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# Seismic Design of High-Rise Buildings with Structural Irregularities

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**ABSTRACT**: An earthquake is the shaking of the earth's surface caused by waves that emerge from a source of disturbance in the ground as a result of energy released from the earth's crest. During an earthquake, failure begins at the weakest place. The discontinuity of the structure's mass, stiffness, and geometry may cause this weakness. Vertical irregularities are one of the many significant reasons of earthquake structural failure, and discontinuous structures are known as irregular structures. Vertical irregular constructions have an uneven distribution of weight, strength, and stiffness over the building height. When these structures are to be built in seismically active locations, the research and layout become more difficult. Using ETABs G+10 storey reinforced concrete building located in zones III and IV with mass and stiffness irregularities are studied by response spectrum method and various seismic parameter such as storey displacement, storey drift, Base shear and time period is studied. Based on the analysis and results obtained, it is observed that Seismic design of high-rise buildings with structural irregularities is effective and efficient.

KEYWORDS: Mass irregularities, stiffness irregularities, response spectrum method, ETABs.

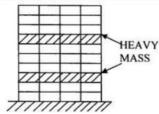
#### I. INTRODUCTION

Earthquake forces are sporadic forces that may or may not affect the structure, but when they do, they have a significant structural influence and can result in structural collapse. As a result, in the event of a multi-story structure, the seismic structure's reaction becomes required. According to the Indian seismic code IS 1893-2002, there are five seismic zones, each with a varied potential for shaking strength. During an earthquake, failure begins at the weakest place. The discontinuity of the structure's mass, stiffness, and geometry may cause this weakness. Vertical irregularities are one of the many significant reasons of earthquake structural failure, and discontinuous structures are known as irregular structures. Vertical irregular constructions have an uneven distribution of weight, strength, and stiffness over the building height. The irregular structure is explicitly defined in the Indian seismic code version of 2002. When these structures are to be built in seismically active locations, the research and layout become more difficult. Plan irregularities

a) Vertical irregularities

Vertical irregularities are mainly of three types, i.e. stiffness irregularity, mass irregularity, and vertical geometric irregularity.

1. Mass irregularity - Mass irregularity is known to occur where any storey's seismic weight is more than 200% of that of its neighbouring stories.



- 2. Stiffnessirregularity (soft storey) Asoftstorey isone inwhich the ateral stiffness of the three stories above is less than 70% or less than 800% of the average lateral stiffness.



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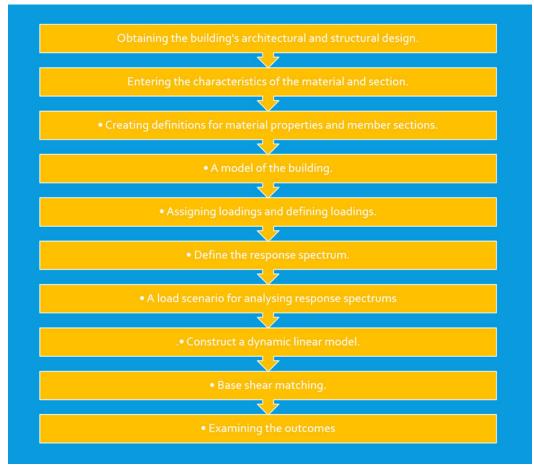
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#### II. OBJECTIVE OF THE STUDY

1] To develop the model of RC frame in seismic zone III and zone IV with mass and stiffness irregularities 2] To study the G+10 storied RC frame, with mass and stiffness by dynamic analysis (response spectrum) and static analysis.

3] To study parameters like time period, base shear, storey displacement, storey drift ratio, in seismic zone III and IV.

#### **III. METHODOLOGY**



#### IV. MODELLING

#### 1. Model with mass irregularity at ground floor

Model regular framed structure with mass irregularity at ground floor consists of length 34 metres and breadth 28 metres having 10 floors is analysed for seismic zones III and the results are noted down

#### 2. Model with mass and stiffness irregularity at mid floor

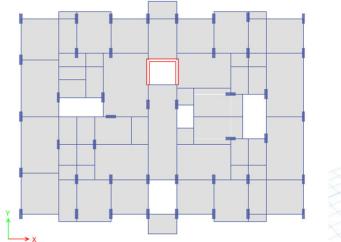
Model 2A regular framed structure with mass irregularity at mid floor consists of length 34 metres and breadth 28 metres having 10 floors is analysed for seismic zones IV and the results are noted down.

