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# Study on Dynamic Response of an Irregular Building in Various Seismic Zones

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**Abstract:** ***Earthquakes are the natural phenomenon which can happen suddenly and can cause vast destruction. Most of the Indian land is insecure because of the vibrations caused by the earthquakes. In the other sense it is impossible to prevent occurrence of earthquakes, but the damages can be controlled by means of effective seismic designs. The design can be done by considering various limit states specified by the codes and applying the economical ones. The structure can be designed as semi elastic and it is economical rather than elastic because designing of structure for total elastic in response is very uneconomical. The present study mainly focuses on determining the variation in reinforcement percentage of an irregular building in various seismic zones in India. The current IS code for seismic design i.e.IS 1893-2002(part 1) suggest that maximum amount reinforcement shall be provided for higher seismic zones. But it doesn't provide clear information, how much percentage of reinforcement can be used for various seismic zones. In this work it was the attempt made to find the percentage required for various seismic zones. For the study an unsymmetrical building plan is used with 9 storeys and analyzed and designed by using STAAD Pro.***

**Keywords:** Building analysis, Earthquakes, Structural irregularity, Reinforcement

## 1. Introduction

Recently several earthquakes have caused severe damages in structures all over world. To protect structures from significant damages, the zone factor of buildings is an important topic in structural engineering. In this paper an nine storey building is modelled in STAAD Pro.. In these building components like beams and columns are analysed & designed in various zones. All the beams and columns, properties are kept same and the building is in an irregular shape. The structure is analysed and designed as per IS-456 2000. In this model the earthquake forces are automatically generated. Earthquakes are the most unpredictable and devastating of all natural disasters, which are very difficult to save over engineering properties and life, against it. Hence in order to overcome these issues we need to identify the seismic performance of the building by various analytical procedures, which ensure the structures to withstand during frequent or minor earthquakes and produce enough caution whenever subjected to major earthquake events. So that can save as many lives as possible. There are several guidelines all over the world which has been repeatedly updating on this topic. The analysis procedure quantifying the earthquake forces and its demand depending on the importance and cost, the method of analysing the structure varies from linear to nonlinear. The behaviour of a building during an earthquake depends on several factors, stiffness, and adequate lateral strength, and ductility, simple and regular configurations. The buildings with regular geometry and uniformly distributed mass and stiffness in plan as well as in elevation suffer much less damage compared to irregular configurations. Nowadays many developed countries have been widely used the irregular buildings in various forms. With the rapid growth of urban population, reinforced concrete building has been used in both the developing and industrialized countries. The extensive use of reinforced concrete construction, especially, in developing countries, is attributed to its relatively low initial cost compared to other materials such as steel. So it is needed to consider the effect of earthquake in designing the buildings. Earthquake consists of random horizontal and vertical movement of the earth's surface. India having different soil conditions and different earthquake intensity places with more than 60% area is prone to earthquakes, should develop earthquake resistant structures in consideration to IS:1893(part: I):2002. India classified into 4 seismic zones namely zone II, III, IV, V, having different types of soils which increases the importance of understanding of effect of base shear in consideration to various types of soils in same zone also. Response of structures to earth's surface vibrations is a function of type of soil available at site conditions. Response acceleration coefficient (Sa/g) for 5% damping is calculated for rock, medium, soft soils. Zone factor value indicates expected intensity of earthquake in different seismic zones In this paper a nine storey building is analysed by STAAD Pro

## 2. Geometric Definition

A nine storey building done using STAAD Pro. Is showed in fig 1. Design of building is done by seismic loads as per IS 1893(PART 1): 2002.

**Table 1:** Design Data

| | |
|---|---|
| *Type of structure* | *Ordinary moment resisting RC frame* |
| Grade of concrete | M 40(Fck=40 N/mm$^2$) |
| Grade of reinforcing steel | Fe 415(fy=415 N/mm$^2$) |
| Plan area | 896m$^2$ |
| Number of stories | G +8 |
| Floor height | 3.5m |
| Column size | 600 x 600mm |
| Beam size | 450 x 300mm |
| Slab thickness | 130 mm |
| Wall thickness | 230 mm |
| Density of concrete | 25N/mm$^3$ |
| Live load on floors and roof | 3 KN/m$^2$ and 1.5 KN/m$^2$ |

