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A Study on Higher Order Load Analysis and Design of Combined Footing Using STADD Foundation

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Abstract: As we know the foundation is the most important member of the building and a precise analysis of footing will result in more safe and economic design. In the present study the comparison of analysis of combined rectangular footing using Rigid (conventional) Method and Finite Element Analysis of combine footing using Winkler Model by using Stadd pro is carried out, masonry or concrete a structure which carries the entire load from superstructure and it will distribute the load on soil bellow it. The strength, stability & support of structure are fully dependent on foundation. If some parts of superstructure fail, then repairs, modifications, additions & alterations are possible to save the structure, but in case of foundation failure it is much difficult and very costly.

Keywords: Combined Rectangular Footing, Finite Element Analysis, Winkler's Model. Foundation is A Structural Member, Made of Brick Work, Staad Foundation.

I. INTRODUCTION

Our project is predicated on style the planning the look and analysis of multi-storied building with combined footing design. Analysis is completed through victimization the STADD-PRO .Notation adopted throughout the project is same as in IS-456-2000 Victimization code analysis for structural style is turning into a lot of rife across the trade because of increasing technological resources. This project served as AN investigation of foundation style alternatives and also the practical blendes of STAAD. Foundation as a style aid for engineers at Static Consulting Ltd. each style improvement and accuracy were tested against hand calculations in an exceedingly accordance with Indian code so as to spot the proficiencies and shortcomings of the code that were documented in a user tips manual. A structure will be outlined as a body which might resist the applied hundreds while not appreciable formations. Civil engineering structures square measure created to serve some Specific functions like human habitation, transportation, bridges, storage etc. in an exceedingly safe and economical Means. A structure is AN assemblage of individual components like fastened components (truss elements), Beam part, column, shear wall block cable or arch. Structural engineering thinks about with the design, planning and also the construction of structures. Structure analysis involves the determination of the forces and displacements of the structures or parts of a structure. Style method involves the choice and particularization of the parts that compose the structural system. The most object of ferro concrete style is to realize a structure which will end in a secure economical resolution.

II. LITERATURE REVIEW

Combined footings usually used to support two columns of unequal loads. In such a case, the resultant of the applied loads would not coincide with the centered of the footing, and the consequent the soil pressure would not be uniform. Another case where a combined footing is an efficient foundation solution is when there are two interior columns which are so close to each other that the two isolated footings stress zones in the soil areas would overlap. The area of the combined footing may be proportioned for a uniform settlement by making its centroid coincide with the resultant of the column loads supported by the footing. There are many instances when the load to be carried by a column and the soil bearing capacity are such that the standard spread footing design will require an extension of the column foundation beyond the property line. In such a case, two or more columns can be supported on a single rectangular foundation. If the net allowable soil pressure is known, the size of the foundation B x L can be determined.

A. Positioning Of Columns

Following are some of the guidelines principles for positioning of columns. Column should be preferably located at or near the corner of the building and at intersection of the walls, because the function of the column is to support beams which are normally placed under walls to support them. The columns, which are near to property line, can be exception from above consideration as the Difficulties are encountered in providing footing for such columns. When centre to centre distance between the intersection of the walls is large or where there are no cross walls, the spacing between two columns is governed by limitations on spans of supported beams because spacing of column beside the span of the beams. As the span of the beam increase as the required depth increase and hence its self weight. On the other hand increase in total load is negligible in case of column due to increase in length. Therefore, column is generally cheaper compared to beams on basis of unit cost. Therefore, large spans of beam should be avoided for economy reasons.

B. Orientation of Columns

Column normally provided in the building are rectangular width of the column not less than the width of support for effective load transfer. As far as possible, the width of the column shall not exceed the thickness of the walls to avoid the offsets. Restrictions on the width of the column necessitate the other side (the depth) of the column to be larger the desired load carrying capacity. This leads to the problems of orientation of columns.

C. Position of Beams

Following are some of the guiding principles for the positioning of beams. Beams shall, normally be provided under the walls and below every concentrated load to avoid these loads directly coming on slabs. Basic principle in deciding the layout of a component member is that heavy loads should be transferred to the foundation along the shortest path. Since beams are primarily provided to support slabs, its spacing shall be decided by the maximum spans of slabs which decide the spacing of beams is governed by loading and limiting thickness. The maximum practical thickness for Residential/Office/Public building is 200mm, while minimum is 100mm.

