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Static Analysis and Design of G+20 RCC Framed Structure by using ETABS Software

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***Abstract:** Practical knowledge is an important and essential skill required by every engineer. For obtaining this skill, an apartment building is analyzed and designed, seismic zone II with (G+20) stories having a car parking facility provided at basement floor. The building has a shear wall around the lift pit. The modelling and analysis of the structure is done by using ETABS and the designing was done. Design of slab, stair case are done manually. The design methods involve load calculations manually and analyzing the whole structure by ETABS. The design methods used in ETABS are limit state design confirming to IS code of practice. From analysis, the parameters like storey displacement, storey drift, base shear and story shear, bending moments are determined and also comparative study is done for both the methods*
***Keywords:** RCC Buildings, seismic zone II, storey displacement, storey drift, Base shear, axial forces, bending moments.*

I. INTRODUCTION

It is not an easy task to build a beautiful and strong building which can withstand against harshed conditions. We all know that today technology has achieved milestones in every field, and that's why even civil engineering needs to be upgraded. This has led to several changes in how civil engineers work and perform. Not just the use of technology has made lives way easier but has also because of the development of some really helpful software, encouraged civil engineers to give their best. “etabs-extended 3d analysis of building systems”, is a engineering software. It is an engineering software that is used in construction and planning and designing of buildings. It has provided a very different options and opportunities to make structures efficiently and in less time with full safety. It is loaded with an integrated system consisting of modeling tools, code-based load analysis, solution to the problems techniques. It can handle the complex and big building models and associated requirements. Etabs software is widely in use nowadays for construction of buildings.

A. Multi-Storey Building

A multi-story building is a structure that upholds at least two stories over the ground. There is no formal restriction on the height of such a building or the number of floors a multi-story building may contain, though taller buildings do face more practical difficulties. But, from a structural engineer's point of view the tall building or multistoried building can be defined as one that, by virtue of its height, is affected by lateral forces due to wind or earthquake or both to an extent that they play an important role in the structural design. Tall structures have fascinated mankind from the beginning of civilization. The Egyptian Pyramids, one among the seven marvels of world, built in 2600 B.C. are among such antiquated tall designs. Such designs were built for protection and to show pride of the populace in their civilization. The development in present day multistoried structure development, which started in late nineteenth 100 years, is expected to a great extent for business and private purposes. The development of the high-rise building has followed the growth of the city closely. The process of urbanization, that started with the age of industrialization, is still in progress in developing countries like India. Industrialization causes migration of people to urban centers where job opportunities are significant. The land available for buildings to accommodate this migration is becoming scarce, resulting in rapid increase in the cost of land. Thus, developers have looked up the sky to make profits. The result is multistoried buildings, as they provide a large floor area in a relatively small area of land in urban centers.

B. About ETABS

ETABS is an engineering software product that caters to multistory building analysis and design. Displaying apparatuses and formats, code-based load remedies, examination strategies and arrangement procedures, all direction with the lattice like calculation novel to this class of design. Fundamental or high-level frameworks under static or dynamic circumstances might be assessed utilizing ETABS.

For a refined appraisal of seismic execution, modular and direct-coordination time-history investigations might couple with P-Delta and Large Displacement impacts. Nonlinear connections and concentrated PMM or fiber pivots might catch material nonlinearity under monotonic or hysteretic conduct. Instinctive and coordinated highlights make uses of any intricacy functional to carry out. Interoperability with a progression of plan and documentation stages makes ETABS an organized and useful instrument for plans which range from straightforward 2D casings to expand present day tall structures.

C. Importance of Seismic Analysis

Seismic study is a very important study. It helps in understanding the behavior of structures of various types subjected to earthquake loads, and how we can protect the inhabitants of that structure in the event of an earthquake Seismic concentrate additionally assists with understanding the different kinds of seismic waves that start, assisting us with planning the zones of continuous quakes and stable zones. The study of seismic activity of a particular zone helps in establishing minimum standards of safety for that zone, making life easier to continue post-earthquake.

D. Aim and Objective

The objectives are as listed below:

- ✓ The objective is to design the G+20 building (structural system) by using ETABS
- ✓ To prepare a 3D model of a multi-storey RCC building using ETABS software.
- ✓ Analyze building for seismic analysis and Dead load, Live load and Earthquake load using static method and dynamic method structure.
- ✓ Comparison of static and dynamic methods, displacement, story drift, base shear
- ✓ To design the building against the effect of seismic forces or to make the structure earthquake resistant.
- ✓ To get the knowledge and to design the structural elements like beams, columns, slabs

II. DESIGN PHILOSOPHY

A. Structure Details And Materials

1) Type of Structure Building = G+20 Residential
2) Depth of foundation = 2m Below GL.
3) Depth of plinth =1.5 m
4) Floor to floor height = 3.m
5) Seismic Zone = II Zone
6) Importance Factor= 1
7) Response Reduction Factor = 5
8) Soil Type = Medium Type II
9) Live load = 3 KN /M^2
10) Thickness of wall = 300mm and 150mm
11) Column size = 600 x 600mm
12) Beam size = 300 x 600mm
13) Grade of concrete M35 , grade of steel fe 415
14) Safe bearing capacity 300 kn/m^2
15) Slab =150 mm , Shear Wall = 250mm
16) AAC blocks having unit weight 6 kn/m^2

B. Load and Details

1) Internal wall under primary beam = 5.4 kn / m
2) External wall under primary beam =5.61 kn / m
3) Parapet wall = 5.61 kn / m
4) Super impose load on floor = 4 Kn/m^2
5) Live load = 3 kn / m^2
6) Live load on terrace and head room = 1.5 kn / m^2
7) Earthquake load = as per 1993 part 1 2016
8) Wind loads auto select in etabs

