

Effect of Seismic Forces on RC Structure with Setback Building

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Abstract— The goal of the study is to analyses the setback constructing for stability and seismic forces. Setback constructing design and analyses such structure with keen observation thinking about different factors affecting them. As it is once more essential to analyses such shape for important forces like earthquake. Preserving this in thoughts, on this undertaking the take a look at is performed for finding out the end result that makes setback building stable towards forces performing on it with and without thinking about seismic forces. Setback buildings are a subset of vertically irregular homes in which there are discontinuities with admire to geometry. However, geometric irregularity additionally introduces discontinuity inside the distribution of mass, stiffness and strength along the vertical path. Majority of the studies on setback homes have centered on the elastic response. The conduct of those sorts of constructing is something one of a kind. There may be a want of more paintings to be achieved in this regard. So this research work is an attempt to reach on more accurate end to reduce earthquake impact on the structure.

Keywords: Setback, Seismic Forces, Irregular, Stability

I. INTRODUCTION

A. Aim

To examine seismic balance of setback rc structure with change in geometry.

B. Objective

- 1) To examine the seismology of India.
- 2) To have a look at the impact of earthquake on rc shape.
- 3) To look at the torsion and twisting.
- 4) To look at the seismic evaluation method.
- 5) To examine the seismic evaluation of setback shape.
- 6) To find out the effect of setback geometry of shape power.

C. Need

Earthquake is one of the most negative of herbal dangers. It's far the unexpected movement of earth motive because of the discharge of stress strength. It can causes numerous damages to buildings, earth floor, surroundings and existence of common man.

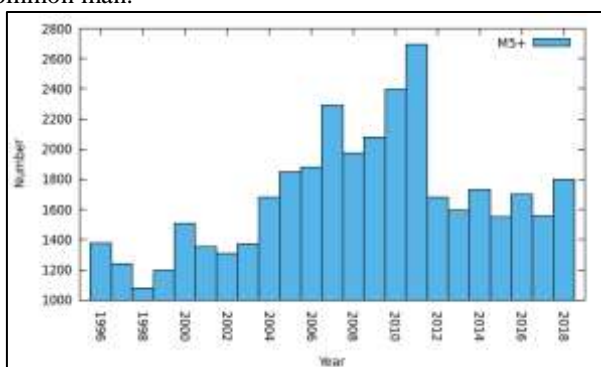


Fig. 1.1: No. of earthquakes as per years up to 2018

From the above graph it's far proven that, in every year there are primary wide variety of earthquake happens. This occurrence of earthquake reasons the intense damages to the buildings and breaks the life of peoples.

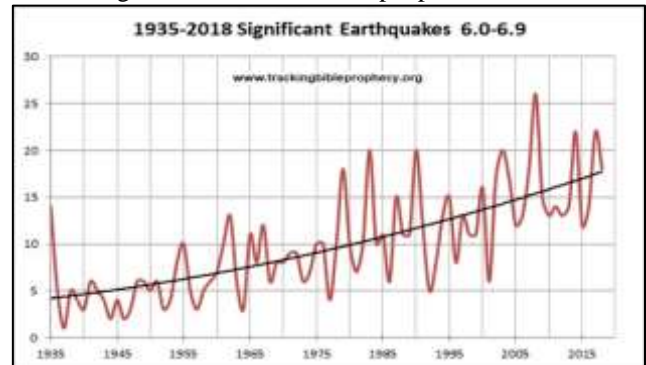


Fig. 1.2: Magnitude of earthquake (6.0-6.9) for year 1935-2018

Additionally, from the above graph we discovered that, the significance of the earthquake is in between 6.0-6.9 and its miles elevated yr by means of 12 months which also can also reasons the damages and effect badly over environment. For this reason to decrease this and to conquer the effect of earthquakes, constructing have to be nicely built by providing metal bars and factors like beam, columns, partitions, footing as well.

Also, to reduce the effect of earthquake it is vital to decide seismic responses of such buildings. There are exceptional strategies of seismic analysis of structure.

II. METHODOLOGY

Every problem is solved with the proper analysis of cause and providing a complete solution. Similarly this study is done to check the performance of structure having different offsets. At first simple frames analysis for various seismic aspects are studied. For that purpose literature on the current topic done by various authors is studied and all the importance informative sources i.e.