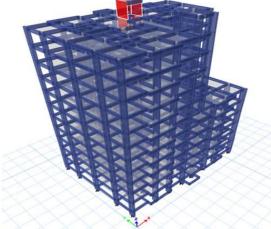


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3D regular model of Building

Plan of Building Building size- 34mx 28m Beams of size 200X900 is used Columns of size 300x900 is used Slab of thickness 125mm Live load on floor – 2.00, 3.00 KN/m2 Live load on roof - 1.50 KN/m2 Zone factor – II,III,IV,V Soil type – Medium Importance factor – 1

#### V. EXPERIMENTAL RESULTS

#### Storey displacement

The maximum values of displacements are tabulated by comparing X and Y directions. The values of displacement of different models are obtained by subjecting the models to static analysis and response spectrum analysisshows max displacement.

| S.  | MODEL                                    | For<br>Zone II | For<br>Zone III | For<br>Zone IV | For<br>Zone V | 160   |
|-----|--|----------------|-----------------|----------------|---------------|---|
| NO. |  | (mm)           | (mm)            | (mm)           | (mm)          |   |
| 1   | MODEL<br>WITH MASS<br>IR @ GF<br>STOREY  | 38.238         | 61.181          | 91.771         | 137.656       | 80  |
| 2   | MODEL<br>WITH MASS<br>IR @ MID<br>STOREY | 37.534         | 60.054          | 90.081         | 135.121       | 40<br>20<br>MAX DISPL FOR ZONE IV<br>MAX DISPL FOR ZONE V<br>MAX DISPL FOR ZONE V                         |
| 3   | MODEL<br>WITH MASS<br>IR @ TOP<br>STOREY | 40.476         | 64.761          | 97.142         | 145.713       | 0<br>MODEL WITH MODEL WITH MODEL WITH<br>MASS IR @ GF MASS IR @ MID MASS IR @ TOP<br>STOREY STOREY STOREY |

Table: Max Displacement values for different storey mass irregularity Graph of maximum displacement models (Static analysis in X direction)



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#### For For For For 90 Zone Zone zone Zone SL 80 MODEL Π Ш IV V NO **WAX DISPLACEMNT IN m 10 1** (mm) (mm) (mm) (mm) 1 MODEL WITH MAX DISPL FOR ZONE II MASS IR @ GF MAX DISPL FOR ZONE III STOREY 21.625 34.6 51.899 77.849 MAX DISPL FOR ZONE IV 2 MODEL WITH MASS IR @ MAX DISPL FOR ZONE V MID STOREY 10 21.143 33.829 50.743 76.115 0 3 MODEL WITH MODEL WITH MODEL WITH MODEL WITH MASS IR @ MASS IR @ GF MASS IR @ MID MASS IR @ TOP TOP STOREY 21.58 36.587 54.881 82.322 STOREY STOREY STOREY

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Table:Max Displacement values for different storey mass Graph of maximum displacement irregularity models (Static analysis in Y direction)

| SL<br>NO | MODEL                                    | For<br>Zone<br>II<br>(mm) | For<br>Zone<br>III<br>(mm) | For<br>Zone<br>IV<br>(mm) | For<br>Zone V<br>(mm) | 140<br>E <sup>120</sup><br>E 100 |                                      |                                       |                                       |  |
|----------|--|---------------------------|----------------------------|---------------------------|-----------------------|----------------------------------|--------------------------------------|---------------------------------------|---------------------------------------|--|
| 1        | MODEL<br>WITH MASS<br>IR @ GF<br>STOREY  | 31.802                    | 50.884                     | 76.326                    | 114.489               | 00 DISPLACEMIN                   |                                      | 1                                     |                                       | MAX DISPL FOR ZONE I<br>MAX DISPL FOR ZONE I<br>MAX DISPL FOR ZONE I |
| 2        | MODEL<br>WITH MASS<br>IR @ MID<br>STOREY | 32.797                    | 52.475                     | 78.713                    | 118.07                | ×40<br>×40<br>20                 |                                      |                                       |                                       | MAX DISPL FOR ZONE \   |
| 3        | MODEL<br>WITH MASS<br>IR @ TOP<br>STOREY | 34.21                     | 54.736                     | 82.104                    | 123.155               |                                  | MODEL WITH<br>MASS IR @ GF<br>STOREY | MODEL WITH<br>MASS IR @ MID<br>STOREY | MODEL WITH<br>MASS IR @ TOP<br>STOREY |  |

Table:Max Displacement values for different storey mass Graph of maximum displacement irregularity models (Response spectrum analysis in X direction)



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#### For For 90 For For Zone Zone SL Zone II Zone III 80 MODEL IV V **E** 70 NO (mm) (mm) **DISPLACEMNT IN** (mm) (mm) 60 50 MAX DISPL FOR ZONE II 1 MODEL WITH 40 MAX DISPL FOR ZONE III MASS IR @ GF 69.58 30 STOREY 19.33 33.092 46.391 MAX DISPL FOR ZONE IV 6 MAXI 20 2 MAX DISPL FOR ZONE V MODEL WITH 10 MASS IR @ 71.42 19.84 MID STOREY 31.744 47.617 5 0 3 MODEL WITH MODEL WITH MODEL WITH MODEL WITH MASS IR @ GF MASS IR @ MID MASS IR @ TOP MASS IR @ 81.47 STOREY STOREY STOREY TOP STOREY 22.633 36.212 54.319 8