C. E TABS Modelling and Analysis

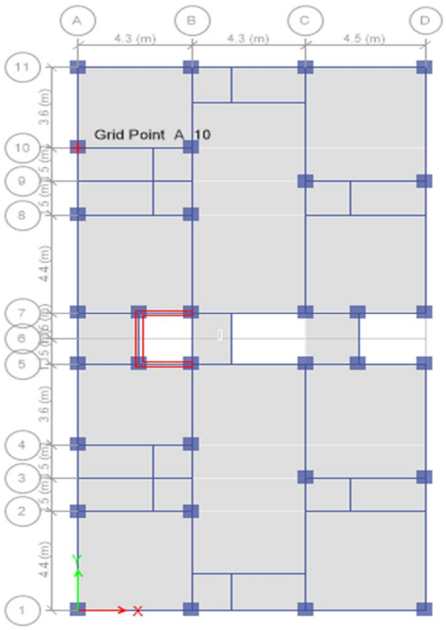

Fig-1. Plan view of building

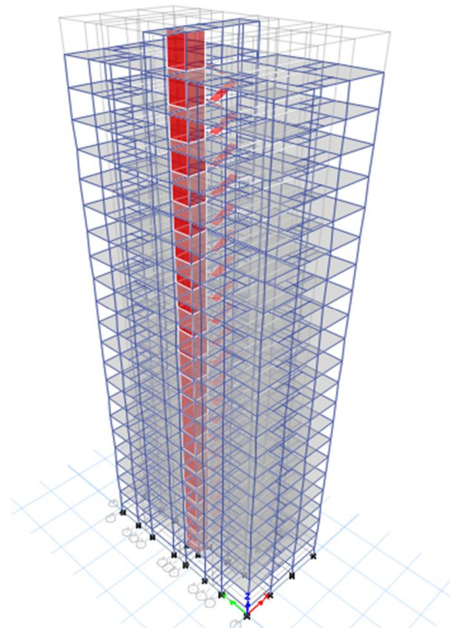

Fig-2. view of structural element

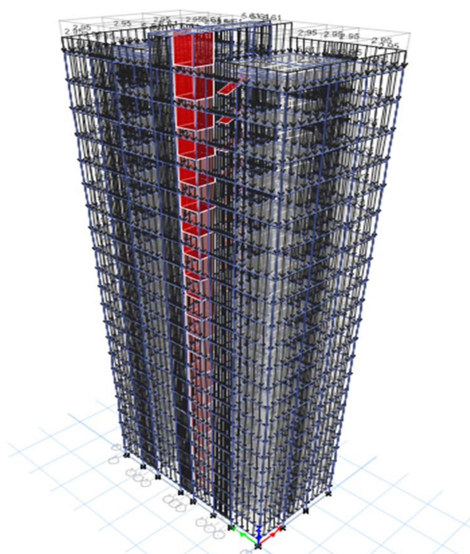

Fig-3. Assigning of load combinations

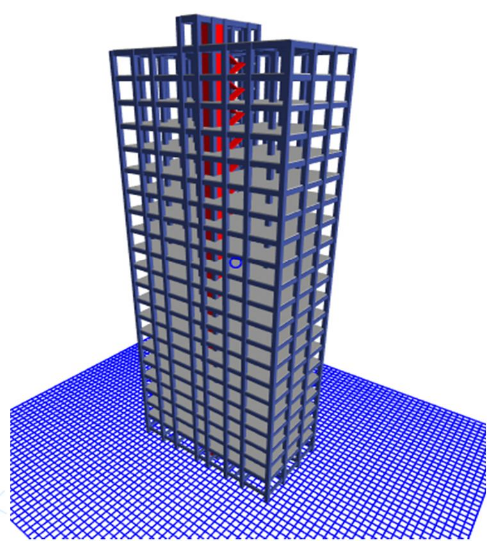

Fig-4 . 3d view of building

III. ANALYSIS RESULT AND DISCUSSION

In this there are some important modal checks are perform, base reactions are calculated as per program calculated ,moment Diagram, Shear Force Diagram, auto wind load application , auto seismic load application ,story displacement , story stiffness etc also Auto Design of member of structure by Etabs is performed.

1) Analyze the Structure and Check the Behavior
2) Analyze the Model by Run Analysis
3) Check Analysis Run Log to check that Model does not run into Instability
4) Check Storey Drift Limitation as per CL.7.11.1.1 of IS 1893 (Part 1) : 2016
5) Check Torsional Irregularity as per C1.7.1 and Table 5 of IS 1893 (Part 1) : 2016

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A. *Application of Wind Load*

