Turkish Online Journal of Qualitative Inquiry (TOJQI)
Volume 12, Issue 10, October 2021: 2704-2715

Design And Analysis Of G+11 Residential Building Using Equivalent Static Method

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ABSTRACT

As we follow the approach of progressed innovation, modify structures that is residential & commercial buildings are outlined with expanded adaptability, expanding their helplessness to outside excitation. Subsequently, these structures are powerless to intemperate modes of seismic tremors. To secure such gracious structures from noteworthy basic harm, the tectonic reactions of these structures is analyzed along with the determination of forces such as support responses, node displacements, beam results etc., and included within the basic plan for a ground shaking safe structure. The fundamental purpose of this paper is to make an earthquake resistant building by performing seismic analysis of the designed structure using “Static Equivalent Method of Analysis”. The analysis and design of the structure is done by utilizing STAAD.Pro software. For this reason, a G+11 building plan in Lucknow city is undertaken which lies in earthquake Zone-III as per IS 1893:2016 on medium soil type with Zone factor 0.16, for Ordinary Moment Resistant Frame, Importance factor 1.2, Response Reduction Factor is 3 and Damping ratio 5%. Main motto of paper is an analysis of seismicity on the RCC building frame on G+11

Keywords: STAAD Pro. V8i, Seismic analysis, Residential building, resistant

INTRODUCTION

In Present days, the development is increasing very rapidly in urban areas due to this the population is in turn increasing in urban areas day by day since, people migrate to urban cities. Because of the limited space and increasing population the requirement of multi-storied buildings is increased. Today it is impossible to imagine a developed city without multi storied buildings.

Generally, in the small building such as single story or double story buildings, we consider only vertically acting forces, effect of lateral forces is neglected. But when we will design the multi-storied buildings then both vertical as well as lateral forces highly affect the buildings. From designing point of view, multi-storied building not only transfers the gravity load but also it resists the effect of lateral load. Since last few years, lateral forces are the major cause of failure in high-rise buildings. Many studies are carried and research paper are also published for the improvement in the performance of multi-storey buildings against the lateral forces. In lateral forces, the horizontal component of seismic force is the major cause of damage of building.

For design of earthquake resistant building, the entire area is divided into four different zones, which is an important parameter for design. The other parameter for designing the earthquake resisting buildings are zone factor, importance factor, damping ratio, response reduction factor, type of soil and ductility of the structure.

After reading some research paper, we observe that the G+11 residential building is influenced by the wind and earthquake pressure loads. They done their seismic analysis of building using dynamic method and used parameters such as Zone – III, type of soil- medium soil, response reduction factor (R)–3 for OMRC (ordinary moment resisting frame, Floor height – 3.3m, earthquake load – IS: 1893-2002 (Part -1), Grade of concrete – M25. The actual relative displacement due to applied load between the story in the structure is below the permissible limit and hence structure is safe. They have shown that the deflections in the lateral directions should be within safe limits

In this paper, we designed G+11 floor building. There is no irregularity in the building and seismic analysis is done on the building by Equivalent Static Method. The analysis of the building is done by the software STAAD PRO. All the designing and analysis is based on IS code 1893:2016. Building is designed in Lucknow city which comes under zone III of seismicity. The main objective is to adjust the basic design of multi storied building with seismic impact which resist the structural damage without structural collapse.

IMPLEMENTATION FACTORS

1. Seismic definitions
2. Seismic parameters
   - Code Used: IS 1893-2016 (Part 1)
   - **Seismic Zone Factor** *(Z)* – It is the value of peak ground acceleration considered by the standard for the design of structures located in each seismic zone.
     Zone – III, Z = 0.16
3. **Response Reduction Factor** *(R)* – This factor indicates the base shear in a structure. R gives an indication of the level of over strength and ductility that structure which is excepted to have. Hence, the structure can be designed for much lower force than is implied by the strong shaking by considering the following factor. (R.C. building with ordinary moment resisting frames)
   R=3
   Importance Factor *(I)* – This factor gives the value of estimate design seismic force. This value depends on the functional use of the structure, characterized by hazardous consequences of its failure, post-earthquake functional needs, historical value, or economic importance. (Residential or commercial buildings)
   I=1.2
   (The values of all the above factors are taken from IS 1893-2016)
4. Other Parameter
   - Rock/soil type – Medium (Soil type II)
   - Structure type – Building with RC structures