III. SPANNING OF SLABS

Span of slabs is decided by the position of supporting beams of walls. The slab can be made to span in one-direction (one-way) or two-direction (two-way), depending on support conditions, aspect ratio that is Ly/Lx, ratio of reinforcement in the two directions. The designer is free to decide as to whether slab should be designed as one way or two ways. The points to be considered in making a decision i.e. whether slab should be designed as one way or two ways.

- The slab acts as two way slab when $(L_y/L_x) < 2$.
- A slab acts as one-way when $(L_y/L_x) > 2$
- A two-way slab is economical compare to one way slab, because steel along with directions acts as main steel and transfers loads to all the supports, while in one-way slab, main steel is provided along short span only and load is transferred to either of two supports.
- Two ways is advantageous, essentially for large spans (greater then 3m) and for live loads greater than 3
- KN/Esq. For short spans and light loads steel required for two way slab does not appreciably differ as compare to steel for one way slab because of requirement of main steel.

Slabs are plain structural members forming floors and roofs of building whose thickness is quite small compared to their other dimensions. These carry load primarily by flexure and are in various shapes such as square, rectangular, circular and triangular in buildings, tanks etc. inclined slabs may be used as ramps for multistoried as parking. A staircase is considered to be an inclined slab. Slab may be supported by beams or by walls and may be simply supported or continuous over one or more supports. When the ratio of the length to the width of a slab is more than 2, and then most of the load is carried by the shorter span and in such a case is known as one-way in case the ratio is less than 2 then it is called a Two-way slab, which is further classified as restrained and simply supported slabs. The various other types of the slabs are flat slabs, which rest directly on columns with beams and Grid Floors or Ribbed slabs.

- The thickness of the reinforced concrete slabs ranges from75mm to 300mm slabs are designed just like beams keeping the breadth of slab as unity depending on the system of units. Thus the total slab is assumed to the consisting of strips of unit width compression reinforcement is used only in exceptional basis in a slab. Shear stress in a slab are very low and hence shear reinforcement is never provided and if necessary it is preferred to increase the depth of the slab to reduce the stress than providing the reinforcement. Temperature reinforcement is provided at right angles to the main longitudinal reinforcement in a slab. The design of the slab is purely is accordance with the code IS-456 2000 the designing process of the slabs the following assumption are made.M_{20} Concrete and Fe_{415} steel is used both for design and execution purpose.
- The overall depth of the slab is restricted to 150mm with a clear cover of 20mm.
- The main reinforcement consists of Tor steel bars and temperature reinforcement consists of mild steel bars.
- The total depth of the section is obtained from the maximum bending moment of all moments on the span.

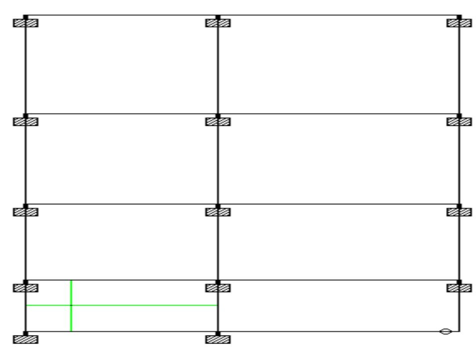

Fig1. Column Layout.

III. TYPES OF COMBINED FOOTING

Plan the geometric proportions and shape are so fixed that the centroid of the footing area coincides with the resultant of the column loads. This results in uniform pressure below the entire area of footing. Trapezoidal footing is provided when one column load is much more than the other. As a result, the both projections of footing beyond the faces of the columns will be restricted. Rectangular footing is provided when one of the projections of the footing is restricted or the width of the footing is restricted. Longitudinally, the footing acts as an upward loaded beam spanning between columns and cantilevering beyond. Using statics, the sheer force and bending moment diagrams in the longitudinal direction are drawn. Moment is checked at the faces of the column. Shear force is critical at distance's' from the faces of columns or at the point of contra flexure. Two-way shear is checked under the heavier column. The footing is also subjected to transverse bending and this bending is spread over a transverse strip near the column

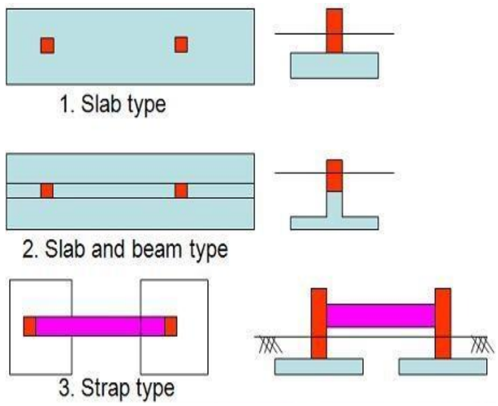

Fig2.

