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Designing and contrastive inquisition of spread-isolated and strap-combined footing underlying economical criterion and behavioural aspects pursuant to Chhattisgarh region in India

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Abstract

Footing in civil engineering can be defined as structural rudiments that transfuse column or wall loads to the fundamental soil underneath the structure. Footing make sure that load transmission to the soil occurs without anomalize its safe bearing capacity, to forestall excessive settlement of the edifice to a tolerable limit, to denigrate discriminative settlement, and to prevent sliding and overturning. In this paper we have done an elaborative designing of spread and strap footings wherein the load effect is considered to be same. In order to antomize in a proper manner we have considered two isolated spread footings and one combined strap footing. The whole analysis of both footings is based on many parameters out of which most importantly our engrossment lies on the exercise based on economical point of view and on the behavioural aspects of both the footings. The observations taken are based on footings used in applicable places such as residential or commercial buildings surrounding the area of Chhattisgarh region, in India.

Keywords: Spread footing, Strap footing, Feasibility study, Designing, Bearing Capacity, Shear force.

Introduction

A structure is generally considered to have two main portions: i. The Superstructure, ii. The Substructure.

The substructure transmits the loads of the super structure to the supporting soil and is generally termed as foundation. Footing is that portion of the foundation which ultimately delivers the load to the soil and is thus in contact with it. The load of the superstructure is transmitted to the foundation or substructure through either columns or walls.

The object of providing foundation to a structure is to distribute the load to the soil in such a way that the maximum pressure on the soil does not exceed in permissible bearing value, and at the same time the settlement is within the permissible limits. Foundations are classified under two heads: shallow foundation and deep foundation. A foundation is shallow if its depth is equal to or less than its width. In case of deep foundation the depth is greater than the width of the common deep foundations are pier foundation, pile foundation and well foundation, whereas the common shallow foundations are spread footing, strap footing, acknowledgment aft footing[1]. Footings can be bifurcated into many types however in this paper our main focus lies on two types of footings namely: i. Strap footing, ii. Spread footing.

In this paper, we shall study in elaborate about the above discussed footings and also compare them based on various parameters.

Strap footing: A strap footing consists of spread footings of two columns connected by a strap beam. This type of footing is useful when the external column (wall column) is very near to other's boundary so that its footing cannot be spread beyond boundary. Typically, columns are centred on column footings but in conditions where columns are located directly adjacent to the property line, the column footings maybe offset so that they do not encroach onto the adjacent property[2]. This results in an eccentric load on a portion of footing causing it to tilt to one side. The strap beam restraints the tendency of the footing to overturn by connecting it to nearby footings. In case of strap footing the individual spread footings have very large areas under the columns, resulting in decrease in maximum bending moment (BM) and shear force (SF). Beam connecting two spread foundation does not transfer any loads of the two columns pass through the combined C.G. of the combined loads of the two columns pass through the combined C.G. of the two footing areas. Once this criterion is achieved the pressure distribution below each individual footing will be uniform. The function of the strap beam is to transfer the load of the heavily loaded outer column to the inner one. In doing so the strap beam is subjected to bending moment and shear force and it should be suitably designed to withstand these[3].

Spread footing: A spread footing generally known as a footing is a type of shallow foundation used to transmit the load of an isolated column or that of a wall, on the subsoil. It generally rectangular prism of concrete, larger in lateral dimensions than the column or wall it supports. The spread footing behaves like an inverted cantilever with loads applied in the upward direction. As a rule, a spread footing is a quite rigid element therefore, the applied soil stresses are almost linear and in case of a symmetric (with respect to the pedestal) footing, they are orthogonal. These soil pressures are the loads carried by the footing that behaves like a slab. The real deformation is in the order of a millimeter and although it is not visible to the human eye, it always has that same form. The reinforcement is placed at the lower surface of the footing both along the x and y axis[4].

In order to make our observation more effective let us consider a scenario wherein we are designing a strap footing and a spread footing for load of 1500 kN. For strap footing, in this design we have taken column A of 300 mm. × 300 mm. in size, carrying a load of 600 kN and is on the property line and column B, 400 mm. × 400 mm. in size carrying a load of 900 kN. Similarly, for the spread footing design on the same load of 1500 kN. We decided to design two isolated footings of a column 350 mm. × 350 mm. transmitting an axial load of 750 kN on each footing. The safe bearing capacity (BC) of soil is 120 tonnes/m^2. We are using M20 mix and FE-415 steel for both footings. All observations are based for the above defined parameters for both the footings discussed in this paper[5].

