INTERNATIONAL JOURNAL OF ADVANCE RESEARCH, IDEAS AND INNOVATIONS IN TECHNOLOGY

ISSN: 2454-132X
Impact factor: 4.295
(Volume 4, Issue 2)
Available online at: www.ijariit.com

Analysis and design of the seismic-resistant multistorey building with shear walls and raft foundation

Jay Kumar Sah
1656021@kiit.ac.in
Kalinga Institute of Industrial Technology, Bhubaneswar, Odisha

Prem Shankar Singh
1656020@kiit.ac.in
Kalinga Institute of Industrial Technology, Bhubaneswar, Odisha

Chinmay Kumar Kundu
chinmay.kundufce@kiit.ac.in
Kalinga Institute of Industrial Technology, Bhubaneswar, Odisha

ABSTRACT

The earthquakes occurring in different parts of the world including Nepal and India have caused damage to structures, properties and loss of human lives.The recent high-intensity earthquake of magnitude in Gorkha, Nepal 7.8 on April 25,2015 has caused damage to public buildings and loss of human lives.Thus, the necessary steps are to be taken to minimize the loss of life and property for planning and designing earthquake resistant structures following the seismic codal provisions as the earthquake cannot be prevented.Practical knowledge is an important and essential skill required by every engineer. For obtaining this skill, a multistorey building is analysed and designed, located in Zone III with B+G+13 storeys with a 3-meter height for each storey having a car parking facility provided at basement. The building has a shear wall around the lift pit. The structure is modelled and analyzed using STAAD.Pro V8i.Design of beam, column, slab, shear wall, and raft foundation by SAFE are done. The saving of time is must important factor for structural engineer as there is the tough competition in today's rapidly urbanized market and to cope with the scarcity of land, an attempt is made here for the "ANALYSIS AND DESIGN OF SEISMIC RESISTANT MULTISTOREY BUILDING WITH SHEAR WALLS AND RAFT FOUNDATION" using STAAD.Pro.

Keywords: *Analysis and design, Seismic resistant, Residential Building, Shear wall, Raft foundation, STAAD Pro, SAFE.*

1. INTRODUCTION

The vulnerabilities of the structures designed inadequately represents seismic risk to life of occupants and damage of property. Rapid urbanization and scarcity of land has led to construction of large number of multistorey buildings. The buildings should be designed with the view in mind to resist minor, moderate and major levels of earthquake ground motion possibly with minimum structural damage and without structural collapse. Single footings are necessary on weak sub-surfaces for constructing building structures. In such situations, the raft foundation will be appropriate for constructing low to medium rise building structures. To ensure the safety against the seismic forces an attempt is made to design the multistorey RC framed building structure having shear walls and supported by mat foundation by following Indian standard codal provision IS 1893:2002 and structure design by STAAD.Pro V8i.

2. OBJECTIVE

The main objective of the study is:

1. To design an earthquake resistance multistorey building and analyze its structural member.
2. To analyze the building using STAAD.Pro V8i and design the raft foundation by SAFE.
3. To get the practical knowledge to plan and complete the project on earthquake resistant framed structural multistorey building.
4. To design the structural elements like beam, column, slab, raft foundation, shear wall etc.
5. To provide a structure which will be safe, serviceable, economical and aesthetically pleasant.
6. To develop self-confidence as professional to attain the similar project and to give the client full satisfaction in the near future.

