Design Single Footing for Multi-Story Building by Auto Desk Robot

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ABSTRACT

In this research a model of reinforced concrete building of 9 story has been analyzed and designed by using Autodesk robot of 2018 according to ACI-code provisions, then the loads at the base of the building are utilized to design two types of footing for the building which are single isolated and combined footing using Autodesk Robot 2018 and hand calculation. The results show that there is a little difference between the two methods that are used to design the footings. But using Autodesk Robot can be beneficial to save time and ease of the work. Autodesk Robot 2018 is very efficient and power software for analysis, design, detailing and documentation for concrete and steel structures as well.

Keywords: *RC Building, Autodesk robot of 2018, ACI-code, Single Isolated Footing,*

1. Introduction

Engineering that is specifically focused on designing cost-effective and efficient load-bearing structures is known as structural engineering. Buildings, bridges, walls, dams, and tunnels are just a few examples of the large structures that are essential to everyday life and are designed using mechanics. In order for structures to perform their required purposes, structural engineers must create them in a way that prevents them from collapsing or performing adversely. The process of choosing the position, kind, and dimensions of structural components to withstand forces acting on a structure is known as structural design. The super structure, which is located above the plinth level, and the substructure, which is located below the plinth, are the two main components of a structure. The substructure, also referred to as the foundation, serves as the framework for all structures. "Foundation dirt" refers to the soil that the foundation is built upon. The superstructure is the term used to describe the portion of a building that rises above the foundation and the ground. The soil below the foundations supports them in turn. Soil also serves as the structure's foundation and carries all of the structure's weight.

There are two types of footing s according to depth of the footing from G.L shallow and deep footings. In this project the selected footings for the building under study was shallow footings (single and combined) .The design of the footings first done by hand calculations according to ACI-2014 code ,then the design of same footings were repeated by using Auto-desk Robot 2108 .Auto desk Robot 2108 is very important and accurate software is used to analysis and design of concrete and steel buildings .The Robot 2108 soft introduce large data of analysis and design with civil drawings including reinforcement details in Auto cad format . Also the Robot 2108 soft introduce estimation data for quantities. The main aims of the project can be summarized below:

Learn how to make model of multi-story R.C building by Auto desk Robot. Analysis and display the results in graphs and tables. Design footing of the structure by robot and comparing them with hand calculation. Preparation civil drawing for reinforcement detail for footing. Make complete report for the project to be submitted for evaluation as graduation requirement.

2. Background

P. Rajaram, A. Murugesan, G.S. Thirugnanam (2010) evaluated on RC's behaviour It carries the beam column joint that is subjected to cyclic loading. Beam column joints are a crucial part of reinforced concrete moment resisting frames and should be carefully planned and detailed, particularly when the frame is being loaded by earthquakes. Bond and shear failure mechanisms, which are brittle in nature, control the breakdown of beam column joints during earthquakes. As a result, a modern international code places a high value on providing adequate longitudinal bar anchorage and concrete core confinement in resisting shear. Codes stipulate special ductility criteria in order to reduce earthquake forces. IS 13920:-1993 provides information on how to achieve ductility in reinforced concrete structures. The analysis and design of two bay, five-story R.C.C. moment-resisting frames for general buildings using ETABS in accordance with IS 1893-2002 code procedures and specifically as recommended by IS 13920-1993 are discussed in this study.

M. S. Aainawala et al. (2014) performed the comparison of shear walls in multi-story R.C.C. buildings. For various scenarios of shear wall position, they applied the earthquake load to a building for G+12, G+25, and G+38 located in zones II, III, IV, and V, respectively. In each scenario, they estimated the lateral displacement and story drift. It was found that multi-story R.C.C. buildings with shear walls are more cost-effective than those without. According to analysis, displacement at various levels is significantly less in multi-story buildings with shear walls than in R.C.C. buildings without shear walls. This is significant for shear wall utilisation and building design.

Prakash Sangamnerkar et al. (2015) studied the comparison of the static and dynamic performance of regularly framed reinforced concrete buildings. Comparison of static and lively behaviour of a six storey's structure is studied in this study and it is analysed by using computerised solution available in all four seismic zones i.e. II, III, IV and V. This is crucial for earthquake resistance and building design.

Mohit Sharma et. al. (2015) considered a Regular reinforced concrete framed structure with G+30 stories. A multi-storey building underwent a dynamic examination. These structures have a plan area of 25 x 45 metres, each storey is 3.6 metres tall, and the depth of the foundation is 2.4 metres. The overall height of the chosen structure, including the depth of the foundation, is 114 metres. STAAD-Pro software was used to perform the static and dynamic analysis on a computer utilising the design parameters specified in IS-1893-2002-Part-1 for Zones 2 and 3. The values of axial forces as determined by static and dynamic analysis were found to be relatively similar.

3. Methods of analysis and design of the single and combined footing according to ACI- 2014 code

3.1 Structural Design of Single Footings

Structural analysis and reinforced concrete principles to design of single footings like finding dimensions of footing, reinforcement requirements, shear requirements, and checking column-footing bearing stress.

The producer of design is based on analysis of footing by Conventional Rigid Method by aids of ACI-2014 code requirements.

