COMPUTER AIDED DESIGN

OF FOOTINGS

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WAKNAGHAT

CERTIFICATE

This is to certify that the work entitled, **"COMPUTER AIDED DESIGN OF FOOTING"** submitted by **Mohit Lamba, Tandin Norbu and Yogesh Baisoya** in partial fulfillment for the award of degree of Bachelor of technology in Civil Engineering of **Jaypee University of Information Technology** has been carried out under my supervision. This work has not been submitted partially or wholly to any other University or Institute for the award of this or any other degree or diploma.

(Dr. Ashok Kumar Gupta)

Jaypee University of Information Technology

Solan,Waknaghat.

Certified the above mentioned project work has been carried out by the said group of students.

Head of Department.

Jaypee University of Information Technology.

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The success of any project depends largely on the encouragement and guidelines of many others. Therefore we take this opportunity to express our sincere gratitude to the people who have been instrumental in the successful completion of the project.

We would like to express our sincere appreciation and gratitude to our guide Ashok Kumar Gupta without whose able guidance, tremendous support and continuous motivation the project would not have been carried to perfection. We sincerely thank him for spending all his valuable time and energies during the execution of project.

The successful compilation of final year project depends on the knowledge and attitude inculcated in the total length of course. So we want to express our sincere gratitude to all the faculties who taught us during the four years of B. Tech.

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CONTENTS

LIST OF SYMBOLS

1. A = area
2. A_s = surface area of pile shaft.
3. A_p = cross-sectional area of pile toe.
4. A_{si} =surface area of pile stem in the i^{th} layer where i varies from to n.
5. B = width of the footing
6. b_c = width of the column
7. C_p = average cohesion at pile tip
8. Ć = average cohesion throughout the length of pile
9. D= depth of the footing
10. d = effective depth
11. f_y = characteristic strength of steel
12. F = factor of safety
13. H =height of drop of hammer
14. K = coefficient of earth pressure
15. M_R = moment of resistance
16. N_c, N_q, N_γ = Terzaghi's bearing capacity factors
17. P_D = effective overburden pressure at pile toe
18. P'= upward reaction
19. p_t = percentage of steel
20. q' = effective overburden pressure at the base level of footing.
21. Q_a = allowable soil pressure
22. Q_f = ultimate load on pile
23. Q_{un} = bearing capacity of a pile
24. Q_{ug} = bearing capacity of group of pile
25. r_f = average skin friction.
26. r_p = unit point or the resistance
27. S =penetration or set
28. τ_{bd} =design bond stress
29. σ_s = stress in bar at the section considered at design load
30. V= column load kN
31. V_u = shear force due to design loads
32. W = weight of hammer
33. W_f = self weight of the footing

34. ϕ= diameter of bar

35. δ = angle of wall friction between pile and soil, in degrees (may be taken equal to ϕ)

36. α = reduction factor

37. c = unit cohesion

ABSTRACT

In this project, the analysis and design of various types of footings is done. The footings are designed using IS: 6403-1981 for shallow foundations and IS: 2911-1979 for deep foundations and are analyzed under various load combinations.

Before the design process appropriate site investigation data are collected thorough geotechnical investigation, in order to plan the design process more accurately. The soil irregularities are also considered during the design process.

The language used to develop the software is turbo C++. The load through structure and bearing capacity of soil were calculated manually but the analysis and design results were obtained through the developed software. At all stages, effort is to provide optimally safe design along with keeping the economic consideration.

Section 1

INTRODUCTION

1.1 General

The foundation of a structure is that part of the structure which is in direct contact with the subsoil and transmits the load of the structure to it. The major purpose of a foundation is the proper transmission of the load of the structure to the soil in such a way that the soil is not over stressed and does not undergo deformations that would cause undesirable settlements.

The various types of foundations can be grouped into two categories: (i) shallow foundations, and (ii) deep foundations. These are classified on the basis of the depth of foundation D_f which is defined as the vertical distance between the base of the foundation and the ground surface, unless the base of the foundation is located beneath a basement or beneath the bed of a river. In these cases the depth of the foundation is referred to the level of the basement floor or the river bed. Terzaghi (1943) suggested that a shallow foundation is one, in which the value of ratio D_f/B <=1, B being the width of the base of the foundation. Foundations with D_f/B ratio greater than 1 fall under the category of deep foundation. For shallow foundations, D_f/B commonly ranges between 0.25 and 1; whereas for deep foundations, it is usually between 5 and 20.

1.2 shallow foundations

If the soils close to the ground are adequate to support the required building loads, the most economical system is shallow spread footings. A footing is an enlarged, usually concrete, base that distributes the load directly to the underlying soil. Footings must sit beneath the frost line on firm soil that allows for proper drainage.

Types of spread footing/shallow footing:

1.2.1 Single footing

Shape of single footing may be square, rectangle, or circular. Trapezoidal or any other unsymmetrical shape should be avoided. (Fig 1)

1.2.2 Combined Footing

Two columns may be combined because of the area limitation of one column due to existent of property line or other structure. (Fig 2)

1.2.3 Strip Footing

Two or more columns may be combined in single direction of line for economy (continuous slab is cheaper then cantilever slab) and to reduce differential settlement between adjacent columns. (Fig 3)

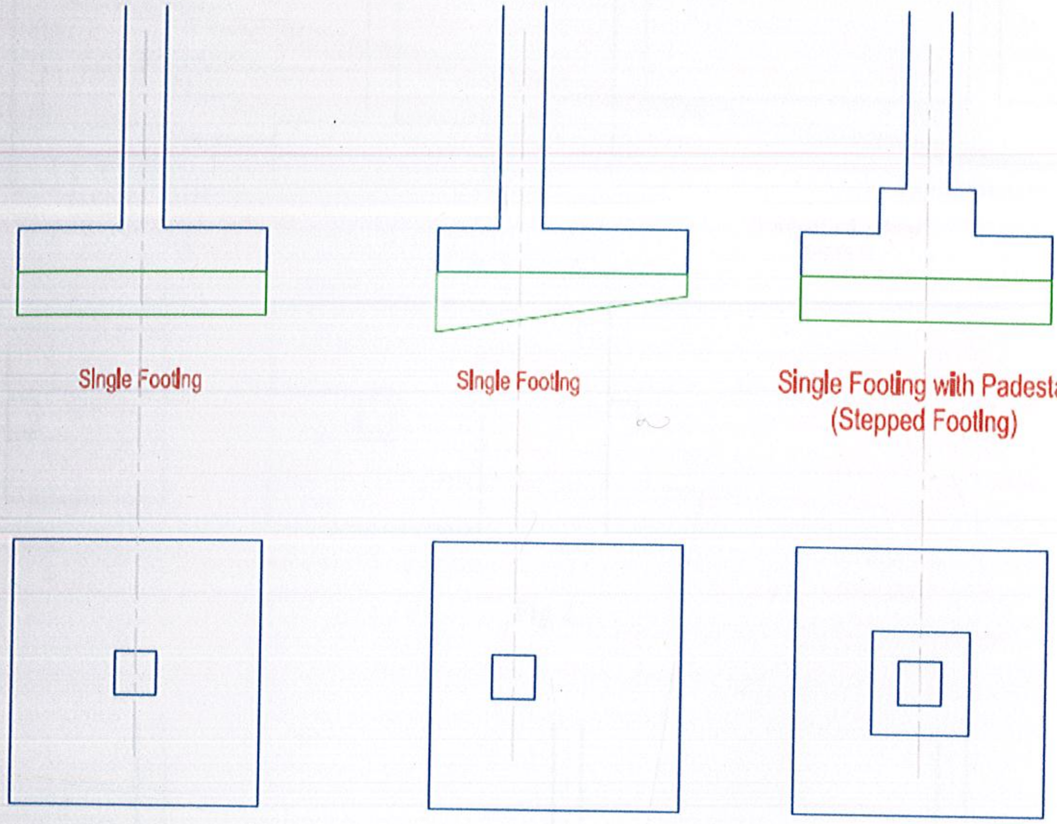

Single Footing
Single Footing
Single Footing with Padestal
(Stepped Footing)

Fig 1

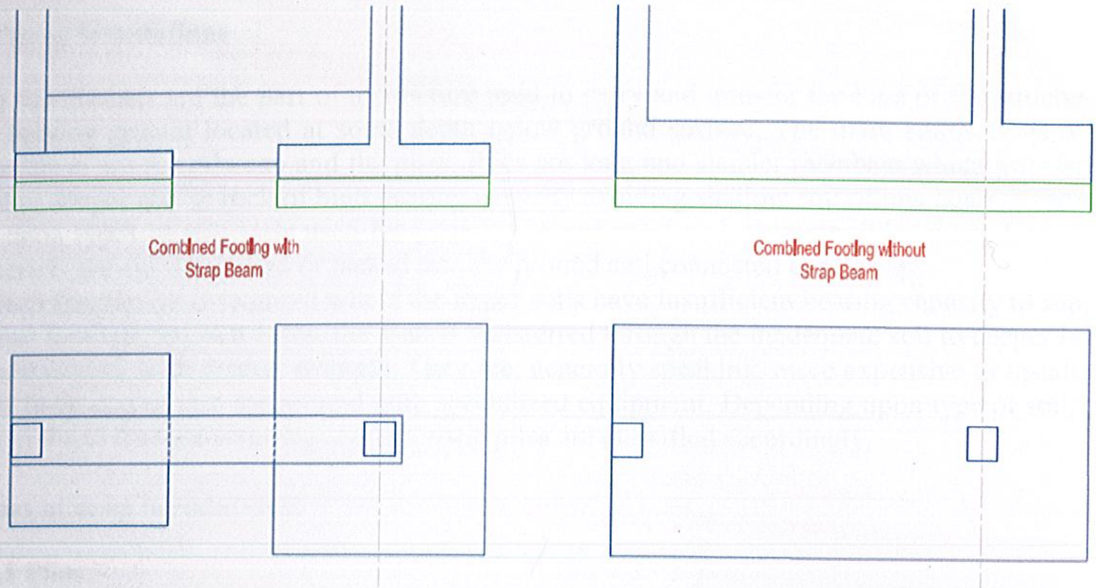

Combined Footing with
Strap Beam
Combined Footing without
Strap Beam

Fig 2

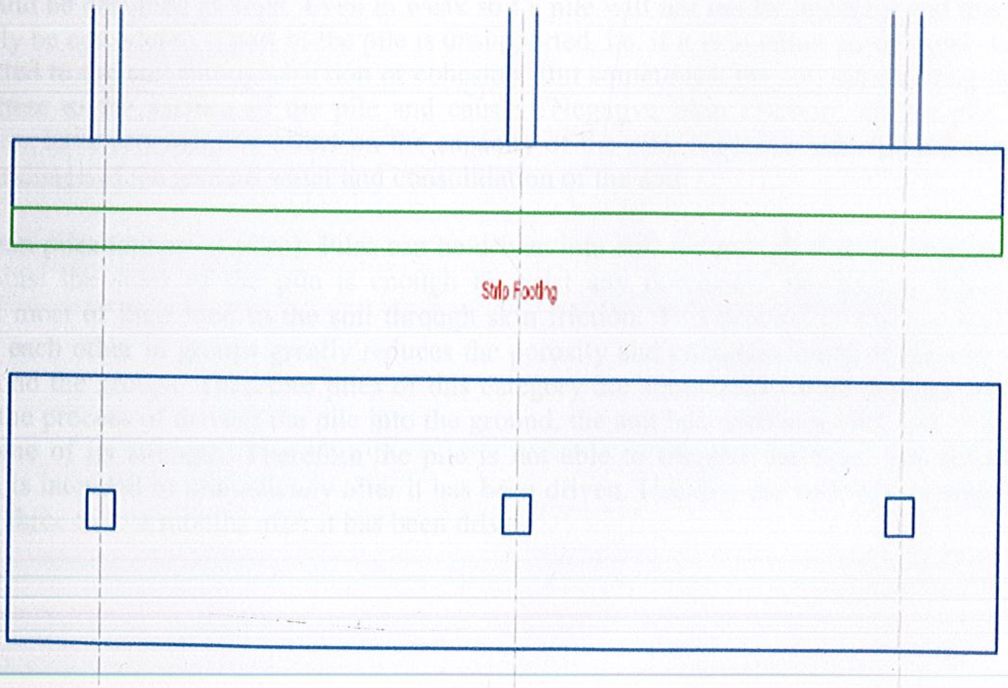

Strip Footing

Fig 3

1.3 Deep foundations

Pile foundations are the part of a structure used to carry and transfer the load of the structure to the bearing ground located at some depth below ground surface. The main components of the foundation are the pile cap and the piles. Piles are long and slender members which transfer the load to deeper soil or rock of high bearing capacity avoiding shallow soil of low bearing capacity the main types of materials used for piles are Wood, steel and concrete. Piles made from these materials are driven, drilled or jacked into the ground and connected to pile caps.
A deep foundation is required where the upper soils have insufficient bearing capacity to support spread footings. In such cases, the load is transferred through the inadequate soil to deeper layers of soil or rock with greater strength. They are, generally speaking, more expensive to install and have to be driven into the ground with specialized equipment. Depending upon type of soil, pile material and load transmitting characteristic piles are classified accordingly.

Types of deep foundations:

1.3.1 Piles

a) End Bearing: Piles can be driven down to a point where they bear on bedrock or other sound substrate. These piles transfer their load on to a firm stratum located at a considerable depth below the base of the structure and they derive most of their carrying capacity from the penetration resistance of the soil at the toe of the pile The pile behaves as an ordinary column and should be designed as such. Even in weak soil a pile will not fail by buckling and this effect need only be considered if part of the pile is unsupported, i.e. if it is in either air or water. Load is transmitted to the soil through friction or cohesion. But sometimes, the soil surrounding the pile may adhere to the surface of the pile and causes "Negative Skin Friction" on the pile. This, sometimes have considerable effect on the capacity of the pile. Negative skin friction is caused by the drainage of the ground water and consolidation of the soil.

b) Friction piles (cohesion piles): Piles can be driven into soil far enough that the friction of the soil against the sides of the pile is enough to resist any downward movement. These piles transmit most of their load to the soil through skin friction. This process of driving such piles close to each other in groups greatly reduces the porosity and compressibility of the soil within and around the groups. Therefore piles of this category are sometimes called compaction piles. During the process of driving the pile into the ground, the soil becomes moulded and, as a result loses some of its strength. Therefore the pile is not able to transfer the exact amount of load which it is intended to immediately after it has been driven. Usually, the soil regains some of its strength three to five months after it has been driven.

