Seismic Behavior of RCC Structure With Different Substructures

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Abstract- *Foundation is the first element of any structure that encounters seismic forces. The various types of seismic waves, reaches and affects the foundations first and then the superstructure. Different types of foundations respond differently to seismic forces. In this research work, RCC structure is analyzed for the seismic behavior of different types of foundations like isolated footings, raft foundations, strap footing etc. Seismic analysis is done in STAAD Pro to compare values of nodal displacement, storey drift, storey and base shear, shear force and moment development. Comments are made considering stability aspects of the structure.*

Keywords- Seismic, Substructures, Isolated Footing, Strap Footing, Raft Footing, Base Shear, Shear Strength, Nodal Displacement, Story Drift, Shear Force, Bending Moment, Earthquake resistant.

I. INTRODUCTION

An earthquake is a sudden shaking or trembling vibrations of the ground produced in the earth's crust when rocks in which elastic strain has been building up suddenly rupture, and then rebound. The vibrations can range from barely noticeable to catastrophically destructive where the surface of the Earth can be altered by thrusting up cliffs or opening great cracks in the ground.

Many earthquakes occur each year, on average greater than 800,000, but most are small and not felt by humans. A severe earthquake, with a magnitude of greater than 8.0, can be expected every 8 to 10 years. But a significant number of smaller earthquakes, which are still capable of destruction, occur each year.

Earthquake events are natural occurrences, but earthquake-related losses are in large measure the result of social processes and activities that affect the extent to which people and property are placed at risk. Combating the earthquake problem requires in-depth understanding of those social processes and the translation of this understanding into effective action programs. The general public has become more concerned about earthquakes and the great damage they can cause. It is a major challenge to ensure that our constructions are made earthquakes resistant to limit the damages in future.

II. AIM & OBJECTIVES

The aim of this dissertation is to study the seismic behavior of RCC structure with different substructures.
Objectives are as below:

1. To study the various reasons and concept of earthquake.
2. To study the methods of seismic analysis of RCC structure as given by IS 1893:2012.
3. To study various analysis and design considerations.
4. To perform seismic analysis of RCC structure with different substructures.
5. To study and compare the nodal displacement, reaction, base shear and storey drift of the structure considered.
6. To comment on the suitability of substructure for seismic stability on basis of modeling and analysis considered in dissertation

III. SCOPE OF THE STUDY

The seismic analysis of a G+10 RCC framed structure with following details is carried out using STAAD Pro software.

Zone - IV
Soil Condition - Medium
Importance Factor - 1.0
Frame Type - Ordinary Moment Resisting Frame (OMRF)

IV. PROJECT METHODOLOY

A brief overview of steps needed for the completion of this dissertation is given below.

Part – I

a. Introduction
A general idea about the topic along with need and scope is stated.
b. Literature Review
Literatures of various works done previously are reviewed.
c. Methodology
Total breakdown structure of line of work is given.

Part – II
a. Detailed Study-Various types of foundations, loading cases, seismic considerations in IS 1893:2002 are studied.
b. Analysis for Various Case Considerations
Analyses of RCC structure with various types of substructures namely, isolated footing, strip footing, raft foundation are carried out.

Part – III
a. Observations
Comparison between observations obtained from the various analyses is done.
b. Results
Results are derived on the basis of the comparison made.
c. Conclusion
Conclusion of the dissertation is stated along with the various limitations.
d. References
Various literatures reviewed are entitled

V. DATA COLLECTION

A. Foundation

The foundations are classified in two categories namely shallow foundations and deep foundations.
Shallow foundations are used when surface soils are sufficiently strong and stiff to support the imposed loads.
Isolated Footing, Strip Foundation, Combined footing, Strap/ Cantilever Footing, Raft / Mat Foundation these footings are lies in shallow foundation.

Deep Foundation A cylindrical / box foundation having a ratio of depth to base width greater than 5 or depth greater than 3 m is considered as Deep Foundation. Piles, Caisson / Well, Compensated Foundations are considered in deep foundation.

B. Computation of Design load

The dead loads and live loads on columns are usually computed by tributary area method, in which it is assumed that a column carries the entire load in the floor area enclosed by lines equidistant from its adjacent columns.

According to IS 1904-1978, foundations should be proportioned for the following combinations of loads - (i) Dead load + Live load, (ii) Dead load + Live load + Wind load or Seismic load

If wind load (or seismic load) is less than 25% of that due to dead and live loads, it may be neglected and the foundation should be designed for combination (i) given above. However, if wind load (or seismic load) is more than 25% of that due to dead and live loads, the foundation should be designed for combination (ii) given above. The foundation pressure should not exceed the safe bearing capacity by more than 25% in the second case.