After this preliminary study, the detailed analysis is done for finding the various standards for the RCC frame structures for which basically designed based on the RCC and Seismic Code. Parameters such as zone factor, base shear, Story Shear etc are studied.

In next stage as per IS 1893-1983 various formulations are done for Seismic analysis of buildings and various methods of analysis of structure subjected to earthquake forces are studied and all these details are then studied and mentioned in our report. In this stage only IS code analysis is done for calculating base shear at each story level

Then in further step seismic study is done. Various considerations about seismic effect are studied. After that experimental work is done by considering problem for further study in which Simple symmetrical G+5 Frame is manually analysed.

In next stage it is decided to consider a model analysis for the same with considering seismic effect of different zones.

III. DETAILED STUDIES

A. Seismology of India:

Seismology is the look at of earthquakes and seismic waves that flow via and around the earth. A seismologist is a scientist who research earthquakes and seismic waves. Seismological research related to estimating shallow and deep crustal structures in diverse tectonic domain names of the India land mass. The earthquake incidence strategies inside the Himalayas, the Burma plate, and the Sumatra trench, in addition to crustal deformation measurements inside the plate-boundary and plate-indoors regions.

B. Seismological map of India

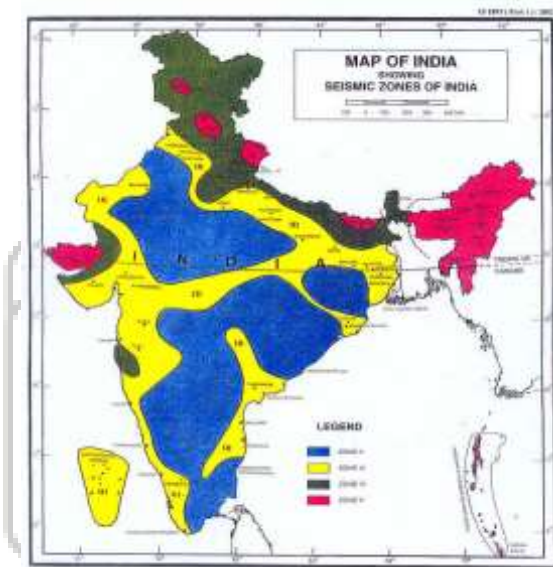


Fig. 3.1: India earthquake map

Earthquakes are the shaking, rolling or surprising shock of the earth's floor. Those are the herbal means of releasing pressure. There are about 20 plates along the earth's floor and those plates moves continuously and slowly past every other, towards every other & away from each different for that reason causing unique phenomenon in the world's surface.

India lies on the north-western quit of the indo australian plate, which encompasses india, australia, a prime portion of the indian ocean and other smaller international locations. This plate is colliding in opposition to the big eurasian plate and going below the eurasian plate. This process of 1 tectonic plate getting under some other is responsible for making India an earthquake inclined USA some of huge earthquakes came about in and round India during the last century. Some of these took place in populated and urbanized regions and hence precipitated outstanding harm. The varying geology at specific locations in the usa means that the chance of destructive earthquakes taking place at exceptional locations is distinctive. As a result, a seismic zone map is required to become aware of those areas.

Every state incorporates out mapping of its territory based on all natural failures like earthquake, cyclone, flood

and volcano and so on. This mapping is accomplished on the premise of past history and factors answerable for such disaster of present in that location. This mapping facilitates people to design their domestic and different infrastructure so that they don't emerge as the sufferer of such catastrophe and can withstand disasters with as minimal as possible lack of lifestyles and belongings. Code of practice of all countries for layout of buildings and different structure encouraged layout tips based on such mapping or zoning.

In India, the United States has been divided into four zones. In advance there had been five zones but after Bhuj earthquake of 2001, the region i have been removed. Each use in the global has such zoning for all such natural failures. India is split into 4 seismic zones i.e. Zones ii, iii, iv and v. Those zones are divided on the idea of most considered earthquake and provider life of shape in every seismic sector.

