOAD =18541
THE LENGTH,SKIN FRICTION&ALLOWABLE BEARING CAPACITY ARE GIVEN AS FOLLOWS
       skin friction                 allowable bearing presure
           4.98                            256.83
          16.73                           1115.41
          27.80                           1103.41
```

5.4.2 Program for determining the length of pile

[PROGRAM-11]

```
!     Last change:  MS   31 Jan 102    7:29 am
program pile
implicit none
REAL dia,fr3,dif,lt
integer i,n
!INTEGER  ,DIMENSION(:),ALLOCATABLE::
REAL ,DIMENSION(:),ALLOCATABLE::su,l,fs,qall
!PRINT,"how many soil layers do you have?"
!READ*,n
OPEN(11,FILE='pile1.txt',STATUS='old')
READ(11,*)
READ(11,10)N
10 FORMAT(33x,i2)
ALLOCATE(l(n))
ALLOCATE(fs(n))
```

```
ALLOCATE(qall(n))
ALLOCATE(su(n))
READ(11,20)dia
20 FORMAT(26x,f4.1)
READ(11,30)fr3
!PRINT*,fr3
30 FORMAT(16x,f9.2)
READ(11,*)
READ(11,*)
do i=1,n
READ(11,40)fs(i),qall(i)
40 FORMAT(11x,f7.2,20x,f7.2)
end do
!PRINT*,FS
!PRINT*,QALL
OPEN(21,FILE='pile2.txt',STATUS='old')
READ(21,*)
READ(21,*)
READ(21,*)
READ(21,*)
do i=1,n
READ(21,50)L(I)
50 FORMAT(2X,f5.1)
END DO
!PRINT*,n
!PRINT*,l

!PRINT*,"enter the skin friction for each layer:",fs

!PRINT*,"enter the allowable bearing capacity of each layer:",qall
su(i-1)=0.0
do i=1,n
SU(i)=Su(i-1)+3.14*dia*l(i)*fs(i)
dif=fr3-qall(i)*3.14*dia*dia*0.25
if (su(i).lt.dif) then
lt=lt+l(i)
ELSEIF(su(i).gt.dif) then
lt=lt+(dif-su(i-1))/(3.14*dia*fs(i))
exit
end if
end do
PRINT*,fr3

PRINT*,"the total length for the pile suficient for the axial force is:",lt
```

```
end program
```

5.4.3 Program for determining the capacity of pile group

[PROGRAM-11]

```
PROGRAM Pilegdesign
!This program will read number of pile spaces in two directions
! and  spacing of piles and will determine the maximum pile reaction.

IMPLICIT NONE
INTEGER I,L,M,N,O
REAL ,DIMENSION(:),ALLOCATABLE::su,lg,fs,qall,capl,ltot,dif
REAL ,DIMENSION(:),ALLOCATABLE::SUg
REAL S,SUMSQRX,SUMSQRY,SUMX2,SUMY2
REAL SFR3,SM1,SM2,PMAX
REAL dia,lt
REAL PerPg,APg,CPg,Ne
!READ*,L,M,S

!Open a file containing pile geometry
OPEN(34,FILE='PileG.TXT',STATUS='OLD')
READ(34,*)
READ(34,11)L
11 FORMAT(43X,I3)
READ(34,12)M
12 FORMAT(43X,I3)
READ(34,13)S
13 FORMAT(14X,F4.1)

SUMSQRX=0.0
DO I=1,L
SUMSQRX=SUMSQRX+I*I
END DO
SUMSQRY=0.0
DO I=1,M
SUMSQRY=SUMSQRY+I*I
END DO

 !Sumation of X2=m*s2*{1+4+9+16+...+l2}
 !Sumation of Y2=l*s2*{1+4+9+16+...+m2}
 ! where s=pile spacing
 ! m=number of pile spaces in the Y-direction
 ! l=number of pile spaces in the x-direction
```

```
 !number of piles in X-direction=l+1
 !number of piles in Y-direction =m+1
 !Total number of piles(n) =(l+1)x(m+1)
 ! numbers in the brackets are sum of squares of intigers from 1 up to l
SUMX2=M*S**2*SUMSQRX
SUMY2=L*S**2*SUMSQRY
!Pile reaction in each member=Q/n +-My(x)/Sumx2+-Mx(y)/Sumy2
!In the above equation X and Y are the relative coordinates of
! each pile where X=l*s and y=m*s



OPEN(35,FILE='TotalR.TXT',STATUS='OLD')
READ(35,*)
READ(35,*)
READ(35,33)SFR3,SM1,SM2
33 FORMAT(20X,F10.3,14X,F10.3,10X,F10.3)
N=(L+1)*(M+1)
PMAX=SFR3/N+SM2*M*S/SUMX2+SM1*L*S/SUMY2
 PRINT*,"THIS IS THE END OF PROGRAM"

 PRINT*,SFR3
 !The length of the pile group will be determined for the
 !maximum pile reaction
!*****************************************************************
!REAL dia,PMAX,lt
!integer o
!
!PRINT,"how many soil layers do you have?"
!READ*,o
OPEN(11,FILE='pile1.txt',STATUS='old')
READ(11,*)
READ(11,10)O
10 FORMAT(33x,i1)
ALLOCATE(lg(O))
ALLOCATE(fs(O))
ALLOCATE(qall(O))
ALLOCATE(su(O))
ALLOCATE(SUg(O))
ALLOCATE(capl(O))
ALLOCATE(ltot(O))
ALLOCATE(dif(O))
READ(11,20)dia
20 FORMAT(25x,f3.1)
!READ(11,30)PMAX
```

```
!PRINT*,PMAX
!30 FORMAT(16x,f10.1)
READ(11,*)
READ(11,*)
READ(11,*)
do i=1,O
READ(11,40)fs(i),qall(i)
40 FORMAT(8x,f7.2,20x,f7.2)
end do
OPEN(21,FILE='pile2.txt',STATUS='old')
READ(21,*)
READ(21,*)
READ(21,*)
READ(21,*)
do i=1,O
READ(21,50)Lg(I)
50 FORMAT(2X,f5.1)
END DO

Ltot(i-1)=0.0
do i=1,O
Ltot(i)=Ltot(i-1)+lg(i)
END do

do i=1,O
PRINT*,fs(i)
end do

!DEtermine capacity of each layer
CapL(1)=3.14*dia**2*0.25*qall(1)+fs(1)*lg(1)*3.14*dia
!PRINT*,Capl(1)
CapL(2)=3.14*dia**2*0.25*qall(2)+3.14*dia*(fs(1)*lg(1)+fs(2)*lg(2))
!PRINT*,Capl(2)
CapL(3)=3.14*dia**2*0.25*qall(3)+3.14*dia*(fs(1)*lg(1)+fs(2)*lg(2)+fs(3)*lg(3))
!PRINT*,Capl(3)



PerPG=2.0*(s*(l+m)+2.0*dia)
APg=(l*s+dia)*(m*s+dia)



su(i-1)=0.0
```

```
do i=1,O
SU(i)=Su(i-1)+3.14*dia*lg(i)*fs(i)
!PRINT*,su(i)
END do
SUg(i-1)=0.0
do i=1,O
SUg(i)=Sug(i-1)+PerPG*lg(i)*fs(i)
PRINT*,SUg(i)
END do

DO i=1,O
dif(i)=PMAX-qall(i)*3.14*dia*dia*0.25
end do
if (Capl(3).lt.PMAX) then
PRINT*,"The soil strata is not enough"
Endif
if (Capl(3).gt.PMAX) then
lt=(dif(3)-su(2))/(3.14*dia*fs(3))+lg(1)+lg(2)
CPg=(lt-(lg(1)+lg(2)))*PerPG*fs(3)+APg*Qall(3)+SUg(2)
endif
IF (dif(3).lt.0.0) THEN
lt=lg(1)+lg(2)
CPg=APg*Qall(3)+SUg(2)
END IF
if (Capl(2).gt.PMAX) then
lt=(dif(2)-su(1))/(3.14*dia*fs(2))+lg(1)
CPg=(lt-lg(1))*PerPG*fs(2)+APg*Qall(2)+SUg(1)
endif
IF (dif(2).lt.0.0) THEN
lt=lg(1)
CPg=APg*Qall(2)+SUg(1)
END IF
if (Capl(1).gt.PMAX) then
lt=dif(1)/(3.14*dia*fs(1))
CPg=lt*PerPG*fs(1)+APg*Qall(1)
end if
if (dif(1).lt.0.0) then
lt=lg(1)-0.5
CPg=lt*PerPG*fs(1)+APg*Qall(1)
end if

PRINT*,"The Capacity of each pile=",PMAX
PRINT*,"the total length for the pile suficient for the axial force is:",lt
!*****************************************************************
```

```
!DETERMINATION OF PILE GROUP CAPACITY (CPg)
!Length of pile group=(number of pile spaces)*(pile spacing)+diameter of pile
!Pile group length=l*s+dia
!Pile group Width=m*s+dia
!Perimeter of pile group(PerPg)=2*(l*s+m*s+2*dia)
!                         =2*(s*(l+m)+2*dia)
!Area of pile group(APg)=(l*s+dia)*(m*s+dia)
!PILE GROUP CAPACITY (CPg)=Area of Pile group*Qall+Sum of {Perimeter of Pile*fs}
!                     =APg*Qall+Sum of {PerPg*fs}
PRINT*,"The Total Capacity of Pile Group=",CPg
PRINT*,APg
PRINT*,PerPg