C. Load Combination and Increase in Permissible Stresses

(IS 1893 (Part I) : 2002, Clause 6.3)

When earthquake forces are considered on a structure, these shall be combined as below where the terms DL, IL and EL stand for the response quantities due to dead load, imposed load and designated earthquake load respectively.

Load factors for plastic design of steel structures In the plastic design of steel structures, the following load combinations shall be accounted for:

1) 1.7 (DL + IL)
2) 1.7 (DL ± EL)
3) 1.3 (DL + IL ± EL)

Design of reinforced and prestressed concrete structures, the Following load combinations shall be accounted for:

1) 1.5 (DL + IL)
2) 1.2 (DL + IL ± EL)
3) 1.5 (DL ± EL)
4) 0.9 DL ± 1.5 EL

D. Analysis

Seismic analysis is a subset of structural analysis and is the calculation of the response of a structure to earthquakes. There are various types of seismic analysis of structures as stated below-

1. Linear static analysis ¬ Equivalent Static Method
2. Linear dynamic analysis ¬ Response Spectrum Method & Elastic Time History Method
3. Nonlinear static analysis ¬ Push over Analysis

4. Nonlinear dynamic analysis ¬ Inelastic Time History Analysis

In this dissertation static coefficient method is carried out for analysis.

E. Calculation of design horizontal seismic coefficient according to IS 1893:2012

The total design seismic base shear (VB) along any principal direction shall be determined by following expression

$V_B = W \times A_h$

Where, W is the total weight of the building calculated using the structural details and

Ah is calculated as shown below:

$A_h = Z\, I\, S_g / 2\, R\, g$

Where, Z is Zone factor given in Table 2 of IS 1893:2002, is for the Maximum Considered Earthquake (MCE) and service life of structure in a zone. The factor 2 in the denominator of Z is used so as to reduce the Maximum Considered Earthquake (MCE) zone factor to the factor for Design Basis Earthquake (DBE). I is Importance factor, R is Response reduction factor, Sa/g is Average response acceleration coefficient for rock or soil sites.

F. Design lateral force at each floor i

The design base shear (VB) shall be distributed along the height of the building as per the following expression:

$$Q_i = V_B \frac{W_i h_i^2}{\sum_{i=0}^{n} W_i h_i^2}$$

Where, Qi = Design lateral force at floor i,
Wi = Seismic weight of floor i,
hi = Height of floor i measured from base,
And n = Number of storey in the building is the number of levels at which the masses are located.

VI. MODELING & ANALYSIS

A. Necessary Data and Case Considerations

The seismic analysis of a G+10 RCC framed structure with following details is carried out using STAAD Pro V8i software.

Structural Data:

Size of Beams = 0.30 x 0.45 m
Size of Columns = 0.30 x 0.60 m
Thickness of Slab = 0.15 m

Seismic Data:
Zone – IV
Soil Condition – Medium
Importance Factor - 1.5
Frame Type - Ordinary Moment Resisting Frame (OMRF)
Response Reduction Factor = 1.0
Foundation Depth = 2m

B. Load Calculations

Superstructure (For all cases considered)