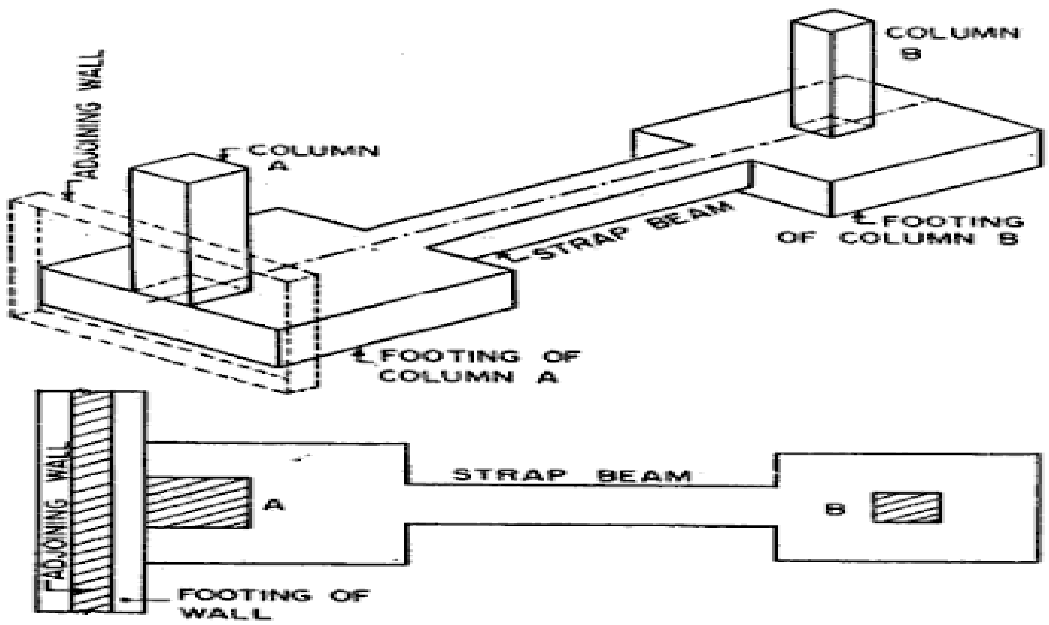

Figure-1: Strap Footing[7].

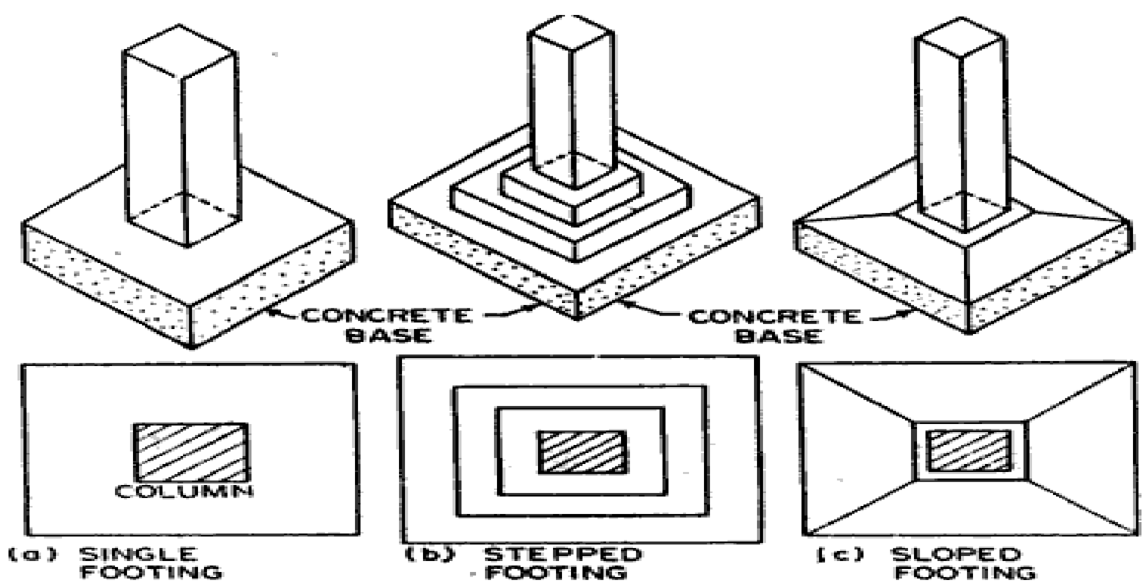

Figure-2: Spread Footing[8].

Designing with strap footing

Designing constants: For above concrete and steel we have following values:

c=σcbc=7N/mm²; t=σst = 230 N/mm²; *kc*=0.289; *jc*= 0.904; *R*c = 0.914.

Size of Footings: Assuming width of two footings is B meters each. Dimension of footing A=L1 and dimension of footing B be L2 centrally settled under B.

W1=600kN, W2=900kN,
Weight of footing W'=0.1(600+900) =150 kN.

Hence, B(L1+L2)=$\frac{600+900+150}{120}$ = 13.75 m^2

or L1+L2=$\frac{13.75}{B}$ (1)

Here $\bar{x}$ = length of C.G. of forces from centre of column B,

$\therefore \bar{x} = \frac{W1l}{W1 + W2} = \frac{600 \times 5}{600 + 900}$ = 2 m.

If $\bar{x}$ is also magnitude of length of C.G. of areas, from centre of column B, here $\bar{x} = \frac{B \times L1\left(l + \frac{b1}{2} - \frac{L1}{2}\right)}{B\,(L1 + L2)}$

Substituting the values of $\bar{x}$, B1=l1 we get,

$$2 = \frac{L1\ (5 + 0.15 - 0.5\ L1)}{(L1 + L2)} \qquad (2)$$

Substituting the value of (L1+L2) from (1) and choosing B=2.5 m. we get,

$$\frac{L1(5 + 0.15 - 0.5\,L1)}{(L1 + L2)} = 2$$

From which L1= 3.025 m = 3m (say), ∴ L2=$\frac{13.75}{2.5} - 3.0$ =2.5 m.