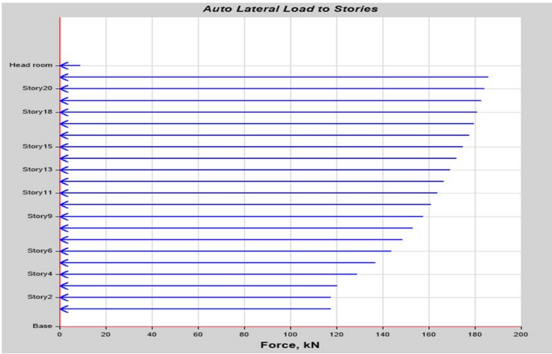

Fig-5. Load Pattern WLX

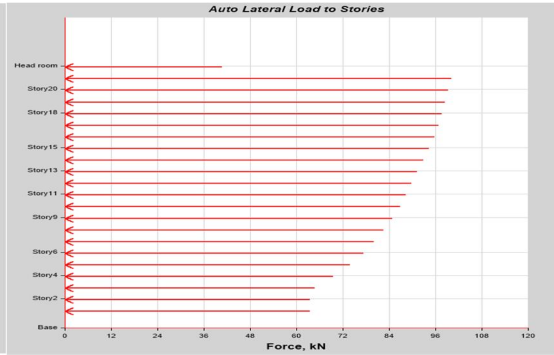

Fig-6 . Load Pattern WLY

B. *Application of Seismic Load*

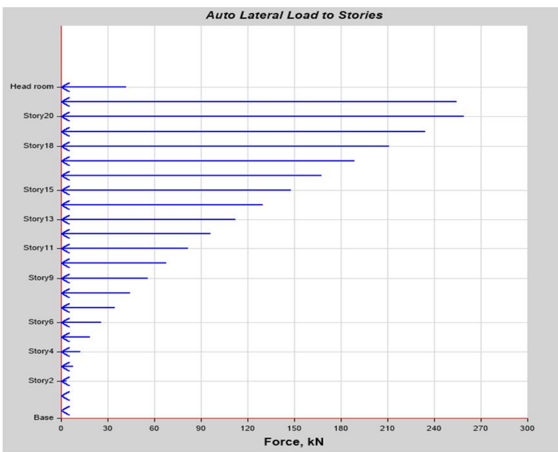

Fig-7. Load Pattern EQX

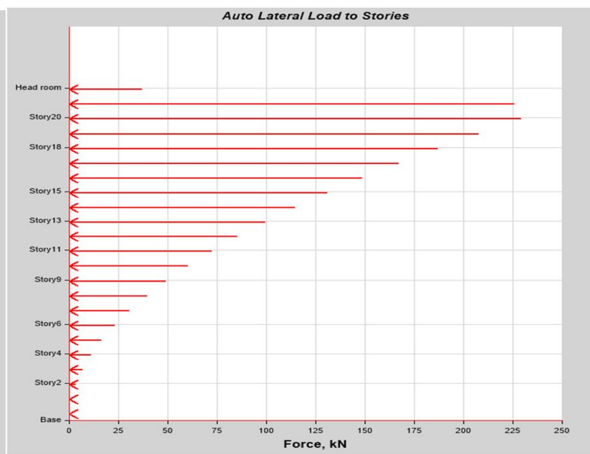

Fig-8. Load Pattern EQY

Table-1. Application of wind and seismic loads

Story	Elevation (m)	Location	X-Dir (kn)	Y-Dir (kn)	X-Dir (kn)	Y-Dir (kn)
			WLX	WLY	EQX	EQY
Head room	67.5	Top	8.8415	40.7477	41.7716	37.0151
Terrace	64.5	Top	185.7838	100.1551	254.6863	225.6853
Story20	61.5	Top	184.227	99.3158	258.9965	229.5047
Story19	58.5	Top	182.6767	98.48	234.3448	207.6601
Story18	55.5	Top	181.1329	97.6478	210.9258	186.9078
Story17	52.5	Top	179.5947	96.8186	188.7393	167.2476
Story16	49.5	Top	177.7144	95.8049	167.7854	148.6797
Story15	46.5	Top	174.9933	94.338	148.064	131.2041
Story14	43.5	Top	172.1659	92.8137	129.5753	114.8206
Story13	40.5	Top	169.3614	91.3018	112.3191	99.5294
Story12	37.5	Top	166.58	89.8024	96.2955	85.3304
Story11	34.5	Top	163.8217	88.3154	81.5045	72.2237
Story10	31.5	Top	161.0486	86.8204	67.9461	60.2092
Story9	28.5	Top	157.4405	84.8753	55.6203	49.2869

Story8	25.5	Top	153.0219	82.4933	44.5271	39.4568
Story7	22.5	Top	148.6273	80.1242	34.6664	30.719
Story6	19.5	Top	143.6282	77.4292	26.0383	23.0733
Story5	16.5	Top	137.0284	73.8713	18.6428	16.52
Story4	13.5	Top	128.7966	69.4335	12.4799	11.0588
Story3	10.5	Top	120.1982	64.7982	7.5496	6.6899
Story2	7.5	Top	117.7258	63.4654	3.8518	3.4132
Story1	4.5	Top	117.7186	63.4614	1.3867	1.2288
GF	1.5	Top	0	0	0.0825	0.0731
Base	0	Top	0		0	0

C. Tortional irregularity check

The designer should review the structural arrangement of the structural elements to ensure that the code requirements against building irregularity will be satisfied. Building Irregularity checks are depending on the code that we are using, although there are similarities. The most common checks under a building irregularity are the torsional irregularity check which will be tackled by applying check as per IS 1893: 2016 (Part-1) Clause 7.1 and Table No. 5. The code states that the ratio of maximum horizontal displacement at one end minimum horizontal displacement at another end should not exceed **1.5**

