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Design and Analysis of a Multistorey Residential Building with and without Earthquake Effect

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ABSTRACT

Design and analysis of multistorey building subjected to earthquake forces is a complex task, as earthquake forces are random in nature, and are unpredictable. Structural analysis is a branch which deals with structural behavior of the building elements. Earthquake is an unexpected movement of the earth's surface. Such tectonic earthquake that occurs naturally causes great losses of life and property. Earthquake resistant structures are specially designed to minimize the loss and damage that may occur during an earthquake.

The objective of this project is to Design and Analysis of a multistorey residential building (G+10) by using STAAD.ProV8i software. STAAD.ProV8i is one of the best software's for the design of structures. In this project the analysis of G+10 building of Vijayawada, Krishna district, Andhra Pradesh, India (seismic ZoneIII) is done with and without earthquake forces for finding the shear forces, bending moments, deflections & reinforcement details for the structural components of building, such as Beams, columns, & footings is done to develop the economic design. We conclude that STAAD.Pro is a very powerful tool which can save much time and is very accurate in Designs. At last, the structural behaviour of the building is studied under both the loading cases.

KEYWORDS: *Analysis, Design, Earthquake, STAAD.Pro, Structural Behaviour, Tectonic, Economic Design.*

I. INTRODUCTION

1.1 General

A building is a structure with a roof and walls, standing on columns over supported on foundation. This is more or less permanently in one place, such as a house or a factory. Buildings come in a variety of sizes, shapes and functions. Buildings are important indicators of social progress of the country. Every human has desired to own comfortable homes on a one spends his two-third life times in the houses. There are the few reasons which are responsible that the person does utmost effort and spend hard earned savings to save his own house.

1.2 OBJECTIVE OF THE PROJECT

- To design and analysis of a G+10 multistorey residential building by using STAAD.Pro, software.

The building is to be designed for both seismic and non-seismic design cases in the STAAD.Pro.

- To show the differences among the structural behavior of both the buildings.

1.3 STUDY OF EARTHQUAKES

Earthquake is the shaking of the Earth's crest resulting from the sudden release of energy in the Earths lithosphere. Earthquakes are recorded by instrument called seismographs. The recording that it makes is called as a seismogram. The machine used is a seismometer. The Ritcher magnitude scale is the most common standard of measurement for Earthquakes. It was invented in 1935, by Charles F.Ritcher of the California institute of technology. The Ritcher scale is used to rate the magnitude of an Earthquake.

1.4 EARTHQUAKE ZONAL STUDIES INDIA

The Indian subcontinent has a history of devastating earthquakes. The major reason for the high frequency and intensity of the earthquakes is that the Indian plate is driving into Asia at a rate of approximately 47 mm/year. The latest version of seismic zoning map of India given in the earthquake resistant design code of India [IS 1893 (Part 1) 2002] assigns four levels of seismicity for India in terms of zone factors. In other words, the earthquake zoning map of India divides India into 4 seismic zones (Zone 2, 3, 4 and 5). According to the present zoning map, Zone 5 expects the highest level of seismicity whereas Zone 2 is associated with the lowest level of seismicity.

1.5 ESTABLISHMENT OF ANDHRA PRADESH SEISMIC NETWORK

Andhra Pradesh state in the southern peninsular India has a low to moderate seismic hazard. The state falls in seismic zones II and III (as per Bureau of Indian standards map 2002). The capital city of Hyderabad lies in zone II. The area under south-eastern districts of Chittoor, Nellore and Kadapa come under zone III. Districts of Godavari and Krishna river basins and their delta region lie in zone III.

1.6 RESIDENTIAL BUILDING: Residential buildings may range from small huts to multimillion-dollar high rise apartment blocks able to house thousands of people.

- Residential building has different names for their use depending if they are seasonal include.

Residential buildings are the buildings, which are used for normal residential purposes and should

- facilitate activities such as sleeping, living and cooking. A human being generally spends 14-16 hours of his daily life in residential building, for purposes like sleeping, cooking, eating and for full filling his daily needs.

1.7 SOFTWARES USED:

1.7.1 AUTO CAD:

Auto CAD is a standard drafting tool developed and maintained by Autodesk. The word auto came from Autodesk company and CAD stands for computer aided drafting. Drafting means the drawing which drawn to a scale.

1.7.2 STAAD.ProV8i:

STAAD.Pro is a designing software tool developed and maintained by Bentley. STAAD stands for STrucrural Analysis and Design. In this project the design and analysis of G+10 multistoried residential building is carried out by using STAAD.Prov8i software. By using IS 456:2000 recommendations for R.C frame design. Is 1893:2002 for earth quake analysis.