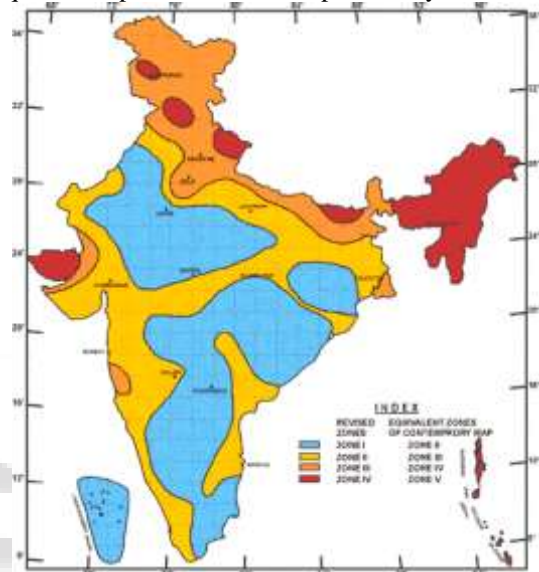


Fig. 3.2: Indian earthquake zone map

As per Bureau of Indian Standards {IS 1893(part 1): 2002}, grouped out the India into four seismic zones such as zone V, IV III II and I.

C. Seismic zone have been categorized as follows:

1) Zone V:

The areas of this zone have the highest risk of effects by an earthquake. The earthquake intensity for this zone is MSK-IX or greater. The zone factor for this zone is 0.36, which is indicative of effective (zero period) level earthquake in this zone. This zone is called as Very High Damage Risk Zone. Some of the regions which fall under this zone are Ran of Kutch, Eastern regions etc.

2) Zone VI:

The areas of this zone have the lesser risk to effects by an earthquake as compared to zone V. The earthquake intensity for this zone is between MSK VIII to MSK-IX. The zone factor for this zone is 0.24. This zone is called as High Damage Risk Zone. Some of the regions which fall under this zone are Northern regions, North Eastern regions, Delhi etc.

3) Zone III:

The areas of this zone have the lesser risk by an earthquake. The earthquake intensity for this zone is MSK VII. The zone factor for this zone is 0.16. This zone is called as Moderate Damage Risk Zone. Some of the regions which fall under this

zone are some parts of Gujarat & Maharashtra, Andaman Nicobar Islands etc.

4) **Zone II:**

The areas of this zone have the least risk of an earthquake. The earthquake intensity for this zone is MSK VI. The zone factor for this zone is 0.10. This zone is called as Low Damage Risk Zone. Larger parts of India come under this zone. Out of all these zones, Zone II is seismically least active region, while zone V is the most. i.e. the damage and effect of earthquake would be higher.

5) **Zone I:**

Since the current division of India into earthquake hazard zones does not use Zone 1, no area of India is classed as Zone I. Future changes in the classification system may or may not return this zone to use.

D. Effect of earthquake on RC structure:

Earthquake is the most dangerous natural phenomenon that generates sizable destruction in structures. It is reported that two sources of mistakes which would seriously endanger structures are ignoring the ways an earthquake affects buildings and shoddy construction practices.

That is why a proper understanding of the seismic effects on a structure is extremely important, and designers and contractors should consider the influence of seismic forces on buildings in order to be able to set prevention measures against failures and collapses.

As earthquake hits structures, it generates inertia forces which could be greatly destructive causing deformations and, horizontal and vertical shaking.

1) **Types of earthquake effects:**

- 1) Inertia Forces in Structures
- 2) Effect of Deformations in Structures
- 3) Horizontal and Vertical Shaking
- 4) Other effect

a) **Inertia Forces in Structures:**

The generation of inertia forces in a structure is one of the seismic influences that detrimentally affect the structure. When an earthquake causes ground shaking, the base of the building would move but the roof would be at rest. However, since the walls and columns are attached to it, the roof is dragged with the base of the building. The tendency of the roof structure to remain at its original position is called inertia. The inertia forces can cause shearing of the structure which can concentrate stresses on the weak walls or joints in the structure resulting in failure or perhaps total collapse. Finally, more mass means higher inertia force that is why lighter buildings sustain the earthquake shaking better.

