Analysis and Design of G+3 Residential Building using STRUDS

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Abstract - *The process of structural planning and design requires not only imagination and conceptual thinking but also sound knowledge of science of structural engineering besides the knowledge of practical aspects, such as recent design codes, bye laws, backed up by ample experience, intuition and judgment. It is emphasized that any structure to be constructed must satisfy the need efficiently for which it is intended and shall be durable for its desired lifespan.*

STRUDS software is used to analyze and design the G+3 residential building. The purpose of using the software is that it is user friendly and has unique features like it designs the structural components individually along with their analysis and results. Another useful feature of this software is that Shear force, Bending moment, Torsion diagrams at each level of the building can be viewed. The AutoCAD plan along with its specification from the construction site is selected. After studying the plan and its criteria designing the structural components of building namely slabs, beams, columns and footings are carried out. This is followed by manual design and comparisons of results obtained through software.

***Key Words*: STRUDS1, Analysis2, Design3, Slabs4, Beams5, Columns6, Footings7.**

1. INTRODUCTION

The design process of structural planning and design requires not only imagination and conceptual thinking but also sound knowledge of science of structural engineering besides the knowledge of practical aspects, such as recent design codes, bye laws, backed up by ample experience, intuition and judgment. The purpose of standards is to ensure and enhance the safety, keeping careful balance between economy and safety. The process of design commences with planning of the structure, primarily to meet its functional requirements. It is emphasized that any structure to be constructed must satisfy the need efficiently for which it is intended and shall be durable for its desired life span.

Need for the design is to plan a structure, which meets the basic requirements of structural design are as follows:

- Serviceability
- Safety
- Strength
- Durability
- Economy
- Aesthetic appearance
- Feasibility, practicability and acceptability
- All the component members are to be arranged so that they transmit their self-weight and other superimposed loads to foundation or supporting structure by cheapest means to satisfy the requirements of architecture and structural stability.

2. STRUDS

It is abbreviated for "STRUCTURAL ANALYSIS DESIGN AND DETAILING SOFTWARE". This software performs structural analysis for vertical as well as horizontal [seismic/wind] loads for RC framed structures and performs design as per IS norms.

Following are the salient features of STRUDS.

- Design of multi-storey and high rise reinforced concrete buildings quickly and easily.
- Design all building components including slabs, beams, columns, shear walls and foundations
- Apply a variety of loads like UDL, point loads and external moments to the model
- Design steel trusses supported by concrete columns
- Perform seismic analysis as per IS:1893
- Generate detailed CAD drawings, design schedules, BOQ and calculation reports
- Import and export building models with other structural software
- Perform advanced 3D space frame analysis, with optional plane grid and plane frame analysis
- Perform wind load analysis to code IS:875
- Apply seismic analysis by response spectrum analysis
- Consider floor diaphragm effect in analysis
- Perform torsion analysis due to eccentricity between center of mass and center of rigidity
- Undertake shear wall analysis
- Produce analysis results for forces and displacements
- Produce clear diagrams for shear force, bending moment and deflections
- Product written and graphical representation for end moments and end reactions
- Produce detailed calculation reports

- Prepare floor-wise design schedules for all components
- Adopt ductile detailing as per IS:13920 and normal detailing as per SP-34
- Generate multi-layered DXF drawings for slabs, beams, columns, shear walls and footings
- Produce BOQ / material lists of concrete and steel components including slabs, beams, columns, foundations.
- Export models to other structural software