!The ratio of the load capacity of pile group (CPg) to the total load
!capacity of the piles acting as individual piles (n*Qult) is the
!efficiency factor  Ne
!Since the length of the pile group is determined with the maximum
!capacity of individual piles n*Qult=N*PMAX
 Ne=CPg/(N*PMAX)
PRINT*,"The Efficiency Factor is=",Ne

OPEN(10,FILE='Data11.txt',STATUS='old')
DO I=1,17
READ(10,*)
END DO
WRITE(10,3)N
3 FORMAT('NUMBER OF CONCRETE PILES=',I4)
WRITE(10,4)LT
4 FORMAT('LENGTH OF CONCRETE PILES=',F4.1)
WRITE(10,6)LT
6 FORMAT('DIAMETER OF CONCRETE PILES=',F4.2)


    END PROGRAM
```

6. Developing a Program Supporting Cost Estimation of Commonly Used Reinforced Concrete Foundation

Quantity surveying may be described as a branch of technical accountancy dealing with building and civil engineering works, and the quantity survey today is no longer thought of as a man who counts bricks ,but as an expert advisor on any aspect of building costs. He is also regarded as the financial administer of the building team. His duty range from cost planning to post-contract financial management, and they increase in scope with the increasing complexity of the building industry.

These various functions of which the quantity surveyor is an expert all center around and stem from the bill of quantities, that document which is the financial hub of the major building contract and from which the quantity surveyor drives his reputation.

The preparation of this document is a very costy and laborious business. Moreover ,its preparation delays the tender date and holds up the building contract.

Therefore bill of quantities are a vital necessity in any system of competitive tendering, and it is partly the realization of this fact which is tending to spread the practice of the quantity surveyor's art around the world today.

The problem of how to produce the bill of quantities quickly ,accurately and economically must always be the concern of the quantity surveyor's and indeed always has been.

The program in this chapter estimates the cost of isolated foundation. The cost of foundation varies from place to place depending upon the availability man power and construction materials. As a result prices for constructing a foundation is not fixed .Prices should be known for estimation of foundation.

The program in this part reads data which are required for quantifying the cost of foundation according to the following format.

6.1 Cost Estimation of Isolated foundation

6.1.1 Data required for cost estimation of isolated foundation

Total building dimensions and unit price of items for foundation construction should be known.

An example is shown below.

TOTAL LENGTH OF BUILDING (LBLDG)=25.0

TOTAL WIDTH OF BUILDING (WBLDG) =40.0

DEPTH OF BULK EXCAVATION (BULKD)=0.8

UNIT PRICE FOR CLEAR OF THE SITE (UPCL)= 2.0

UNIT PRICE FOR BULK EXCAVATION (UPBULK)=12.0

UNIT PRICE FOR EXCAVATION OF ISOLATED FOOTING FROM REDUCED LEVEL(UPEXVIF)=12.0

UNIT PRICE FOR SELECTED MATERIAL FILL(UPSLCTM)=25.0

UNIT PRICE FOR CART AWAY OF EXCAVATED SOIL(UPCARTA)=15.0

UNIT PRICE FOR PLACING HARD CORE(UPHARDC)=18.0

UNIT PRICE FOR CASTING LEAN CONCRETE UNDER ISOLATED FOOTING (UPTFAREA)=18.0

UNIT PRICE FOR CASTING CONCRETE UNDER ISOLATED FOOTING (UPCONC)=18.0

UNIT PRICE FOR FORMWORK (UPFORMW)=42.0

UNIT PRICE FOR REINFORCEMENT IN KG (UPREINF)=8.0

By reading the above data the program calculates the quantity of foundation for all items.

6.1.2 Take of sheet for Excavation and Earth work

6.1.2.1 Clear of the site

The area to be cleared in most construction is calculated by increasing 1m in each side of the building.

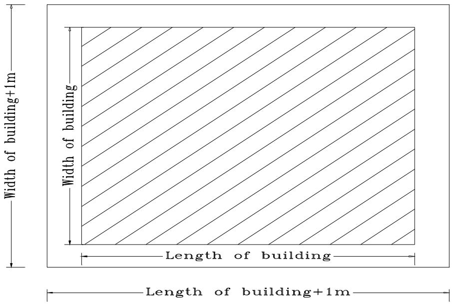


Fig 6.1 Area of site clearing

The total area of site clearing is the product of Length of building plus 1m and width of building +1m.

In the program the length,width of building,and area of site clearing are symbolized as LBLDG ,WBLDG and SCL respectively.

Hence

SLC=(LBLDG+1)*(WBLDG+1)

6.1.2.2 Bulk Excavation

The volume of bulk excavation is the product of site clearing area and depth of bulk excavation.

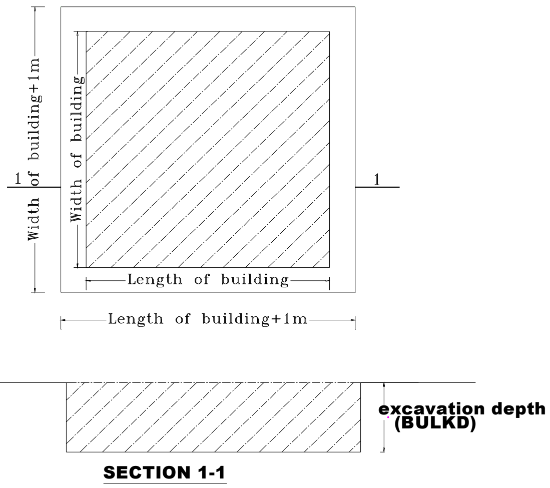


Fig 6.2 Bulk Excavation volume

In the program volume of bulk excavation and depth of bulk excavation are symbolized as BULKEXV and BULKD respectively.

BULKEXV=SLCSCxBULKD

<u>6.1.2.3 Excavation for Isolated Footing from Reduced Level</u>

The volume of excavation for isolated footing is calculated by summing the total excavation for each isolated footing from reduced level.

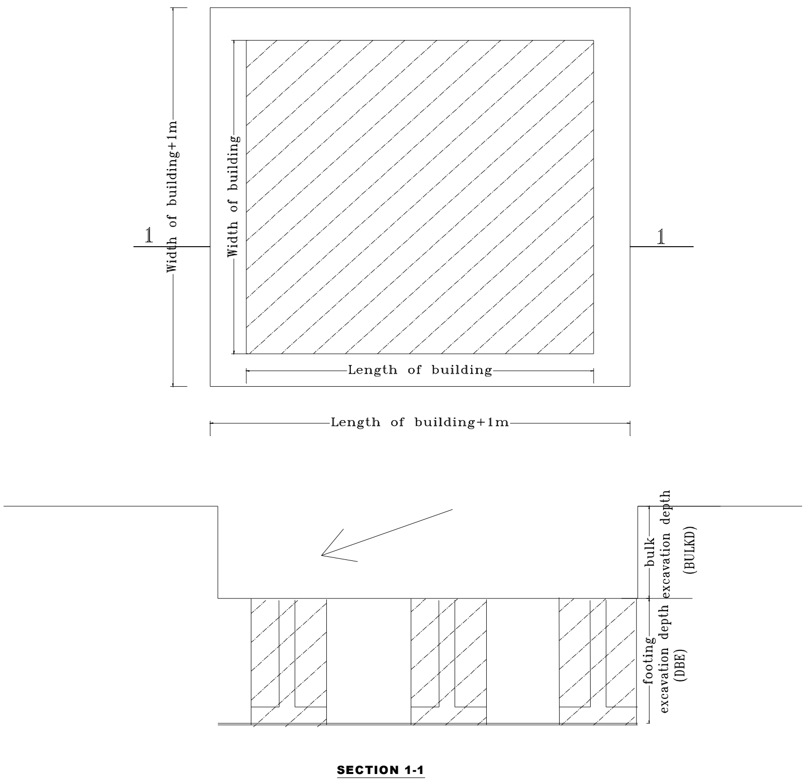


Fig 6.3 Excavation for isolated footing from reduced level

6.1.2.4 Selected Material Fill

The amount of selected material fill is the sum of excavation for isolated footing and volume of bulk excavation less the volume occupied by stone hard core and concrete footings.

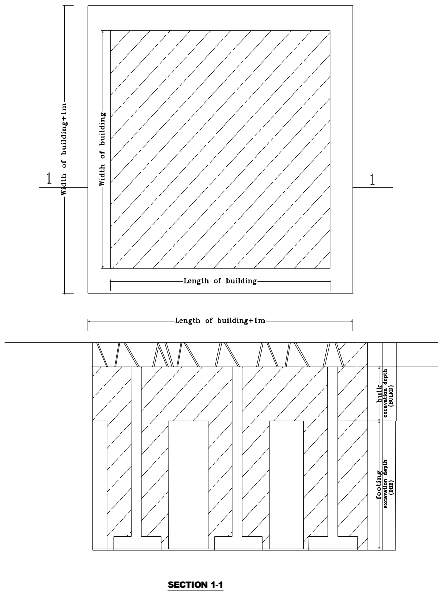


Fig 6.4 Selected material fill

Volume of selected material fill=Bulk excavation volume+Excavation for isolated footing-Volume of hardcore-Volume of concrete in footings and columns.

VSLMF=BULKDx(LBLDG+1)X(WBLDG+1)BULKD+FSIZE(I)XFSIZE(I)Xbulkd-0.25mx(LBLDG+1)X(WBLDG+1)-VOLUME OF CONCRETE IN FOOTINGS AND COLUMNS

6.1.2.5 Load and Cart away Excavated Materials

If the soil excavated is not good for foundation construction it will be carted away. The surplus for removal is the total excavated material less the quantity needed for back fill. An allowance must be made for the increase in bulk when the material is in the loose.

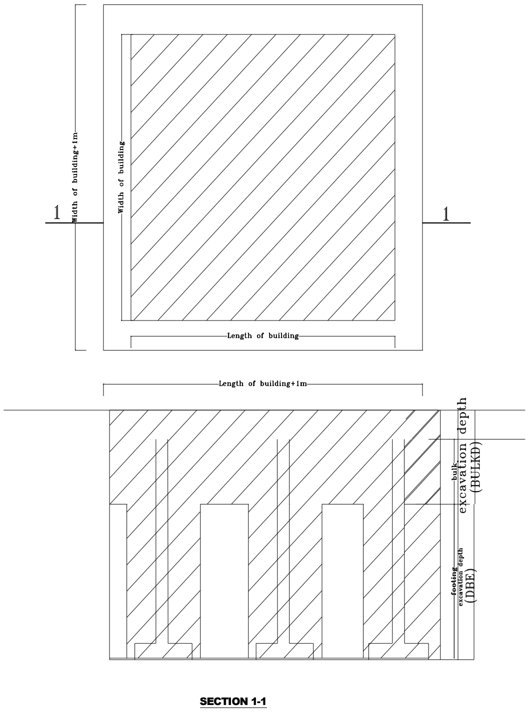


Fig 6.5 Cart away soil

Volume of cart away soil=Volume of site clearing+Bulk excavation volume+Excavation for isolated footing

VCARTA=BULKDx(LBLDG+1)X(WBLDG+1)+(FSIZE(I)+1)X(FSIZE(I)+1)XBULKD+0.20 mx(LBLDG+1)X(WBLDG+1).

5.1.2.6 Basaltic or Equivalent Stone Hardcore

Basaltic or equivalent stone hardcore well rammed and blinded with crushed stone to average thickness of 25cm are placed above layer of properly compacted selected material fill.

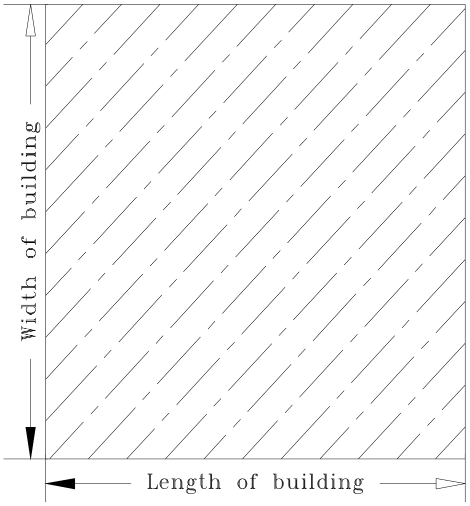


Fig 6.6 Area of hardcore

Area of hardcore=area of floor resting on ground floor

AHARDC=(WBLDG)X(WBLDG)

6.1.3 Take of sheet for Concrete work

<u>6.1.3.1 Lean concrete</u>

Lean concrete are placed at the base of footings,beams resting on ground floor and ground floor slab.The total quantity of lean concrete is the sum of total area of footings and slab resting on ground.

ALC=ΣFSIZE(i)Xfsize(i)+(WBLDG)X(WBLDG)

6.1.3.2 Volume of Concrete

The total volume of concrete is the sum of concrete in all footings and foundation columns

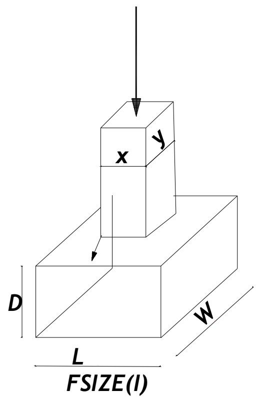


Fig 6.7 Volume of concrete

TVC=ΣFSIZE(i)Xfsize(i)xD(i)+Volume of concrete in foundation columns.

6.1.3.3 Weight of reinforcement

The total weight of reinforcement is the total sum of reinforcement in all footings. The program in this paper calculates the reinforcement required /m^2 for all footings. In this part the total weight of reinforcement is calculated by multiplying the total reinforcement area in both direction and the reinforcement required /m^2.

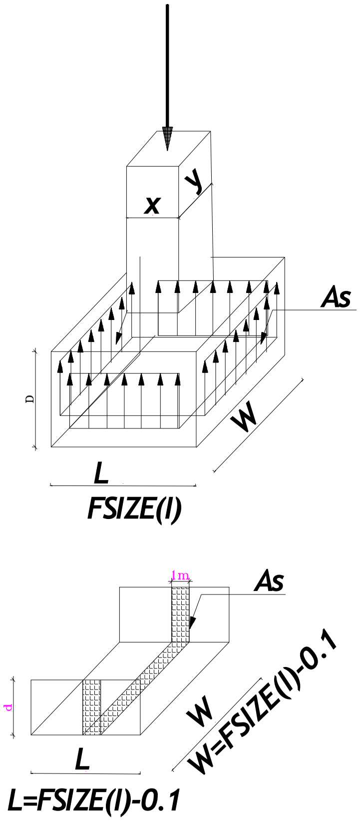


Fig 6.8 Amount of reinforcement

ASTOT=$\sum$2x(FSIZE(I)+2XD(I)-0.2)x(FSIZE(I)-0.1m)

6.1.5 Program performing take of sheet for specification and bill for isolated foundation

[PROGRAM-12]