- **Damping** — The effect of internal friction, inelasticity of materials, slipping, sliding, etc., in reducing the amplitude of oscillation; it is expressed as a fraction of critical damping. Damping ratio – 5% (value is taken from IS 1893 -2016)

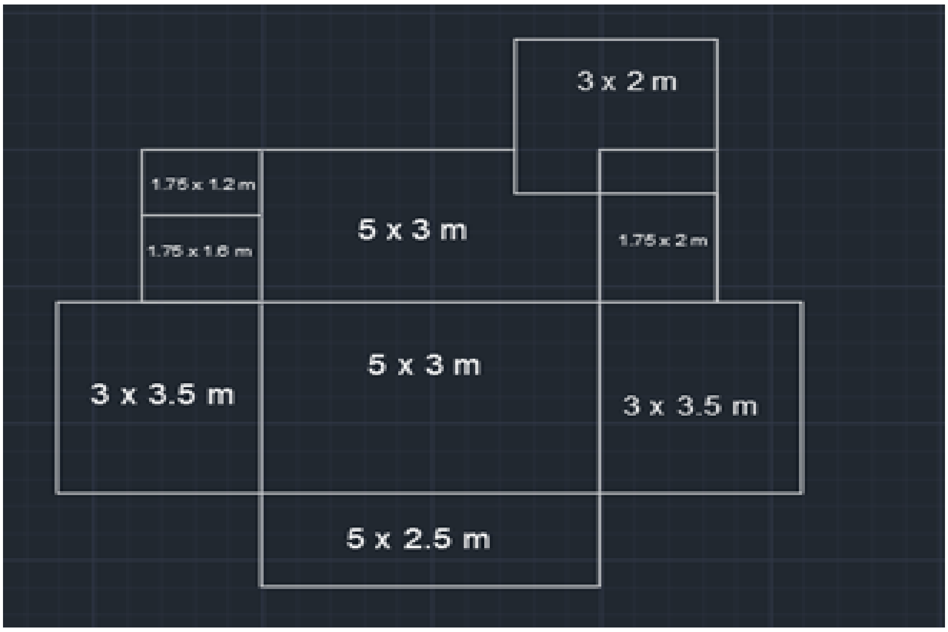
5. Seismic Self-weight factor – 1.5
6. Member weight
   - Loading type – UNI
   - Weight – 12.85 KN\m
7. Floor weights
   - Pressure Load – 7.125 KN\m^2

8. Define Y Range
   - Minimum – 3 m
   - Maximum – 33m
9. Load Case Details
   - Load type – Seismic
   - Title – EQ+X (Factor=1), EQ-X (Factor= -1) EQ+Z (Factor=1), EQ-Z (Factor= -1)
10. Dead Load
    - Self-Weight Factor -1.5
    - UNI Y: -12.85 KN
    - Floor: - Y RANGE
    - Total floor load: -7.125 KN\m
    - Range Minimum – 3m
      Maximum – 33m
11. Live Load
    - Floor: Y RANGE
    - Pressure Load: -2 KN\m^2
    - Range -: Minimum – 3m
      Maximum – 30m

METHODOLOGY

1. **Single line Plan in AutoCAD: -** The first step is to draw the line plan in AutoCAD software and converting it into a dxf.file for importing it to Staad Pro. for further design steps

Figure 1: Single line plan in AutoCAD

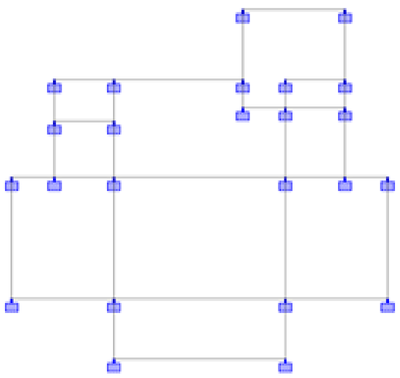


The dimensions of each room in a building are shown below: -

- 2 Bed Room – 3m x 3.5m
- Dining Room – 5m x 3m
- Kitchen – 3m x 2m
- Store Room – 1.75m x 2.0m
- WC – 1.75m x 1.20m
- Bath Room – 1.75m x 1.60m
- Front Verandah – 5m x 2.5m
- Lift Area–5m x 3m