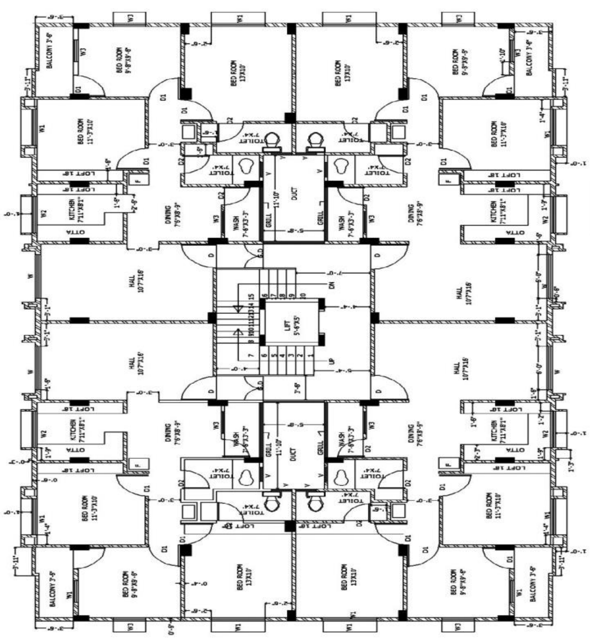
a. Dead Loads

Self-Weight of Beams, Columns = -1 (↓) (Y-Direction) (Factor entered in STAAD)
Self-Weight of Slab = (25.00 x 0.15) = 3.75 kN/m2
Weight of 0.23 m Thick Walls = (20.0 x 0.23 x 2.8) = 12.88 kN/m
Weight of 0.115 m Thick Walls = (20.0 x 0.115 x 2.8) = 6.44 kN/m
Weight of 0.23 m Thick Parapet Walls = (20.0 x 0.23 x 1.4) = 6.44 kN/m

b. Live Loads

On all floors except Terrace = 1.5 kN/m2 (Clause 7.3.1, IS: 1893-2002, Part-I)
On Terrace = 0.0 kN/m2 (Clause 7.3.2, IS: 1893-2002, Part-I)

C. Floor Plan of Building



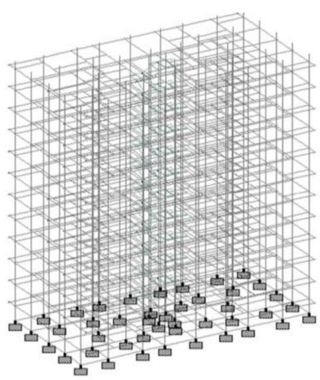
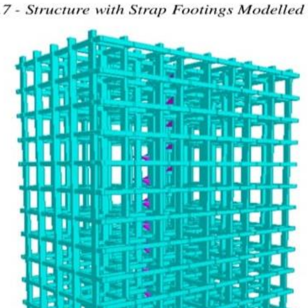
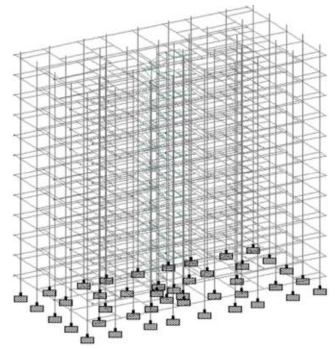


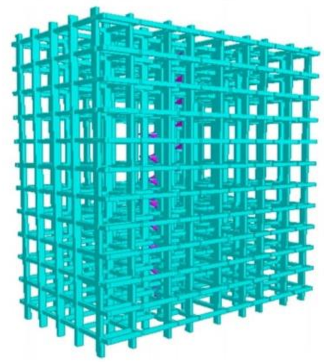
Fig. No. 5.7 - Structure with Strap Footings Modelled in STAAD Pro



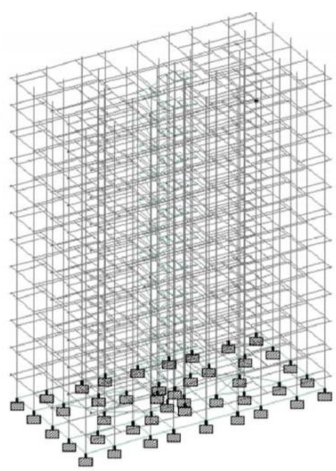
5.8 – 3D Rendered View of Structure with Strap Footings Modelled in STAAD



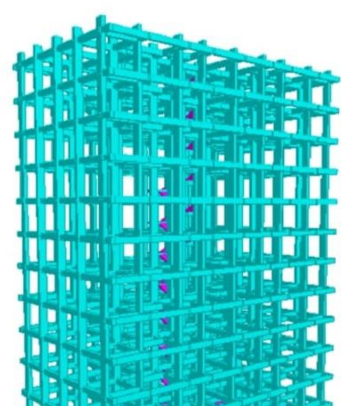
Vo. 5.5 - Structure with Isolated Footings Modelled in STAAD Pro



) Rendered View of Structure with Isolated Footings Modelled in STAAD I



g. No. 5.9 - Structure with Raft Footings Modelled in STAAD Pro



– 3D Rendered View of Structure with Raft Footings Modelled in STAAD

VII. OBSERVATIONS

On the basis of analysis results for various loading combinations as specifies in IS 1893:2002 and static coefficient method, the observations related to translational displacement, rotational displacement, drift values, shear force and bending moment in the member and the base shear values are marked for the nodes along the outer edge as well as for the probable crushing junction i.e. staircase landing.