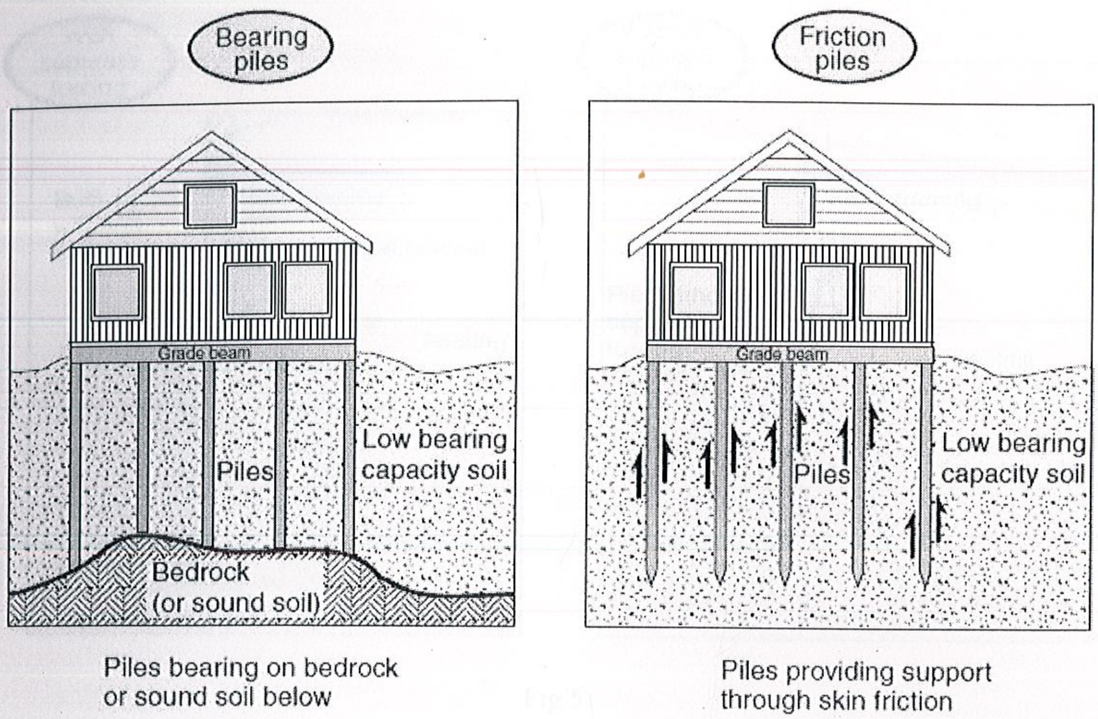


Fig 4

1.3.2 Piers

Piers are columns that may be completely concealed in the soil or may project above it. Most of you will be familiar with the piers that are commonly used to build exterior wood decks and porches. These piers may be poured concrete, often with the concrete poured into a cardboard cylinder in a hole dug in the ground. Piers usually, but not always, have footings (Figure 5). Piers can either be thought of as posts or columns, or can be thought of as short piles that bear on their ends.

1.3.3 Caissons:

Caissons are foundation systems created by drilling holes and filling them with concrete. A caisson pile is a cast-in-place pile that has a hollow tube driven into the ground. The earth is excavated from the tube, and concrete is poured into the tube. Some caisson piles are flared out at the bottom to create a larger bearing surface. These are sometimes called bell caissons.

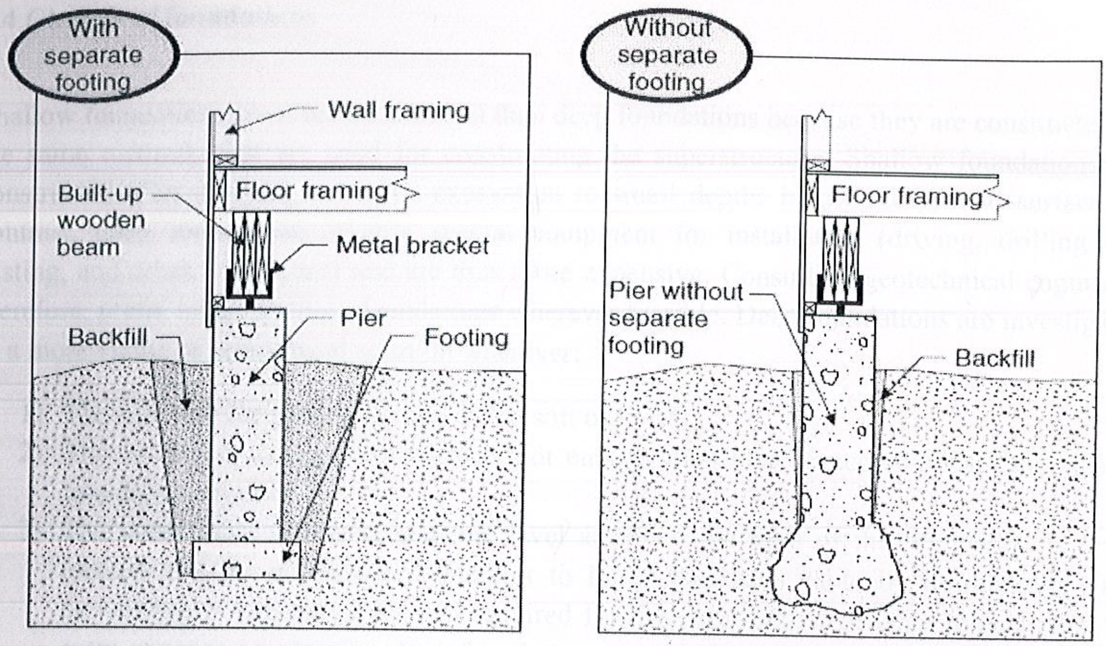

With separate footing
Wall framing
Built-up wooden beam
Floor framing
Metal bracket
Pier
Backfill
Footing
Without separate footing
Floor framing
Pier without separate footing
Backfill

Fig 5

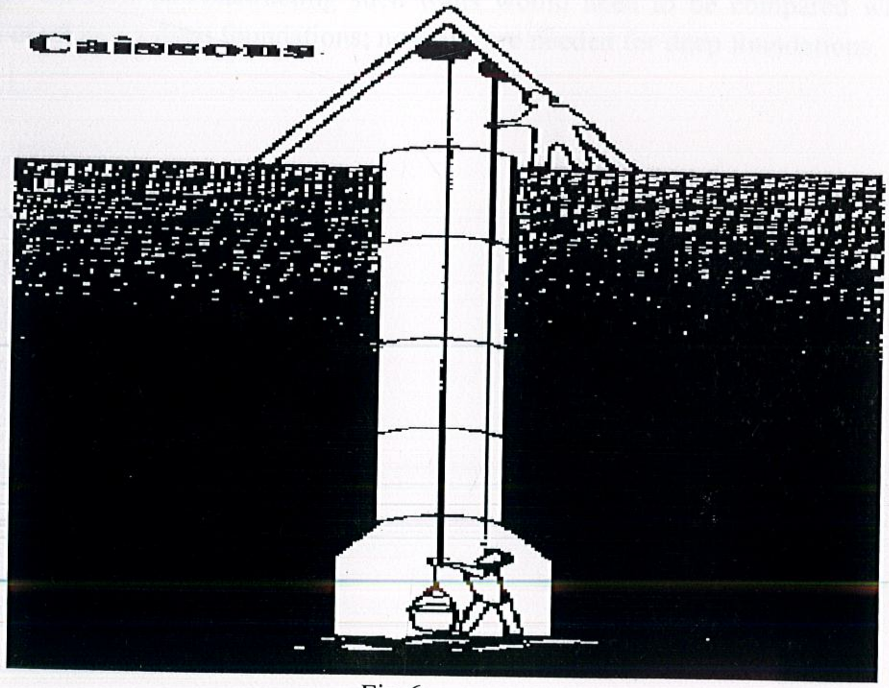

Caissons

Fig 6

1.4 Choices of foundations

Shallow foundations are more economical than deep foundations because they are constructed by the same methods that are used for constructing the superstructure. Shallow foundations are constructed after carrying out open excavation to small depths below the ground surface. In contrast, deep foundations require special equipment for installation (driving, drilling and casting, and other techniques) and are thus more expensive. Consulting geotechnical engineers, therefore, prefer to use shallow foundations wherever feasible. Deep foundations are investigated as a more viable or economical solution wherever:

1) The soil near the ground surface is too soft or loose,
2) The loads are so high that there is not enough plan area to accommodate the size of foundation required,
3) The water table is higher than the level at which the base of the foundation is to be located and for construction one has to lower the water table by dewatering; since dewatering is expensive and not required for the construction of deep foundations, the extra expense of adopting deep foundations would have to be compared with the extra expense of dewatering, and
4) The presence of adjacent buildings in congested built-up areas imposes restrictions on open excavation and calls for construction of walls to restrain displacement of existing buildings; the cost of constructing such walls would need to be compared with extra expense of adopting deep foundations; no walls are needed for deep foundations.

Section 2

BEARING CAPACITY

A) SHALLOW FOUNDATIONS

2.1 Terzaghi's Bearing Capacity Theory.

The ultimate bearing capacity of shallow foundations is usually determined by using a bearing capacity theory in which a failure mechanism is postulated and the load intensity at failure is expressed in terms of the shearing resistance mobilized and the geometry of the problem. The theory is based on the limiting equilibrium approach, wherein the forces acting on the soil wedge immediately beneath the foundation are examined for static equilibrium condition and the ultimate bearing capacity determined. The limiting equilibrium approach is also used by most other investigators to obtain the bearing capacity equation.

At working loads, the state of stress in the soil in zones I, II and III of fig 7 is indeterminate. There are few points common to all the theories using this approach.

a) The footing is a long strip or a continuous footing resting on a deep, homogeneous soil stratum having shear parameters c and ϕ. The analysis is made on the basis of a two-dimensional or plane strain-condition.
b) The soil fails in general shear failure mode.
c) The load is vertical and concentric.
d) The ground surface is horizontal.

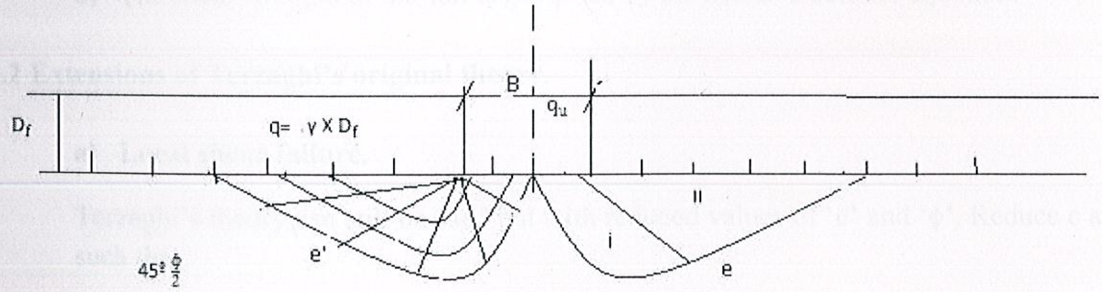


Fig 7

Terzaghi (1943) developed a general bearing capacity equation for a uniformly loaded strip footing. The chief features of the analysis and the basic assumptions involved are as below

a) The footing has a large L/B ratio and hence a two-dimensional or plane strain condition is envisaged.
b) The base of the footing is laid at shallow depth. That is $D_f <= B$.
c) The shearing resistance of the soil between the surface and the depth D_f is neglected. The footing is considered as a surface footing with a uniform surcharge (q) equal to γ X D_f at the level of the base of the footing.

Terzaghi's bearing capacity equation for continuous footing:

$$q_u = c\,N_c + qN_q + 0.5\,\gamma' B N_\gamma$$

Where, q_u = ultimate bearing capacity ($\frac{kN}{m^2}$).

N_c, N_q, N_γ = Terzaghi's bearing capacity factors.

B= width or diameter of the footing.

C= cohesion ($\frac{kN}{m^2}$).

q= effective vertical stress at base level = γ X D_f = ($\frac{kN}{m^2}$)

a) General shear failure is assumed to take place and the soil volume is unchanged prior to failure.
b) The shear strength of the soil is governed by the Mohr- Coulomb equation.

2.2 Extensions of Terzaghi's original theory.

a) **Local shear failure.**

Terzaghi's theory can still be used but with reduced values of 'c' and 'ϕ'. Reduce c and ϕ such that,

$(c)_{New} = 2/3\ c$

$\tan(\phi)_{New} = (2/3)\tan(\phi)$

b) **Square and circular footings.**

Such footings generate 3-D rupture surfaces. Terzaghi's modified equations are,

$q_u = 1.3c\, N_c + qN_q + 0.4\, \gamma' BN_\gamma$; square

$q_u = 1.3c\, N_c + qN_q + 0.3\, \gamma' BN_\gamma$; circular.

c) Effect of water table

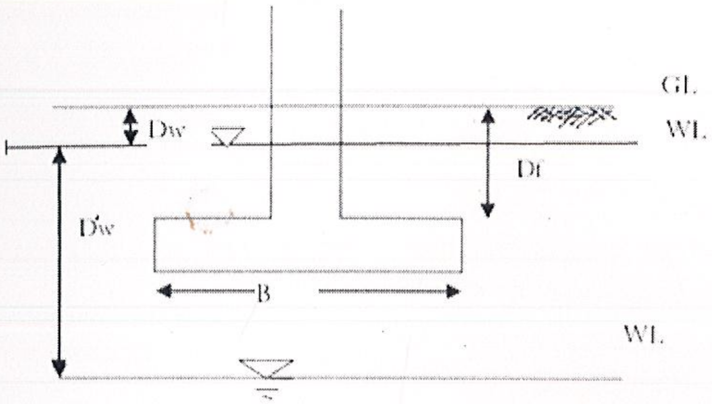


Fig 8

Case 1:

If D'_w is the depth of water table measured from the base of the footing (fig 1.1), for De_w >= B, $\gamma = \gamma_t$ of both the terms.

Case 2:

If the water table is at the base of the footing, that is, when $D'_w = 0$, the submerged unit weight γ' should be used in the term $0.5\, \gamma B N_\gamma$. When $D'_w <= B$, value of γ to be used is given by the equation

$\gamma = \gamma' + (D'_w / B)(\gamma_t - \gamma')$

Case 3:

If the water table rises up to the ground surface, submerged unit weight γ' is used in calculating the surcharge q in the term qN_q. If D_w, the depth of water table measured from the ground surface is such that $0 < D_w < D_f$, the value of γ to be used in the calculation of q is given by the equation

$\gamma = \gamma' + (D_w / D_f)(\gamma_t - \gamma')$

Hence the net ultimate bearing capacity of a strip footing on a granular soil may be written as

$q_{nu} = q_u - \gamma D_f$

$q_{nu} = q'(N_q - 1) + 0.5\, \gamma' BN_\gamma$

q' = effective overburden pressure at the base level of footing.

γ = effective unit weight of soil beneath the footing.

