Analysis of High-Rise Commercial Building (G+15) with Alternatively Oriented Floor

Dyanesh.T[1], Dr.M.Rama[2]
[1] *PG Student, Government College of Technology, Coimbatore, Tamil Nadu, India*
[2]*M.E., Ph.D., Associate Professor, Government College of Technology, Coimbatore, Tamil Nadu, India*

Abstract - ***High rise Structures are increasing nowadays due to enormous growth in population, economy and decreasing land availability. Thus, multi-storey structures are facilitating accommodation of numerous people in limited area. To plan and analyse high rise building (G+15) with alternatively oriented floor slab using STAAD Pro is dealt in this study since varying structural shapes creates various effects on building. These alternatively oriented floor slab is planned to create different structural shape which is expected to resist lateral load such as wind and seismic force than regular shaped building. In addition of this study, it is assessing the building behaviour when subjected to different load combinations. For developing structural and architectural plans, AUTO CAD software is to be used. The structure is analysed using STAAD Pro as per IS standard. Most prominent effects due to seismic and wind load on alternatively oriented floored high-rise structure is analysed in computerised way is the primary objective in this study.***

Keywords: ***High rise building, alternatively oriented floor, Computerised structural analysis.***

1. INTRODUCTION

Building frame is a three-dimensional structure which consists of column, beams and slabs which are currently many innovative techniques have been developed in the construction fields. Buildings are built in different sizes, shapes and functions. Also, these are built economically and quickly with requirements of the people.

High rise Structures are surfaced and getting prominent these days due to land scarcity, increasing business, domestic space demand, profitable growth, technological advancement and inventions in structural systems. The exploding population and urbanization create an adding demand for altitudinous structures. The high-rise structure can accommodate numerous people on a lower land than would be the case with low- rise structure on the same land by perpendicular metamorphosis of vertical expansion. Thus, multi-storey structures are constructed which can helps to accommodate numerous people in limited area. As per National building code 2005 of India, A building having height more than 15 m is called high rise building. Varying and complicated shaped of structures behaves more efficient than usual high-rise structure which is evident on various literature study [1] [2] [3] [4] [5].

In this study, it is considered High rise structure with alternatively oriented floor level which creates unusual structural shape than normal high-rise buildings. Architectural design and analysis of the unusual shape buildings leads towards difficult and challenges structural designers. So, Initially, the study is taken on behaviour of differently shaped structure and thinks of this behaviour of these alternatively oriented floor model which is expected to be more stable than the regular floored structure. The main objective of this paper is to plan and analyse high rise building (G+15) with alternatively oriented floor slab using STAAD Pro. The most challenging area of structural engineering is designing structures to resist wind load and seismic loads. Hence, these alternatively oriented floor slab which creates different structural shape should resist lateral load such as wind and seismic force than regular shaped building [1] [2] [3] [4] [5]. Complicated sectional shapes of high-rise structures are expected to be good with regard to wind-resistant design than the conventional shaped high-rise building. The objective of this study is to assess the building behaviour of different floor orientation and when subjected to different load combinations [6] [7]. For developing structural and architectural plans, AUTO CAD software is to be used. The structure is analysed and designed using STAAD Pro as per IS standard.

This report presents details of structural analysis and design of the building for varying loading conditions.

In extent, the report specifies the details of structural layout, mathematical model, material properties, loads and load combinations, Static & seismic load analysis results, design summary for slabs, beams, columns, and staircase and foundation design calculations. The sizes and details of the sections of RC elements are based on detailed analysis, which is elaborated in this report. The key objectives of the study are

- Creation of building model on STAADPRO.
- To observe the behavior of building of chosen profile.
- Observation of severity of forces acting on the structure under some load combination.
- Study of the reaction forces, shear force, bending moment and displacement.

