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International
Journal
Of Modern Engineering Research (IJMER)

Comparisons of Shallow Foundations in Different Soil Condition

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ABSTRACT: *Soil is considered by the engineer as a complex material produced by weathering of the solid rock. Footings are structural elements that transmit column or wall loads to the underlying soil below the structure. Footings are designed to transmit these loads to the soil without exceeding its safe bearing capacity. Each building demands the need to solve a problem of foundation on different types of soil. The main aim of this project is to design the appropriate foundation as per size and shape on cohesive, non-cohesive and rocky soil. In this paper different foundation are studied for a middle side and corner column of a building with different bearing capacities. Based on the study and judicial judgment the type of foundation is decided as per depth, quantity of steel and quantity of concrete and try to find which shape of the foundation is more stable, economical and ways to reduce the ease of construction of the building.*

Keywords: *Isolated footing, Bearing capacity, depth, quantity of concrete and quantity of steel.*

I. INTRODUCTION

Foundation design involves a soil study to establish the most appropriate type of foundation and a structural design to determine footing dimensions and required an amount of reinforcement. Because the compressive strength of the soil is generally much weaker than that of the concrete, the contact area between the soil and footing is much larger than that of the columns and walls. The soil is a universally available natural material derived from rocks and rocky minerals. The bearing capacity of soil is the most important property which governs the design of foundation. Soils are classified into three types: cohesive or fine grained soil, non-cohesive or coarse grained soil and rocks.

Footings or foundation are structural elements, which transfer the load to the soil from column, walls or lateral loads from earth retaining structures. The foundations are classified into two types, superficial foundation or shallow foundation and deep foundation. A superficial foundation is a structural member whose cross section is of large dimensions with respect to height and whose function is to transfer loads of a building at depths relatively short, less than 4 m approximately with respect to the level of the surface of natural ground. Shallow foundation includes: Wall Footing or Strip Footing, Isolated spread Footing, Combined Footing, Cantilever or Strap Footing, Mat or raft Footing. If the soil conditions are weak then deep foundation are more suitable. The deep foundation includes: Pile foundation, under reamed pile foundation and well foundation. The design of foundation includes three major aspects i.e., stability, economy, and ease of construction. Stability analysis aims at removing the possibility of failure of foundation by tilting, overturning, uprooting and sliding due to load intensity imposed on soil by foundation being in excess of the ultimate capacity of the soil. The most important aspect of the foundation design is the necessary check for the stability of foundation under various loads imposed on it by the column, which it supports. The economy of the structure depends upon the material cost and labor cost. Material cost mainly depends upon the quantity of steel and concrete whereas labor cost is mainly depends on the shuttering cost and ease of construction. For the appropriate design of foundation these three aspects should be satisfied. This paper explains the design of a shallow footing for different types like square, rectangular, circular, trapezoid (sloped) and stepped footing for G+10 building with different types of soil have different bearing capacities for middle side and corner column of the building. Results shows comparison of depth of foundation, the quantity of steel required and quantity of concrete required with limit state method.

For the foundation design, load analysis of G+10 multi-story residential building done on STADD pro. The building is subjected to self-weight, dead load, live load as per IS 875(Part 1, Part 2):1987. Wind loads are also considered on building as per Indian standard codes of practice IS 875(Part 3):1987. The wind loads on the building are calculated assuming the building to be located at Ahmedabad. The member forces are calculated with load combinations for Limit State Method given in IS 456: 2000 and the foundations are designed for the most critical middle column.

II. MODELING OF LOADS

The basic loads considered in this study are dead load, live loads and wind loads. The values of Dead loads (DL) are calculated from the unit weights as specified in IS 875 (Part 1): 1987. The live load (LL) intensities for the various areas of residential buildings are obtained from IS 875 (Part 2): 1987. The summary of dead load and live loads considered for the building is given in Table1

Table 1 Dead Load and Live Load

Load Description	Value
Dead Load • DL of Slab (Thickness of slab 0.125m) • Floor Finish	3.125 kN/m^2 1 kN/m^2
Wall load • 100 mm thick interior wall • 150 mm thick exterior wall • 150 mm thick parapet wall	2.8 kN/m 4.2 kN /m 2.1 kN/m
Dead Load of Staircase • Load of inclined slab + load of riser, trade and landing slab	6.715 kN/m^2
Live Load • Live Load on slab • Live Load on stair	2 kN/m^2 3 kN/m^2

2.1 The Lateral Wind Force (F_z) as per IS875 (Part 3):1987

According to the provisions of Bureau of Indian Standards for wind loads, IS 875 (Part 3):1987 design wind speed, V_z at any height z is found by equation,

$V_z = V_b k_1 k_2 k_3$

where, V_b is basic wind speed in m/s, k_1 is probability factor (risk coefficient) as per Clause 5.3.1, k_2 is terrain, height and structure size factor as per Clause 5.3.2 and k_3 is topography factor as per Clause 5.3.3. The lateral force along wind load on a structure on a strip area (Ae) at any height, z is found by equation

$F_z= C_f A_e P_z$

Where, C_f is force coefficient for building, calculated from clause no 6.3.3.2(fig.4A). As per clause for flat-sided member, the force coefficients are calculated for two mutually perpendicular directions relative to a reference axis on the structural member. They are designated as C_{fn} and C_{ft}, give the forces normal and transverse, respectively to the reference plane Normal force, $F_n = C_{fn} P_z A_e$ Transverse force, $F_t = C_{ft} P_z A_e$, A_e is effective frontal area considered for the structure at height z, P_z is design pressure at height, z found by equation

$P_z = 0.6 V_z^2$(N/m2)

The data considered for the wind load calculations are wind speed, Vb=39m/s, force coefficient, C_f =1.3, K_1=1.0, K_2 is varying with height as per Terrain Category III class A, K_3=1, Life of the structure is 50 years, the lateral force Fz is considered in kN/m and these wind intensities at various heights are given as input to the STAAD.Pro software as given in Table 2 and Table 3

Table 2 Wind Force At Various Heights In Normal Z Direction

Height (m)	V_b(m/s)	k1	k2	k3	V_z(m/sec)	P_z (kN/m^2)	C_f	A_e (m^2)	Force on end column (kN/m)	Force on middle Column (kN/m)
3.05	39	1	0.91	1	35.49	0.76	1.3	52.46	3.38	6.76
6.1	39	1	0.91	1	35.49	0.76	1.3	52.46	3.38	6.76
9.15	39	1	0.91	1	35.49	0.76	1.3	52.46	3.38	6.76
12.2	39	1	0.94	1	36.66	0.81	1.3	52.46	3.61	7.21
15.25	39	1	0.97	1	37.83	0.86	1.3	52.46	3.84	7.68

18.3	39	1	1	1	39	0.91	1.3	52.46	4.08	8.16
21.35	39	1	1.02	1	39.78	0.95	1.3	52.46	4.25	8.49
24.4	39	1	1.03	1	40.17	0.97	1.3	52.46	4.33	8.66
27.45	39	1	1.05	1	40.95	1.01	1.3	52.46	4.50	9.00
30.5	39	1	1.06	1	41.34	1.03	1.3	52.46	4.59	9.17
33.55	39	1	1.07	1	41.73	1.04	1.3	52.46	4.67	9.35

TABLE 3 Wind force at various heights in transverse X direction

Height (m)	V_b(m/s)	k1	k2	k3	V_z (m/sec)	P_z (kN/m^2)	C_f	A_e (m^2)	Force on end column (kN/m)	Force on middle Column (kN/m)
3.05	39	1	0.91	1	35.49	0.76	1.3	33.86	2.73	5.45
6.1	39	1	0.91	1	35.49	0.76	1.3	33.86	2.73	5.45
9.15	39	1	0.91	1	35.49	0.76	1.3	33.86	2.73	5.45
12.2	39	1	0.94	1	36.66	0.81	1.3	33.86	2.91	5.82
15.25	39	1	0.97	1	37.83	0.86	1.3	33.86	3.10	6.20
18.3	39	1	1	1	39	0.91	1.3	33.86	3.29	6.59
21.35	39	1	1.02	1	39.78	0.95	1.3	33.86	3.43	6.85
24.4	39	1	1.03	1	40.17	0.97	1.3	33.86	3.49	6.99
27.45	39	1	1.05	1	40.95	1.01	1.3	33.86	3.63	7.26
30.5	39	1	1.06	1	41.34	1.03	1.3	33.86	3.70	7.40
33.55	39	1	1.07	1	41.73	1.04	1.3	33.86	3.77	7.54

2.2 Load Combinations

The variation in loads due to unforeseen increases in loads, constructional inaccuracies, type of limit state etc. are taken into account to define the design load. The design load is given by: design load = Υ_fx characteristic load (Clause 36.4 of IS 456: 2000). Where, Υ_f given Partial safety for loads for loads given in Table18 of IS 456: 2000 is given in Table 4.

TABLE 4 Partial safety factor (Υ_f)for loads (According to IS 456: 2000)

Load combination	Limit state of collapse			Limit state of serviceability		
	DL	IL	WL	DL	IL	WL
DL + IL	1.5	1.5	-	1.0	1.0	-
DL+ WL	1.5 or 0.9*	-	1.5	1.0	-	1.0
DL+ IL + WL	1.2	1.2	1.2	1.0	0.8	0.8

Notes: (*) This value is to be considered when stability against overturning or stress reversal is critical.
1. DL = Dead load; IL = Imposed load or Live load; WL = Wind load
2. While considering earthquake effects, substitute EL for WL
3. For the limit states of serviceability, the values of given in this table are applicable for short tern effects. While assessing the long term effects due to creep the dead load and that part of the live load likely to be permanent may only be considered.

III. DESIGN OF FOUNDATION

Table 5 Building Model

Beam size	200 mm x 250 mm
Rectangular column size	200 mm x 450 mm
Rectangular column size	300 mm x 450 mm
Square column size	400 mm x 400 mm
Circular Column size	450 mm
Height of story	3.05 m

Figure from AutoCAD 2013

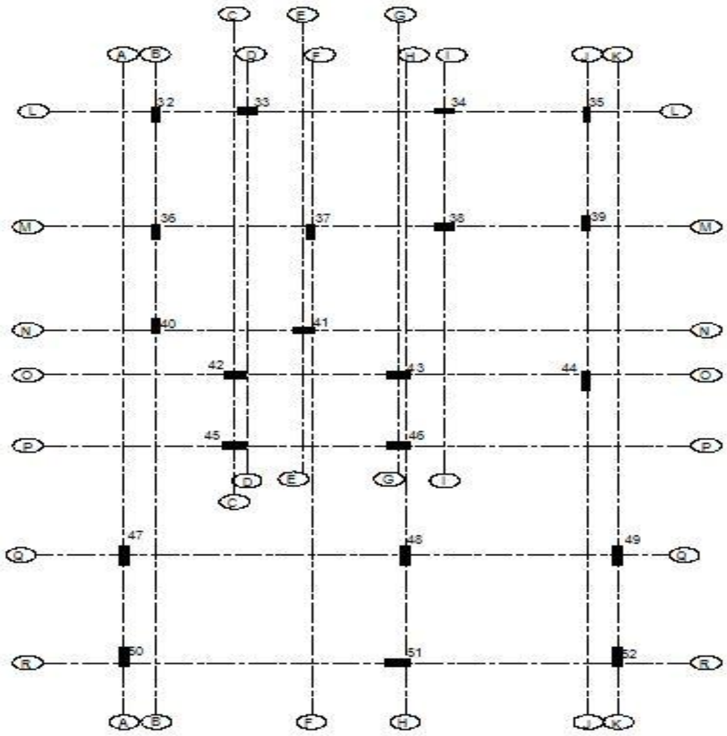

Fig. 1 Centre line plan for the columns of a building

For designing purpose of different shapes of footing under this load square and circular column are assumed in place of rectangular column in STADD model. From STADD results middle column no 48, side column no. 47 and corner column no. 50 has maximum critical load of 2681 kN, 1639 kN and 1518kN. For comparisons of result same load is required, for calculation purpose ± 1 ton of load due to shape of column is done on all shapes of columns load. Average loads for calculation is 2691 kN for middle column, 1650 kN for side column and 1530 kN for corner column. Now design of square, rectangular and circular footing done on these columns for 100kN/m2, 180kN/m2 and 250kN/m2 bearing capacities and also study the effect of geometry on all shapes by designing of stepped and sloped (trapezoid) footing for square, rectangular and circular column. Results of design are shown below

3.1 Middle Column Foundation Design

Square Footing: Result of plain, trapezoid and stepped footing design shown in Table 6, Table 7and Table 8.