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Table 5.4: Max Displacement values for different storey mass Graph of maximum displacement irregularity models (Response spectrum analysis in Y direction)

| SL<br>NO | MODEL  | For<br>Zone<br>II<br>(mm) | For<br>Zone<br>III<br>(mm) | For<br>Zone<br>IV<br>(mm) | For<br>Zone V<br>(mm) | 160<br>140<br>2<br>120                 |   |
|----------|--|---------------------------|----------------------------|---------------------------|-----------------------|--|---|
| 1 2      | MODEL WITH<br>STIFFNESS IR<br>@ GF<br>STOREY<br>MODEL WITH<br>STIFFNESS IR | 38.415                    | 61.465                     | 92.197                    | 138.295               | 00 100 001 000 000 000 000 000 000 000 | MAX DISPL FOR Z MAX DISPL FOR Z MAX DISPL FOR Z   |
| 3        | @ MID<br>STOREY<br>MODEL WITH<br>STIFFNESS IR<br>@ TOP<br>STOREY           | <u>39.965</u><br>38.498   | <u>63.945</u><br>61.597    | 95.917<br>92.396          | 143.876               | - 0                                    | MODEL WITH MODEL WITH<br>STIFFNESS IR @ STIFFNESS IR @<br>GF STOREY MID STOREY TOP STOREY |

Table: Max Displacement values for different storey stiffnessGraph of maximum displacement irregularity models (Static analysis in X direction)

| meg      | ularity models (Sta                           | lie unurysn               | 5 m zi une                 | cuon)                     |                          |   |
|----------|---|---------------------------|----------------------------|---------------------------|--------------------------|---|
| SL<br>NO | MODEL   | For<br>Zone<br>II<br>(mm) | For<br>Zone<br>III<br>(mm) | For<br>Zone<br>IV<br>(mm) | For<br>Zone<br>V<br>(mm) |   |
| 1        | MODEL WITH<br>STIFFNESS IR<br>@ GF<br>STOREY  | 21.77                     | 34.832                     | 52.247                    | 78.371                   | 60  |
| 2        | MODEL WITH<br>STIFFNESS IR<br>@ MID<br>STOREY | 22.583                    | 36.133                     | 54.199                    | 81.299                   | 30 Image: max displ for zone iv   20 Image: max displ for zone iv   10 Image: max displ for zone iv                     |
| 3        | MODEL WITH<br>STIFFNESS IR<br>@ TOP<br>STOREY | 21.279                    | 34.046                     | 51.069                    | 76.603                   | 0<br>MODEL WITH MODEL WITH MODEL WITH<br>STIFFNESS IR @ G STIFFNESS IR @ STIFFNESS IR @<br>STOREY MID STOREY TOP STOREY |

Table 5.6: Max Displacement values for different storey stiffnessGraph of maximum displacement irregularity models (Static analysis in Y direction)



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|    |              | For    | For    | For    | For     | 140  |
|----|--------------|--------|--------|--------|---------|--|
| SL | MODEL        | Zone   | Zone   | Zone   | Zone V  | 10   |
| NO | MODEL        | II     | III    | IV     | (mm)    | £ 120  |
|    |              | (mm)   | (mm)   | (mm)   |         | E E  |
| 1  | MODEL WITH   |        |        |        |         | ₹ 100  |
|    | STIFFNESS IR |        |        |        |         |  |
|    | @ GF         |        |        |        |         | A SU MAX DISPL FOR ZONE I                    |
|    | STOREY       | 34.829 | 55.726 | 83.589 | 125.383 | 60 ■ MAX DISPL FOR ZONE I                    |
| 2  | MODEL WITH   |        |        |        |         | MAX DISPL FOR ZONE I                         |
|    | STIFFNESS IR |        |        |        |         |  |
|    | @ MID        |        |        |        |         | 20   |
|    | STOREY       | 34.29  | 54.864 | 82.296 | 123.443 |  |
| 3  | MODEL WITH   |        |        |        |         |  |
|    | STIFFNESS IR |        |        |        |         | MODEL WITH MODEL WITH MODEL WITH             |
|    | @ TOP        |        |        |        |         | STIFFNESS IR @ STIFFNESS IR @ STIFFNESS IR @ |
|    | STOREY       | 32.702 | 52.324 | 78.486 | 117.729 | GF STOREY MID STOREY TOP STOREY              |

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Table: Max Displacement values for different storey stiffness Graph of maximum displacement irregularity models (Response spectrum analysis in X direction)