Table1. Density of Materials Used

Density of materials used	
MATERIAL	DENSITY
i) Plain concrete	24.0 KN/m³
ii) Reinforced	25.0 KN/m³
iii) Flooring material (c.m)	20.0KN/m³
iv) Brick masonry	19.0KN/m³
v) Fly ash	5.0KN/m³

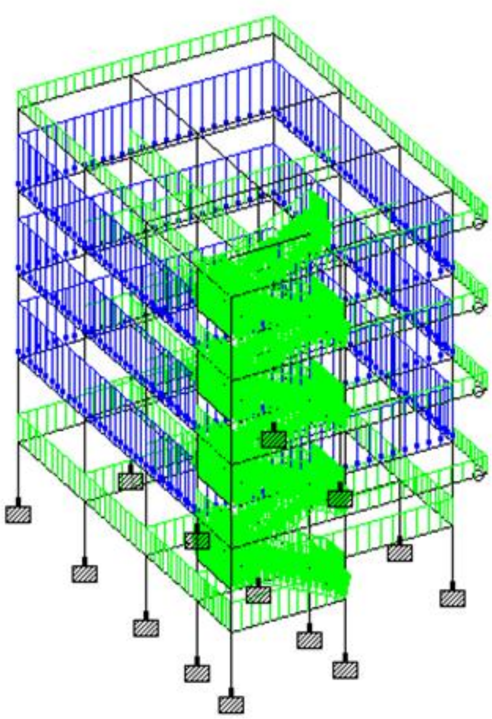

Fig3. Wall loads acting on the structure.

Table2. Load Case Details

Self weight	-1 kn/m
External Wall load	-12 kn/m
Internal wall load	-6 kn/m
Parapet wall load	-3.5 kn/m
Staircase load	-6.65kn/m
Floor load	-6.65 kn/m^2
Floor load on terrace	-5.65 kn/m^2
Load combination	1.5 * self weight
Load combination	1.5 * Dead load
Load combination	1.5 * Live load
Wind load X+ve	Wind load X1 direction Type 1 YR 3 12
Wind load Z+ve	Wind load Z1 direction type 1 YR 3 12
Wind load X-ve	Wind load X -1 direction type 1 YR 3 12

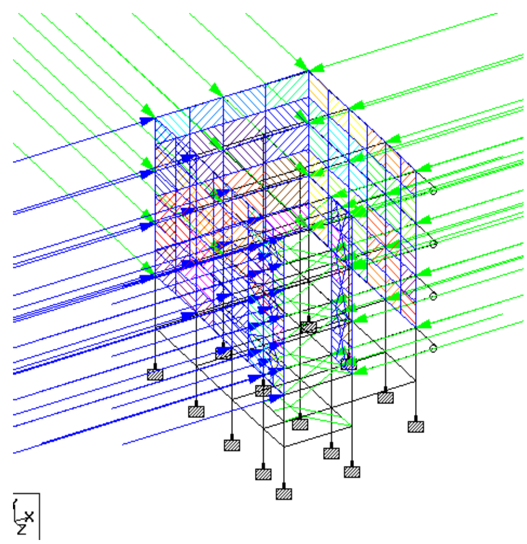

Fig4. Wind loads acting on the structure.

IV. COMBINED FOUNDATION DESIGN

Column Dimensions

Column Shape: Rectangular
Column Length - X (Pl): 0.450 m
Column Width - Z (Pw): 0.230 m

Pedestal

Include Pedestal? No
Pedestal Shape: N/A
Pedestal Height (Ph): N/A
Pedestal Length - X (Pl) : N/A
Pedestal Width - Z (Pw): N/A

For Column A

Column Dimensions
Column Shape: Rectangular
Column Length - X (Pl): 0.450 m Column Width - Z (Pw) : 0.230 m Pedestal
Include Pedestal? No
Pedestal Shape: N/A
Pedestal Height (Ph): N/A
Pedestal Length - X (Pl): N/A
Pedestal Width - Z (Pw): N/A