```
!   Last change:  MS   14 Aug 102    8:57 pm
!This program will quantify   formwork area, reinforcement in footings,concrete volume
!area of lean concrete
PROGRAM footingQUANTITY
IMPLICIT NONE
INTEGER I,N
REAL ,DIMENSION(:),ALLOCATABLE::
FSIZE,DT,AS,FORMW,CONCV,REINF,EXVIF,FAREA
REAL SFORMW,SCONCV,SREINF,TEXVIF,EXISRD,BULKD,FD,TFAREA
PRINT*,"HOW MANY FOOTINGS DO YOU HAVE?"
READ*,N
```

```
ALLOCATE(FSIZE(N))
ALLOCATE(DT(N))
ALLOCATE(AS(N))
ALLOCATE(FORMW(N))
ALLOCATE(CONCV(N))
ALLOCATE(REINF(N))
ALLOCATE(EXVIF(N))
ALLOCATE(FAREA(N))

OPEN(10,FILE='DATA1.TXT',STATUS='OLD')
READ(10,*)
READ(10,*)
READ(10,*)
READ(10,*)
READ(10,*)
READ(10,16)FD
16 FORMAT(3X,F4.1)
READ(10,*)
READ(10,26)BULKD
26 FORMAT(31X,F3.1)
EXISRD=FD-BULKD-0.20
WRITE(*,4)EXISRD,FD,BULKD
4 FORMAT(3X,F5.2,3X,F7.2,3X,F7.2)
OPEN(11,FILE='DATA2.TXT',STATUS='OLD')
READ(11,*)
READ(11,*)
READ(11,*)
READ(11,*)
READ(11,*)
READ(11,*)
READ(11,*)
DO I=1,N
READ(11,91)FSIZE(I),DT(I),AS(I)
91 FORMAT(16X,F9.1,F7.2,F10.3)
```

```
   END DO
  DO I=1,N
  FORMW(I)=4.0*FSIZE(I)*DT(I)
  CONCV(I)=FSIZE(I)*FSIZE(I)*DT(I)
  REINF(I)=FSIZE(I)*FSIZE(I)*AS(I)
  EXVIF(I)=EXISRD*(FSIZE(I)+1)**2
  FAREA(I)=FSIZE(I)*FSIZE(I)
  END DO
  DO I=1,N
  SFORMW=SFORMW+FORMW(I)
  SCONCV=SCONCV+CONCV(I)
  SREINF=SREINF+REINF(I)
  TEXVIF=TEXVIF+EXVIF(I)
  TFAREA=TFAREA+FAREA(I)
  END DO
OPEN(17,FILE='DATA17.TXT',STATUS='OLD')
WRITE(17,30)
30 FORMAT(" THIS IS THE TOTAL QUANTITY OF FOUNDATION ")

WRITE(17,40)
40 FORMAT("FOOTING   FOOTING    FOOTING         FORMWORK    CONCRETE
REINFORCEMENT ")
WRITE(17,41)
41 FORMAT("SIZE     DEPTH   REINFORCEMENT            VOLUME    IN FOOTING ")
DO I=1,N
WRITE(17,50)FSIZE(I),DT(I),AS(I),FORMW(I),CONCV(I),REINF(I)
50 FORMAT(F3.1,F10.2,F17.3,3F10.3)
END DO

WRITE(17,60)
60 FORMAT("                 THE TOTAL QUANTITY OF FORMWORK    CONCRETE
REINFORCEMENT   ")
WRITE(17,70) SFORMW,SCONCV,SREINF,TEXVIF
70 FORMAT("         THE TOTAL SUM     ",F14.3,F8.2,2X,F10.3,3X,F10.2)
```