2.3 IS Code Recommendations for bearing capacity

IS: 6403 – 1981 recommends that for the computation of the ultimate bearing capacity of a shallow foundation in

a) general shear failure,

$$q_d = c\,N_c s_c d_c i_c + q(N_q-1)\,s_q d_q i_q + 0.5\,\gamma B N_\gamma s_\gamma d_\gamma i_\gamma W'$$

b) local shear failure,

$$q'_d = c\,N'_c s_c d_c i_c + q\,(N'_q-1)\,s_q d_q i_q + 0.5\,\gamma B N'_\gamma s_\gamma d_\gamma i_\gamma W'$$

2.3.1 The shape factors are given in the table below. (*IS 6403:1981* clause 5.1.2.1)

Shape factors

SL no.	SHAPE OF BASE	s_c	s_q	s_γ
i.	Continuous strip	1.00	1.00	1.00
ii.	Rectangle	1+0.2B/L	1+0.2B/L	1+0.4B/L
iii.	Square	1.3	1.2	0.8
iv.	Circle	1.3	1.2	0.6

Use B as the diameter in the bearing capacity formula.

Table 1

2.3.2 The depth factors shall be as under:

$$d_c = 1 + 0.2\,D_f/B\,\sqrt{N\phi}$$

$$d_q = d_\gamma = 1 \text{ for } \phi < 10°$$

$$d_q = d_\gamma = 1 + 0.1 D_f/B\,\sqrt{N\phi} \text{ for } \phi > 10°$$

2.3.3 The inclination factor shall be as under:

$$i_c = i_q = \left(1 - \frac{\alpha}{90}\right)^2$$

$$i_\gamma = \left(1 - \frac{\alpha}{\phi}\right)^2$$

Where α = inclination of the load to the vertical in degrees

2.3.4 Factors for eccentric-inclined loads:

When the footing is subjected to an eccentric-inclined loads. The eccentricity may be one way or two ways as shown in fig 9a and fig 9b respectively.

One-way eccentricity (fig 9a): if the load has an eccentricity e, with respect to the centroid of the foundation in only one direction, then the dimension of the footing in the direction of eccentricity shall be reduced by a length equal to 2e. The modified dimension shall be used in the bearing capacity equation and in determining the effective area of the footing in resisting the load.

Two-way eccentricity (fig 9b): if the load has double eccentricity (e_L and e_B) with respect to the centroid of the footing, then the effective dimensions of the footing to be used in determining the bearing capacity as well as in computing the effective area of the footing in resisting the load shall be determined as given below:

L' = L - $2e_L$

B' = B - $2e_B$

A' = L' x B'

In computing the shape and depth factors for eccentrically – obliquely loaded footings, effective width (B') and effective length (L') will be used in place of total width (B) and total length (L). For a design, eccentricity should be limited to one-sixth of the foundation dimension to prevent the condition of uplift occurring beneath the part of the foundation.

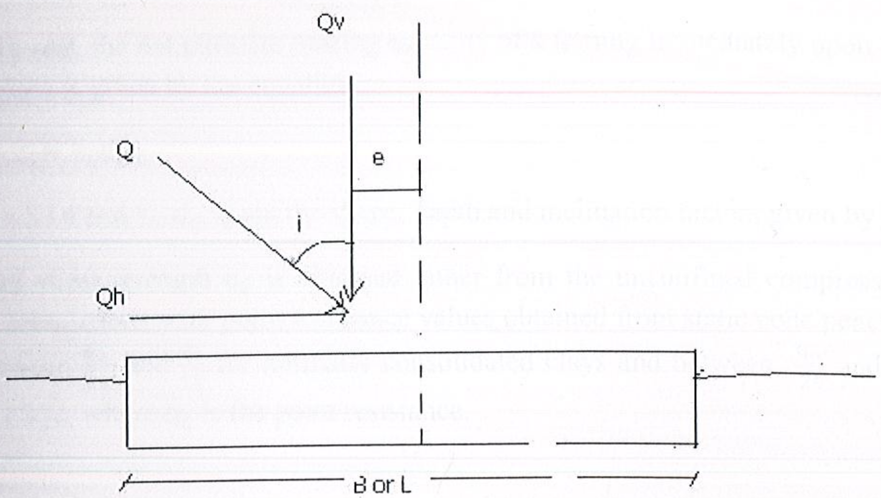

Qv
Q
e
i
Qh
B or L

Fig 9 a

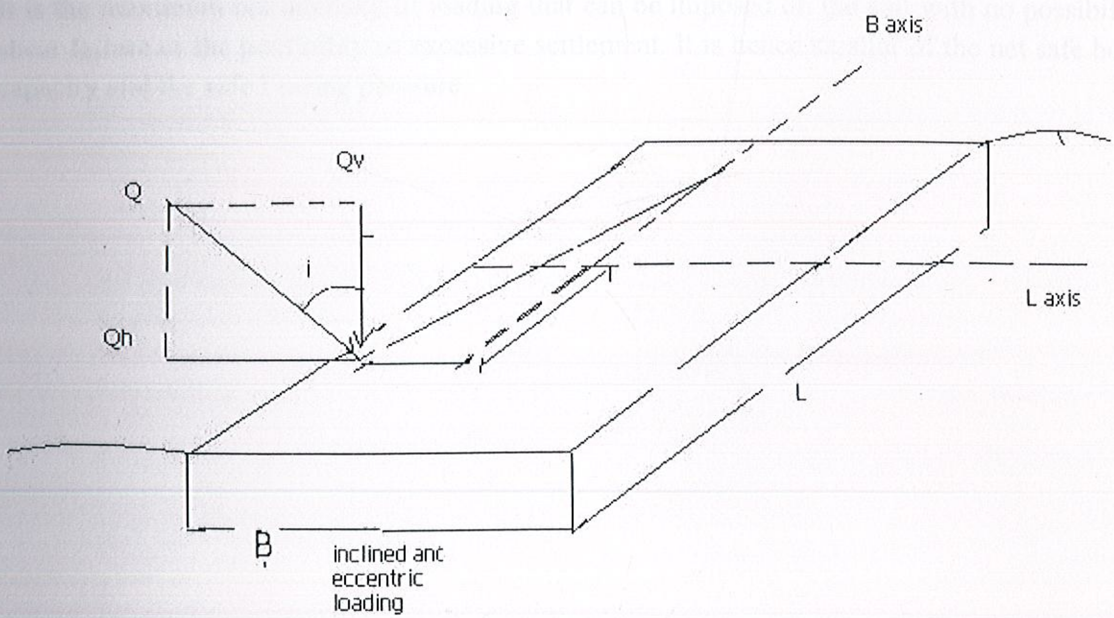

B axis
Qv
Q
i
Qh
L axis
L
B
inclined anc
eccentric
loading

Fig 9b

For local shear failure, the recommendations of IS: 6403 – 1981 are similar to those given in (EQ) 2.2 -a

For a **cohesive soil**, the net ultimate bearing capacity of a footing immediately upon construction ($\phi = 0$ condition) is given by the equation

$$q_{nu} = c_u N_c s_c d_c i_c$$

In which $N_c = 5.14$ and s_c, d_c, i_c are the shape, depth and inclination factors given by table 1.

The undrained shear strength c_u is obtained either from the unconfined compressive strength tests or from correlations with point resistance values obtained from static cone penetration tests. c_u Varies between $\frac{q_u}{18}$ and $\frac{q_u}{15}$ for normally consolidated clays and between $\frac{q_u}{26}$ and $\frac{q_u}{22}$ for over consolidated clays, where q_c is the point resistance.

2.4 Allowable bearing pressure

It is the maximum net intensity of loading that can be imposed on the soil with no possibility of shear failure or the possibility of excessive settlement. It is hence smaller of the net safe bearing capacity and the safe bearing pressure.

B) LOAD CARRYING CAPACITY OF PILES

2.5 Dynamic formulae

a) Engineering News formula

The Engineering News formula was proposed by A.M wellington (1888), in the following form

$$Q_a = \frac{WH}{F(S+C)}$$

Where

Q_a = allowable load

W = weight of hammer (kg)

H = height of fall (cm)

F = factor of safety = 6

S = final set (penetration) per blow, usually taken as average penetration, cm per blow for the last 5 blows of drop hammer, or 20 blows of steam hammer,

C= empirical constant = 2.5cm for drop hammer and 0.25cm for single and double acting hammer

b) Hiley's formula.

Indian standard IS: 2911 (part ii) 1964 gives the following formula based on original expression by Hiley:

$$Q_f = \frac{\eta_h W H \eta_b}{(S+C)/2}$$

Where

Q_f = ultimate load on pile

W= weight of hammer, in kg

H =height of drop of hammer, in cm

S =penetration or set, in cm, per blow

C = total elastic compression.

2.6 Static formulae

When a compressive load is applied at the top of a pile, the pile will tend to move vertically downward relative to the surrounding soil. This will cause shear stresses to develop between the soil and the surface of the shaft. As a result, the applied load is distributed as friction load along a certain length of the pile measured from the top. As the load at the top is increased, the friction load distribution will extend more and more towards the tip of the pile, till at a certain load level, the entire length of the pile is involved in generating the frictional resistance. This is the this is the ultimate skin friction of the pile, Q_f . It is only when the load at the top of the pile exceeds Q_f that the load in excess of Q_f begins to be transferred to the soil at the base of the pile fails by punching shear failure. The load in bearing at this stage is the ultimate point load.

Ultimate bearing capacity = total ultimate skin friction +end bearing resistance

$Q_f = R_f + R_p$ or $Q_f = A_s r_f + A_p r_p$

Where

A_s = surface area of pile upon which the skin friction acts.

A_p = area of cross section of a pile on which bearing resistance acts.

r_f = average skin friction.

r_p = unit point or the resistance.

2.7 Bearing capacity of pile groups

Pile groups driven into sand may provide reinforcement to the soil. In some cases, the shaft capacity of the pile driven into sand could increase by factor of 2 or more. But in the case of piles driven into sensitive clays, the effective stress increase in the surrounding soil may be less for piles in a group than for individual piles. This will result in lower shaft capacities. Figure 10 under axial or lateral load, in a group, instead of failure of individual piles in the group, block failure (the group acting as a block) may arise.

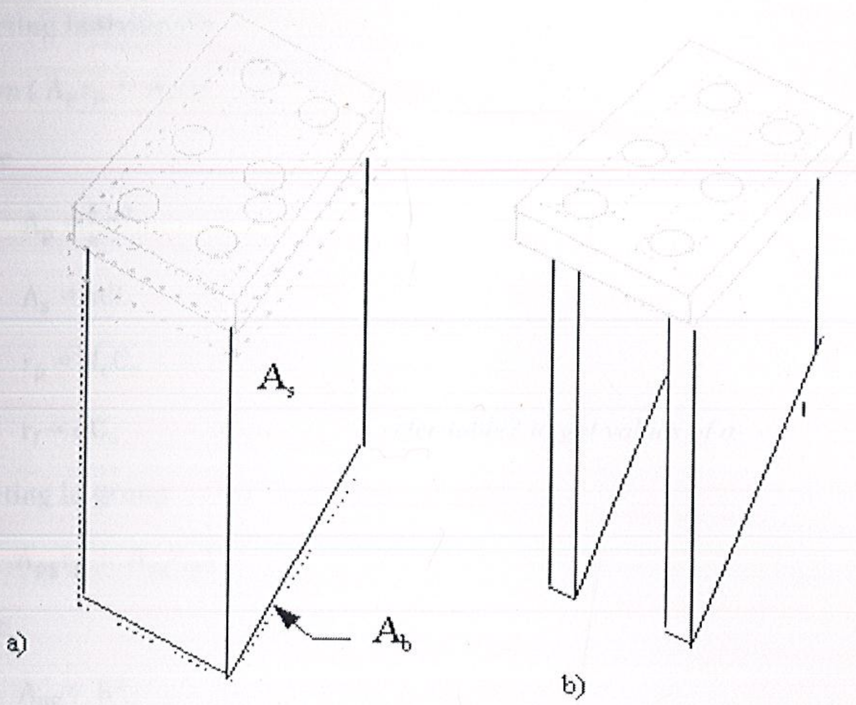


Fig 10

The ultimate load of a pile group.

$Q_u = PLr_f + A\, r_p$

Where

A = cross- sectional area of a pile group = BxB

P = perimeter of pile group = 4B

r_f = average skin friction=shear strength of the soil = Ć = q_u /2

r_p= unit toe or point resistance.

Ć = average undrained cohesion along the length of pile

L = length of the pile.

2.7.1 Piles acting individually

$Q_{un} = n\,(A_p r_p + A_s r_f)$

Where

$A_p = \frac{\pi}{4} d^2$

$A_s = \pi d L$

$r_p = N_c C_u$

$r_f = \alpha C_u$ *refer table2 to get values of α*

2.7.2 Piles acting in group

$Q_{ug} = A_{pg} r_p + A_{sg} r_{fg})$

Where

$A_{pg} = B^2$

$A_{sg} = 4BL$

$r_{fg} = C_u$

The bearing capacity of a pile group may be either of the following:

a) equal to the bearing capacity of individual piles multiplied by the number of piles in the group or
b) It may be less.

(IS: 2911 part 1 sec 1 1979)

2.8 Piles in granular soils (IS: 2911 (part i/sec 1))

The ultimate bearing capacity Q_u of piles in granular soils is given by the following formula:

$Q_u = A_p\,(\frac{1}{2}\,D_\gamma N_\gamma + P_D N_q) + \sum_{n=1}^{n} K\,P_{Di}\,\tan\delta\,A_{si}$

Where

A_p = cross- sectional area of pile toe in cm^2

D = stem diameter in cm;

γ = effective unit weight of soil at pile toe in $\frac{kN}{cm^3}$;

P_D = effective overburden pressure at pile toe in $\frac{kgf}{cm^2}$;

N_q And N_γ = bearing capacity factors depending upon the angle of internal friction ϕ at toe

$\sum_{n=1}^{n}$. = summation for n layers in which pile is installed;

K = coefficient of earth pressure;

P_{Di} = effective overburden pressure in $\frac{kgf}{cm^2}$ for i^{th} layer where i varies from 1 to n

δ = angle of wall friction between pile and soil, in degrees (may be taken equal to ϕ); and

A_{si} =surface area of pile stem in cm^2 in the i^{th} layer where i varies from 1 to n.

Q_{un} = bearing capacity of a pile

Q_{ug} = bearing capacity of group of pile

2.9 Piles in cohesive soils

The ultimate bearing capacity Q_u of piles in granular soils is given by the following formula:

$$Q_u = A_p N_c C_p + \alpha\, \acute{C}.\, A_s$$

Where

A_p = cross-sectional area of pile toe in cm^2.

N_c = bearing capacity factor usually taken as 9,

C_p = average cohesion at pile tip in $\frac{kgf}{cm^2}$;

α = reduction factor,

Ć = average cohesion throughout the length of pile in $\frac{kgf}{cm^2}$;

A_s = surface area of pile shaft in cm^2.