Net upward pressure (Po) =$\frac{600 + 900}{2.5\ (3 + 2.5)}$= 109kN/$m^2$

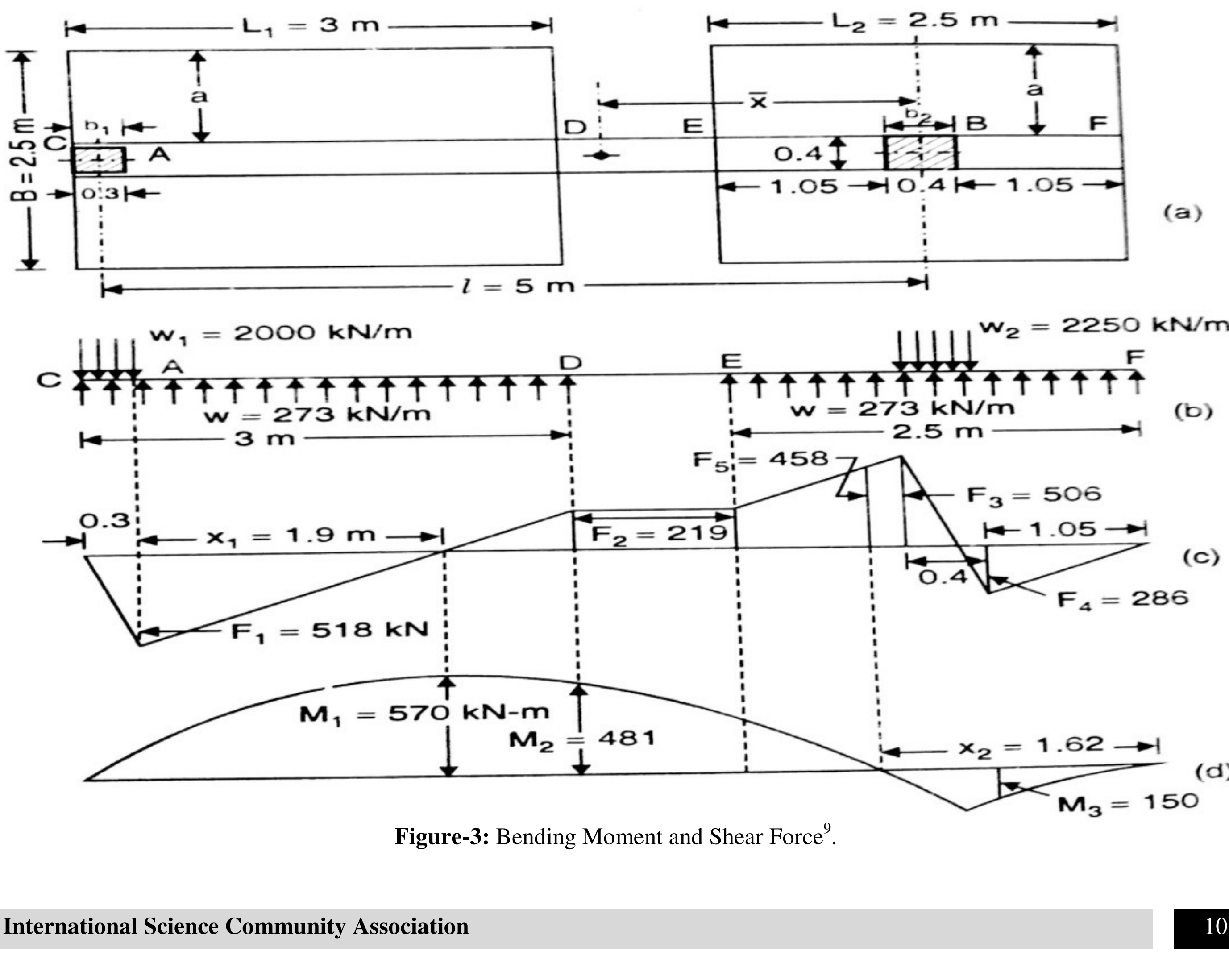

Figure-3: Bending Moment and Shear Force[9].

Design of footing slab: Here length of strap beam = 400 mm, ∴ Overhang, over beam is a=$\frac{1}{2}$ (2.5-0.4) = 1.05 m

Max bending moment M= Po$\frac{a^2}{2}$ = 109 $\frac{(1.05)^2}{2}$ = 60 kN-m = 60 × 10^6 N-mm, so d = $\sqrt{\frac{60*10^6}{0.914\times 1000}}$ = 257 mm.

Keeping cover to centre of steel = 60 mm. D= 257 +60 =317 mm. However, keep D= 320 m. so that d = 320 – 60 =260 mm. Reduce to total depth to 20 mm. at the edges, so that d= 200-60 =140mm there, $A_{st} = \frac{M}{\sigma_{st} j_c \;\; d} = \frac{60 * 10^6}{230 \times 0.904 \times 260}$ =1110 mm^2

Using 16 mm Φ bars having A_Φ=201mm^2, spacing s=$\frac{1000 \times 201}{1110}$ = 181 mm, Hence provide 16 mm Φ bars @ 180 mm c/c.

Let us check this for development length: L_d = 45 Φ = 45 × 16 =720 mm.

Using 60 mm side cover, actual length available = 1050 -60 = 990 mm > d. Hence, O.K.
Distribution reinforcement = $\frac{0.12}{100}$ × 1000$\frac{(300+200)}{2}$ = 312 mm^2, ∴ Spacing of 10 mm Φ bars = $\frac{1000\times 78.5}{312}$ = 250 mm c/c.

BMD and SFD for strap beam: Upward force w per meter, on beam (w) = p_0 B = 109× 2.5 = 273 kN/m.

Downward force intensity under column A = w_1 = 600/0.3 = 2000 kN/m., Downward force intensity under of column B = w_2 = 900/0.4 = 2250 kN/m.

The force and moment diagram on beam is shown in Figure-3.
S.F. at internal face of column
A = F_1 = (2000× 0.3) - (273× 0.3) =518 KN.

S.F at edge D = F_2 = 273× 0.3 – 600 = 219 kN and S.F at edge E = F_2= 219 KN and S.F. at internal edge of column
B = F_3 = 219+ 273{$\frac{1}{2}$ (2.5-0.4)} = 506 KN.

S.F. at outer edge of column B = F_4 = 900-506-(273× 0.4) = 286 KN = 273 × {$\frac{1}{2}$ (2.5-0.4)} = 286 kN.

