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# Dynamic Analysis & Assessment of Irregularity In Irregular High-Rise Structures

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**ABSTRACT:** In the field of structural engineering ductile structural members have a large capacity to undergo huge amount of inelastic deformation without losing its actual strength. The structural material which is generally used as an engineering material should have an ability to deform up to a stage of plasticity without undergoing necking (fracture) so, because of this important property steel is used which helps the designers to design various elements, whenever unexpected overloading takes place in case of gravity and lateral loads which were suddenly imposed on the structure. This research work helps to examine the structural performance and behaviour of various irregular plans of steel buildings with amount of percentage of Irregularity occurring due to Re-entrant corners of Horizontal Irregularities by considering the occupancy category of the structure. These 4 different Irregular models were analysed using ETABS 2016 by using Response Spectrum method as per the Guidelines of IS 1893-2016 and Eccentrically Braced frames were placed in the direction of maximum percentage of Irregularity obtained in order to minimize the lateral displacements and various dynamic response characteristic of High-rise Building.

**KEYWORDS:** Analytical Modelling, Seismic analysis, Irregularity Checks, Drift unity check, Base Shear and Time Period

## I. INTRODUCTION OF IRREGULAR BUILDING

If we see the Residential Buildings the construction of commercial buildings gained importance also their method of construction also gained importance. Because of aesthetics and a lack of available land, the tendency of constructing irregularly shaped buildings has rapidly increased. Studies from the past have revealed that under strong ground motion, structures with irregular configurations suffer damage. Structures' structural imperfections play a significant role in lowering their seismic performance. Buildings with structural defects may collapse after an earthquake because to uneven distribution of the story drift, severe torsion, etc. Depending upon the occupancy use of the structure loading [1], criteria is selected based on IS code Provisions. Damage from earthquake ground motion typically starts in areas where there are structural flaws in the lateral load resisting frames in multi-storeyed framed buildings. In These problems may occasionally be brought about by differences in stiffness, strength, or mass between neighbouring storeys. Such storey transitions are frequently accompanied by abrupt changes in the frame geometry throughout the height. There are several instances [2] of buildings failing in previous earthquakes as a result of such vertical discontinuities.

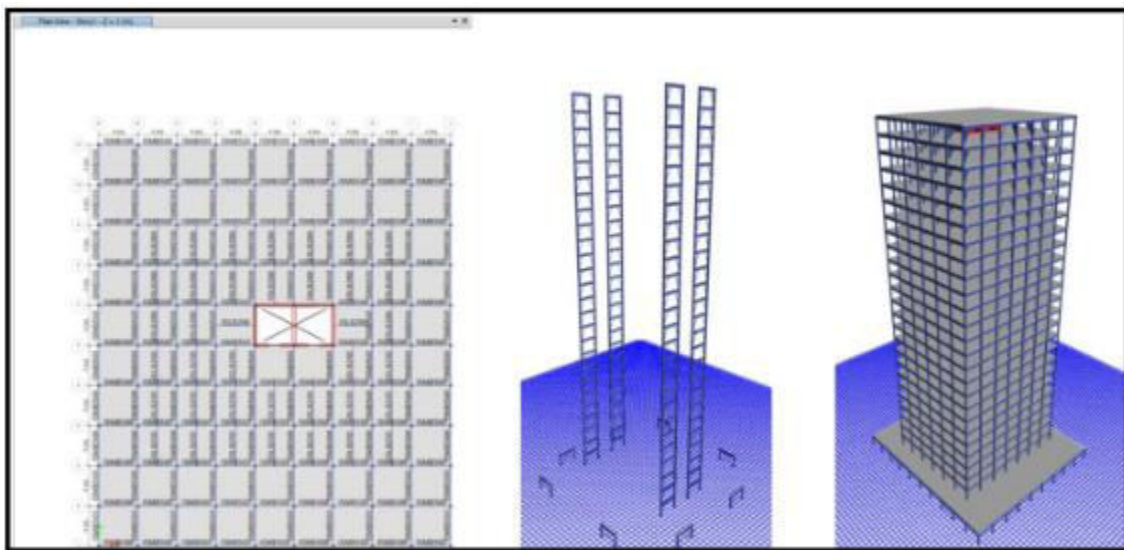
When the models created using finite elements were subjected to a 135-degree angle of seismic incidence as opposed to a zero-degree angle of seismic incidence, a significant increase in the demand for seismic response was seen. The study also demonstrates that, as compared to a finite element technique, the fundamental time period of a structure based on standard code exhibits a lower value [3]. Identification of the built environment's seismic performance was crucial for reducing the risk caused by earthquakes. It was accomplished by creating various analytical techniques that guarantee the structure will hold up during significant earthquakes and generate enough caution whenever one occurs. A structure's behaviour during an earthquake is influenced by a number of characteristics, including stiffness, appropriate lateral strength, ductility, and simple and regular configurations [4].