1.7.3 STAAD.Foundation:

STAAD.Foundation is extension for STAAD.Pro, in which the designing of foundation is executed. The output of the STAAD.Pro file is exported in to the STAAD.Foundation and the foundation to be analyzed.

II. LITERATURE REVIEW

D. R. Deshmukh et.al (2016): He developed, a Model of G+19 storey building, analysis and design using STAAD.Pro software. Building plan size is 33.6m × 18.8m. The building is situated in Pune in earthquake zone III. Comparison of results of earthquake load applied on the structure by STAAD-Pro and manual calculations both by seismic coefficient method. Deflection obtained by STAAD pro is checked by IS Codal limitation for serviceability.

Pushkar Rathod et.al (2017): He studied a G+21 multistoried building (3-dimensional frame) by using STAAD.Pro. The design of G+21 building involves manual load calculations and the whole structure is analysed by STAAD Pro. Limit State Design method is used in STAAD.Pro analysis conforming to IS Code of Practice. He compared the results with manual calculations.

R. Sanjaynath et.al (2018): He designed a G+20 multistorey residential building. First of all, the planning is done using AutoCAD. The design involves load calculations manually and the structure is analyzed using STAAD.Pro. For analysing the structure, the loads are very important which are calculated using IS 875. The LIMIT STATE METHOD of design has been adopted. Deflection and shear tests are checked for beams, columns and slabs. The tests proved to be safe. Both theoretical and practical work has been done.

III. DRAWINGS AND SPECIFICATIONS

3.1 GENERAL:

Plans: These are the drawings showcasing the floor plans from the top, defining the doors, windows and other interior elements of the floor, including the furniture layout.

Elevations: Elevations are defined as the exterior views of the buildings from either side of the buildings. It defines exactly how a building will exhibit from outside once the construction is completed.

Sections: Sections are formed when we slice down a building from the along x axis or either y axis.

3.2 VARIOUS TYPES OF PLANS:

3.2.1 SITE PLAN

The plans which shows the layout plan and the site area of the building plot. The site layout of the G+10 residential building is shown below.

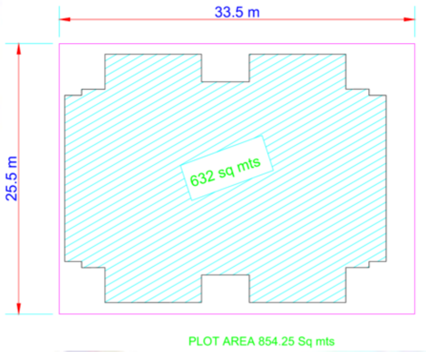

Fig. 3.1 site plan

3.2.2 CENTER LINE PLAN

This plan shows the center line of the whole building on the basis of the walls and beams along their position. The centerline plan of the G+10residential building is as shown below. It is used as structural plan in STAAD.Pro.

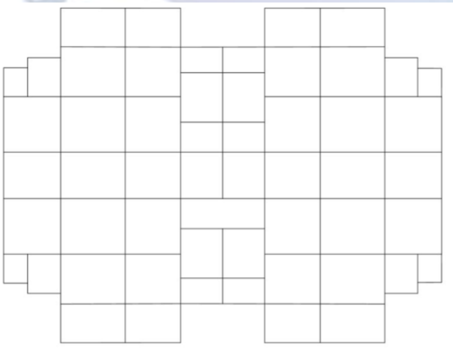

Fig. 3.2 centerline plan

3.2.3 VARIOUS FLOOR PLANS

The ground floor and first floor plan of the G+10 residential building is as shown below.

