Seismic Analysis & Design of G+5 Residential Building

K Aparna Srivastav
Department of Civil Engineering
Prasad V Potluri Siddhartha Institute of Technology, Kanuru, Vijayawada, AP, India.

Abstract- The method of analysis & design of multi-storey (G+5) Residential building located in zone 3.The scope behind presenting this project is to learn relevant Indian standard codes are used for design of various building elements such as beam, column, slab, foundation and stair case by using a software STAAD.Pro under the seismic load and wind load acting on the structure. The calculation of base shear manually and also the dead load, live load and wind load acting on the frame of the structure. The structure was analysed with various combination as per code IS 1893: 2002 part -1. On 10 primary loads with (DL, LL, WL, EL) .and also 26 load combinations were analysed and the worst load combination is find out and design is carried to the worst load combination using STAAD.Pro.The analyse& design the same structure without considering the lateral loads to show the variations in steel & concrete quantity for the both structures and check the storey drift condition by using the STAAD.Pro.We used STAAD.Pro for analysis and design of structure and STAAD.etc for slab and pile foundation design. We also used the AUTOCAD for our designs of the structures. The main advantage of displacing the drawing in AutoCAD is user has more flexibility to modify the drawings in AutoCAD as per his decision.
Keywords – Analysis & design of multi-storey (G+5) Residential building, STAAD.Pro, AutoCAD

I. INTRODUCTION

1.1. General:

The earthquake causes vibratory ground motions at the base of the structure, and the structure actively responds to these motions. For the structure responding to a moving base, there is an equivalent system. The base is fixed and the structure is acted upon by forces (called inertia forces) that cause the same distributions that occur in the moving-base system. In design system it is customary to assume the structure as a fixed- base system acted upon by inertia forces. Seismic design involves two distinct steps
1). Determining (or estimating) the earthquake forces that will acted on the structure, and,
2).Designing the structure to provide adequate strength, stiffness, and energy dissipation capabilities to with stand these forces.

1.2. Behavior of structure:

Building and other structures are composed of horizontal and vertical structural elements that resist lateral forces. The horizontal elements, diaphragms and horizontal bracings are used to distribute the lateral forces to vertical elements. The vertical elements that are used to transfer lateral forces to the ground are shear walls, braced frames and moment resisting frames. The structure must include complete lateral and vertical force resisting systems, capable of providing adequate energy dissipation capacity to withstand the design ground motions within the prescribed limits, deformation and strength demand.

1.3. Soft storey:

Many of RC buildings constructed recent times have special feature of the ground is left open for the purpose of parking, i.e. columns in the ground storey do not have any partition walls (of either masonry or RC) between them.
An open ground storey has two distinct characteristics
1). Flexible in the ground storey, i.e. the large displacement occurs between foundation and first floor.
2). Weak in ground storey i.e. the total horizontal earthquake force it can carry in the ground storey is significantly smaller than of the storey above that it can carry.

1.4. Statement of project:

The structure consisting of two apartments and one stair case. The building will be used for residential purpose, Stilt floor shall be leave for parking purpose. Main beams rest centrally on columns to avoid local eccentricity. Grade of concrete is M25 and Grade of steel is Fy415. Seismic loads, wind loads are considered acting in the direction (along either of two principal directions) and not along the vertical direction.

1.5.1. Structure Data:

- Live load : 2.0 KN/m^2.

- Thickness of slab :120 mm
- Location :Vijayawada in Zone III
- Type of Soil : Medium soil, Type II as per IS 1893 (Part 1)-2002[III]
- Allowable bearing pressure :150 KN/m^2
- Each Storey height : 3 m.
- Ground floor height : 4 m.
- Floors : G.F+5 upper floors.
- Floor finishing : 1.0 KN/m^2
- Roof finishing : 1.0 KN/m^2
- Wall thickness : 230 mm for exterior walls.

: 120 mm for interior walls.

- Outer Column sizes : 450 X 450 mm.
- Interior Column sizes : 300 X 300 mm.
- Beams at the plinth level : 230 x 230 mm.
- Beams in all floors : 230 x 520 mm.
- Wind load : As per IS: 875-1987(Part 3)[IX].
- Earthquake load : As per IS: 1893(part 1)- 2002[III]

II. LITERATURE REVIEW

SudhirK.Jain: Reviewed the new code of IS 1893 (Part-1): 2002[I].contains a discussion on clauses that are confusing and need classifications. The topographical and editorial errors are pointed out. Suggestions are also included for next revision of the code.