2. **Modelling: -**The first step is to draw the line plan in AutoCAD software and converting it into a dxf. file format for importing it to Staad Pro. Go on main window and start performing translational repeat for several floor of building followed by assigning thickness to beam & columns.
   - Beam cross section – 300mm x 230mm, in X & Z direction.
   - Column cross section – 450mm x 300mm, in Y direction.
   - Assigning fixed support at bottom nodes of Building.

Figure 2: Plan of building frame



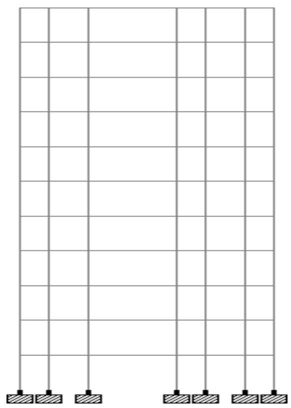
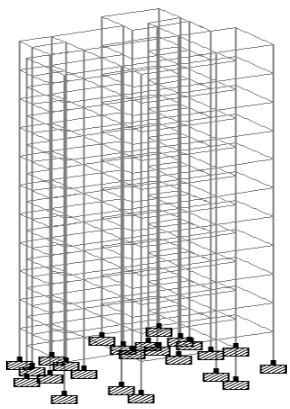


Figure 3: Staad Model



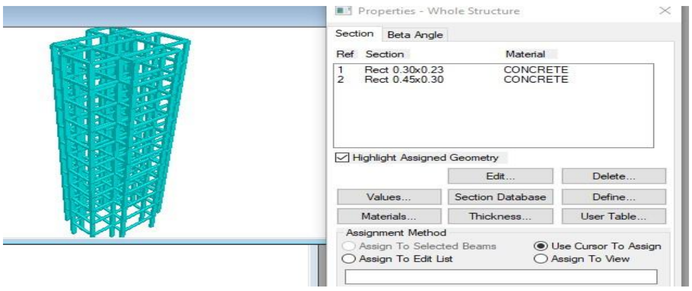


Figure 4: Beam and Column Cross-section

3. **Load & Definitions**

Add different loads which are going to act on building and then assign each of them.

- **<u>Dead load</u>** – Dead load is the self-weight of the structure which is also known as permanent or static loads. This is constant and independent with respect of time.

- IS code 875 (part 1) gives instruction that the Self weight factor is taken to be - 1.5
- Member Load: UNI – (-12.85) KN/m, it is brick load.

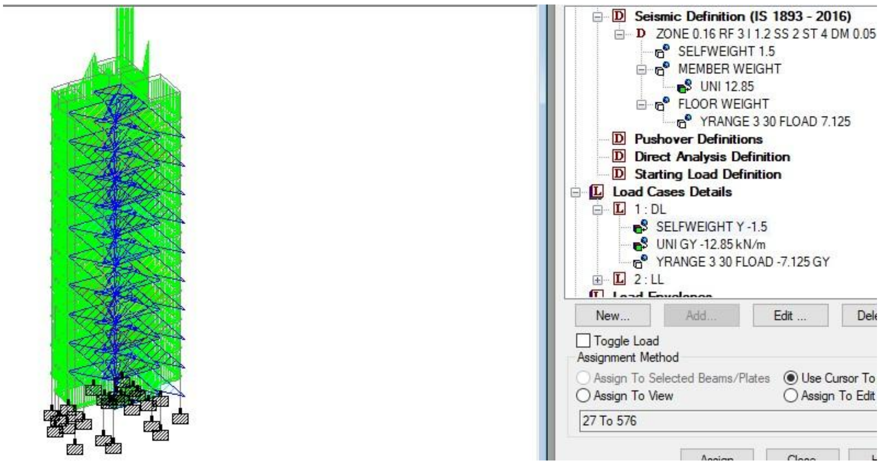


Figure 5: Dead load Case details

- **Calculation of Brick load: -**

Brick load = Density x Thickness x Wall height x Beam Depth

where,

Density of Brick – 19.1 KN/m^3 First class Brick. Brick thickness – 0.65 m. (Standard value)