In CD distance, shear force is 0 at x_1 far from the inner face of column A, its value being given by$x_1 = \frac{518}{273} = 1.9\ m.$

Hogging BM will be highest at this section, the values are:

$$M_1 = (2000 \times 0.3)(1.9 + 0.15) - 273\frac{(0.3+1.9)^2}{2} = 570\ kN - m.$$

Hogging BM at the edge D is given by:

$$M_2 = (2000 \times 0.3)(3 - 0.15) - 273\frac{(3)^2}{2} = 481\ kN - m.$$

Sagging B.M. at the outside face of column B is:

$$M_3 = \frac{273}{2}\left[\frac{1}{2}(2.5 - 0.4)\right]^2 = 150\ \text{kN} - \text{m}.$$

Let the point of contraflexure occur at x_2 from point F.

$$M_x = 0 = 273\left(\frac{x_2^2}{2}\right) - (2250 \times 0.4)(x_2 \times 1.25),$$
$$\textit{which gives}$$

Shear force at the point of contraflexure is given by:
$F_5 = (2250 \times 0.4) - (273 \times 1.62) = 458\ kN$

Depth of strap beam: Since it projects above the footings, T-beam action will be available in range CD. Maximum bending moment is M_1 = 570 kN-m. However, since T-beam action is available here, the critical section will be at D, where the beam acts as a rectangular beam because of absence of footing slab. Bending moment at D = M_2 = 481 kN-m = 481 × 10^6 N-mm.

∴ d = $\sqrt{\frac{481\times 10^6}{0.914 \times 400}}$ = 1147 mm. Ω1150 mm.

Let us find the moment of resistance of T-beam, with d= 1150 mm.

Average thickness of slab = $\frac{320\times 200}{2}$ = 260 mm = D_f

For an isolated T-beam, width of flange is given by: $b_f = \frac{l_0}{\left(\frac{l_0}{b} + 4\right)} + b_w$

l_0 = distance between points of zero moments in beam = (5+0.15+1.25) – 1.62 = 4.78 m =4780 mm.

b= actual width of flange = 2.5 m = 2500 mm. and b_w= width of web = 400 mm. and $b_f = \frac{4780}{\left(\frac{4780}{2500} + 4\right)}$+ 400 = 1208 mm.

Taking lever arm = 0.9 d, the moment of resistance of T-beam is given by

$$M_r = 0.45\ b_f\, \sigma_{cbc}\, D_f\left[\frac{2\,k\,d - D_f}{k}\right] = 0.45 \times 1208 \times 7 \times 260\left[\frac{2 \times 0.289 \times 1150 - 260}{0.289}\right] = 1385\times 10^6 \text{ N-mm} = 1385 \text{ kN-m}$$

which is much more than the hogging bending moment M_1 = 570 kN-m. Hence, d = 1150 mm is safe.

Reinforcement in strap beam

For hogging bending moment M_1, lever arm = 0.9 d and the area of steel is given by

$$A_{st1} = \frac{M_1}{\sigma_{st}} = \frac{570 \times 10^6}{230 \times 0.9 \times 1150} = 2395\ mm^2$$

For hogging B.M. M_2, area of steel is given by:
$:A_{st2} = \frac{481 \times 10^6}{230 \times 0.904 \times 1150} = 2012\ mm^2$

Hence provided reinforcement is equal to 2395 mm^2.

Using 20 mm Φ bars having A_Φ = 314 mm^2, so
No. of bars = 2395/314 = 7.63 = 8.

Let us check the reinforcement for development of stresses, at P.O.C., so as to fulfil criterion:$\frac{M}{V} + L_0 \geq L_d$

Assuming that the 8 bars, provided at the top face of the beam, are available at the point of contraflexure (P.O.C.), we have

$$M = \sigma_{cbc} A_{st} j_c d = 230 \times (8 \times 314) \times 0.9 \times 1150$$
$$= 598 \times 10^6\ N - mm$$

V = S.F. at point of contraflexure (P.O.C.) = F_5 = 458 kN

$L_0 = 12\ \Phi$ or d, whichever is more $= 1150$ mm.
$L_0 = 45\ \Phi = 45 \times 20 = 900\ mm.$

$$\frac{M}{V} + L_0 = \frac{598 \times 10^6}{458 \times 1000} + 1150 = 1305 + 1150 = 2455\ mm.$$

Which is more than L_d. This suggests that it is not necessary to take all the 8 bars upto the point of contraflexure. However, we will continue all the bars upto a distance of L_0(=1150 mm) from the point of contraflexure, or to a distance of 1620-1150 = 470 mm from the end of beam. After that, discontinue al the bars, except 3 bars which will serve as anchor bars for shear stirrups.

Similarly at the face of support near A, the above reinforcement should satisfy the criterion.

$$\frac{M}{V} + L_0 \geq L_d$$

Where: $M = 598 \times 10^6\ N - mm\ as\ above$;

$V = shear\ force = 518\ kN$

$L_0 = \frac{b}{2} - cover = 150 - 60 = 90\ mm;$
$L_d = 45\Phi = 45 \times 20 = 900\ mm$

$$\frac{M}{V} + L_0 = \frac{598 \times 10^6}{518 \times 10^6} + 90 = 1154 + 90 = 1244\ mm.$$

Which is more than L_d. Hence, satisfactory

Hence 8 bars of 20 mm Φ will be enough. Bars are used in two Φ stirrups, and 50 mm nominal cover, D = d + 20/2 + 20 + 10 + 50 = d + 90 = 1150 + 90 = 1240 mm.

Maximum sagging B.M. occurs at the outer face of the colun B, where bending moment $M_3 = 150\ kN - m.$ Using 12 mm Φ bars and 10 mm Φ bars stirrups with 50 mm nominal cover, available d = 1240 – 12/2 – 10 – 50 = 1240 – 66 = 1174 mm.

$$A_{st} = \frac{150 \times 10^6}{230 \times 0.904(1174)} = 615\ mm^2$$

Using 12 mm Φ bars having A_Φ = 113.1 mm^2. No. of bars = 615/113.1 = 5.43Ω 6 of stress at P.O.C. so as to fulfil criterion

$$\frac{M}{V} + L_0 \geq L_d$$
Where

$$M = \sigma_{st} A_{st} j_c d = 230 \times (6 \times 113.1) \times 0.904 \times 1174$$
$$= 165 \times 10^6\ N - mm$$

$$V = S.F. at\ the\ point\ of\ contraflexure = 458\ kN$$
$$= 458 \times 10^6\ N$$

$L_0 = 12\ \Phi$ or d, whichever is more $= 1174$ mm.