2. SOFTWARE USED

Basic modelling and analysis software used are

- AutoCAD (version 2021) - for drawing different layouts, details, plans, elevations, sections and different sections licensed by Auto Desk
- STAAD.Pro (V8i SS6 & CONNECT Edition V22 Update 10) – for structural analysis and design software licensed by Bentley

3. METHODOLOGY

Sequential order of the project from commencement to conclusion are given below

- Literature review
- Structural planning of the building
- Creating model on STAAD PRO
- Assigning properties & support condition
- Calculation of applied loads
- Defining various load combination
- Structural analysis of the building
- If fails, Remodel and analyse again
- Extracting outputs
- Preparation of tables and graphs.
- Understanding the Behaviour from output
- Summarising the results

4. NUMERICAL SIMULATION

4.1. BUILDING DESCRIPTION:

Basic building parameters and descriptions were listed below in the Table.1. to understand the basic structural and design parameters provided. The Fig.1 to Fig 5. Shows the architectural plan from Ground floor to roof which clearly shows how the building floors alternatively provided,

Table.1. Building Description

Parameters	Description
Model	G+15
Location	Coimbatore
Floor to Floor Height	3.65 m
Depth of Foundation	2.90 m
Total Building Height	51.1 m (Above ground level)
Live Load	5 kN/m^2
Exterior Wall Thickness	0.23 m
Grade of Concrete	M30
Grade of Steel	Fe500
Seismic Zone	III
SBC of foundation	200 kN/m^2
Soil Type	Hard soil
Structure Type	RC Frame Building

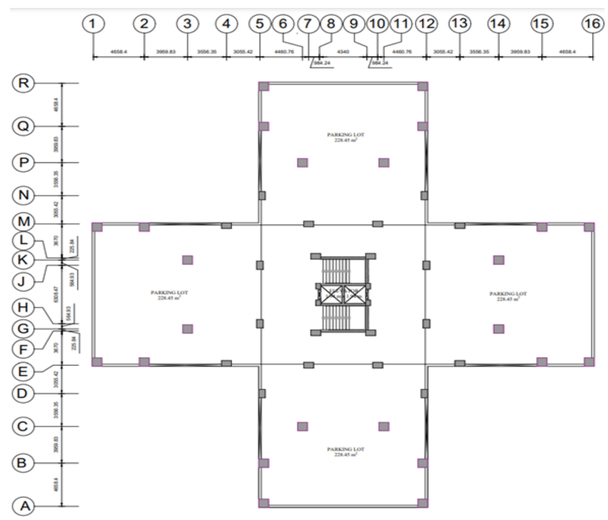

Fig.1.Ground floor layout (Parking)

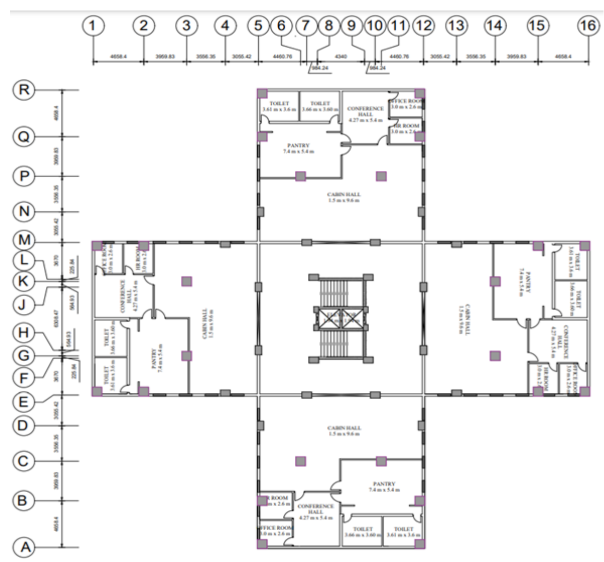

Fig.2. Level 1 floor layout (G+1 alone)