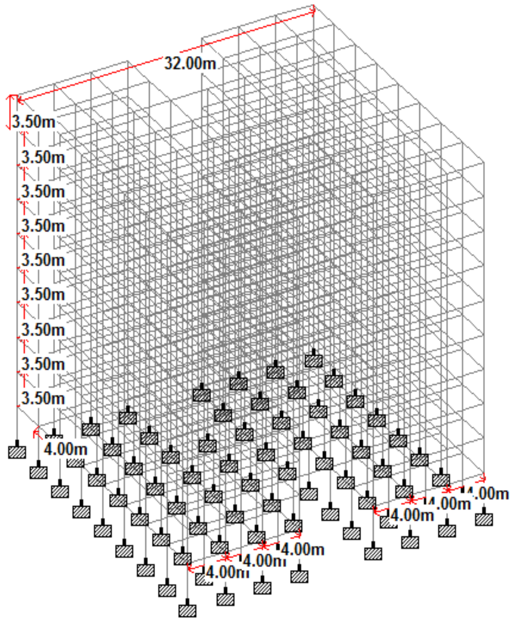


**Figure 1:** General Layout of Building

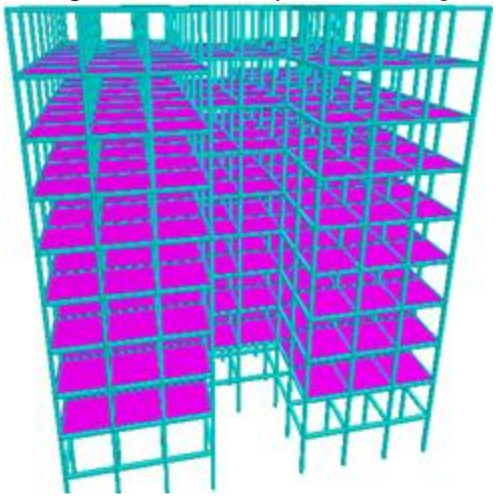

**Figure 2:** Model of H shaped building using STAAD Pro.

## 3. Load Calculation

The following load combinations are used in the seismic analysis, as mentioned in the code IS 1893(Part-1): 2002, Clause no. 6.3.1.2.

1.5(DL+LL)
2. 1.2(DL+LL+EQX)
3. 1.2(DL+LL- EQX)
4. 1.2(DL+LL+ EQZ)
5. 1.2(DL+LL- EQZ)
6. 1.5(DL+ EQX)
7. 1.5(DL- EQX)
8. 1.5(DL+ EQZ)
9. 1.5(DL-EQZ)
10. 0.9DL+ 1.5EQX
11. 0.9DL- 1.5EQX
12. 0.9DL+ 1.5EQZ
13. 0.9DL-1.5EQZ

Earthquake load was considered in +X,-X, +Z and –Z directions. Thus a total of 13 load combinations are taken for analysis. Since large amount of data is difficult to handle manually, all the load combinations are analyzed using software STAAD Pro.

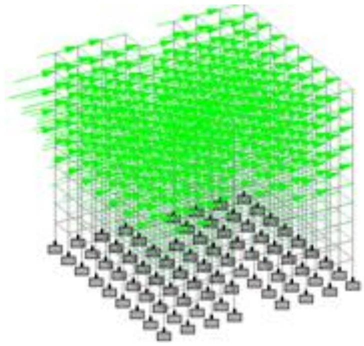

**Figure 3:** Structure subjected to earthquake loading in +X direction

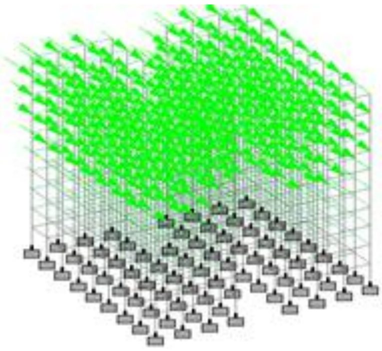

**Figure 4:** Structure subjected to earthquake loading in +Z direction

## 4. Comparison of Beams and Columns in Different Levels and Different Zones

In this case Design of beam using load combinations, and which Shows the beam design result in various floor level and Percentage of steel change as under