$L_d = 45\Phi = 45 \times 12 = 540\ mm$;

$\frac{M}{V} + L_0 = \frac{165 \times 10^6}{458 \times 10^6} + 1174 = 1534\ mm.$ Which is more than L_d, and hence safe.

Hence provide 6-12 mm Φ bars at the lower face, and continue these to a point distant $L_0(= 1174\ mm)$ from the point of contraflexure, or to a point distant 1174 + 1620 Ω 2800 mm from the end of the beam. After that, discontinue all the bars, except 3 bars which will serve as anchor bars.

Reinforcement for diagonal tension: $100\frac{A_{st}}{bd} = \frac{100 \times 8 \times 314}{400 \times 1150} =$ 0.546 %. Hence from table (), τ_{st} = 0.31 N/ mm^2

∴ Shear resistance of concrete, $V_c = 0.31 \times 400 \times 1150$ = 142600 N =142.6 kN. Hereshear reinforcement is required as SF is higher than 142.6 kN.

At internal face of column A, shear force $F_1 = 518$kN.
∴ $V_s = F_1 - V_c = 518 - 142.6 = 375.4$kN.

Using 10 mm Φ 4-lgd stirrups, A_{sv} = 4× $\frac{\pi}{4}(10)^2$ = 314 mm^2

∴ Spacing $S_v = \frac{A_{sv}\sigma_{sv}d}{V_s} = \frac{314 \times 230 \times 1150}{375.4 \times 10^3}$ = 221 mm Ω 220 mm c/c.

Distance of point where shear force is 142.6 kN, from the inner face of column = $\frac{518-142.6}{273} \approx$ 1.38 m. Hence the distance from end of beam = 1.38 + 0.3 = 1.68 m.

Hence, provide 10 mm Φ 4-lgd stirrups @ 220 mm c/c from end of the beam to 1.68 m.

At inner side of column B, shear force $F_3 = 506$ kN. Hence spacing of 10 mmΦ 4-lgd stirrups is given by
$S_v = \frac{314\times 230\times 1150}{(506-142.6)10^3} = 228$mmΩ220 mm c/c.

So, provide stirrups @ 220 mm c/c from point E to the inner face of the column. Like these, at the outer side of column B, shear force $F_4 = 286$ kN.
$S = \frac{314\times 230\times 1150}{(286-142.6)10^3} = 578$mm. This is too large.

However, using 8 mm Φ 4-lgd stirrups, having $A_{sv} = 4\times \frac{\pi}{4}(8)^2$ = 201 mm^2
$S = \frac{201\times 230\times 1150}{(286-142.6)10^3} = 370$mm. subject to a maximum of 300 mm. Max spacing of stirrups $S_v = \frac{2.175 A_{sv} f_y}{b} = \frac{2.174\times 201\times 415}{400} = 45\,mm$, subject to a maximum of 300 mm. Hence, keep $S_v = 300\,mm$ from the outer side of the column to end of beam. At the point D, shear force $F_2 = 219\ kN$.

$S_v = \frac{201\times 230\times 1150}{(219-142.6)10^3} = 695$mm, subject to maximum of 300 mm.

Hence, for the remaining portion, provide 8 mm Φ 4-lgd stirrups of spacing 300 mm c/c.