Design Procedure of Single footings

Step 1: Find or check the footing dimensions (B, L) according using un-factored loads:

*$q_c = \Sigma P/A$ where ΣP = D + L un-factored loads, A = area of the footing

or $q_c = \Sigma P/A \pm 6_{ex}/B \pm 6_{ey}/L$ if the load is eccentric $e_x = M_y/\Sigma P$ and $e_y = M_x/\Sigma P$

Check for safety $q_c < q_{all}$ of soil

Step 2: Calculate ultimate contact pressure on soil (q_{cu}) using factored loads:

$q_u = \Sigma P_u/A$ where ΣP_u = 1.2D+ 1.6L un-factored loads, A= area of the footing

Or $q_u = \Sigma Pu/A \pm 6e_x/B \pm 6e_y/L$ if the load is eccentric $e_x = M_{uy}/\Sigma P_u$ $e_y = M_{ux}/\Sigma P_u$

Step 3: find or check the thickness of the footing by shear 3.1 Wide shear requirements: calculate shear stress vu at section of distance (d) from col. Face

$v_u) \, w = qu \, . \, X_1/d \leq \phi v_c$

a) Punching shear requirements: shear stress vu at section of (d/2) around the col

$v_u) = P_u - q_u \, (a+d)(b+d)(2(a+d)+2(b+d))d \leq \phi v_c$

d = is effective depth of section = T - 0.1 T thickness of footing in m

Step 4: Find maximum moment at face of column

Find max ultimate moment at face of column

$M_u = q_u \, . x_2^2 \, /2$

Use basic of reinforced concrete to find required steel A_s for section 1m x T

$M_u = \phi \, b \, d^2 \, f_y \, \rho(1 - 0.59 \, \rho f_y / f'_c)$

$A_s = \rho * b * d$

Then check the found A_s, $\rho = \rho_{min} \leq \rho = \rho_{max}$

Step 5: other checks

Check the bearing stress between column and footing

Check the development length of reinforcement bars L_d

Note: this procedure is right for all type of single footings for rectangular footing the procedure is repeated in other direction while in square and strip or wall footing one direction is enough.

Step 6: Draw reinforcement details by AutoCAD

Note: this procedure is right for all type of single footings for rectangular footing the procedure is repeated in other direction while in square and strip or wall footing one direction is enough.

4. Modelling by Robot 2108 for Analysis

4.1 Description the model of the Project

The project involves multi-story concrete building of 9 story using Autodesk Robot 2018 as shown in Fig 1

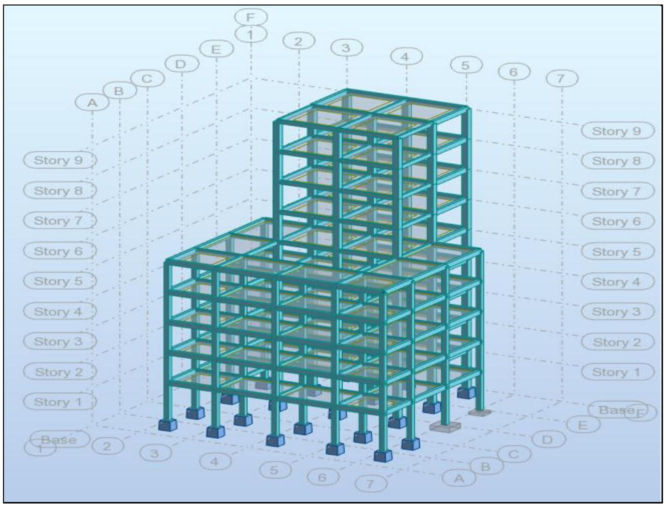


Fig 1: 3D Model of Building

4.2 Story Data

The building consists of 9 stories with details shown in table 1

Name	Top Level	Hight
Story 1	4	4
Story 2	7.2	3.2
Story 3	10.4	3.2
Story 4	13.6	3.2
Story 5	16.8	3.2
Story 6	20	3.2
Story 7	23.2	3.2
Story 8	26.4	3.2
Story 9	29.6	3.2

Table 1: Story data

4.3 Plans

The plan of different story of the building under the study is shown in figures 2 & 3.

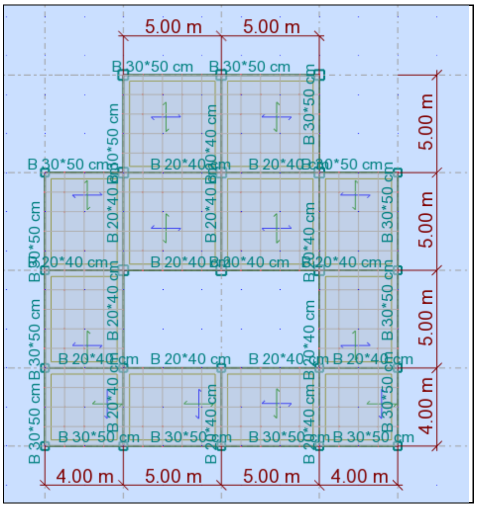


Fig 2: Plan Story 1-5

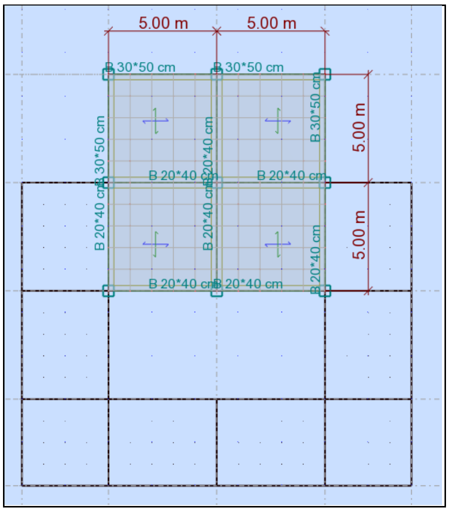


Fig 3: Plan Story 6-9

4.4 Concrete sections

The size and shape of different concrete section used in modelling are as below:

Columns:

1) (50*50 cm)

2- (40*40 cm)

Beams:

Outer: 30*50 cm

Inner: 20*40 cm

Slabs: 16 cm

4.5 Loads

1- Additional dead = 1.5 KN/m^2

(Portions, tiles, pipes, ducts, cables)

2 - Live load = 2.5 KN/m^2

4.5.1 Load Combinations

1- Service: $SDD_aL=1D+1D_a+1L$

2- Ultimate: $1.2D+1.2D_a+1.6L$

4.6 Foundation Soil Properties

The foundation soil under the footing as in fig is saturated gravelly sand of

γ_{sat}= 22.8 kN/m^3

ϕ = 30 ,

C = 0 kP_a

And the water table is at footings base level

5.1 Analysis the model and results

The model of building is analysed by Robot 2108 for loads and load combinations according to ACI-2104 code. The important result of analysis of course are the reaction under columns support at footings level .Fig 4.5(3D), Fig. 4.6 (plan) and table 4.2 show the reaction values at different columns at different loadings and load combination which will be used in next chapter for design the footings.

5.1.1 Reaction under the column supports at level of Footings

The analysis of the structure is done by Autodesk Robot 2018 where the reaction under the columns for load combinations are presented in table 2

column	SDDaL (kN)	UDDaL (kN)	size of column (m)	
1	362,66	462,45	0,4	0,4
3	563,66	726,47	0,4	0,4
5	509,12	655,75	0,4	0,4
7	286,67	363,96	0,4	0,4
9	511,2	658,57	0,4	0,4
11	569,99	735,54	0,4	0,4
13	511,2	658,57	0,4	0,4
15	286,67	363,96	0,4	0,4
17	509,12	655,75	0,4	0,4
19	563,66	726,47	0,4	0,4
21	362,66	462,45	0,4	0,4
23	688,46	894,85	0,4	0,4
25	526,37	682,08	0,4	0,4
27	688,46	894,85	0,4	0,4
29	1141,55	1477,88	0,5	0,5
33	1211,01	1569,91	0,5	0,5
35	1141,55	1477,88	0,5	0,5
37	1402,06	1816,5	0,5	0,5
39	2002,89	2616,09	0,5	0,5
41	1402,06	1816,5	0,5	0,5
43	819,51	1045,4	0,5	0,5
45	1217,52	1569,79	0,5	0,5
47	819,51	1045,4	0,5	0,5

Table 2: Column reactions under load combinations

5.1.2 Other Results

Some other results like deformation, moment, shear of columns, beams and slabs also can be found by Robot and shown in figures 4, 5, 6 and 7.