**Table 2:** Shows Comparison of Beam at Different Level In Zone II

| *Zone II* | *Reinforcement* | *Left Joint* | *Mid Joint* | *Right Joint* | *Total* | *Change At Diff: Floor W.R.T top floor* |
|---|---|---|---|---|---|---|
| 9th floor | Top rein | 258.07 | 258.07 | 258.07 | 774.21 | |
| | Bottom rein | 258.07 | 258.07 | 258.07 | 774.21 | |
| | | | | | **1548.42** | |
| 8th floor | Top rein | 258.07 | 258.07 | 258.07 | 774.21 | |

| | | | | | | |
|---|---|---|---|---|---|---|
| | Bottom rein | 258.07 | 258.07 | 258.07 | 774.21 | |
| | | | | | **1548.42** | - |
| 7th floor | Top rein | 258.07 | 258.07 | 258.07 | 944.66 | |
| | Bottom rein | 258.07 | 258.07 | 258.07 | 774.21 | |
| | | | | | **1688.87** | 9.07% |
| 6th floor | Top rein | 258.07 | 258.07 | 258.07 | 774.21 | |
| | Bottom rein | 258.07 | 258.07 | 258.07 | 774.21 | |
| | | | | | **1548.42** | - |
| 5th floor | Top rein | 277.13 | 258.07 | 258.07 | 793.27 | |
| | Bottom rein | 258.07 | 258.07 | 277.15 | 793.29 | |
| | | | | | **1586.56** | 2.46% |
| 4th floor | Top rein | 324.77 | 257.46 | 257.46 | 839.69 | |
| | Bottom rein | 257.46 | 257.46 | 322.40 | 837.32 | |
| | | | | | **1677.01** | 8.30% |
| 3rd floor | Top rein | 341.30 | 258.07 | 258.07 | 857.44 | |
| | Bottom rein | 258.07 | 258.07 | 344.03 | 860.17 | |
| | | | | | **1717.61** | 10.63 |
| 2nd floor | Top rein | 346.61 | 258.07 | 258.07 | 862.75 | |
| | Bottom rein | 258.07 | 258.07 | 346.60 | 891.17 | |
| | | | | | **1753.92** | 13.2% |
| 1st floor | Top rein | 357.65 | 258.07 | 258.07 | 873.79 | |
| | Bottom rein | 258.07 | 258.07 | 375.03 | 891.17 | |
| | | | | | **1764.96** | 13.9% |
| Ground | Top rein | 355.57 | 258.07 | 258.07 | 871.71 | |
| | Bottom rein | 258.07 | 258.07 | 354.46 | 870.6 | |
| | | | | | **1742.31** | 12.5% |

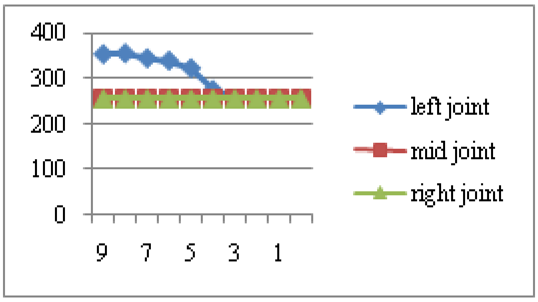


**Figure 5:** Graphical representation of required Ast in successive External Beam

When considering the maximum shear force in a floor it was easy to find out the maximum reinforcement needed in that floor, through that the percentage of variation in reinforcement in beams can be find out.

**Comparison of beam at different level in zone III**

In this case Design of beam using load combinations, and which shows the beam design result in various floor level and Percentage of steel change as under