|    |           | For Zone | For    | For    | For    | 90  |
|----|-----------|----------|--------|--------|--------|---|
| SL | MODEL     | II       | Zone   | Zone   | Zone   | 50  |
| NO | MODEL     | (mm)     | III    | IV     | V      | 80  |
|    |           | (11111)  | (mm)   | (mm)   | (mm)   | E 70  |
| 1  | MODEL     |          |        |        |        |   |
|    | WITH      |          |        |        |        | 60  |
|    | STIFFNESS |          |        |        |        | 50 ■ MAX DISPL FOR ZONE II                      |
|    | IR @ GF   |          |        |        |        | ≥ 50 MAX DISPL FOR ZONE II                      |
|    | STOREY    | 21.776   | 34.842 | 52.263 | 78.395 | ¥ 40 —— A max displ for zone III                |
| 2  | MODEL     |          |        |        |        | a 30 ■ MAX DISPL FOR ZONE IV                    |
|    | WITH      |          |        |        |        |   |
|    | STIFFNESS |          |        |        |        | ¥ 20 − MAX DISPL FOR ZONE V                     |
|    | IR @ MID  |          |        |        |        |   |
|    | STOREY    | 22.211   | 35.537 | 53.306 | 79.959 |   |
| 3  | MODEL     |          |        |        |        |   |
|    | WITH      |          |        |        |        | MODEL WITH MODEL WITH MODEL WITH                |
|    | STIFFNESS |          |        |        |        | STIFFNESS IR @ GF STIFFNESS IR @ STIFFNESS IR @ |
|    | IR @ TOP  |          |        |        |        | STOREY MID STOREY TOP STOREY                    |
|    | STOREY    | 19.883   | 31.813 | 47.72  | 71.58  |   |

Table: Max Displacement values for different storey stiffness Graph of maximum displacement irregularity models (Response spectrum analysis in Y direction)

#### **Storey Drift**

The lateral movement of a floor with respect to the floor below is known as storey drift. The values of drift of different models are obtained by subjecting the models to static analysis and response spectrum analysis shows max drift.



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| SL | MODEL     | For Zone | For Zone | For Zone | For Zone | 0.005   |
|----|-----------|----------|----------|----------|----------|---|
| NO | MODEL     | II       | III      | IV       | V        | 0.0045  |
| 1  | MODEL     |          |          |          |          | 0.004   |
|    | WITH      |          |          |          |          |   |
|    | MASS IR @ |          |          |          |          |   |
|    | GF STOREY | 0.001261 | 0.002017 | 0.003026 | 0.004539 | ■ MAX DRIFT FOR 70NE II                             |
| 2  | MODEL     |          |          |          |          | <b>Ř</b> 0.0025 ——————————————————————————————————— |
|    | WITH      |          |          |          |          | 5 0.002 — MAX DRIFT FOR ZONE III                    |
|    | MASS IR @ |          |          |          |          |   |
|    | MID       |          |          |          |          | 0.001 - ■ MAX DRIFT FOR ZONE V                      |
|    | STOREY    | 0.001219 | 0.00195  | 0.002924 | 0.004387 | 0.0005  |
| 3  | MODEL     |          |          |          |          |   |
|    | WITH      |          |          |          |          | MODEL WITH MODEL WITH MODEL WITH                    |
|    | MASS IR @ |          |          |          |          | MASS IR @ GF MASS IR @ MID MASS IR @ TOP            |
|    | TOP       |          |          |          |          | STOREY STOREY STOREY                                |
|    | STOREY    | 0.001322 | 0.002115 | 0.003172 | 0.004758 |   |

Table 5.17: Max Drift values for different storey mass irregularityGraph of maximum drift models (Static analysis in X direction)

| SL |           | For Zone | For Zone | For Zone | For Zone | 0.0035          |              |                            |                        |
|----|-----------|----------|----------|----------|----------|-----------------|--------------|----------------------------|------------------------|
| NO | MODEL     | II       | III      | IV       | V        | 0.0053          |              |                            |                        |
| NO |           | (mm)     | (mm)     | (mm)     | (mm)     | 0.003           |              |                            |                        |
| 1  | MODEL     |          |          |          |          |                 |              |                            |                        |
|    | WITH      |          |          |          |          | <b>1</b> 0.0025 |              |                            |                        |
|    | MASS IR @ |          |          |          |          | Δ               |              |                            |                        |
|    | GF STOREY | 0.000772 | 0.001235 | 0.001853 | 0.002779 | <b>2</b> 0.002  |              |                            | MAX DRIFT FOR ZONE II  |
| 2  | MODEL     |          |          |          |          | <b>0</b> 0.0015 |              |                            | MAX DRIFT FOR ZONE III |
|    | WITH      |          |          |          |          | x               |              | - <b>1</b>                 |                        |
|    | MASS IR @ |          |          |          |          | ₹ 0.001         |              |                            | MAX DRIFT FOR ZONE IV  |
|    | MID       |          |          |          |          |                 |              |                            | MAX DRIFT FOR ZONE V   |
|    | STOREY    | 0.00076  | 0.001215 | 0.001823 | 0.002734 | 0.0005          |              |                            |                        |
| 3  | MODEL     |          |          |          |          | 0               |              |                            |                        |
|    | WITH      |          |          |          |          |                 | MODEL WITH M | IODEL WITH MODEL WITH      |                        |
|    | MASS IR @ |          |          |          |          |                 |              | ASS IR @ MID MASS IR @ TOP |                        |
|    | TOP       |          |          |          |          |                 | STOREY       | STOREY STOREY              |                        |
|    | STOREY    | 0.000795 | 0.001271 | 0.001907 | 0.00286  |                 |              |                            |                        |