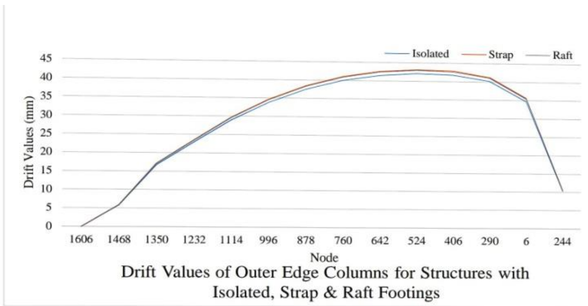


Fig. No. 6.3 – Graph Showing Comparison between Drift Values of Outer Edge Columns for Structures with Isolated, Strap & Raft Footings

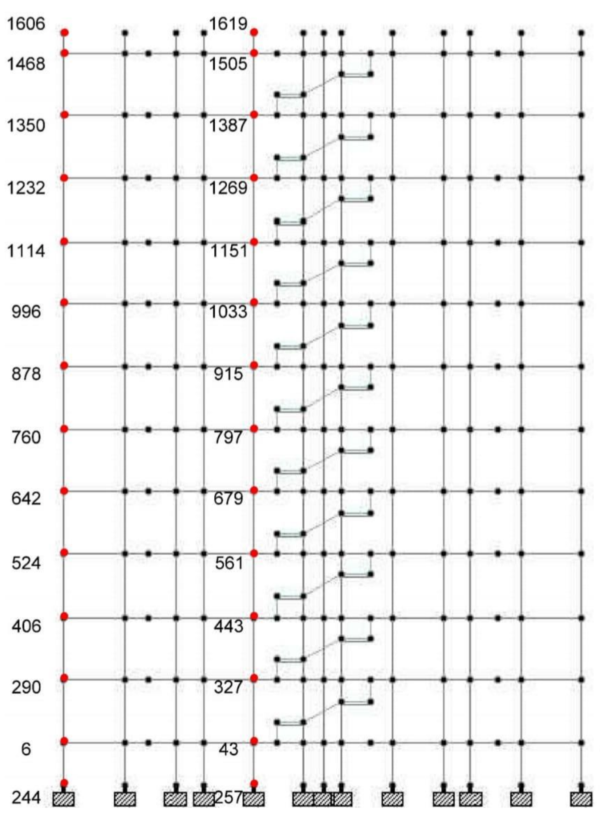


Fig. 6.2 – Drawing Showing Location and Number of Outer Edge and Staircase Edge Nodes

When comparison is made for translational displacement of case 1, 2 and 3, it is observed that in all the three cases, the drift values for top storey is comparatively very less as compared to next nodal values. When comparison is made for drift values of nodes of outer edge and near staircase junction, it is found that the values are less for nodes near staircase junction. When comparison is made among various cases, it is seen that nodal displacement value and corresponding drift value is greater for structure with strap footing followed by structure with raft foundation and then for the structure with isolated footing. However, the difference between the nodal displacement values of structure with strap and raft footing is in decimals and is negligible.

VIII. CONCLUSION

The aim of the dissertation work was to study the behavior of structure with different support conditions subjected to seismic forces. For this, the G+10 RCC building is modeled and analyzed with change in support conditions i.e. isolated, strap and raft foundation. On the basis of observations, various conclusions can be drawn as specified below.

1. The Drift value at top is minimum whereas increases successively up to fourth floor. Similarly, drift values of inner nodes are less as compared to outer nodes. The comparative drift values of all three cases show negligible difference in decimals and thus reflect equivalent auxilatory behavior.
2. Again the bending moment and shear force is greater for columns at top as compared to successive lower columns. There is a rapid growth in bending moment and shear force values for a building with strap footing as that compared to raft and isolated footing. The values of Fy i.e. vertical force is greater for structure with strap footing.
3. Base shear and storey shear calculations table shows that as the analysis counts, the total weight of structure 'W' which is multiplied by horizontal seismic coefficient so as to get the base shear and further storey shear values.
4. Hence extra amount of mass contributed due to the provision of strap beams or raft, is increasing the overall weight of structure and when multiplied by the constant parameter A_h (horizontal seismic coefficient for considered location) gives higher base shear values and thus more storey shear distribution.
5. For maintaining the stability, the reactions contracts the moments and forces acting and thus the building with more weight is showing greater reaction values. It can be seen clearly that the behavior of RC structure highly depends upon the mass or inertia even though the provision of bands or plates are provided in the form of strap beams or raft foundation.

IX. ACKNOWLEDGMENT

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