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# Comparative Study on Percentage Variation of Steel In Different Seismic Zones Of India

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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 for various seismic zones of India. The current IS code for seismic design i.e.IS 1893-2002 part one suggest that maximum reinforcement should 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 the following work attempt is made to find the percentages required for various seismic zones by considering the effects of infill and without infill. For the study a symmetrical building plan is used with 13 storeys and analyzed and designed by using structure analysis software tool ETABS-2013. The study also includes the determination of base shear, displacement, moment and shear and the results are compared between gravity loads and various seismic zones. These parameters have also considers the effect of masonry infills.***

***Key Words:*** *ETABS, Percentage Steel, Seismic Zones, Base Shear.*

## 1. INTRODUCTION

An earthquake is a natural phenomenon that leads to the vast devastation of engineered systems and facilities. In the present scenario earthquake engineering attracts major attention of scientist because this is the event which cannot be accurately predicted it is the sadden event which happens due to various reasons such as;

1. Movement of tectonic plates.
2. Sudden slips at the faults.
3. Building of dams.
4. Volcanic earthquakes.
5. Due to explosive.
6. Due to mining etc.

Many reaches have been conducted on this topic and still it is continuing, because more we try to learn more we can minimize the damages and save the lives. According to studies have been made on the seismology about 90% earthquake happens due to tectonics. If we come to civil engineering an engineer's job is to provide maximum safety in the structures designed and maintain the economy. Whenever a structure is designed for natural incident such as earthquake we design it to behave the following limits state.

**i. Serviceability.**

In this case structure will suffer less or no structural damage. Buildings which are important in their nature such as hospital, assembly halls, and nuclear plants are designed under this category because even after earthquake it should be serviceable.

ii. **Damageability.**

In this type, if an earthquake occurs some damaged will happen and it can repaired and put to re-use. Permanents building fall in these categories.

iii. **Collapse.**

In this case building is free to damaged but the supports will be remains safe to bear the permanents loads.

In earthquake analysis the force that actually acts on the structure at the time of earthquake are much higher than the forces which are designed. The lateral forces applied during seismic analysis are highly unpredictable. Thus, the design criteria should provide minimum requirements to maintain safety against earthquake and major fails and loss of lives.

The collapse of structure can be minimize if following points taken into consideration.

- The pattern of failure can be made ductile instead of brittle, if ductility is assured dissipation of energy produced will show small amount of deterioration.
- Failure of flexure should come before shear failure.
- The columns should not fail before beams.
- The joints should be hard compare to members which will meet into them.

Due to these reasons earthquake engineering gaining popularity. For designing a safe structure we should consider detailing of structure, choosing without inherent ductility that is concrete, masonry etc. if we introduce the reinforcement in the structure we can increase the ductility of the structure. In earthquake engineering ductility is the major fact that responds to motion of the ground. But incorporation of reinforcement in the structure mainly affects the economy of the structure. Present IS code 1893-2002 gives information to provide maximum amount in the seismic design but it does not specifies at what extent the percentage of reinforcement should be increased in seismic design. The present study mainly focuses on comparison of percentage of steel from zone to zone with gravity load and comparison of moment, shear, displacement and base shear compare to normal design.

### 1.1 Objectives of Study

The present work is computing and evaluating imaginary RC Framed structure wt considering the following illustrated objectives.

- Preparation of 3D building modules with and without masonry infill.
- To study the behavior of structure with and without masonry infill if seismic load is applied.
- Determination of variation in percentage of steel from zone to zone.
- Determination of displacement subjected to earthquake loading from zone to zone.
- To determine the base shear for various seismic zones with and without masonry infill effect.
- To find out the bending moment selecting any one section for various seismic zones.
- To find out the shear force selecting any one section for different seismic zones.
- Developing the necessary guidelines to ensure the satisfactory behavior of structure during earthquake.