The following observations are made from this paper

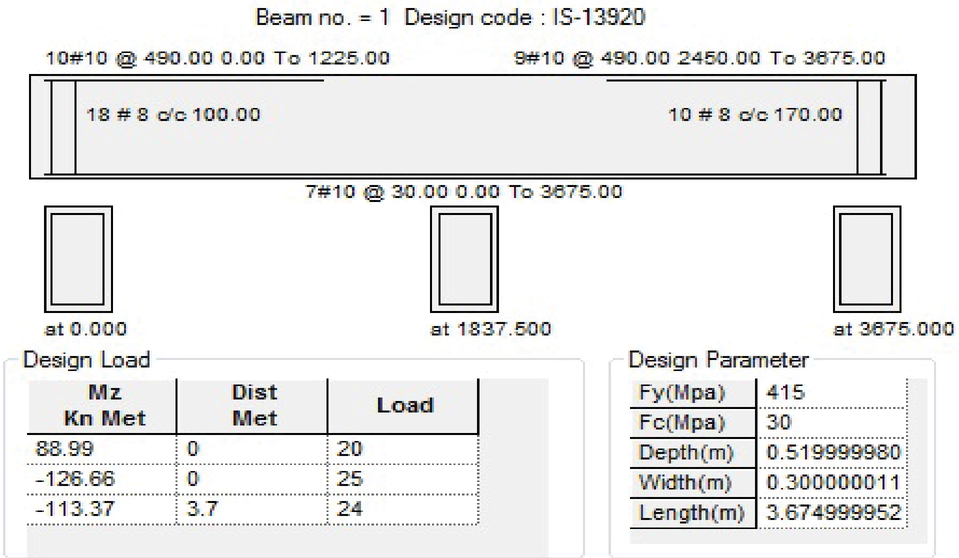
1. The seismic zone map now contains only four zones as compared to the five zones earlier, and relative values of zone factors are different.
2. The design spectrum shape depends on the type of soil and foundation soil factor (β) has been dripped.
3. The minimum design force based in empirical fundamental period of the building even if the dynamic analysis gives a very high value of natural period and thus low seismic force.
4. Most India buildings are soft storey buildings as per coda definitions simply because the ground storey height is usually different from that in the upper storey.
5. In the load combination the load factor 0.90 for gravity load, 1.5 for earthquake loads is used in RC structures.

Comments and suggestions on earthquake intensity, risk level, service life of structure, response spectrum etc is given.

The author suggests that there is need to simplify provisions on torsion in buildings, treatment of soft storey buildings, treatment of building, treatment of building with masonry infill walls etc.

*M.S.AlphaSheth:*Discussed a case for a simplified methodology of detailing for ordinary buildings in Zones with moderate seismic hazard which will greatly ease the application of earthquake engineering for buildings in zone III. The author argues that the simplification of ductile detailing in zone III would greatly encourage its wide spread implementation. IS 13920:1993[II] covers the requirements for design and detailing of monolithic special reinforced concrete, moment resisting frames (SMRF) so as to give them adequate toughness and ductile to resist severe earthquake shaking without collapse and moderate shaking with some non- structural damage. Code suggests same ductile detailing required for zones III, IV and V. The intensity of shaking in zone III towns and cities was much lower. To compensate for the reduction in the toughness due to a relaxation of the ductile criteria, the response reduction factor R be less than the value of 5 for special RC moment resistance frame but may be more than 3.0 for RC moment resisting frames. Some of provisions are explained for flexural members, columns and structural walls etc. The author suggests that concluded that, in zones II and III, buildings may be designed with less stringent ductility detailing but with an increase in design seismic force.

III. EXPERIMENT AND RESULT



BeamDesign:

EUDL CONSIDERED ON MEMBER # 1 IS 20.61 N/MM.

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B E ANM N O. 1 D E S I G N R E S U L T S

M30 Fe415 (Main) Fe415 (Sec.)

LENGTH: 3675.0 mm SIZE: 300.0 mm X 520.0 mm COVER: 25.0 mm

SUMMARY OF REINF. AREA (Sq.mm)

SECTION	0.0 mm	918.8 mm	1837.5 mm	2756.2 mm	3675.0 mm
TOP REINF.	779.62 (Sq. mm)	465.63 (Sq. mm)	465.63 (Sq. mm)	465.63 (Sq. mm)	688.30 (Sq. mm)
BOTTOM REINF.	531.57 (Sq. mm)	465.63 (Sq. mm)	465.63 (Sq. mm)	465.63 (Sq. mm)	465.63 (Sq. mm)