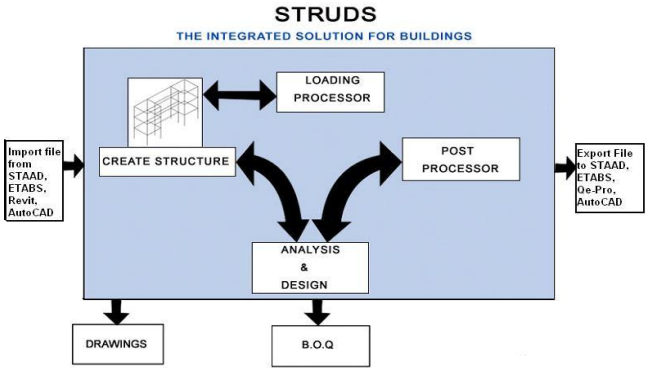
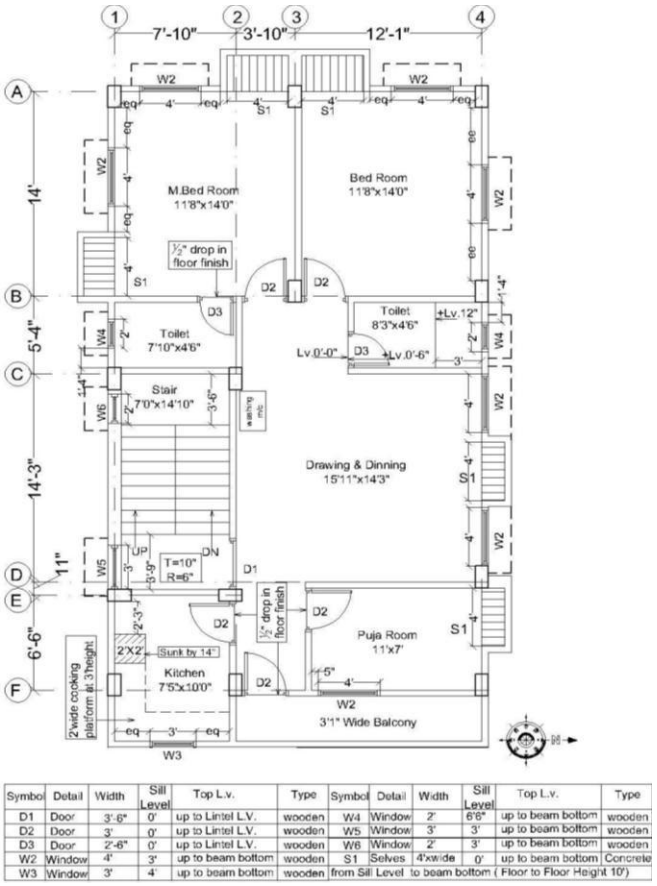


Fig-1: STRUDS-Flow diagram

3. ANALYSIS DESIGN AND RESULTS FROM STRUDS



Symbol	Detail	Width	Sill Level	Top L.v.	Type	Symbol	Detail	Width	Sill Level	Top L.v.	Type
D1	Door	3'-6"	0'	up to Lintel L.V.	wooden	W4	Window	2'	6'6"	up to beam bottom	wooden
D2	Door	3'	0'	up to Lintel L.V.	wooden	W5	Window	3'	3'	up to beam bottom	wooden
D3	Door	2'-6"	0'	up to Lintel L.V.	wooden	W6	Window	2'	3'	up to beam bottom	wooden
W2	Window	4'	3'	up to beam bottom	wooden	S1	Selves	4'xwide	0'	up to beam bottom	Concrete
W3	Window	3'	4'	up to beam bottom	wooden	from Sill Level to beam bottom (Floor to Floor Height 10')					