```
WRITE(17,80)TEXVIF
80 FORMAT("EXCAVATION FOR ISOLATED FOOTING FROM REDUCED LEVEL=",F14.3)
WRITE(17,81)TFAREA
81 FORMAT("TOTAL QUANTITY OF LEAN CONCRETE UNDER ISOLATED FOOTING =",F14.3)
OPEN(18,FILE='DATA18.TXT',STATUS='OLD')
WRITE(18,90)TEXVIF
90 FORMAT("THE TOTAL QUANTITY OF FOUNDATION excavation= ",F7.2)
OPEN(19,FILE='DATA19.TXT',STATUS='OLD')
WRITE(19,92)TFAREA
92 FORMAT("TOTAL QUANTITY OF LEAN CONCRETE UNDER ISOLATED FOOTING =",F7.2)
OPEN(21,FILE='DATA21.TXT',STATUS='OLD')
WRITE(21,93)SCONCV
93 FORMAT("TOTAL QUANTITY OF CONCRETE IN ISOLATED FOOTINGS =",F7.2)
OPEN(22,FILE='DATA22.TXT',STATUS='OLD')
WRITE(22,94)SFORMW
94 FORMAT("TOTAL QUANTITY OF FORMWORK FOR ISOLATED FOOTINGS =",F7.2)

END PROGRAM
```

Output of Take of sheet Program (data-17)

```
THIS IS THE TOTAL QUANTITY OF FOUNDATION
FOOTING  FOOTING   FOOTING       FORMWORK   CONCRETE  REINFORCEMENT
SIZE     DEPTH   REINFORCEMENT              VOLUME    IN FOOTING
1.5      0.42          850.201      2.520     0.945     0.416
1.8      0.50           65.079      3.607     1.623     0.629
1.7      0.47          116.475      3.203     1.361     0.552
1.5      0.42          850.201      2.520     0.945     0.416
1.9      0.52          118.978      3.960     1.881     0.705
2.2      0.59          297.172      5.201     2.860     0.968
2.1      0.56          351.987      4.712     2.474     0.872
1.9      0.52          118.978      3.960     1.881     0.705
1.9      0.52          111.427      3.960     1.881     0.705
```

```
2.1      0.59          290.491     4.964     2.606     0.890
2.0      0.56          345.221     4.488     2.244     0.797
1.9      0.52          111.427     3.960     1.881     0.705
1.9      0.52          118.978     3.960     1.881     0.705
2.2      0.59          297.172     5.201     2.860     0.968
2.1      0.56          351.987     4.712     2.474     0.872
1.9      0.52          118.978     3.960     1.881     0.705
1.5      0.42          850.201     2.520     0.945     0.416
1.8      0.50           65.079     3.607     1.623     0.629
1.7      0.47          116.475     3.203     1.361     0.552
1.5      0.42          850.201     2.520     0.945     0.416
           THE TOTAL QUANTITY OF FORMWORK   CONCRETE  REINFORCEMENT
         THE TOTAL SUM             76.736   36.55      13.622       328.06
EXCAVATION FOR ISOLATED FOOTING FROM REDUCED LEVEL=       328.060
TOTAL  QUANTITY  OF  LEAN  CONCRETE  UNDER  ISOLATED  FOOTING  =
69.830

Data-18

THE TOTAL QUANTITY OF FOUNDATION excavation=  328.06
```

6.1.3 Program for Specification and Bill of Quantities of Isolated Foundation.

[PROGRAM-13]

```
!    Last change:  MS   23 Sep 102    8:38 am
PROGRAM SPECIFICATION
!Program for Specification and Bill of Quantities of
!          Isolated Foundation
IMPLICIT NONE
!INTEGER ,DIMENSION(:),ALLOCATABLE::JID
!INTEGER N
REAL
LBLDG,WBLDG,CLSITE,UPCL,UPBULK,UPSLCTM,UPEXVIF,COSTBULKEX,COSTC
L,COSTEXVIF,COSTSLCTM
REAL BULKEX,BULKD,TEXVIF,SLCTM,TFAREA,UPTFAREA,COSTFAREA
```

```
REAL CARTA,UPCARTA,COSTCARTA
REAL HARDC,UPHARDC,COSTHARDC
REAL SCONCV,UPCONC,COSTCONC
REAL SFORMW,UPFORMW,COSTFORMW
REAL SREINF,UPREINF,COSTREINF
REAL SUM1,SUM2
!REAL ,DIMENSION(:),ALLOCATABLE:: FSIZE
!ALLOCATE(FSIZE(N))
!PRINT*,"HOW MANY FOOTINGS DO YOU HAVE?"
!READ*,N
OPEN(10,FILE='DATA11.TXT',STATUS='OLD')
READ(10,*)
READ(10,5)LBLDG
5 FORMAT(33x,f6.2)
READ(10,15)WBLDG
15 FORMAT(33x,f6.2)
READ(10,25)BULKD
25 FORMAT(34x,f4.2)
READ(10,35)UPCL
35 FORMAT(41x,f4.1)
READ(10,45)UPBULK
45 FORMAT(41x,f6.2)
READ(10,55)UPEXVIF
55 FORMAT(75x,f6.2)
READ(10,65)UPSLCTM
65 FORMAT(47x,f6.2)
READ(10,66)UPCARTA
66 FORMAT(52x,f6.2)
READ(10,67)UPHARDC
67 FORMAT(42x,f6.2)
READ(10,68)UPTFAREA
68 FORMAT(72x,f6.2)
READ(10,69)UPCONC
69 FORMAT(64x,f6.2)
```

```
READ(10,70)UPFORMW
70 FORMAT(34x,f6.2)
READ(10,71)UPREINF
71 FORMAT(45x,f6.2)

OPEN(18,FILE='data18.TXT',STATUS='OLD')
READ(18,6)TEXVIF
6 FORMAT(47x,F7.2)
CLSITE=(WBLDG+1.0)*(LBLDG+1.0)
COSTCL=UPCL*CLSITE
BULKEX=CLSITE*BULKD
COSTBULKEX=UPBULK*BULKEX
COSTEXVIF=UPEXVIF*TEXVIF
SLCTM=BULKD*CLSITE+TEXVIF
COSTSLCTM=UPSLCTM*SLCTM
CARTA=(0.2+BULKD)*CLSITE+TEXVIF
COSTCARTA=UPCARTA*CARTA
HARDC=LBLDG*WBLDG
COSTHARDC=UPHARDC*HARDC
COSTCONC=UPCONC*SCONCV
OPEN(19,FILE='DATA19.TXT',STATUS='OLD')
READ(19,7)TFAREA
7 FORMAT(59x,f6.2)
COSTFAREA=TFAREA*UPTFAREA
OPEN(21,FILE='DATA21.TXT',STATUS='OLD')
READ(21,8)SCONCV
8 FORMAT(52x,f6.2)
COSTCONC=UPCONC*SCONCV
OPEN(22,FILE='DATA22.TXT',STATUS='OLD')
READ(22,9)SFORMW
9 FORMAT(53x,f6.2)
COSTFORMW=UPFORMW*SFORMW
OPEN(23,FILE='DATA23.TXT',STATUS='OLD')
READ(23,10)SREINF
```

```
10 FORMAT(41x,f6.2)
COSTREINF=UPREINF*SREINF
OPEN(20,FILE='BOQ.TXT',STATUS='OLD')
WRITE(20,60)
60 FORMAT(/,'        SPECIFICATION AND BILL OF QUANTITIES ',/,                    &
'ITEM     DESCRIPTION                UNIT    QUANTITY    UNIT     COST ',/,    &
'                                    PRICE    ',/,           &
'*************************************************************************
*',//,   &
'    1 EXCAVATION AND EARTH WORK                                 ',//)

WRITE(20,75)CLSITE,UPCL,COSTCL
75 FORMAT('1.1 Clear of the site to remove top',/,4x,'top soil to average depth of 20cm.
m2',4X,F7.2,3X,F7.2,3X,F10.2,//)
!READ(20,*)
!READ(20,*)
WRITE(20,85)BULKEX,UPBULK,COSTBULKEX
85 FORMAT('1.2 Bulk excavation in ordinary soil',/,4x,'to a depth not exceeding 150cm.
m3', 4X,F7.2,3X,F7.2,3X,F10.2,//)
WRITE(20,86)TEXVIF,UPEXVIF,COSTEXVIF
86 FORMAT('1.3 Excavation for isolated footing in',/,4x,'ordinary soil to a depth
not',/,4X,'exceeding 150cm.                  m3'&
,4X,F7.2,3X,F7.2,3X,F10.2,//)
WRITE(20,87)SLCTM,UPSLCTM,COSTSLCTM
87 FORMAT('1.4 Back fill under hard core with non',/,4x,'expansive selected materials
',/,4X,'and well ram in layers not'           &
,/,4x,'exceeding 20cm                    m3',4X,F7.2,3X,F7.2,3X,F10.2,//)
WRITE(20,88)CARTA,UPCARTA,COSTCARTA
88 FORMAT('1.5 Cart away surplus excavated',/,4x,'away from the site not',/,4X,'exceeding
2km form the site          m3'            &
,4X,F7.2,3X,F7.2,3X,F10.2,//)
WRITE(20,89)HARDC,UPHARDC,COSTHARDC
89 FORMAT('1.6 Basaltic or equvalent stone',/,4x,'hard core well rammed
and',/,4X,'consolidated and blinded with ',/,4X,     &
'crushed stone to a finished',/,4x,'thickness of 25cm                              m3'
,4X,F7.2,3X,F7.2,3X,F10.2,////)
```