## 2. Literature Review

**[1] G Papa Rao and Kiran Kumar (2013),** the author's researches on the changes in the percentage of steel and volume of concrete for the Rcc framed structure for various seismic zones of India. They have designed the structure for gravity load and seismic forces which might be effect on building. According to their research they concluded that the variation in support reactions for exterior columns increased from 11.59% to 41.71% and in case of edge columns it is 17.72% to 63.7% from Zone II to Zone V, and as in the case of interior columns it is very less.

In case of concrete quantities, volume of concrete has been increased for exterior and edge columns from Zone III to ZoneV because of increase in support reactions with the effect of lateral forces and variation is very small in interior columns. Percentage variation of steel in external beams are 0.54% to 1.23% and in internal beams it is noted 0.78% to 1.4%. The bottom reinforcement is not changed for seismic and non seismic design.

**[2] Purnachandra Saha, P.Prabhu Teja &,P Vijay Kumar (2012),** this research is mainly focuses on variation in percentage of steel when building is designed for different seismic zones. As per their research work they concluded that percentage variation of steel in beams are not varying much as compared to columns. Variation is around 0.07% in columns and overall variation is around 0.91% from Zone-2 to Zone-5.

**[3] Md Zubair Ahmed, Arshad, & Abdul Khadeer, (2015)** the study was conducted to compare percentage of steel quantities for buildings subjected to gravity loads, seismic forces along with wind load. After analysis and design they got to the conclusion that percentage of reinforcement in column with maximum load is 1.985% to 45.438%, in case of beams it was 35.112% to 95.867% for basement floors. As the concrete grade increased reinforcement area decreased. Steel percentage is more in exterior and edge columns while it is less in interior columns and in case of beam external beams require less percentage of reinforcement compare to internal beams.

**[4] Perla Karunakar (2014)** the author put his efforts to find out the performance and variation in steel percentage and concrete quantities in various seismic zones and impact on overall cost of construction. According to his research the concrete quantities are increased in exterior and edge columns due to increase in support reactions however variation is very small in interior column footings. Reinforcement variation for whole structure between gravity and seismic loads are 12.96, 18.35, 41.39, 89.05%.the cost variation for ductile vs. non ductile detailing are 4.06%.

**[5] S V Narsa Reddy ,T Anusha, , T Sandeep (2014)** this study was conducted to find out the performance and changes in reinforcement percentage and concrete quantities. The following study includes comparison of percentage steel and concrete quantities of structures designed for gravity and seismic forces. The authors come to the final point stating that variation in concrete quantities between gravity and seismic zones are 1.4, 1.94, 2.69 and 3.8%. And in case of steel it is 12.96, 18.35, 41.39, 89.05% respectively.

**[6] S. Thenmozhi ,Sunayana Varma, A Malar (2014)** in this study authors made comparison between base shear of Rc frame building situated in various seismic zones of India. They found that Etabs software gives high base shear results compared to Staad Pro and manual calculations. According to their research base shear increased 5.45% and 18.67% in case of Staad pro Etabs compared to manual results for zone2. Similarly for zone3, 4, 5 it has been increased 1.07% to 18.67%.

**[7] Lakshmi Gayathri, J C Wason, V.Thiruvengadam (2004)** this research concentrates on cost modeling of structure designed and detailed in various seismic zones of India. The model provides quantities of concrete, reinforcement and shuttering materials for unit area of floors. In conclusion the author states that a eight storied structure situated in zone5, the reinforcement percentage has increase up to 69% comparing to gravity loading case, and it also stated that for a ten storied building situated in zones 2, 3, 4 & 5 cost increased as 5, 10, 20 and 30% respectively.

**[8] J. C. Wason, V. Thiruvegadam, K. I. Prakash** the study shows the cost modeling and quantity of a building foundation for RC multistoried structure designed for earthquake forces for various seismic zones of India. In this study three types of foundations have been selected i.e. isolated foundation, pile foundation and raft foundation for various values of bearing pressures of the soils. The research gives the foundation cost and structural quantities for unit floor area of structure located in various earthquake regions. According to this study following results are achieved. For isolated foundation, variations in concrete quantities are between 0.05 to 0.10 $m^3/m^2$ because of changes in allowable soil bearing pressure. The reinforcement changes from 3 to 9 $kg/m^2$. In case of pile foundation, quantity of concrete is $0.16m^3/m^2$ and need of reinforcement changes between 10 to 13 $kg/m^2$ because of variation in earthquake zones. In raft foundation, quantity of concrete is $0.12m^3/m^2$ and reinforcement changes from 5.2 to 8 $kg/m^2$.