Table-2. Tortional Irregularity Check

Story	Load Case	Direction	Maximum	Average	Ratio	Check
			mm	mm		
Head room	ELX	X	40.484	40.418	1.002	O.K.
Terrace	ELX	X	39.546	38.884	1.017	O.K.
Story20	ELX	X	37.976	37.35	1.017	O.K.
Story19	ELX	X	36.307	35.716	1.017	O.K.
Story18	ELX	X	34.536	33.981	1.016	O.K.
Story17	ELX	X	32.664	32.145	1.016	O.K.
Story16	ELX	X	30.702	30.219	1.016	O.K.
Story15	ELX	X	28.662	28.217	1.016	O.K.
Story14	ELX	X	26.559	26.151	1.016	O.K.
Story13	ELX	X	24.409	24.038	1.015	O.K.
Story12	ELX	X	22.227	21.894	1.015	O.K.
Story11	ELX	X	20.029	19.734	1.015	O.K.
Story10	ELX	X	17.833	17.575	1.015	O.K.
Story9	ELX	X	15.654	15.433	1.014	O.K.
Story8	ELX	X	13.51	13.323	1.014	O.K.
Story7	ELX	X	11.416	11.263	1.014	O.K.
Story6	ELX	X	9.39	9.269	1.013	O.K.
Story5	ELX	X	7.45	7.36	1.012	O.K.
Story4	ELX	X	5.618	5.554	1.011	O.K.
Story3	ELX	X	3.919	3.878	1.01	O.K.
Story2	ELX	X	2.394	2.373	1.009	O.K.
Story1	ELX	X	1.109	1.102	1.007	O.K.
head room	ELY	Y	40.227	36.955	1.089	O.K.
Terrace	ELY	Y	40.707	36.687	1.11	O.K.

Story20	ELY	Y	39.671	35.683	1.112	O.K.
Story19	ELY	Y	38.471	34.545	1.114	O.K.
Story18	ELY	Y	37.102	33.268	1.115	O.K.
Story17	ELY	Y	35.566	31.851	1.117	O.K.
Story16	ELY	Y	33.874	30.298	1.118	O.K.
Story15	ELY	Y	32.039	28.62	1.119	O.K.
Story14	ELY	Y	30.075	26.829	1.121	O.K.
Story13	ELY	Y	28.001	24.94	1.123	O.K.
Story12	ELY	Y	25.832	22.967	1.125	O.K.
Story11	ELY	Y	23.588	20.928	1.127	O.K.
Story10	ELY	Y	21.287	18.839	1.13	O.K.
Story9	ELY	Y	18.948	16.717	1.133	O.K.
Story8	ELY	Y	16.589	14.581	1.138	O.K.
Story7	ELY	Y	14.231	12.45	1.143	O.K.
Story6	ELY	Y	11.896	10.345	1.15	O.K.
Story5	ELY	Y	9.606	8.291	1.159	O.K.
Story4	ELY	Y	7.39	6.316	1.17	O.K.
Story3	ELY	Y	5.281	4.457	1.185	O.K.
Story2	ELY	Y	3.322	2.761	1.203	O.K.
Story1	ELY	Y	1.586	1.3	1.22	O.K.

D. Story Drift Check

Story Drift is nothing but relative displacement between floors above and/or below the story under consideration. Story drift in any story shall not exceed 0.004 times the story height, under the action of design base shear VB with no load factor that is, partial safety factor for all loads taken as 1.0 which is nothing but service load combinations. The check is given in Clause 7.11.1 of IS 1893 (Part-1): 2016 as per Indian Standard 1893:2016 Clause 7.11.1.1 Story Drift Limitation Allowable Drift = 0.004 × Story Height = 0.004 × 3000= 12 mm

Table-3. Story Drift Check

Story	Load Combinations	Direction	ETABS Drift	Storey Drift	Allowable Drift	Check
Head room	B02: 1.0 (DL+SIDL+WLX)	X	0.000712	2.0292	12	O.K.
Terrace	B02: 1.0 (DL+SIDL+WLX)	X	0.000718	2.0463	12	O.K.
Story20	B02: 1.0 (DL+SIDL+WLX)	X	0.000743	2.1176	12	O.K.
Story19	B02: 1.0 (DL+SIDL+WLX)	X	0.000771	2.1974	12	O.K.
Story18	B02: 1.0 (DL+SIDL+WLX)	X	0.000799	2.2772	12	O.K.
Story17	B02: 1.0 (DL+SIDL+WLX)	X	0.000827	2.3570	12	O.K.
Story16	B02: 1.0 (DL+SIDL+WLX)	X	0.000852	2.4282	12	O.K.
Story15	B02: 1.0 (DL+SIDL+WLX)	X	0.000875	2.4938	12	O.K.
Story14	B02: 1.0 (DL+SIDL+WLX)	X	0.000895	2.5508	12	O.K.

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Story13	B02: 1.0 (DL+SIDL+WLX)	X	0.000912	2.5992	12	O.K.
Story12	B02: 1.0 (DL+SIDL+WLX)	X	0.000924	2.6334	12	O.K.
Story11	B02: 1.0 (DL+SIDL+WLX)	X	0.000932	2.6562	12	O.K.
Story10	B02: 1.0 (DL+SIDL+WLX)	X	0.000936	2.6676	12	O.K.
Story9	B02: 1.0 (DL+SIDL+WLX)	X	0.000934	2.6619	12	O.K.
Story8	B02: 1.0 (DL+SIDL+WLX)	X	0.000926	2.6391	12	O.K.
Story7	B02: 1.0 (DL+SIDL+WLX)	X	0.000911	2.5964	12	O.K.
Story6	B02: 1.0 (DL+SIDL+WLX)	X	0.000888	2.5308	12	O.K.
Story5	B02: 1.0 (DL+SIDL+WLX)	X	0.000855	2.4368	12	O.K.
Story4	B02: 1.0 (DL+SIDL+WLX)	X	0.000807	2.3000	12	O.K.
Story3	B02: 1.0 (DL+SIDL+WLX)	X	0.000738	2.1033	12	O.K.
Story2	B02: 1.0 (DL+SIDL+WLX)	X	0.000633	1.8041	12	O.K.
Story1	B02: 1.0 (DL+SIDL+WLX)	X	0.000475	1.3538	12	O.K.
GF	B02: 1.0 (DL+SIDL+WLX)	X	0.000243	0.6926	12	O.K.