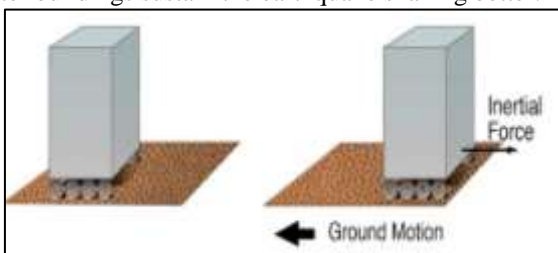


Fig. 3.3: Direction of Inertia Forces

b) **Effect of Deformations in Structures**

When a building experiences earthquake and ground shaking occurs, the base of the building moves with the ground shaking. However, the roof movement would be different

from that of the base of the structure. This difference in the movement creates internal forces in columns which tend to return the column to its original position. These internal forces are termed stiffness forces. The stiffness forces would be higher as the size of columns gets higher. The stiffness force in a column is the column stiffness times the relative displacement between its ends.

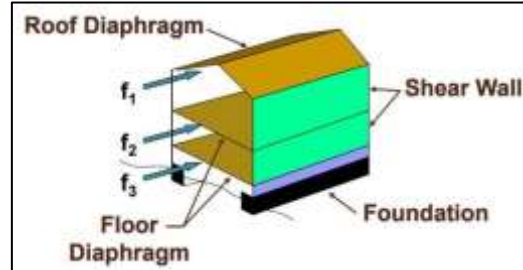


Fig. 3.4: Lateral Force Resisting System in a House

c) **Horizontal and Vertical Shaking**

Earthquake causes shaking of the ground in all the three directions X, Y and Z, and the ground shakes randomly back and forth along each of these axis directions. Commonly, structures are designed to withstand vertical loads, so the vertical shaking due to earthquakes (either adds or subtracts vertical loads) is tackled through safety factors used in the design to support vertical loads.

However, horizontal shaking along X and Y directions is critical for the performance of the structure since it generates inertia forces and lateral displacement and hence adequate load transfer path shall be provided to prevent its detrimental influences on the structure.

Proper inertia force transfer path can be created through adequate design of floor slab, walls or columns, and connections between these structural elements. It is worth mentioning that the walls and columns are critical structural members in transferring the inertial forces. It is demonstrated that, masonry walls and thin reinforce concrete columns would create weak points in the inertia force transfer path.

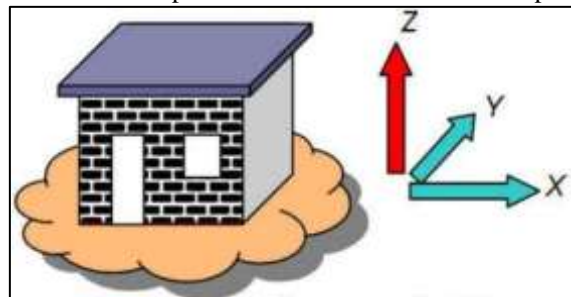


Fig. 3.5: Principal Directions of a Building

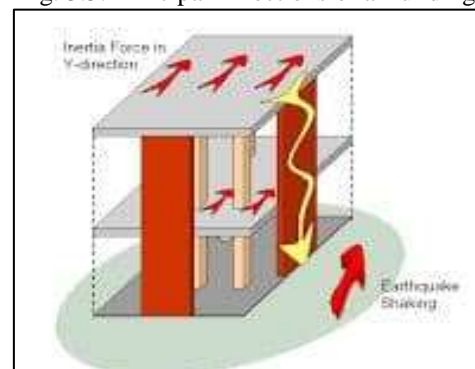


Fig. 3.6: Load Path for Lateral Inertia Forces

d) Other effect

Apart from the direct influences of earthquakes on a structure which are discussed above, there are other effects such as liquefaction, tsunami, and landslides. These are the indirect effects of strong earthquakes that can cause sizable destruction.

E. Torsion and Twisting:

1) Torsion:

The twisting or wrenching of a body by the exertion of forces tending to turn one end or part about a longitudinal axis while the other is held fast or turned in the opposite direction

2) Twisting:

a) Building Twist

The more modern versions of these swings can be seen today in the children's parks in urban areas; they have a plastic cradle tied with steel chains to a steel framework. Consider a rope swing that is tied identically with two equal ropes. It swings equally, when you sit in the middle of the cradle. Buildings too are like these rope swings; just that they are inverted swings. The vertical walls and columns are like the ropes, and the floor is like the cradle. Buildings vibrate back and forth during earthquakes. Buildings with more than one storey are like rope swings with more than one cradle. Thus, if you see from sky, a building with identical vertical members and that are uniformly placed in the two horizontal directions, when shaken at its base in a certain direction, swings back and forth such that all points on the floor move horizontally by the same amount in the direction in which it is shaken.