**[9] Brijesh Chandra & Jai Krishna (1965)** this study comprising of determining the steel reinforcement quantity in structures for the purpose of economical & efficient results. In the study suggestions are made up by considering energy factor for deciding the maximum percentage of steel.

As per their study the amount of steel should be such that energy absorbed by the reinforcement at the time of earthquake is not more than the energy absorption limit of masonry, and quantity of reinforcement should not be very small, so that the large deformations takes place in reinforcement.

## 3. Description of Sample Building

In the study symmetric building models has been taken for all cases. The building model has divided into two categories.

- Models without infill.
- Models with infill(Base soft storey)

**i) Models without infill:**

**Model 1:**

Building does not have any masonry infill in any storey and only gravity load is applied no seismic zones considered.

**Model 2:**

Building does not have masonry infill and seismic load applied by considering zone-2.

**Model 3:**

Building does not contain masonry infill and seismic zone-3 is considered.

**Model 4:**

Building has no walls in all storeys and seismic zone-4 is considered.

**Model 5:**

Building has no walls in all storeys and seismic zone-5 is considered.

**ii) Models with infill (Base soft storey)**

**Model 6:**

Building has employed with 230mm masonry infill to all storeys except base and only gravity load is considered.

**Model 7:**

Building has infill all around the storey except base storey and seismic zone-2 is considered.

**Model 8:**

In this model infill is provided in all storeys except base and earthquake zone-3 is taken.

**Model 9:**

The building is employed with infills except base and seismic zone-4 is applied.

**Model 10:**

Building has masonry infill in all storeys except base and earthquake zone-5 is employed.

## 4. Design Data

| | |
|---|---|
| **Material Properties:** | |
| Young's modulus of (M40) concrete, E | = 31.622x106 kN/$m^2$ |
| Young's modulus of (M30) concrete, E | = 27.386x106 kN/$m^2$ |
| Density of Reinforced Concrete | = 25kN/$m^3$ |
| Modulus of elasticity of brick masonry | = 3500x$10^3$kN/$m^2$ |
| Density of brick masonry | = 20kN/$m^3$ |
| Assumed Live load | = 4 KN/$m^2$ |
| Assumed Floor finish | = 1KN/$m^2$ |
| **Member Properties:** | |
| Thickness of slab | = 0.15m |
| Column size (with infill) | =0.55 x 0.55m |
| Column size (without infill) | =0.6 x 0.6m |
| Beam size | = 0.3 x 0.45m |
| Thickness of wall | =0.230m |
| Earthquake Live Load on Slab as per clause 7.3.1 and 7.3.2 of IS 1893 (Part-I) - 2002 is calculated as: | |
| Roof (clause 7.3.2) | = 0 |
| Floor (clause 7.3.1) | = 0.5x4=2kN/m2 |
| Type of structure | =RCC framed structure |
| Floor to floor height | =3.5m |
| Plinth height | =2m |
| Type of soil taken | =Hard rocky |
| Seismic zones considered | =2, 3, 4 & 5 |
| Type of wall | = Brick masonry |