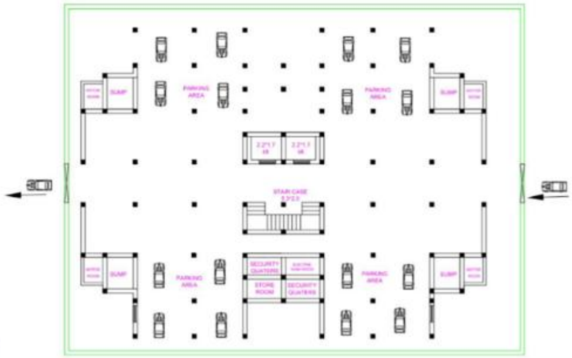

Fig. 3.3 ground floor plan

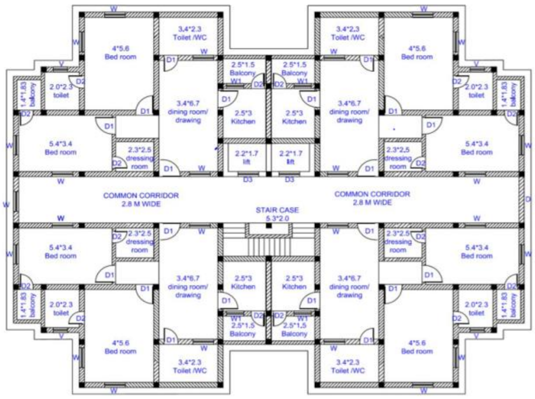

Fig-3.4 G +1 to 10 floor plans

3.3 SPECIFICATIONS OF THE STRUCTURE

1. Building type : Multistorey Residential building.
2. Location of the building: Gannavaram, Krishna District, Andhra Pradesh,
3. Size of building plot : 33.5m x 25.5m
4. Period of construction : 20 months.
5. Area of the plot : $854.25 m^2$.
6. Plinth area : $632\ m^2$.
7. No of floors : G+10.
8. Hight of ground floor : 3.2m.
9. Hight of each floor : 3.2m.
10. Seismic zone : Zone - III
11. Basic wind speed : 56 m/second.
12. Height of water table : 10m below G.L.
13. Foundation type : Isolated square footing.
14. Depth of foundation : 4 m.
15. Max Size of concrete -bed : 2100mm x 2100mm.
16. Min Size of concrete bed : 750mm x750mm.
17. Grade of main reinforcement : fe500.
18. Plinth beam size : 400mm x 400 mm.
19. Damp proof course : 80mm thick Chemical

D.P.C. over the Floor

20. Ground floor thickness : 200mm.
21. Size of columns : 400mm x 500mm.
22. Size of beams : 600mm x 400mm
23. Thickness of slab : 150mm.
24. Main wall thickness : 300mm thick.
25. Partition wall thickness : 200mm thick.
26. Height of parapet wall : 600 mm.
27. Size of door (D1) : 1200mm x 2100mm.
28. Size of door (D2) : 1000mm x 2100mm.
29. Size of window (W1) : 1000mm x 2000mm.
30. Size of window (W2) : 1000mm x 1000mm.

IV. METHODOLOGY

4.1 STEP BY STEP PROCESS OF METHODOLOGY FOR STAGES

1. DRAWING OF PLANS

i. **Preparation of site plan**

Based on location and area available, a suitable site plan is prepared.

ii. **Preparation of detailed plan**

On the basis of requirements of the structure, prepare a plan which helps in resisting the earthquake effects.

iii. **Preparation of centreline plan**

Using detailed plan as a reference, prepare a centreline plan for building, which is exported in to STAAD.pro.

this centreline plan is used as a structural plan in STAAD.Pro.

iv. **Preparation of column layout plan**

Using detailed plan as a reference, draw a column layout plan which helps in positioning the footings.

2. STAAD.Pro DESIGNING

i. **Model generation**

Export DXF file of structural plan, which is drawn in the AutoCAD. By using translation repeat option, construct a G+10 building in STAAD.Pro.

ii. **Section properties**

Define the sizes of beams and columns. And define the thickness of slabs.

iii. **Material Properties**

Specify the material such as concrete.

iv. **Supports**

Define supports at end of columns at bottom.

v. **Loads**

Assign loads such as, self-weight, live load, wind load and Earthquake load.

vi. **Analysis**

Indicate the type of analysis to be performed and associate option.

vii. **Design**

Specify the suitable commands for concrete and steel design as per IS 456.

viii. **Postprocessing**

Give commands to Extract and Review Analysis, Result.

3. STAAD.FOUNDATION DESIGNING

i. **Creation of model**

Open foundation design option and include all the load cases. Then start the foundation design.

ii. **Job setup**

Create a new job for isolated square footing. Use Indian standard code and SI units.

iii. **Design**

Design the isolated footing design.

iv. **Results**

Results for each footing is appeared and checks are also be done for each footing.

4.2 SYUDY OF BUILDING LOADS

Loads, these are the main reason that the structures are to be designed up to their maximum output. If the structure is not able bear the load acting on it, structure will fail and leads to loss of many lives and property. The types of loads acting on structures for buildings and other structures can be broadly classified as vertical loads, horizontal loads and longitudinal loads. The vertical loads consist of dead load, live load. The horizontal loads comprise of wind load and earthquake load.

4.3 DEAD LOADS (DL): The first vertical load that is considered is dead load. Dead loads are permanent or stationary loads which are transferred to structure throughout the life span. Dead load is primarily due to self-weight of structural members, permanent partition walls, fixed permanent equipment and weight of different materials. It majorly consists of the weight of roofs, beams, walls and column etc. which are otherwise the permanent parts of the building. IS 875: 1987 is the Indian standard code used for calculation of dead loads of the structures. The calculation of dead loads of each structure are calculated by the volume of each section and multiplied with the unit weight.