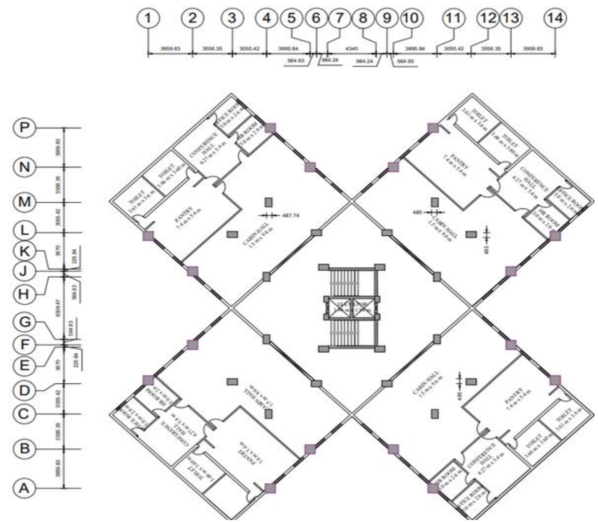

Fig.3.Even level floor layout (G+2,4,6,8,10,12&14)

Fig.4. Odd level floor layout (G+3,5,7,9,11,13&15)

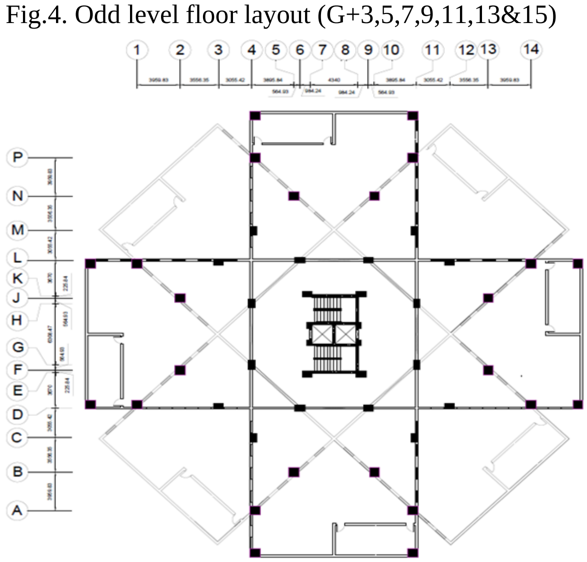

Fig.5. Floor overlay layout (G to G+15) plan

4.2. CREATING MODEL ON STAAD PRO

Structure to be analyse is initially modelled in the STAAD.Pro, Structure model is displayed below Fig.6.

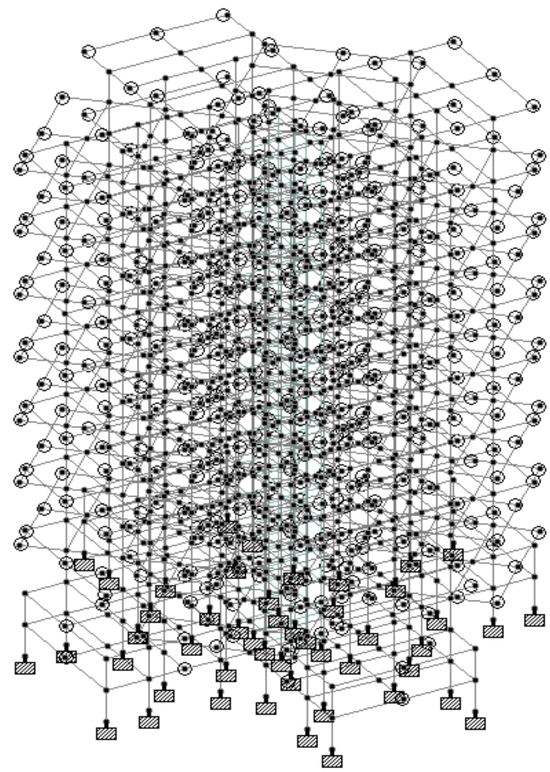

Fig.6. Staad.pro model

4.3. ASSIGNING PROPERTIES & SUPPORT CONDITION

Member sizes and support conditions followed are tabulated and mentioned below in Table.2. and the rendered view of created models were shown in Fig.7. & Fig.8.