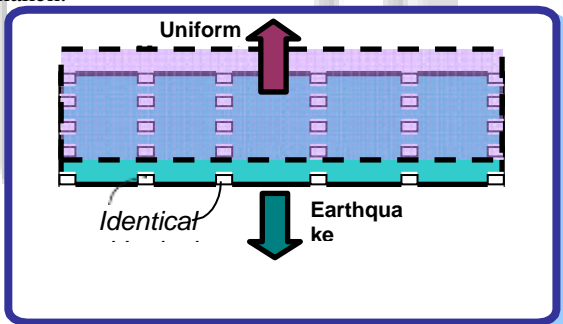


Fig. 3.7: Identical vertical members placed uniformly in plan of building cause all points on the floor to move by same amount.

Again, let us go back to the rope swings on the tree: if you sit at one end of the cradle, it twists (i.e., moves more on the side you are sitting). This also happens sometimes when more of your friends bunch together and sit on one side of the swing. Likewise, if the mass on the floor of a building is more on one side (for instance, one side of a building may have a storage or a library), then that side of the building moves more underground movement. This building moves such that its floors displace horizontally as well as rotate.

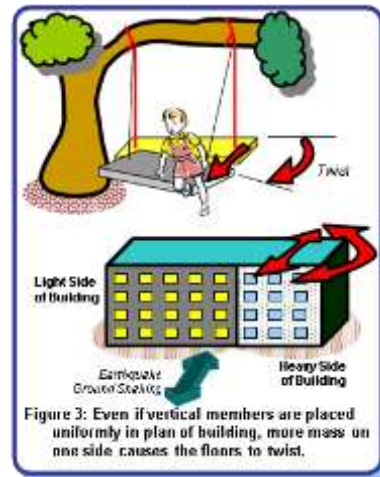


Figure 3: Even if vertical members are placed uniformly in plan of building, more mass on one side causes the floors to twist.

Fig. 3.8: Even if vertical members placed uniformly in plan of building.

Once more, let us consider the rope swing on the tree. This time let the two ropes with which the cradle is tied to the branch of the tree be different in length. Such a swing also twists even if you sit in the middle. Similarly, in buildings with unequal structural members (i.e., frames and/or walls) also the floors twist about a vertical axis and displace horizontally. Likewise, buildings, which have walls only on two sides (or one side) and flexible frames along the other, twist when shaken at the ground level.

Buildings that are irregular shapes in plan tend to twist under earthquake shaking. For example, in a propped overhanging building, the overhanging portion swings on the relatively slender columns under it. The floors twist and displace horizontally.

b) Twist does to Building Members

Twist in buildings, called torsion by engineers, makes different portions at the same floor level to move horizontally by different amounts. This induces more damage in the frames and walls on the side that moves more (Figure 6). Many buildings have been severely affected by this excessive torsional behavior during past earthquakes. It is best to minimize (if not completely avoid) this twist by ensuring that buildings have symmetry in plan (i.e., uniformly distributed mass and uniformly placed lateral load resisting systems). If this twist cannot be avoided, special calculations need to be done to account for this additional shear forces in the design of buildings; the Indian seismic code (IS 1893, 2002) has provisions for such calculations. But, for sure, buildings with twist will perform poorly during strong earthquake shaking.

F. Seismic analysis methods

The seismic analysis type that should be used to analyses the structure depends upon

- External action
- The behavior of structure or structural materials
- The type of structural model selected

Seismic analysis methods can be divided into the following five categories-

- 1) Equivalent static analysis
- 2) Response spectrum analysis
- 3) Linear dynamic analysis
- 4) Non-linear static analysis
- 5) Non-linear dynamic analysis

IV. SEISMIC ANALYSIS OF SETBACK STRUCTURE:

A. Manual problem on regular building

The plan and elevation of a four-story RCC building is shown in fig. The building is located in seismic zone VI. The type of soil encountered is soft soil and it is proposed to design the building with an ordinary RC moment-resisting frame. (OMRF) The intensity of DL is 10 KN/m² and the floors are to cater to an IL of 4 KN/m². Determine the seismic load on the structure by static analysis