```
SUM1=COSTCL+COSTBULKEX+COSTEXVIF+COSTSLCTM+COSTCARTA+COSTH
ARDC

WRITE(20,76)SUM1

76 FORMAT('                         TOTAL CARRIED TO SUMMARY=',F10.2,///)

WRITE(20,77)

77
FORMAT('*******************************************************************
**************',//)


WRITE(20,90)

90 FORMAT('      2.CONCRETE WORK     ',//)


WRITE(20,91)TFAREA,UPTFAREA,COSTFAREA

91 FORMAT('2.1 50mm thick lean concrete in',/,4x,'class C-5 with minimum
cement',/,4X,'content of 150kg/m3 under ',/,4X,         &

'isolated foundation            m3',4X,F7.2,3X,F7.2,3X,F10.2,//)


WRITE(20,92)SCONCV,UPCONC,COSTCONC

92 FORMAT('2.2 Reinforced concrete in C 25 with',/,4x,'minimum cement content of
360kg/m3',/,4X,'filled into formwork and vibrated ' &

,/,4X,'around steel reinforcement,formwork',/,4x,'and steel reinforcement  shall be',/,4x,
&

'measured separetly             m3',4X,F7.2,3X,F7.2,3X,F10.2,//)

WRITE(20,93)SFORMW,UPFORMW,COSTFORMW

93 FORMAT('2.3 Provide cut and fix in position',/,4x,'sawn zigba wood formwork to
',/,4X,'isolated footing            m2' &

,4X,F7.2,3X,F7.2,3X,F10.2,//)


WRITE(20,94)SREINF,UPREINF,COSTREINF

94 FORMAT('2.4 Steel reinforcement according to',/,4x,'structural drawing,price
shall',/,4X,'include cutting,bending,placing ' &

,/,4X,'in position and tying wires',//,4x,'          Dia __mm deformed bars
kg',4X,F7.2,3X,F7.2,3X,F10.2,//)


SUM2=COSTFAREA+COSTCONC+COSTFORMW+COSTREINF

WRITE(20,95)SUM2
```

```
95 FORMAT('                              TOTAL CARRIED TO SUMMARY=',F10.2,///)

PRINT*,"YOU CAN GET THE OUTPUT IN BOQ.TXT"
PRINT*,TFAREA
END PROGRAM
```

6.1.5 Specification and Bill of Quantities of Isolated Foundation Using the Software.

```
        SPECIFICATION AND BILL OF QUANTITIES
ITEM     DESCRIPTION                 UNIT    QUANTITY     UNIT      COST
                                                          PRICE
****************************************************************************

    1 EXCAVATION AND EARTH WORK


1.1 Clear of the site to remove top
```

	top soil to average depth of 20cm.	m2	1066.00	2.00	2132.00
1.2	Bulk excavation in ordinary soil to a depth not exceeding 150cm.	m3	852.80	2.00	1705.60
1.3	Excavation for isolated footing in ordinary soil to a depth not exceeding 150cm.	m3	28.06	2.00	56.12
1.4	Back fill under hard core with non expansive selected materials and well ram in layers not exceeding 20cm	m3	880.86	25.00	22021.50
1.5	Cart away surplus excavated away from the site not exceeding 2km form the site	m3	1094.06	15.00	16410.90
1.6	Basaltic or equvalent stone hard core well rammed and consolidated and blinded with crushed stone to a finished thickness of 25cm	m3	1000.00	18.00	18000.00
				TOTAL CARRIED TO SUMMARY=	60326.12

****

2.CONCRETE WORK

2.1	50mm thick lean concrete in class C-5 with minimum cement content of 150kg/m3 under isolated foundation	m3	9.83	8.00	78.64
2.2	Reinforced concrete in C 25 with minimum cement content of 360kg/m3				

```
    filled into formwork and vibrated
    around steel reinforcement,formwork
    and steel reinforcement  shall be
    measured separetly                   m3       6.55     18.00        117.90


2.3 Provide cut and fix in position
    sawn zigba wood formwork to
    isolated footing                     m2       6.74     42.00        283.08


2.4 Steel reinforcement according to
    structural drawing,price  shall
    include cutting,bending,placing
    in position and tying wires

        Dia __mm deformed bars            kg       3.62      8.00         28.96


                                       TOTAL CARRIED TO SUMMARY=    508.58
```

6.2 Program for Cost Eastimation of Mat Foundations

The program in this chapter estimates the cost of Mat foundation.

The program in this part reads data which are required for quantifying the cost of foundation according to the following format. The quantity of reinforcement bars and concrete volume are imported from the structural analysis software (SAFE).

6.2.1 Datas required for cost eastimation of Mat foundation

DATA11.TXT

```
!SUMMARY OF TAKE OF SHEET
TOTAL LENGTH OF BUILDING (LBLDG)=26.0
TOTAL KG (UPREINF)=8.0
MAT FOUNDATION CONCRETE SLAB DEPTH=0.4WIDTH OF BUILDING (WBLDG) =21.0
DEPTH OF BULK EXCAVATION (BULKD)=0.8
UNIT PRICE FOR CLEAR OF THE SITE (UPCL)= 2.0
```

```
UNIT PRICE FOR BULK EXCAVATION (UPBULK)=12.0
UNIT PRICE FOR SELECTED MATERIAL FILL(UPSLCTM)=25.0
UNIT PRICE FOR CART AWAY OF EXCAVATED SOIL(UPCARTA)=15.0
UNIT PRICE FOR PLACING HARD CORE(UPHARDC)=18.0
UNIT PRICE FOR CASTING LEAN CONCRETE UNDER ISOLATED FOOTING (UPTFAREA)=18.0
```

6.2.2 Take of sheet for Excavation and earth work

<u>6.2.2.1 Clear of the site</u>

The area to be cleared in most construction is calculated by increasing 1m in each side of the building.

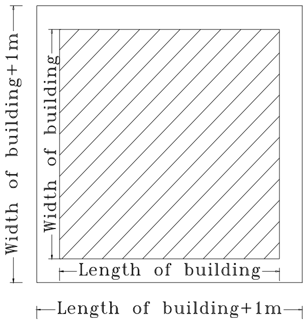


Fig 6.9 Clear of site for mat foundation

The total area of site clearing is the product of

Length of building plus 1m and width of building +1m.

In the program the length,width of building,and area of site clearing are symbolized as LBLDG ,WBLDG and SCL respectively.

Hence

SLC=(LBLDG+1)*(WBLDG+1)

6.2.2.2 Bulk Excavation

The volume of bulk excavation is the product of site clearing area and depth of bulk excavation.

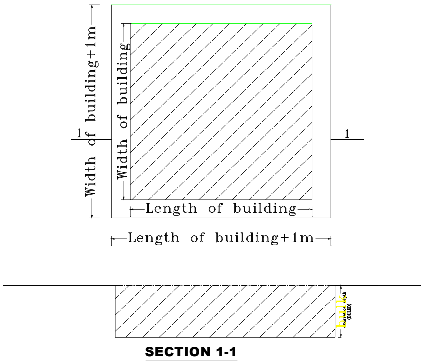


Fig 6.10.Bulk excavation for mat foundation

In the program volume of bulk excavation and depth of bulk excavation are symbolized as BULKEXV and BULKD respectively.

BULKEXV=SLCSCxBULKD

6.2.2.3 Selected Material Fill

The amount of selected material fill is the sum of bulk excavation and site clearing less the volume occupied by stone hard core and concrete volume below ground level.

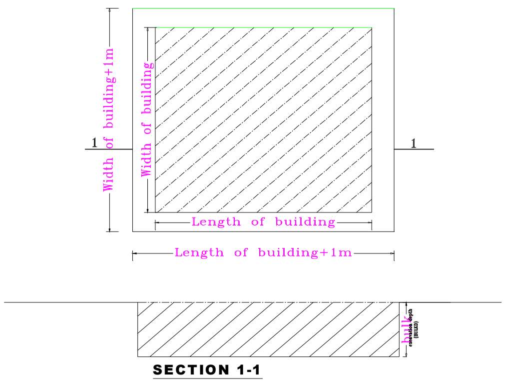


Fig 6.11 Selected material fill for mat foundation

Volume of selected material fill=Bulk excavation volume+Volume of site clearing.

VSLMF=BULKDx(LBLDG+1)X(WBLDG+1)+0.25mx(LBLDG+1)X(WBLDG+1)-VOLUME OF CONCRETE BELOW GROUND LEVEL

6.2.2.4 LOAD AND CART AWAY EXCAVATED MATERIALS

If the soil excavated is not good for foundation construction it will be carted away.The surplus for removal is the total excavated material less the quantity needed for back fill.An allowance must be made for the increase in bulk when the material is in the loose.

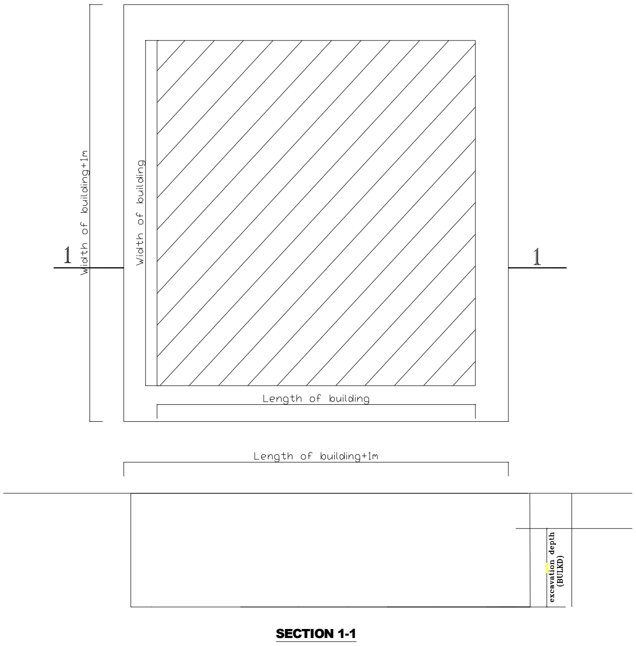


Fig 6.12 Cart away of excavated soil

Volume of cart away soil=Volume of site clearing+Bulk excavation volumeVCARTA=BULKDx(LBLDG+1)X(WBLDG+1)+0.20mx(LBLDG+1)X(WBLDG+1)
.

6.2.2.5 Basaltic or Equivalent Stone Hardcore

Basaltic or equivalent stone hardcore well rammed and blinded with crushed stone to average thickness of 25cm are placed above layer of properly compacted selected material fill.

Area of hardcore=area of floor resting on ground floor

AHARDC=(WBLDG)X(WBLDG)

6.2.3 Take of sheet for Concrete work

6.2.3.1 Lean concrete

Lean concrete are placed at the base of mat slab.

The total quantity of lean concrete is the the total area of mat slab.

ALC=(WBLDG)X(WBLDG)

6.2.3.2 Volume of Concrete

The total volume of concrete is the the total volume of concrete in mat foundation.

TVC= Volume of concrete in mat foundation.

6.2.3.2 Total weight of reinforcement

The total weight of reinforcement in mat foundation system is obtained from SAFE.

DATA21.TXT