Table.2. Building properties and support

Member	Dimension provided
Column Dimensions	1.200x1.200 m – Foundation 1.000x1.000 m – For critical 0.850x0.850 m – upto G+4 0.675x0.975 m - upto G+10 0.450X0.600 m - upto G+15
Beam Dimensions	0.475x0.975 m – walkthrough 0.23x0.45 m – other than walkthrough
Slab Thickness	0.18 m
Support provided	Fixed

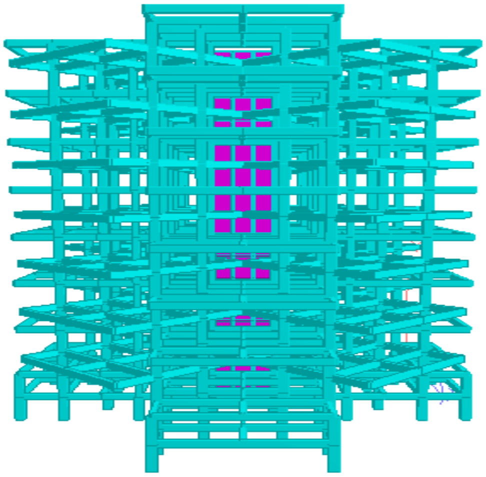

Fig.7. 3D model in staad.pro (elevation)

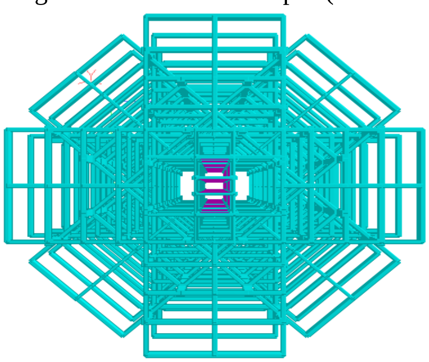

Fig.8. 3Dmodel in staad.pro (top view)

4.4. CALCULATION OF APPLIED LOADS

Load set details and notations followed were tabulated below in Table.3

Table.3. Applied load

LOAD SET	LOAD	NOTATION
LOAD 1 LOAD 2 LOAD 3 LOAD 4	SEISMIC LOAD	EX+ EX- EZ+ EZ-
LOAD 5	DEAD LOAD	DL Member Floor
LOAD 6	LIVE LOAD	LL Floor
LOAD 7 LOAD 8 LOAD 9 LOAD 10	WIND LOAD	WLX+ WLX- WLZ+ WLZ-

4.5. TYPES OF LOADS USED:

The considered loads for analysis and these loads are considered in accordance to

- IS:875 (part 1):1987 - Dead loads
- IS:875 (part 2):1987 - Imposed loads
- IS 875(Part3):2015 - Wind Loads on Buildings and Structures
- IS:875 (part 5):1987 - Part 5 special loads and load combinations
- IS 1893 (Part I): 2002 - Earthquake Resistant Design of Structures (5th Revision).

The basic wind and seismic parameters provide were clearly mentioned in the below Table.4-Table.5

Table.4. Wind load parameter

Height (m)	k_2	Vz (m/s)	Pressure kN/m^2	
			X-Dir	Y-Dir
0	1.05	40.95	1.0	0
3.65	1.05	40.95	1.1	0
7.3	1.05	40.95	1.1	0
10.95	1.058	41.25	1.1	0
14.6	1.087	42.39	1.1	0
18.25	1.11	43.27	1.2	0
21.9	1.126	43.9	1.2	0
25.55	1.137	44.33	1.2	0
29.2	1.148	44.76	1.2	0
32.85	1.157	45.13	1.2	0
36.5	1.166	45.48	1.3	0
40.15	1.175	45.84	1.3	0
43.8	1.184	46.2	1.3	0
47.45	1.194	46.55	1.3	0
51.1	1.201	46.85	1.3	0