3. METHODOLOGY

A multistorey residential building is analysed and designed, located in Zone III with B+G+13 storeys with a 3-meter height for each storey having a car parking facility provided at basement. The dimensional model is created from the plan with 25×25m dimensioned plan having 5×5 bays and total height 45 m. The building has a shear wall around the lift pit. Here, we have taken the Ordinary moment resisting frame building in earthquake zone III with response factor 3 and importance factor 1. Then, the analysis is of the structure and design of the members with reinforcement details for B+G+13 residential building RCC frames according to the specified criteria is done. In order to determine the design earthquake force and distribute along different floor levels and elements of the building, static analysis is done. Design of beam, column, slab, shear wall, and raft foundation are done. For this purpose, STAAD.Pro V8i is used. In this method the earthquake force is applied at the nodes or joints of the building and calculated. Limit state method following IS codes is used for the analysis in STAAD.Pro V8i. Sseismic code IS:1893-2002 is used for earthquake design. Using conventional manual methods, it takes long time and is difficult in calculations for complicated and high rise structures. STAAD.Pro provides us accurate platform to analyse and design structures in a fast, efficient and easy way. The analysis of the structure, maximum shear forces, bending moments, storey displacements are computed. From the analyzed model the total load acting on the base joints are calculated separately for designing the foundation. To transmit approximately uniform loading due to numbers of columns or load bearing walls to the supporting soil, a raft foundation is analysed here by SAFE software. The main objective of the reinforced concrete structural design is to achieve a safe and more economical structure.

4. ANALYSIS AND DESIGN

4.1 Model data

Location	Bhubaneswar, Orrissa
Structural system	R.C.C. framed structure
Dimensional Plan	25 m × 25 m with 5 × 5 bays
Number of storey	B + G + 13 storey
Floor height	3 m
Types of beam	Square (500 mm × 500 mm)
Types of column	Square (700 mm × 700 mm) in upper floors Square (750 mm × 750 mm) in basement and foundation
Types of slab	Two way slab
Types of foundation	Raft
Types of soil	Medium
Walls	230 mm thick brick masonry walls
Plaster	12.5 mm (inner) & 20 mm (outer)
Analysis method	STAAD.Pro V8i
Concept of design	Limit state design
Grade used for concrete	M25
Grade used for steel	Fe500
Dead load	As per IS 875:Part-1:1987
Floor finish	1 kN/m^2
Live load	3 kN/m^2 at typical floors 1 kN/m^2 on roof (As per IS 875:Part-II:1987)
Seismic load	As per IS1893:Part-1:2002
Wind load	As per IS: 875:III:1987
Topography	Plain terrain
Bearing capacity of soil	265 kN/m^2
Depth of raft	1.55 m

4.2 Plan and elevation

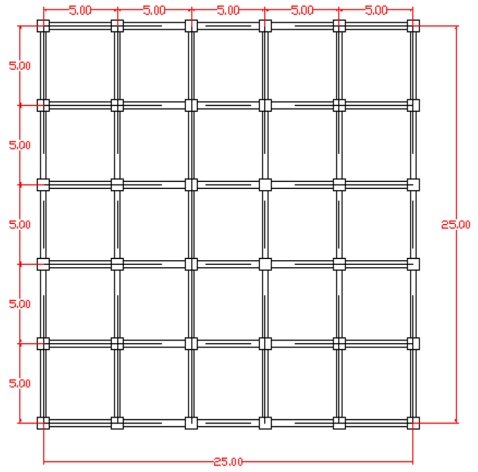


Chart-1: Plan view

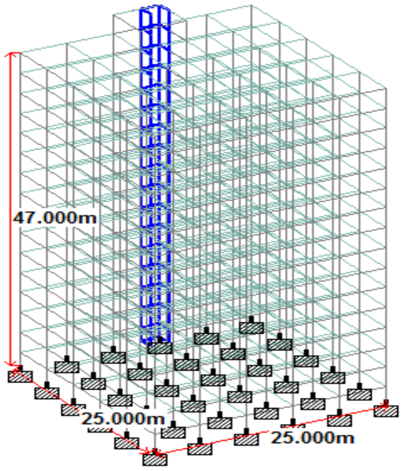


Chart-2: 3D model view in STAA

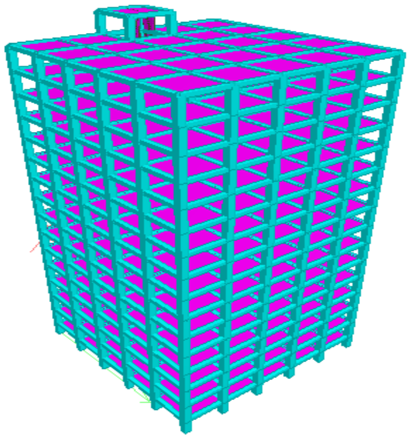


Chart-3: 3D rendered view of model in STAAD

4.3 Load Combinations

The building is analyzed for all the load combinations with different load factors. The outputs from the maximum load combination is used for the design. The combinations of the loads are stipulated by the codes IS 456:2000, IS 875 1987 (Part 1,2, 3) and IS 1893 part 1:2002 for the design of the structures.