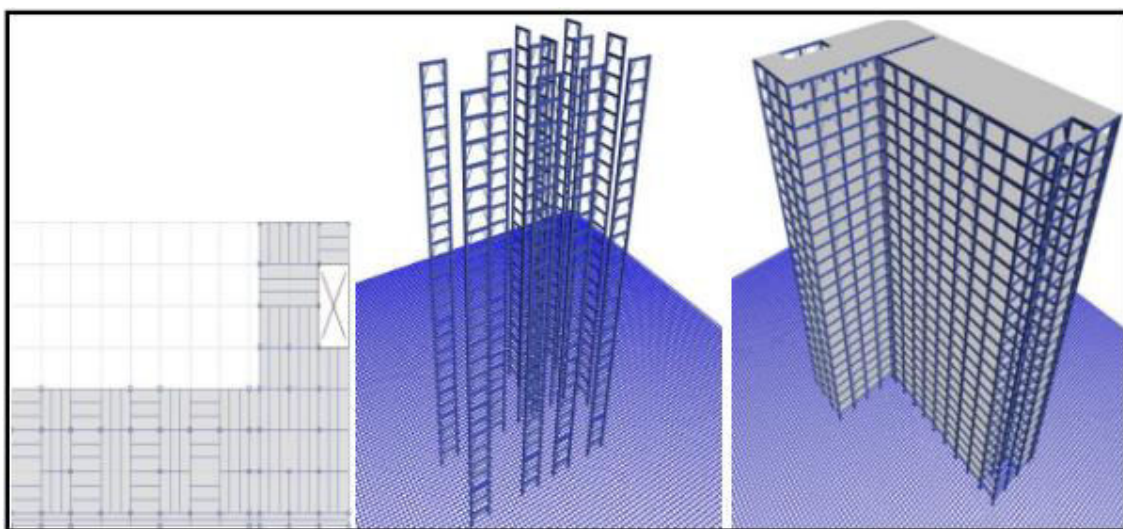
## II. ANALYTICAL MODELS AND SPECIFICATION

Modelling of Structure's with 5 Different Irregular Plans Comprising of Fig. 1. (a) Square, (b) L-Shape, (c) Cruciform shape, (d) IRM and (e) U-Shaped is done using ETABS 2019. Structural members for our models assumed are Grade of Concrete as M40 and Steel Fe-345, Slab Type-Composite Metal Deck, Main Beams ISMB 500, Secondary Beams- ISJB 200. The Parameter for Elastic Modulus is taken as 2.319GPA[5].

Based upon the percentage of Irregularity [6] Calculated as per code Provision IS 1893-2016. Lateral Force Resisting System Eccentric Braced Frames were Installed to check and compare the behaviour of Analytical Models. The Dynamic Analysis Response Spectrum Analysis is performed with the help of Equivalent Lateral Force Method in Determining the Story Forces and Base Shears. And comparison is done between EBF & Shear Walls Best Performing Structural System is adopted.