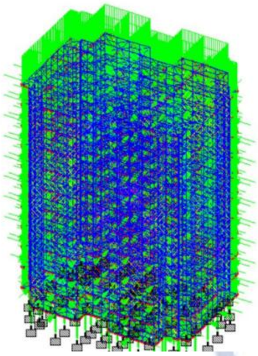

Fig. 4.1 Assigning of dead load

4.4 LIVE LOADS: Live loads are produced by the use and occupancy of a building. Loads include those from human occupants, furnishings, no fixed equipment, storage, and construction and maintenance activities. In STAAD we assign live load in terms of U.D. L we have to create a load case for live load and select all the beams to carry such load. After the assignment of the live load the structure appears as shown below.

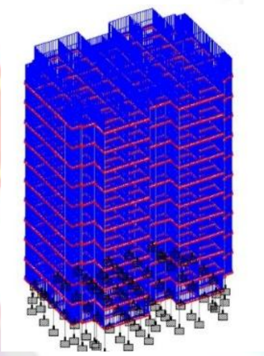

Fig. 4.2 Assigning live load

4.5 WIND LOADS: In the list of loads we can see wind load is present both in vertical and horizontal loads. This is because wind load causes uplift of the roof by creating a negative (suction) pressure on the top of the roof. Wind produces non static loads on a structure at highly variable magnitudes. The variation in pressures at different locations on a building is complex to the point that pressures may become too analytically intensive for precise consideration in design.

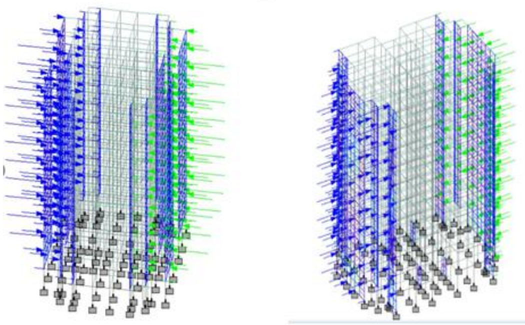

Fig. 4.3 Wind forces ix X & Z directions

4.6 FLOOR LOAD:

Floor load is calculated based on the load on the slabs. Assignment of floor load is done by creating a load case for floor load. After the assignment of floor load our structure looks as shown in the below figure. The intensity of the floor load taken is 3.75 kN/m^2 -ve sign indicates that floor load is acting downwards.

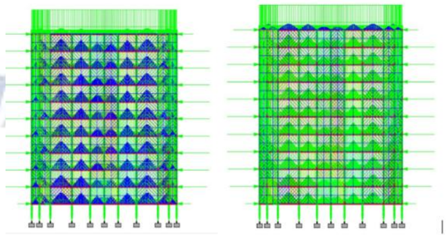

Fig. 4.4 Floor and roof loads

4.7 EARTHQUAKE LOADS (EL)

Earthquake forces constitute to both vertical and horizontal forces on the building. The total vibration caused by earthquake may be resolved into three mutually perpendicular directions, usually taken as vertical and two horizontal directions.

4.8 LOAD COMBINATIONS: In this project, design and analysis of G+10 multistoried residential building is done for two cases:

i. Building subjected for earthquake forces and,

ii. Building subjected for other than earthquake loads (except snow load).

On the basis of Indian standard code, IS 456:2000, the intensities for both the cases are as follows:

i. 1.2 (D.L + L.L + E.L) for structure subjected for earthquake forces only.

ii. 1.2 (D.L + L.L + W.L) for structure subjected for seismic and non-seismic forces.

V. DESIGNING AND ANALYSIS OF STRUCTURE

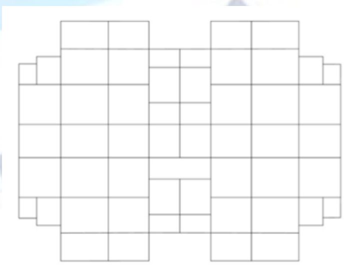

Fig. 5.1 Structural plan of building

A. DESIGN OF MULTISTOREY RESIDENTIAL BUILDING BY USING STAAD.PRO WITH EARTHQUAKE EFFECT.

Step - 1: Creation of centre line plan of the building by using AutoCAD. Save the plan in DXF format.

Step - 2: Export the DXF file into STAAD.Pro. Here the 2d cad plan is exported. and kept it as Y axis upwards. Use translational repeat option and generate a G+10 building structure.

Step - 3: 3D view of structure. Here we have used the Transitional repeat command in Y direction to get the 3D view of structure.