Table: Max Drift values for different storey mass irregularity models Graph of maximum drift (Static analysis in Y direction)

|    |              |          |          |         |         |   | 0.0045   |              |            |            |                        |
|----|--------------|----------|----------|---------|---------|---|----------|--------------|------------|------------|------------------------|
| SL |              | For Zone | For Zone | For     | For     |   | 0.004    |              |            |            |                        |
|    | MODEL        | II       | III      | Zone IV | Zone V  |   | 0.0035   |              |            |            |                        |
| NO |              | (mm)     | (mm)     | (mm)    | (mm)    | ļ | 0.0033   |              |            |            |                        |
| 1  | MODEL WITH   |          |          |         |         | 0 | a 0.0025 |              | - <b>-</b> |            |                        |
|    | MASS IR @ GF |          |          | 0.00263 | 0.00395 | Í | ж        |              |            |            | MAX DRIFT FOR ZONE II  |
|    | STOREY       | 0.001098 | 0.001757 | 6       | 4       |   | 0.002    |              |            |            | MAXDRIFT FOR ZONE III  |
| 2  | MODEL WITH   | 0.001020 | 01001707 |         |         |   | 0.0015   |              |            |            | ■ MAX DRIFTFOR ZONE IV |
| 2  | MASS IR @    |          |          | 0.00267 | 0.00401 |   | 0.001    |              |            |            | MAX DRIFT FOR ZONE V   |
|    |              | 0.001114 | 0.0000   | 0.00207 | 0.00401 |   | 0.0005   |              |            |            |                        |
|    | MID STOREY   | 0.001114 | 0.00096  | 5       | 2       |   | 0        |              |            |            |                        |
| 3  | MODEL WITH   |          |          |         |         |   | Ū        | MODEL WITH   | MODEL WITH | MODEL WITH |                        |
|    | MASS IR @    |          |          | 0.00279 | 0.00419 |   |          | MASS IR @ GF | -          | -          |                        |
|    | TOP STOREY   | 0.001165 | 0.001864 | 6       | 4       |   |          | STOREY       | STOREY     | STOREY     |                        |

Table: Max Drift values for different storey mass irregularity modelsGraph of maximum drift

(Response spectrum analysis in X direction)



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#### SL For Zone For Zone For Zone For Zone 0.003 MODEL NO Π III IV V 1 MODEL 0.0025 WITH 0.002 **WAX STOREY DRIFT** 0.001 0.001 MASS IR @ 0.000654 0.002354 GF STOREY 0.001122 0.00157 MAX DRIFT FOR ZONE II 2 MODEL MAX DRIFT FOR ZONE III WITH MASS IR @ MAX DRIFT FOR ZONE IV MID MAX DRIFT FOR ZONE V STOREY 0.000656 0.00104 0.001574 0.002361 0.0005 3 MODEL 0 WITH MODEL WITH MODEL WITH MODEL WITH MASS IR @ MASS IR @ GF MASS IR @ MID MASS IR @ TOP TOP STOREY STOREY STOREY 0.000784 0.001255 0.001882 0.002823 STOREY

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Table: Max Drift values for different storey mass irregularity modelsGraph of maximum drift (Response spectrum analysis in Y direction)

| SL<br>NO | MODEL     | For Zone<br>II | For Zone<br>III | For Zone<br>IV | For Zone<br>V | 0.006          |                |                |                |                        |
|----------|-----------|----------------|-----------------|----------------|---------------|----------------|----------------|----------------|----------------|------------------------|
| NO       |           | (mm)           | (mm)            | (mm)           | (mm)          | 0.005          |                |                |                |                        |
| 1        | MODEL     |                |                 |                |               | 0.005          |                |                |                |                        |
|          | WITH      |                |                 |                |               |                |                |                |                |                        |
|          | STIFFNESS |                |                 |                |               | 0.004          |                |                |                |                        |
|          | IR @ GF   |                |                 |                |               | Σ              |                |                |                | MAX DRIFT FOR ZONE II  |
|          | STOREY    | 0.001182       | 0.001891        | 0.002837       | 0.004255      | <b>8</b> 0.003 |                |                |                |                        |
| 2        | MODEL     |                |                 |                |               | TS )           |                |                |                | MAX DRIFT FOR ZONE III |
|          | WITH      |                |                 |                |               | ₹ 0.002        |                |                |                | MAX DRIFT FOR ZONE IV  |
|          | STIFFNESS |                |                 |                |               | Σ              |                |                |                | MAX DRIFT FOR ZONE V   |
|          | IR @ MID  |                |                 |                |               | 0.001          |                |                | -              |                        |
|          | STOREY    | 0.001386       | 0.002217        | 0.002982       | 0.004988      |                |                |                |                |                        |
| 3        | MODEL     |                |                 |                |               | 0              |                |                |                |                        |
|          | WITH      |                |                 |                |               |                | MODEL WITH     | MODEL WITH     | MODEL WITH     |                        |
|          | STIFFNESS |                |                 |                |               |                | STIFFNESS IR @ | STIFFNESS IR @ | STIFFNESS IR @ |                        |
|          | IR @ TOP  |                |                 |                |               |                | GF STOREY      | MID STOREY     | TOP STOREY     |                        |
|          | STOREY    | 0.00121        | 0.001937        | 0.002905       | 0.004357      |                |                |                |                |                        |