(a)

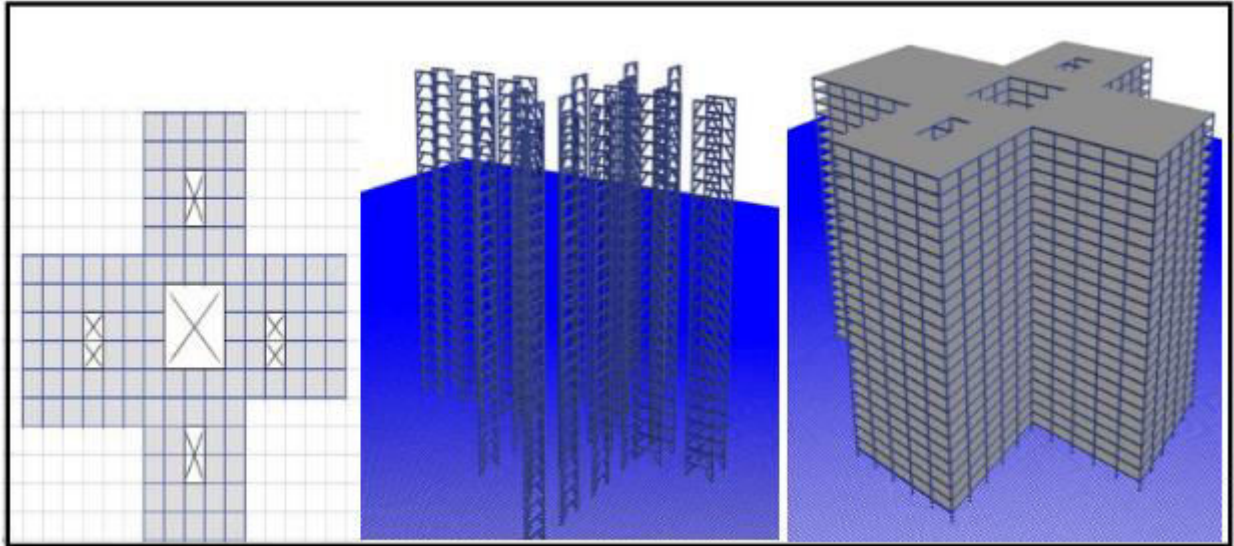


(b)