Fig-2: 1st Floor working plan for the building

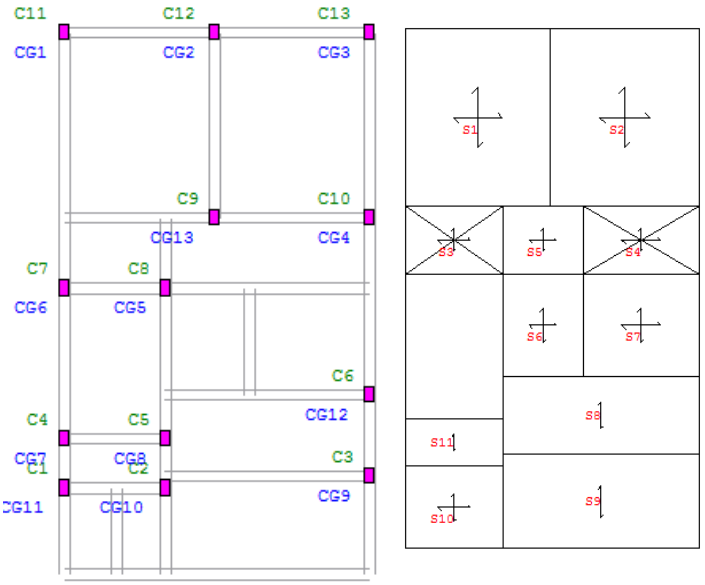


Fig-3: Slab, Column and Beam Layout Plan

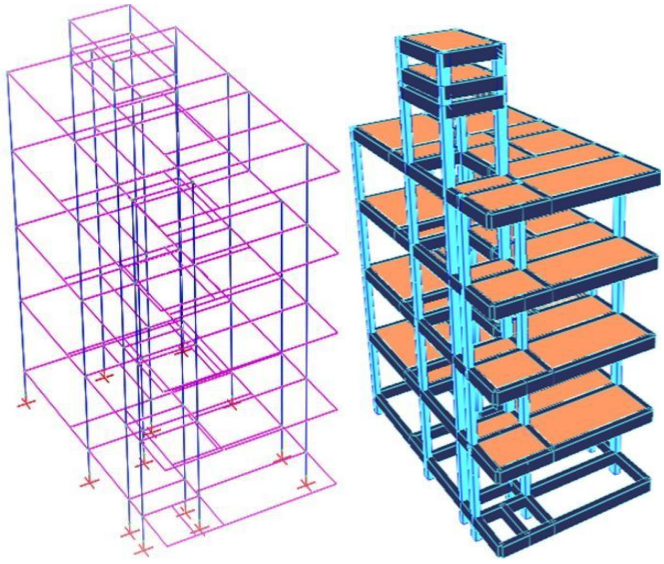


Fig-4: 3D Skeleton & Render view of the building

Table -1: Model specification for analysis and design

Type of structure	RCC Framed structure
No. of floors	Ground Floor + 3 floors
Location	Patna Bihar
Type of Soil	Soft Soil
Types of Footing	Trapezoidal Footing
Allowable bearing pressure	250 kN/m2
Story height	3 m
Plinth level	0.6 m
Outer periphery walls	230 mm thick
Inner periphery walls	115mm thick
Partition walls	115mm thick
Slab thickness	125 mm
Concrete & Steel	M20 Grade, Fe500

Table -2: Live loads and EQ load

Floor Live load	3 kN/m²
Roof Live load	1.5 kN/m²
Floor Finish	1 kN/m²
Floor Finish (roof)	0.75 kN/m²
Wall load (External)	10.4 kN/m
Wall load (Internal)	7.8 kN/m
Seismic zone factor, Z	0.240
Importance factor, I	1.000
Response reduction factor, R	3.000
Percentage damping	5%
Soil type	Soft soil

3.1 Ground Floor Slab Design Details

Totally there are 11 slabs in the structure, which comprises of both one way and two way slabs. Reinforcement for all the slabs in both directions was 8mm @ 200 mm c/c.

Table -3: Ground floor slab design details

Slab No.	lx (m)	ly (m)	ly/ lx	Moment (kNm)
GS1	3.557	4.269	1.2	6.977
GS2	3.679	4.269	1.16	7.117
GS3	2.389	1.626	1.469	3.873
GS4	2.866	1.626	1.762	4.429
GS5	1.982	2.462	1.242	1.953
GS6	2.866	2.462	1.164	3.202
GS7	4.848	1.882	2.576	2.256
GS8	4.848	2.260	2.145	4.166
GS9	2.389	1.980	1.206	2.989
GS10	1.982	1.626	1.219	1.282
GS11	2.389	1.143	2.089	1.066

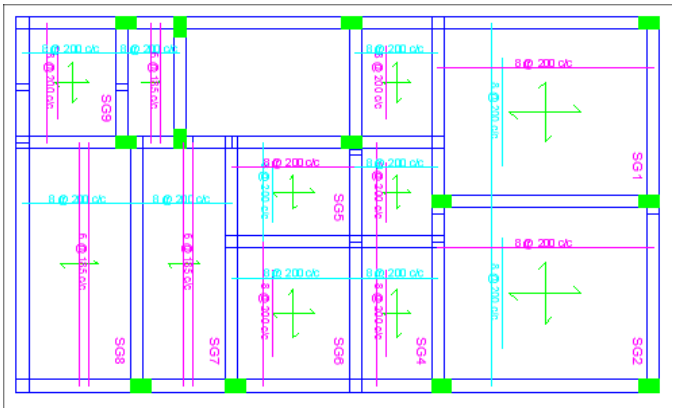


Fig-5 Ground floor slab detailed in AutoCAD

3.2 Beams

In each floor there are totally 35 beams which comprises of both singly reinforced and doubly reinforced beams. Beam size of 250mm x 450mm is constant throughout the floor and the stirrups provided for all the beams are 4-Legged- 8mm diameter bars at 150mm c/c.