Table: Max Drift values for different storey stiffness irregularityGraph of maximum drift models ((Static analysis in X direction)



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| SL |           | For Zone | For Zone | For Zone | For Zone | 0.0035                                       |
|----|-----------|----------|----------|----------|----------|--|
| NO | MODEL     | II       | III      | IV       | V        | 0.0035                                       |
| NO |           | (mm)     | (mm)     | (mm)     | (mm)     | 0.003  |
| 1  | MODEL     |          |          |          |          |  |
|    | WITH      |          |          |          |          | 0.0025                                       |
|    | STIFFNESS |          |          |          |          |  |
|    | IR @ GF   |          |          |          |          | ■ MAX DISPL FOR ZONE II                      |
|    | STOREY    | 0.000736 | 0.001178 | 0.001767 | 0.002651 |  |
| 2  | MODEL     |          |          |          |          |  |
|    | WITH      |          |          |          |          | MAX DISPL FOR ZONE IV                        |
|    | STIFFNESS |          |          |          |          |  |
|    | IR @ MID  |          |          |          |          | 0.0005 MAX DISPL FOR ZONE V                  |
|    | STOREY    | 0.00085  | 0.001361 | 0.002041 | 0.003062 |  |
| 3  | MODEL     |          |          |          |          |  |
|    | WITH      |          |          |          |          | MODEL WITH MODEL WITH MODEL WITH             |
|    | STIFFNESS |          |          |          |          | STIFFNESS IR @ STIFFNESS IR @ STIFFNESS IR @ |
| 1  | IR @ TOP  |          |          |          |          | GF STOREY MID STOREY TOP STOREY              |
|    | STOREY    | 0.000733 | 0.001172 | 0.001758 | 0.002637 |  |

Table : Max Drift values for different storey stiffness irregularityGraph of maximum drift models ((Static analysis in Y direction)

| CI       |           | For Zone | For Zone | For Zone | For Zone |
|----------|-----------|----------|----------|----------|----------|
| SL<br>NO | MODEL     | II       | III      | IV       | V        |
| NO       |           | (mm)     | (mm)     | (mm)     | (mm)     |
| 1        | MODEL     |          |          |          |          |
|          | WITH      |          |          |          |          |
|          | STIFFNESS |          |          |          |          |
|          | IR @ GF   |          |          |          |          |
|          | STOREY    | 0.001114 | 0.001782 | 0.002673 | 0.00401  |
| 2        | MODEL     |          |          |          |          |
|          | WITH      |          |          |          |          |
|          | STIFFNESS |          |          |          |          |
|          | IR @ MID  |          |          |          |          |
|          | STOREY    | 0.001235 | 0.001977 | 0.002965 | 0.004447 |
| 3        | MODEL     |          |          |          |          |
|          | WITH      |          |          |          |          |
|          | STIFFNESS |          |          |          |          |
|          | IR @ TOP  |          |          |          |          |
|          | STOREY    | 0.001073 | 0.001717 | 0.002576 | 0.003864 |

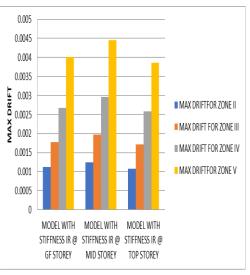
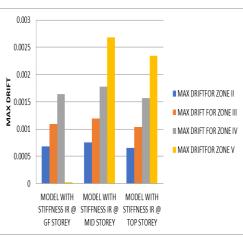


Table: Max drift values for different storey stiffness irregularity models Graph of maximum drift (Response spectrum analysis in X direction)

| (response speer and analysis in real and et on) |           |          |          |          |          |  |  |
|---|-----------|----------|----------|----------|----------|--|--|
| SL  | MODEL     | For Zone | For Zone | For Zone | For Zone |  |  |
| NO  | MODEL     | II       | III      | IV       | V        |  |  |
| 1   | MODEL     |          |          |          |          |  |  |
|   | WITH      |          |          |          |          |  |  |
|   | STIFFNES  |          |          |          |          |  |  |
|   | S IR @ GF |          |          |          |          |  |  |
|   | STOREY    | 0.000684 | 0.001095 | 0.001642 | 0.000024 |  |  |
| 2   | MODEL     |          |          |          |          |  |  |
|   | WITH      |          |          |          |          |  |  |
|   | STIFFNES  |          |          |          |          |  |  |
|   | S IR @    |          |          |          |          |  |  |
|   | MID       |          |          |          |          |  |  |
|   | STOREY    | 0.000754 | 0.001192 | 0.00178  | 0.002682 |  |  |
| 3   | MODEL     | 0.000651 | 0.001042 | 0.001563 | 0.002345 |  |  |
|   |           |          |          |          |          |  |  |





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| WITH     |  |  |
|----------|--|--|
| STIFFNES |  |  |
| S IR @   |  |  |
| TOP      |  |  |
| STOREY   |  |  |