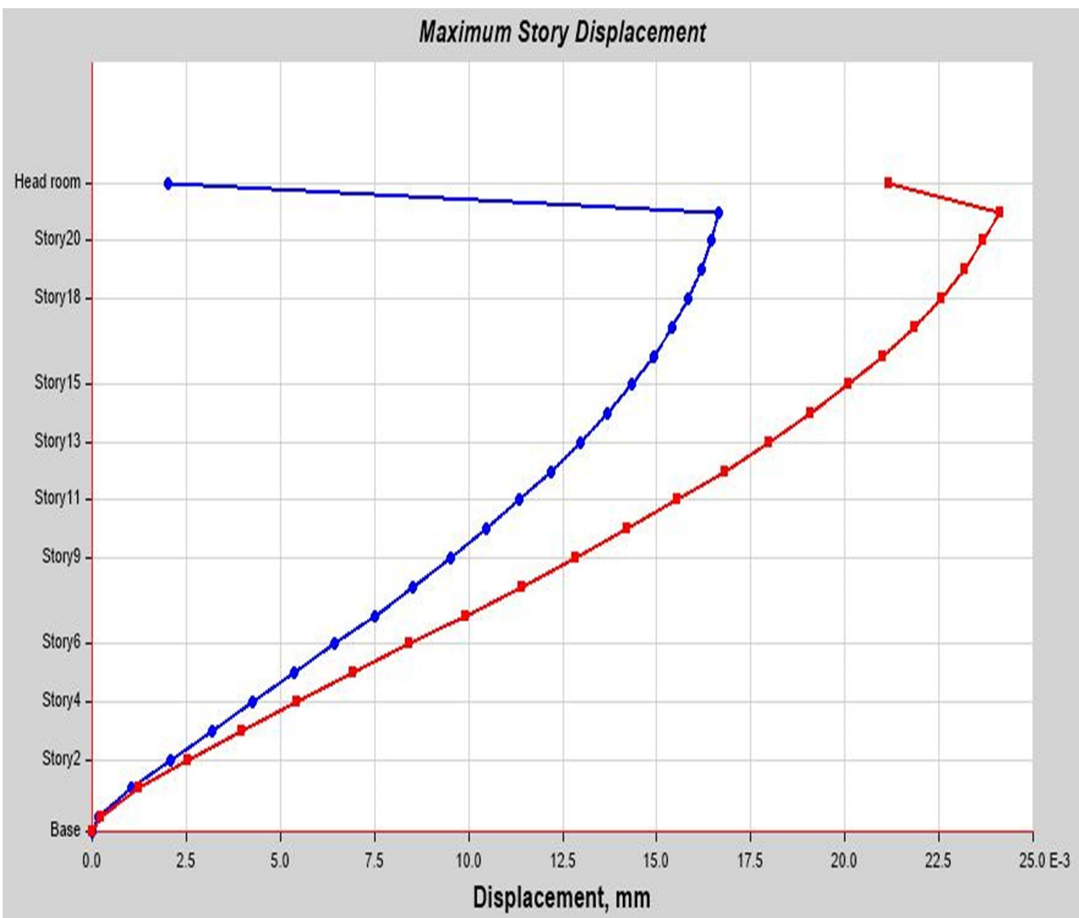

Fig-9. Maximum Story Displacement

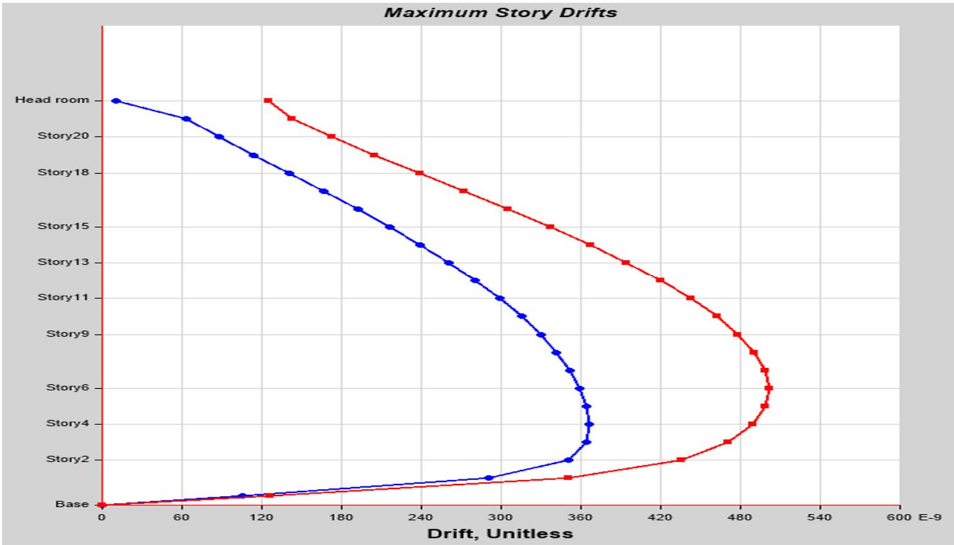

Fig-10. Maximum Story Drift

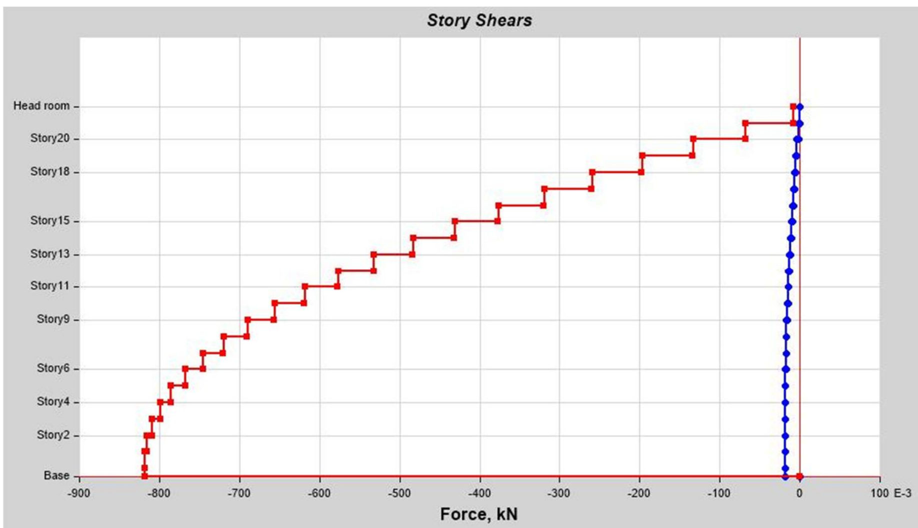

Fig-11. Maximum Story Shear

Fig-12. Story Overturning Moment