Step - 4: Supports and Property Assigning. After the creation of structure, the supports at the base of structure are specified as fixed. Also, the materials were specified and cross section of beams and columns members was assigned.

Step - 5: 3D rendering view. After assigning the property the 3d rendering view of the structure can be shown.

Step - 6: Assigning of Wind Loads. Wind loads are defined as per IS 875 PART 3 based on intensity calculated and exposure factor. Then loads are added in load case details in W+X, W-X, W +Z, W-Z directions.

Step - 7: Assigning of Dead Loads. Dead loads are calculated as per IS 875 PART 1 for external walls, internal walls, parapet wall including self-weight of structure.

Step - 8: Assigning of Live Loads. Live loads are assigned for every floor as 4 kN/m^2 based on IS 875 PART-2.

Step - 9: Assigning of Earthquake load: Earthquake loads are defined by choosing a location in STAAD.Pro. the loads will automatically generated.

Step - 10: Adding of Load Combinations. After assigning all the loads, the load combinations are given with suitable factor of safety as per IS 875 PART-5.

Step - 11: Analysis after the completion of all the above steps we have performed the analysis and checked for errors.

Step - 12: Design Finally concrete design is performed as per IS 456:2000 by defining suitable design commands for different structural components. After the assigning of commands again we performed analysis for any error