Note1 – the following values of α may be taken depending upon the consistency of the soils:

consistency	N value	Value of α
Soft to very soft	<4	1
Medium	4 to 8	0.7
Stiff	8 to 15	0.4
Stiff to hard	>15	0.3

Table2

Note 2- static formula may be used as a guide only for bearing capacity estimates. Better reliance may be put on load test of piles.

Note 3 –for working out safe load a minimum factor of safety 2.5 should be used on the ultimate bearing capacity estimated by static formulae.

Section 3

DESIGN OF FOUNDATIONS

3.1 General Design considerations

1. The thickness at the edge of footing shall not be less than 150 mm for footings on soil to minimize corrosion that can be caused by ground salts and 300 mm for the footing slab above the top of piles or the footing on piles.
2. Since the column transfers the load on top of footing by bearing, the bearing pressure shall not exceed 0.45 f_{ck} when bearing or supporting area is of same size as loaded area. However, when supporting area, i.e., area of footing A_1 is larger than loading area, i.e., area of column base A_2, the above bearing pressure shall be increased by $\sqrt{A_1/A_2} < 2.0$. The area A_1 is taken as that of lower base of the largest frustrum of a pyramid or cone contained wholly within the footing with area A_2 on the top with a side slope 1 in 2. If these stresses are exceeded, the transfer of forces should be accomplished by the reinforcement bars extended into the footing or by the providing dowel (starter) bars extending into column a distance of L_d (47ϕ for M20 grade concrete and HYSD steel of grade Fe415). If the depth required to provide a distance L_d is very large, it is economical to provide pedestal or sloping footing.
3. Area of extended longitudinal bars or dowels (minimum of four bars with $\phi > (\phi + 3$ mm)) shall be greater than 0.5 percent of cross-sectional area of supporting column or pedestal.
4. The rectangular columns should preferably be provided with rectangular footings with base projecting equal distance beyond column faces.
5. The steel shall not be less than the minimum specified for slabs, i.e., 0.12 percent for Fe415 and 0.15 per cent for Fe250 grade steels.
6. The structural design is carried out for factored load using limit states design method. The design basically consists of determining the thickness of footing and its reinforcement. The thickness should be sufficient to resist shear force without shear reinforcement and bearing without compression reinforcement.
7. **Proportioning of footing**: The footing shall be so proportioned as to sustain the design load without exceeding the permissible soil pressure, and to ensure the settlement to be nearly uniform as possible.
8. **Design of shear**: Both wide-beam or one way and punching or two-way shears are considered for estimating the thickness of the footing. For one-way bending shear the footing is considered a wide beam with width equal to the width of the base, and the shear is taken at a distance d from the face of the column. Punching or two-way shear indicates the tendency of column to punch through the footing slab. The punching shear is resisted along the surface of a truncated prism around the column load called critical perimeter as distance d/2 from the column face. The maximum value of shear stress as stipulated by **IS 456: 2000** is $0.25 f_{ck}$.

9. **Design for bending moment**: the design bending moment is computed at:

1. The face of column for the footings supporting reinforced concrete columns.

2. Half-way between centre line and edge of wall for footings under masonry walls.

3.2 Structural design

3.2.1 Design procedure for spread footings:

The following procedure may be adopted for the design of column footings:

1. For the given materials, calculate the design constants.

2. Consider the self weight of the footing in the range of 5 to 10 percent of the load carried by the column. Determine the area of the footing from the service loads transferred from the column and self weight of footing, and safe bearing capacity of soil. Decide a suitable layout and determine dimensions of the required type of footing.

3. Calculate the upward factored pressure on the footing exerted by the underlying soil.

4. Estimate the thickness of the footing slab required from: (a) bending moment consideration, (b) shear considerations: (i) by treating the footing as a wide- beam and (ii) by assuming two-way action of footing.

Adopt the largest value of depth obtained in steps (a), b (i) and b (ii).

5. Check for self weight of footing.

6. Calculate reinforcement in x- and y- directions from bending moment considerations. These steels shall not be less than the minimum specified for slabs. i.e., 0.12 percent for Fe415 and 0.15 percent for Fe250 grade steels. *(IS 456 : 2000)*

7. Choose diameter of bars for the required development length and distribute steel as specified in the code. i.e., the diameter of reinforcing bars shall not exceed one-eighth of the total thickness of the slab.

8. Draw reinforcement details.

3.2.1.1 Design of Square footing includes:

1. Assume column dimensions

$b_c * b_c$

2. Area of footing

$A = \frac{(V + W_f)}{q_a}$, A = B x B,

3. Net upward reaction

$p' = \frac{V}{A}$

4. Calculate bending moment at the face of the column

$M_{xx} = \frac{P'}{8} B (B - b_c)^2 \times 10^6$ Nmm

5. Compute the depth of the slab using the ultimate moment of resistance equation.

$M_R = Q_u bd^2$

Grade of steel	Q_u
Fe250	0.1498 f_{ck}
Fe415	0.1388 f_{ck}
Fe500	0.1338 f_{ck}

Table3

$M_R = 0.138\, f_{ck}.b.d^2 = M_{xx}$ (put b =*1000mm)*

Q_u = constant

Width of the section b will be used as B.

Refer step no.4 of section 3.2.1 for more details.

6. Check for punching shear (IS 456 has adopted a simple equation):

The stress obtained by dividing the ultimate design shear V_u by the cross-sectional area is known as nominal shear stress τ_v,

$\tau_v = \frac{V_u}{b.d}$

7. Compute reinforcement required using

$0.87f_y . A_{st} (d- \frac{f_y.A_{st}}{f_{ck}.b})=M_{xx}$ (put b = 1000) *Equation from IS 456:2000*

(Assumption: value of $\frac{x_u}{d}$ is less than limiting value given in article 38.1 of IS 456:2000)

8. Reinforcement is provided uniformly along the total width of the footing in both directions.

9. Check for nominal shear at section x_1x_1, redesign if necessary, and shear reinforcement needed.

10. Check for development length.

$$L_d = \frac{\phi\sigma_s}{4\,\tau_{bd}}$$

Grade of concrete	M20	M25	M30	M35	M40 and above
Design bond stress, τ_{bd}, N/mm^2	1.2	1.4	1.5	1.7	1.9

Table4 (Design bond stress)

$$L_d = \frac{0.87 f_y \phi}{4\,\tau_{bd}}$$

Where,

b_c = width of the column in m

A = area

q_a = allowable soil pressure in $\frac{kN}{m^2}$

V= column load kN

B = width of the footing in m

W_f = self weight of the footing (5 to 10 % of the weight carried by the column)

P'= upward reaction in $\frac{kN}{m^2}$

M_R = moment of resistance Nmm

D= depth of the footing in m

V_u = shear force due to design loads

d = effective depth

ϕ = diameter of bar

σ_s = stress in bar at the section considered at design load

= 0.87 f_y for mild steel

=0.75f_y for HYSD steel

τ_{bd} =design bond stress given in the table

f_y = characteristic strength of steel

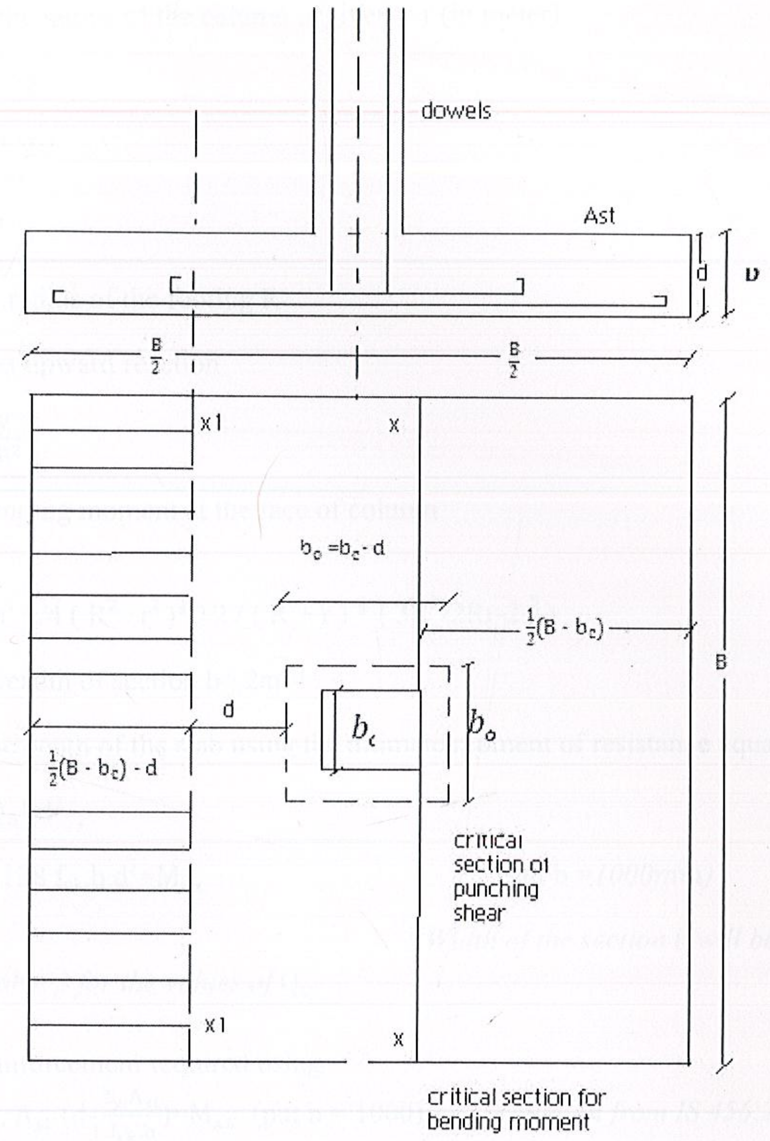

dowels
Ast
d
D
B/2
B/2
x1
x
b₀ = b_c - d
½(B - b_c)
B
d
b_c
b₀
½(B - b_c) - d
critical section of punching shear
x1
x
critical section for bending moment

Fig 11

3.2.1.2 Design of circular footing includes:

1. We assume the radius of the column is given = r (in meter)

2. Area of footing

$$A = \frac{(V + W_f)}{q_a}$$

$A = \pi R^2$

Get the radius of the footing R

3. Calculate Net upward reaction

$$p' = \frac{V}{\pi R^2}$$

4. Calculate bending moment at the face of column

$$M_{xx} = p' \pi/4 \, (R^2 - r^2) * 0.2 / (R + r) * (3R^2 - 2Rr - 2r^2)$$

5. Calculate breadth of section $b = 2\pi r/4$

6. Compute the depth of the slab using the ultimate moment of resistance equation.

$M_R = Q_u bd^2$

$M_R = 0.138\, f_{ck}.b.d^2 = M_{xx}$ (put b =*1000mm)*

Width of the section b will be used as B.

Refer table 3 for the values of Q_u.

7. Compute reinforcement required using

$$0.87f_y.\, A_{st}\, (d - \frac{f_y.A_{st}}{f_{ck}.b}) = M_{xx}$$ (put b = 1000) *Equation from IS 456:2000*

(Assumption: value of $\frac{x_u}{d}$ is less than limiting value given in article 38.1 of IS 456:2000)

8. Check for development length.

$$L_d = \frac{\phi \sigma_s}{4\, \tau_{bd}}$$

Refer table 4 for various values of Design bond stress, τ_{bd}.

$$L_d = \frac{0.87 f_y \phi}{4\, \tau_{bd}}$$

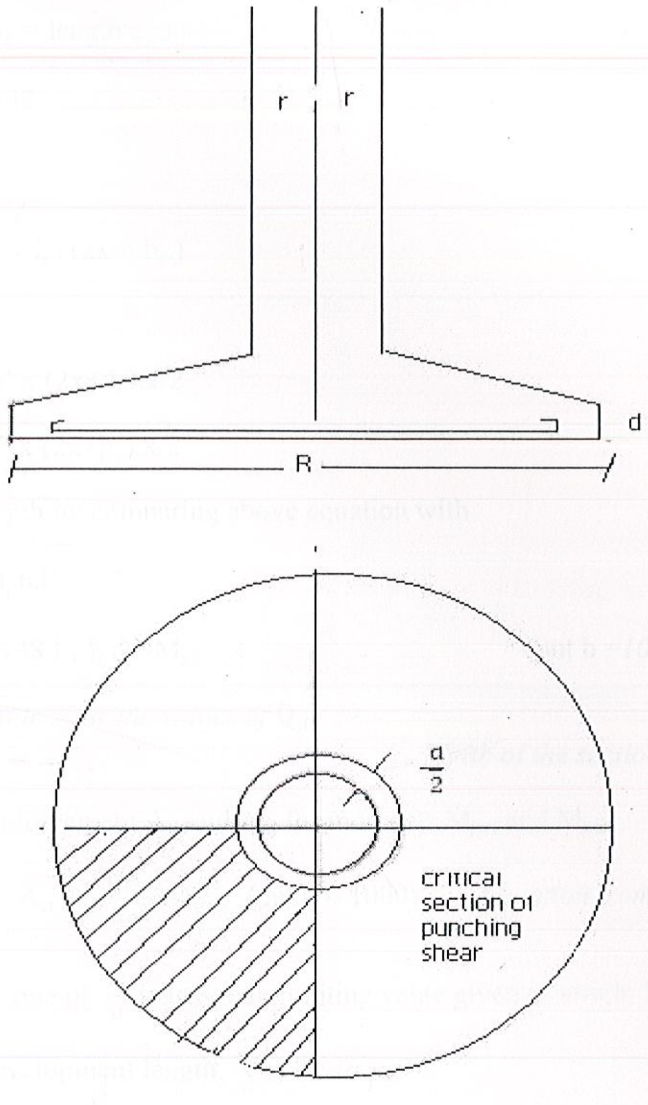


Fig 12

3.2.1.3 Design of rectangular footing includes:

1. Assume column dimensions l_c x b_c

   l_c and b_c = length and breadth of the column.

2. Area of footing

   $$A = \frac{(V + W_f)}{q_a}$$

   $$A = (2x + l_c)\,(2x + b_c)$$

3. Calculate

   $$M_{xxl} = p' \times (2x + l_c).x/2$$

   $$M_{xxb} = p' \times (2x + b_c).x/2$$

4. Calculate depth by comparing above equation with

   $$M_R = Q_u bd^2$$

   $$M_R = 0.138\, f_{ck}.b.d^2 = M_{xx} \qquad \text{(put b =}\mathit{1000)}$$

   Refer table 3 for the values of Q_u

   Width of the section b will be used as B.