SHEAR DESIGN RESULTS AT DISTANCE d (EFFECTIVE DEPTH) FROM FACE OF THE SUPPORT

SHEAR DESIGN RESULTS AT 710.0 mm AWAY FROM START SUPPORT

VY = 79.02 MX = -0.46 LD= 25

Provide 2 Legged 8í @ 170 mm c/c

SHEAR DESIGN RESULTS AT 710.0 mm AWAY FROM END SUPPORT

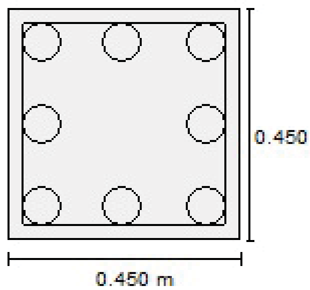
VY = -80.37 MX = 0.10 LD= 24

Provide 2 Legged 8í @ 170 mm c/c

EUDL CONSIDERED ON MEMBER # 2 IS 20.47 N/MM.

Column Design:

Beam no. = 31 Design code : IS-13920



Design Load

Load	3
Location	End 1
Pu(Kns)	-149.11
Mz(Kns-Mt)	5.86
My(Kns-Mt)	70.68

Design Parameter

Fy(Mpa)	415
Fc(Mpa)	30
As Reqd(mm²)	1528
As (%)	0.79
Bar Size	16
Bar No	8

COLUMN DESSIGN

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C O L U M N   N O.   31 D E S I G N   R E S U L T S

M30 Fe415 (Main) Fe415 (Sec.)

LENGTH: 4000.0 mm CROSS SECTION: 450.0 mm X 450.0 mm COVER: 40.0 mm

** GUIDING LOAD CASE: 3 END JOINT: 1 SHORT COLUMN

REQD. STEEL AREA : 1528.10 Sq.mm.

REQD. CONCRETE AREA: 191013.05 Sq.mm.

MAIN REINFORCEMENT : Provide 8 - 16 dia. (0.79%, 1608.50 Sq.mm.)

(Equally distributed)

CONFINING REINFORCEMENT : Provide 12 mm dia. rectangular ties @ 100 mm c/c

Over a length 670.0 mm from each joint face towards Midspan as per Cl. 7.4.6 of IS-13920.

2 number overlapping hoop along with crossties are provided along Y direction. (Clause 7.3.2 of IS-13920)

2 number overlapping hoop along with crossties are provided along Z direction. (Clause 7.3.2 of IS-13920)

TIE REINFORCEMENT : Provide 8 mm dia. rectangular ties @ 225 mm c/c

SECTION CAPACITY BASED ON REINFORCEMENT REQUIRED (KNS-MET)

Puz : 3188.74 Muz1 : 78.22 Muy1 : 78.22

INTERACTION RATIO: 0.98 (as per Cl. 39.6, IS456:2000)

SECTION CAPACITY BASED ON REINFORCEMENT PROVIDED (KNS-MET)

WORST LOAD CASE: 3

END JOINT: 1 Puz : 3212.68 Muz : 82.82 Muy : 82.82 IR: 0.92

= 0.04766

Moment Co-efficient in longer dir. at span , α_y

= 0.03500

Moment Co-efficient in longer dir. at edge , α'_y

= 0.04700

Factored Moment at ,

Span in shorter direction , M_{ux}
$= \alpha_x * W * L_x^2$ = 6616.82975 Nmm

Span in longer direction , M_{uy}
$= \alpha_y * W * L_x^2$ = 6514.12673 Nmm

Support in shorter direction , M'_{ux}
$= \alpha'_x * W * L_x^2$ = 8870.78524 Nmm

Support in longer direction , M'_{uy}
$= \alpha'_y * W * L_x^2$ = 8747.54162 Nmm

Width of the Slab , b

= 1 mm

Limiting Moment of resistance of section

Along X-Direction , $M_{u,lim-x}$

= 24902.41494 Nmm

Along Y-Direction , $M_{u,lim-y}$

= 20407.56354 Nmm

Area Of steel reinf. in X-Dir. at span bottom , A_{stx}

= 0.20181 sq. mm

Area Of steel reinf. in Y-Dir. at span bottom , A_{sty}

= 0.22165 sq. mm

Area Of steel reinf. in X-Dir. at support top , A'_{stx}

= 0.27516 sq. mm

Area Of steel reinf. in Y-Dir. at support top , A'_{sty}

= 0.30402 sq. mm

Minimum Area Of steel reinf. in X-Dir. , $A_{stx-min}$

= 0.14400 sq. mm

Minimum Area Of steel reinf. in Y-Dir. , $A_{sty-min}$

= 0.14400 sq. mm

Cross-sectional Area Of steel in X-Dir. , $A\phi_x$
$= \pi * \phi_x^2/4$ = 78.53975 sq. mm