Table.5. Seismic load parameter

Zone factor (Z)	0.16
Response reduction factor (R)	3 (RC building - OMRF)
Importance factor (I)	1
Soil type	I (rock)
Rock and soil site factor (SS)	1
Type of structure (ST)	1
Height of structure (h)	54.75 m
Dimension lx & lz	45.92 m
Period in X direction (Px)=0.09h/√lx	0.707 sec
Period in Z direction (Pz)= 0.09h/√lz	0.707 sec
Structure type	RC MRF building
Damping ratio	5%
Dead load factor	1
Live load reduction factor > 3 kN/m2	0.5
(Z/2) x R/I	0.0192

4.6. DEFINING VARIOUS LOAD COMBINATION

Designing structures to resist wind load and seismic loads. Hence, these alternatively oriented floor slab which creates different structural shape should resist lateral load such as wind and seismic force than regular shaped building. Most considered loads are taken with different Load combinations which are tabulated below in Table.6. About 100 combinations of loads were taken from all the possible load cases considering both Limit state of strength and serviceability for the overall analysis.

4.7. STRUCTURAL ANALYSIS OF THE BUILDING

Computerised structural analysis done successfully s displayed below Fig.9.

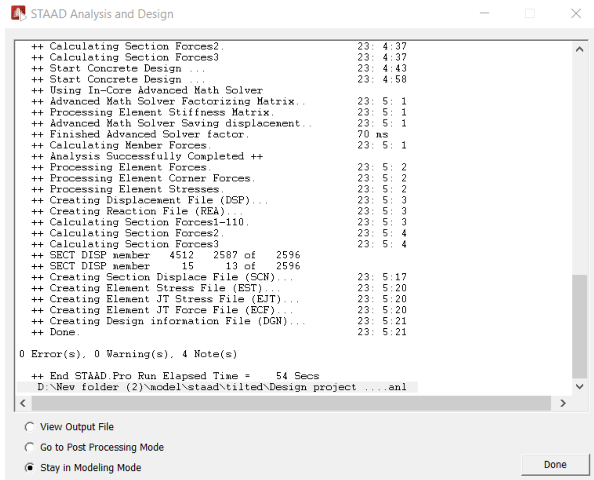

Fig.9. Analysis output in staad.pro

4.8. EXTRACTING OUTPUTS AND UNDERSTANDING THE BEHAVIOUR FROM OUTPUT

4.8. Forces summary:

Force from moment and shear at critical nodes and beams are listed in below Table.6 and Fig.10-11.

Table.6. Force summary

	L/C	Node	F_x kN	F_y kN	F_z kN	M_x kN-m	M_y kN-m	M_z kN-m
Max Fx	1.5DL+1.5LL	277	19330.84	127.1	121.9	-0.35	-86.435	142.126
Min Fx	E+X	279	-2647.69	-57.2	-414.4	-1.86	1163.61	-60.061
Max Fy	1.2EX+1.2DL+1.2LL	1224	17.916	799.6	0.69	-95.89	-1.525	1946.906
Min Fy	1.2E+X+1.2DL+1.2LL	1250	17.944	-799.6	-0.69	95.89	-1.527	1946.895
Max Fz	1.5E-Z+1.5DL	535	8266.071	-38.0	743.2	6.603	-1441.06	-192.232
Min Fz	1.5E+Z+1.5DL	807	8265.875	-38.0	-743.2	-6.6	1441.239	-192.024
Max Mx	1.5E+Z+1.5DL	308	12.346	717.6	-4.9	570.63	-1.082	1241.384
Min Mx	1.5E-Z+1.5DL	959	12.346	717.6	4.9	-570.64	1.082	1241.224
Max My	1.5E+Z+1.5DL	1286	17975.81	184.4	-674.8	4.437	1960.064	-120.232
Min My	1.5E-Z+1.5DL	45	17975.75	184.4	674.8	-4.436	-1960.05	-120.217
Max Mz	1.5DL+1.5LL	288	-0.241	-599.0	-0.0	0	-0.289	2174.448
Min Mz	1.5E-X+1.5DL	1218	9400.124	-530.9	2.0	3.026	-4.947	-1902.95