5. Compute reinforcement A_{tl} and A_{tb} for moments M_{xxl} and M_{xxb}

   $$0.87 f_y .\, A_{st}\, (d - \frac{f_y.A_{st}}{f_{ck}.b}) = M_{xx} \quad \text{(put b = 1000)}$$ *Equation from IS 456:2000*

(Assumption: value of $\frac{x_u}{d}$ is less than limiting value given in article 38.1 of IS 456:2000)

6. Check for development length.

   10. Check for development length.

   $$L_d = \frac{\phi \sigma_s}{4\, \tau_{bd}}$$

   Refer table 4 for various values of Design bond stress, τ_{bd}.

   $$L_d = \frac{0.87 f_y \phi}{4\, \tau_{bd}}$$

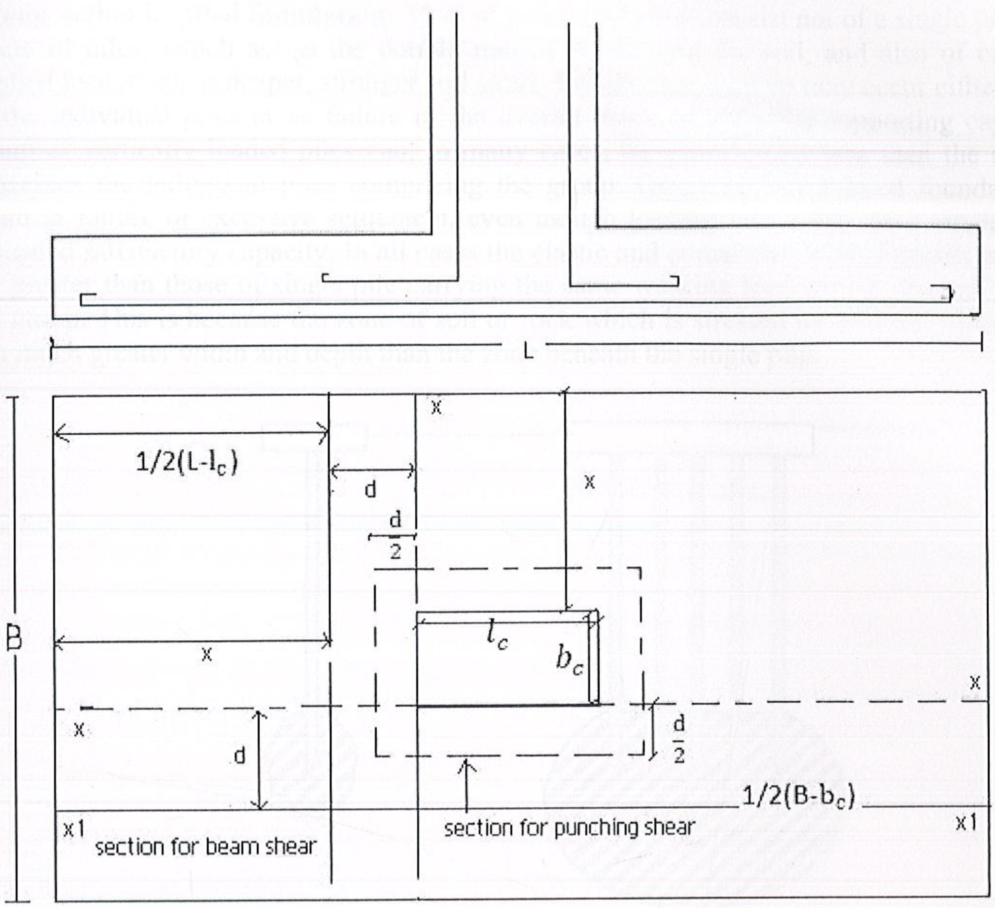

L
1/2(L-lc)
x
d
d/2
x
B
x
lc
bc
x
x
d
d/2
1/2(B-bc)
x1
section for beam shear
section for punching shear
x1

Fig13

3.3 Design of Pile group

Group action in piled foundation: Most of pile foundations consist not of a single pile, but of a group of piles, which act in the double role of reinforcing the soil, and also of carrying the applied load down to deeper, stronger soil strata. Failure of the group may occur either by failure of the individual piles or as failure of the overall block of soil. The supporting capacity of a group of vertically loaded piles can, in many cases, be considerably less than the sum of the capacities the individual piles comprising the group. Grope action in piled foundation could result in failure or excessive settlement, even though loading tests made on a single pile have indicated satisfactory capacity. In all cases the elastic and consolidation settlements of the group are greater than those of single pile carrying the same working load as that on each pile within the group. This is because the zone of soil or rock which is stressed by the entire group extends to a much greater width and depth than the zone beneath the single pile.

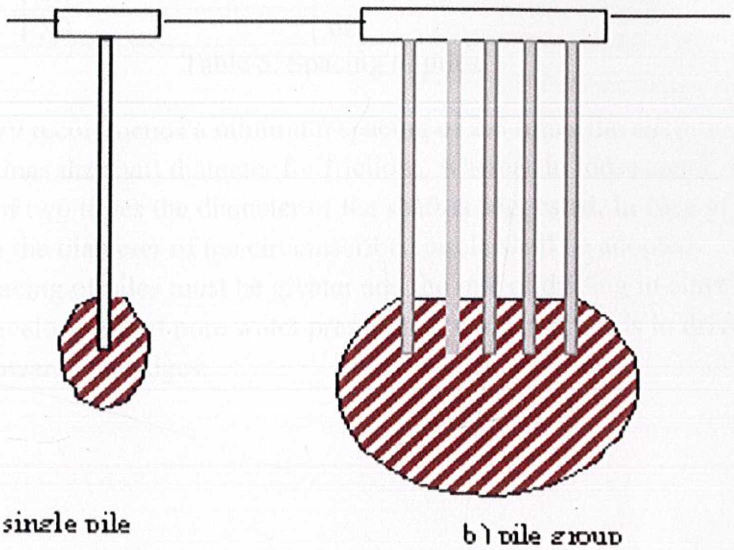


Fig14

The pile tops are connected together with a reinforced slab or beam called pile cap. The pile cap helps the pile group to act as an integral; unit. A pile group and having pile cap standing clearly above the ground is known as fee standing pile group and this type of construction is used when it is required to keep the pile cap away from direct contact with soils which are expansive in nature. A pile group in which pile cap rests on the soil, partially of fully buried below ground level is known as piled foundation. In a piled foundation, the pile cap may, under certain soil conditions, help in transmitting a part of the load to the soil on which it rests.

3.3.1 Spacing of piles

The spacing of piles in a group depends on many factors such as length, size, and shape of piles, soil characteristics and magnitude and type of loads. When the piles are spaced closely the soil is highly stressed and it may cause the shear failure of soil or excessive settlement of pile group.

The spacing of the piles could be increased, but large spacing will require massive and heavy pile caps. This will further increase the load on piles. The minimum spacing of piles is recommended by different codes of practice. The British Code of Practice (2004: 1972) suggests a minimum spacing equal to the perimeter of the pile for a friction pile and twice the least width for an end bearing pile. The Norwegian Code of Practice on piling, Den Norske Pelekomite (1973) gives the recommendations for minimum pile spacing as given in table

Length of pile	Friction piles in sand	Friction piles in clay	Point bearing piles
Less than 12 m	3B	4B	3B
12 to 24 m	4B	5B	4B
Greater than 24 m	5B	6B	5B

Table 5. Spacing of piles.

IS: 2911(part i) – 1979 recommends a minimum spacing of 2.5 times the shaft diameter for point bearing piles, three times the shaft diameter for frictions, whereas in loose sands or fill deposits, a minimum spacing of two times the diameter of the shaft is suggested. In case of piles of non-circular cross-section the diameter of the circumscribed circle shall be adopted. In case, driven piles are used, the spacing of piles must be greater and the rate of driving in clays must be such as not to allow the development of pore water pressure. A good practice is to drive piles from the centre of the group towards the edges.

3.3.2 Proportioning and design of pile foundations

The selection of the pile, shape, size and length, number of piles required to carry the design load, spacing between the piles and arrangement of piles in the group – all these put together constitute proportioning.

There may be three cases that can occur in practice, namely (a) group of vertical piles subjected to a central vertical load, (b) group of vertical piles subjected to an eccentric vertical load, and (c) group of piles subjected to vertical load, lateral load, and moment.

Group of vertical piles subjected to a central vertical load

a) Selection of type of pile – First a soil profile representing the results of exploratory boring should be prepared. Usually, the soil profile provides all the information required to decide appropriate type of pile for the given situation. Driven piles can be precast and installed according to specifications. Cast-in-situ piles are suitable where the length can be adjusted according to pile conditions. The cast-in-situ piles take very much less load as compared to driven piles
b) Length of pile – if point bearing piles are appropriate, it may be possible to judge the required length with reasonable accuracy on the basis of soil profile. The length of friction piles in soft clay can be determined by making an estimate of the factor of safety of the pile group against complete failure. For precast pile the length is usually taken 10-15 m and diameter from .2 to .3 m. Cast in-situ the length is usually taken 15- 25 m and diameter from .2 to .3 m.
c) Size of pile –
   Factors affecting the selection of size of piles are as follows:
   i) The permissible compressive stress on each pile determines the area required or diameter of pile.
   ii) Pile size should be minimized in order to reduce down drag force if applicable, minimize weight, and reduce cost.
   iii) It may in some cases be economical to increase pile size if by so doing the number of piles can be reduced to a practical minimum.
   iv) The question of drive ability of a chosen pile size in a given stratum also needs to be examined.
d) Estimation of pile capacity – the ultimate bearing capacity of a pile can be computed using the equations given section 2.6
e) Spacing of the piles - depends mainly on the type of the pile and soil. See clause 3.3.1
f) Geometry of piles in a group – the piles is arranged in most compact form.
g) Stability of a pile group – if the foundation is supported by friction piles in soft clay or plastic silt, the ultimate bearing capacity of the pile group should be estimated and the design load must not be allowed to exceed one third of the ultimate value.

h) Estimation of settlement – the settlement of a pile group may range from a few millimeters to several centimeters, depending on the soil conditions, the number of piles and the area covered by the structure. Settlements of 150 mm or more may have very undesirable effects on the superstructure. Hence if a foundation rests on friction piles driven into soft clay or if the points of point bearing piles are located above soft strata, settlement computations should be carried out.

i) Design of pile – load shared by different piles: firstly the load taken by each pile is obtained as given

$$V_p = \frac{V}{n}$$

Where V_p = load taken by each pile

V = total load acting on the pile, and

n = number of piles.

Effective length of pile – a pile is usually designed as a column for the load coming on it. In good ground, the lower point of contra flexure can be taken to be at a depth below ground level of about one-tenth of the exposed length. If the top stratum is soft clay or silt, the lower point of contra flexure is taken at about half the depth of penetration into this stratum, but not less than one-tenth of the exposed length of pile. In case the ratio of effective length of pile to the least lateral dimension exceeds 12, the pile should be designed of contra flexure may be taken at one- fourth of the exposed length below the top of pile. If the pile is not fixed the end conditions should be taken into account in determining effective length.

Reinforcement in pile – the reinforcement in the pile is obtained using

$$V = 0.4f_{ck}A_c + 0.67\ f_{sy}A_{sc}$$

Where

V = axial load on the member,

A_{sc}= area of longitudinal reinforcement for column,

A_c = area of concrete = $(A - \frac{p\,A_g}{100})$

A_g = Gross area of concrete = bD

b = width of column, and

D = depth of column.

P = percentage of reinforcement,

$$\frac{V}{f_{ck}bD} = 0.4 + \frac{P}{100f_{ck}}(0.67f_{ck} - 0.4f_{ck})$$

As per IS: 456 – 2000, the strength of a column with helical reinforcement may be taken as 1.05 times the strength of the column with lateral ties. I.e. equal to 1.o5 V provided the ratio of the volume of helical reinforcement to the volume of the core shall not be less than

$$0.36(\frac{A_g}{A_c} - 1)\frac{f_{ck}}{f_{sy}}$$

Where

A_g = Gross area of the section,

A_c = area of the core of the helically reinforced column measured to the outside diameter of the helix,

f_{ck}= characteristic compression strength of the concrete, and

f_{sy} = characteristic strength of the helical reinforcement, but not exceeding 415 Mpa

a) Longitudinal reinforcement – the area of main longitudinal reinforcement should not be less than the following percentages of the cross-sectional area of the pile:

1) For piles with length less than 30 times the least width	$1\frac{1}{4}$ percent
2) For piles with length 30 to 40 times the least width	$1\frac{1}{2}$ percent
3) For piles with length greater than 40 times the least width	2 percent

b) Lateral reinforcement – these should be in the form of hoops or links and should not be less than 5 mm in diameter. The volume of reinforcement should be as follow:

1) In the body of pile	not less than 0.2 percent of the gross volume of piles
2) At each end of pile for a length of about three times the least width	Not less than 0.6 percent of the gross volume of piles

Stresses during driving - precast concrete piles should also be checked for stresses developed in the pile during driving. Driving stress is given by

$$\text{Driving stress} = \frac{\text{driving resistance}}{A}(\frac{2}{\sqrt{\eta}} - 1)$$

Where

A = cross-sectional area of pile.

= area of concrete + equivalent area of reinforcement, and

η = efficiency of blow.

Design of pile cap.

Pile caps are the structural elements that tie a group of piles together. Pile caps may support bearing walls, isolated columns, or groups of several columns. Pile caps are use to transmit the force forces from the columns or walls to the piles. Plan dimensions of a pile cap depend on the spacing between the piles and their arrangement. The design of a pile cap is based on the same principles as involved in the design of footings and rafts. Its depth is based on the shear and development length for the column bars.

General guidelines for the design of pile caps are as follows:

1) Piles should be arranged so that centroid of the group coincides with the line of action of load.
2) A clear overhang of pile cap beyond the outermost pile should be kept greater then 100mm. this takes into account the non verticality of the piles.
3) (a) The pile cap should be deep enough to allow for necessary overlap of the column and pile reinforcement. (b) The pile cap should be deep enough to ensure full transfer of load from the column to the cap in punching shear.
4) Computation of moments and shears may be based on the assumption that the reaction from any pile is concentrated at the centre of the pile. Section for determining the maximum bending moment will be the face of the column (fig 15). Shear at the section located at effective depth'd' of pile cap from the face of the column.