**Table 3:** Shows the change in reinforcement of beam in zone III

| *Zone III* | *Reinforcement* | *Left Joint* | *Mid Joint* | *Right Joint* | *Total* | *Change At Diff: Floor W.R.T Top Floor* |
|---|---|---|---|---|---|---|
| 9th floor | Top rein | 258.07 | 258.07 | 258.07 | 774.21 | |
| | Bottom rein | 258.07 | 258.07 | 258.07 | 774.21 | |
| | | | | | **1548.42** | |
| 8th floor | Top rein | 258.07 | 258.07 | 258.07 | 774.21 | |
| | Bottom rein | 258.07 | 258.07 | 258.07 | 774.21 | |
| | | | | | **1137.88** | 26.51% |
| 7th floor | Top rein | 303.34 | 258.07 | 258.07 | 819.48 | |
| | Bottom rein | 258.07 | 258.07 | 304.63 | 820.77 | |
| | | | | | **1640.25** | 6% |
| 6th floor | Top rein | 399.53 | 257.46 | 257.46 | 914.45 | |
| | Bottom rein | 257.46 | 257.46 | 401.90 | 916.82 | |
| | | | | | **1831.27** | 18.42% |
| 5th floor | Top rein | 471.80 | 258.07 | 258.07 | 475.82 | |
| | Bottom rein | 258.07 | 258.07 | 475.03 | 677.39 | |
| | | | | | **1153.21** | 25.52% |
| 4th floor | Top rein | 528.53 | 258.07 | 258.07 | 509.09 | |
| | Bottom rein | 258.07 | 258.07 | 527.45 | 676.36 | |
| | | | | | **1185.45** | 23.44% |
| 3rd floor | Top rein | 565.27 | 257.46 | 257.46 | 534.01 | |
| | Bottom rein | 257.46 | 257.46 | 557.73 | 656.41 | |
| | | | | | **1190.42** | 23.12% |
| 2nd floor | Top rein | 569.59 | 256.23 | 256.23 | 550.36 | |
| | Bottom rein | 256.23 | 256.23 | 569.57 | 676.33 | |
| | | | | | **1226.69** | 20.77% |
| | | | | | | |
| 1st floor | Top rein | 555.85 | 257.46 | 257.46 | 668.03 | |
| | Bottom rein | 256.23 | 256.23 | 565.71 | 783.24 | |
| | | | | | **2359.02** | 52% |
| Ground | Top rein | 592.32 | 256.23 | 256.23 | 1116.59 | |
| | Bottom rein | 256.23 | 256.23 | 571.59 | 1242.43 | |
| | | | | | **1451.27** | 6.27% |

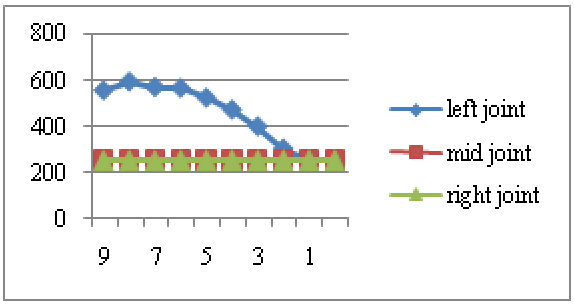


**Figure 6:** Graphical representation of required Ast in successive External Beam

When considering the maximum shear force in a floor it was easy to find out the maximum reinforcement needed in that floor, through that the percentage of variation in

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reinforcement in beams can be find out. it shows that amount of reinforcement in second floor is greater than all other floors in seismic zone III.

**Comparison of beam at different level in zone IV**

In this case Design of beam using load combinations, and which Shows the beam design result in various floor level and Percentage of steel change as under.

**Table 4:** Comparison of beam at different level in zone IV

| *Zone Iv* | *Reinforcement* | *Left Joint* | *Mid Joint* | *Right Joint* | *Total* | *Change At Diff: Floor W.R.T Top Floor* |
|---|---|---|---|---|---|---|
| 9th floor | Top rein | 258.07 | 258.07 | 258.07 | 774.21 | |
| | Bottom rein | 258.07 | 258.07 | 258.07 | 774.21 | |
| | | | | | **1548.42** | |
| 8th floor | Top rein | 295.45 | 258.07 | 258.07 | 811.59 | |
| | Bottom rein | 258.07 | 258.07 | 295.96 | 812.10 | |
| | | | | | **1623.69** | 14.2% |
| 7th floor | Top rein | 461.19 | 258.07 | 258.07 | 977.33 | |
| | Bottom rein | 258.07 | 258.07 | 463.12 | 979.26 | |
| | | | | | **1956.59** | 26.3% |
| 6th floor | Top rein | 616.89 | 255.00 | 255.00 | 1126.89 | |
| | Bottom rein | 255.00 | 255.00 | 620.64 | 1130.64 | |
| | | | | | **2257.53** | 45.7% |
| 5th floor | Top rein | 738.37 | 258.07 | 258.07 | 1254.51 | |
| | Bottom rein | 258.07 | 258.07 | 743.57 | 1259.71 | |
| | | | | | **2514.22** | 62.3% |
| 4th floor | Top rein | 825.56 | 258.07 | 258.07 | 1325.23 | |
| | Bottom rein | 258.07 | 258.07 | 831.92 | 1348.06 | |
| | | | | | **2689.76** | 73% |
| 3rd floor | Top rein | 867.27 | 257.46 | 257.46 | 1382.19 | |
| | Bottom rein | 257.46 | 257.46 | 874.80 | 1389.72 | |
| | | | | | **2035.51** | 31.4% |
| 2nd floor | Top rein | 892.89 | 257.46 | 257.46 | 1407.81 | |
| | Bottom rein | 257.46 | 257.46 | 900.26 | 1415.18 | |
| | | | | | **1591.15** | 27% |
| 1st floor | Top rein | 912.79 | 255.00 | 255.00 | 1422.79 | |
| | Bottom rein | 257.46 | 257.46 | 902.59 | 1417.51 | |
| | | | | | **2840.3** | 83% |
| Ground | Top rein | 907.18 | 257.46 | 255.38 | 1420.02 | |
| | Bottom rein | 253.46 | 144.27 | 966.76 | 1364.49 | |
| | | | | | **2784.51** | 79% |