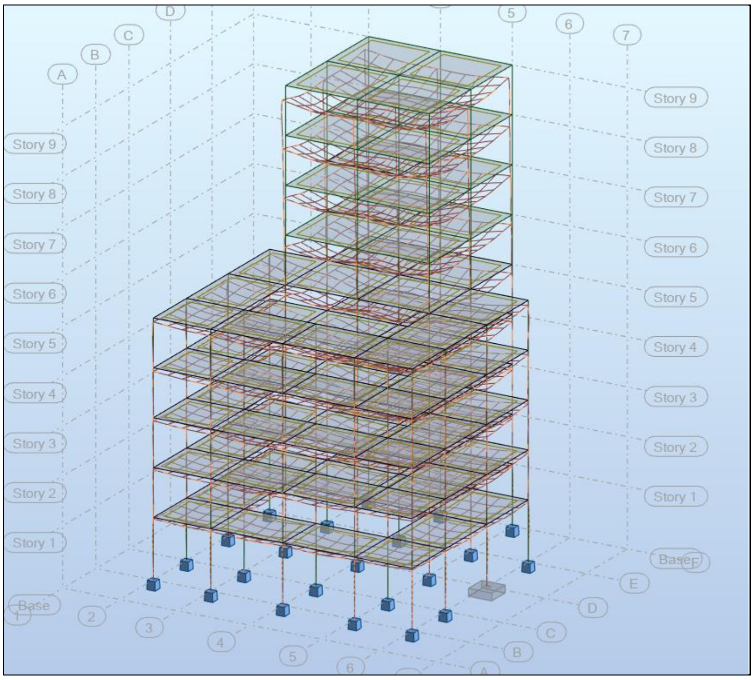


Fig 4 : Deformation of the model under SDD$_a$l

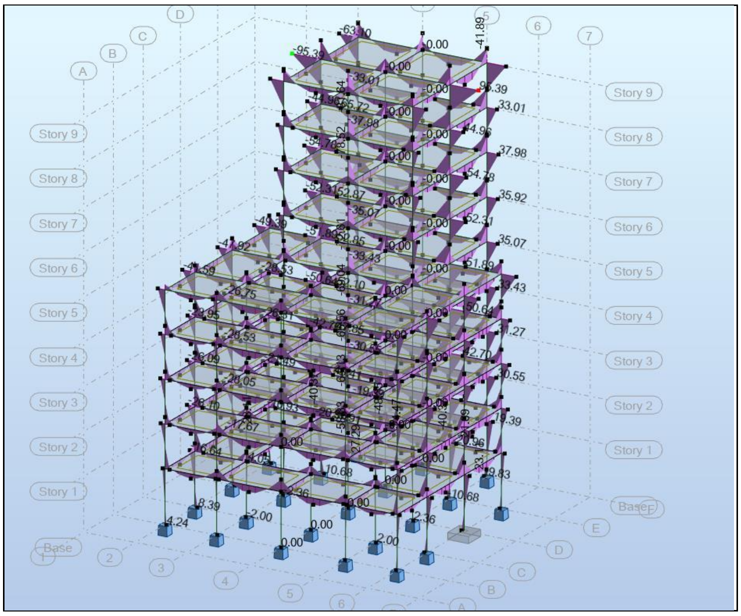


Fig 5: Moment of the model under UDD$_a$L

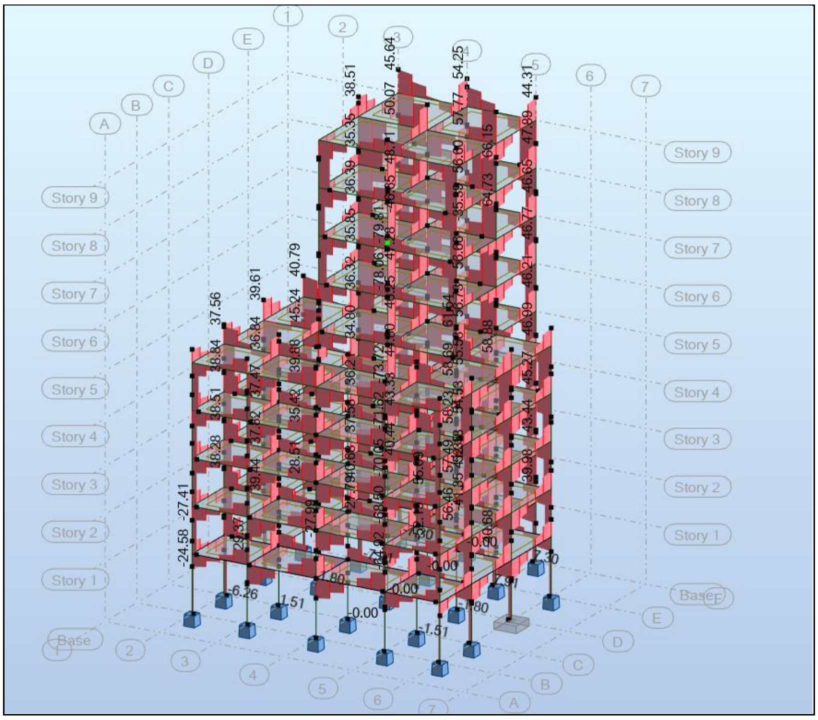


Fig 6: Shear of the model under UDD$_a$L

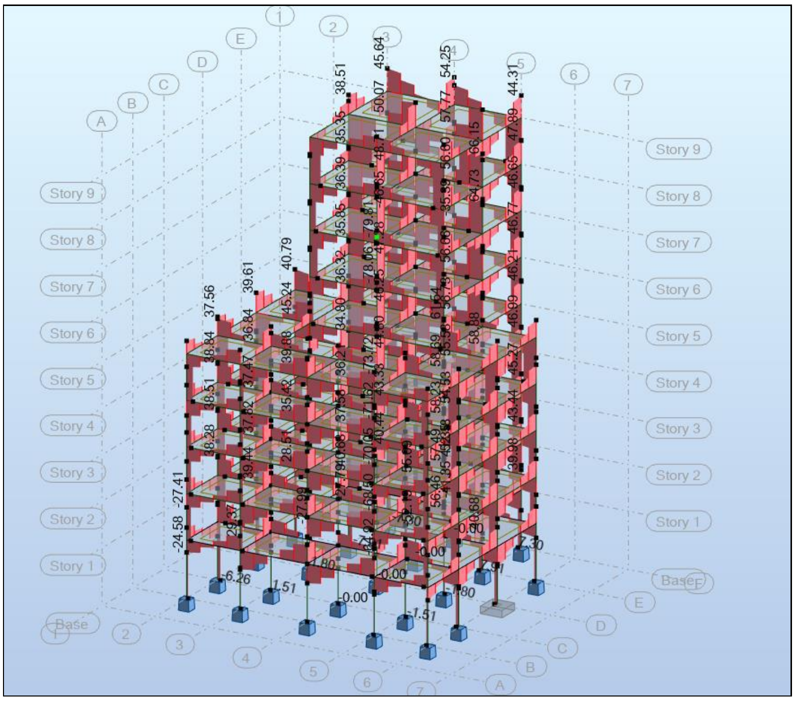


Fig 7: Shear of the model under UDD$_a$L

5. Design of Footings

The type of footings and design these footing by hand calculations then by Robot 2108 according to ACI-2014 Code. Then preparation reinforcement detail drawings for footing using Robot 2018.

5.1 Type of footings

According to reaction under columns supports from chapter 4 the following footing type are suggested as illustrated in fig 8 and 9.

Table 3: Reactions under Column from Robot 2018

column	SDDaL (kN)	UDDaL (kN)	size of column (m)	
1	362,66	462,45	0,4	0,4
3	563,66	726,47	0,4	0,4
5	509,12	655,75	0,4	0,4
7	286,67	363,96	0,4	0,4
9	511,2	658,57	0,4	0,4
11	569,99	735,54	0,4	0,4
13	511,2	658,57	0,4	0,4
15	286,67	363,96	0,4	0,4
17	509,12	655,75	0,4	0,4
19	563,66	726,47	0,4	0,4
21	362,66	462,45	0,4	0,4
23	688,46	894,85	0,4	0,4
25	526,37	682,08	0,4	0,4
27	688,46	894,85	0,4	0,4
29	1141,55	1477,88	0,5	0,5
33	1211,01	1569,91	0,5	0,5
35	1141,55	1477,88	0,5	0,5
37	1402,06	1816,5	0,5	0,5
39	2002,89	2616,09	0,5	0,5
41	1402,06	1816,5	0,5	0,5
43	819,51	1045,4	0,5	0,5
45	1217,52	1569,79	0,5	0,5
47	819,51	1045,4	0,5	0,5