For Column B

Column Dimensions
Column Shape: Rectangular
Column Length - X (Pl): 0.450 m
Column Width - Z (Pw): 0.230 m Pedestal
Include Pedestal? No
Pedestal Shape: N/A
Pedestal Height (Ph) : N/A Pedestal Length - X (Pl) : N/A
Pedestal Width - Z (Pw) : N/A

For Column C

Column Dimensions
Column Shape : Rectangular
Column Length - X (Pl) : 0.450 m Column Width - Z (Pw) : 0.230 m Pedestal
Include Pedestal? No
Pedestal Shape: N/A
Pedestal Height (Ph) : N/A Pedestal Length - X (Pl) : N/A
Pedestal Width - Z (Pw) : N/A

For Column D

Column Dimensions
Column Shape: Rectangular
Column Length - X (Pl) : 0.300 m Column Width - Z (Pw) : 0.230 m Pedestal
Include Pedestal? No
Pedestal Shape: N/A
Pedestal Height (Ph) : N/A Pedestal Length - X (Pl) : N/A
Pedestal Width-Z(Pw): N/A Length of left overhang:1.000m
Length of right overhang: 1.000 m
Is the length of left overhang fixed? No
Is the length of right overhang fixed? No
Minimum width of footing (Wo) : 2.500 m
Minimum Thickness of footing (Do) : 500.000 mm
Maximum Width of Footing (Wo): 40000.000 mm
Maximum Thickness of Footing (Do): 1500.000 mm
Maximum Length of Footing (Lo): 40000.000 mm
Length Increment: 50.000 mm
Depth Increment: 50.000 mm

Cover and Soil Properties

Pedestal Clear Cover: 50.000 mm
Footing Clear Cover: 50.000 mm
Unit Weight of soil: 22.000 kN/m3
Soil Bearing Capacity: 100.000 kN/m2
Soil Surcharge: 0.000 kip/in2
Depth of Soil above Footing: 0.000 in
Depth of Water Table: 120.000 in

Concrete and Rebar Properties:

Unit Weight of Concrete: 25.000 kN/m3
Compressive Strength of Concrete: 25.000 N/mm2
Yield Strength of Steel: 415.000 N/mm2
Minimum Bar Size: Ø12
Maximum Bar Size: Ø60
Minimum Bar Spacing: 50.000 mm
Maximum Bar Spacing: 400.000 mm

V. DESIGN CALCULATIONS

A. Footing Size Calculations

Reduction of force due to buoyancy = 0.000 kN
Area from initial length and width,Ao=LoX Wo=39.050 sq m
Min. area required from bearing pressure, Amin=P/qmax = 38.258 sq m
Note: Amin is an initial estimation.
P=Critical Factored Axial Load (without self weight/ buoyancy/ soil).
Qmax = Respective Factored Bearing Capacity.
Final footing dimensions are:
Length of footing, L: 16.070 m
Width of footing, W: 2.950 m
Depth of footing, Do: 0.500 m Area, A : 47.406 sq m

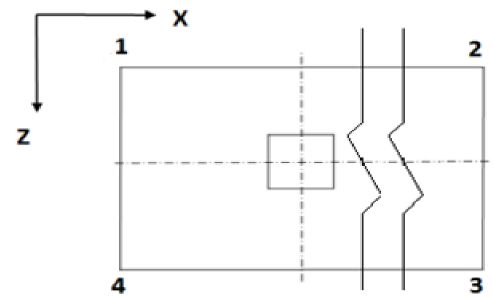

Fig5.

Table3. Calculated Pressures at Four Corners

Load Case	Pressure at corner 1 (q_1) (kN/m^2)	Pressure at corner 2 (q_2) (kN/m^2)	Pressure at corner 3 (q_3) (kN/m^2)	Pressure at corner 4 (q_4) (kN/m^2)	Area of footing in uplift (A_u) (sq. m)
5	97.6443	66.2146	68.1674	99.5972	0.000
5	97.6443	66.2146	68.1674	99.5972	0.000
5	97.6443	66.2146	68.1674	99.5972	0.000
5	97.6443	66.2146	68.1674	99.5972	0.000

Table4. If A_u is zero, there is no uplift and no pressure adjustment is necessary. Otherwise, to account for uplift, areas of negative pressure will be set to zero and the pressure will be redistributed to remaining corners.