Table -4: Beam Reinforcement Details

Beam 250x450 mm	Bottom Reinforcement	Top Reinforcement
B1	2#16	2#16
B2	2#16	2#12
B3	2#20,1#16	2#20+2#16
B4	2#16	3#16+1#12
B5	4#16	3#16+3#12
B6	2#16	5#16
B7	1#12	3#12
B8	5#12	3#12
B9	2#12	2#16
B10	2#16	2#12
B11	2#16	2#16+1#16
B12	2#16	2#20+1#16
B13	4#12	3#16
B14	4#12	3#16+1#12
B15	2#16	3#16
B16	4#12	3#16+1#12
B17	2#12	5#16
B18	4#12	3#20+2#16
B19	4#12	2#20+1#12
B20	2#16	2#16
B21	2#16	3#16+3#12
B22	2#12	2#16
B23	2#16	3#20+3#12
B24	3#16	4#20+4#12
B25	4#12	4#16
B26	2#16	3#16+3#12
B27	5#12	3#16+1#12
B28	5#12	3#16+1#12
B29	2#16	3#16+1#12
B30	2#16	4#16
B31	2#12	2#12
B32	2#16+1#12	3#20+3#16
B33	5#12	3#20+3#16
B34	2#16+1#12	2#16
B35	2#16	2#16+1#12

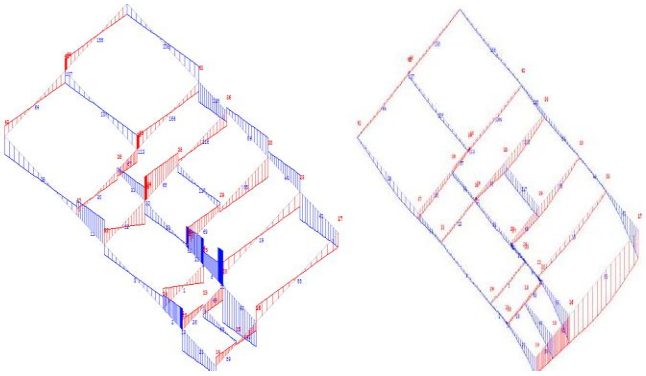


Fig-6: SFD & BMD of Ground Floor beams

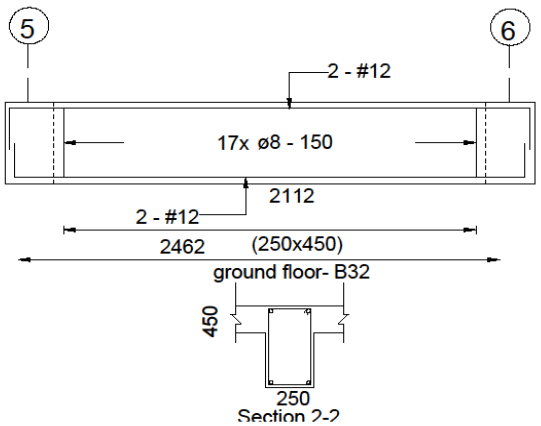


Fig-7: Beam between grid 5 and 6 detailed in AutoCAD

3.3 Columns

Totally there are 13 columns in the building. The design details of all the columns are extracted. In table below complete column details of C13 column is mentioned. Similar details are obtained for all other columns also.

Table -5: Column size and reinforcement details for column C13

Column No.	Floor-Level	Column size (mm	Axial Load	Main Steel (mm)	Lateral ties (mm	Ast Prov mm^2	Ast Perct
C13	GF	250 x 400	545.77	#12 – 20	#8 @ 190	2262	2.26
	1st floor	250 x 400	456.52	#12 - 14	#8 @ 190	1583	1.58
	2nd floor	250 x 400	327.65	#12 - 12	#8 @ 190	1357	1.35
	3rd floor	250 x 400	201.55	#12 - 10	#8 @ 190	1131	1.13
	Roof	250 x 400	90.96	#12 - 10	#8 @ 190	1131	1.13