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E. Deflection Diagrams

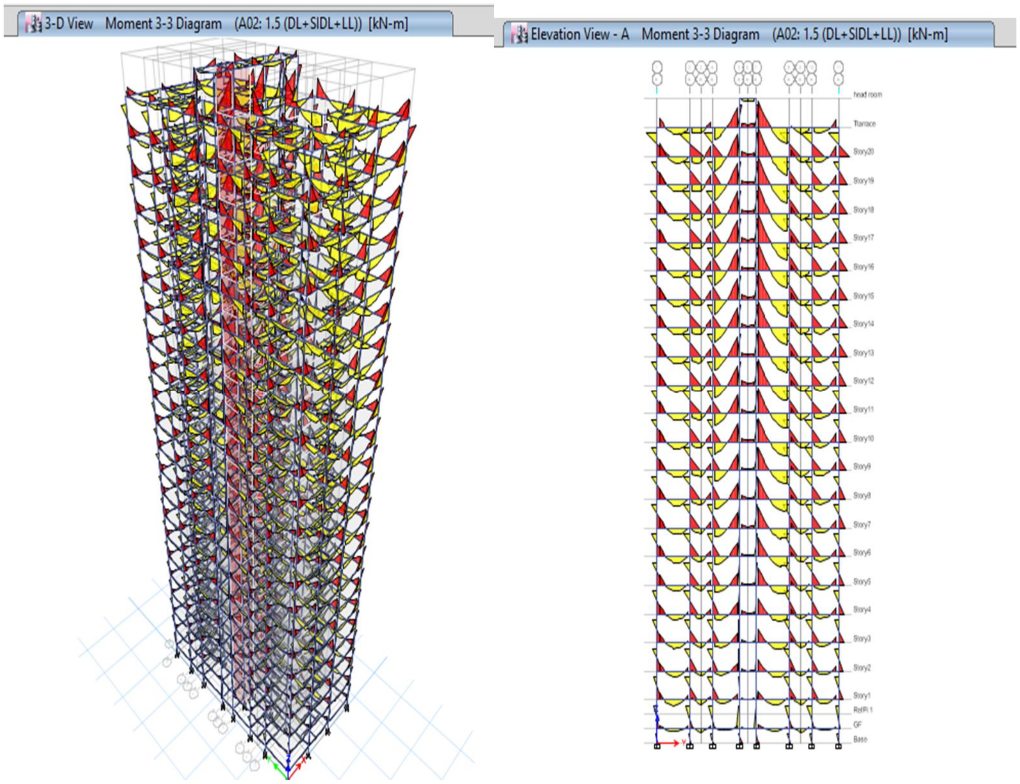


Fig-13. Bending Moment Diagrams

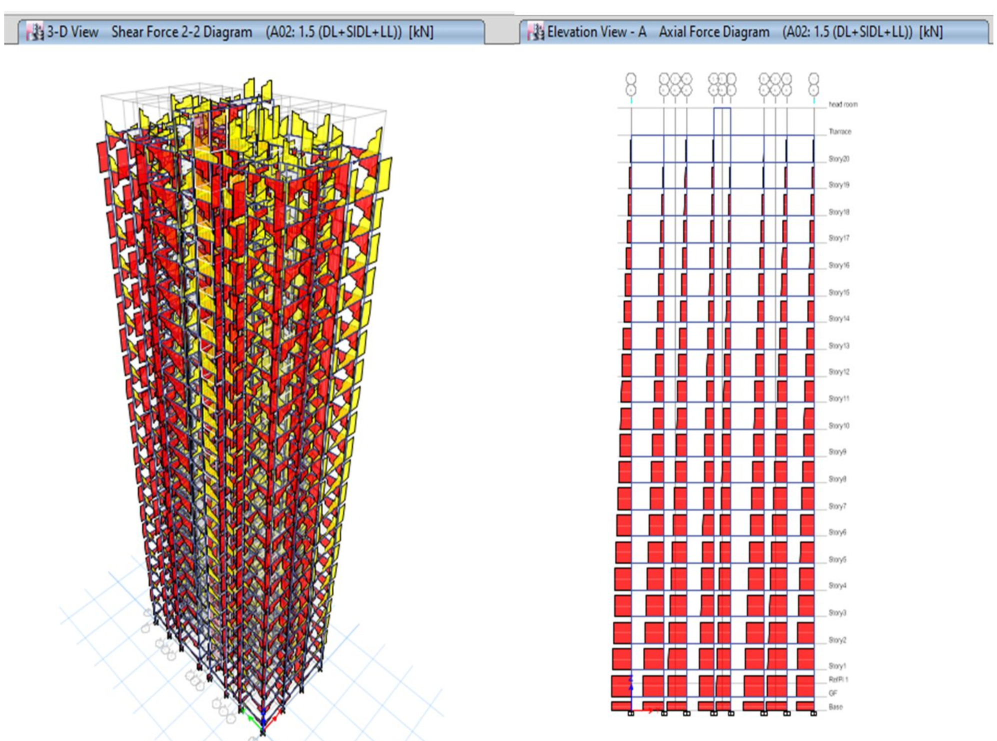
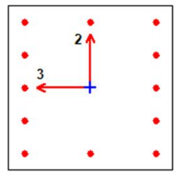