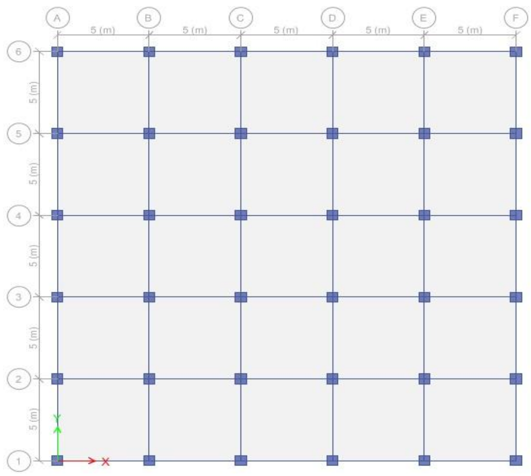

**Figure-1:** Layout Plan for With & Without Infill Models

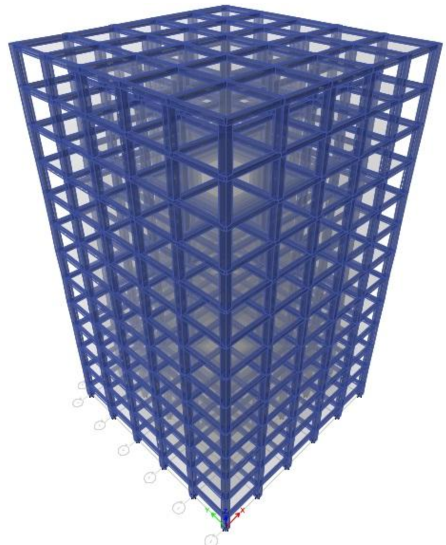

**Figure-2:** 3D model of 13 storeyed Building without walls

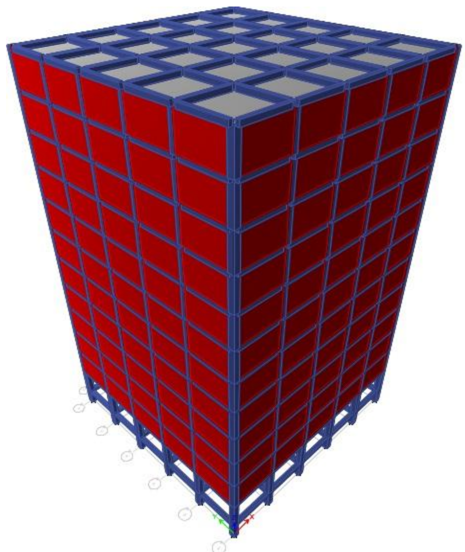

**Figure-3:** 3D model of 13 storeyed Building with walls

## 5. Outcomes

The fallowing work carried to study the percentage variation in steel for different seismic zones of India by considering the effects of infill, non infill, soft storeys. The study also includes various parameters which are studied such as base shear, displacement, bending moment and shear forces. These parameters have also included the effects of infill and without infill and soft storeys. The overall study is conducted by applying the all four seismic zones. In the present work ten symmetrical building models are used, five building models are applied with masonry infill with base and ground soft storey and another five models are kept as bare frame. In each case i.e. infill and non infill one model is applied with gravity loads and remaining models are made by using various seismic zones. Finally the results are compared with each other by considering gravity load and seismic zones, infill and without infill. The seismic analysis for the study has been carried by equivalent static method of analysis.

### 5.1 Steel Percentage

| Location Of Column | Percentage of Steel Reinforcement in Column(without wall) | | | | |
|---|---|---|---|---|---|
| | Gravity Load | Zone-2 | Zone-3 | Zone-4 | Zone-5 |
| Exterior | 2.41 | 2.44 | 2.49 | 2.52 | 2.63 |
| Edge | 2.78 | 2.79 | 2.81 | 2.86 | 2.99 |
| Interior | 2.57 | 2.59 | 2.62 | 2.63 | 2.68 |