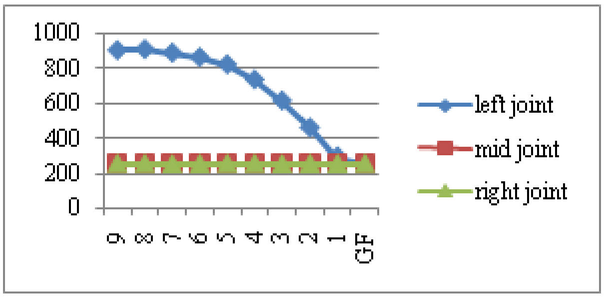


**Figure 7:** Graphical representation of required Ast in successive External Beam

When considering the maximum shear force in a floor it was easy to find out the maximum reinforcement needed in that floor, through that the percentage of variation in reinforcement in beams can be find out. When taking the results it shows that amount of reinforcement in second floor is greater than all other floors in seismic zone IV.

**Comparison of reinforcement in beam at different level in zone V**

In this case Design of beam using load combinations and which Shows the beam design result in various floor level and Percentage of steel change

**Table 5 :** Comparison of beam at different level in zone V

| *Zone V* | *Reinforcement* | *Left Joint* | *Mid Joint* | *Right Joint* | *Total* | *Change At Diff: Floor W.R.T Top Floor* |
|---|---|---|---|---|---|---|
| 9th floor | Top rein | 258.07 | 258.07 | 258.07 | 774.21 | |
| | Bottom rein | 258.07 | 258.07 | 258.07 | 774.21 | |
| | | | | | **1548.42** | |
| 8th floor | Top rein | 449.03 | 258.07 | 258.07 | 965.17 | |
| | Bottom rein | 258.07 | 258.07 | 258.07 | 774.21 | |
| | | | | | **1739.38** | 35% |
| 7th floor | Top rein | 724.53 | 258.07 | 258.07 | 1240.67 | |
| | Bottom rein | 258.07 | 258.07 | 721.32 | 1237.46 | |
| | | | | | **2478.13** | 38% |
| 6th floor | Top rein | 966.66 | 253.46 | 253.46 | 1473.58 | |
| | Bottom rein | 253.46 | 253.46 | 960.66 | 1467.58 | |
| | | | | | **2941.16** | 42% |
| 5th floor | Top rein | 1134.79 | 256.23 | 256.23 | 1647.25 | |
| | Bottom rein | 256.23 | 256.23 | 1143.12 | 1655.58 | |
| | | | | | **3302.83** | 49% |
| 4th floor | Top rein | 1306.25 | 257.46 | 257.46 | 1821.17 | |
| | Bottom rein | 257.46 | 144.51 | 1316.93 | 1718.9 | |
| | | | | | **3540.07** | 51.5% |
| 3rd floor | Top rein | 1253.23 | 257.46 | 255.00 | 1768.15 | |
| | Bottom rein | 257.46 | 257.46 | 1349.51 | 1864.43 | |
| | | | | | **3632.58** | 52% |
| 2nd floor | Top rein | 1458.54 | 257.46 | 257.46 | 1971 | |
| | Bottom rein | 256.23 | 256.23 | 1418.54 | 1931 | |
| | | | | | **3902** | 54% |
| 1st floor | Top rein | 1516.66 | 257.46 | 255.00 | 2029.12 | |
| | Bottom rein | 257.46 | 257.46 | 1477.49 | 1992.41 | |
| | | | | | **4021.53** | 82% |
| Ground Floor | Top rein | 1467.77 | 257.46 | 257.46 | 1982.69 | |
| | Bottom rein | 257.46 | 257.46 | 1462.58 | 1977.5 | |
| | | | | | **3960.19** | 56% |