1) DESIGN OF BEAM

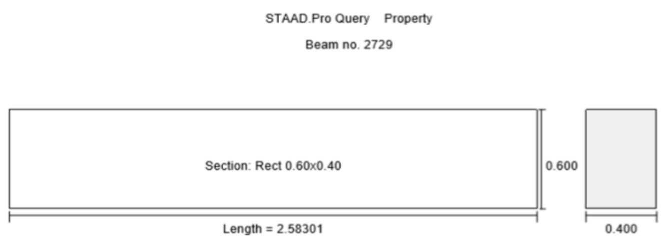

Fig. 5.1.1 Beam Properties

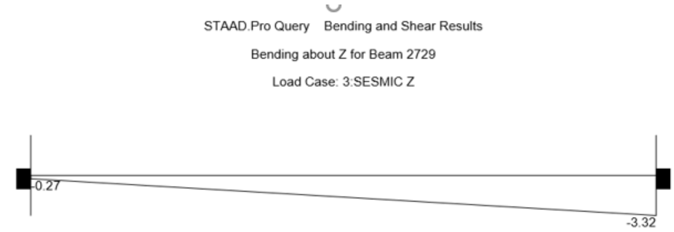

Fig. 5.1.2 Bending About Z

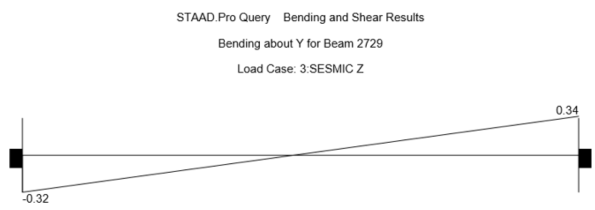

Fig. 5.1.3 Bending About Y

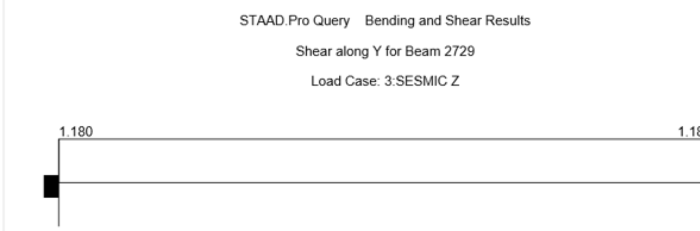

Fig. 5.1.4 Shear About Y

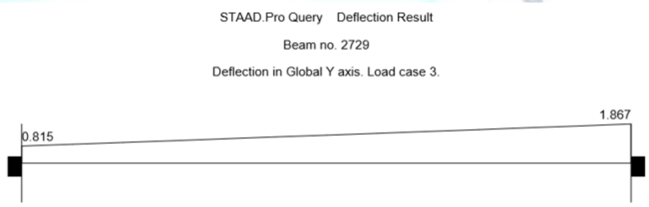

Fig. 5.1.5Deflection About Y

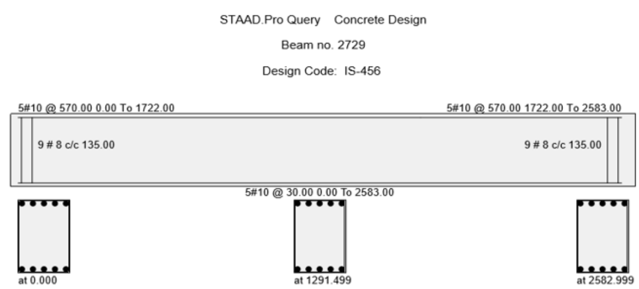

Fig. 5.1.6 Concrete design

5.1.2 DESIGN OF COLUMN

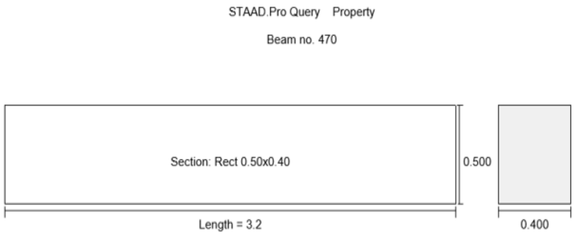

Fig. 5.17 Column Property

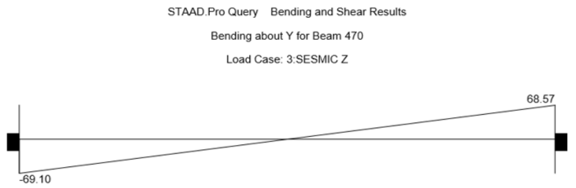

Fig. 5.1.8Bending About Y

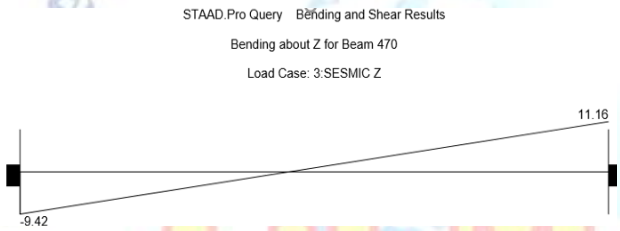

Fig. 5.1.9 Bending About Z

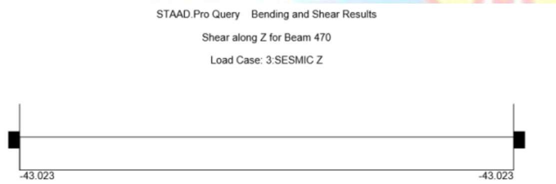

Fig. 5.1.10 Shear About Z

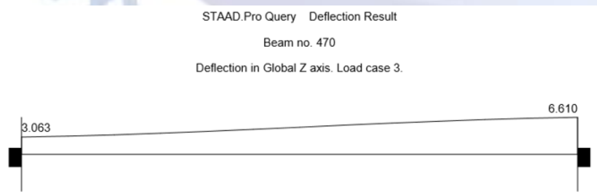

Fig. 5.1.11 Deflection About Z

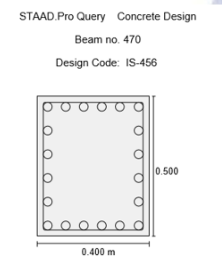

Fig. 5.1.12 Concrete Design

5.1.3 FOUNDATION DESIGN

Foundation no = 20
Length (L) = 5.100
Width (W) = 5.100m
Depth (D) = 0.456m
Area (A) = 26.010m^2

5.2 DESIGN OF MULTI STORIED RESIDENTIAL BUILDING BY USING STAAD.PRO WITHOUT EARTHQUAKE EFFECT.

Step - 1: Creation of centre line plan of the building by using AutoCAD. Save the plan in DXF format.

Step - 2: Export the DXF file into STAAD.Pro. Here the 2d cad plan is exported. and kept it as Y axis upwards. Use translational repeat option and generate a G+10 building structure.

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Step - 5: 3D rendering view. After assigning the property the 3d rendering view of the structure can be shown.

Step - 6: Assigning of Wind Loads. Wind loads are defined as per IS 875 PART 3 based on intensity calculated and exposure factor. Then loads are added in load case details in W+X, W-X, W +Z, W-Z directions.

Step - 7: Assigning of Dead Loads. Dead loads are calculated as per IS 875 PART 1 for external walls, internal walls, parapet wall including self-weight of structure.

Step - 8: Assigning of Live Loads. Live loads are assigned for every floor as 4 kN/m^2 based on IS 875 PART-2.

Step - 9: Adding of Load Combinations. After assigning all the loads, the load combinations are given with suitable factor of safety as per IS 875 PART-5.

Step - 10: Analysis after the completion of all the above steps we have performed the analysis and checked for errors.

Step - 11: Design Finally concrete design is performed as per IS 456:2000 by defining suitable design commands for different structural components. After the assigning of commands again we performed analysis for any errors.