**Table-1:** Reinforcement Percentage in
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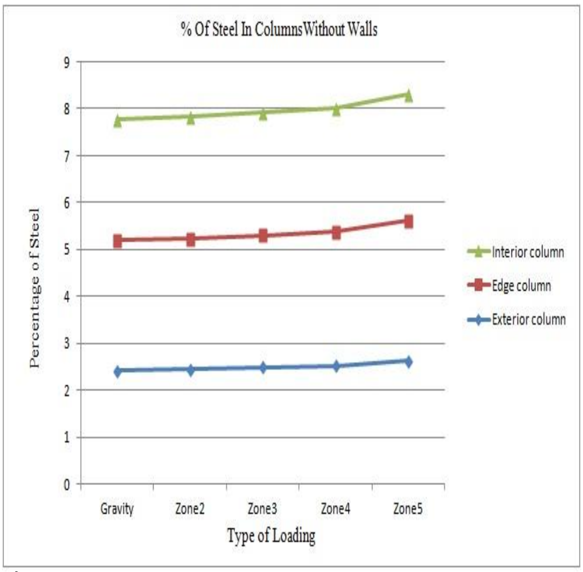


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**Figure-4:** Variation in Reinforcement Percentage in Columns (without walls)

| Location Of Column | Percentage of Steel Reinforcement in Column(with wall) | | | | |
|---|---|---|---|---|---|
| | Gravity Load | Zone-2 | Zone-3 | Zone-4 | Zone-5 |
| Exterior | 0.8 | 0.82 | 0.83 | 0.85 | 1.7 |
| Edge | 1.55 | 1.58 | 1.61 | 1.73 | 2.35 |
| Interior | 2.78 | 2.81 | 2.83 | 2.87 | 2.91 |

**Table-2:** Reinforcement Percentage in Columns (with walls)

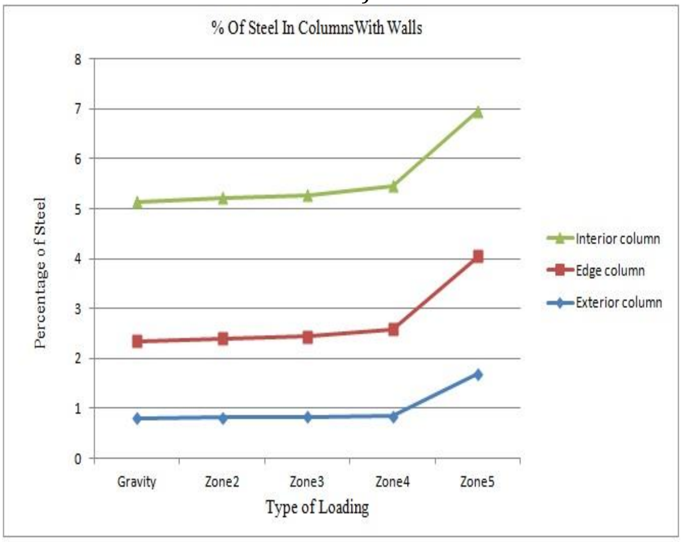


**Figure-5:** Variation in Reinforcement Percentage in Columns (with walls)

| Location Of Beams | Percentage of Steel Reinforcement in Beams (without wall) | | | | |
|---|---|---|---|---|---|
| | Gravity Load | Zone-2 | Zone-3 | Zone-4 | Zone-5 |
| External Beam | 0.32 | 0.4 | 0.47 | 0.56 | 0.7 |
| Internal Beam | 0.48 | 0.56 | 0.59 | 0.66 | 0.81 |