Table-1: Load combinations

Dead load (DL)	Live load (LL)	Earthquake load (EQ)	Wind load (WL)
1.5	1.5	0	0
1.5	0	±1.5	0
1.2	1.2	±1.2	0
0.9	0	±1.5	0
1.2	1.2	0	±1.2
0	1.5	0	±1.5

While designing the building for both wind and seismic loads, the maximum value of the two is taken. Structure is analyzed by taking all the above combinations as per code since wind and earthquake do not come at same time. In the STAAD.Pro, all these combinations are built for the analysis and the structural member is designed from the results of the critical combinations.

4.4 Raft foundation design

Raft foundation will be done for a B+G+13 storey building for economical consideration. In column loads section the raft foundation will be discussed for verification. The raft foundation is one rigid body of combined footing which supports several columns and covers the entire area under the structure. Here, the bearing stress is around 265 kN/m^2 of the soil profile. The raft foundation is used for the soil where the columns have high axial loads. The area of the footing will be big for spread footing. So, to overcome it, the raft foundation would be much economical and practical. Here, the raft foundation is designed with uniform thickness as full plate.

4.5 Raft dimensions

SAFE software is used for modeling of raft foundation. The spacing of the raft on x side is 5 meters and y side is also 5 meters.the edge is provided one meter around the edge columns. The raft plan is shown in the figure below. The total area of the raft = ((5×5) +1+1) × ((5×5) + 1 + 1) = 27× 27 = 729 m^2

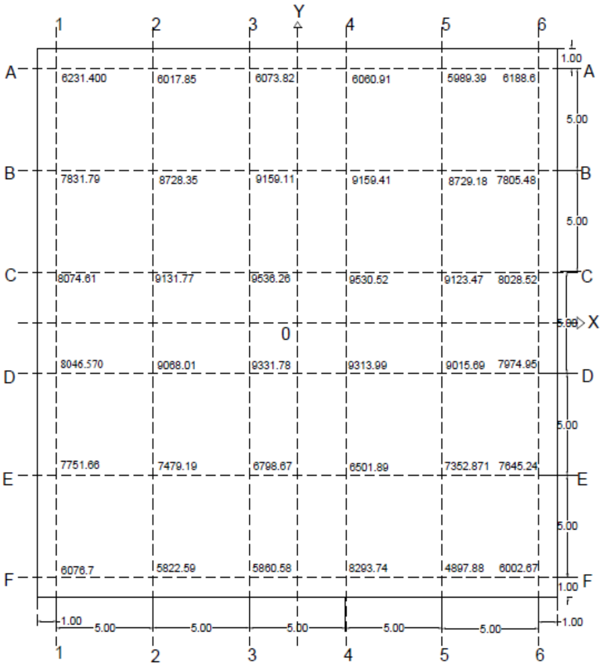


Chart-4: Raft layout and column loads

4.6 Column loads in raft

Table-2: Column loads in the raft

Column No.	Factored load (kN)
1	6076.700
2	5822.590
3	5860.580
4	8293.740
5	4897.880
6	6002.670
7	7751.660
8	7479.190
9	6798.670
10	6501.890
11	7352.871
12	7645.240
13	8046.570
14	9068.010
15	9331.780
16	9313.990
17	9015.690
18	7974.950
19	8074.610
20	9131.770
21	9536.260
22	9530.520
23	9123.470
24	8028.520
25	7831.790
26	8728.350
27	9159.110
28	9159.410
29	8729.180
30	7805.480
31	6231.400
32	6017.850

33	6073.820
34	6060.910
35	5989.390
36	6188.600
Total	**274635.111**

Total load on the columns = 274635.111 kN

Net upward pressure intensity = $\frac{274635.111}{1.5x729}$ = 251.15 kN/m^2

Adopt 265 kN/m^2.