TABLE 6 Square plain footing design

Bearing Capacities of soil in kN/ m^2	100 kN/m^2	180 kN/m^2	250 kN/m^2
Size of Footing in m	5.6 x 5.6	4.2 x 4.2	3.6 x 3.6
Depth in m	0.62	0. 62	0.70
Bending Moment in kNm	1608.88	1159.89	958.46
Permissible shear stress in N/mm^2	1.17	1.17	0.89
Area of steel in m^2	8265.80	6003.99	4217.94
No. of bars of tor steel	16mm dia bars 41 no.	16mm dia bars 30 no.	16mm dia bars 21 no.
Spacing in mm c/c	136	141	172
Provided Area of Steel in m^2	8266	6004	4218
Length of bar in m	5.5	4.1	3.5
Total length of bar in m	452	245	147
Weight of bar per m	1.581	1.581	1.581
Quantity of steel in tonn	0.72	0.39	0.23
Quantity of concrete in m^3	19.44	10.85	9.12

TABLE 7 Square trapezoid footing design

Bearing Capacities in kN/ m^2	100 kN/m2	180 kN/m2	250 kN/m^2
Size of Footing in m	5.6 x 5.6	4.2 x 4.2	3.6 x 3.6
Depth in m	0.87	0.92	0.93
Thickness in m	0.20	0.20	0.20
Bending Moment in kNm	1110.89	804.79	673.18
Permissible Shear Stress in N/mm^2	1.2	1.1	1.1
Area of Steel in m^2	5121.91	3414.54	2810.22
No. of bars of tor steel	12mm dia bars 46 no.	12mm dia bars 31 no.	12mm dia bars 25 no.
Spacing in mm c/c	124	139	145
Provided Area of Steel in m^2	5122	3415	2810
Length of bar in m	5.5	4.1	3.5
Total length of bar in m	499	248	174
Weight of bar per m	0.89	0.89	0.89
Quantity of steel in tonn	0.44	0.22	0.15
Quantity of concrete in m^3	16.85	9.95	7.40

TABLE 8 Square stepped footing design

Bearing Capacities in kN/ m^2	100 kN/m^2	180 kN/m^2	250 kN/m^2
Size of Footing in m	5.6 x 5.6	4.2 x 4.2	3.6 x 3.6
Depth D1 in m	1.22	1.17	1.1
Depth inD2 in m	0.6	0.55	0.46
Depth in D3 in m	0.2	0.23	0.21
Bending Moment in kNm	1608.88	1159.89	958.46
Permissible Shear Stress in N/mm^2	0.33	0.34	0.37
Area of Steel in m^2	3940.44	2968.11	2623.3
No. of bars of tor steel	12mm dia bars 35 no.	12mm dia bars 27 no.	12mm dia bars 24 no.
Spacing in mm c/c	160	156	150
Provided Area of Steel in m^2	3955	3051	2712
Length of bar in m	5.5	4.1	3.5
Total length of bar in m	385	221.40	168
Weight of bar per m	0.89	0.89	0.89
Quantity of steel in tonn	0.3427	0.1970	0.1495
Quantity of concrete in m^3	14.94	8.53	5.56

Circular Footing: Result of plain, trapezoid and stepped footing design shown in Table 9, Table 10and Table 11.

TABLE 9 Circular plain footing design

Bearing Capacities in kN/ m^2	100 kN/m^2	180 kN/m^2	250 kN/m^2
Radius in m	3.2	2.4	2
Depth in m	1.14	0.97	0.91
Bending Moment in kNm	1143.99	824.25	661.96
Permissible Shear Stress in N/mm^2	0.48	0.63	0.68
Area of Steel in m^2	3638.46	3093.83	2591.79
No. of bars of tor steel	12mm dia bars 32 no.	12mm dia bars27 no.	12mm dia bars 23no.
Spacing in mm c/c	141	124	123
Bars all around	4	4	4
Provided Area of Steel in m^2	4090	3546	3044
Length of bar in m	4.53	3.39	2.83
Total length of bar in m	328	213	152
Weight of bar per m	0.89	0.89	0.89
Quantity of steel in tonn	0.2916	0.1896	0.1356
Quantity of concrete in m^3	36.49	17.54	11.43

TABLE 10 Circular trapezoid footing design

Bearing Capacities in kN/ m^2	100 kN/m^2	180 kN/m^2	250 kN/m^2
Radius in m	3.2	2.4	2
Depth in m	1.41	1.22	1.10
Bending Moment in kNm	1192.06	871.62	708.58
Permissible Shear Stress in N/mm^2	0.38	0.50	0.60

Area of Steel in m^2	3019.64	2556.64	2322.79
No. of bars of tor steel	12mm dia bars 27 no.	12mm dia bars 23 no.	12mm dia bars 21no.
Spacing in mm c/c	169	150	138
Bars all around	4	4	4
Provided Area of Steel in m^2	3472	2557	2323
Length of bar in m	4.53	3.39	2.83
Total length of bar in m	278	181	139
Weight of bar per m	0.89	0.89	0.89
Quantity of steel in tonn	0.2475	0.1609	0.1236
Quantity of concrete in m^3	45.34	22.07	13.82

TABLE 11 Circular stepped footing design

Bearing Capacities in kN/ m^2	**100 kN/m^2**	**180 kN/m^2**	**250 kN/m^2**
Radius in m	3.2	2.4	2
Depth D1 in m	1.14	0.97	0.88
Depth D2 in m	0.55	0.50	0.50
Depth D3 in m	0.40	0.44	0.45
Bending Moment in kNm	1140.04	819.10	655.93
Permissible in N/mm^2	0.48	0.63	0.73
Area of Steel in m^2	3594.63	3068.25	2709.46
No. of bars of tor steel	12mm dia bars 32 no.	12mm dia bars 27no.	12mm dia bars 24 no.
Spacing in mm c/c	126	109	101
Bars all around	4	4	4
Provided Area of Steel in m^2	4047	3520	3161
Length of bar	4.53	3.39	2.83
Total length of bar	324	211	158
Weight of bar per m	0.89	0.89	0.89
Quantity of steel in tonn	0.2885	0.1882	0.1409
Quantity of concrete in m^3	17.88	9.31	6.75

Rectangular Footing: Result of plain, trapezoid and stepped footing design shown in Table 12, Table 13, Table 14

Table 12 Rectangular plain footing design

Bearing Capacities in kN/ m^2	100 kN/m^2	180 kN/m^2	250 kN/m^2
Size of Footing in m	4.6 x 6.8	3.4 x 5.1	2.9 x 4.4
Depth in m	0.82	0.82	0.90
Bending Moment in kNm	1993.95	1424.38	1187.74
Permissible Shear Stress in N/mm^2	1.09	1.05	0.82
Area of Steel in m^2(Y-Y)	7176.14	5126.29	3872.28
Area of Steel in m^2(X-X)	4961.79	3481.43	2582.42
Balance steel	957.54	667.43	371.42
No. of bars of tor steel (Y-Y)	16mm dia bars 36 no.	16mm dia bars 26 no.	16mm dia bars 19 no.
No. of bars of tor steel (X-X)	12mm dia bars 36 no.	12mm dia bars 25 no.	12mm dia bars 20 no.
No. of bars in balance steel at corner	10	6	6
Spacing in m c/c (Y-Y)	129	131	151
Spacing in m c/c (X-X)	128	136	145
Provided Area of Steel in m^2(X-X)	7176	5226	3872
Provided Area of Steel in m^2(Y-Y)	4068	2825	2260
Length of bar (L) in m	161	86	54
Length of bar (B) in m	241	125	88
Length of bar of balance steel in m	45	20	17
Weight of bar per m	1.5815	1.5815	1.5815
Weight of bar per m	0.89	0.89	0.89
Quantity of steel in tonn (Y-Y)	0.3253	0.1670	0.1119
Quantity of steel in tonn (X-X)	0.2147	0.1113	0.0783
Total quantity of steel in tonn	0.5399	0.2783	0.1902
Quantity of concrete in m^3	25.65	14.22	11.48

Table 13 Rectangular trapezoid footing design

Bearing Capacities in kN/ m^2	100 kN/m^2	180 kN/m^2	250 kN/m^2
Size of Footing in m	4.6 x 6.8	3.4 x 5.1	2.9 x 4.4
Depth in m	1.02	0.09	1.11
Thickness in m	0.20	0.20	0.20
Bending Moment in kNm	1372.65	991.48	832.78
Permissible Shear Stress in N/mm^2	0.84	0.75	0.72
Area of Steel in m^2(Y-Y)	3418.58	2216.22	1789.63
Area of Steel in m^2(X-X)	5040.58	3324.34	2724.08
Balance steel	593.58	408.22	320.63
No. of bars of tor steel (Y-Y)	16mm dia bars 25 no.	16mm dia bars 16 no.	16mm dia bars 13 no.
No. of bars of tor steel (X-X)	12mm dia bars 45 no.	12mm dia bars 29 no.	12mm dia bars 24 no.
No. of bars in balance steel at corner	6	6	6
Spacing in m c/c (Y-Y)	184	213	223
Spacing in m c/c (X-X)	103	116	120
Provided Area of Steel in m^2(Y-Y)	5025	3216	2613
Provided Area of Steel in m^2(X-X)	5041	3324	2724
Length of bar (L) in m	113	53	36
Length of bar (B) in m	299	147	106
Length of bar of balance steel in m	27	20	17
Weight of bar per m	1.5815	1.5815	1.5815
Weight of bar per m	0.89	0.89	0.89
Quantity of steel in tonn (Y-Y)	0.2206	0.1148	0.0841
Quantity of steel in tonn (X-X)	0.2660	0.1309	0.0944
Total quantity of steel in tonn	0.4866	0.2457	0.1785
Quantity of concrete in m^3	15.41	8.98	6.81

Table 14 Stepped rectangular footing design

Bearing Capacities in kN/ m^2	100 kN/m^2	180 kN/m^2	250 kN/m^2
Size of Footing	4.6 x 6.8	3.4 x 5.1	2.9 x 4.4
Depth D1 in m	1.51	1.44	1.35
Depth D2 in m	0.68	0.72	0.68
Depth D3 in m	0.19	0.25	0.27
Bending Moment in kNm	1993.95	1424.38	1187.74
Permissible Shear Stress in N/mm^2	0.22	0.22	0.24
Area of Steel in m^2 (Y-Y)	3912.49	2938.80	2626.73
Area of Steel in m^2 (X-X)	2603.14	1921.35	1690.37
Balance steel	502.14	339.35	334.37
No. of bars of tor steel (Y-Y)	12mm dia bars 35 no.	12mm dia bars 26 no.	12mm dia bars 23 no.
No. of bars of tor steel (X-X)	12mm dia bars 19 no.	12mm dia bars 14 no.	12mm dia bars 12 no.
No. of bars in balance steel at corner	6	6	6
Spacing in m c/c (Y-Y)	133	131	125
Spacing in m c/c (X-X)	242	243	242
Provided Area of Steel in m^2(Y-Y)	3912	2939	2627
Provided Area of Steel in m^2(X-X)	2147	1582	1356
Length of bar in m (L)	156	86	65
Length of bar in m (B)	127	70	53
Length of bar of balance steel in m	27	20	17
Weight of bar per m	0.89	0.89	0.89
Quantity of steel in tonn (Y-Y)	0.1387	0.0764	0.0579
Quantity of steel in tonn (X-X)	0.1373	0.0799	0.0619
Total quantity of steel in tonn	0.2760	0.1563	0.1199
Quantity of concrete in m^3	16.59	9.96	7.32

3.2 Side Column Foundation Design

Square Footing: Result of plain, trapezoid and stepped footing design shown in Table 15, Table 16 and Table 17.