```
UNIT PRICE FOR FORMWORK (UPFORMW)=42.0
UNIT PRICE FOR REINFORCEMENT IN
```

DATA21.TXT

By reading the above data the program calculates the quantity of foundation items.

6.2.4 Program for Specification and Bill of Quantities of Mat Foundation.

[PROGRAM-14]

```
!    Last change:  MS   31 Jan 102   10:30 am
PROGRAM SPECIFICATION
!Program for specification and bill of Quantities of
!             Mat Foundation
IMPLICIT NONE
!INTEGER ,DIMENSION(:),ALLOCATABLE::JID
```

```
!INTEGER N
REAL
  LBLDG,WBLDG,CLSITE,UPCL,UPBULK,UPSLCTM,COSTBULKEX,COSTCL,COSTSL
  CTM
REAL BULKEX,BULKD,SLCTM,TFAREA,UPTFAREA,COSTFAREA,DT
REAL CARTA,UPCARTA,COSTCARTA
REAL HARDC,UPHARDC,COSTHARDC
REAL SCONCV,UPCONC,COSTCONC
REAL SFORMW,UPFORMW,COSTFORMW
REAL SREINF,UPREINF,COSTREINF
REAL SUM1,SUM2
OPEN(10,FILE='DATA11.TXT',STATUS='OLD')
READ(10,*)
READ(10,5)LBLDG
5 FORMAT(33x,f6.2)
READ(10,15)WBLDG
15 FORMAT(33x,f6.2)
READ(10,25)BULKD
25 FORMAT(34x,f4.2)
READ(10,35)UPCL
35 FORMAT(41x,f4.1)
READ(10,45)UPBULK
45 FORMAT(41x,f6.1)
READ(10,65)UPSLCTM
65 FORMAT(47x,f6.2)
READ(10,66)UPCARTA
66 FORMAT(52x,f6.2)
READ(10,67)UPHARDC
67 FORMAT(42x,f6.2)
READ(10,68)UPTFAREA
68 FORMAT(72x,f6.2)
READ(10,69)UPCONC
```

```
69 FORMAT(64x,f6.2)
READ(10,70)UPFORMW
70 FORMAT(34x,f6.2)
READ(10,71)UPREINF
71 FORMAT(45x,f6.2)
READ(10,72)DT
72 FORMAT(36x,f6.2)
CLSITE=(WBLDG+1.0)*(LBLDG+1.0)
COSTCL=UPCL*CLSITE
BULKEX=CLSITE*BULKD
COSTBULKEX=UPBULK*BULKEX
SLCTM=BULKD*CLSITE
COSTSLCTM=UPSLCTM*SLCTM
CARTA=(0.2+BULKD)*CLSITE
COSTCARTA=UPCARTA*CARTA
HARDC=LBLDG*WBLDG
TFAREA=LBLDG*WBLDG
COSTHARDC=UPHARDC*HARDC
COSTCONC=UPCONC*SCONCV
COSTFAREA=TFAREA*UPTFAREA
SFORMW=2.0*DT*(LBLDG+WBLDG)
OPEN(21,FILE='DATA21.TXT',STATUS='OLD')
READ(21,8)SCONCV
8 FORMAT(47x,f6.2)
READ(21,10)SREINF
10 FORMAT(58x,f6.2)
COSTCONC=UPCONC*SCONCV
COSTFORMW=UPFORMW*SFORMW
COSTREINF=UPREINF*SREINF
OPEN(20,FILE='BOQ.TXT',STATUS='OLD')
WRITE(20,60)
60 FORMAT(/,'        SPECIFICATION AND BILL OF QUANTITIES ',/,                    &
```

```
'ITEM    DESCRIPTION              UNIT   QUANTITY    UNIT     COST  ',/,    &
'                                 PRICE    ',/,          &
'***************************************************************************'
  ,//,   &
'   1 EXCAVATION AND EARTH WORK                                    ',//)

WRITE(20,75)CLSITE,UPCL,COSTCL
75 FORMAT('1.1 Clear of the site to remove top',/,4x,'top soil to average depth of 20cm.
  m2',4X,F7.2,3X,F7.2,3X,F10.2,//)
!READ(20,*)
!READ(20,*)
WRITE(20,85)BULKEX,UPBULK,COSTBULKEX
85 FORMAT('1.2 Bulk excavation in ordinary soil',/,4x,'to a depth not exceeding 150cm.
  m3', 4X,F7.2,3X,F7.2,3X,F10.2,//)
WRITE(20,87)SLCTM,UPSLCTM,COSTSLCTM
87 FORMAT('1.3 Back fill under hard core with non',/,4x,'expansive selected materials
  ',/,4X,'and well ram in layers not'         &
,/,4x,'exceeding 20cm                    m3',4X,F7.2,3X,F7.2,3X,F10.2,//)
WRITE(20,88)CARTA,UPCARTA,COSTCARTA
88 FORMAT('1.4 Cart away surplus excavated',/,4x,'away from the site not',/,4X,'exceeding
  2km form the site          m3'          &
,4X,F7.2,3X,F7.2,3X,F10.2,//)
WRITE(20,89)HARDC,UPHARDC,COSTHARDC
89 FORMAT('1.5 Basaltic or equvalent stone',/,4x,'hard core well rammed
  and',/,4X,'consolidated and blinded with ',/,4X,     &
'crushed stone to a finished',/,4x,'thickness of 25cm                  m3'
  ,4X,F7.2,3X,F7.2,3X,F10.2,////)
SUM1=COSTCL+COSTBULKEX+COSTSLCTM+COSTCARTA+COSTHARDC
WRITE(20,76)SUM1
76 FORMAT('                              TOTAL CARRIED TO SUMMARY=',F10.2,///)
WRITE(20,77)
```

```
77
   FORMAT('*****************************************************************
   **************',//)

WRITE(20,90)
90 FORMAT('         2.CONCRETE WORK     ',//)

WRITE(20,91)TFAREA,UPTFAREA,COSTFAREA
91 FORMAT('2.1 50mm thick lean concrete in',/,4x,'class C-5 with minimum
   cement',/,4X,'content of 150kg/m3 under ',/,4X,            &
'isolated foundation                  m3',4X,F7.2,3X,F7.2,3X,F10.2,//)

WRITE(20,92)SCONCV,UPCONC,COSTCONC
92 FORMAT('2.2 Reinforced concrete in C 25 with',/,4x,'minimum cement content of
   360kg/m3',/,4X,'filled into formwork and vibrated ' &
,/,4X,'around steel reinforcement,formwork',/,4x,'and steel reinforcement  shall be',/,4x,
   &
'measured separetly                  m3',4X,F7.2,3X,F7.2,3X,F10.2,//)
WRITE(20,93)SFORMW,UPFORMW,COSTFORMW
93 FORMAT('2.3 Provide cut and fix in position',/,4x,'sawn zigba wood formwork to
   ',/,4X,'isolated footing                    m2' &
,4X,F7.2,3X,F7.2,3X,F10.2,//)

WRITE(20,94)SREINF,UPREINF,COSTREINF
94 FORMAT('2.4 Steel reinforcement according to',/,4x,'structural drawing,price
   shall',/,4X,'include cutting,bending,placing ' &
,/,4X,'in position and tying wires',//,4x,'    Dia __mm deformed bars
   kg',4X,F7.2,3X,F7.2,3X,F10.2,//)