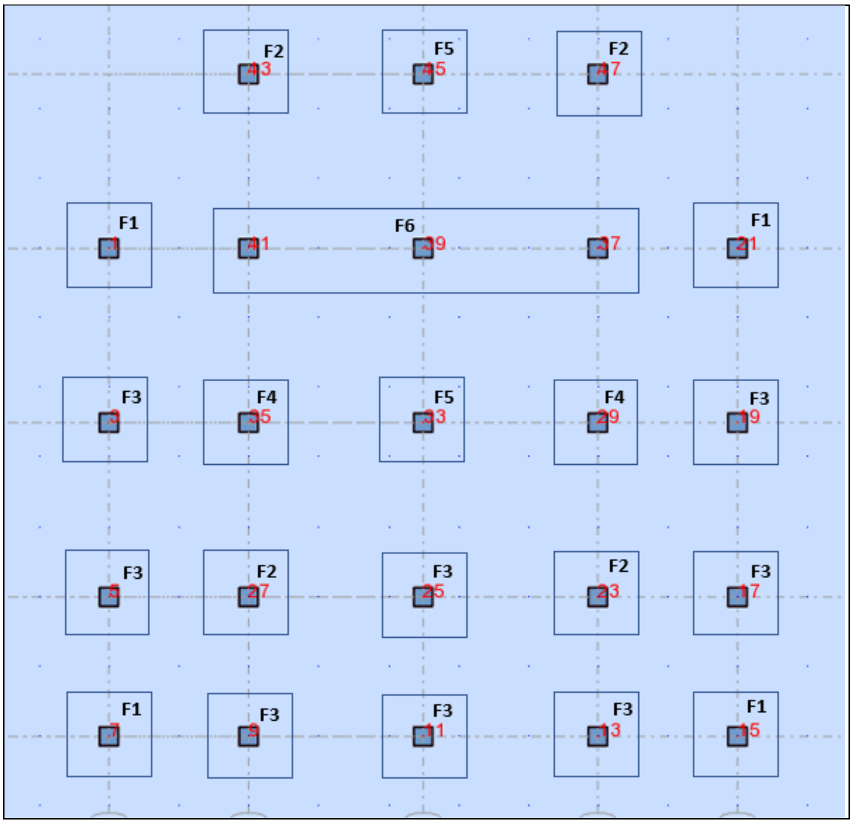


Fig 8: Plan for suggested Footings

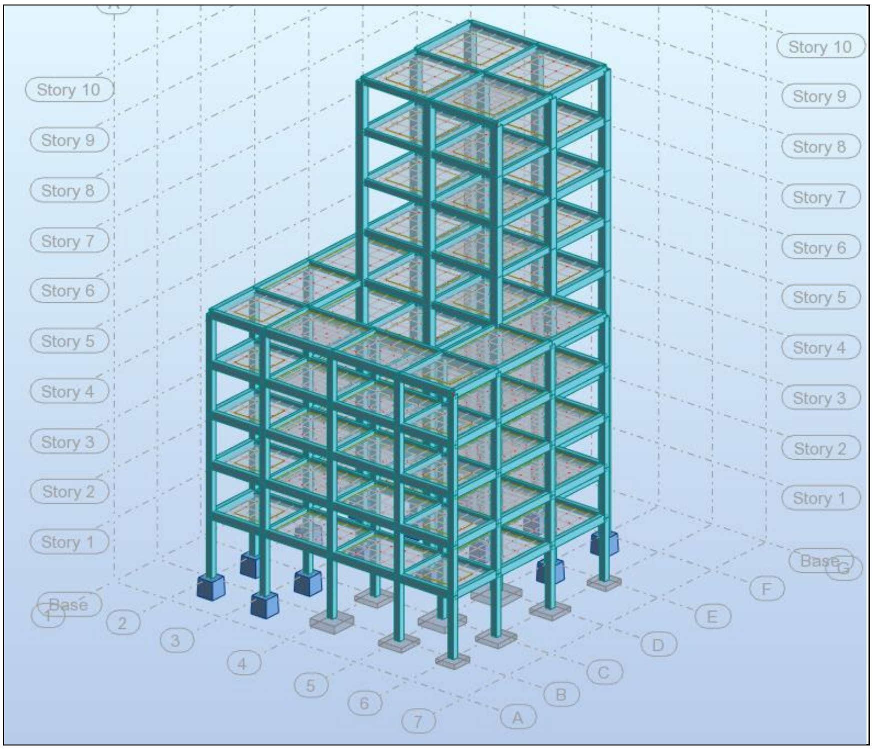


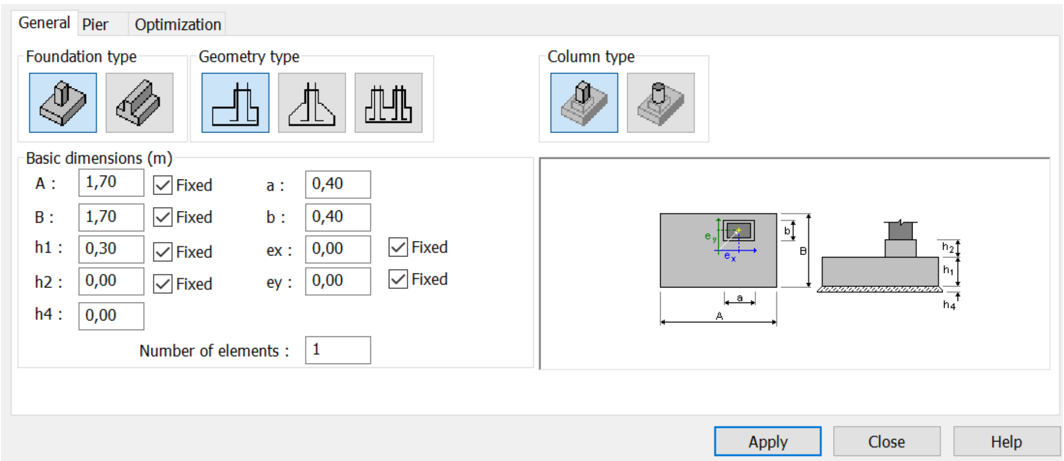
Fig 9: 3D View for Shape and Size of suggested Footing

Where 5 single footing of different sizes and 1 combined footing are suggested for the design as detailed in table 4

Table 4: Type of suggested footings under columns

Footing symbol	Type	Column no.
F1	Single	7,15,1,21
F2	Single	23,27,47,43
F3	Single	3,5,11,9,17,19,25
F4	Single	29,35
F5	Single	33,45
F6	Combined	37,39,41

5.2 Design of single footings by Robot 2018



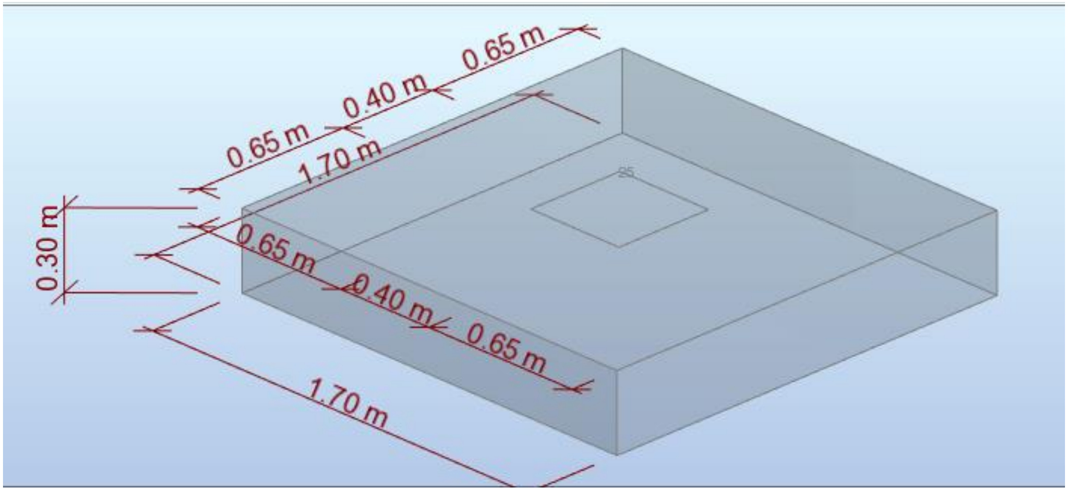


Fig 10: Size and shape of footing column number 3, 5, 9, 11, 17, 19, 25

Design combinations:

	State		Name	Description
1	ULS		UDDa	N=682,08 Mx=-8,03 Fy=6,17
2	SLS		SDDa	N=526,37 Mx=-6,09 Fy=4,68
3	ULS	*	UDDa	N=682,08 Mx=-8,03 Fy=6,17
4	SLS	*	SDDa	N=526,37 Mx=-6,09 Fy=4,68

Global coefficients:

	Capacity	1.007	>	1
	Contact surface	3.739	>	1
	Stability for sliding	105.4	>	1
	Average settlement	44.84	>	1
	Settlement difference	7.462e	>	1
	Stability for rotation	62.13	>	1

5.3 Bearing Capacity checking for F1 under col

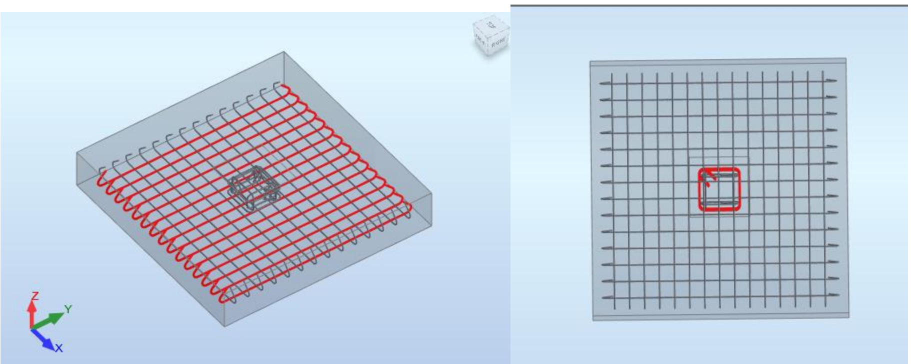
Global coefficients:

⇨	Punching/Shear	1.074	>	1
		M (kN*m)		A (mm2/m)
⇨	Bottom reinforcement - X	101.14		628
⇨	Bottom reinforcement - Y	104.87		652
	Top reinforcement - X	0.00		0
	Top reinforcement - Y	0.00		0

Combination coefficients:

Design combinations:

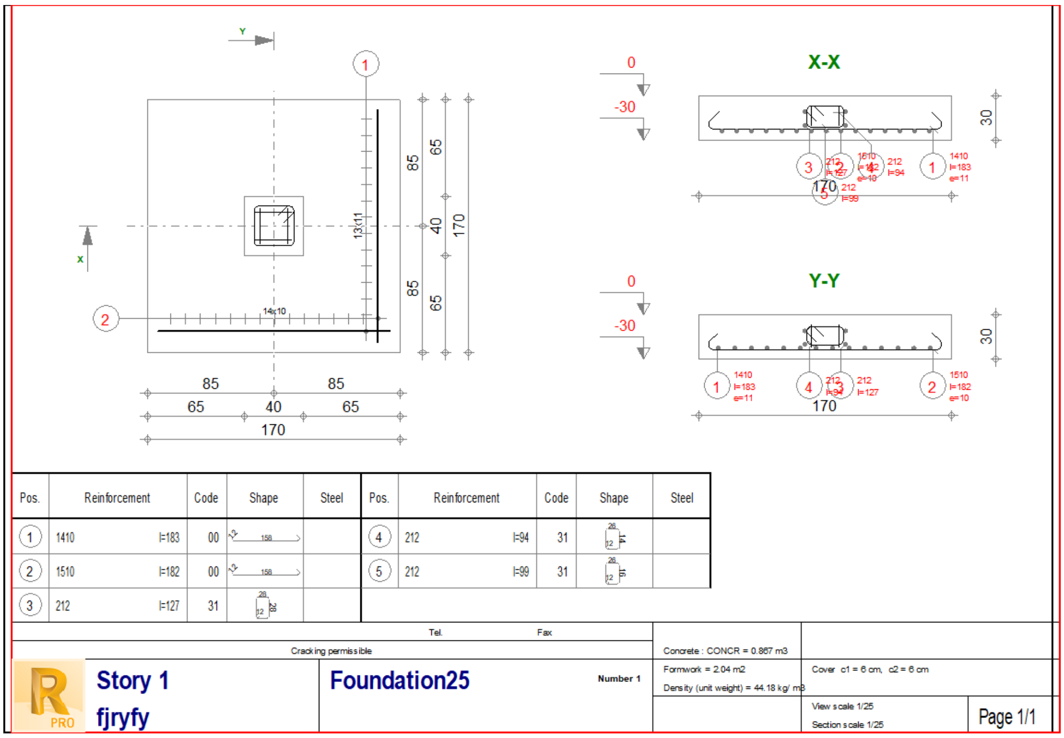
	State		Name	Description
1	ULS		UDDaL	N=682.08 Mx=-8.03 Fy=6.17
2	SLS		SDDaL	N=526.37 Mx=-6.09 Fy=4.68
3	ULS	*	UDDaL	N=682.08 Mx=-8.03 Fy=6.17
4	SLS	*	SDDaL	N=526.37 Mx=-6.09 Fy=4.68



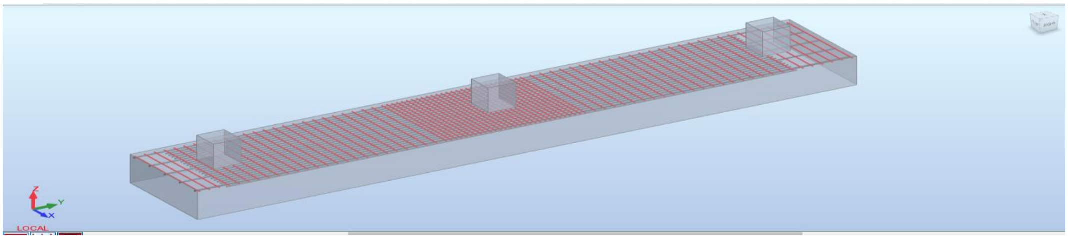
General | Detailed | Summary table

	No.	Reinforcement Type	Steel Grade	Diameter (mm)	Shape Code	Number	(m)	(m)	(m)	(m)
1	1	bottom in the X directi		10	00	14	A = 1,5			
2	2	bottom in the Y directio		10	00	15	A = 1,5			
3	3	transversal		12	31	2	A = 0,2	B = 0,2	C = 0,2	D = 0,2
4	4	transversal		12	31	2	A = 0,2	B = 0,1	C = 0,2	D = 0,1
5	5	transversal		12	31	2	A = 0,2	B = 0,1	C = 0,2	D = 0,1

5.4 Civil drawings of a footing as a sample



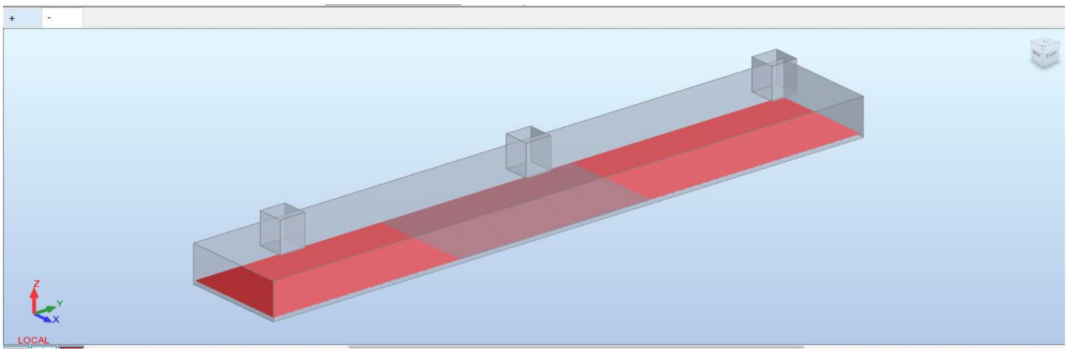
5.5 Design of combined footings by Robot 2018