Wall height = 3m Beam depth = 230mm

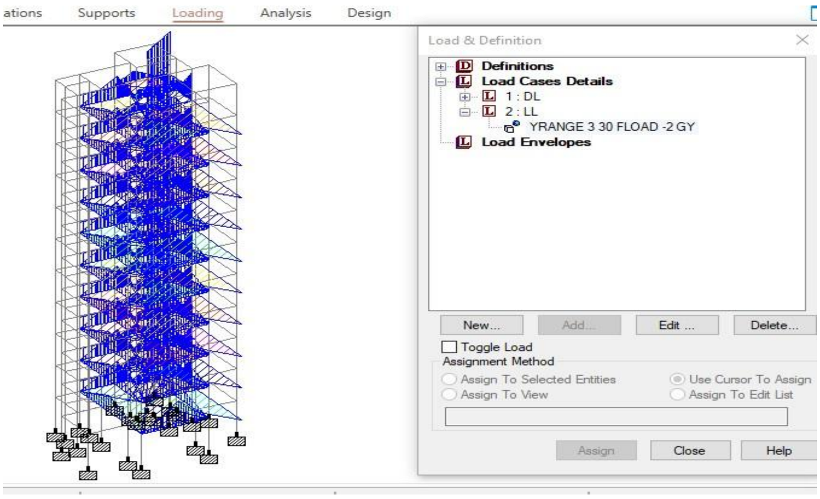
Brick Load = 19.1× 0.65×3× 0.23

= **8.566 KN/m × 1.5**

= 12.85 KN/m

Pressure – (-2 KN/m^2) for Residential building (According to IS CODE 875 Part – 2).

Figure 6: Live load case details

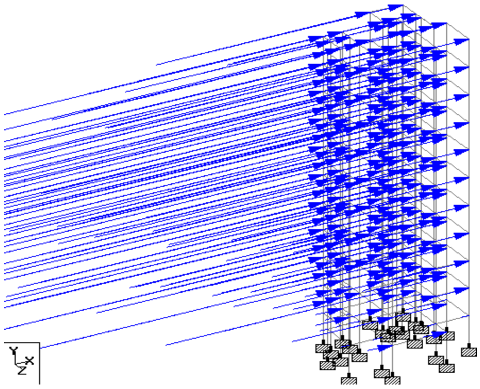


- **<u>Seismic load</u>: -** It is the basic concept of earthquake engineering. It represents how much seismic energy a structure would need to endure in a specific geographic location. As per IS code 1893:2016, the seismic loads are assigned for +X, -X, +Z, -Z directions with suitable seismic factor.

  Below figure shows the seismic forces in +X direction according to IS 1893:2016, these variations can be obtained for rest of the three directions.

- **<u>Floor load</u>**
Calculation of total floor load: - Reinforced concrete unit weight – 25 KN/m^3 Slab Thickness RCC - 150 mm
Dead load due to slab = 25 KN/m^3×0.15m×1m
= 3.75 KN/m
Floor finishing = 1kN/m^2×1m = 1 KN/m Total Floor load = 3.75 + 1
= **4.75 KN/m × 1.5**
= **7.125 KN/m**
- **<u>Live Load</u>: -** Live Loads are forces that may cause stresses, deformation, displacement and acceleration on a building.

Figure 7: Seismic force in +X direction



4. **Design: -** If any error does not appear then proceed by providing concrete as per IS 456: 2000 and analyze the designed G+11 building.
5. **Structure Analysis on STAAD Pro**:- By using the Run Analysis Command, we had analysed and done a detailed study of forces and bending moments which accept through the Postprocessing modes.