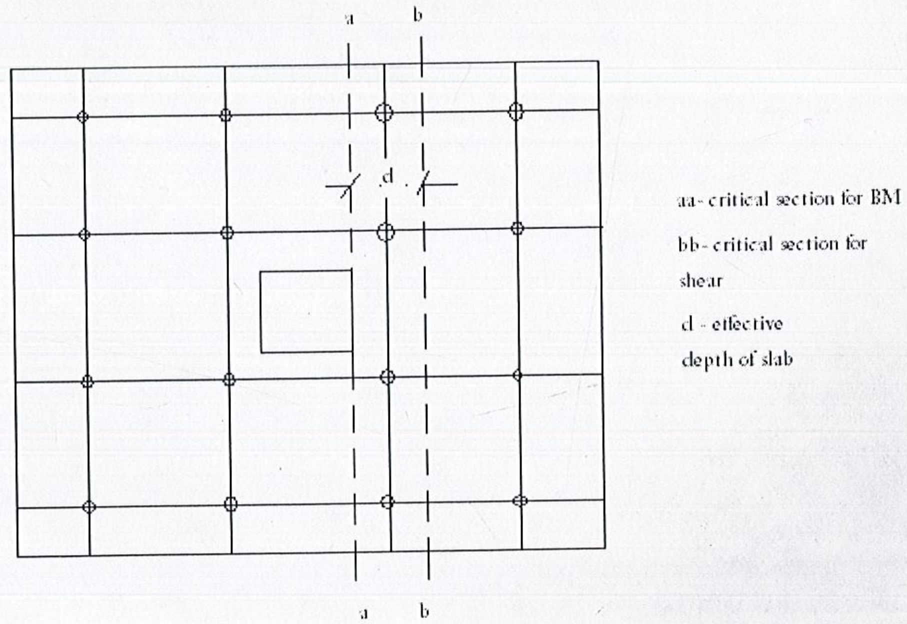


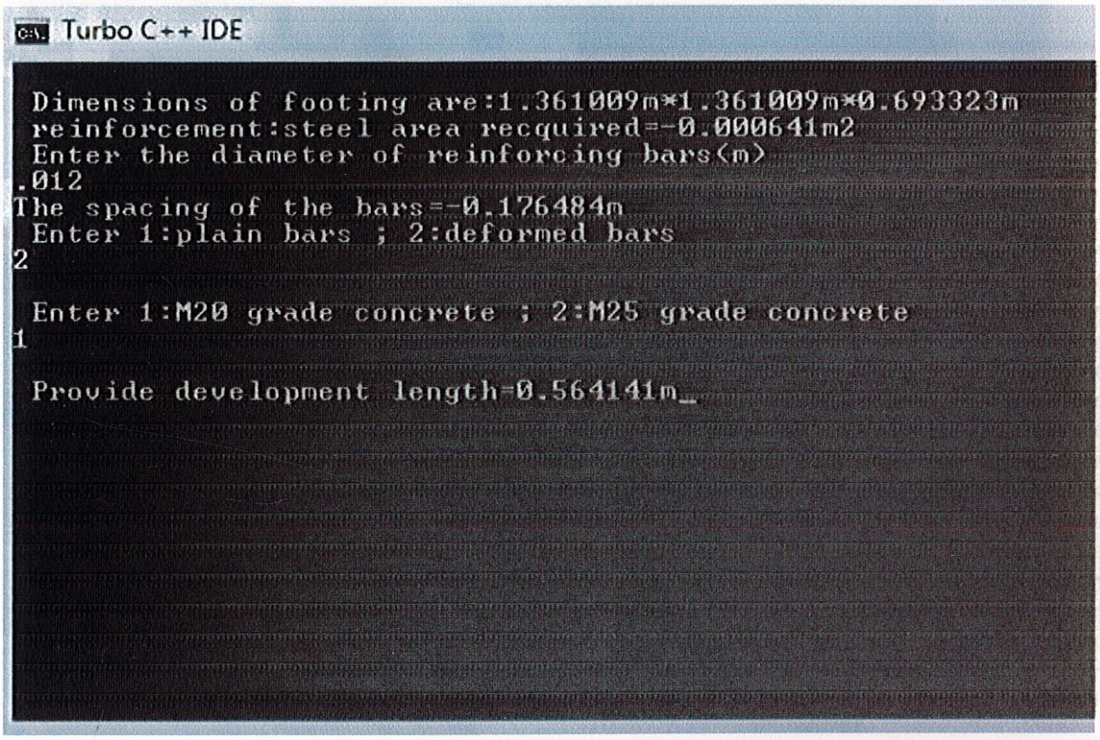
Fig 15

5) Minimum thickness of pile caps at edges should not be less than 300 mm.

Question 1 *(ref: example 7.1 of Analysis and Design of Substructures- SWAMI SARAN)*

Design an isolated footing for a column of 500 mm x 500 mm size subjected to a vertical load of 2400kN, moment of 400kN-m and shear load of 360kN. The allowable bearing pressure of the soil is $1425.22 \frac{kN}{m^2}$. Material specified is the concrete of M20 and HYSD steel.

OUTPUT

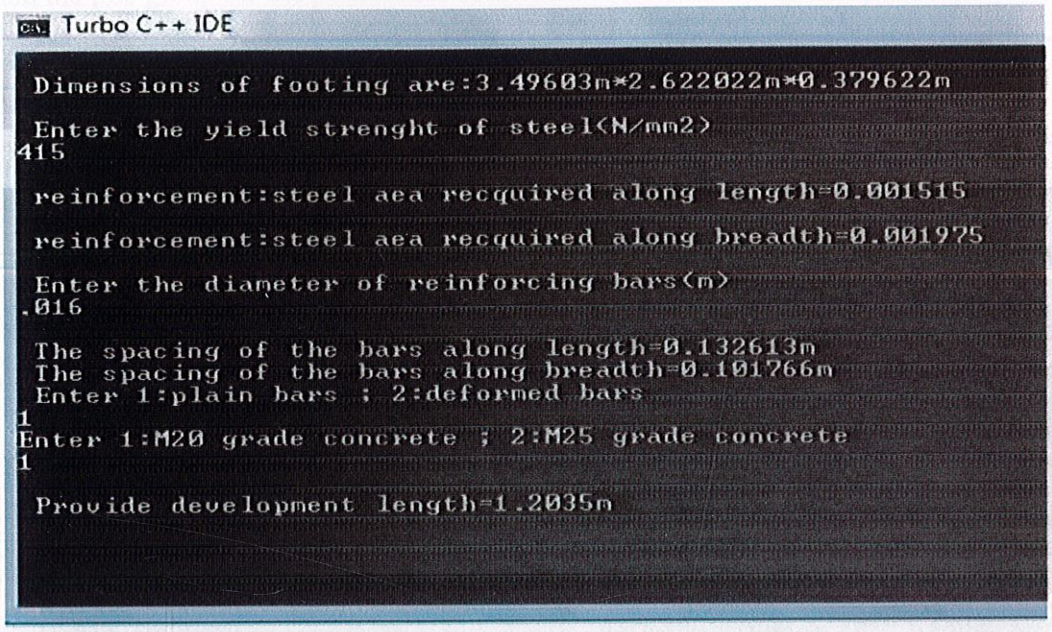


Question 2(*ref: example 7.3 of Analysis and Design of Substructures- SWAMI SARAN)*

A rectangular column 450 mm x 600 mm transfers a vertical load of 1000kN, without any moment. The allowable soil pressure is 120 $\frac{kN}{m^2}$. Design a rectangular footing to support the column. Material specified is the concrete of M20 and HYSD steel.

$$\Phi = 39^{\circ},\ \gamma_t = 18\frac{kN}{m^2}.$$

OUTPUT



```
Turbo C++ IDE
Dimensions of footing are:3.49603m*2.622022m*0.379622m
Enter the yield strenght of steel(N/mm2)
415
reinforcement:steel aea recquired along length=0.001515
reinforcement:steel aea recquired along breadth=0.001975
Enter the diameter of reinforcing bars(m)
.016
The spacing of the bars along length=0.132613m
The spacing of the bars along breadth=0.101766m
Enter 1:plain bars ; 2:deformed bars
1
Enter 1:M20 grade concrete ; 2:M25 grade concrete
1
Provide development length=1.2035m
```

Question 3*(ref: example 8.6 of Analysis and Design of Substructures- SWAMI SARAN)*

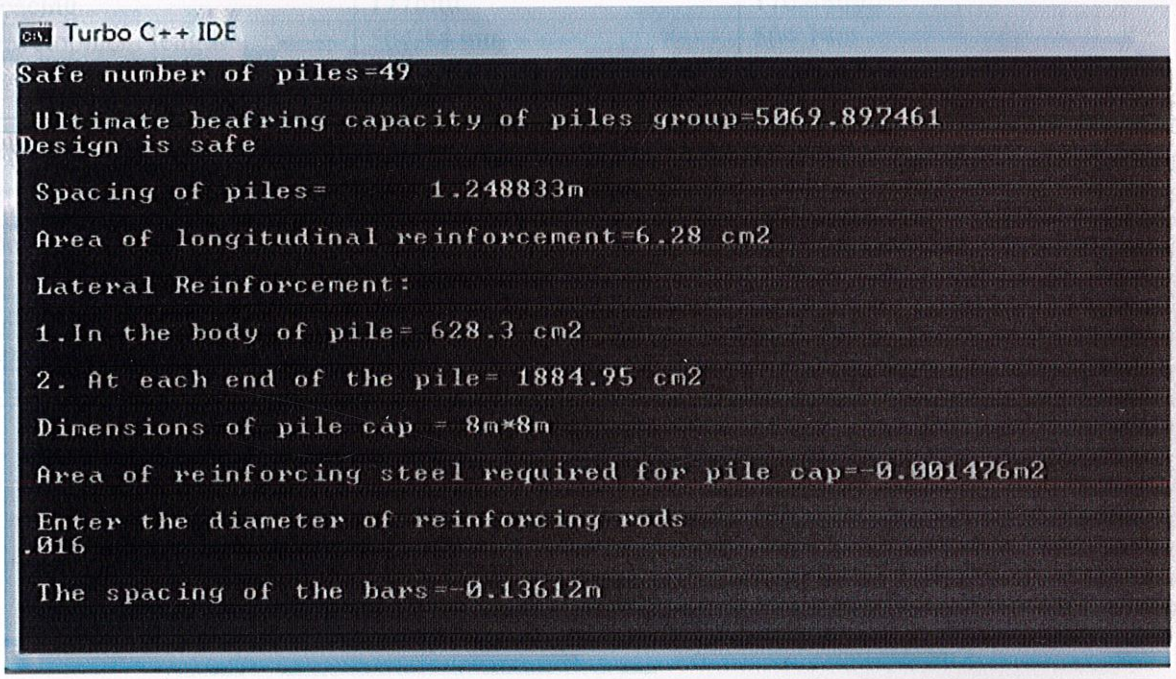
Design a pile group sonsisting of RCC piles for a column of size 650 mm x 650 mm carrying load of 5000 kN. The soil exploration data reveal that the subsoil consists of deposit of soft clay extending to a great depth. The other data of the deposit are

saturated unit weight = 19 kN/m^3

Unconfined compression strength = 40 kN/m^2

Proportion the pile group for the permissible settlement of 50 mm. Design the piles and the pile cap.

OUTPUT



Section 5

DISCUSSION

QUESTION 1

Property	Output from the reference	Output from the program
Depth	700 mm	693.32mm
Length	1.75 m	1.361m
Reinforcement	548.50 mm^2	641.00mm^2
Spacing	177mm	176.48mm
Development length	564.14 mm	564.14m

QUESTION 2

Property	Output from the reference	Output from the program
Depth	390 mm	379.622
Length of footing	3.49m x 2.62 m	3.49603m x 2.622m
Reinforcement	1762.6 mm^2	1745 mm^2
Spacing	116mm	116.5mm
Development length	1287mm	1203mm

QUESTION 3

Property	Output from the reference	Output from the program
No of piles	49	49
Spacing of piles	1.25 m	1.248833m
Area of longitudinal reinforcement	6.28 cm^2	6.28cm^2
Area of lateral reinforcement a) in the body of pile b) at each end the pile	628.3 cm^2 1885 cm^2	628.3 cm^2 1885 cm^2
Dimensions of pile cap	8m x 8m	8m x 8m
Area of reinforcement of pile cap	0.0015 m^2	0.001476m^2
Spacing of reinforcement of pile cap	136mm	136mm
Ultimate bearing capacity	5070 kN/m^2	5069.897 kN/m^2

CONCLUSIONS

A program has been developed using turbo C++ in order to design footings. Program is user-interactive. It has been found that program works satisfactorily. Few problems have been solved and presented in this work.

Suggestion for further work:

This program may be further extended for the design of raft and well foundations. This program may further be interface with AutoCAD like software so that the results from the program may be directly be plotted and drawing may be prepared.