Table: Max Drift values for different storey stiffness irregularity models Graph of maximum drift (Response spectrum analysis in Y direction)

#### TIME PERIOD

| SL<br>NO | MODEL                                       | For<br>Zone<br>II<br>(SEC) | For<br>Zone III<br>(SEC) | For<br>Zone<br>IV<br>(SEC) | For<br>Zone<br>V<br>(SEC) |   |
|----------|---|----------------------------|--------------------------|----------------------------|---------------------------|---|
| 1        | MODEL<br>WITH<br>MASS IR<br>@ GF<br>STOREY  | 1.605                      | 1.605                    | 1.605                      | 1.605                     | MAX TIME PERIOD FOR ZONE  |
| 2        | MODEL<br>WITH<br>MASS IR<br>@ MID<br>STOREY | 1.66                       | 1.66                     | 1.66                       | 1.66                      | H 1.6 H 1.55 H 1.5 |
| 3        | MODEL<br>WITH<br>MASS IR<br>@ TOP<br>STOREY | 1.794                      | 1.794                    | 1.794                      | 1.794                     | 1.5<br>MODEL WITH MODEL WITH MODEL WITH<br>MASS IR @ GF MASS IR @ MID MASS IR @ TOP<br>STOREY STOREY STOREY   |

Table: Max time period values for different storey massGraph of Time Period irregularity models (Static analysis and response spectrum

in X and Y direction)

#### **Base Shear**

Base shear is a measure of the maximum expected lateral force that will happen due to the seismic ground motion at the base of the structure. Since base shear value directly proportional to weight of the building, the regular model is having fewer loads compared to other models.

|    | I       | Б       | Г        | F 7      | гд       | ]  |
|----|---------|---------|----------|----------|----------|--|
|    |         | For     | For      | For Zone | For Zone | 7000                                     |
| SL | MODEL   | Zone II | Zone III | IV       | V        | 1000                                     |
| NO | MODEL   | (kN)    | (kN)     | (kN)     | (kN)     | <b>ü</b> 6000                            |
|    |         |         |          |          |          |  |
| 1  | MODEL   |         |          |          |          | S000 MAX TIME PERIOD FOR ZONE            |
|    | WITH    |         |          |          |          | SUUU MAX TIME PERIOD FOR ZONE            |
|    | MASS IR |         |          |          |          |  |
| 1  | @ GF    | 1631.07 | 2609.71  | 3914.57  | 5871.86  | MAX TIME PERIOD FOR ZONE                 |
|    | STOREY  |         |          |          |          | <u> </u>                                 |
| 2  | MODEL   |         |          |          |          |  |
|    | WITH    |         |          |          |          |  |
|    | MASS IR |         |          |          |          | ZONE IV                                  |
|    | @ MID   | 1631.07 | 2448.59  | 3672.89  | 5509.33  |  |
|    | STOREY  |         |          |          |          |  |
| 3  | MODEL   |         |          |          |          |  |
|    | WITH    |         |          |          |          | MODEL WITH MODEL WITH MODEL WITH         |
|    | MASS IR |         |          |          |          | MASS IR @ GF MASS IR @ MID MASS IR @ TOP |
| 1  | @ TOP   | 1607.11 | 2571.38  | 3857.07  | 5785.61  | STOREY STOREY STOREY                     |
|    | STOREY  |         |          |          |          |  |



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| SL<br>NO | MODEL  | For<br>Zone II<br>(SEC) | For<br>Zone III<br>(SEC) | For Zone<br>IV<br>(SEC) | For Zone<br>V<br>(SEC) | 6000   |
|----------|--|-------------------------|--------------------------|-------------------------|------------------------|--|
| 1        | MODEL<br>WITH<br>STIFFNES<br>S IR @ GF<br>STOREY     | 1415.02                 | 2264.03                  | 3396.05                 | 5094.07                | 4000   |
| 2        | MODEL<br>WITH<br>STIFFNES<br>S IR @<br>MID<br>STOREY | 1415.02                 | 2124.25                  | 3186.38                 | 4779.56                | 3000 MARTIME PERIOD FOR ZONE<br>III<br>2000 MARTIME PERIOD FOR ZONE<br>III<br>2000 MARTIME PERIOD FOR ZONE<br>III<br>2000 MARTIME PERIOD FOR ZONE<br>MARTIME PERIOD FOR ZONE |
| 3        | MODEL<br>WITH<br>STIFFNES<br>S IR @<br>TOP<br>STOREY | 1394.24                 | 2230.78                  | 3346.16                 | 5019.25                | 0<br>MODEL WITH MODEL WITH MODEL WITH<br>MASS IR @ FF MASS IR @ MID MASS IR @ TOP<br>STOREY STOREY STOREY  |

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Table: Maximum base shear values for different storey stiffnessGraph of Base Shear irregularity models (Static analysis in Y direction)

#### VI. CONCLUSION

#### 1. Displacement

#### a) Static analysis

#### Mass irregularity

From the results of top storey displacement, it is noted that the maximum reduction in lateral displacement for static analysis is seen in Model with mass irregularity at middle floor, the reduction is about 6.53% and 1.78% compared to model with mass irregularity at top and ground storey for zone IV.