Figure 8: Variation of bending moment acting on the designed structure

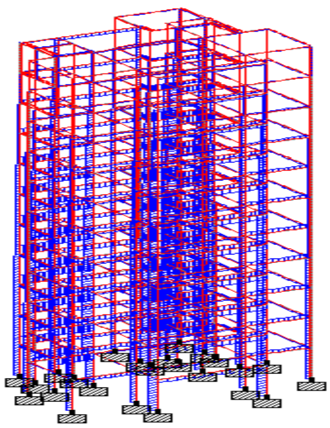
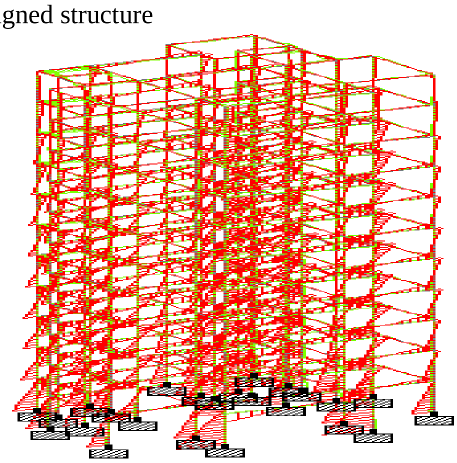


Figure 9: Variation of shear force acting on the designed structure

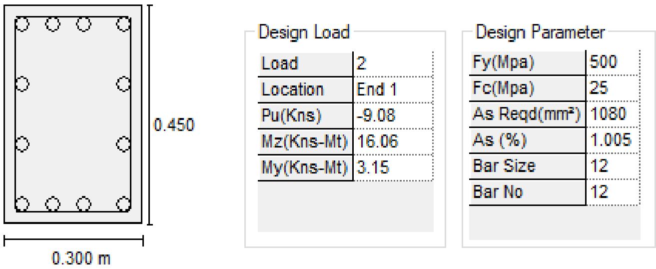


After complete analysis of structure, bending moment and shear force variations are obtained from the post processing mode of the Staad Pro. as shown in above figures.

6. **Structural Design on STAAD Pro and Output Generation: -** Reinforcement is done according to IS 456:2000. The design parameters M25 concrete and Fe415 have been relegated to the individual beam and

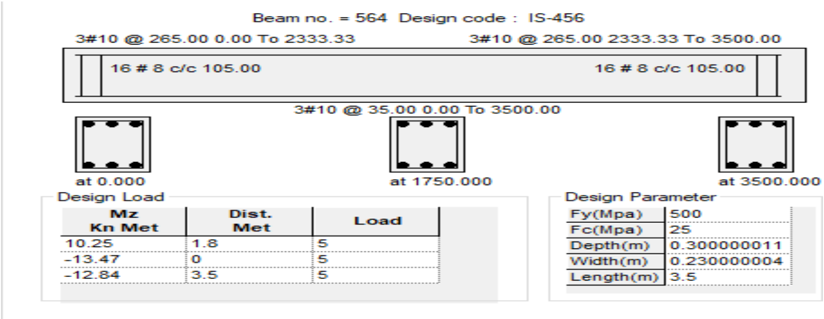
column member. After the ultimate result of the designed structure, as an output record, we got the structural design of every individual beam and column member.

Figure 10: Column Output



The column results of each and every column of the building can be obtained by selecting that particular column no. Here the above output is of column no.
542. The figure is showing the reinforcement details of column with 12#12mm.

Figure 11: Beam output



The beam results are obtained same as column results. Beam output of beam no. 564 shows that 3 no. of bars with 10mm diameter is provided at top and bottom respectively. The values of design load and parameters are given by the software engine itself.

RESULTS AND DISCUSSION

- **Maximum & Minimum Deflection: -** Analysis of deflection is observed from beam results section under "Post Processing" mode. For this user have to select particular beam and then can check the deflection of that particular beam. Same criteria are followed for column also.