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APPENDIX

```
#include<iostream.h>
#include<conio.h>
#include<math.h>
void continuous(float,float);
void square(float,float);
void circular(float,float);
void rectangular(float,float);
void shallow(float,float);
void details()
{       float Q;
        int p,tos;
        cout<<"Please enter the allowable bearing capacity of soil(KN/m2)"<<endl;
        cin>>Q;
        cout<<"\n Enter the coloumn load(KN)"<<endl;
        cin>>p;
        cout<<"\n Enter the type of soil:1-Cohesive, 2-Non-Cohesive"<<endl;
        cin>>tos;
        shallow(Q,p);
}
void shallow(float q,float P)
{     clrscr();
        int ch;
        cout<<"\n\n Plz enter type of column "<<"\n" <<"1-Square column"<<"\n"<<"2-
Rectangular"<<"\n"<<"3-Circular column"<<"\n"<<"4-Continuous column"<<endl;
        cin>>ch;
```

```
switch(ch)
{       case 1:  square(q,P);
        break;
        case 2:  rectangular(q,P);
        break;
        case 3: circular(q,P);
        break;
        case 4: continuous(q,P);
        break;
        default:cout<<"Wrong Entry";
        break;
};
getch();
}
void square(float a,float v)
{       clrscr();
        float T,D,Y,Q,q,ch,Ld,t,M,b,A,sv,B,d,fck,fy;
        double f,c,e,Ast;
        cout<<"\n Enter the dimension of coloumn(m)"<<endl;
        cin>>b;
        A= 1.1*v/a;
        B=sqrt(A);
        cout<<"\n Enter characteristic compressive strength of concrete(M20 or M25)in
N/mm2"<<endl;
        cin>>fck;
```

```
cout<<"Enter the yield strenght of steel in N/mm2"<<endl;
cin>>fy;
M=v*(B*pow((B-b),2)/(8*A));
d=sqrt(M/(0.138*fck*pow(10,3)));
cout<<"\nEnter the unit weight of soil(Y)"<<endl;
cin>>Y;
cout<<"\n Enter the angle of shearing resistance"<<endl;
cin>>q;
D=(a/Y)*pow(((1-sin(q))/(1+sin (q))),2);
T=D+d;
if(B<T)
{
        cout<<"\n Since B<D therefore go for deep foundation"<<"\n as recommended by
IS:6403 article 2.2.5"<<endl;
        int ch1;
        cout<<"Enter 1:Shallow foundation"<<"\n 2:Deep foundation"<<endl;
        cin>>ch1;
        if(B<T&&ch1==2)
        {getch();
        clrscr();

float Astc,dpc,BM,As,vp,n,Z,Dh,lp,C,cs,X,s,svc;
int x,m,Lc;
cout<<"Enter the depth of hard strata below the ground surface(m)"<<endl;
cin>>Dh;
```

```
if(Dh<=15)
{	cout<<"DRIVEN PRECAST CONCRETE PILES"<<endl<<endl;
	lp=10;
	cout<<"Enter the value of average unconfined compressive
strenght(KN/m2)"<<endl;
	cin>>C;
	cs=C/3;
	n=v/(cs*3.14*0.2*lp);
	x=1;
	while(pow(x,2)<n)
	{	x=x+1;
	}
	m=x*x;
	clrscr();
	getch();
	lp=lp*n/m;
	X=(x-1)*0.05+0.2;
	Z=4*X*lp+pow(X,2)*cs*9;
	if(Z>=v)
	{	cout<<"\n Safe number of piles="<<m<<endl;
		cout<<"\n Ultimate bearing capacity of piles group="<<Z<<endl<<"\t
DESIGN IS SAFE"<<endl;}
	else
	{ while(Z<v)
		{	x=x+1;
			X=(x-1)*0.05+0.2;
```

```
                        Z=4*X*lp+pow(X,2)*cs*9;
            }
                        cout<<"\n Safe number of piles="<<m<<endl;
                        cout<<"\n Ultimate bearing capacity of piles
group="<<Z<<endl<<"\t DESIGN IS SAFE"<<endl;

        }

    s=(1.57*0.2*m-0.4)/(2*sqrt(m)-2);
    cout<<"\n Spacing of piles="<<"\t"<<s<<"m"<<endl;

    }

    else
    {       cout<<"CAST IN SITU CONCRETE PILES"<<endl<<endl;
            lp=15;
            cout<<"Enter the value of average unconfined compressive
strenght(KN/m2)"<<endl;
            cin>>C;
            cs=C/3;
            n=v/(cs*3.14*0.2*lp);
            x=1;
            while(pow(x,2)<n)
            {   x=x+1;
            }
            m=x*x;
```

```
clrscr();
lp=lp*n/m;
X=(x-1)*.05+0.2;
Z=4*X*lp+pow(X,2)*cs*9;
if(Z>=v)
{	cout<<"\n Safe number of piles="<<m<<endl;
	cout<<"\n Ultimate beafring capacity of piles
group="<<Z<<endl<<"Design is safe"<<endl;}
else
{
while(Z<v)
	{	x=x+1;
		X=(x-1)*0.05+0.2;
		Z=4*X*lp+pow(X,2)*cs*9;
	}
		cout<<"Safe number of piles="<<m<<endl;
		cout<<"\n Ultimate beafring capacity of piles
group="<<Z<<endl<<"Design is safe"<<endl;

}
s=(1.57*0.2*m-0.4)/(2*sqrt(m)-2);
cout<<"\n Spacing of piles="<<"\t"<<s<<"m"<<endl;
}
cout<<"\n Area of longitudinal reinforcement=6.28 cm2"<<endl;
cout<<"\n Lateral Reinforcement:"<<endl;
cout<<"\n 1.In the body of pile= 628.3 cm2"<<endl;
```

```
cout<<"\n 2. At each end of the pile= 1884.95 cm2"<<endl;
Lc=(sqrt(m)-1)*s+0.7;
cout<<"\n Dimensions of pile cap = "<<Lc<<"m*"<<Lc<<"m"<<endl;
BM=(1.5*3*v*(3*s-d))/(2*m*s);
float J,G,K;
J=(pow(b,2)*pow(10,6));
G=1364*v;
K=J+G;
dpc=(sqrt(K)-b*pow(10,3))/2000;
f=0.87*pow(fy,2)/(fck*pow(10,3));
c=0.87*pow(10,3)*fy*dpc;
e=BM;
Astc=(c-sqrt(pow(c,2)+4*f*e))/(2*f);
cout<<"\n Area of reinforcing steel required for pile cap="<<Astc<<"m2"<<endl;
cout<<"\n Enter the diameter of reinforcing rods"<<endl;
cin>>Q;
svc=(3.14*pow(Q,2)/4)/Astc;
cout<<"\n The spacing of the bars="<<svc<<"m";

}

else if(B<T&&ch1==1)
{       clrscr();
t=(1.5*v)/(4*(b+d)*d);          //check for punching shear
        if(fck==20)
```

```
{       if(t<1120)
        cout<<"Safe against punching shear";
        else while(t>1120)
        {       d=d+0.025;
                t=(1.5*v)/(4*(b+d)*d);

        }
}
if(fck==25)
{           if(t<1.14)
        cout<<"Safe against punching shear";
        else while(t>1.14)
        {               d=d+25;
                t=(1.5*v)/(4*(b+d)*d);
                        }
}
cout<<"\n Dimensions of footing are:"<<B<<"m*"<<B<<"m*"<<d<<"m";

f=0.87*pow(10,3)*pow(fy,2)/fck;
c=0.87*pow(10,3)*fy*d;
e=M;
Ast=(c-sqrt(pow(c,2)+4*f*e))/(2*f);
cout<<"\n reinforcement:steel area recquired="<<Ast<<"m2";
cout<<"\n Enter the diameter of reinforcing bars(m)"<<endl;
cin>>Q;
```

```
sv=(3.14*pow(Q,2)/4)/Ast;
cout<<"The spacing of the bars="<<sv<<"m";
cout<<"\n Enter 1:plain bars ; 2:deformed bars"<<endl;
cin>>ch;
if (ch==1)
{   int ch1;
cout<<"\n Enter 1:M20 grade concrete ; 2:M25 grade concrete"<<endl;
cin>>ch1;
if (ch1==1)
{       t=1.2;
}
else
t=1.4;
}
else if (ch==2)
{       int ch2;
        cout<<"\n Enter 1:M20 grade concrete ; 2:M25 grade concrete"<<endl;
        cin>>ch2;
        if (ch2==1)
        t=1.92;
        else
        t=2.24;
}

Ld=(0.87*Q*fy)/(4*t);
```

```
        cout<<"\n Provide development length="<<Ld<<"m";
        getch();
}   }
else
{       clrscr();
t=(1.5*v)/(4*(b+d)*d);                  //check for punching shear
        if(fck==20)
        {   if(t<1120)
            cout<<"Safe against punching shear";
            else while(t>1120)
            {       d=d+0.025;
                    t=(1.5*v)/(4*(b+d)*d);

            }
        }
        if(fck==25)
        {       if(t<1.14)
            cout<<"Safe against punching shear";
            else while(t>1.14)
            {           d=d+25;
                    t=(1.5*v)/(4*(b+d)*d);
                        }
        }
        cout<<"\n Dimensions of footing are:"<<B<<"m*"<<B<<"m*"<<d<<"m";
```

```
f=0.87*pow(10,3)*pow(fy,2)/fck;
c=0.87*pow(10,3)*fy*d;
e=M;
Ast=(c-sqrt(pow(c,2)+4*f*e))/(2*f);
cout<<"\n reinforcement:steel area recquired="<<Ast<<"m2";
cout<<"\n Enter the diameter of reinforcing bars(m)"<<endl;
cin>>Q;
sv=(3.14*pow(Q,2)/4)/Ast;
cout<<"The spacing of the bars="<<sv<<"m";
cout<<"\n Enter 1:plain bars ; 2:deformed bars"<<endl;
cin>>ch;
if (ch==1)
{    int ch1;
cout<<"\n Enter 1:M20 grade concrete ; 2:M25 grade concrete"<<endl;
cin>>ch1;
if (ch1==1)
{       t=1.2;
}
else
t=1.4;
}
else if (ch==2)
{       int ch2;
        cout<<"\n Enter 1:M20 grade concrete ; 2:M25 grade concrete"<<endl;
        cin>>ch2;
```

```
                    if (ch2==1)
                    t=1.92;
                    else
                    t=2.24;
               }

               Ld=(0.87*Q*fy)/(4*t);
               cout<<"\n Provide development length="<<Ld<<"m";
               getch();
          }
}
void rectangular(float a,float v)
{         clrscr();
          float Q,q,T,Y,D,ch,Ld,b,t,A,L,B,d,fck,fy,sv1,sv2,Astl,Astb,l,Mx,My,x,y,m,p,i,o,d1,d2;
          cout<<"\n Enter the length of coloumn(m)"<<endl;
          cin>>l;
          cout<<"\n Enter the breadth of the coloumn(m)"<<endl;
          cin>>b;
          A= 1.1*v/a;
          B=sqrt(A*b/l);
          L=B*l/b;
          y=(B/2-b/2);
          x=(L/2-l/2);
          p=v/A;
          Mx=p*y*(2*x+l)*y/2;
```

```
My=p*x*(2*y+b)*x/2;
cout<<"\n Enter characteristic compressive strength of concrete(N/mm2)"<<endl;
cin>>fck;
d1=sqrt(Mx/(0.138*fck*1000));
d2=sqrt(My/(0.138*fck*1000));
if(d1>=d2)
{d=d1;}
else
{ d=d2;}
cout<<"\n Enter the unit weight of soil(Y)"<<endl;
cin>>Y;
cout<<"\n Enter the angle of shearing resistance"<<endl;
cin>>q;
D=v/Y*pow(((1-sin (q))/(1+sin (q))),2);
T=D+d;
if(B<T)
{	cout<<"\n Since B<D therefore go for deep foundation "<<"\n as recommended by
IS:6403 article 2.2.5"<<endl;
		int ch1;
		cout<<"Enter 1:Shallow foundation"<<"\n 2:Deep foundation"<<endl;
		cin>>ch1;
		if(B<T&&ch1==2)
		{getch();
		clrscr();
		float Astc,dpc,BM,As,vp,n,Z,Dh,lp,C,cs,X,s,svc;
```

```
int x,m,Lc;
cout<<"\n Enter the depth of hard strata below the ground surface(m)"<<endl;
cin>>Dh;
if(Dh<=15)
{       cout<<"DRIVEN PRECAST CONCRETE PILES"<<endl<<endl;
        lp=10;
        cout<<"Enter the value of average unconfined compressive
strenght(KN/m2)"<<endl;
        cin>>C;
        cs=C/3;
        n=v/(cs*3.14*0.2*lp);
        cout<<"n="<<n;
        x=1;
        while(pow(x,2)<n)
        {       x=x+1;
        }
        m=x*x;
        clrscr();
        getch();
        lp=lp*n/m;
        X=(x-1)*0.05+0.2;
        Z=4*X*lp+pow(X,2)*cs*9;
        if(Z>=v)
        {       cout<<"\n Safe number of piles="<<m<<endl;
                cout<<"\n Ultimate beafring capacity of piles
group="<<Z<<endl<<"Design is safe"<<endl;}
```

```
else
{    while(Z<v)
     {         x=x+1;
               X=(x-1)*0.05+0.2;
               Z=4*X*lp+pow(X,2)*cs*9;
     }
               cout<<"\n Safe number of piles="<<m<<endl;
               cout<<"\n Ultimate beafring capacity of piles
group="<<Z<<endl<<"Design is safe"<<endl;
}

     s=(1.57*0.2*m-0.4)/(2*sqrt(m)-2);
     cout<<"\n Spacing of piles="<<s<<"m"<<endl;

     }

     else
     {    cout<<"CAST IN SITU CONCRETE PILES"<<endl<<endl;
          lp=15;
          cout<<"\n Enter the value of average unconfined compressive
strenght(KN/m2)"<<endl;
          cin>>C;
          cs=C/3;
          n=v/(cs*3.14*0.2*lp);
          x=1;
          while(pow(x,2)<n)
```

```
{       x=x+1;
}
m=x*x;
clrscr();
lp=lp*n/m;
X=(x-1)*.05+0.2;
Z=4*X*lp+pow(X,2)*cs*9;
if(Z>=v)
{           cout<<"\n Safe number of piles="<<m<<endl;
            cout<<"\n Ultimate beafring capacity of piles
group="<<Z<<endl<<"Design is safe"<<endl;}
else
{
while(Z<v)
            {           x=x+1;
                        X=(x-1)*0.05+0.2;
                        Z=4*X*lp+pow(X,2)*cs*9;
            }
                        cout<<"\n Safe number of piles="<<m<<endl;
                        cout<<"\n Ultimate beafring capacity of piles
group="<<Z<<endl<<"Design is safe"<<endl;
}
s=(1.57*0.2*m-0.4)/(2*sqrt(m)-2);
cout<<"\n Spacing of piles="<<s<<"m"<<endl;
}
cout<<"\n Area of longitudinal reinforcement=6.28 cm2"<<endl;
```

```
cout<<"\n Lateral Reinforcement:"<<endl;
cout<<"\n 1.In the body of pile= 628.3 cm2"<<endl;
cout<<"\n 2. At each end of the pile= 1884.95 cm2"<<endl;
Lc=(sqrt(m)-1)*s+0.7;
cout<<"\n Dimensions of pile cap = "<<Lc<<"m*"<<Lc<<"m"<<endl;
float u;
if(b>l)
u=b;
else
u=l;
BM=1.5*3*v/m*((3*s-u)/2*s);
float f,c,e,J,G,K;
J=(pow(b,2)*pow(10,6));
G=1364*v;
K=J+G;
dpc=(sqrt(K)-b*pow(10,3))/2000;
f=0.87*pow(fy,2)/(fck*pow(10,3));
c=0.87*pow(10,3)*fy*dpc;
e=BM;
Astc=(c-sqrt(pow(c,2)+4*f*e))/(2*f);
cout<<"\n Area of reinforcing steel required for pile cap="<<Astc<<"m2"<<endl;