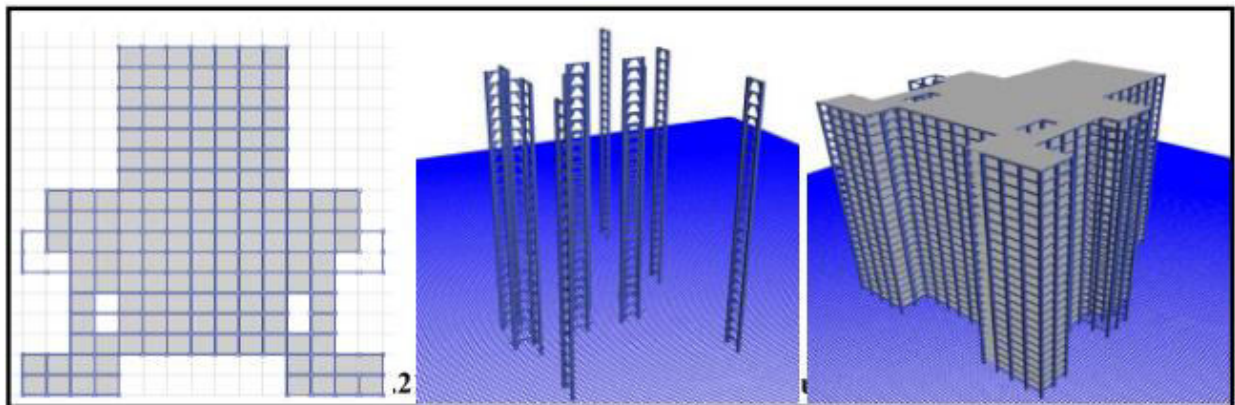


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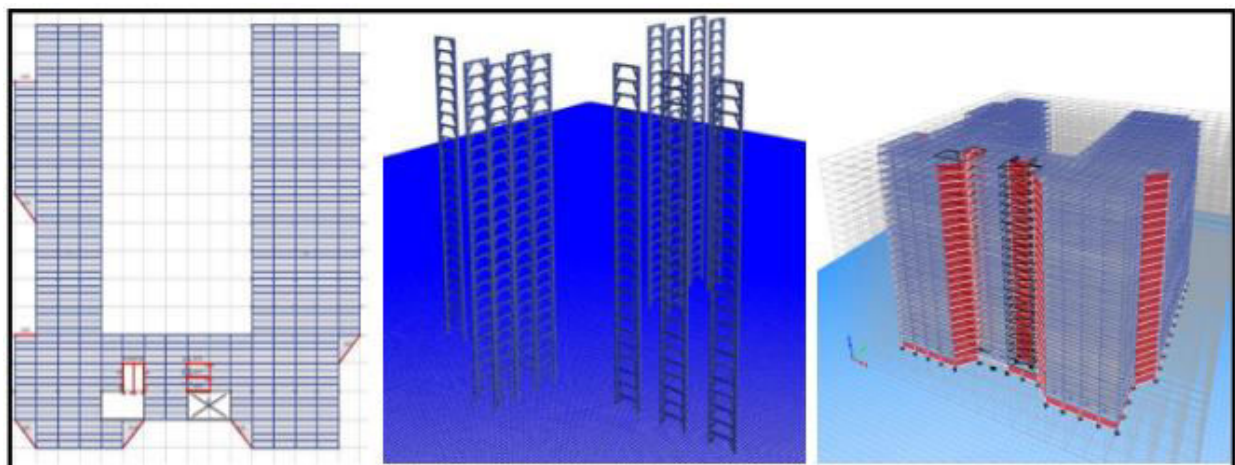
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(c)



(d)



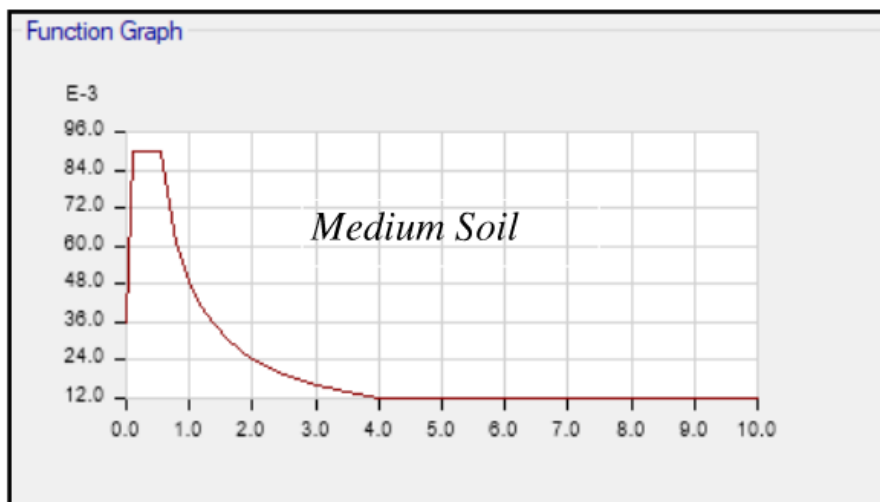
(e)

### III. SEISMIC ANALYSIS RESPONSE SPECTRUM

This Analysis Approach makes it possible to take into account a buildings multiple reaction modes ( in frequency domain ).This is required by many building codes, with the exception of very simple or exceptionally complex structures. Computer Analysis Finite Element Software can be used to discover these modes for a structure based depending on Modal Frequency and Modal Mass response is recorded from the structure's overall reaction compared to design spectrum. Here are a few combinations Techniques [6] Involved are:

- 1.Total Absolute peak values are compared
- 2.Square Root of Summation of Squares( SRSS)
- 3.For a Closely spaced modes, the complete quadratic combination ( CQC ) approach is an advancement to SRSS.