SUM2=COSTFAREA+COSTCONC+COSTFORMW+COSTREINF
WRITE(20,95)SUM2
95 FORMAT('                                  TOTAL CARRIED TO SUMMARY=',F10.2,///)
```

```
PRINT*,"YOU CAN GET THE OUTPUT IN BOQ.TXT"
PRINT*,TFAREA
END PROGRAM
```

6.2.5 Specification and Bill of Quantities of Mat Foundation Using the Software

```
        SPECIFICATION AND BILL OF QUANTITIES
ITEM     DESCRIPTION                  UNIT    QUANTITY     UNIT      COST
                                                           PRICE
****************************************************************************

    1 EXCAVATION AND EARTH WORK


1.1 Clear of the site to remove top
    top soil to average depth of 20cm.  m2     594.00      2.00      1188.00


1.2 Bulk excavation in ordinary soil
    to a depth not exceeding 150cm.     m3     475.20      2.00       950.40


1.3 Back fill under hard core with non
    expansive selected materials
    and well ram in layers not
    exceeding 20cm                       m3     475.20     25.00     11880.00
```

1.4	Cart away surplus excavated away from the site not exceeding 2km form the site	m3	594.00	15.00	8910.00
1.5	Basaltic or equvalent stone hard core well rammed and consolidated and blinded with crushed stone to a finished thickness of 25cm	m3	546.00	18.00	9828.00

TOTAL CARRIED TO SUMMARY= 32756.40

****

2.CONCRETE WORK

2.1	50mm thick lean concrete in class C-5 with minimum cement content of 150kg/m3 under isolated foundation	m3	546.00	8.00	4368.00
2.2	Reinforced concrete in C 25 with minimum cement content of 360kg/m3 filled into formwork and vibrated around steel reinforcement,formwork and steel reinforcement shall be measured separetly	m3	27.50	18.00	495.00
2.3	Provide cut and fix in position sawn zigba wood formwork to isolated footing	m2	37.60	42.00	1579.20
2.4	Steel reinforcement according to structural drawing,price shall include cutting,bending,placing in position and tying wires				
	Dia __mm deformed bars	kg	4.20	8.00	33.60

```
                                   TOTAL CARRIED TO SUMMARY=   6475.80
```

6.3 Program for Cost Estimation of Pile Foundations

The program in this chapter estimates the cost of Pile foundation.

The program in this part reads data which are required for quantifying the cost of foundation according to the following format.

6.3.1 Data required for quantifying the cost of pile foundation

DATA11.TXT

```
!SUMMARY OF TAKE OF SHEET
TOTAL LENGTH OF BUILDING (LBLDG)=25.0
TOTAL WIDTH OF BUILDING (WBLDG) =40.0
UNIT PRICE FOR CLEAR OF THE SITE (UPCL)= 2.0
UNIT PRICE FOR CART AWAY OF EXCAVATED SOIL(UPCARTA)=15.0
UNIT PRICE FOR PLACING HARD CORE(UPHARDC)=18.0
UNIT PRICE FOR CASTING LEAN CONCRETE UNDER ISOLATED FOOTING (UPTFAREA)=18.0
UNIT PRICE FOR CASTING CONCRETE IN PILE CAPS (UPCONC)=18.0
UNIT PRICE FOR FORMWORK (UPFORMW)=42.0
```

```
UNIT PRICE FOR REINFORCEMENT IN KG (UPREINF)=8.0
UNIT PRICE FOR CASTING CONCRETE IN PILES (UPPCONC)=680.0
UNIT PRICE FOR DRILING HOLES FOR PILE INSTALATION (UPPEXV)=58.0
PILE CAP CONCRETE SLAB DEPTH=0.4
NUMBER OF CONCRETE PILES=  99
LENGTH OF CONCRETE PILES= 7.4
```

6.3.2 Program for Specification and Bill of Quantities of Pile Foundation

[PROGRAM-15]

```
!    Last change:  MS   31 Jan 102   11:21 am
PROGRAM SPECIFICATION
!Program for specification and bill of Quantities of
!            Pile Foundation
IMPLICIT NONE
!INTEGER ,DIMENSION(:),ALLOCATABLE::P
!INTEGER
REAL LBLDG,WBLDG,CLSITE,UPCL,COSTCL
REAL TFAREA,UPTFAREA,COSTFAREA,DT
REAL N,lt,dia
REAL CARTA,UPCARTA,COSTCARTA
REAL HARDC,UPHARDC,COSTHARDC
REAL SCONCV,UPCONC,COSTCONC
REAL PCONC,UPPCONC,COSTPCONC
REAL PEXV,UPPEXV,COSTPEXV
REAL SFORMW,UPFORMW,COSTFORMW
REAL SREINF,UPREINF,COSTREINF
REAL SUM1,SUM2
OPEN(10,FILE='DATA11.TXT',STATUS='OLD')
READ(10,*)
READ(10,5)LBLDG
5 FORMAT(33x,f6.2)
READ(10,15)WBLDG
15 FORMAT(33x,f6.2)
READ(10,35)UPCL
```

```
35 FORMAT(41x,f4.1)
READ(10,66)UPCARTA
66 FORMAT(52x,f6.2)
READ(10,67)UPHARDC
67 FORMAT(42x,f6.2)
READ(10,72)UPTFAREA
72 FORMAT(41x,f4.1)
READ(10,55)UPCONC
55 FORMAT(64x,f6.2)
READ(10,70)UPFORMW
70 FORMAT(45x,f6.2)
READ(10,71)UPREINF
71 FORMAT(45x,f6.2)
READ(10,7)UPPCONC
7 FORMAT(52x,f6.2)
READ(10,8)UPPEXV
8 FORMAT(59x,f6.2)
READ(10,2)DT
2 FORMAT(29x,f6.2)
READ(10,3)N
3 FORMAT(26x,f6.2)
READ(10,4)LT
4 FORMAT(26x,f6.2)
READ(10,6)DIA
6 FORMAT(28x,f6.2)
CLSITE=(WBLDG+1.0)*(LBLDG+1.0)
COSTCL=UPCL*CLSITE

CARTA=(0.2)*CLSITE
COSTCARTA=UPCARTA*CARTA
HARDC=LBLDG*WBLDG

TFAREA=LBLDG*WBLDG
COSTHARDC=UPHARDC*HARDC
```

```
SCONCV=TFAREA*DT
COSTCONC=UPCONC*SCONCV
COSTFAREA=TFAREA*UPTFAREA
SFORMW=N*lT*3.14*dia

PCONC=lT*N*3.14*DIA*DIA*0.25
Pexv=lT*N*3.14*DIA*DIA*0.25
COSTPCONC=UPPCONC*PCONC
COSTPEXV=UPPEXV*PEXV

OPEN(21,FILE='DATA21.TXT',STATUS='OLD')
READ(21,9)SCONCV
9 FORMAT(47x,f6.2)
READ(21,10)SREINF
10 FORMAT(58x,f6.2)
COSTCONC=UPCONC*SCONCV
COSTFORMW=UPFORMW*SFORMW
COSTREINF=UPREINF*SREINF
OPEN(20,FILE='BOQ.TXT',STATUS='OLD')
WRITE(20,60)
60 FORMAT(/,'        SPECIFICATION AND BILL OF QUANTITIES ',/,                  &
'ITEM     DESCRIPTION               UNIT    QUANTITY     UNIT      COST  ',/,     &
'                                   PRICE    ',/,          &
'************************************************************************
*',//,   &
'    1 EXCAVATION AND EARTH WORK                                  ',//)

WRITE(20,75)CLSITE,UPCL,COSTCL
75 FORMAT('1.1 Clear of the site to remove top',/,4x,'top soil to average depth of 20cm.
m2',4X,F7.2,3X,F7.2,3X,F10.2,//)
!READ(20,*)
!READ(20,*)
!WRITE(20,85)BULKEX,UPBULK,COSTBULKEX
!85 FORMAT('1.2 Bulk excavation in ordinary soil',/,4x,'to a depth not exceeding 150cm.
m3', 4X,F7.2,3X,F7.2,3X,F10.2,//)
```

```
WRITE(20,86)PEXV,UPPEXV,COSTPEXV

86 FORMAT('1.3 Excavation for isolated pile in ',/,4x,'ordinary soil to the required depth.
m3', 4X,F7.2,3X,F7.2,3X,F10.2,//)

WRITE(20,88)CARTA,UPCARTA,COSTCARTA

88 FORMAT('1.4 Cart away surplus excavated',/,4x,'away from the site not',/,4X,'exceeding
2km form the site          m3'          &

,4X,F7.2,3X,F7.2,3X,F10.2,//)

WRITE(20,89)HARDC,UPHARDC,COSTHARDC

89 FORMAT('1.5 Basaltic or equvalent stone',/,4x,'hard core well rammed
and',/,4X,'consolidated and blinded with ',/,4X,    &

'crushed stone to a finished',/,4x,'thickness of 25cm                              m3'
,4X,F7.2,3X,F7.2,3X,F10.2,////)

SUM1=COSTCL+COSTCARTA+COSTHARDC

WRITE(20,76)SUM1

76 FORMAT('                              TOTAL CARRIED TO SUMMARY=',F10.2,///)

WRITE(20,77)

77
FORMAT('*****************************************************************
**************',//)


WRITE(20,90)

90 FORMAT('        2.CONCRETE WORK     ',//)


WRITE(20,91)TFAREA,UPTFAREA,COSTFAREA

91 FORMAT('2.1 50mm thick lean concrete in',/,4x,'class C-5 with minimum
cement',/,4X,'content of 150kg/m3 under ',/,4X,          &