Figure12: Deflection in upper beams

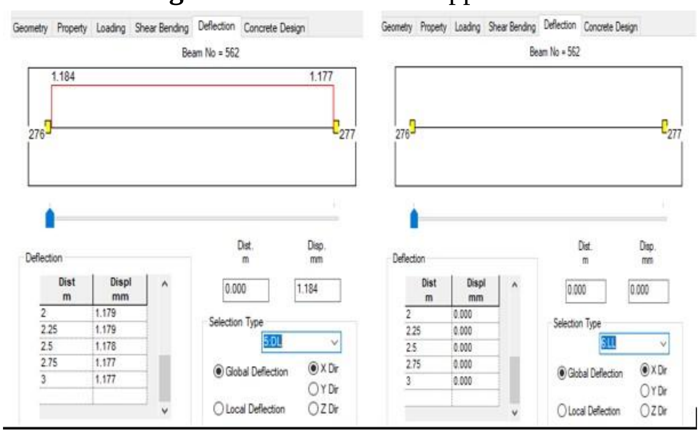
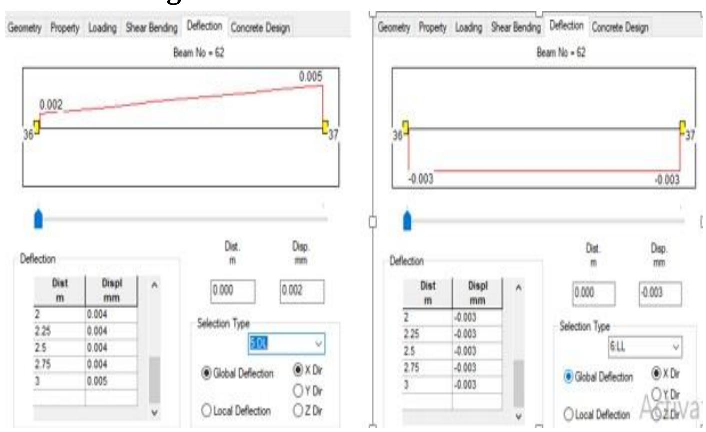


Figure 13: Deflection in lower beams



For beam no. 562, due to Dead load; at node 276 there is deflection of 1.184 mm while that for node no. 277 it is recorded as 1.177 mm. Similarly values of deflection can be read out for Live load also.

For beam no. 62, deflection at node 36 due to Dead load is 0.002 mm while at node 37 is 0.005 mm in Global X direction. Deflection due to Live load at node 36 is observed as -0.003 mm (negative value indicates that deflection of beam is in vertical direction) and at node 37 it is recorded as -0.003 mm.

Figure 14 : Deflection limits as per National Building Code 2016 (Volume 1)

Table 6 Deflection Limits
(*Clause* 11.6.1)

Type of Building (1)	Deflection (2)	Design Load (3)	Member (4)	Supporting (5)	Maximum Deflection (6)
Industrial buildings	Vertical	Imposed load and wind load	Purlins and Girts	Elastic cladding	Span / 150
				Brittle cladding	Span / 180
		Imposed load	Simple span	Elastic cladding	Span / 240
				Brittle cladding	Span / 300
		Imposed load	Cantilever span	Elastic cladding	Span / 120
				Brittle cladding	Span / 150
		Imposed load, wind load and crane load	Rafter supporting	Profiled metal sheeting	Span / 180
				Plastered sheeting	Span / 240
		Crane load (Manual operation)	Gantry	Wheels of crane	Span / 500
		Crane load (Electric operation up to 50 t)	Gantry	Wheels of crane	Span / 750
		Crane load (Electric operation over 50 t)	Gantry	Wheels of crane	Span / 1 000
	Lateral	No cranes (due to wind)	Column	Elastic cladding	Height / 150
				Masonry/Brittle cladding	Height / 240
		Crane load and wind load	Gantry (lateral)	Crane (absolute)	Span / 400
				Relative displacement between rails supporting wheels of crane	10 mm
		Crane load and wind load	Column/frame	Gantry (Elastic cladding)	Height / 200
				Gantry (Brittle cladding; cab operated)	Height / 400
Other buildings	Vertical	Imposed load	Floor and roof	Elements not susceptible to cracking	Span / 300
				Elements susceptible to cracking	Span / 360
		Imposed load	Cantilever	Elements not susceptible to cracking	Span / 150
				Elements susceptible to cracking	Span / 180
	Lateral	Wind load	Building	Elastic cladding	Height / 300
				Battle cladding	Height / 500
		Wind load	Inter-storey drift	—	Storey height/300