Load Case	Pressure at corner 1 (q_1) (kN/m^2)	Pressure at corner 2 (q_2) kN/m^2)	Pressure at corner 3(q_3) (kN/m^2)	Pressure at corner 4 (q_4) (kN/m^2)
5	97.6443	66.2146	68.1674	99.5972
5	97.6443	66.2146	68.1674	99.5972
5	97.6443	66.2146	68.1674	99.5972
5	97.6443	66.2146	68.1674	99.5972

Table5. Check for stability against overturning

Load Case	Moment X (kNm)	Moment Z (kNm)	Resisting Moment X (kNm)	Resisting Moment Z (kNm)	Ratio X	Ratio Z
1	4.852	506.803	1591.950	8672.064	328.122	17.111
2	17.051	519.298	2378.771	12958.232	139.507	24.953
3	4.309	31.729	1928.026	10502.825	447.471	331.016
5	22.758	1995.281	5797.044	31579.098	254.722	15.827
6	2.422	335.815	879.415	4790.570	363.091	14.265
4	15.172	1330.187	4156.042	22639.827	273.924	17.020

Design for Flexure

Sagging moment along length

Critical load case : 5

Effective Depth = $D-(cc+0.5\times d_b)$ = 0.444 m

Governing moment (M_u) = 295.791 kNm

Limiting Factor1 (K_{umax}) = $\frac{700}{(1100+0.87\times f_y)}$ = 0.479107

Limiting Factor2 (R_{umax}) = $0.36\times f_{ck}\times k_{umax}\times(1-0.42\times k_{umax})$ = 3444.291146 kN/m^2

Limit Moment Of Resistance (M_{umax}) = $R_{umax}\times B\times d_e^2$ = 2002.995014 kNm

M_u <= M_{umax} hence, safe

Hogging moment along length

Critical load case : 5

Effective Depth = $D-(cc+0.5\times d_b)$ = 0.444 m

Governing moment (M_u) = 198.236 kNm

Limiting Factor1 (K_{umax}) = $\frac{700}{(1100+0.87\times f_y)}$ = 0.479107

Limiting Factor2 (R_{umax}) = $0.36\times f_{ck}\times k_{umax}\times(1-0.42\times k_{umax})$ = 3444.291146 kN/m^2

Limit Moment Of Resistance (M_{umax}) = $R_{umax}\times B\times d_e^2$ = 2002.995014 kNm

M_u <= M_{umax} hence, safe

Transverse direction

Critical load case : 5

Effective Depth = $D-(cc+0.5\times d_b)$ = 0.444 m

Governing moment (M_u) = = 1244.256 kNm

Limiting Factor1 (K_{umax}) = $\frac{700}{(1100+0.87\times f_y)}$ = 0.479107

Limiting Factor2 (R_{umax}) = $0.36\times f_{ck}\times k_{umax}\times(1-0.42\times k_{umax})$ = 3444.291146 kN/m^2

Limit Moment Of Resistance (M_{umax}) = $R_{umax}\times B\times d_e^2$ = 10911.212337 kNm

M_u <= M_{umax} hence, safe

Check trial depth for one way shear(along length)