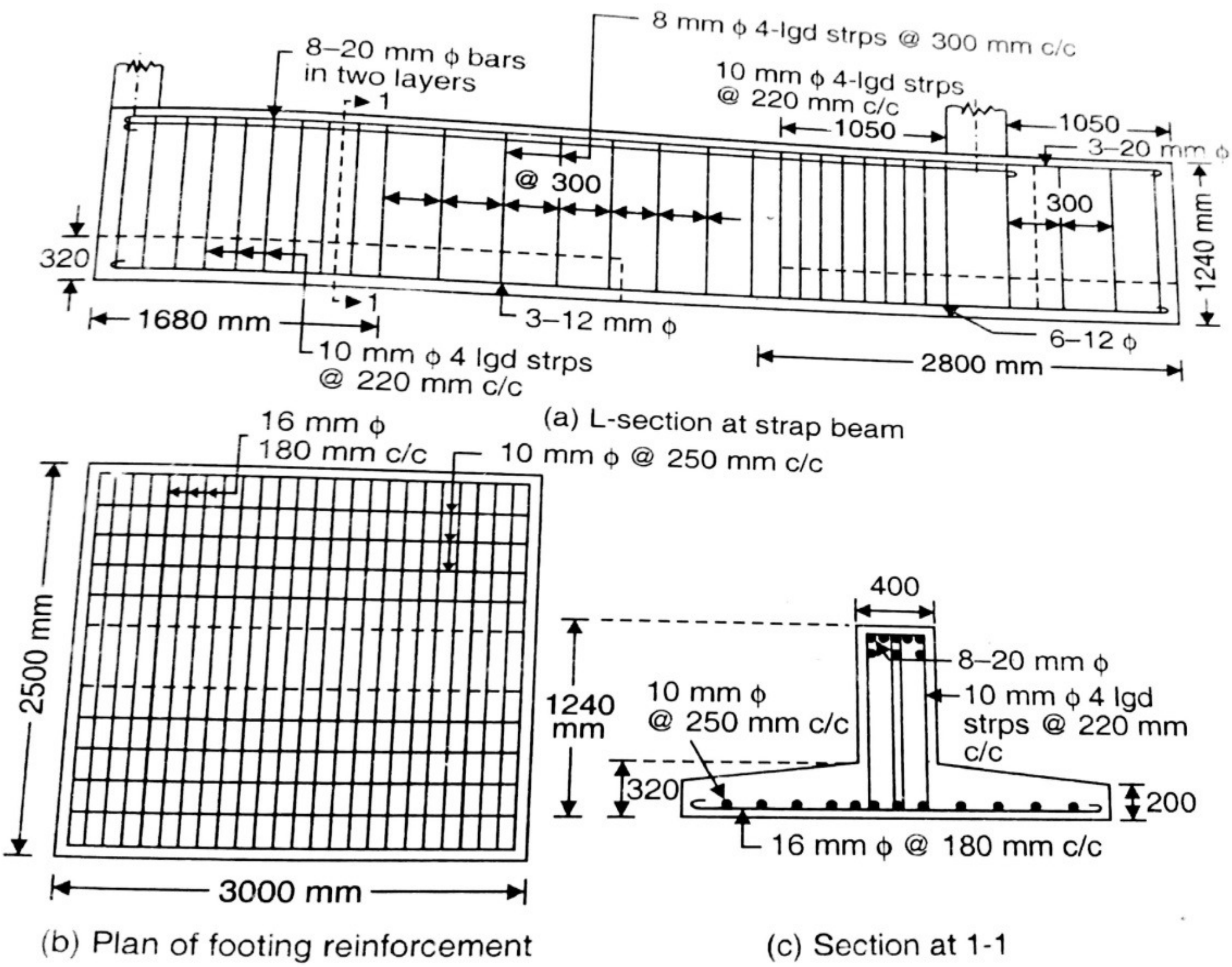

Figure-4: Reinforcement Detailing of Strap Footing[10].

Designing with spread footing

For spread footing we have decided to design two isolated footings for a column 350 $mm \times 350\ mm$, transmitting an axial load of 750 kN (each column). SBC of soil is 120 tonnes/ m^2.

Designing constants: For M20 concrete and Fe-415 steel combination-$K_c = 0.289$, $j_c = 0.904$, $R_c = 0.914$

Size of Footings: W=750 kN, Assume $W' = 10\% = 75$ KN (Weight of concrete)[6]

So area of footing A = $\frac{750+75}{120}$ = 6.875 m^2 so Providing, 2.7 m× 2.7 m size of footing.

Actual upward pressure intensity $P_0 = \frac{750}{2.7\times 2.7} = 102.88 \frac{\text{KN}}{m^2}$

Design of footing: Peak BM occurs on face of the column and it's magnitude is: M = $P_0 \frac{B}{8}(B-b)^2$ KN – m = $\frac{102.88\times 2.7}{8}(2.7-0.35)^2$ KN – m. = 191.75 KN – m.

The section of the footing at the column face will be trapezoidal, as shown in Figure. Let the effective depth at the column face be d and that at the edge be 0.2d.

Slope d = $\frac{(B-b)}{\text{d} - 0.2d} = \frac{(2.7-0.35)\times 1000}{0.8d} = \frac{2938}{d}$ (i)

The moment of resistance of section is given by

$M_r = R_b\, d^2 cos^2\alpha + d \times$ c $\times \frac{k^2\, d^3}{12}(2-k)$
[adapting $cos^2\alpha = 0.85\ for\ practical\ purpose$]

$$M_r = 0.914 \times 350 \times d^2 \times 0.85 + \frac{2938 \times 7}{d} \times \frac{0.289^2 \times d^3}{12}(2-0.289)\, d^3$$

$M_r = 271.92\ d^2 + 244.91\ d^2 = 516.23\ d^2$ (ii)

Total force of compression is

C= $\frac{1}{2}k\, b\, c\, dcos^2\alpha + d \times$ c $\times \frac{k^2\, d^2}{6} = \frac{1}{2} \times 0.289 \times 350 \times d \times 7 \times 0.85 + \frac{2938}{d} \times 7 \times \frac{0.289^2 \times d^2}{6}$
C= 300.92 d + 286.28d = 586.60 d (iii)

∴ Lever arm for the section =$\frac{516.23d^2}{586.60d} = 0.88d$, ∴ Lever arm factor j = 0.88

Alternatively taking the section to be an equivalent rectangle of width
= b+$\frac{1}{8}(B-b)$ = 350 +$\frac{1}{8}(2700-350) = 643.75\ mm.$

$M_r = R_c bd^2 = 0.914 \times 643.75 \times d^2 = 588.39\ d^2$ found in equation (ii)

Since both the values are quite close, we can take the trapezoidal section to beam equivalent rectangle of width

b+$\frac{1}{8}(B-b)$. Adapting M_r= $516.23d^2$, and equating it to the B.M. we get:$516.23d^2 = 191.75 \times 10^6$

Or d= 610 mm, effective depth at the end = 0.2 d = 130 mm.

Check for shear: i. For beam shear, ii. The section that is to be checked for beam shear is 610 mm from the column face, where force is given by

V = $P_0 B\left\{\frac{1}{2}(B-b) - d\right\} = 102.88 \times 27 \times \{\frac{1}{2}(2.7-0.35) -$ .610 = 156.94 kN.

The section of footing shown in Figure, the effective depth at that location= 130 + $\frac{610-130}{1175}(1175-610)$ = 960.81 mm.

Top width of the section = 350 + $\frac{2200-130}{1175} \times 60 = 1684.2\ mm.$

Depth of N.A. = 360.81 × 0.289 = 104.27 mm.