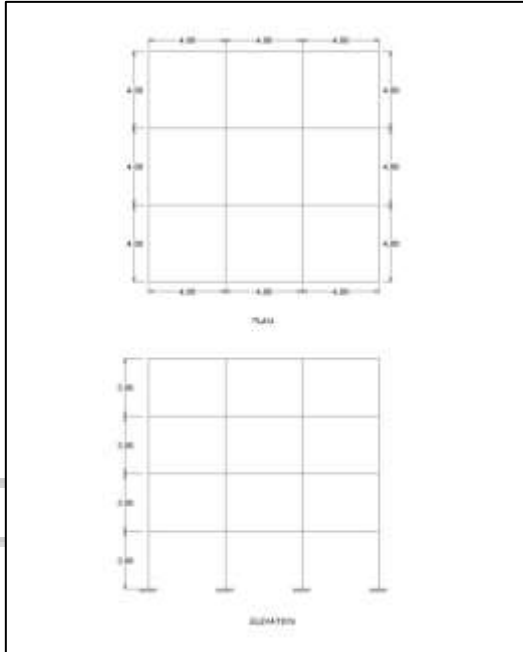


Fig. 4.1: Regular Building

Solution:

Design parameter:

For seismic zone VI, zone factor, $Z = 0.24$

(IS Code 1893: 2002 Table No 5.2)

Importance factor, $I = 1.5$

(IS Code 1893: 2002 Table No 5.3)

Response reduction factor, $R = 3$

(IS Code 1893: 2002 Table No 5.4)

Seismic weight:

Floor area = $12 \times 12 = 144 \text{ m}^2$

For live load up to an including 4 KN/m^2

Percentage of live load to be considered = 50%

The total seismic weight on the floors is

$$W = \sum W_i$$

Where W_i is sum of loads form all the floors which includes DLs and appropriate percentage of live loads.

Story level	W_i (KN)	h_i (m)	$\frac{W_i h_i}{\sum W_i h_i}$	$\frac{W_i h_i^2}{\sum W_i h_i^2}$	Lateral force V_i at ith level for EL In x and y direction (kn)
4	1440	12	0.487	0.487	483.88
3	1728	9	0.329	0.329	326.89
2	1728	6	0.146	0.146	145.06
1	1728	3	0.0365	0.0365	36.266
$\sum W_i h_i^2$			425088		

Seismic weight contribution from first floor (W_1) = $144 \times (10 + 0.50 \times 4) = 1728 \text{ KN}$

Seismic weight contribution from second floor (W_2) = $144 \times (10 + 0.50 \times 4) = 1728 \text{ KN}$

Seismic weight contribution from third floor (W_3) = $144 \times (10 + 0.50 \times 4) = 1728 \text{ KN}$

Seismic weight contribution from roof (W_4) = $144 \times 10 = 1440 \text{ KN}$

Hence, the total seismic weight of structure (W) = $W_1 + W_2 + W_3 + W_4$

$$W = 1728 + 1728 + 1728 + 1440$$

$$W = 6624 \text{ KN}$$

Fundamental natural period of vibration, is given as

$$T_a = \frac{0.09h}{\sqrt{d}}$$

Where h is height of the building in meters and d is the base dimension in meters at plinth level along the direction of the lateral load.

$$T_a = \frac{0.09 \times 12}{\sqrt{12}}$$

$$T_a = 0.3117 \text{ s}$$

Since the building is symmetrical in plan, the fundamental natural period of vibration will be the same in both direction. For soft soil and $T_a = 0.3117 \text{ s}$

$$\frac{s_a}{g} = 2.5$$

$$A = \frac{Z I (s/g)}{2R} = \frac{(0.24 \times 1.5 \times 2.5)}{2 \times 3} = 0.15$$

Design base shear V_B is given as

$$V_B = A b W = 0.15 \times 6624$$

$$V_B = 993.6 \text{ KN}$$

The force distribution with building height is given in table 3.1 and is shown in Fig.