Critical load case for maximum shear force along the length of footing : 5

Shear Force(S) = 313.289 kN

Shear Stress(T_v) = 239.188494 kN/m^2

Percentage Of Steel(P_t) = 0.1443

Shear Strength Of Concrete(T_c) = 285.963 kN/m^2

T_v< T_c hence, safe

Check trial depth for two way shear

Critical Load case for Punching Shear Check : 5

Shear Force(S) = 496.227 kN

Shear Stress(T_v) = 356.387 kN/m^2

K_s = $\min[(0.5+\beta),1]$ = 1.000

Shear Strength(T_c)= $0.25\times\sqrt{f_{ck}}$ = 1250.0000 kN/m^2

K_s X T_c = 1250.0000 kN/m^2

T_v<= K_s X T_c hence, safe

Critical Load case for Punching Shear Check : 5

Shear Force(S) = 804.775 kN

Shear Stress(T_v) = 577.984 kN/m^2

K_s = $\min[(0.5+\beta),1]$ = 1.000

Shear Strength(T_c)= $0.25\times\sqrt{f_{ck}}$ = 1250.0000 kN/m^2

K_s X T_c = 1250.0000 kN/m^2

T_v<= K_s X T_c hence, safe

Critical Load case for Punching Shear Check : 5

Shear Force(S) = 690.498 kN

Shear Stress(T_v) = 495.911 kN/m^2

K_s = = 1.000

Shear Strength(T_c)= = 1250.0000 kN/m^2

K_s X T_c = 1250.0000 kN/m^2

hence, safe

Critical Load case for Punching Shear Check : 5

Shear Force(S) = 625.600 kN

Shear Stress(T_v) = 449.302 kN/m^2

K_s = = 1.000

Shear Strength(T_c)= = 1250.0000 kN/m^2

K_s X T_c = 1250.0000 kN/m^2

hence, safe

Critical Load case for Punching Shear Check : 5

Shear Force(S) = 512.955 kN

Shear Stress(T_v) = 407.371 kN/m^2

Selection of reinforcement

Top reinforcement along length

Minimum Area of Steel (A_{stmin}) = 1770.000 mm2

Calculated Area of Steel (A_{st}) = 1256.644 mm2

Provided Area of Steel ($A_{st,Provided}$) = 1770.000 mm2

A_{stmin} <= $A_{st,Provided}$ Steel area is accepted

Selected bar Size (d_b) = Ø12

Minimum spacing allowed (S_{min}) = 50.000 mm

Selected spacing (S) = 189.200 mm

S_{min} <= S <= S_{max} and selected bar size < selected maximum size.. The reinforcement is accepted.

Along width

Minimum Area of Steel (A_{stmin}) = 9641.984 mm2

Selected bar Size (d_b) = Ø12

Minimum spacing allowed (S_{min}) = 50.000 mm

Selected spacing (S) = 187.741 mm

S_{min} <= S <= S_{max} and selected bar size < selected maximum bar size.. The reinforcement is accepted.

Bottom reinforcement along length

Minimum Area of Steel (A_{stmin}) = 1770.000 mm2

Calculated Area of Steel (A_{st}) = 1890.490 mm2

Provided Area of Steel ($A_{st,Provided}$) = 1890.490 mm2

A_{stmin}<= $A_{st,Provided}$ Steel area is accepted

Selected bar Size (d_b) = Ø12

Minimum spacing allowed (S_{min}) = = 50.000 mm

Selected spacing (S) = 177.375 mm

S_{min} <= S <= S_{max} and selected bar size < selected maximum bar The reinforcement is

Along width

Minimum Area of Steel (A_{stmin}) = 9641.984 mm2

Calculated Area of Steel (A_{st}) = 7907.358 mm2

Provided Area of Steel ($A_{st,Provided}$) = 9641.984 mm2

A_{stmin}<= $A_{st,Provided}$ Steel area is accepted

Selected bar Size (d_b) = Ø12

Minimum spacing allowed (S_{min}) = = 50.000 mm

Selected spacing (S) = 187.741 mm

= S <= S_{max} and selected bar size < selected maximum bar size...

The reinforcement is accepted.

Along width

Minimum Area of Steel (A_{stmin}) = 9641.984 mm2

Calculated Area of Steel (A_{st}) = 7907.358 mm2

Provided Area of Steel ($A_{st,Provided}$) = 9641.984 mm2

A_{stmin}<= $A_{st,Provided}$ Steel area is accepted

Selected bar Size (d_b) = Ø12

Minimum spacing allowed (S_{min}) = = 50.000 mm

Selected spacing (S) = 187.741 mm

= S <= S_{max} and selected bar size < selected maximum bar size...

The reinforcement is accepted.

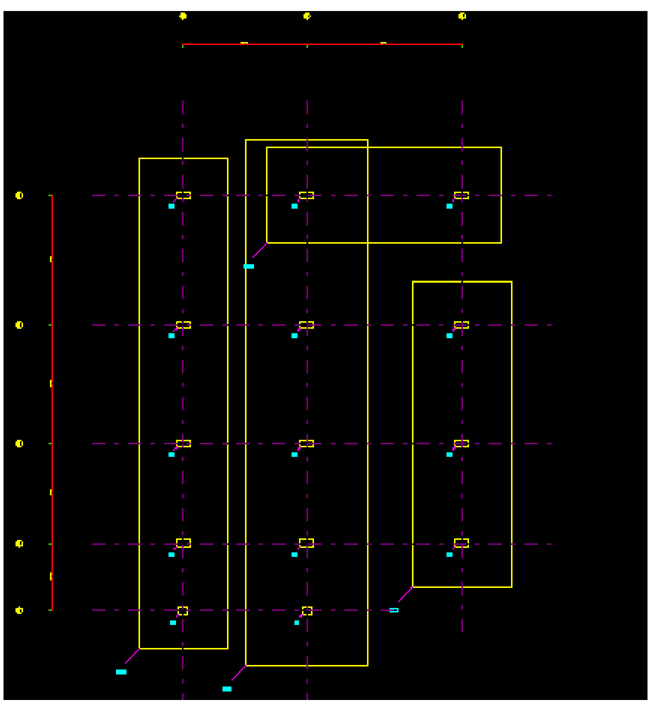

Fig6.