**Table-3:** Reinforcement Percentage in Beams (without walls)

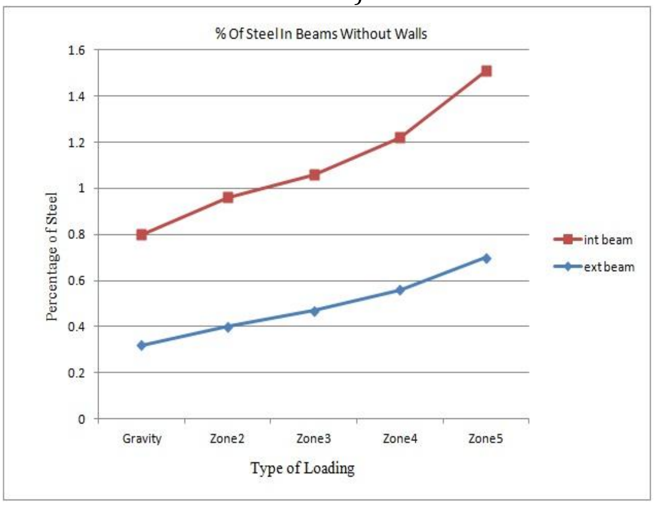


**Figure-6:** Variation in Reinforcement Percentage in Beams (with walls)

| Location Of Beams | Percentage of Steel Reinforcement in Beams (with wall) | | | | |
|---|---|---|---|---|---|
| | Gravity Load | Zone-2 | Zone-3 | Zone-4 | Zone-5 |
| External Beam | 0.37 | 0.38 | 0.41 | 0.42 | 0.43 |
| Internal Beam | 0.37 | 0.37 | 0.39 | 0.4 | 0.41 |

**Table-4:** Reinforcement Percentage in Beams (with walls)


**Figure-7:** Variation in Reinforcement Percentage in Beams (with walls)

| Location Of Column | Difference in Steel Percentage with GL(without Wall) | | | |
|---|---|---|---|---|
| | Zone-2 & GL | Zone-3 & GL | Zone-4 & GL | Zone-5 & GL |
| Exterior | 1.24 | 3.32 | 4.56 | 9.12 |
| Edge | 0.35 | 1.08 | 2.87 | 7.55 |
| Interior | 0.778 | 1.945 | 2.33 | 4.28 |

**Table-5:** Difference in Steel Percentage in Columns (Without walls)

| Location Of Column | Difference in Steel Percentage with GL(with Wall) | | | |
|---|---|---|---|---|
| | Zone-2 & GL | Zone-3 & GL | Zone-4 & GL | Zone-5 & GL |
| Exterior | 2.5 | 3.75 | 6.25 | 12.5 |
| Edge | 1.935 | 3.87 | 11.612 | 51.612 |
| Interior | 1.08 | 1.8 | 3.23 | 4.67 |

**Table-6:** Difference in Steel Percentage in Columns (With walls)

| Location Of Beams | Difference in Steel Percentage with GL(without Wall) | | | |
|---|---|---|---|---|
| | Zone-2 & GL | Zone-3 & GL | Zone-4 & GL | Zone-5 & GL |
| External Beam | 25 | 46.87 | 75 | 83 |
| Internal Beam | 16.66 | 22.916 | 37.5 | 68.75 |

**Table-7:** Difference in Steel Percentage in Beams (Without walls)

| Location Of Beams | Difference in Steel Percentage with GL(with Wall) | | | |
|---|---|---|---|---|
| | Zone-2 &GL | Zone-3 &GL | Zone-4 &GL | Zone-5 &GL |
| External Beam | 2.7 | 10.81 | 13.51 | 16.21 |
| Internal Beam | 0 | 5.405 | 8.108 | 10.81 |

**Table-7:** Difference in Steel Percentage in Beams (With walls)

From the results it can be observed that due to presence of infill the steel percentage has been reduced and in case of non infill it is increased in case of columns. As in the case of beams the same results have achieved in infill case percentage gets decreased and in non infill it gets increased. According to this it can be states that the masonry infill can slightly affect on steel percentage due to structural integrity.

### 5.2 Base Shear

| Description | Model & Zone | Base Shear KN |
|---|---|---|
| Without Walls | 2 | 305.973 |
| | 3 | 489.557 |
| | 4 | 734.336 |
| | 5 | 1101.504 |
| With Walls | 2 | 1339.5467 |
| | 3 | 2143.2748 |
| | 4 | 3214.9122 |
| | 5 | 4822.3683 |

**Table-8:** Base Shear values with and without walls

Above table shows the base shear values for various seismic zones and models, from the above results it can be seen that base shear values are increasing with increase in zone factor, it can also be seen that base shear values for infill case are more compare to non infill case.