For zone V the maximum reduction in lateral displacement for static analysis is seen in Model with mass irregularity at middle floor, the reduction is about 6.77% and 2.68% compared to model with mass irregularity at top and ground storey.

#### **Stiffness irregularity**

From the results of top storey displacement, it is noted that the maximum reduction in lateral displacement for static analysis is seen in Model with stiffness irregularity at top floor, the reduction is about 4.34% and 0.44% compared to model with mass irregularity at middle and ground storey for zone IV.

For zone V, the maximum reduction in lateral displacement for static analysis is seen in Model with stiffness irregularity at top floor, the reduction is about 6.49% and 2.68% compared to model with mass irregularity at middle and ground storey.

#### b) Response spectrum analysis

#### Mass irregularity

From the results of top storey displacement, it is noted that the maximum reduction in lateral displacement for response spectrum analysis is seen in Model with mass irregularity at ground floor, the reduction is about 14.82% and 11.44% compared to model with mass irregularity at top and middle storey for zone IV.

For zone V, the maximum reduction in lateral displacement for static analysis is seen in Model with mass irregularity at middle floor, the reduction is about 5.98% and 3.81% compared to model with mass irregularity at top and ground storey.

#### **Stiffness irregularity**

From the results of top storey displacement, it is noted that the maximum reduction in lateral displacement for static analysis is seen in Model with stiffness irregularity at top floor, the reduction is about 4.29% and 6.45% compared to model with mass irregularity at middle and ground storey for zone IV.

For zone V, the maximum reduction in lateral displacement for static analysis is seen in Model with stiffness irregularity at top floor, the reduction is about 4.25% and 6.42% compared to model with mass irregularity at middle and ground storey.



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#### 2. Storey Drift a) Static Analysis Mass irregularity

From the results of top storey drift it is noted that the maximum reduction in lateral drift for static analysis is seen in Model with mass irregularity at middle floor, the reduction is about 16.59% and 13.53% compared to model with mass irregularity at top and ground storey for zone IV.

For zone V, the maximum reduction in storey drift for static analysis is seen in Model with mass irregularity at middle floor, the reduction is about 16.32% and 3.36% compared to model with mass irregularity at top and ground storey.

#### **Stiffness irregularity**

From the results of top storey drift it is noted that the maximum reduction in lateral drift for static analysis is seen in Model with stiffness irregularity at middle floor, the reduction is about 16.32% and 3.36% compared to model with mass irregularity at top and ground storey for zone IV.

For zone V, the maximum reduction in storey drift for static analysis is seen in Model with stiffness irregularity at ground floor, the reduction is about 12.26% and 4.123% compared to model with mass irregularity at top and middle storey.

#### b) Response Spectrum Analysis

#### Mass irregularity

From the results of top storey drift it is noted that the maximum reduction in lateral drift for response spectrum analysis is seen in Model with mass irregularity at middle floor, the reduction is about 23.93% and 2.72% compared to model with mass irregularity at top and ground storey for zone IV.

For zone V, the maximum reduction in storey drift for response spectrum analysis is seen in Model with mass irregularity at middle floor, the reduction is about 24.11% and 3.16% compared to model with mass irregularity at top and ground storey.

#### Stiffness irregularity

From the results of top storey displacement, it is noted that the maximum reduction in lateral displacement for static analysis is seen in Model with stiffness irregularity at ground floor, the reduction is about 21.69% and 3.18% compared to model with mass irregularity at top and middle storey for zone IV.

For zone V, the maximum reduction in lateral displacement for static analysis is seen in Model with stiffness irregularity at ground floor, the reduction is about 21.69% and 3.18% compared to model with mass irregularity at middle and ground storey.

#### 3. Time period

From the results of top time period it is noted that the maximum reduction in time period of building is seen in Model with mass irregularity at top floor, the reduction is about 4.85% and 4.58% compared to model with mass irregularity at top and middle storey for zone IV and V.

### 4. Base shear

#### Mass irregularity

From the results of top storey displacement, it is noted that the maximum reduction in base shear for static analysis is seen in Model with mass irregularity at middle floor, the reduction is about 6.17% and 4.77% compared to model with mass irregularity at top and ground storey for zone IV. For zone V, the maximum reduction in lateral displacement for static analysis is seen in Model with mass irregularity at middle floor, the reduction is about 4.77% and 6.17% and 6.17% compared to model with mass irregularity at top and ground storey.

#### Stiffness irregularity

From the results of top storey displacement, it is noted that the maximum reduction in lateral displacement for static analysis is seen in Model with stiffness irregularity at top floor, the reduction is about 4.77% and 6.17% compared to model with mass irregularity at middle and ground storey for zone IV.

For zone V, the maximum reduction in lateral displacement for static analysis is seen in Model with stiffness irregularity at middle floor, the reduction is about 4.77% and 6.17% compared to model with mass irregularity at top and ground storey.

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