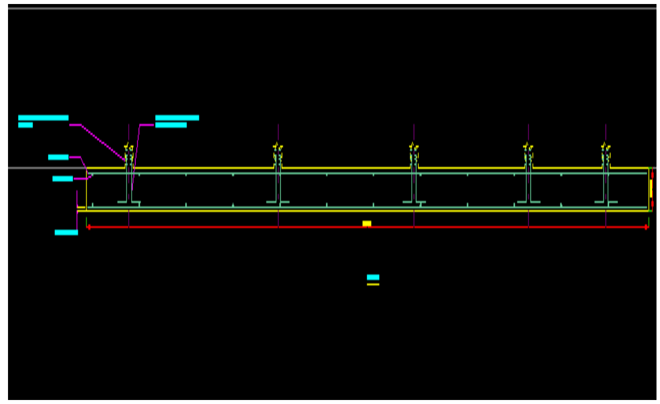

Fig7.

Table6.

Footing No.	Left Overhang (m)	Right Overhang (m)	Length (m)	Width (m)	Thickness (m)
1	1.225	1.225	16.070	2.950	0.500
2	1.800	1.800	17.220	4.100	0.500
3	1.325	1.325	7.870	3.150	0.500
4	1.425	1.425	10.000	3.350	0.500

Table7.

Footing No.	Footing Reinforcement			
-	Main Steel Top	Main Steel Bottom	Secondary Steel Top	Secondary Steel Bottom
1	Ø12 @ 185 mm c/c	Ø12 @ 175 mm c/c	Ø12 @ 185 mm c/c	Ø12 @ 185 mm c/c
2	Ø12 @ 185 mm c/c	Ø12 @ 60 mm c/c	Ø12 @ 185 mm c/c	Ø12 @ 110 mm c/c
3	Ø12 @ 105 mm c/c	Ø12 @ 185 mm c/c	Ø12 @ 185 mm c/c	Ø12 @ 185 mm c/c
4	Ø12 @ 140 mm c/c	Ø12 @ 190 mm c/c	Ø12 @ 185 mm c/c	Ø12 @ 170 mm c/c

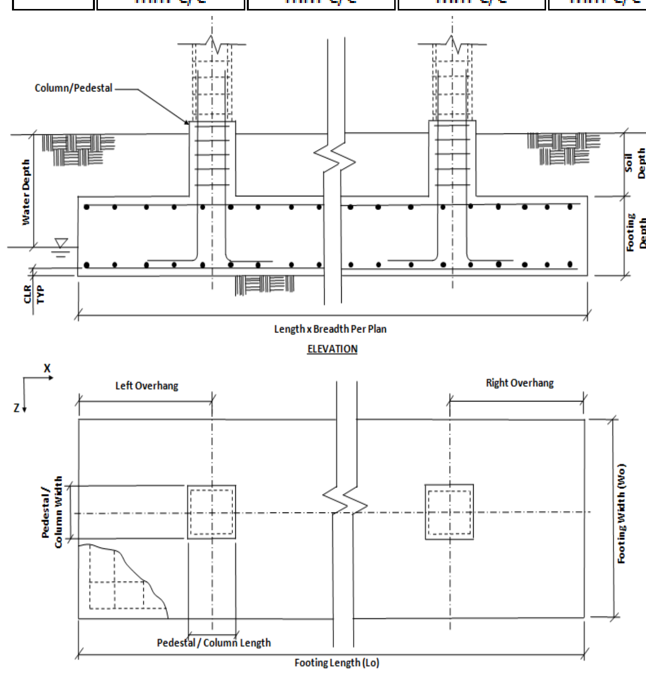

Fig8.

VI. CONCLUSION

The design of beam, column, combined footing and staircase are done in limit state method which is safe at control of deflection and in all aspects Using staad.pro & stadd foundation software, the design consideration has been taken as per the IS codes. The design is safe in all conditions on comparison with drawing. Manual design and the geometrical model using staad.pro the area of AST required for the beam, column, footing and slab are comparatively similar to that of the requirement.

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