### 5.3 Displacement

| Displacement In Both X & Y Directions In mm(With Wall) | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Story No | | | | | | | | | | | | | |
| Load Case | Gl | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
| Gravity load | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Zone-2 | 0 | 0.5 | 1.8 | 1.9 | 2.1 | 2.2 | 2.4 | 2.5 | 2.6 | 2.8 | 2.9 | 3.1 | 3.2 | 3.3 |
| Zone-3 | 0 | 0.7 | 2.8 | 3.1 | 3.3 | 3.5 | 3.8 | 4 | 4.2 | 4.5 | 4.7 | 4.9 | 5.1 | 5.2 |
| Zone-4 | 0 | 1.1 | 4.3 | 4.6 | 5 | 5.3 | 5.6 | 6 | 6.4 | 6.7 | 7 | 7.3 | 7.6 | 7.8 |
| Zone-5 | 0 | 1.6 | 6.4 | 7 | 7.4 | 7.9 | 8.5 | 9 | 9.5 | 10.1 | 10.5 | 11 | 11.4 | 11.7 |

**Table-9**: Displacement (mm) along Longitudinal and Transverse direction (With wall)

The displacement which likely to happen due to seismic force is calculated and tabulated. The displacement which is maximum at each floor level corresponding to ground is shown in table 9 and 10, for the equivalent analysis. For the purpose of comparison displacement values are divided into two types, firstly comparison between seismic zones and gravity load and secondly is between infill and non infill case.

| Displacement In Both X & Y Directions In mm(without Wall) | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Story No | | | | | | | | | | | | | |
| Load Case | Gl | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
| Gravity load | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Zone-2 | 0 | 0.2 | 1.2 | 2.5 | 3.8 | 5.2 | 6.6 | 7.8 | 9 | 10.1 | 11 | 11.7 | 12.2 | 12.5 |
| Zone-3 | 0 | 0.3 | 1.9 | 4 | 6.1 | 8.3 | 10.5 | 12.5 | 14.4 | 16.1 | 17.6 | 18.7 | 19.5 | 19.9 |
| Zone-4 | 0 | 0.3 | 1.8 | 3.8 | 5.9 | 8 | 10.1 | 12 | 13.9 | 15.6 | 17 | 18.2 | 19.1 | 19.7 |
| Zone-5 | 0 | 0.5 | 2.7 | 5.7 | 8.8 | 12 | 15.1 | 18.1 | 20.8 | 23.4 | 25.5 | 27.3 | 28.7 | 29.5 |

**Table-10**: Displacement (mm) along Longitudinal and Transverse direction (Without wall)

From the tables it can be seen that displacement is more at top floors and it is gradually reducing to bottom floors, this is because of the floor rotation which is more at the top floors. In some cases if concrete core wall is provided in the structure the displacement will be linear because of core wall, core wall resist the rotation of the floors.

## 6. Conclusions

1. The total variation in percentage steel in columns for infill case with maximum loading from seismic zone-2 to zone-5 are 1.935% to 51.612% compared to gravity loads.
2. The total variation in percentage steel in columns for without infill case with maximum loading from seismic zone-2 to zone-5 are 1.24% to 9.12% compared to gravity loads.
3. The amount of variation of percentage steel in beams for infill case with maximum loading from zone-2 to zone-5 are 2.7% to 16.21% compared to gravity loads.
4. The variation in percentage steel in beams for non infill case with maximum loading from seismic zone-2 to zzone-5 are 16.66% to 68.75% compared to gravity loads.
5. From the beam and column percentage of steel results, it can be state the variation in steel percentage in beams are more compared to columns.
6. In analysis if grade of concrete increases the area of reinforcement decreases.
7. The reinforcement percentage in edge and interior columns are more compare to exterior columns.
8. The percentage reinforcement in external beams are more compare to internal beams.
9. In case of beams, the reinforcement percentage in bottom middle portion is same in all cases.
10. The base shear in both cases i.e. with infill and without infill increases as the seismic one increase.
11. The displacement of structures increased as the seismic zone increase in both infill and non infill cases.
12. The moments in building increases gradually according to seismic zones, but in some cases certain variation in values has been noticed.

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