Figure 15: Results for maximum & minimum displacement

Postprocessing: Displacements Reactions Beam Results Plate Results Solid Results Dynamics
All Summary

	Node	L/C	Horizontal X mm	Vertical Y mm	Horizontal Z mm	Resultant mm	Rotational rX rad	rY rad	rZ rad
Max X	124	1 EQ + X	26.263	-0.106	-0.812	26.276	-0.000	0.001	-0.001
Min X	124	2 EQ - X	-26.263	0.106	0.812	26.276	0.000	-0.001	0.001
Max Y	139	2 EQ - X	-10.242	0.253	2.452	10.534	0.000	-0.002	0.000
Min Y	99	5 DL	-0.580	-1.216	-0.387	1.401	-0.002	-0.000	-0.000
Max Z	128	1 EQ + X	8.383	-0.164	2.757	8.826	0.000	-0.001	-0.000
Min Z	128	2 EQ - X	-8.383	0.164	-2.757	8.826	-0.000	0.001	0.000
Max rX	97	5 DL	0.372	-1.203	-0.208	1.276	0.002	-0.000	-0.000
Min rX	99	5 DL	-0.580	-1.216	-0.387	1.401	-0.002	-0.000	-0.000
Max rY	139	1 EQ + X	10.242	-0.253	-2.452	10.534	-0.000	0.002	-0.000
Min rY	139	2 EQ - X	-10.242	0.253	2.452	10.534	0.000	-0.002	0.000
Max rZ	52	2 EQ - X	-11.091	0.075	0.293	11.095	0.000	-0.000	0.002
Min rZ	52	1 EQ + X	11.091	-0.075	-0.293	11.095	-0.000	0.000	-0.002
Max Rst	123	1 EQ + X	26.262	0.106	1.263	26.293	0.000	0.001	-0.001

From the table, maximum displacement of 26.293 mm is observed at node 123 due to seismic load in +X-direction and the minimum displacement of -26.263 mm at node 124 due to seismic load in -X direction. According IS 456:200 code maximum permissible storey displacement is limited to H/500, where H= total height of the building; 33000/500= 66 mm > 26.293 mm hence results are reliable.

- **Maximum & Minimum Reactions: -**

Figure 16: Results for maximum & minimum reactions

Postprocessing: Displacements Reactions Beam Results Plate Results Solid Results

All Summary Envelope

	Node	L/C	Horizontal Fx kN	Vertical Fy kN	Horizontal Fz kN	Moment Mx kN-m	Moment My kN-m	Moment Mz kN-m
Max Fx	18	2 EQ -X	105.689	-465.980	-4.306	-16.058	13.930	-233.162
Min Fx	18	1 EQ +X	**-105.689**	465.980	4.306	16.058	-13.930	233.162
Max Fy	3	5 DL	15.463	**2495.869**	-29.846	-29.608	0.304	-17.978
Min Fy	19	2 EQ -X	75.195	**-1709.271**	-19.346	-45.173	10.043	-203.370
Max Fz	1	5 DL	10.652	2024.429	**28.367**	28.339	0.149	-10.345
Min Fz	3	5 DL	15.463	2495.869	**-29.846**	-29.608	0.304	-17.978
Max Mx	21	1 EQ +X	-60.762	936.680	27.793	**53.613**	-10.474	174.087
Min Mx	21	2 EQ -X	60.762	-936.680	-27.793	**-53.613**	10.474	-174.087
Max My	18	2 EQ -X	105.689	-465.980	-4.306	-16.058	**13.930**	-233.162
Min My	18	1 EQ +X	-105.689	465.980	4.306	16.058	**-13.930**	233.162
Max Mz	3	1 EQ +X	-83.746	-651.650	-7.589	-19.815	-12.584	**304.159**
Min Mz	3	2 EQ -X	83.746	651.650	7.589	19.815	12.584	**-304.159**

It is clearly shown that maximum reaction is 2495.869 KN in vertical direction due to dead load at node 3 and minimum reaction is -1709.271 KN in vertical direction due to seismic load in –X-direction at node 19.