General | Detailed | Summary table | Wire fabrics - general | Wire fabrics - detailed

	No.	Reinforcement Type	Steel Grade	Diameter (mm)	Shape Code	Number	Spacing (m)	(m)
		Plate504						
1	1	top in the X direction		14	00	81		A = 1,9
2	2	top in the Y direction		32	00	17		A = 10,
3	3	top in the Y direction		32	00	5		A = 11,
4	4	bottom in the X directi		16	00	95		A = 1,9
5	5	bottom in the Y directio		8	00	146		A = 3,8
6	6	bottom in the Y directio		8	00	49		A = 11,

Fig 11: Steel details for top of combined footing column number 37, 39, 41

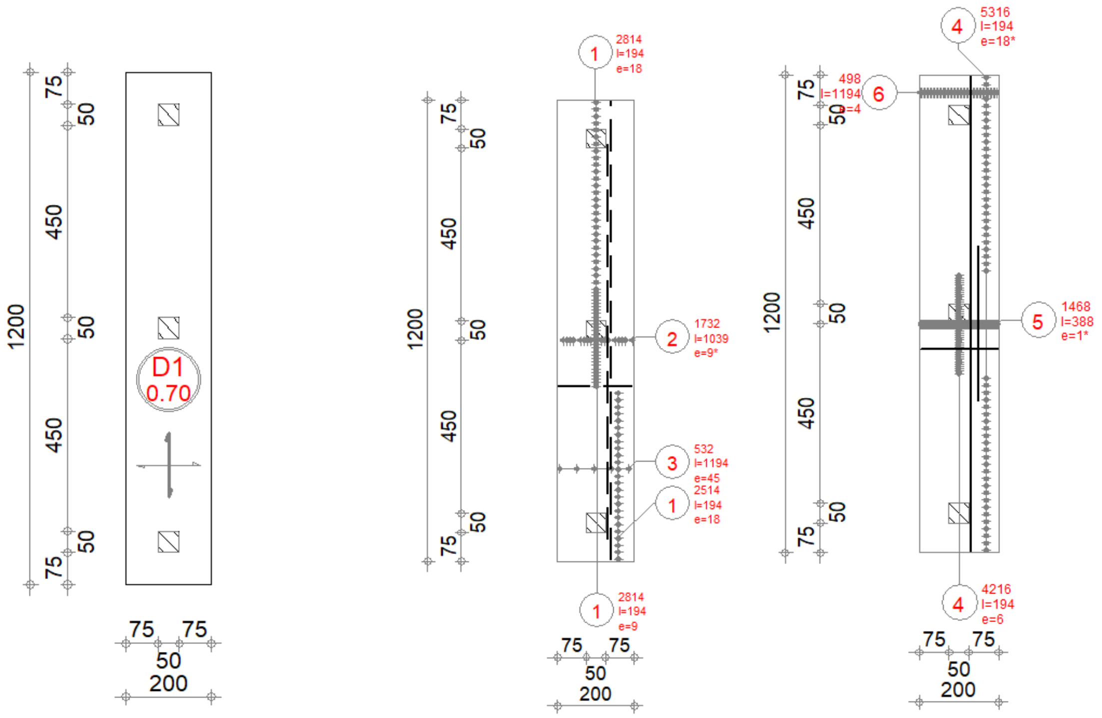


General | Detailed | Summary table | Wire fabrics - general | Wire fabrics - detailed

	No.	Reinforcement Type	Steel Grade	Diameter (mm)	Shape Code	Number	(m)
1	1	top in the X direction		14	00	81	A = 1,9
2	2	top in the Y direction		32	00	17	A = 10,
3	3	top in the Y direction		32	00	5	A = 11,
4	4	bottom in the X directi		16	00	95	A = 1,9
5	5	bottom in the Y directio		8	00	146	A = 3,8
6	6	bottom in the Y directio		8	00	49	A = 11,

Fig 12: Steel details for bottom of combined footing column number 37, 39, 41

5.6 Civil drawings of a footing as a sample



Pos.	Reinforcement		Code	Shape	Steel
1	8114	l=194	00	194	
2	1732	l=1039	00	1039	
3	532	l=1194	00	1194	
4	9516	l=194	00	194	
5	1468	l=388	00	388	
6	498	l=1194	00	1194	

6. Conclusions and recommendations

Conclusions

The following points can be concluded the full detailed design of single footing by hand calculation are done according to ACI- 2104 code. The design of footings by Robot 2018 is done for comparison of results with hand calculation. The comparison of results between hand calculation and Robot 2018 shown very good vergence where. Design of footings by Robot 2018 can do design of very large number of footings in very short time resulting saving in time. Design of footings by Robot 2018 introduces very large data of analysis and design results with steel detailing while the results in word documentation can be saved and the drawings can be saved in Auto cad format. The amount of material needed will be reduced according to manual and computational calculations, making the construction both safe and healthy for the environment.

Recommendations

The following points are recommended for the future works:

1) For more detailed geometry it is recommended to add core shear walls for stair and elevators

2) Adding extra loading like wind and seismic to generalize the case.

3) As Robot 2018 has ability to produce civil drawing and detailing, so it is recommended to submit set of drawing for the project

4) As Robot 2018 has ability to produce a lot of details of calculation, so it is recommended to submit complete documentations involving input data, analysis results and design calculation.

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