Table 15 Square plain footing design

Bearing Capacities of soil in kN/ m^2	100 kN/m^2	180 kN/m^2	250 kN/m^2
Size of footing in m	4.4 x 4.4	3.3 x 3.3	2.8 x 2.8
Depth in m	.65	.92	1.05
Bending Moment in kNm	3000.10	2109.23	1693.44
Permissible shear stress in N/mm^2	1.10	.58	.43
Area of steel in m^2	15823.95	7080.56	4868.30
No. of bars of tor steel	20mm dia bars 50 no.	16mm dia bars 35 no.	16mm dia bars 24 no.
Spacing in m c/c	87	94	116

Provided Area of Steel in m^2	15823.95	7080.56	4868.30
Length of bar in m	4.3	3.2	2.7
Total length of bar in m	433	225	131
Weight of bar per m	2.46	1.5815	1.5815
Quantity of steel in tonn	1.0662	0.3566	0.2068
Quantity of concrete in m^3	12.58	10.02	8.23

Table 16 Square trapezoid footing design

Bearing Capacities in kN/ m^2	100 kN/m^2	180 kN/m^2	250 kN/m^2
Size of footing in m	4.4 x 4.4	3.3 x 3.3	2.8 x 2.8
Depth in m	0.95	1.09	1.09
Thickness in m	0.2	0.2	0.2
Bending Moment in kNm	522.74	372.84	302.4
Permissible Shear Stress in N/mm^2	0.44	0.35	0.34
Area of Steel in m^2	6671.29	4074.13	3300.61
No. of bars of tor steel	16mm dia bars 33 no.	16mm dia bars 20 no.	16mm dia bars16 no.
Spacing in m c/c	133	163	171
Provided Area of Steel in m^2	6671	4074	3300
Length of bar in m	4.3	3.2	2.7
Total length of bar in m	285	130	89
Weight of bar per m	1.5815	1.5815	1.5815
Quantity of steel in tonn	0.4514	0.2052	0.1402
Quantity of concrete in m^3	6.73	4.49	3.3

Table 17 Square stepped footing design

Bearing Capacities in kN/ m^2	100 kN/m^2	180 kN/m^2	250 kN/m^2
Size of footing in m	4.4 x 4.4	3.3 x 3.3	2.8 x 2.8
Depth D1 in m	1.84	1.72	1.60
Depth D2 in m	0.9	0.91	0.89
Depth D3 in m	0.6	0.55	0.53
Bending Moment in kNm	3000.10	2109.23	1693.44
Permissible Shear Stress in N/mm^2	0.16	0.17	0.17
Area of Steel in m^2	4702.69	3547.29	3072.67
No. of bars of tor steel	16mm dia bars 23 no.	16mm dia bars 18 no.	16mm dia bars 15 no.
Spacing in m c/c	188	187	183
Provided Area of Steel in m^2	4703	3547	3073
Length of bar in m	4.3	3.2	2.7
Total length of bar in m	201	113	83
Weight of bar per m	1.5815	1.5815	1.5815
Quantity of steel in tonn	0.3182	0.1786	0.1306
Quantity of concrete in m^3	17.03	9.42	6.61

Rectangular Footing: Result of plain, trapezoid and stepped footing design shown in Table 18, Table 19 and Table 20.

Table 18 Rectangular plain footing design

Bearing Capacities in kN/ m^2	100 kN/m^2	180 kN/m^2	250 kN/m^2
Size of footing in m	5.4 x 3.6	4 x 2.7	3.4 x 2.3
Depth in m	0.89	1.10	1.08
Bending Moment in kNm	2499.26	1762.56	1434.80
Permissible Shear Stress in N/mm^2	0.69	0.44	0.44
Area of Steel in m^2(Y-Y)	8772.93	4821.79	4000.31
Area of Steel in m^2(X-X)	3136.82	1732.27	1432.45
Balance steel	627.37	263.27	189.45
No. of bars of tor steel (Y-Y)	16mm dia bars 44 no.	16mm dia bars 24 no.	16mm dia bars 20 no.
No .of bars of tor steel (X-X)	12mm dia bars 23 no.	12mm dia bars 13 no.	12mm dia bars 11 no.
No. of bars in balance steel at corner	6	6	6
Spacing in m c/c (Y-Y)	82	113	116
Spacing in m c/c (X-X)	157	208	209
Provided Area of Steel in m^2(Y-Y)	8773	4822	4000
Provided Area of Steel in m^2(X-X)	3277	2147	1921
Length of bar (L) in m	3.5	2.6	2.2
Length of bar (B) in m	5.3	3.9	3.3
Total length of bar in m (Y-Y)	153	62	44
Total length of bar in m (X-X)	154	74	56
Weight of bar per m	1.5815	1.5815	1.5815
Weight of bar per m	0.89	0.89	0.89
Quantity of steel in tonn (Y-Y)	0.1368	0.0659	0.0499

Quantity of steel in tonn(X-X)	0.2416	0.0986	0.0692
Total quantity of steel in tonn	0.3784	0.1646	0.1192
Quantity of concrete in m^3	17.30	11.88	8.44

Table 19 Rectangular trapezoid footing design

Bearing Capacities in kN/ m^2	100 kN/m^2	180 kN/m^2	250 kN/m^2
Size of footing in m	5.4 x 3.6	4 x 2.7	3.4 x 2.3
Depth in m	1.3	1.34	1.38
Thickness in m	0.2	0.2	0.2
Bending Moment in kNm	1735.59	1241.14	1234.00
Permissible Shear Stress in N/mm^2	0.49	0.45	0.46
Area of Steel in m^2 (Y-Y)	1734.18	1173.94	1001.77
Area of Steel in m^2 (X-X)	4659.92	3204.18	3077.26
Balance steel	321.18	231.94	138
No. of bars of tor steel (Y-Y)	10mm dia bars 18 no.	10mm dia bars 12 no.	10mm dia bars 11 no.
No. of bars of tor steel (X-X)	16mm dia bars 23 no.	16mm dia bars 16 no.	16mm dia bars 15 no.
No. of bars in balance steel at corner	6	6	6
Spacing in m c/c (Y-Y)	200	225	209
Spacing in m c/c (X-X)	155	169	150
Provided Area of Steel in m^2 (Y-Y)	1884	1413	1335
Provided Area of Steel in m^2 (X-X)	4659	3204	3077
Length of bar in m (L)	3.5	2.6	2.2
Length of bar in m (B)	5.3	3.9	3.3
Total length of bar (Y-Y)	84	47	37
Total length of bar (X-X)	123	62	51
Weight of bar per m	0.618	0.618	0.618
Weight of bar per m	1.5815	1.5815	1.5815
Quantity of steel in ton (Y-Y)	0.0519	0.0289	0.0231
Quantity of steel in ton (X-X)	0.1943	0.0983	0.0799
Total quantity of steel in tonn	0.2462	0.1272	0.1030
Quantity of concrete in m3	9.18	5.42	4.13

Table 20 Stepped rectangular footing design

Bearing Capacities in kN/ m^2	100 kN/m^2	180 kN/m^2	250 kN/m^2
Size of footing in m	5.4 x 3.6	4 x 2.7	3.4 x 2.3
Depth D1 in m	1.89	1.67	1.52
Depth D2 in m	1.01	0.93	0.88
Depth D3 in m	0.45	0.40	0.38
Bending Moment in kNm	2499.26	1762.56	1434.8
Permissible Shear Stress in N/mm^2	0.16	0.19	0.21
Area of Steel in m^2 (Y-Y)	3892.40	3130.07	2821.81
Area of Steel in m^2 (X-X)	1422.61	1123.07	1005.14
Balance steel	245.11	181.07	141.64
No. of bars of tor steel (Y-Y)	16mm dia bars 19 no.	16mm dia bars 16 no.	16mm dia bars 14 no.
No. of bars of tor steel (X-X)	10mm dia bars 15 no.	10mm dia bars 12 no.	10mm dia bars 11 no.
No. of bars in balance steel at corner	6	6	6
Spacing in m c/c (Y-Y)	186	173	164
Spacing in m c/c (X-X)	240	225	209
Provided Area of Steel in m^2(X - X)	3892	3130	2822
Provided Area of Steel in m^2(Y - Y)	1649	1413	1335
Length of bar in m (L)	3.5	2.6	2.2
Length of bar in m (B)	5.3	3.9	3.3
Total length of bar in m(Y-Y)	103	61	46
Total length of bar in m (X-X)	74	47	37
Weight of bar per m	0.618	0.618	0.618
Weight of bar per m	1.5815	1.5815	1.5815
Quantity of steel in tonn	0.1623	0.0960	0.0733
Quantity of steel in tonn	0.0454	0.0289	0.0231
Total quantity of steel in tonn	0.2077	0.1250	0.0964
Quantity of concrete in m3	15.78	8.42	5.57

3.3 Corner Column Foundation Design

Square Footing: Result of plain, trapezoid and stepped footing design shown in Table 21, Table 22 and Table 23.