Width of N.A.(b′) = 1684.2 +$\frac{2700-1684.2}{230.81} \times 104.27 = 2143.1\ mm.$

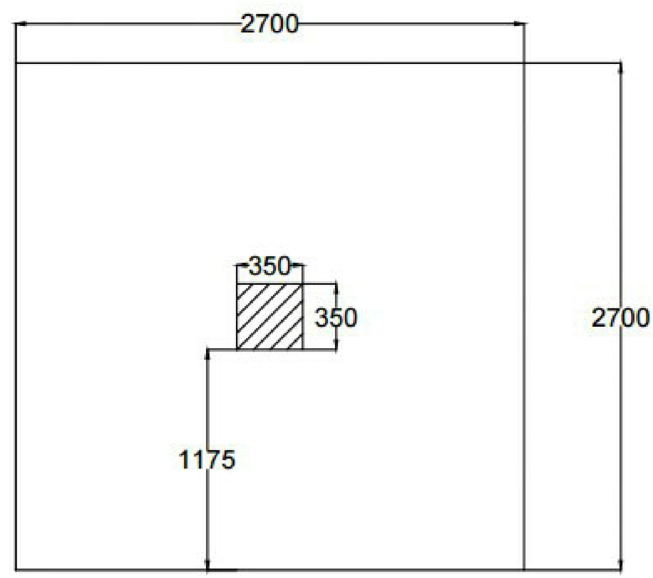

Figure-5: Plan of Spread Footing.

$\therefore \tau_v = \frac{V}{\text{b'd}} = \frac{156.94\times 1000}{2143.1\times 360.81} = 0.203 \frac{N}{mm^2}$

For M20 concrete and Fe-415 steel combination, P = 0.44% and hence $\tau_c = 0.28\ /\ mm^2$, Thus, $\tau_v < \tau_c$ which is safe.

For two way shear: Perimeter ABCD = 2[(a+d)+(b+d)] = 4[350+610] = 3840 mm.

Area of ABCD = 0.960 × 0.960 = 0.9216 m^2.

Punching shear = 102.88× $[2.7 \times 2.7 - 0.9216] = 655.18\ kN.$

$$\tau_v = \frac{655.18 \times 1000}{3840 \times 610} = 0.28 \frac{N}{mm^2}$$

Allowable shear $\tau_c$is given by

$$\tau_c = 0.16\sqrt{f_{ck}} = 0.16\sqrt{20} \approx 0.71 \frac{N}{mm^2}$$

K_5 adopt max = 1, so $K_5 = 1$;

$K_5\tau_c = 1 \times 0.71 = 0.71\ N/\ mm^2$which is safe.

Steel Reinforcement: $A_{st} = \frac{M}{\sigma_{st}\ j\ d} = \frac{191.75\times 10^6}{230\times 0.99\times 610} =$ 1553.08 mm^2**,** Using 12 mm Φ bars, $A_\Phi = 113\ mm^2$, ∴ No. of bars $= \frac{1553.08}{113} \approx$ 14 bars.

Hence, provide 14 Nos. of 12 mm Φ bars, uniformly spaced in the width 2.7 m in each direction.

Effective depth to the centre of bottom layer = 610+12 = 622 mm, Hence, provide overall depth of 650 mm and reduce it to 150 mm.

Check for development length: $L_d = 45\Phi = 45 \times 12 = 540\ mm$;

Provide 50 mm side cover length, available $= \frac{1}{2}(B - b) = \frac{1}{2}(2700 - 350) - 50 = 1125\ mm.$ (Hence O.K.), The details of the reinforcement are given in Figure-5.

Check for transfer of load at the column base: $A_2 = 350 + 350 = 122500\ mm^2$, at the rate of spread

$A_1 = \left(350 + 2(2 \times 650)\right)^2 = 8702500\ mm^2$

Hence, $\sqrt{\frac{A_1}{A_2}} = \sqrt{\frac{8702500}{122500}}$= 8.43 > 2, Adopt a maximum value of $\sqrt{\frac{A_1}{A_2}}$= 2

∴ Permissible bearing stress = 0.25 $f_{ck}\sqrt{\frac{A_1}{A_2}}$= $0.25 \times 20 \times 2 = 10\ N/\ mm^2$, Actual bearing stress = $\frac{750000}{350\times 350} = 6.12\ N/\ mm^2$ which is hence satisfactory.

Note: In case the permissible bearing stress is less than the actual bearing pressure load transfer is done by the provision of dowels bars. In the present case, the load transfer is there without exceeding the permissible bearing stress. However, it is always a good practice to extend all the column bars into the foundation and anchored.

Estimation and costing

For Strap footing: Details of measurements and calculation of quantities for strap footing is given in Table-1a and abstract of cost of RCC foundation is given in Table-1b.

For Spread footing: Details of measurements and calculation of quantities for spread footing is given in Table-2a and abstract of cost of RCC foundation is given in Table-2b.

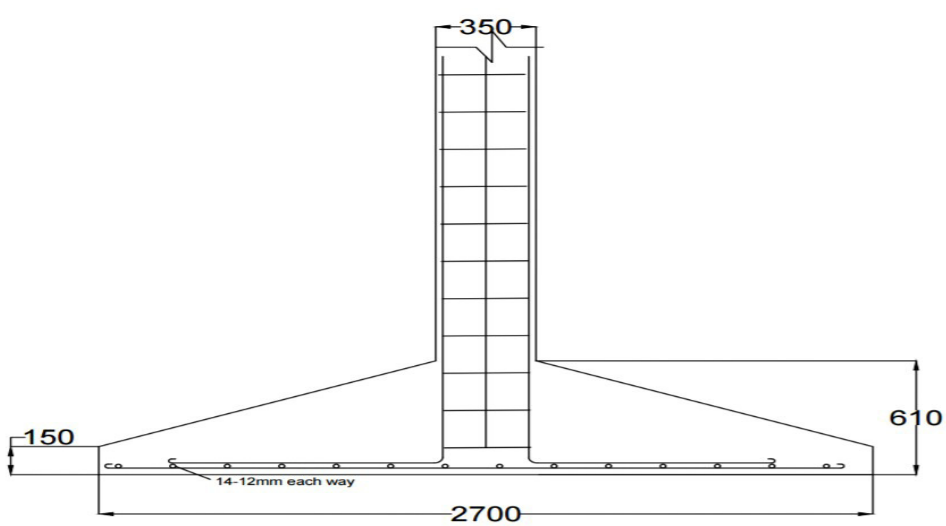

Figure-6: Cross-sectional view of Spread Footing.