Table-3: Properties taken in raft design

Soil type	Medium sand
Effective bearing stress of the soil	q_e=265 kN/m^2
Subgrade modulus	15900 kN/m^3
Characteristic compressive strength of concrete	25 MPa
Reinforcement strength of steel	500 MPa

4.7 Raft thickness

The diagonal tension shear is checked for determining the thickness of the raft foundation. For this calculation, the maximum ultimate column load is used.

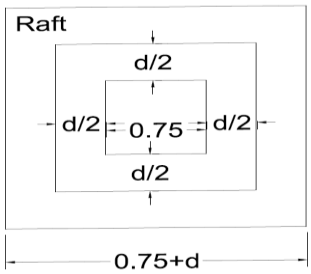


Chart-5: Diagonal tension shear area

Shear strength of concrete, $\tau_c' = \tau_v = 0{,}25\sqrt{f_{ck}} = 0.25\times\sqrt{25} = 1.25$ N/mm^2

Perimeter $b_0 = 4\ (d + 750) = 4d + 3000$

$\tau_v = V_u/(b_0\times d) = (1.5\times9536.26\times1000)/\ (4d + 3000)\ d = 1.25$

d = 1357.48 mm

Adopt d = 1475 mm

Thickness of the raft = 1475 +50 + 25 = 1550 mm

4.8 Raft depth check

One-way shear:

d = 1023.05 mm < d = 1475 mm (Ok)

Two-way shear (interior column):

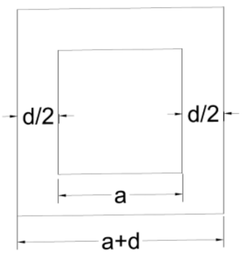


Chart-6: Two-way shear area

d = 270.175 mm < d = 1475 mm (Ok)

4.9 SAFE punching shear check

In SAFE software we can check the modelled raft or slab punching shear. Here, the punching shear factors of the raft has not exceeded one which denotes the load shear is not more than shear resistance. Figure below shows the punching shear factors of the raft.

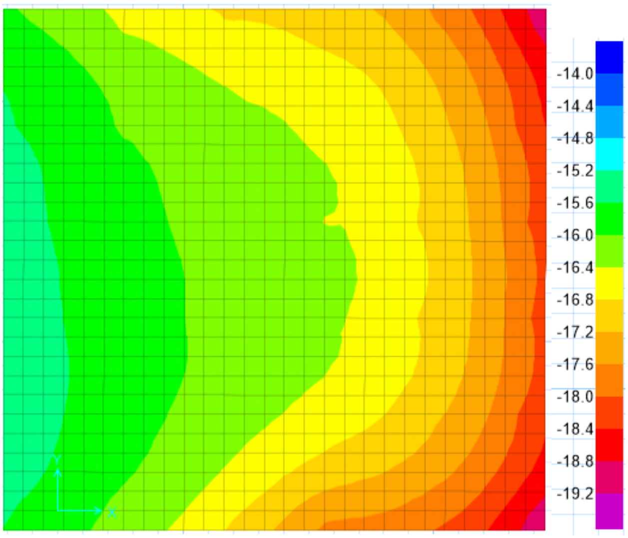


Chart-7: settlement of raft using SAFE software

4.10 SAFE results of moment strips

The raft foundation is automatically classified into various strips in SAFE software. Column strips are in both directions. The strip moments are analyzed per one-meter width of the strip in SAFE software.

X direction strips

The column strips have one-meter width in x strips based upon which moments are calculated. Figure below shows the moment diagram of x strips.