Cross-sectional Area Of steel in Y-Dir. , $A\phi_y$
$= \pi * \phi_y^2/4$ = 50.26544 sq. mm

Spacing in shorter Dir. at span , S_x

= 280.000 mm

Spacing in longer Dir. at span , S_y

= 220.000 mm

Maximum Spacing in shorter Dir. , S_{x-max}

= 280.000 mm

Maximum Spacing in longer Dir. , S_{y-max}

= 250.000 mm

Spacing in shorter direction at edge , S'_x

= 280.000 mm

Spacing in longer direction at edge , S'_y

= 160.000 mm

Calculation Of Shear

Factored shear force in shorter direction , V_{ux}

= 16.82210 N

Factored shear force in longer direction , V_{uy}

= 16.69968 N

Shear stress developed at shorter span , $\tau_{cx,dev}$
$= V_{ux}/ (b * d_x)$ = 0.17707 MPa

Shear stress developed at longer span , $\tau_{cy,dev}$
$= V_{uy}/ (b * d_y)$ = 0.19418 MPa

Percentage of steel reinf. in shorter dir. at top , P'_{tx}

= 0.28965

Permissble shear stress at the section along Y-axis , τ_{cx}

= 0.38237 MPa

Percentage of steel reinf. in longer dir. at top , P'_{ty}

= 0.35352

Permissble shear stress at the section along X-axis , τ_{cy}

= 0.41559 MPa

Design Data

Clear Length of shorter span of the slab , L_x

= 3240.000 mm

Clear Length of longer span of the slab , L_y

= 3620.000 mm

Panel Type is
Interior Panel

Uniformly Distibuted Live Load , W_l

= 0.00200 N/sq. mm

Characteristic Strength of concrete , F_{ck}

= 20.000 N/sq. mm

Characteristic Strength of steel , F_y

= 415.000 N/sq. mm

Unit Weight Of Concrete, γ_c

= 0.0000249 N/cubic mm

Bar size for reinf. in shorter Dir. , ϕ_x

= 10.000 mm

Bar size for reinf. in longer Dir. , ϕ_y

= 8.000 mm

Clr. Cover to the outermost Reinf. Bar of the slab , d'

= 20.000 mm

Calculation Of Reinforcement

Overall Depth of the Slab, D

= 120.000 mm

Dead Load Of Slab , W_d
$= D * \gamma_c$ = 0.00299 N/sq. mm

Effective Depth Of The Slab , d
$= D - d' - \phi_x/2$ = 95.000 mm

Effective Thickness Of the Slab along X-Dir , d_x
= d = 95.000 mm

Effective Thickness Of the Slab along Y-Dir , d_y
$= d - \phi_x/2 - \phi_y/2$ = 86.000 mm

Effective Length of shorter span of the slab , L_{ex}
$= L_x + d$ = 3335.000 mm

Effective Length of longer span of the slab , L_{ey}
$= L_y + d_y$ = 3706.000 mm

Ratio of longer to shorter span , r
$= L_y/L_x$ = 1.111

Max. Factored Load among all comb. ,W

= 0.01349 N/sq. mm

Moment Co-efficient in shorter dir. at span , α_x

= 0.02845

Moment Co-efficient in shorter dir. at edge , α'_x

= 0.03767

Moment Co-efficient in longer dir. at span , α_y

= 0.02400

Moment Co-efficient in longer dir. at edge , α'_y

= 0.03200

Factored Moment at ,

Span in shorter direction , M_{ux}
$= \alpha_x * W * L_x^2$ = 4267.18073 Nmm

Span in longer direction , M_{uy}
$= \alpha_y * W * L_x^2$ = 3599.75913 Nmm

Support in shorter direction , M'_{ux}
$= \alpha'_x * W * L_x^2$ = 5650.82128 Nmm