Fig-14. Shear Force and Axial Force Diagram

F. Etabs Concrete Frame Column Design

IS 456:2000 Column Section Design



Column Element Details Type: Ductile Frame (Summary)

Level	Element	Unique Name	Section ID	Combo ID	Station Loc	Length (mm)	LLRF
Story9	C3	2444	C 600 X 600	A02: 1.5 (DL+SIDL+LL)	2400	3000	0.437

Section Properties

b (mm)	h (mm)	dc (mm)	Cover (Torsion) (mm)
600	600	60	30

Material Properties

E_c (MPa)	f_{ck} (MPa)	Lt.Wt Factor (Unitless)	f_y (MPa)	f_{ys} (MPa)
29580.4	35	1	415	415

Design Code Parameters

γ_C	γ_S
1.5	1.15

Axial Force and Biaxial Moment Design For P_u , M_{u2} , M_{u3}

Design P_u kN	Design M_{u2} kN-m	Design M_{u3} kN-m	Minimum M_2 kN-m	Minimum M_3 kN-m	Rebar Area mm²	Rebar % %
3815.2885	77.2648	-94.6192	94.6192	94.6192	2880	0.8

Axial Force and Biaxial Moment Factors

	K Factor Unitless	Length mm	Initial Moment kN-m	Additional Moment kN-m	Minimum Moment kN-m
Major Bend(M3)	0.83111	2400	19.3367	0	94.6192
Minor Bend(M2)	0.921595	2400	-51.9313	0	94.6192

Shear Design for V_{u2} , V_{u3}

	Shear V_u kN	Shear V_c kN	Shear V_s kN	Shear V_p kN	Rebar A_{sv} /s mm²/m
Major, V_{u2}	30.8773	228.9604	129.6005	193.4769	665.06
Minor, V_{u3}	86.2888	228.9604	129.6005	139.8106	665.06

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Joint Shear Check/Design

	Joint Shear Force kN	Shear V_{Top} kN	Shear $V_{u,Tot}$ kN	Shear V_c kN	Joint Area cm²	Shear Ratio Unitless
Major Shear, V_{u2}	N/A	N/A	N/A	N/A	N/A	N/A
Minor Shear, V_{u3}	N/A	N/A	N/A	N/A	N/A	N/A

(1.4) Beam/Column Capacity Ratio

Major Ratio	Minor Ratio
N/A	N/A

Additional Moment Reduction Factor k (IS 39.7.1.1)

A_g cm²	A_{sc} cm²	P_{uz} kN	P_b kN	P_u kN	k Unitless
3600	28.8	6566.4	2870.5253	3815.2885	0.744374

Additional Moment (IS 39.7.1)

	Consider M_a	Length Factor	Section Depth (mm)	KL/Depth Ratio	KL/Depth Limit	KL/Depth Exceeded	M_a Moment (kN-m)
Major Bending (M_3)	Yes	0.8	600	3.324	12	No	0
Minor Bending (M_2)	Yes	0.8	600	3.686	12	No	0