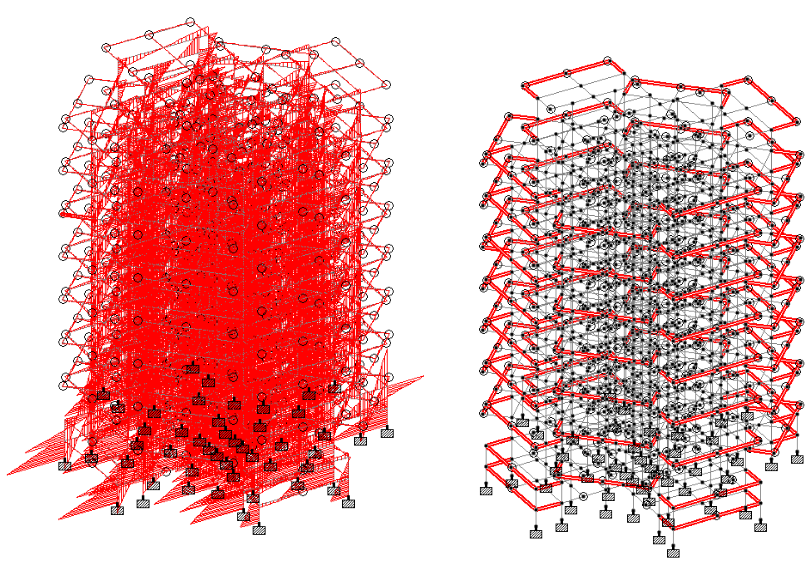

Fig.10. Bending moment diagram

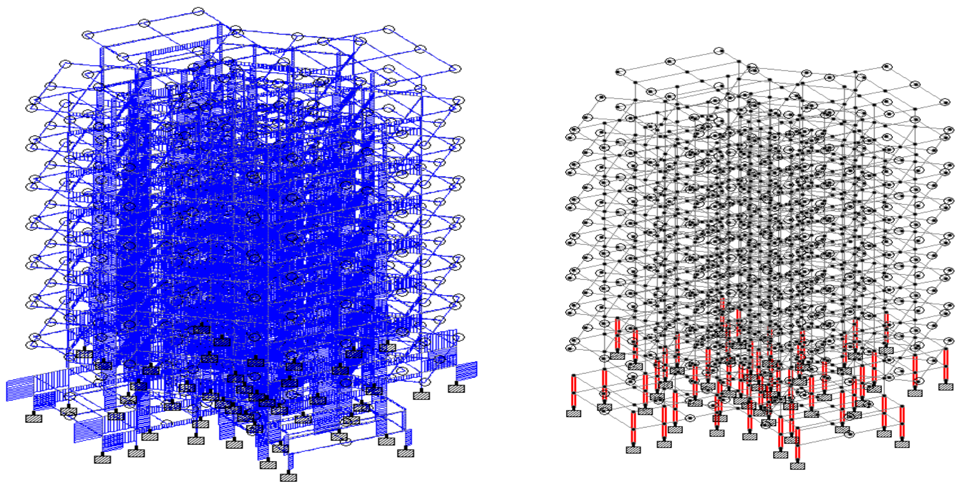

Fig.11. Shear force diagram

4.8. Displacement summary

Displacement from varying effect of forces at critical nodes are listed in below Table.7 and Fig.12.