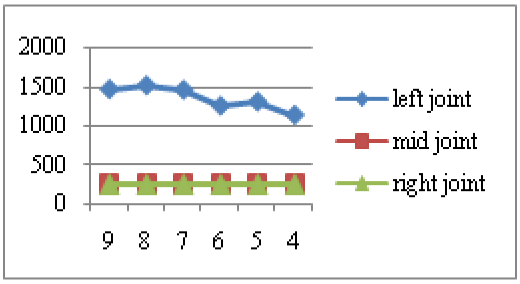


**Figure 8:** Graphical representation of required Ast in successive beam

When considering the maximum shear force in a floor it was easy to find out the maximum reinforcement needed in that floor, through that the percentage of variation in reinforcement in beams can be find out. When taking the results it shows that amount of reinforcement in second floor is greater than all other floors in seismic zone II.

**Table 6:** Comparison of columns at different level in different zones

| *Storey level* | *Column no* | *Zone II* | *Zone III* | *Zone IV* | *Zone V* |
|---|---|---|---|---|---|
| 9 | 133 – 209 | 2880 | 3168 | 4896.00 | 5184.00 |
| 8 | 342 – 418 | 2880 | 2880 | 2880 | 3744.00 |
| 7 | 551 – 627 | 2880 | 2880 | 2880 | 3744.00 |
| 6 | 760 – 836 | 2880 | 2880 | 2880 | 3456.0 |
| 5 | 969 – 1045 | 2880 | 2880 | 2880 | 3456.00 |
| 4 | 1178 – 1254 | 2880 | 2880 | 2880 | 3168.00 |
| 3 | 1387 – 1463 | 2880 | 2880 | 2880 | 2880 |
| 2 | 1596 – 1672 | 2880 | 2880 | 2880 | 2880 |
| 1 | 1805 – 1881 | 2880 | 2880 | 2880 | 2880 |
| G | 2014 – 2090 | 2880 | 2880 | 2880 | 2880 |

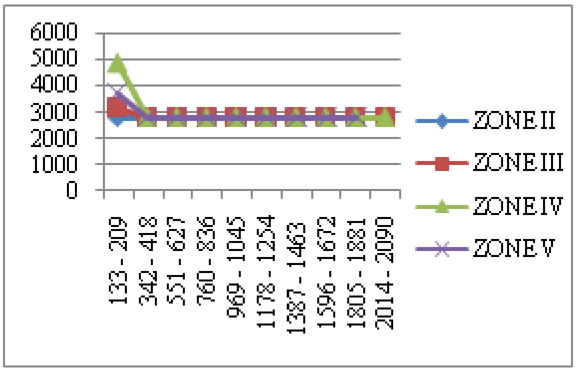


**Figure 9:** Graphical representation of required Ast in successive columns

When considering the section capacity required in a floor and taking $P_{uz}$i and $M_{uz}$ values we can find out the maximum reinforcement needed in that floor, through that the percentage of variation in reinforcement in columns can be find out. When taking the results it shows that amount of reinforcement changes only in ground floor and all other floors have same reinforcement in seismic zones from II - IV.

## 5. Conclusion

- Maximum reinforcement required in first floor beams 13.9% to 87% from zone II to zone V.
- Maximum moment in first floor beams.
- Maximum reinforcement required in ground floor columns 11.49% to 44.32% from zone II to zone V.
- Variation in reinforcement in left joint and right joint is higher than mid joint.
- The moments in building increases gradually according to seismic zones, but in some cases certain variation in values has been noticed
- Reinforcement increases from zone IV to V.
- Maximum amount of reinforcement required for an irregular building is in zone IV and zone V.
- The variation of percentage steel in an unsymmetrical structure is greater compare to a symmetrical structure.

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