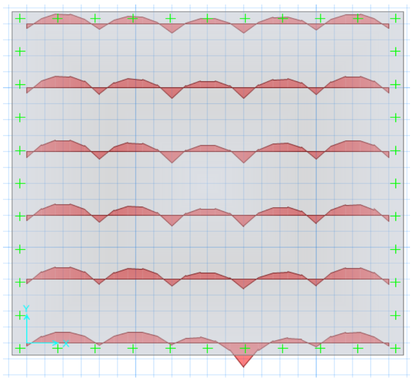


Chart-8: X-strips moment diagram

Strip notation	Strip Field	Maximum Moment Value (kNm)	
		Positive	Negative
CSX1	Column strip	4839.600	4647.528
CSX2	Column strip	3782.901	3709.647
CSX3	Column strip	3922.439	3892.541
CSX4	Column strip	3930.043	3916.653
CSX5	Column strip	3809.274	3805.180
CSX6	Column strip	3283.223	3267.757

Y direction strips

The column strips have one-meter width in y strips based upon which moments are calculated. Figure below shows the moment diagram of y strips.

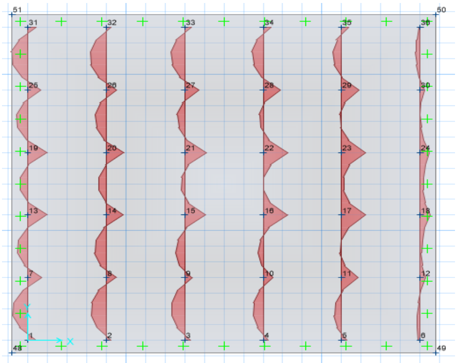


Chart-9: Y-strips moment diagram

The analysis outputs of y strip moments are shown in the table below. Top reinforcement are designed from the negative moments and bottom reinforcement are designed from the positive moments.

Table-4 Y-strips moment values

Strip notation	Strip Field	Maximum Moment Value (kNm)	
		Positive	Negative
CSY1	Column strip	3213.416	3235.255
CSY2	Column strip	3558.746	3579.652
CSY3	Column strip	3688.704	3747.853
CSY4	Column strip	5774.099	3719.582
CSY5	Column strip	3535.509	3567.273
CSY6	Column strip	3176.197	3236.423

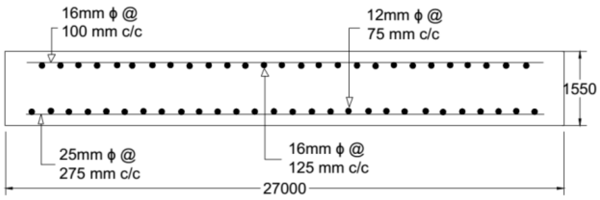
4.11 Comparison table

Table-5: Comparison between manual and SAFE design

	Moment value kNm/m	Manual design		SAFE design	
X-strip					
Bottom as	4839.600	4Φ25@275mm	1963.5 sq.mm/m	4Φ25@275mm	1963.5 sq.mm/m
Top as	4647.528	10Φ16@100mm	2010.62 sq.mm/m	10Φ16@100mm	2010.62 sq.mm/m
Y-strip					
Bottom as	5774.099	16Φ12@75mm	1809.56 sq.mm/m	16Φ12@75mm	1809.56 sq.mm/m
Top as	3747.853	9Φ16@125mm	1809.56 sq.mm/m	9Φ16@125mm	1809.56 sq.mm/m

4.12 Detailing

Reinforcement detail is as shown below:



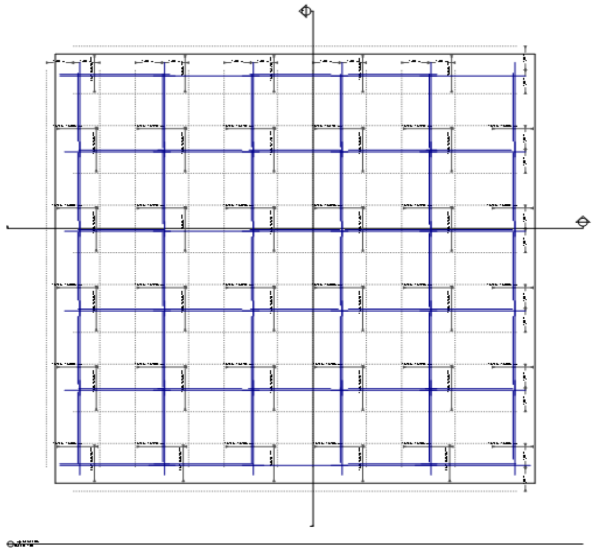


Chart-10: Reinforcement details of the raft

5. CONCLUSION

The following specific conclusion from present work are:

- Accuracy is improved by using STAAD Pro software.
- The beams and columns that failed are known and better section is provided by the software for the further design of the proposed plan of the building.
- The base shear, maximum storey displacement, storey drift, axial, shear, bending moment with their diagrams are known for the different load combinations.
- The storey drift is within the permissible value.
- SAFE software design output of the raft foundation is matched with the manual design.
- The punching shear factors are less than 1 and settlement is less than 50 mm.

6. REFERENCES

[1] Abd-el-Rahim Hamdy H. A. et.al (2010), "Role Of Shear Walls in High Rise Buildings", Journal of Engineering Sciences, Assiut University, Vol. 38, No. 2, pp. 403 -420, March, 2010.
[2] Björk Hauksdóttir, (2007), "Analysis of a reinforced concrete shear wall", M,Sc thesis.
[3] Cemalettin Dönmez and M. Alper Çankaya "Effect of Infill Walls on the Drift Behavior of Reinforced Concrete Frames Subjected to Lateral-Load Reversals", Journal of Earthquake Engineering, Volume 17, Issue 5, 2013
[4] Hugo Bachmann (2002):"Seismic Conceptual Design of Buildings – Basic principles for engineers, architects, building owners, and authorities" (Biel 2002, 81p.)
[5] Khan Nasreen. M. (2016), "Analysis And Design Of Apartment Building", IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 3 Issue 3, March 2016.
[6] Kumar Amit et.al (2014), "Analysis and Capacity Based Earthquake Resistant Design of Multi Storied Building", IOSR Journal of Engineering (IOSRJEN), Vol. 04, Issue 08 (August. 2014), ||V1|| PP 07-13
[7] K. Bhattacharya et.al.(2004),"Effect of soil-flexibility on dynamic behaviour of building frames on raft foundation", Journal of Sound and Vibration 274 (2004) 111–135
[8] Móczár Balázs et.al (2016), "A comparative study of soil-structure interaction in the case of frame structures with raft foundation", Original scientific paper, DOI: 10.1515/rmzmag-2016-0001
[9] Narayanan Sambu Potty et.al (2011), "Assessment Of Building For Seismic Resistance",Malaysian Journal of Civil Engineering 23(1):86-104 (2011)
[10] Nini Win, Kyaw Lin Htat, "comparative study of static and dynamic analysis of irregular reinforced concrete building due to earthquake", international journal of scientific engineering and technology research , ISSN 2319-8885 vol 03 ,issue 07,may 2014
[11] Prof. Rajendra J.Thakai .et.al, "Parametric study on behaviour of raft foundation for an irregular high rise building", international journal for scientific research and development, ISSSN 2321 -0613 vol 4 issue 6 2016
[12] Shah H.J. (2016),"Design Example of a Six Storey Building",IITK-GSDMA-EQ26-V3.0,Indian Institute of Technology Kanpur
[13] Singh B. Akash et.al (2017), "Seismic Study Of G+5 RC Framed Structure Supported On Raft Foundation", International Journal of Civil Engineering and Technology (IJCIET) Volume 8, Issue 4, April 2017, pp. 467–476 Article ID: IJCIET_08_04_054
[14] Vimala B.K. et.al (2015), "Analysis and Design of Multistoried Residential and Commercial Building with Base Isolation Techniques", International Journal of Innovative Research in Science, Engineering and Technology Vol. 4, Issue 5, May 2015