Support in longer direction , M'_{uy}
$= \alpha'_y * W * L_x^2$ = 4799.67883 Nmm

Width of the Slab , b

= 1 mm

Limiting Moment of resistance of section

Along X-Direction , $M_{u,lim-x}$

= 24902.41494 Nmm

Along Y-Direction , $M_{u,lim-y}$

= 20407.56354 Nmm

Area Of steel reinf. in X-Dir. at span bottom , A_{stx}

= 0.14400 sq. mm

Area Of steel reinf. in Y-Dir. at span bottom , A_{sty}

= 0.14400 sq. mm

Area Of steel reinf. in X-Dir. at support top , A'_{stx}

= 0.17115 sq. mm

Area Of steel reinf. in Y-Dir. at support top , A'_{sty}

= 0.16082 sq. mm

Minimum Area Of steel reinf. in X-Dir. , $A_{stx-min}$

= 0.14400 sq. mm

Minimum Area Of steel reinf. in Y-Dir. , $A_{sty-min}$

= 0.14400 sq. mm

Cross-sectional Area Of steel in X-Dir. , $A\phi_x$
$= \pi * \phi_x^2/4$ = 78.53975 sq. mm

Cross-sectional Area Of steel in Y-Dir. , $A\phi_y$
$= \pi * \phi_y^2/4$ = 50.26544 sq. mm

Spacing in shorter Dir. at span , S_x

= 280.000 mm

Spacing in longer Dir. at span , S_y

= 250.000 mm

Maximum Spacing in shorter Dir. , S_{x-max}

= 280.000 mm

Maximum Spacing in longer Dir. , S_{y-max}

= 250.000 mm

Spacing in shorter direction at edge , S'_x

= 280.000 mm

Spacing in longer direction at edge , S'_y

= 250.000 mm

Calculation Of Shear

Factored shear force in shorter direction , V_{ux}

= 16.06356 N

Factored shear force in longer direction , V_{uy}

= 14.99150 N

Shear stress developed at shorter span , $\tau_{cx,dev}$
$= V_{ux}/ (b + d_x)$ = 0.16909 MPa

Shear stress developed at longer span , $\tau_{cy,dev}$
$= V_{uy}/ (b + d_y)$ = 0.17432 MPa

Percentage of steel reinf. in shorter dir. at top , P'_{tx}

= 0.18015

Permissble shear stress at the section along Y-axis , τ_{cx}

= 0.31169 MPa

Percentage of steel reinf. in longer dir. at top , P'_{ty}

= 0.18700

Permissble shear stress at the section along X-axis , τ_{cy}

= 0.31682 MPa

LOAD CONSIDERATION IN DESIGN OF G+5 BUILDING:

In this study the structure was considered for 36 load combinations. The structure designed for the worst load combinations as mentioned below

COMBINATION NO = 25
COMBINATION NO = 27
COMBINATION NO = 24
COMBINATION NO = 11

CONVENTIONAL CONCRETE DESIGN VS EARTH QUAKE RESISTANT DESIGN:

S.NO	DESCRIPTION	CONVENTIONAL CONCRETE DESIGN (m^3)	EARTHQUAKE RESISTANT DESIGN (N)	INCREASING(%)
1	Concrete	201.21	201.21	**0**
2	Steel	93826.84	142332.42	1.517

In earthquake resistant design the steel quantity increased by 1.517% to the conventional concrete design.

STOREY DRIFT CONDITON:

Hence the base drift = 0.0 at every storey. This says that the structure is safe under the drift condition. Hence shear – walls, Braced columns are not necessary to be provided.

Hence storey drift condition is also checked for the G+5 building.

DESIGN SEISMIC BASE SHEAR VALIDATION:

We calculated the base shear of G+5 building both manually & by using STAAD.Pro.

→The value of base shear calculated manually as follows

Base shear, $V_B = A_h W$ = 0.04x 15783.64 KN = 632 KN

→The value of base shear usingSTAAD.Pro presented as follows:

SA/G PER 1893= 2.500, LOAD FACTOR= 1.000
FACTOR V PER 1893= 0.0400 X 15242.85 KN = 609 KN

Hence, a small difference of 23KN was observed in the base shear calculations of manually &STAAD.Pro and validated as almost equal results for earthquake resistant analysis and design of G+5 building.

IV.CONCLUSION

1. In earthquake resistant design the steel quantity increased by 1.517% to the conventional concrete design. The steel quantity increased in the structure ground floor level to higher floor level of the structure.
2. In this study of G+5 building, seismic load dominates the wind load under the seismic zone III. Basically the wind pressures are high for high rise building based on weather conditions such as coastal areas, hilly stations. For buildings prominently seismic forces create the major cause of damage to the structure.
3. The storey drift condition for considered G+5 building, the base drift = 0.0 at every storey. This says that the structure is safe under the drift condition. Hence shear –walls, Braced columns are not necessary to be provided.Hence storey drift condition is checked for the G+5 building.
4. The structure designed for worst load combinations namely 25,27,24,11 of 36 load combinations.

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