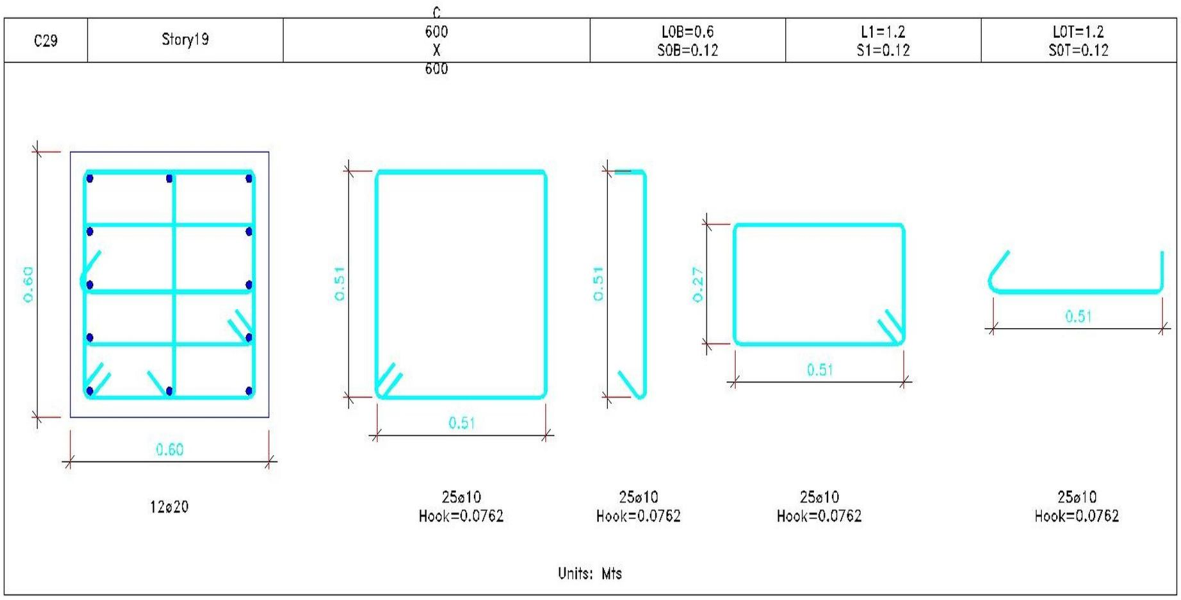

Fig-15. Column Reinforcement Details

G. *Etabs Concrete Frame Beam Design*

IS 456:2000 Beam Section Design

Beam Element Details Type: Ductile Frame (Summary) (Part 1 of 2)

Level	Element	Unique Name	Section ID	Combo ID	Station Loc
Story16	B63	3978	B 300 X 600	Design Load Combinations	300

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Beam Element Details Type: Ductile Frame (Summary) (Part 2 of 2)

Length (mm)	LLRF
4300	1

Section Properties

b (mm)	h (mm)	b_f (mm)	d_s (mm)	d_{ct} (mm)	d_{cb} (mm)
300	600	300	0	25	30

Material Properties

E_c (MPa)	f_{ck} (MPa)	Lt.Wt Factor (Unitless)	f_y (MPa)	f_{ys} (MPa)
29580.4	35	1	415	415

Design Code Parameters

γ_C	γ_S
1.5	1.15

Factored Forces and Moments

Factored M_{u3} kN-m	Factored T_u kN-m	Factored V_{u2} kN	Factored P_u kN
-121.1494	8.9548	107.5538	0

Design Moments, M_{u3} & M_t

Factored Moment kN-m	Factored M_t kN-m	Positive Moment kN-m	Negative Moment kN-m
-121.1494	15.8026	2.3343	-136.952

Design Moment and Flexural Reinforcement for Moment, M_{u3} & T_u

	Design -Moment kN-m	Design +Moment kN-m	-Moment Rebar mm²	+Moment Rebar mm²	Minimum Rebar mm²	Required Rebar mm²
Top (+2 Axis)	-136.952		694	0	694	353
Bottom (-2 Axis)		2.3343	585	11	0	585

Shear Force and Reinforcement for Shear, V_{u2} & T_u

Shear V_e kN	Shear V_c kN	Shear V_s kN	Shear V_p kN	Rebar A_{sv} /s mm²/m
196.6565	0	242.29	96.9831	1167.66

Torsion Force and Torsion Reinforcement for Torsion, T_u & V_{U2}

T_u kN-m	V_u kN	Core b_1 mm	Core d_1 mm	Rebar A_{svt} /s mm²/m
8.9548	107.5538	260	560	383.32

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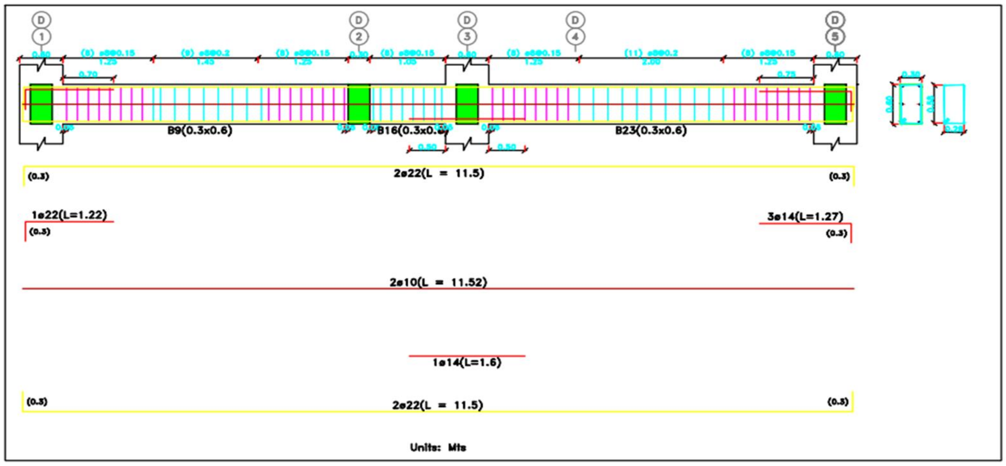

Fig-16. Beam Reinforcement Details

IV. CONCLUSION

1) This project has given an opportunity to re-collect and co-ordinate the various methods of designing and engineering principles which we have learnt in our earlier classes.
2) E tabs software provides adequate strength durability, serviceably ,along with the economy
3) E tabs is based on limit state method
4) Displacement is more as the story increases thus the 20^{th} story is having high displacement
5) The forces and support reaction are minimum as the response factor is taken zone 2
6) Failed beams and columns can be resized by selecting definite beam and columns
7) As the story height increases then the bending moment for beams and columns will also increases
8) Replacement of AAC blocks instead of conventional bricks will reduces the dead load and affect the shear force and bending moment to reduce
9) The dimensions of beams and columns should be increases to resist the seismic load
10) By using ETABS, the analysis and design work can be completed within the stipulated time.
11) The analysis and design results obtain from software are safe when compared with manual calculations as per Is 456 2000 design.
12) Usage of ETABS software minimizes the time required for analysis and design.
13) In ETABS steel reinforcement adapted is adequate when compared to staad pro, this benefits the economicvalue of steel during construction

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