5.2.1 BEAM DESIGN

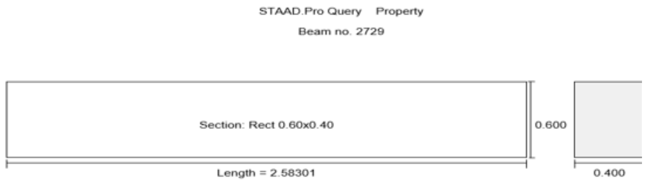

Fig. 5.2.1 Beam Property

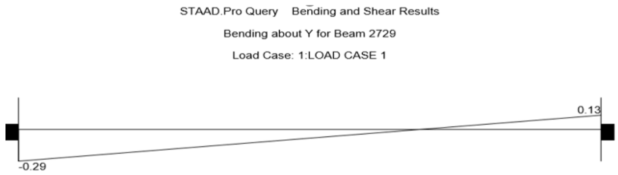

Fig. 5.2.2 Bending About Y

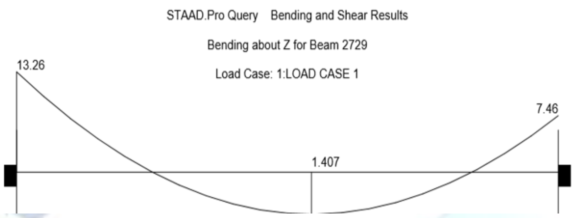

Fig. 5.2.3 Bending About Z

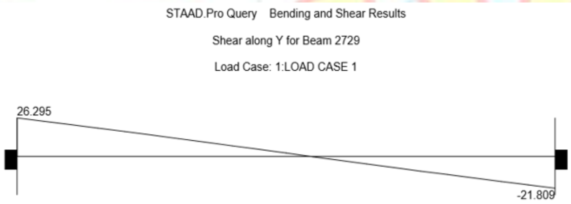

Fig. 5.2.4 Shear About Y

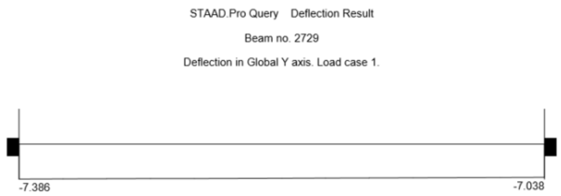

Fig. 5.2.5 Deflection About Y

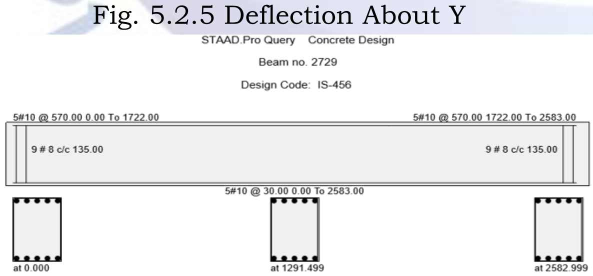

Fig. 5.2.6 Concrete Design

5.2.1 COLUMN DESIGN

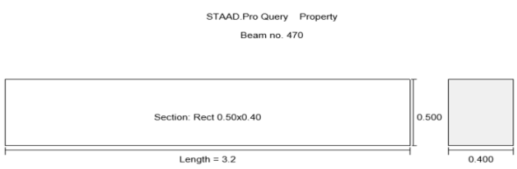

Fig. 5.2.7 Column Property

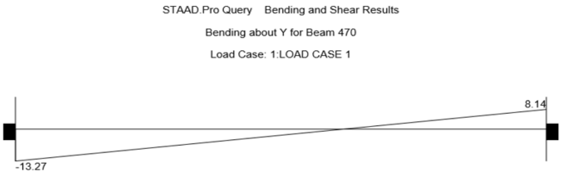

Fig. 5.2.8 Bending About Y

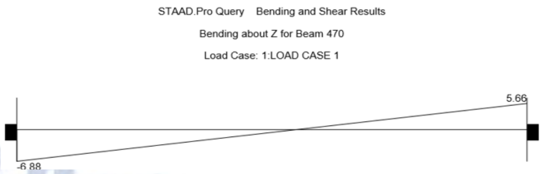

Fig. 5.2.9 Bending About Z

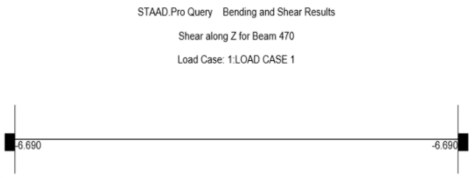

Fig. 5.2.10 Shear About Z

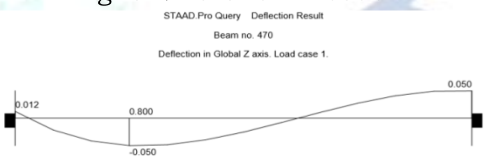

Fig. 5.2.11 Deflection About Z

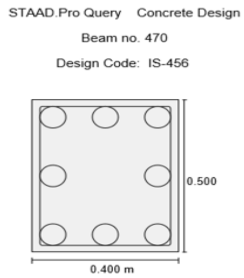

Fig. 5.2.12 Concrete Design

5.2.2 FOUNDATION DESIGN

Foundation no = 20
Length (L) = 4.750m
Width (W) =4.750m
Depth (D) = 0.456m
Area (A) = 22.563m^2

RESULTS AND DISCUSSIONS

RESULTS OF STRUCTURAL MEMBERS DESIGNED WITH AND WITHOUT EARTHQUAKE EFFECT.