'isolated foundation               m3',4X,F7.2,3X,F7.2,3X,F10.2,//)

WRITE(20,92)PCONC,UPPCONC,COSTPCONC

92 FORMAT('2.2 Concrete C-25 in Concrete Piles      m3',4X,F7.2,3X,F7.2,3X,F10.2,//)


WRITE(20,93)SCONCV,UPCONC,COSTCONC

93 FORMAT('2.3 Reinforced concrete in C 25 with',/,4x,'minimum cement content of
360kg/m3',/,4X,'filled into formwork and vibrated ' &

,/,4X,'around steel reinforcement,formwork',/,4x,'and steel reinforcement  shall be',/,4x,
&

'measured separetly                m3',4X,F7.2,3X,F7.2,3X,F10.2,//)
```

```
WRITE(20,94)SFORMW,UPFORMW,COSTFORMW

94 FORMAT('2.3 Provide cut and fix in position',/,4x,'sawn zigba wood formwork to
',/,4X,'pile cap                    m2' &

,4X,F7.2,3X,F7.2,3X,F10.2,//)


WRITE(20,95)SREINF,UPREINF,COSTREINF

95 FORMAT('2.4 Steel reinforcement according to',/,4x,'structural drawing,price
shall',/,4X,'include cutting,bending,placing ' &

,/,4X,'in position and tying wires',//,4x,'          Dia __mm deformed bars
kg',4X,F7.2,3X,F7.2,3X,F10.2,//)


SUM2=COSTFAREA+COSTCONC+COSTFORMW+COSTREINF

WRITE(20,96)SUM2

96 FORMAT('                          TOTAL CARRIED TO SUMMARY=',F10.2,///)


!PRINT*,"YOU CAN GET THE OUTPUT IN BOQ.TXT"

!PRINT*,TFAREA

PRINT*,SFORMW


        END PROGRAM
```

6.3.3 Specification and Bill of Quantities of Mat Foundation Using the Software

```
         SPECIFICATION AND BILL OF QUANTITIES
ITEM     DESCRIPTION                  UNIT    QUANTITY      UNIT      COST
                                                            PRICE
****************************************************************************
```

1 EXCAVATION AND EARTH WORK

1.1	Clear of the site to remove top top soil to average depth of 20cm.	m2	1066.00	2.00	2132.00
1.2	Bulk excavation in ordinary soil to a depth not exceeding 150cm.	m3	852.80	2.00	1705.60
1.3	Excavation for isolated pile in ordinary soil to the required depth.	m3	0.79	8.00	6.30
1.3	Back fill under hard core with non expansive selected materials and well ram in layers not exceeding 20cm	m3	852.80	25.00	21320.00
1.4	Cart away surplus excavated away from the site not exceeding 2km form the site	m3	1066.00	15.00	15990.00
1.5	Basaltic or equvalent stone hard core well rammed and consolidated and blinded with crushed stone to a finished thickness of 25cm	m3	1000.00	18.00	18000.00

TOTAL CARRIED TO SUMMARY= 59147.60

****

2.CONCRETE WORK

2.1	50mm thick lean concrete in class C-5 with minimum cement content of 150kg/m3 under isolated foundation	m3	1000.00	8.00	8000.00

```
2.2 Concrete C-25 in Concrete Piles      m3       0.79     80.00        62.98

2.3 Reinforced concrete in C 25 with
    minimum cement content of 360kg/m3
    filled into formwork and vibrated
    around steel reinforcement,formwork
    and steel reinforcement  shall be
    measured separetly                    m3      27.50     18.00       495.00

2.3 Provide cut and fix in position
    sawn zigba wood formwork to
    pile cap                             m2      52.00     42.00      2184.00

2.4 Steel reinforcement according to
    structural drawing,price  shall
    include cutting,bending,placing
    in position and tying wires

        Dia __mm deformed bars             kg       4.20      8.00        33.60


                                         TOTAL CARRIED TO SUMMARY=  10712.60
```

7. Sample Design and Cost Estimation of Foundation Using the Software Developed in this Paper.

This chapter explains how to utilize the developed programs by solving practical foundation.As a model a three story building which has five bay

with a span length of 5.0m in each direction is taken.The superstructure analysis is done by SAP-2000 version 8.4 software.

7.1 Importing Foundation Reactions

Foundation reactions are taken from the 3-D model of the super structure analysis software by the following arrangements:

i.The model is set to be in X-Y plane or horizontal plane.

ii. Foundation reaction is displayed at foundation level of the model.

iii.From the foundation plane joints showing foundation reactions are selected by crossing a window at foundation plane.

iv. Only reactions are selected from the selection option of the SAP

and the file is saved in text format.

V.The text file showing foundation reaction is opened in Microsoft word software and all text except foundation reactions will be erased and.

vi.The file is saved by the name aa.txt

vii.The SAPOUTprogram.F90 program is executed and forces and moments will be selected and saved in the format which is suitable for the design programs by the name *****.txt

viii.Following the same step the input data like joint id and joint coordinates are saved by the name aa1.txt

ix.The SAPINPprogram.F90 program is executed and joint id and joint coordinates will be selected and saved by the name *****.txt

7.3 Design of Isolated Foundation

The footing design program developed in this paper will read

:input data like joint id from the file written by the SAPIN program.f90 program

:Foundation reaction from SAPOOTprogram.F90

:foundation depth,soil bearing capacity column dimensions and concrete and steel properties from text data.

By using all the above data the program will determine the footing depth,size and reinforcement of each isolated footing and save the file by FOOT.F90.

7.4 Design of Mat Foundation

The mat design program developed in this paper will read

:input data like joint id joint coordinates from the file written by the SAPIN program.f90 program

:Foundation reaction from SAPOOUTprogram.F90

:foundation depth,soil bearing capacity column dimensions and concrete and steel properties

from text data.

:Geometric center of the foundation, length and width of building from mat data.txt file.

By using all the above data the program will determine the footing depth, by checking the footing depth at the corner, side and middle position of the foundation and finally the program selects the critical depth of mat foundation.

7.5 Design of Pile Foundation

The pile design program developed in this paper will read

:input data like joint id joint coordinates from the file written by the SAPIN program.f90 program

:Foundation reaction from SAPOOUTprogram.F90

:foundation depth,soil bearing capacity and concrete and steel properties from text data.

By using all the above data the program will determine the bearing and skin friction resistance of soil at each depth of the stratum and determines the pile length for each column position.

7.6 Cost Estimation of Isolated Foundation

The isolated footing cost estimation program will read

:unit prices of foundation construction items

:depth of bulk excavation and selected material fill

By using all the above data the program will prepare the specification and bill of quantity of foundation construction.

7.7 Cost Estimation of Mat Foundation

The mat foundation cost estimation program will read

:unit prices of foundation construction items

:depth of bulk excavation and selected material fill

:amount of concrete and steel from SAFE

By using all the above data the program will prepare the specification and bill of quantity of foundation construction.

7.8 Cost Estimation Of Pile Foudation

The pile foundation cost estimation program will read

:unit prices of foundation construction items

By using all the above data the program will prepare the specification and bill of quantity of foundation construction.

CONCLUSION

1. The program is based on the fundamental principles and teqnique of analysis of Ethiopian Standard building codes.
2. The programs developed in this paper solves the problems in which other foundations problems cannot solve by the following reasons.
    - The program is compatible with superstructure analysis softwares.The program is developed in such a way that data from superstructure analysis program available can be used.
    - The program simplifies the trial and error trend of determining foundation sizes,depth, etc.
    - In other software's only one type of foundation (example only a footing can be designed at a time.) But in the program developed in this paper the whole building foundation can be designed at a time.
    - The foundation cost can also be estimated with the developed cost estimation program for each of the functionally feasible foundation types.
3. In the whole process by running the developed programs one can automatically design, makes cost computation and choose the most appropriate foundation types in a matter of few minutes. This encourages practicing engineers to optimize function and cost.

RECOMENDATION

The program is developed to act as a bench mark for further study .

Some of the limitation of the developed programs are as follows:

- The program can analyses and design only commonly used foundations like
  - Isolated foundation (Square)
  - Mat Foundation (flat type)
  - Board and cast in place pile foundations.
- In analysis and design of flat type mat foundation reinforcement computation will not be done by using the software
- The developed programs will not compute the settlement of the foundation.Further study is required to make the program more efficient and user friendly.

REFERENCES

1. EBCS-2: part1, Structural use of concrete, Ministry of works and Urban Development, Addis Ababa,1995.
2. EBCS-7: part7, Foundation, Ministry of works and Urban Development, Addis Ababa,1995.
3. G. Zereyohanne,EBCS-2, Design Aids for Reinforced Concrete Sections on the basis of EBCS-2,Ministry of Works and urban Development,. 1997
4. John N.Cerenia, Geotechnical Engineering Foundation Design,John will & Sons,1994
5. Josef E. Boules,Foundation Analysis and Design,McGraw-Hill,1995
6. Shamsher Prakash and Hari D.Sharma,Pile foundation in Engineering Practice, John will & Sons,1990.
7. A.Tefera,Foundation Engineering,Addis Ababa University Press,1992
8. Paul Anderson, Substructure Analysis and Design.
9. K.R.Arora, Soil Mechanics and Foundation Engineering.