Table-1(a): Details of measurements and calculation of quantities for strap footing.

S.No.	Particulars of items of work	No.	Length(m)	Breadth	Height/Depth	Quantity (cum)	Remarks
1.	Earthwork in excavation in foundation.						
	(i) For foundation of size 3m × 2.5m	1	3	2.5	(1.24+0.1)	10.05	
	(ii) For foundation size 2.5m × 2.5 m	1	2.5	2.5	(1.24+0.1)	8.375	
	(iii) Excavation for strap beam	1	1.025	0.4	1.24	0.51	
2.	1:3:6 cement concrete for base						
	(i) For foundation of size 3m × 2.5m	1	3	2.5	0.1	0.75	
	(ii) For foundation size 2.5m × 2.5 m	1	2.5	2.5	0.1	0.625	
					Total	1.375	
3.	1:1.5:3 RCC work in footing						
	(i) Bottom square portion						
	(a) For foundation of size 3m × 2.5m	1	3	2.5	0.2	1.5	
	(b) For foundation size 2.5m × 2.5 m	1	2.5	2.5	0.2	1.25	
	(ii)Trapezoidal portion						
	(a) For foundation of size 3m × 2.5m	1	$\frac{(2.75)^2+(0.4)^2}{2}$		0.12	0.46	
	(b) For foundation size 2.5m × 2.5 m	1	$\frac{(2.5)^2+(0.4)^2}{2}$		0.12	0.38	
	(iii) Strap Beam						
	(a) Upper side of sloped portion	1	6.4	0.4	(1.24-0.32)	2.35	
	(b) Middle portion in level of sloped footing	1	(6.4-5.5)	0.4	0.32	0.11	
					Total	6.05	
4.	Steel Reinforcement (i)Footing reinforcement (a) 3m × 2.5m size footing (b) 2.5m × 2.5 m size of footing	17	2.5	42.5	@1.58 kg/m	67.15 kg	
		10	3	30	@0.617 kg/m	18.51 kg	
		17	2.5	42.5	@1.58 kg/m	67.15 kg	
		10	2.5	25	@0.617 kg/m	15.42 kg	
	(ii) Strap beam						
	(a) At top face	8	5	40	@2.47 kg/m	98.8 kg	
	(b) Corner Stirrups	19	5	95	@0.617 kg/m	58.61 kg	
	Middle Stirrups	7	5	35	@0.395 kg/m	13.82 kg	
					Total	339.46 kg	

Table-1(b): Abstract of cost of RCC foundation[11].

S. No.	Particulars of Item of work	Quantity	Unit	Rate	Cost(Rupees)
1.	Earthwork in excavation in foundation	18.935	cum	185	3502.97
2.	1:3:6 cement concrete for base	1.375	cum	2970	4083.75
3.	1:1.5:3 RCC work in footing	6.05	cum	4231	25,597.55
4.	Steel Reinforcement	339.46	kg	61.5	20,876.79
5.	Total				87,245.33
6.	Add 1.5% for water change				1308.68
7.	Add 10% for contractors profit				88554 8855.4
8.	Grand Total				97,410

Table-2(a): The details of measurements and calculation of quantities of spread footing.

S.No.	Particulars of items of work	No.	Length(m)	Breadth	Height/Depth	Quantity (cum)	Remarks
1.	Earthwork in excavation in foundation.	2	2.7	2.7	(0.61+0.1)	10.35	
2.	1:3:6 cement concrete for base	2	2.7	2.7	0.1	1.458	
3.	1:1.5:3 RCC work in footing (i) Bottom square portion	2	2.7	2.7	1.05	2.187	
	(ii) Trapezoidal portion	2	$\frac{(2.7)^2+(0.35)^2}{2}$		0.46	3.41 5.6	
4.	Steel reinforcement	56	2.7	151.2	0.89 kg	269.13 kg	

Table-2(b): Abstract of cost of RCC foundation[11].

S. No.	Particulars of Item of work	Quantity	Unit	Rate	Cost(Rupees)
1.	Earthwork in excavation in foundation	10.35	cum	185	1914.75
2.	1:3:6 cement concrete for base	1.458	cum	2970	4330.26
3.	1:1.5:3 RCC work in footing	5.6	cum	4231	23,693.6
4.	Steel Reinforcement	269.13	kg	61.5	16,551.86
5.	Total				46,490.47
6.	Add 1.5% for water change				704.11
7.	Add 10% for contractors profit				47194.58 4717.46
8.	Grand Total				51,912

Results and discussion

The results obtained from the above designing procedures can be portrayed under the following pointers: i. During the estimation and costing procedure we have observed that the cost estimation of spread footing in comparison to strap footing is comparatively less. The estimation cost for spread footing is observed to be Rs. 51,912 and for strap footing it is observed to be Rs. 97,410 which is just double as compared to spread footing. These results were obtained for same load of 1500 kN. As a reason of which spread footing is considered to be more befitting than strap footing in an economical point of view. ii. Strap footing being costly, it is used when the external column (wall column) is very near to the property line and wherever there is a problem in failure of foundation by differential settlement. iii. Designing of spread footing is easier as compared to strap footing as a result of which spread footing is preferably used in Chhattisgarh, which belongs to the Seismic Zone-2 i.e. the least active region.

Conclusion

After comprehensive designing of the footings, out of both spread-isolated and strap-combined footing, the observations that were derived resulted to the verity that spread footing can be considered as more feasible in economical and behavioural facets. The Chhattisgarh region, in India, is under the least earthquake active region, as a result of which in most cases spread footing is given higher priority over strap footing. And also, the designing procedure for spread footing being facile in nature is adopted by most amateurs while building any structures whether residential or commercial.

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