Table- 6.1 Beam Results

	With EQ Forces	Without EQ Forces
Beam No	2729	2729
Span, m	2.58	2.58
Size	0.4*0.6	0.4*0.6
Axial Force KN	4.364	0.638
Shear Y KN	31.449	26.295
Shear Z KN	0.225	0.163
Torsion KNm	1.688	1.435
Moment -Y KNm	0.309	0.291

Moment – Z KNm	16.687	13.255
Combined Stress N/mm²	-0.72	-0.573
Shear Stress Y N/mm²	0.154	0.129
Max deflection mm	1.867	-7.386
Top reinforcement	4-12mm dia	4-12mm dia
Bottom reinforcement	5-10mm dia	5-10mm dia
Shear reinforcement	2 legged 8mm stirrups @ 130 mm c/c	2 legged 8mm stirrups @ 135 mm c/c

Max shear in beam with EQ forces is 19.6% more than the beam without EQ forces.

Max moment in the beam with EQ force is 20.7% more than the beam without EQ forces.

Max deflection in the beam with EQ forces is 25% more than the beam without EQ forces.

Table- 6.2 Column Results

	WITH EQ FORCES	WITHOUT EQ FORCES
Column No	470	470
Span, m	3.2	3.2
Size	0.4*0.5	0.4*0.5
Axial Force KN	1422.4	1664.6
Shear Y KN	36.088	3.918
Shear Z KN	43.023	6.69
Torsion KNm	0.074	0.037
Moment -Y KNm	69.103	13.265
Moment – Z KNm	61.313	-6.879
Combined Stress N/mm²	8.164	9.731
Shear Stress Y N/mm²	0.212	-0.02
Max deflection mm	6.61	0.05
Main reinforcement	8-12mm dia	8-12mm dia
Lateral ties	6 mm dia lateral ties @ 110 mmc/c	6 mm dia lateral ties @ 122 mmc/c

Max shear in column with EQ forces is 84.4% more than the column without EQ forces.

Max moment in the column with EQ force is 80% more than the column without EQ forces.

Max deflection in the column with EQ forces is 90% more than the column without EQ forces.

Table- 6.3 Footing Results

	WITH EQ FORCES	WITHOUT EQ FORCES
Footing No	20	20
Size	5.1*5.1	4.75*4.75
Thickness mm	0.456	0.456
Governing Moment M_u KNm	1001.9	1023.71
Limiting Moment of Resistant $M_{u\ Max}$ KNm	3809.5	3548.1
Shear Stress τ_v N/mm²	345.82	403.09
Shear Strength τ_c N/mm²	391.48	407.9
Bottom Reinforcement	Ø10 @ 65.000 mm c/c	Ø10 @ 55.000 mm c/c
Top Reinforcement	Ø8 @ 130 mm c/c	Ø8 @ 90 mm c/c

Max moment in footing with EQ forces is 2% less than the footing without EQ forces.

Max shear stress in the footing with EQ force is 14% less than the footing without EQ forces.

VI. CONCULSION

1. All details of each and every member are obtained by using STAAD pro software.
2. The wind loads combinations are more than Earthquake load combinations in Bending moment and Shear force.
   i. Max shear in beam with EQ forces is 19.6% more than the beam without EQ forces.
   ii. Max moment in the beam with EQ force is 20.7% more than the beam without EQ forces.
   iii. Max deflection in the beam with EQ forces is 25% more than the beam without EQ forces.
   iv. Max shear in column with EQ forces is 84.4% more than the column without EQ forces.
   v. Max moment in the column with EQ force is 80% more than the column without EQ forces.
   vi. Max deflection in the column with EQ forces is 90% more than the column without EQ forces
   vii. Max moment in footing with EQ forces is 2% less than the footing without EQ forces.
   viii. Max shear stress in the footing with EQ force is 14% less than the footing without EQ forces.
3. All the deflection is less than 20mm hence all the sections are safe against deflections.

- **Notations:**

  EQ – Earthquake

  Ø – dia of bars

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