Table no 4.1: Lateral load distribution with height for regular building

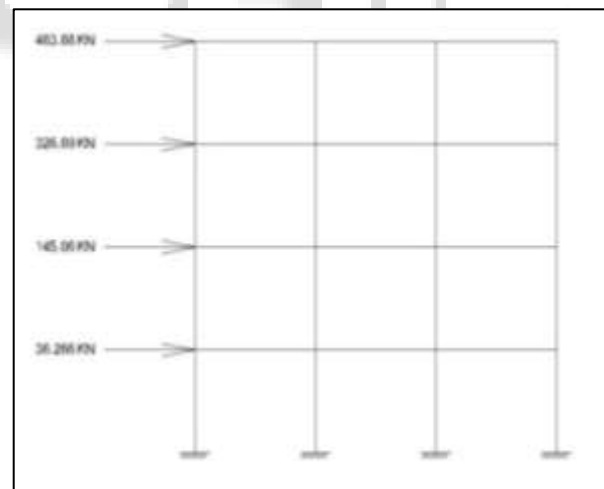


Fig. 4.2: Design Seismic Forces By Static Analysis

B. Manual problem on setback building

The plan and elevation of a four-storey RCC building is shown in fig. The building is located in seismic zone VI. The type of soil encountered is soft soil and it is proposed to design the building with a ordinary RC moment-resisting frame. (OMRF) The intensity of DL is 10 KN/m^2 and the floors are to cater to an IL of 4 KN/m^2 . Determine the seismic load on the structure by static analysis.

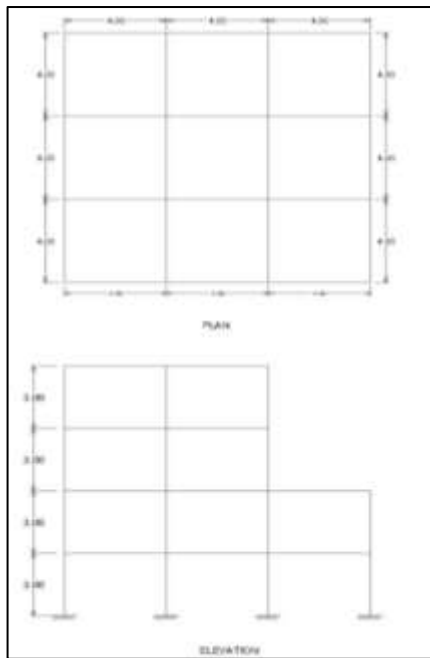


Fig. 4.3: Building Configuration

Solution:

Design parameter:

For seismic zone VI, zone factor, $Z = 0.24$

(IS Code 1893: 2002 Table No 5.2)

Importance factor, $I = 1.5$

(IS Code 1893: 2002 Table No 5.3)

Response reduction factor, $R = 3$

(IS Code 1893: 2002 Table No 5.4)

Seismic weight:

Floor area W_4 and $W_3 = 12 \times 8 = 96 \text{ m}^2$

Floor area W_2 and $W_1 = 12 \times 12 = 144 \text{ m}^2$

For live load up to an including 4 KN/m^2

Percentage of live load to be considered = 50%

The total seismic weight on the floors is

$$W = \sum W_i$$

Where W_i is sum of loads form all the floors which includes DLs and appropriate percentage of live loads.

Seismic weight contribution from first floor (W_1) = $144 \times (10 + 0.50 \times 4) = 1728 \text{ KN}$

Seismic weight contribution from second floor (W_2) = $144 \times (10 + 0.50 \times 4) = 1728 \text{ KN}$

Seismic weight contribution from third floor (W_3) = $96 \times (10 + 0.50 \times 4) = 1152 \text{ KN}$

Seismic weight contribution from roof (W_4) = $96 \times 10 = 960 \text{ KN}$

Hence, the total seismic weight of structure (W) = $W_1 + W_2 + W_3 + W_4$

$$W = 1728 + 1728 + 1152 + 960$$

$$W = 5568 \text{ KN}$$

Fundamental natural period of vibration, is given as

$$T_a = \frac{0.09h}{\sqrt{d}}$$

Where h is height of the building in meters and d is the base dimension in meters at plinth level along the direction of the lateral load.

$$T_a = \frac{0.09 \times 12}{\sqrt{12}}$$

$$T_a = 0.3117\text{s}$$

Since the building is symmetrical in plan, the fundamental natural period of vibration will be the same in both direction. For soft soil and $T_a = 0.3117\text{s}$

$$\frac{s_a}{g} = 2.5$$

$$A = \frac{Z I (s/g)}{2R} = \frac{(0.24 \times 1.5 \times 2.5)}{2 \times 3} = 0.15$$

Design base shear VB is given as

$$VB = A b W = 0.15 \times 5568$$

$$VB = 835.2 \text{ KN}$$

The force distribution with building height is given in table 3.2 and is shown in Fig.