Table 21 Square plain footing design

Bearing Capacities of soil in kN/ m^2	100 kN/m^2	180 kN/m^2	250 kN/m^2
Size of Footing in m	4.3 x 4.3	3.2 x 3.2	2.7 x 2.7
Depth in m	0.87	0.88	1.01
Bending Moment in kNm	2704.41	1869.06	1499.72
Permissible shear stress in N/mm^2	1.08	1.01	0.74
Area of steel in m^2	9692.01	6578.20	4490.42
No. of bars of tor steel	16mm dia bars 48 no.	16mm dia bars 33 no.	16mm dia bars 22 no.
Spacing in mm c/c	90	100	120
Provided Area of Steel in m^2	9692.013	6578.203	4490.416
Length of bar in m	4.2	3.1	2.6
Total length of bar in m	405	203	116
Weight of bar per m	1.5815	1.5815	1.5815
Quantity of steel in tonn	0.6406	0.3209	0.1837
Quantity of concrete in m^3	16.09	9.01	7.36

Table 22 Square trapezoid footing design

Bearing Capacities in kN/ m^2	100 kN/m^2	180 kN/m^2	250 kN/m^2
Size of Footing in m	4.3 x 4.3	3.2 x 3.2	2.7 x 2.7
Depth in m	1.26	1.27	1.28
Thickness in m	0.2	0.2	0.2
Bending Moment in kNm	1886.80	1323.91	1073.87
Permissible Shear Stress in N/mm^2	1.10	1.11	1.11
Area of Steel in m^2	5311.51	3682.98	2954.23
No. of bars of tor steel	16mm dia bars 26 no.	16mm dia bars 18 no.	16mm dia bars 15 no.
Spacing in mm c/c	165	175	185
Provided Area of Steel in m^2	5311.51	3682.97	2954.23
Length of bar in m	4.2	3.1	2.6
Total length of bar in m	222	114	76
Weight of bar per m	1.5815	1.5815	1.5815
Quantity of steel in tonn	0.3511	0.1797	0.1209
Quantity of concrete in m^3	8.55	4.94	3.64

Table 23 Square stepped Footing design

Bearing Capacities in kN/ m^2	100 kN/m^2	180 kN/m^2	250 kN/m^2
Size of Footing in m	4.3 x 4.3	3.2 x 3.2	2.7 x 2.7
Depth D1 in m	1.81	1.64	1.53
Depth D2 in m	0.84	0.87	0.85
Depth D3 in m	0.25	0.30	0.31
Bending Moment in kNm	2836.20	1869.06	1499..72
Permissible Shear Stress in N/mm^2	0.32	0.35	0.37
Area of Steel in m^2	4521.60	3301.89	2850.18
No. of bars of tor bar	16mm dia bars 22 no.	16mm dia bars 16 no.	16mm dia bars 14 no.
Spacing in mm c/c	190	190	185
Provided Area of Steel in m^2	4521.56	3301.90	2850.18
Length of bar in m	4.2	3.1	2.6
Total length of bar in m	189	102	74
Weight of bar per m	1.5815	1.5815	1.5815
Quantity of steel in tonn	0.2988	0.1611	0.1166
Quantity of concrete in m^3	11.92	7.4	5.2

Rectangular Footing: Result of plain, trapezoid and stepped footing design shown in Table 24, Table 25 and Table 26.

Table 24 Rectangular plain footing design

Bearing Capacities in kN/ m^2	100 kN/m^2	180 kN/m^2	250 kN/m^2
Size of footing in m	5.2 x 3.4	3.9 x 2.6	3.3 x 2.2
Depth in m	0.88	0.86	0.85
Bending Moment in kNm	4347.56	3115.28	2513.64
Permissible Stress in N/mm^2	1.13	1.14	1.13
Area of Steel in m^2(Y-Y)	11811.84	12100.28	9851.00
Area of Steel in m^2(X-X)	1461.63	8463.79	6904.91
Balance steel at corner		1019.53	784.27
No. of bars of tor steel(Y-Y)	16mm dia bars 31 no.	16mm dia bars 23 no.	16mm dia bars 19 no.
No. of bars of tor steel (X-X)	20mm dia bars 38 no.	20mm dia bars 27 no.	20mm dia bars 22 no.
No. of bar of balance steel at both corner	8	6	6
Spacing of bar in mm (Y-Y)	110	113	116
Spacing of bar in mm (X-X)	90	96	100
Provided Area of Steel in m^2(Y-Y)	7839	5829	5025
Provided Area of Steel in m^2(X-X)	11812	8464	6905
Length of bar (L) in m	3.3	2.5	2.1
Length of bar (B) in	5.1	3.8	3.2
Total length of bar in m (Y-Y)	129	73	53
Total length of bar in m (X-X)	192	102	70
Weight of bar per m (Y-Y)	1.5815	1.5815	1.5815
Weight of bar per m (X-X)	2.471	2.471	2.471
Quantity of steel in tonn(Y-Y)	0.2035	0.1147	0.0830
Quantity of steel in tonn(X-X)	0.4741	0.2531	0.1739
Total Quantity of steel in tonn	0.6776	0.3678	0.1739
Quantity of concrete in m^3	15.56	8.72	6.17

Table 25 Rectangular trapezoid footing design

Bearing Capacities in kN/ m^2	100 kN/m^2	180 kN/m^2	250 kN/m^2
Size of footing in m	5.2 x 3.4	3.9 x 2.6	3.3 x 2.2
Depth in m	1.33	1.24	1.22
Thickness in m	0.2	0.2	0.2
Bending Moment in kNm	2322.81	1647.50	1342.51
Permissible Shear Stress in N/mm^2	1.11	1.06	0.99
Area of Steel in m^2 (X-X)	6175.41	4796.99	3990.08
Area of Steel in m^2(Y-Y)	3936.50	3126.87	2600.70
Balance steel in corner	772.50	527.87	453.70
No. of bars of tor steel (Y-Y)	16mm dia bars 31 no.	16mm dia bars 24 no.	16mm dia bars 20 no.
No. of bars of tor steel (X-X)	12mm dia bars 28 no.	12mm dia bars 23 no	12mm dia bars 19 no.
No. of bar of balance steel at both corner	8	6	6
Spacing in mm c/c (X-X)	111	109	111
Spacing in mm c/c (Y-Y)	121	113	116
Provided Area of Steel in m^2 (Y-Y)	6175	4797	3990
Provided Area of Steel in m^2 (X-X)	4068	3277	2825
Length of bar in m (L)	3.3	2.5	2.1
Length of bar in m (B)	5.1	3.8	3.2
Total length of bar in m (Y-Y)	157	91	64
Total length of bar in m (X-X)	119	73	53
Weight of bar per m	1.5815	1.5815	1.5815
Weight of bar per m	0.89	0.89	0.89
Quantity of steel in tonn (Y-Y)	0.2478	0.1434	0.1005
Quantity of steel in tonn (X-X)	0.1057	0.0645	0.0467
Total quantity of steel in tonn	0.3535	0.2080	0.1472
Quantity of concrete in m^3	8.58	4.73	3.4

Table 26 Stepped rectangular footing design

Bearing Capacities in kN/m^2	100 kN/m^2	180 kN/m^2	250 kN/m^2
Size of footing in m	5.2 x 3.4	3.9 x 2.6	3.3 x 2.2
DepthD1 in m	1.77	1.59	1.44
Depth D2 in m	0.87	0.81	0.77
Depth D3 in m	0.25	0.3	0.33
Bending Moment in kNm	3336.99	2336.46	1885.23
Permissible Shear Stress in N/mm^2	0.33	0.38	0.43
Area of Steel in m^2 (Y-Y)	3632.41	2910.51	2615.38
Area of Steel in m^2 (X-X)	5577.29	4365.76	3923.71
Balance steel	694.41	537.51	468.38
No. of bars of tor steel (Y-Y)	12mm dia bars 26 no.	12mm dia bars 21 no.	12mm dia bars 19 no.
No. of bars of tor steel (X-X)	16mm dia bars 28 no.	16mm dia bars 22 no.	16mm dia bars 20 no.
No. of bar in balance steel at both corner	6	6	6
Spacing in m (Y-Y)	131	124	116
Spacing in m(X-X)	123	120	113
Provided Area of Steel in m^2(Y-Y)	3616	3051	2825
Provided Area of Steel in m^2(X-X)	5577	4366	3924
Length of bar in m (L)	5.1	3.8	3.2
Length of bar in m (B)	3.3	2.5	2.1
Length of bar in m(Y-Y)	142	83	63
Length of bar in m(X-X)	106	67	53
Weight of bar per m	0.89	0.89	0.89
Weight of bar per m	1.5815	1.5815	1.5815
Quantity of steel in tonn (Y-Y)	0.2238	0.1305	0.0988
Quantity of steel in tonn (X-X)	0.0940	0.0601	0.0467
Total Quantity of steel in tonn	0.3178	0.1906	0.1455
Quantity of concrete in m^3	12.14	6.88	4.86

IV. RESULTS AND DISCUSSION

Comparisons of results are shown in graphs. The graphs are plotted in between depth of foundations and bearing capacities, quantity of steel and bearing capacities and quantity of concrete and bearing capacities of square, rectangular and circular columns of its plain, trapezoid (sloped) and stepped shape footing.

4.1 Graphs

4.1.1Middle Column:

Graph between depth of foundations and bearing capacities

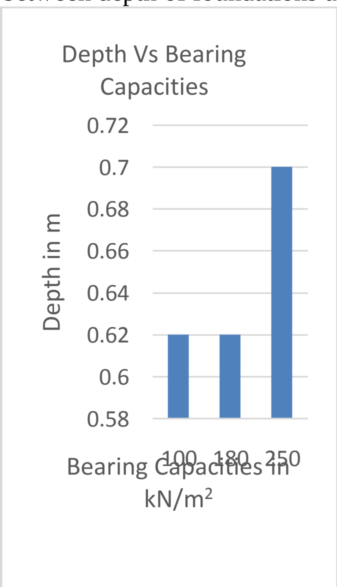

Fig 2 Square Plain Footing

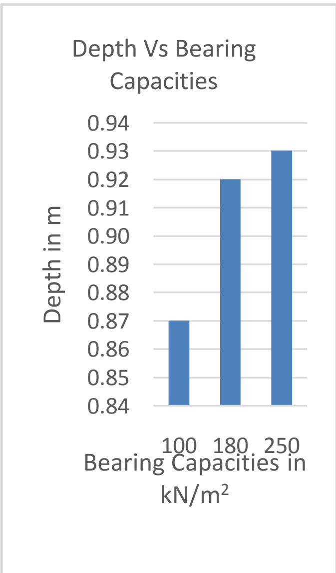

Fig 3 Square Trapezoid Footing

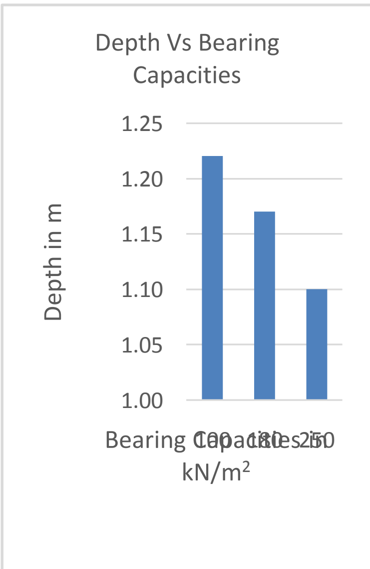

Fig 4 Square Stepped Footing

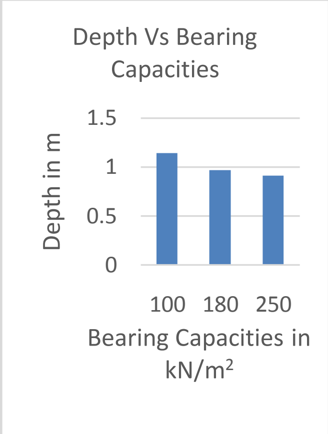

Fig 5 Circular Plain Footing

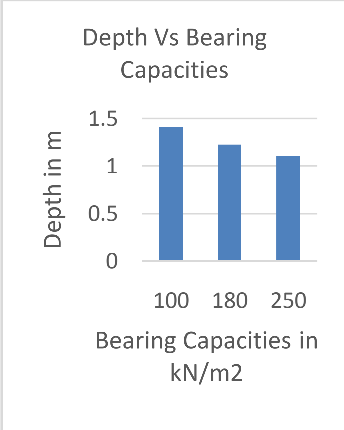

Fig 6 Circular Trapezoid Footing

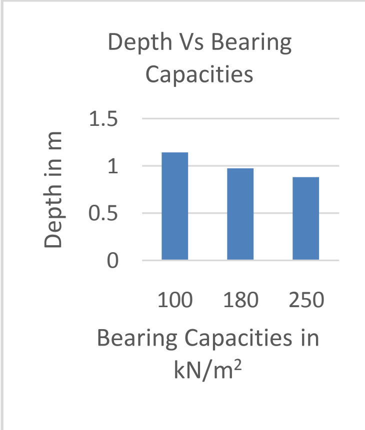

Fig 7 Circular Stepped Footing

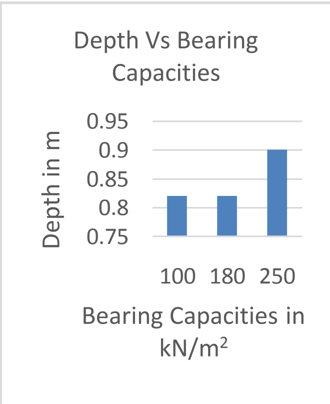

Fig 8 Rectangular Plain Footing

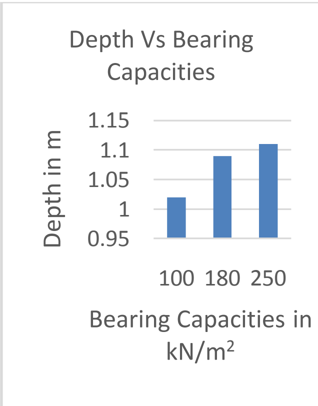

Fig 9 Rectangular Trapezoid Footing

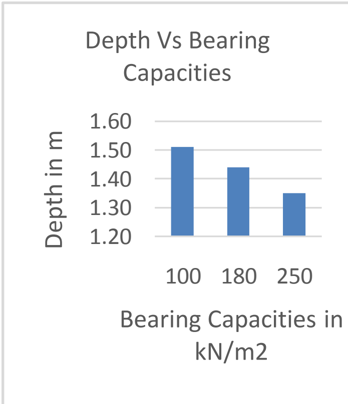

Fig 10 Rectangular Stepped Footing

Graph for Quantity of Concrete

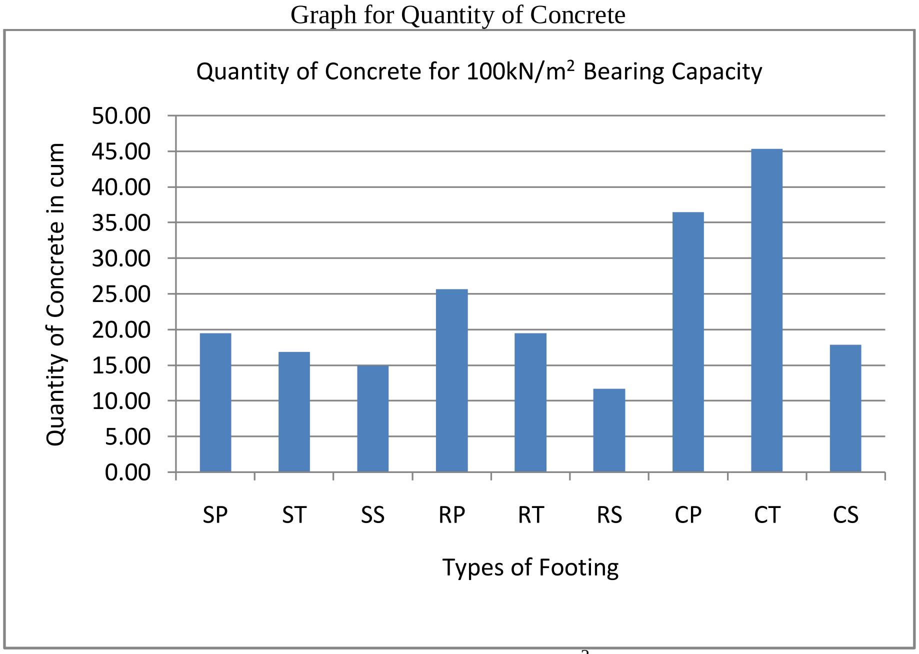

Fig 11 Quantity of Concrete for 100kN/m^2 Bearing Capacity

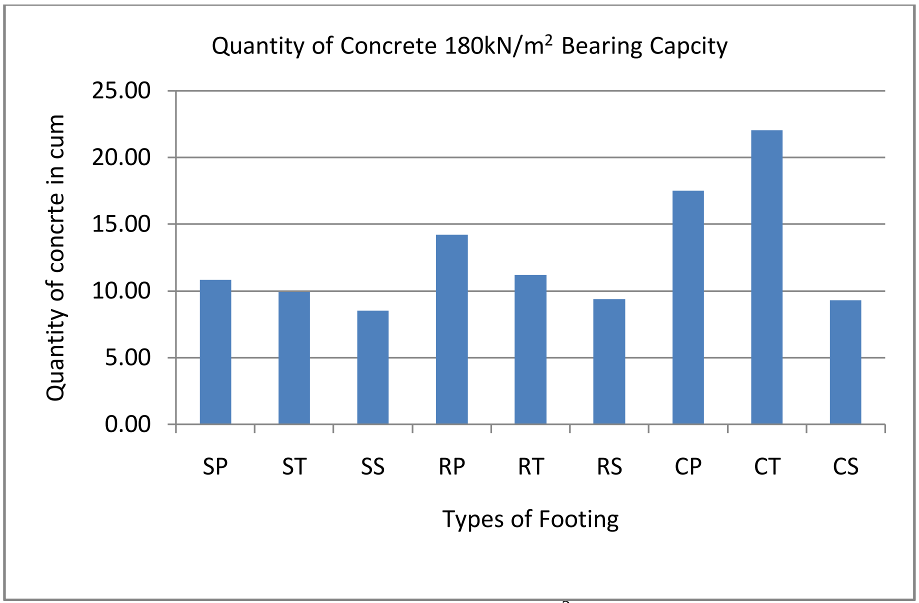

Fig 12 Quantity of Concrete 180kN/m^2 Bearing Capacity

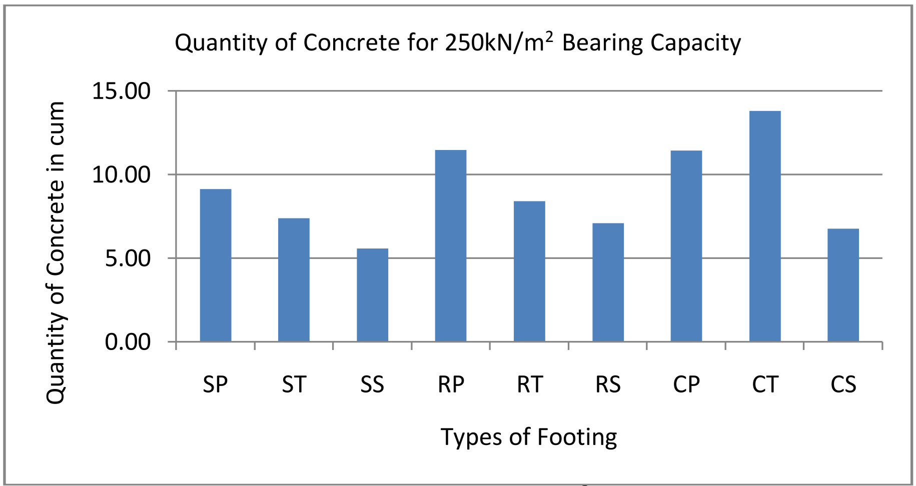

Fig 13 Quantity of Concrete for 250kN/m^2 Bearing Capacity

Graph for Quantity of Steel

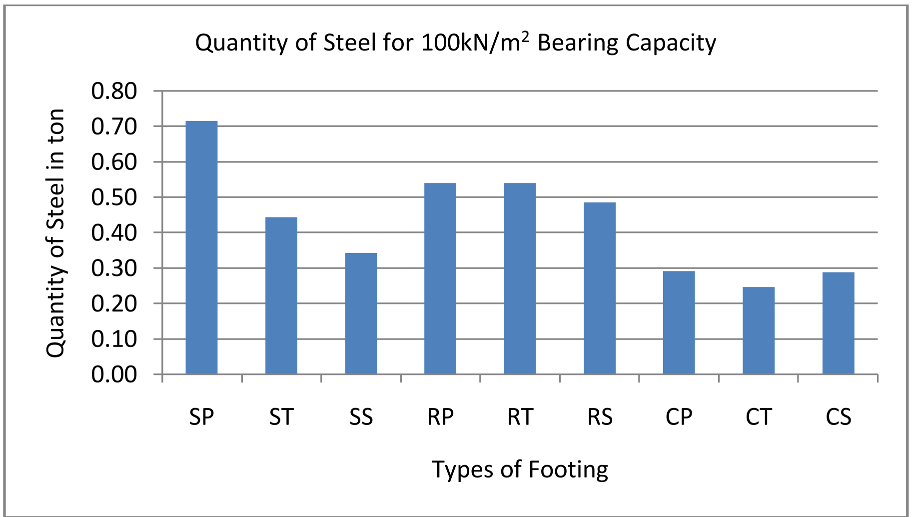

Fig 14 Quantity of Steel for 100kN/m^2 Bearing Capacity

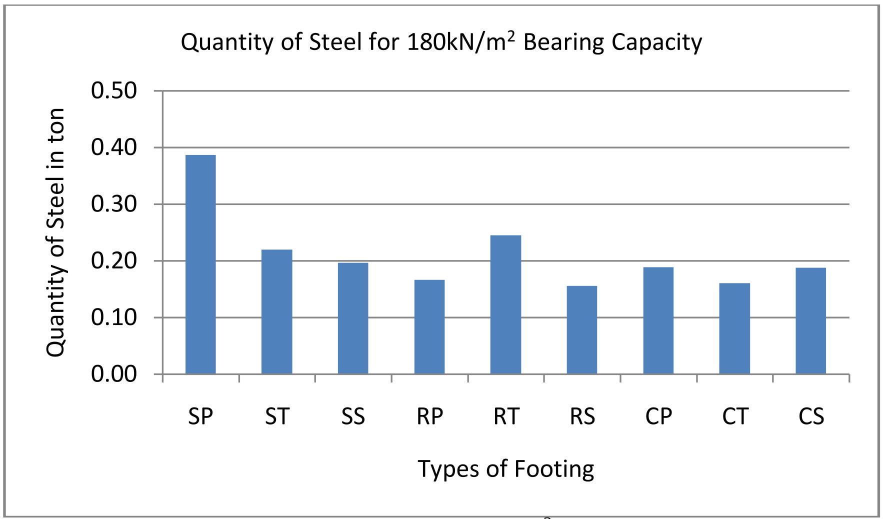

Fig 15 Quantity of Steel for 180kN/m^2 Bearing Capacity

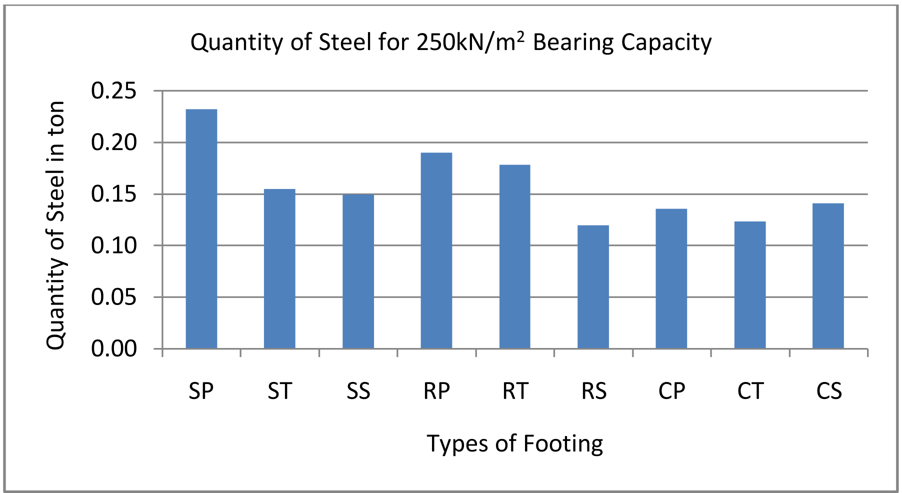

Fig 16 Quantity of Steel for 250kN/m^2 Bearing Capacity

4.1.2Side Column:

Graph between Depth of foundation and bearing capacities

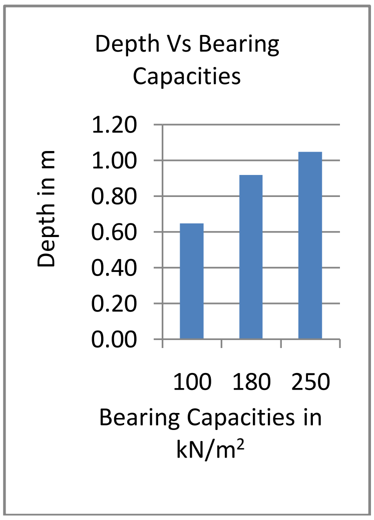

Fig 17 Square Plain Footing

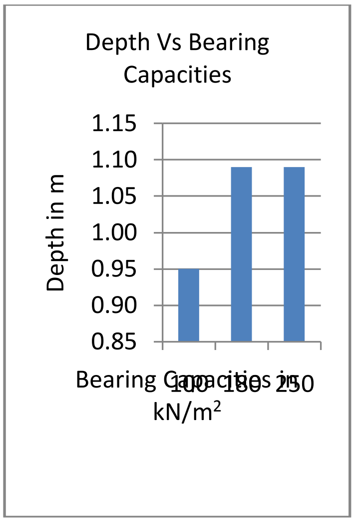

Fig 18 Square Trapezoid Footing

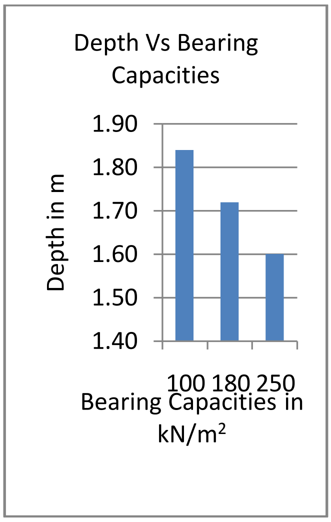

Fig 19 Square Stepped Footing

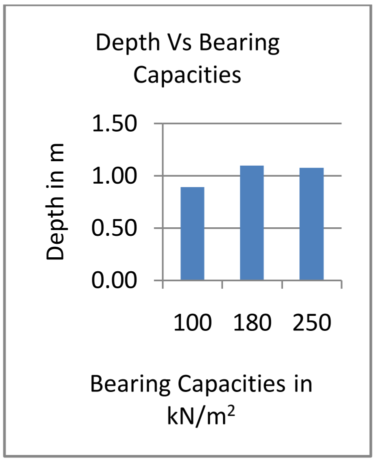

Fig 20 Rectangular Plain Footing

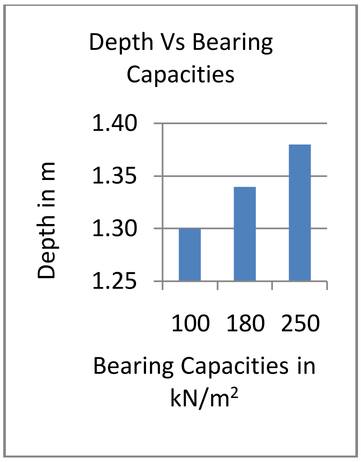

Fig 21 Rectangular Trapezoid Footing

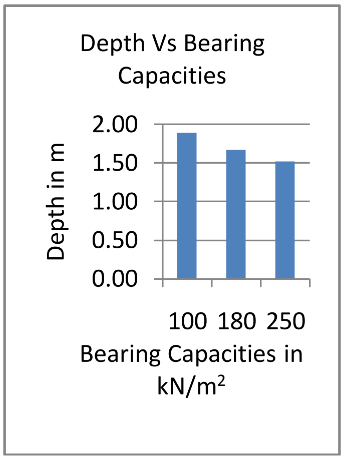

Fig22 Rectangular Stepped Footing

Graph for Quantity of Concrete

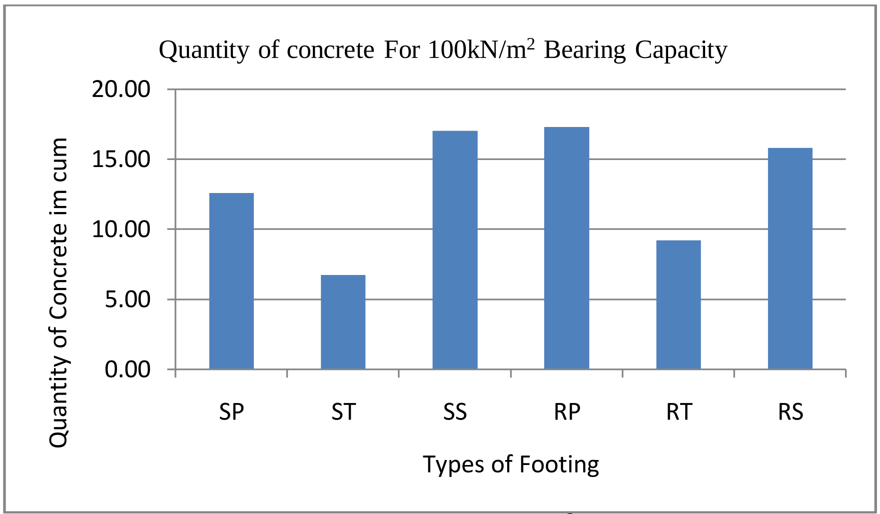

Fig 23 Quantity of Concrete for 100kN/m^{2}Bearing Capacity

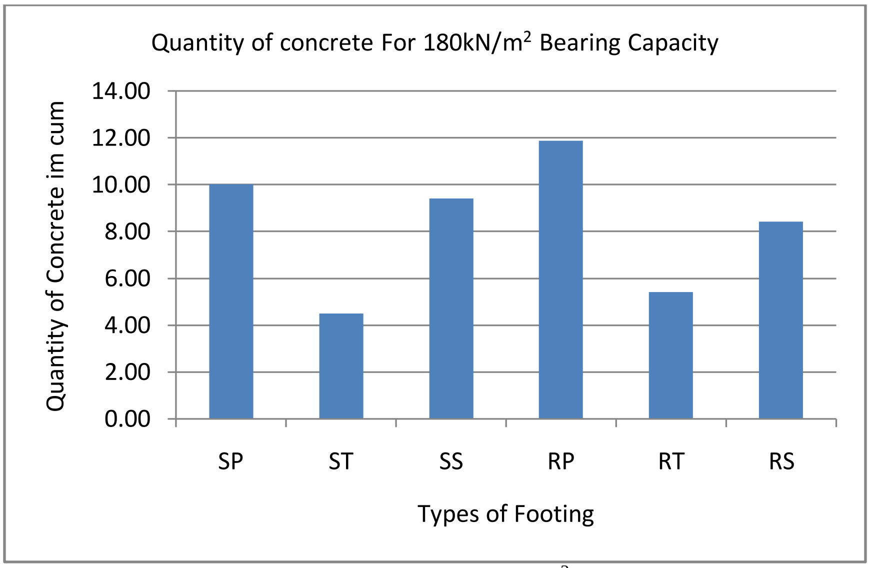

Fig 24 Quantity of Concrete for 180kN/m^2 Bearing Capacity

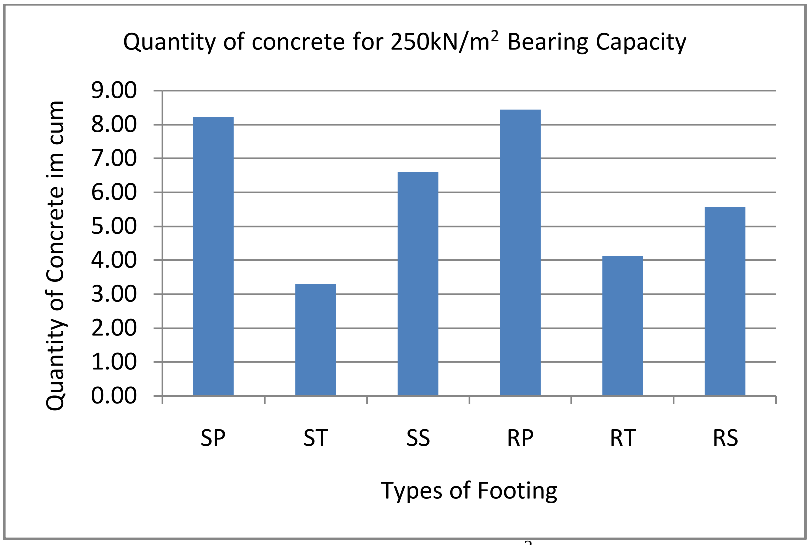

Fig 25 Quantity of concrete for 250kN/m^2 Bearing Capacity

Graph for Quantity of Steel

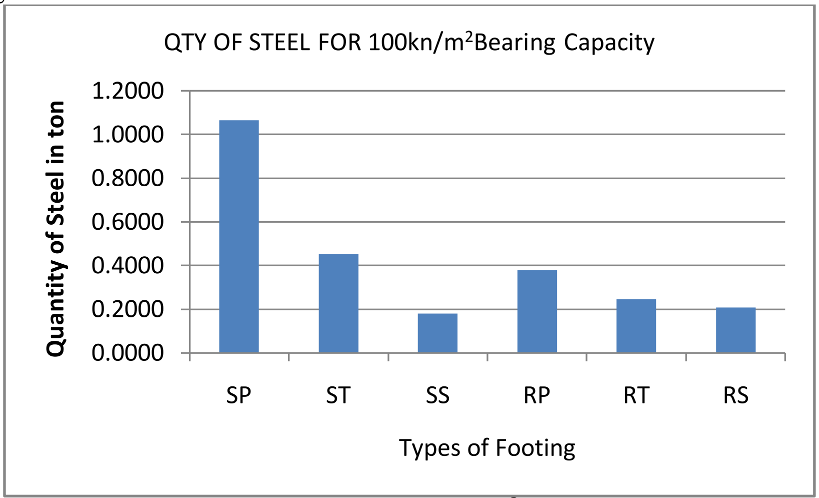

Fig 26 Quantity of Steel for 100kN/m^2 Bearing Capacity

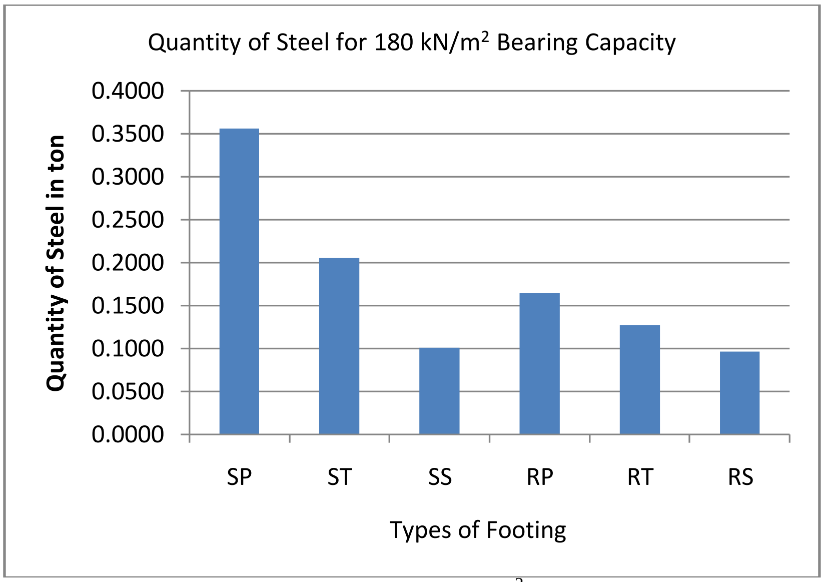

Fig 27Quantity of Steel for180 kN/m^2 Bearing Capacity

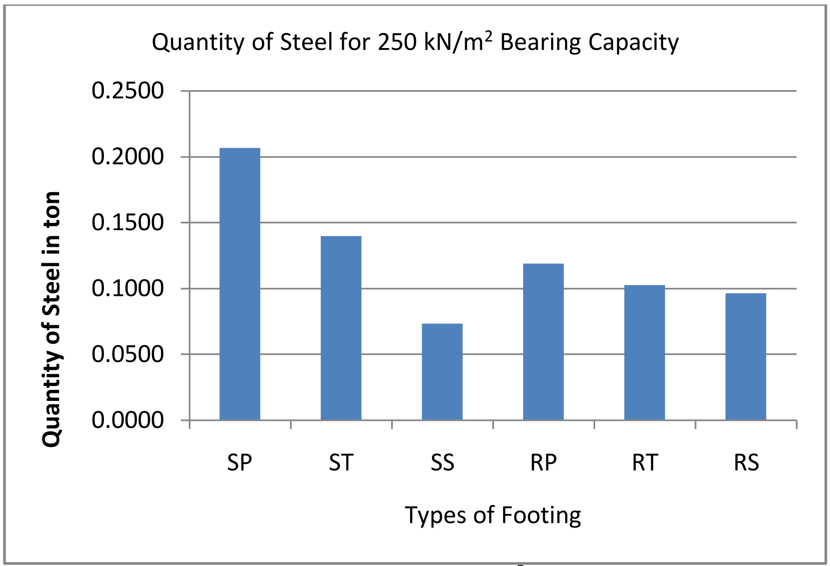

Fig 28 Quantity of Steel for 250kN/m^2 Bearing Capacity

4.1.3Corner Column:
Graph between Depth of foundation and bearing capacities

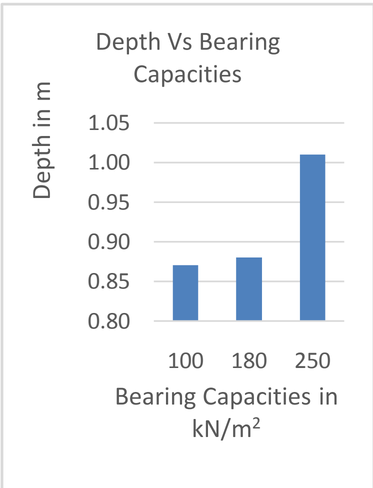

Fig 29 Square Plain Footing

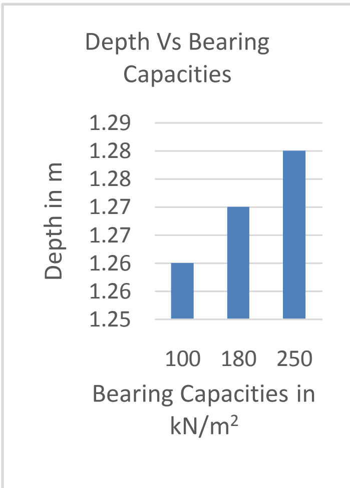

Fig 30 Square Trapezoid Footing

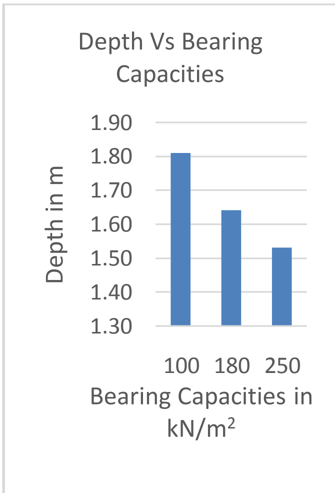

Fig 31 Square Stepped Footing

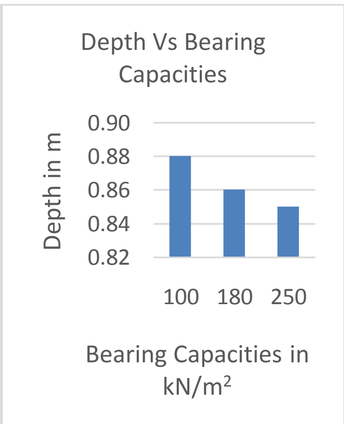

Fig 32 Rectangular Plain Footing

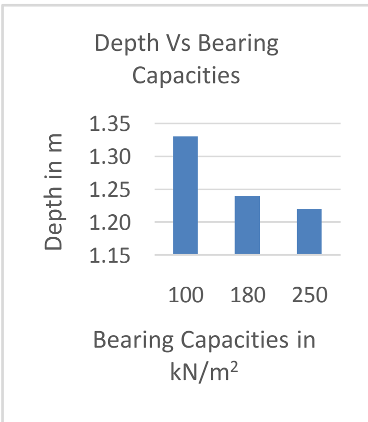

Fig 33 Rectangular Trapezoid Footing

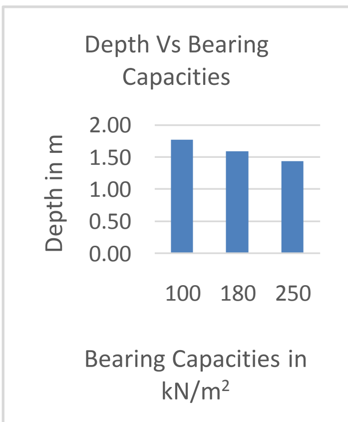

Fig 34 Square Stepped Footing

Graph for Quantity of Concrete

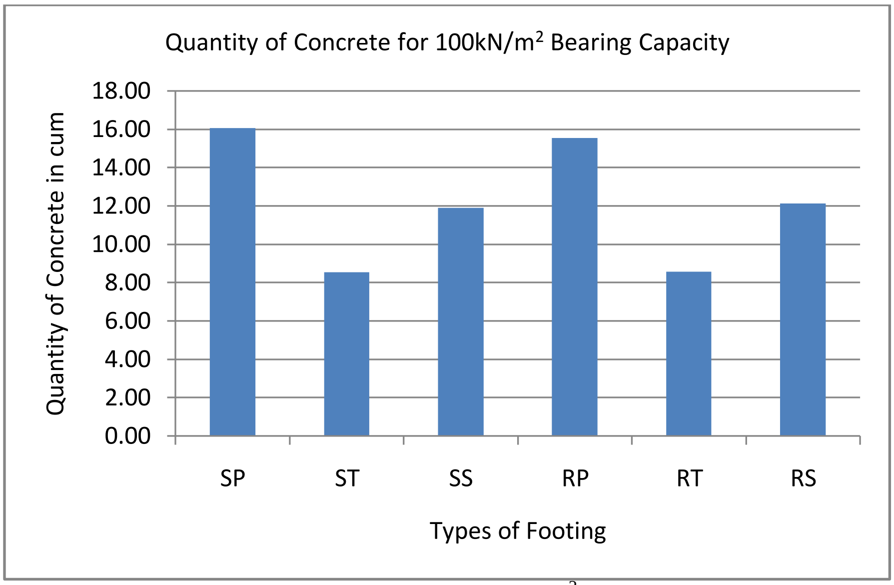

Fig 35 Quantity of Concrete for 100kN/m^2 Bearing Capacity

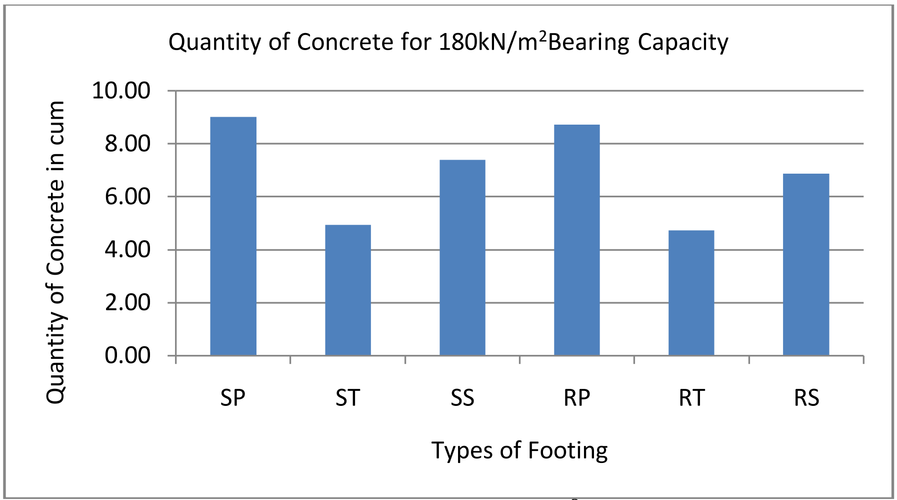

Fig 36 Quantity of Concrete for 180kN/m^2 Bearing Capacity

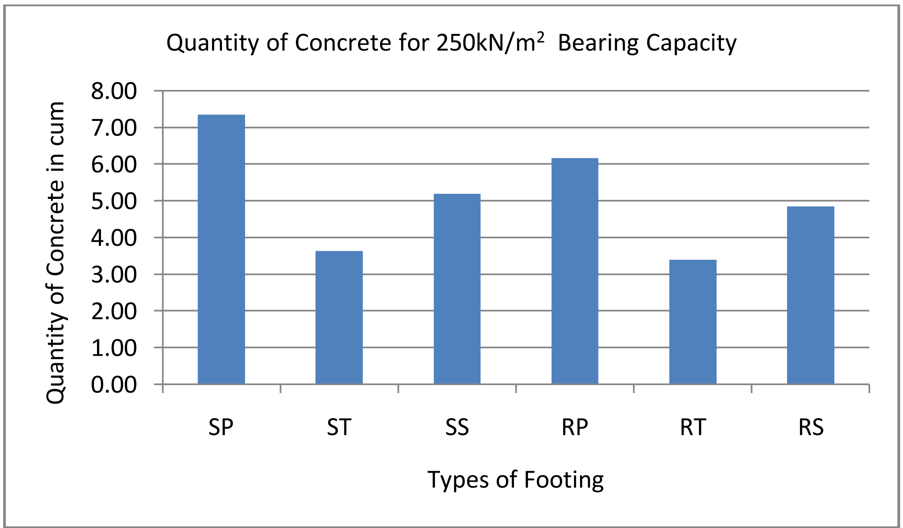

Fig 37 Quantity of Concrete for 250kN/m^2 Bearing Capacity

Graph for Quantity of Steel

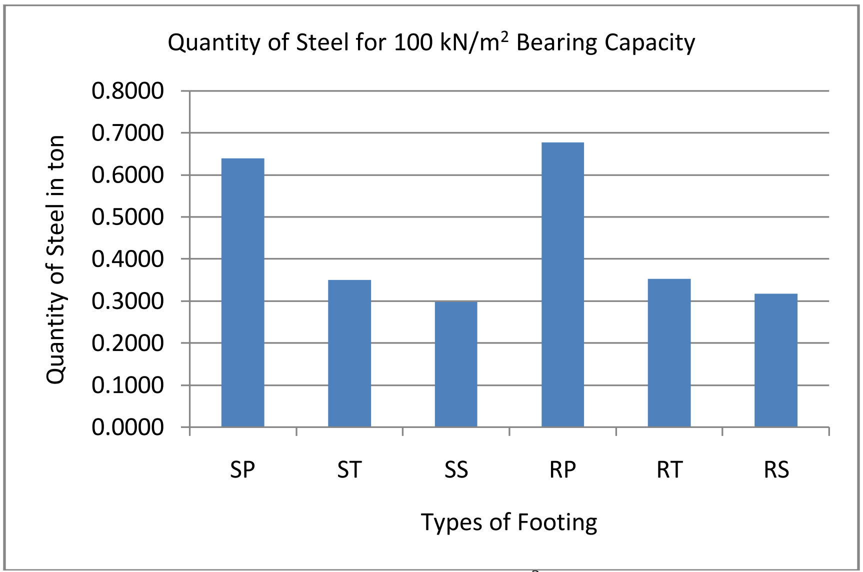

Fig 38 Quantity of Steel for 100kN/m^2 Bearing Capacity

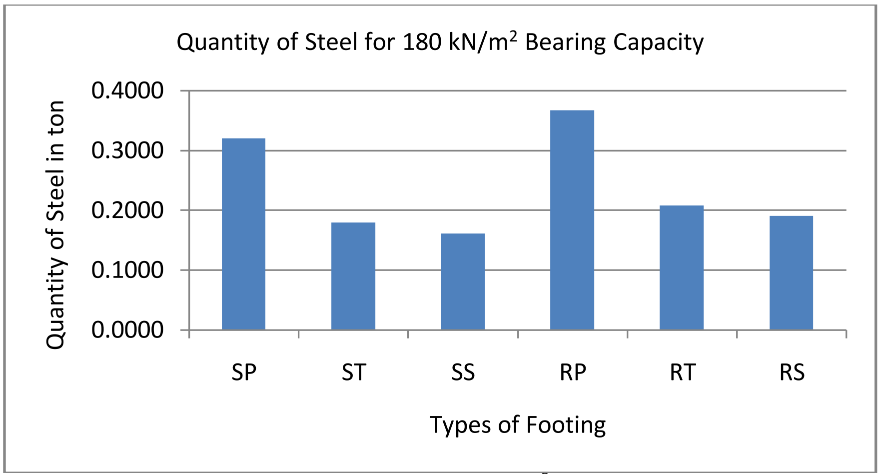

Fig 39 Quantity of Steel for 180kN/m^2 Bearing Capacity

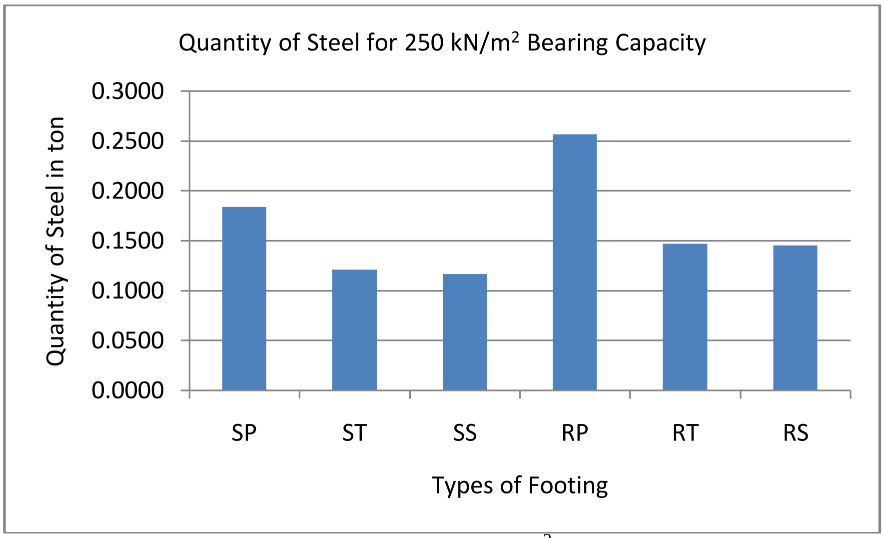

Fig 40 Quantity of Steel for 250kN/m^2 Bearing Capacity

4.2 Cost of Footing

Rate of steel is 44000 Rs. Per tonn is taken from Steel Authority of India Limited (SAIL) and rate of M-20 concrete is 4500 Rs. per cubic meter is taken from as per rate analysis of current market rate.

Cost of quantity of steel required for middle column as tabulated below

Table 27 Cost of Quantity of Steel in Lac

Types of footing	100 kN/m^2	180 kN/m^2	250 kN/m^2
Square plain footing	0.31	0.17	0.10
Square trapezoid footing	0.19	0.09	0.06
Square stepped footing	0.15	0.09	0.07
Circular plain footing	0.12	0.08	0.06
Circular trapezoid footing	0.11	0.07	0.05