- **Maximum & Minimum Bending Moment: -**

Figure 17: Results obtained for maximum & minimum bending moment

Postprocessing: Displacements Reactions Beam Results Plate Results Solid Results Dynamics

All Summary Envelope

	Beam	L/C	Node	Fx kN	Fy kN	Fz kN	Mx kN-m	My kN-m	Mz kN-m
Max Fx	27	5 DL	25	498.612	-8.896	23.284	0.021	46.579	17.757
Min Fx	45	2 EQ - X	19	**-101.265**	-11.028	-1.593	1.947	3.496	-28.199
Max Fy	203	5 DL	97	33.510	**82.270**	-0.016	-0.062	0.170	117.396
Min Fy	103	5 DL	51	5.159	**-79.801**	0.005	-0.017	0.058	116.034
Max Fz	177	5 DL	73	95.061	-19.222	**43.755**	0.191	-60.389	-25.408
Min Fz	179	5 DL	75	98.027	-22.943	**-44.579**	0.448	61.399	-31.337
Max Mx	219	5 DL	101	4.593	66.771	-0.151	**4.843**	0.277	17.824
Min Mx	205	5 DL	97	10.588	-0.898	0.015	**-6.318**	-0.170	-4.747
Max My	177	5 DL	97	109.374	-19.222	43.755	0.191	**70.875**	32.259
Min My	179	5 DL	99	112.340	-22.943	-44.579	0.448	**-72.339**	37.492
Max Mz	153	5 DL	73	-7.859	82.236	-0.009	-0.046	0.111	**119.316**
Min Mz	29	2 EQ - X	3	41.643	-17.365	0.678	1.655	-1.739	**-58.124**

From post processing mode of analysis, bending moment results can be analyzed from the "Beam Results". According to this summary, maximum bending moment is 119.316 KN-m at nodal point 73 due to Dead Load on beam no. 153.Minimum value of bending moment is -72.339 KN-m at node 99 due to Dead Load on beam no. 179.

According to the condition of Maximum Bending Moment; for UDL: –

$BM_{max} = wL^2 /8$

$= (19.975 + 19.975) *1.5* 5^2 / 8$

= 187.266 KN-m > 119.316 KN-m (O.K)

Therefore, maximum values of deflection, displacement and bending moment are within the safe limits and hence the building is reliable enough to resist failures.

Figure 18: 3-D Rendered view

From view toolbar on the right side of the window from 3-D Rendering view the entire structure depicting beams & columns as per plan along with thickness can be viewed as shown above.

From the work carried out in Staad Pro and related software it can be concluded that: -

- Reinforcement details of each & every member is obtained using Staad Pro.
- All the list of failed sections is obtained, which is given by Staad Pro so that we can change the property data for the better section.
- Shear & moment variation, concrete design, deflection of every individual beam and column is acknowledged separately.
- Accuracy is improved by software and also this software reduces lot of time in design work.

CONCLUSION

- Application of primary load cases namely Dead Load and Live Load on the structure and allocation of Seismic parameters in X and Z direction taken after by examination of deflection, displacement and bending moment it is clearly obvious that all the values are lying within permissible limits as endorsed by different codes. Subsequently, software results can be compared with standard benchmarks for checking out unwavering quality of the structure. The value of deflection is watched as
  -0.003 mm (in vertical direction to the applied load), which is exceptionally much smaller than the passable constrain i.e., 13.89 mm as per National Building Code; maximum displacement was found to be 26.293 mm, lesser than passable constrain of 66mm as per IS 456:2000 and maximum bending moment is calculated as 119.316 KN-m which is additionally inside the maximum allowable limit of
  187.266 KN-m according to the condition of maximum bending moment. So, all these judgements demonstrates that all the factors and loads doled out to the structure are correct and the outlined G+11 floor residential building is fundamentally secure and reliable.

- In the nutshell, it can be said that Equivalent Static Analysis is the simplest way to urge the response of existing or new structures. In Spite of the fact which numerous researches have demonstrated that Dynamic Analysis gives much precise results but at the same time Static Analysis appeared that building is able to attain the performance point inside the allowable restrain since seismic coefficients like Importance Factor (I), Response Reduction Factor (R), Zone Factor (Z), are as of now considered so these will unquestionably offset any failure.

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