Table.7. Displacement summary

	L/C	Node	F_x kN	F_y kN	F_z kN
Max X	2021 1.5E+X+0.9DL	126.23	-34.79	0.12	130.944
Min X	2006 1.5E-X+1.5DL	126.23	-57.99	0.20	138.92
Max Y	1 E+X	41.52	9.05	0.21	42.503
Min Y	4000 1.5DL+1.5LL	0.08	-80.	0.08	80.5
Max Z	2023 1.5E+Z+0.9DL	-0.18	-34.77	124.48	129.255
Min Z	2008 1.5E-Z+1.5DL	-0.31	-57.95	-124.49	137.321
Max rX	4000 1.5DL+1.5LL	-0.01	-73.84	-0.01	73.842
Min rX	4000 1.5DL+1.5LL	0.01	-73.84	0.01	73.842
Max rY	2007 1.5E+Z+1.5DL	-0.82	-30.84	124.48	128.251
Min rY	2008 1.5E-Z+1.5DL	-0.82	-30.84	-124.48	128.252
Max rZ	4000 1.5DL+1.5LL	0.01	-73.77	0	73.779
Max X	2021 1.5E+X+0.9DL	126.23	-34.79	0.124	130.944

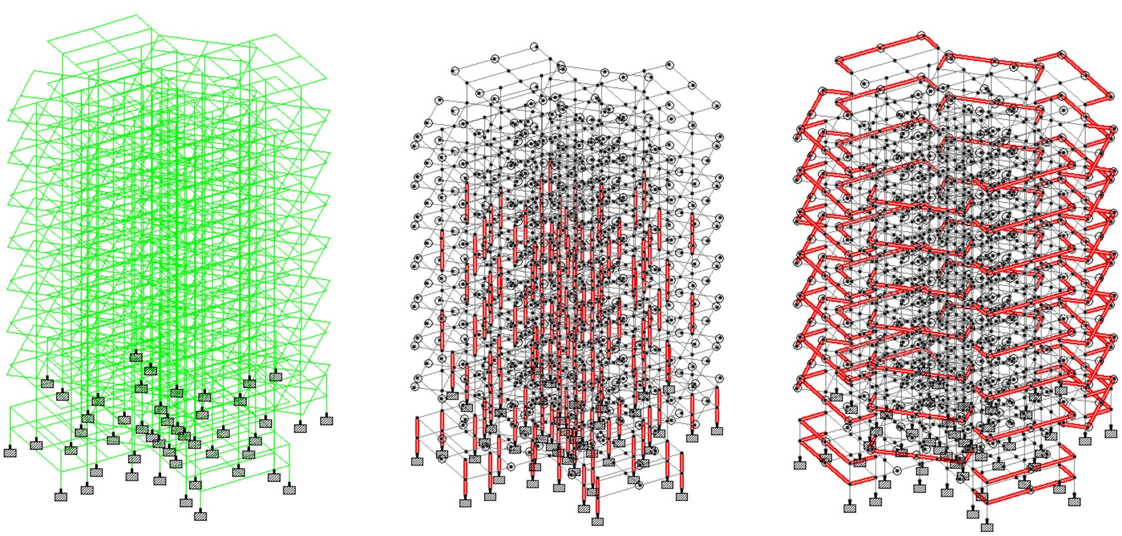

Fig.12. Displacement diagram

5. DISCUSSION AND CONCLUSION

- The plan has been prepared by using Auto CAD and it includes ground floor to G+15 floor plans and structural diagrams.
- The manual design was done using limit state method of design with help of BIS codes.
- Analysis and design are also carried by using STAAD.Pro as addition support to the project.
  - ✓ In the analysis and design of structure using software, it has been found that the beam in cantilever projection experiences greater forces than the others.
  - ✓ Since the beams other than elevator and stair portions running all over the structure with greater span, results in greater the depth in dimension.
  - ✓ Column provided with varying sizes depending on various parameters. Higher the floor height, smaller in size of the column.
  - ✓ Since the isolated footings are greater in size which overlaps over the adjacent column footing, mat footing is adopted for design.
  - ✓ Necessary drawings are given at appropriate places.

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