Circular stepped footing	0.13	0.08	0.06
Rectangular plain footing	0.23	0.12	0.08
Rectangular trapezoid footing	0.21	0.10	0.07
Rectangular stepped footing	0.12	0.06	0.05

Cost of quantity of concrete required for middle column as tabulated below

Table 28 Cost of Quantity of Concrete in Lac

Types of footing	100 kN/m^2	180 kN/m^2	250 kN/m^2
Square plain footing	0.87	0.48	0.41
Square trapezoid footing	0.62	0.36	0.27
Square stepped footing	0.67	0.38	0.25
Circular plain footing	1.64	0.78	0.51
Circular trapezoid footing	2.04	0.99	0.62
Circular stepped footing	0.80	0.41	0.30
Rectangular plain footing	1.15	0.63	0.51
Rectangular trapezoid footing	0.69	0.40	0.30
Rectangular stepped footing	0.74	0.44	0.32

Cost of quantity of steel required for side column as tabulated below

Table 29 Cost of Quantity of Steel in Lac

Types of footing	100 kN/m^2	180 kN/m^2	250 kN/m^2
Square plain footing	0.46	0.15	0.09
Square trapezoid footing	0.19	0.09	0.06
Square stepped footing	0.14	0.07	0.05
Rectangular plain footing	0.16	0.07	0.05
Rectangular trapezoid footing	0.10	0.05	0.04
Rectangular stepped footing	0.09	0.05	0.04

Cost of quantity of concrete required for side column as tabulated below

Table 30 Cost of Quantity of Concrete in Lac

Types of footing	100 kN/m^2	180 kN/m^2	250 kN/m^2
Square plain footing	0.56	0.45	0.37
Square trapezoid footing	0.30	0.20	0.14
Square stepped footing	0.76	0.42	0.29
Rectangular plain footing	0.77	0.53	0.38
Rectangular trapezoid footing	0.41	0.24	0.18
Rectangular stepped footing	0.71	0.37	0.25

Cost of quantity of steel required for corner column as tabulated below

Table 31 Cost of Quantity of Steel in Lac

Types of footing	100 kN/m^2	180 kN/m^2	250 kN/m^2
Square plain footing	0.28	0.14	0.08
Square trapezoid footing	0.15	0.07	0.05
Square stepped footing	0.13	0.07	0.05
Rectangular plain footing	0.29	0.16	0.11
Rectangular trapezoid footing	0.15	0.09	0.06
Rectangular stepped footing	0.13	0.08	0.06

Cost of quantity of concrete required for corner column as tabulated below

Table 32 Cost of Quantity of Concrete in Lac

Types of footing	100 kN/m^2	180 kN/m^2	250 kN/m^2
Square plain footing	0.72	0.40	0.33
Square trapezoid footing	0.38	0.22	0.16
Square stepped footing	0.53	0.33	0.23
Rectangular plain footing	0.70	0.39	0.27
Rectangular trapezoid footing	0.38	0.21	0.15
Rectangular stepped footing	0.54	0.30	0.21

V. CONCLUSION

Based on the studies carried out following conclusions are drawn -

- There are three aspects of design - Stability, economy and ease of construction.
- As shown in the results, design of different types of foundations on three bearing capacities 100 kN/m^2, 180 kN/m^2 and 250 kN/m^2 on middle, side and corner column & comparison of their results between depth & bearing capacities, quantity of steel and quantity of concrete with types of footing and it was found that which foundation was most suitable.