cout<<"\n Enter the diameter of reinforcing rods"<<endl;
cin>>Q;
svc=(3.14*pow(Q,2)/4)/Astc;
cout<<"\n The spacing of the bars="<<svc<<"m";
```

```
}

else if(B<T&&ch1==1)

{       clrscr();

t=(1.5*v)/(2*((l+d)+(b+d))*d);                  //check for punching shear

if(fck==20)

{       if(t<1120)

        cout<<"\n Safe against punching shear";

        else while(t>1120)

        {       d=d+0.025;

                t=(1.5*v)/(2*((l+d)+(b+d))*d);

        }

}

if(fck==25)

{               if(t<1140)

        cout<<"\n Safe against punching shear";

        else while(t>1140)

        {       d=d+0.025;

                t=(1.5*v)/(2*((l+d)+(b+d))*d);

        }
```

```
}
cout<<"\n Dimensions of footing are:"<<L<<"m*"<<B<<"m*"<<d<<"m"<<endl;
cout<<"\n Enter the yield strenght of steel(N/mm2)"<<endl;
cin>>fy;
m=(-0.87*pow(fy,2)*1000/fck);
i=(0.87*fy*d*1000);
Astl=(i-sqrt(pow(i,2)-4*m*Mx))/(2*m);
Astb=(i-sqrt(pow(i,2)-4*m*My))/(2*m);
cout<<"\n reinforcement:steel aea recquired along length="<<Astl<<endl;
cout<<"\n reinforcement:steel aea recquired along breadth="<<Astb<<endl;
 cout<<"\n Enter the diameter of reinforcing bars(m)"<<endl;
 cin>>Q;
  sv1=(3.14*pow(Q,2)/4)/Astl;
 cout<<"\n The spacing of the bars along length="<<sv1<<"m";
  sv2=(3.14*pow(Q,2)/4)/Astb;
 cout<<"\n The spacing of the bars along breadth="<<sv2<<"m";
 cout<<"\n Enter 1:plain bars ; 2:deformed bars"<<endl;
 cin>>ch;
 if (ch==1)
 {    int ch1;
      cout<<"Enter 1:M20 grade concrete ; 2:M25 grade concrete"<<endl;
      cin>>ch1;
      if (ch1==1)
      {     t=1.2;
      }
```

```
else
t=1.4;
}
else if (ch==2)
{       int ch2;
        cout<<"Enter 1:M20 grade concrete ; 2:M25 grade concrete"<<endl;
        cin>>ch2;
        if (ch2==1)
        t=1.92;
        else
        t=2.24;
}

Ld=(0.87*Q*fy)/(4*t);
cout<<"\n Provide development length="<<Ld<<"m";
getch();
}
}
else
{   clrscr();
t=(1.5*v)/(2*((l+d)+(b+d))*d);                    //check for punching shear
if(fck==20)
{       if(t<1120)
        cout<<"\n Safe against punching shear";
        else while(t>1120)
```

```
{   d=d+0.025;
    t=(1.5*v)/(2*((l+d)+(b+d))*d);

}
}
if(fck==25)
{   if(t<1140)
    cout<<"\n Safe against punching shear";
    else while(t>1140)
    {   d=d+0.025;
        t=(1.5*v)/(2*((l+d)+(b+d))*d);

    }
}
cout<<"\n Dimensions of footing are:"<<L<<"m*"<<B<<"m*"<<d<<"m"<<endl;
cout<<"\n Enter the yield strenght of steel(N/mm2)"<<endl;
cin>>fy;
m=(-0.87*pow(fy,2)*1000/fck);
i=(0.87*fy*d*1000);
Astl=(i-sqrt(pow(i,2)-4*m*Mx))/(2*m);
Astb=(i-sqrt(pow(i,2)-4*m*My))/(2*m);
cout<<"\n reinforcement:steel aea recquired along length="<<Astl<<endl;
cout<<"\n reinforcement:steel aea recquired along breadth="<<Astb<<endl;
 cout<<"\n Enter the diameter of reinforcing bars(m)"<<endl;
 cin>>Q;
```

```
sv1=(3.14*pow(Q,2)/4)/Astl;
cout<<"\n The spacing of the bars along length="<<sv1<<"m";
sv2=(3.14*pow(Q,2)/4)/Astb;
cout<<"\n The spacing of the bars along breadth="<<sv2<<"m";
cout<<"\n Enter 1:plain bars ; 2:deformed bars"<<endl;
cin>>ch;
if (ch==1)
{   int ch1;
    cout<<"Enter 1:M20 grade concrete ; 2:M25 grade concrete"<<endl;
    cin>>ch1;
    if (ch1==1)
    {       t=1.2;
    }
    else
    t=1.4;
}
else if (ch==2)
{   int ch2;
    cout<<"Enter 1:M20 grade concrete ; 2:M25 grade concrete"<<endl;
    cin>>ch2;
    if (ch2==1)
    t=1.92;
    else
    t=2.24;
}
```

```
 Ld=(0.87*Q*fy)/(4*t);
 cout<<"\n Provide development length="<<Ld<<"m";
 getch();
 }
}

void circular(float a,float v)
{ clrscr();
 float Q,ch,Ld,M,p,t,sv,r,A,R,d,b,c,fck,fy,Ast;
 cout<<"\n Enter the radius of coloumn"<<endl;
 cin>>r;
 A= 1.1*v/a;
 R=sqrt(A/3.14);
 p=v/A;
 M=p*3.14/4*(pow(R,2)-pow(r,2))*0.2*(3*pow(R,2)-2*R*r-2*pow(r,2))/(R+r);
 cout<<"\n Enter characteristic compressive strength of concrete"<<endl;
 cin>>fck;
 d=sqrt(M/0.138/fck/1000);
 float Y,q,D,T,f,e;
 cout<<"Enter the unit weight of soil(Y)"<<endl;
 cin>>Y;
 cout<<"\n Enter the angle of shearing resistance"<<endl;
 cin>>q;
 D=(a/Y)*pow(((1-sin(q))/(1+sin (q))),2);
```

```
T=D+d;
if((2*r)<T)
{       cout<<"\n Since B<D therefore go for deep foundation "<<"\n as recommended by
IS:6403 article 2.2.5"<<endl;
        int ch1;
        cout<<"Enter 1:Shallow foundation"<<"\n 2:Deep foundation"<<endl;
        cin>>ch1;
        if((2*r)<T&&ch1==2)
    {   clrscr();
float Astc,dpc,BM,As,vp,n,Z,Dh,lp,C,cs,X,s,svc;
int x,m,Lc;
cout<<"\n Enter the depth of hard strata below the ground surface(m)"<<endl;
cin>>Dh;
if(Dh<=15)
{       cout<<"DRIVEN PRECAST CONCRETE PILES"<<endl<<endl;
        lp=10;
        cout<<"\n Enter the value of average unconfined compressive
strenght(KN/m2)"<<endl;
        cin>>C;
        cs=C/3;
        n=v/(cs*3.14*0.2*lp);
        cout<<"n="<<n;
        x=1;
        while(pow(x,2)<n)
        {     x=x+1;
        }
```

```
m=x*x;
clrscr();
getch();
lp=lp*n/m;
X=(x-1)*0.05+0.2;
Z=4*X*lp+pow(X,2)*cs*9;
if(Z>=v)
{     cout<<"\n Safe number of piles="<<m<<endl;
          cout<<"\n Ultimate beafring capacity of piles
group="<<Z<<endl<<"Design is safe"<<endl;}
else
{   while(Z<v)
        {       x=x+1;
                X=(x-1)*0.05+0.2;
                Z=4*X*lp+pow(X,2)*cs*9;
        }
                cout<<"\n Safe number of piles="<<m<<endl;
                cout<<"\n Ultimate beafring capacity of piles
group="<<Z<<endl<<"Design is safe"<<endl;
}

s=(1.57*0.2*m-0.4)/(2*sqrt(m)-2);
cout<<"\n Spacing of piles="<<s<<"m"<<endl;

}
```

```
else
{       cout<<"CAST IN SITU CONCRETE PILES"<<endl<<endl;
        lp=15;
        cout<<"\n Enter the value of average unconfined compressive
strenght(KN/m2)"<<endl;
        cin>>C;
        cs=C/3;
        n=v/(cs*3.14*0.2*lp);
        x=1;
        while(pow(x,2)<n)
        {   x=x+1;
        }
        m=x*x;
        clrscr();
        lp=lp*n/m;
        X=(x-1)*.05+0.2;
        Z=4*X*lp+pow(X,2)*cs*9;
        if(Z>=v)
        {   cout<<"\n Safe number of piles="<<m<<endl;
                cout<<"\n Ultimate beafring capacity of piles
group="<<Z<<endl<<"Design is safe"<<endl;}
        else
        {
        while(Z<v)
                {       x=x+1;
                        X=(x-1)*0.05+0.2;
```

```
Z=4*X*lp+pow(X,2)*cs*9;
}
cout<<"Safe number of piles="<<m<<endl;
cout<<"\n Ultimate beafring capacity of piles group="<<Z<<endl<<"Design is safe"<<endl;
}
s=(1.57*0.2*m-0.4)/(2*sqrt(m)-2);
cout<<"\n Spacing of piles="<<s<<"m"<<endl;
}
cout<<"\n Area of longitudinal reinforcement=6.28 cm2"<<endl;
cout<<"\n Lateral Reinforcement:"<<endl;
cout<<"\n 1.In the body of pile= 628.3 cm2"<<endl;
cout<<"\n 2. At each end of the pile= 1884.95 cm2"<<endl;
Lc=(sqrt(m)-1)*s+0.7;
cout<<"\n Dimensions of pile cap = "<<Lc<<"m*"<<Lc<<"m"<<endl;
BM=(1.5*3*v)/(m*((3*s-2*r)/2*s));
float J,G,K;
J=(pow(b,2)*pow(10,6));
G=1364*v;
K=J+G;
dpc=(sqrt(K)-b*pow(10,3))/2000;
f=0.87*pow(fy,2)/(fck*pow(10,3));
c=0.87*pow(10,3)*fy*dpc;
e=BM;
Astc=(c-sqrt(pow(c,2)+4*f*e))/(2*f);
```

```
cout<<"\n Area of reinforcing steel required for pile cap="<<Astc<<"m2"<<endl;
cout<<"\n Enter the diameter of reinforcing rods"<<endl;
cin>>Q;
svc=(3.14*pow(Q,2)/4)/Astc;
cout<<"\n The spacing of the bars="<<svc<<"m";
}
else if((2*r)<T&&ch1==1)
{ clrscr();
t=(1.5*v)/(2*3.14*(r+d/2)*d);          //check for punching shear
if(fck==20)
{       if(t<1.12)
        cout<<"Safe against punching shear";
        else while(t>1.12)
        {       d=d+25;
                t=(1.5*v)/(4*(b+d)*d);
                }
}
if(fck==25)
{               if(t<1.14)
        cout<<"Safe against punching shear";
        else while(t>1.14)
        {       d=d+25;
                t=(1.5*v)/(4*(b+d)*d);
```

```
        }
    }
    cout<<"\n Radius of footing is:"<<R;
    cout<<"\n Depth of footing is:"<<d;
    cout<<"\n Enter the yield strenght of steel"<<endl;
    b=0.87*fy*d;
    c=0.87*pow(fy,2)/(fck*b);
    cin>>fy;
    Ast=(b+sqrt(pow(b,2)-4*b*M))/2*c;
    cout<<"\n reinforcement:steel aea recquired="<<Ast;
    cout<<"\n Enter the diameter of reinforcing bars"<<endl;
    cin>>Q;
    sv=(3.14*pow(Q,2)*1000/4)/Ast;
    cout<<"The spacing of the bars="<<sv;
    cout<<"\n Enter 1:plain bars ; 2:deformed bars"<<endl;
    cin>>ch;
    if (ch==1)
    {   int ch1;
        cout<<"Enter 1:M20 grade concrete ; 2:M25 grade concrete"<<endl;
        cin>>ch1;
        if (ch1==1)
        {     t=1.2;
        }
        else
        t=1.4;
```

```
}
else if (ch==2)
{       int ch2;
        cout<<"Enter 1:M20 grade concrete ; 2:M25 grade concrete"<<endl;
        cin>>ch2;
        if (ch2==1)
        t=1.92;
        else
        t=2.24;
}

Ld=(0.87*Q*fy)/(4*t);
cout<<"Provide development length="<<Ld;
getch();
} }

else
{ clrscr();

t=(1.5*v)/(2*3.14*(r+d/2)*d);              //check for punching shear
if(fck==20)
{       if(t<1.12)
        cout<<"Safe against punching shear";
        else while(t>1.12)
        {       d=d+25;
```

```
            t=(1.5*v)/(4*(b+d)*d);
            }
}
if(fck==25)
{           if(t<1.14)
      cout<<"Safe against punching shear";
      else while(t>1.14)
      {     d=d+25;
            t=(1.5*v)/(4*(b+d)*d);

      }
}
cout<<"\n Radius of footing is:"<<R;
cout<<"\n Depth of footing is:"<<d;
cout<<"\n Enter the yield strenght of steel"<<endl;
b=0.87*fy*d;
c=0.87*pow(fy,2)/(fck*b);
cin>>fy;
Ast=(b+sqrt(pow(b,2)-4*b*M))/2*c;
cout<<"\n reinforcement:steel aea recquired="<<Ast;
cout<<"\n Enter the diameter of reinforcing bars"<<endl;
cin>>Q;
sv=(3.14*pow(Q,2)*1000/4)/Ast;
cout<<"The spacing of the bars="<<sv;
cout<<"\n Enter 1:plain bars ; 2:deformed bars"<<endl;
```

```
cin>>ch;
if (ch==1)
{   int ch1;
    cout<<"Enter 1:M20 grade concrete ; 2:M25 grade concrete"<<endl;
    cin>>ch1;
    if (ch1==1)
    {       t=1.2;
    }
    else
    t=1.4;
}
else if (ch==2)
{   int ch2;
    cout<<"Enter 1:M20 grade concrete ; 2:M25 grade concrete"<<endl;
    cin>>ch2;
    if (ch2==1)
    t=1.92;
    else
    t=2.24;
}

Ld=(0.87*Q*fy)/(4*t);
cout<<"Provide development length="<<Ld;
getch();
}
```

```
}

void continuous(float a,float v)
{       clrscr();
        float t,T,q,Y,D,B,ch,Q,l,fy,fck,b,p,d,sv,M,Ast,P,Ld;
        B=v*1.1/a;
        cout<<"Enter the width of the wall"<<endl;
        cin>>b;
        cout<<"Enter the lenth of wall"<<endl;
        cin>>l;
        P=v/B;
        M=P/8*(B-b)*(B-b/4)*pow(10,6);
        cout<<"\n Enter the characteristic compressive strength of concrete"<<endl;
        cin>>fck;
        d=sqrt(M/(0.138*fck*1000));
                d=sqrt(M/(0.138*fck*pow(10,3)));
        cout<<"\n Enter the Yeild strength of steel"<<endl;
        cin>>fy;
        Ast=(0.87*fy*d+(sqrt(pow((0.87*fy*d),2)-
4*0.87*pow(fy,2)*M/fck/1000)))/(2*0.87*pow(fy,2)/(fck*1000));
        cout<<"\n reinforcement area recquired="<<Ast<<endl;
        cout<<"Provide longitudinal reinforement="<<0.15*l*b;
        cout<<"\n Enter the diameter of reinforcing bars"<<endl;
        cin>>Q;
        sv=(3.14*pow(Q,2)*1000/4)/Ast;
```

```
cout<<"The spacing of the bars="<<sv;
cout<<"\n Enter 1:plain bars ; 2:deformed bars"<<endl;
cin>>ch;
if (ch==1)
{     int ch1;
        cout<<"Enter 1:M20 grade concrete ; 2:M25 grade concrete"<<endl;
        cin>>ch1;
        if (ch1==1)
        {       t=1.2;
        }
        else
        t=1.4;
}
else if (ch==2)
{       int ch2;
        cout<<"Enter 1:M20 grade concrete ; 2:M25 grade concrete"<<endl;
        cin>>ch2;
        if (ch2==1)
        t=1.92;
        else
        t=2.24;
}

Ld=(0.87*Q*fy)/(4*t);
cout<<"Provide development length="<<Ld;
```

```
        getch();

}

void main()
{       clrscr();
        details();
        getch;
}
```