Story level	W_i (KN)	h_i (m)	$\frac{W_i h_i}{2}$	$\frac{W_i h_i}{\sum W_i h_i / 2}$	Lateral force V_i at i th level for EL In x and y direction (kn)
4	960	12	138240	0.447	373.33
3	1152	9	93312	0.302	252.23
2	1728	6	62208	0.201	167.87
1	1728	3	15552	0.0502	41.92
$\sum W_i h_i / 2$			309312		

Table 4.2: Lateral load distribution with height.

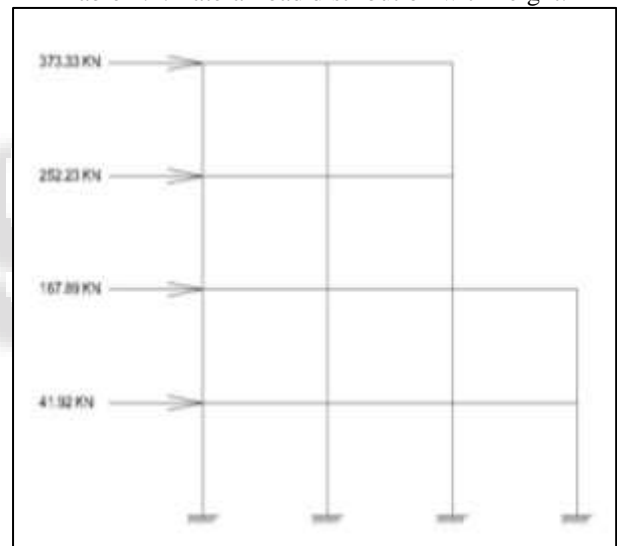


Fig. 4.4: Design Seismic Forces by Static Analysis

V. CONCLUSION

Setback systems are fantastically vulnerable at some point of earthquakes because of its vertical geometrical and mass irregularity, however the vulnerability will become higher if the systems also have stiffness irregularity in elevation. Effective useful efficiency of structures alongside appealing aesthetical look is normally in demand in this modern civilisation. Consequently, there's popular and growing demand for the development of multi-storeyed setback buildings with gentle storey i.e., open ground storey.

This effort reduces the stiffness of the lateral load resisting device and setback configuration generates vertical irregularities in the structure. In keeping with is 1893 (component 1): 2002, any storeys that have a lateral stiffness less than 70% of that of the storey straight away above, or less than 80% of the blended stiffness of the three storeys above, are known as tender storeys. An excessive smooth storey is

one in which the lateral stiffness is much less than 60% of that inside the storey above or much less than 70% of the common stiffness of the three storeys above. And if the lateral electricity of a selected storey is less than 80% of that of the storey right now above, it's far known as weak storey. Setback shape is the only with vertical geometric irregularity, in which the horizontal size of the lateral force resisting machine in any storey is more than a hundred and fifty% of that during adjoining storey.

These structural irregularities are not perfect from stability factor of view, as current earthquakes have proved the structural vulnerability during earthquakes. So, significant studies are needed for accomplishing ultimate overall performance in spite of a terrible configuration. All the structures at some stage in earthquakes are proved to be inclined but the structures with soft storey configuration i.e., systems with stiffness irregularity in elevation are determined to be most prone during earthquake. And the hazard issue will become plenty more if tender storeyed systems have also setback configuration in elevation. Shortage of undeniable ground in hilly regions and urge of extracting herbal beauty of hills, lead us to construct such irregular structures inside the slopes of the hills also. As a result, the hazard aspect of those abnormal systems increases as even the bottom of these systems will become willing at slope. This deadly mixture of geometrical irregularity, mass irregularity, stiffness irregularity and torsional response makes the systems too much vulnerable to live on for the duration of earthquake. Therefore, it's far essential to take a look at the responses of such homes to make such homes earthquake-resistant and prevent their crumble to save the loss of lifestyles and assets.

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