- When bearing capacity increases soil strata strength increases so depth of foundation should be decreased but in this study one remarkable point was noticed that as bearing capacity increases, depth also increased. Figure 2, 3, 4, 5, 6, 7, 8, 9 and 10 shows comparison of depth with bearing capacity of middle column. As seen the value of depth increases as bearing capacity increases in square and rectangular, plain, trapezoid (Sloped) shape foundation. This is because as bearing capacity increases area of foundation decreases and due to this shear center is also shifted & due to this depth increases. Shear center is a point through which if the external load passes then their will only be subjected to bending, it won't be subjected to torsion. As bearing capacity increases area of footing decreases and foundations are fail in one way shear. But stepped footing shows completely opposite behavior because of its shape. Same pattern follows in side column as shown in figure 17, 18, 19, 20, 21 and 22. In corner column figure 29, 30 and 31 square foundation shows same behavior but rectangular foundation shows decrease in depth in all types of foundation. By this study this is clear that stepped foundation gave best results according to depth criteria, this reduces excavation cost and labor cost.
- Fig. 35, 36, and 37 shows comparison of quantity of concrete in different types of foundation. Trapezoidal foundation is most economical in square and rectangular footing because building load spread in trapezoid shape on soil hence that is more suitable in quantity of concrete. The major problem of this shape is its construction, in this compaction of concrete in slope area of trapezoid is difficult and if compaction is not done properly, it reduces the effect of shape. As shown in table 27, 28, 29, 30, 31 and 32 there is not much difference in the cost of trapezoid & stepped footing. Hence it's more suitable to use stepped foundation as chances of failing of construction are less as compared to trapezoidal foundation.
- As shown in figure 11, 12 and 13 circular stepped foundation came out to be the most economical in quantity of concrete. Also, from figure 14, 15 and 16 circular foundation has the minimum quantity of steel as compared to rectangular and square footing. Circular footing is most economical than rectangular and square footing. Circular footing is provided only under the circular column and practically it is found that in building construction the rectangular and square columns are usually needed. Circular columns are provided for ornamental work of buildings. These foundations are normally constructed for bridge piers.
- Fig 14, 15, 16, 26, 27, 28, 38, 39 and 40 shows comparison of steel in all types of foundation for middle, side and corner column. It is found that stepped foundation of all shapes square, rectangular and circular gave better result in comparison of other shape in all middle, side and corner column.

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