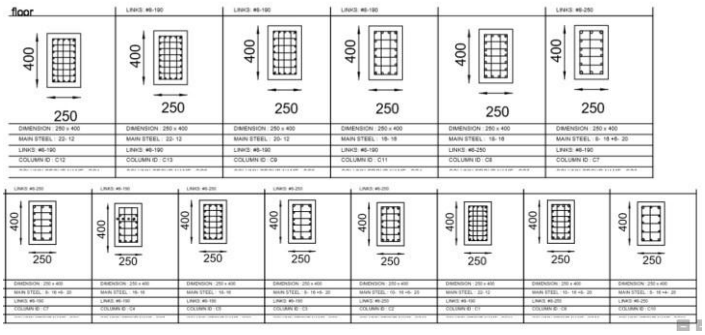


Fig-8: Columns detailed in AutoCAD (Cross section at ground floor)

3.4 Footing

Totally there are 13 footings in the building. STRUDS has designed an isolated trapezoidal footing for all the columns. PCC bed thickness and the minimum depth of footing is 150mm. The footing dimensions and reinforcement details are tabulated in the table below.

Table -6: Footing size and

Footing	Column	PCC size X-Y (mm)	Footing size X-Y (mm)	Total Depth (mm)	Steel II to X	Steel II to Y
FG1	C1	2150X2300	1850X2000	700	12- #12	11- #12
FG2	C2	2525X2675	2225X2375	850	17- #12	16- #12
FG3	C3	2325X2475	2025X2125	750	14- #12	14- #12
FG4	C4	2000X2150	1700X1850	625	10- #12	9- #12
FG5	C5	2225X2375	1575X1725	725	12- #12	12- #12
FG6	C6	1875X2025	1925X2075	550	10- #12	9- #12
FG7	C7	2225X2375	1575X1725	725	13- #12	12- #12
FG8	C8	2475X2625	1925X2075	800	15- #12	14- #12
FG9	C9	2325X2475	2175X2325	725	13- #12	12- #12
FG1	C10	2150X2300	2025X2175	675	12- #12	11- #12
FG1	C11	1775X1925	1850X2000	525	11- #10	8- #12
FG1	C12	1925X2075	1475X1625	575	10- #12	9- #12
FG1	C13	1350X1500	1625X1775	475	9- #10	8- #10

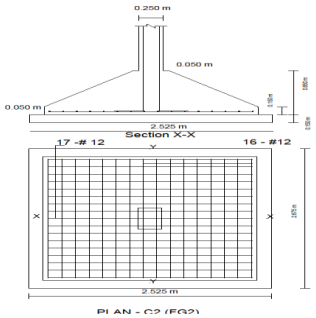


Fig-9: Footing detailed in AutoCAD

4. MANUAL DESIGN DETAILS

Table -7: Slab Design Comparison of SLAB-S2

Details	STRUDS	Manual calculation
Maximum moment	7.117 kN-m	5.472 kN-m
Reinforcement details (both direction)	8# @ 200 mm c/c	8# @ 300 mm c/c

Table -8: Beam Design Comparison of BEAM-B2

Reinforcement	STRUDS	Manual
Tension Reinforcement	2-16mm ϕ	2-12mm ϕ
Compression Reinforcement	2-12mm ϕ	2-12mm ϕ (Hanger bars)
Vertical Stirrups	4L-8 mm ϕ at 150 mm	2L-8 mm ϕ at 225 mm c/c

Table -9: Column Design Comparison of COLUMN-

Details	STRUDS	Manual Design
Column Dimension	325 mm x 475 mm	250 mm x 400 mm
Longitudinal Reinforcement	2840 mm^2 (18-12 mm ϕ + 4-16 mm ϕ)	2945.24 mm^2 6- 25mm ϕ
Lateral ties	8mm ϕ bars at	8mm ϕ bars at 300

Table -10: Footing Design Comparison of FOOTING -FG2

Details	STRUDS (Trapezoidal footing)	Manual Design (m) Square footing
Footing Dimension	2.225 x 2.375 x 0.85 (Depth minimum of 150mm)	2.85 x 2.85 x 1.4
Reinforcement	1709 mm^2 17- #12 Parallel to X 16 - #12 parallel to Y	1608 mm^2 (16 mm ϕ bars @ 125 mm c/c in both directions) 15- #16 in both directions

5. CONCLUSIONS

1. Manual design and analysis of structural elements of buildings is time consuming, it can be reduced by using software such as STRUDS.
2. AutoCAD plans can be easily imported to STRUDS.
3. Detailed report of analysis and design of all the structural elements can be obtained.
4. The advantage of STRUDS is that the detailing of the structural elements can also be obtained as an AutoCAD file report.
5. The design values of the structural elements as obtained from STRUDS are slightly on higher side compared to the manual design calculation.

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