Static approaches are suitable when higher mode effect is unimportant. This is typically true for Regular buildings. Therefore, when structures with these types of Irregularities with Torsional Moments or Non-Orthogonal Structures may be solved with the Linear dynamic approach with linear element stiffness matrix for all the multi-degree of freedom System (MDOF) based on Fig. 2. Response Spectrum Curve .



(a)

### IV. RESULTS AND DISCUSSIONS

#### Irregularity Check :

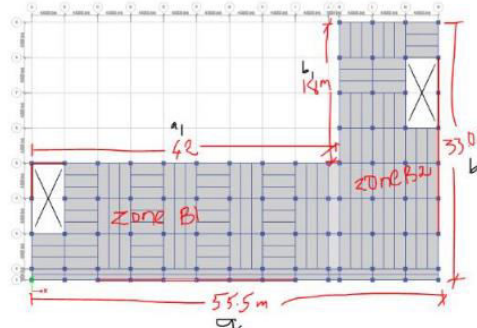
When a Building's Structural Model is Considered to have a Re-Entrant Irregularity in that direction if the projection of its size exceeds 15% of the overall plan dimension in that direction. According to IS 1893:2016 it can be determined using Table 5 of Horizontal Irregularity in Clause 7.1[6] Fig. 3. Shows the Percentage of Irregularity present in Every Ren-entrant Cornersfor all the analysed Building Models as an example programmed manual calculation for L-shaped Building is shown.

After performing Irregularity Checks it can be observed that Side B1 has Re-Entrant Corner of 75.7% and at Side B2 has 54.5% which is greater than the acceptable limit of 0.15% from codal provision of IS 1893:2016.



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Re-Entrant Irregularity Check:

**Zone B1:**

$$a_1 := 42 \text{ m}$$

$$a := 55.5 \text{ m}$$

$$B_1 := \frac{a_1}{a} = 0.757$$

$$\text{Permissible}_{\text{ReentrantIrregularity}} := 0.15 \text{ percent}$$

(a)

```
check := || if B1 < PermissibleReentrantIrregularity || = "not-ok re-entrant irregularity exist"
          || "Re-Entrant Irregularity <15%,ok" ||
          || else ||
          || "not-ok re-entrant irregularity exist" ||
```

**Zone B2:**

$$b_1 := 18 \text{ m}$$

$$b := 33.02 \text{ m}$$

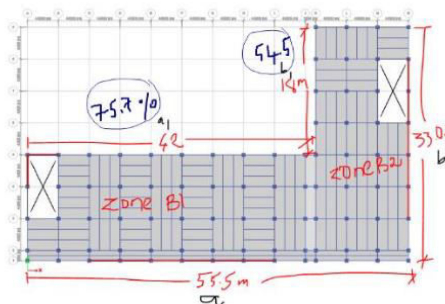
$$B_2 := \frac{b_1}{b} = 0.545$$

$$\text{Permissible}_{\text{ReentrantIrregularity}_2} := 0.15 \text{ percent}$$

```
check2 := || if B2 < PermissibleReentrantIrregularity2 || = "not-ok re-entrant irregularity exist"
           || "Re-Entrant Irregularity <15%,ok" ||
           || else ||
           || "not-ok re-entrant irregularity exist" ||
```

Note : At Side B1 it has an irregularity of Re-entrant corner of 75.7 % and at Side B2 it has 54.5% which is greater than the acceptable limit of 0.15% as per IS 1893(Part 1):2016 Clause 7.1.

Building plan is irregular because the Plan's structural configuration features a projection that exceeds 15% of the total plan direction.

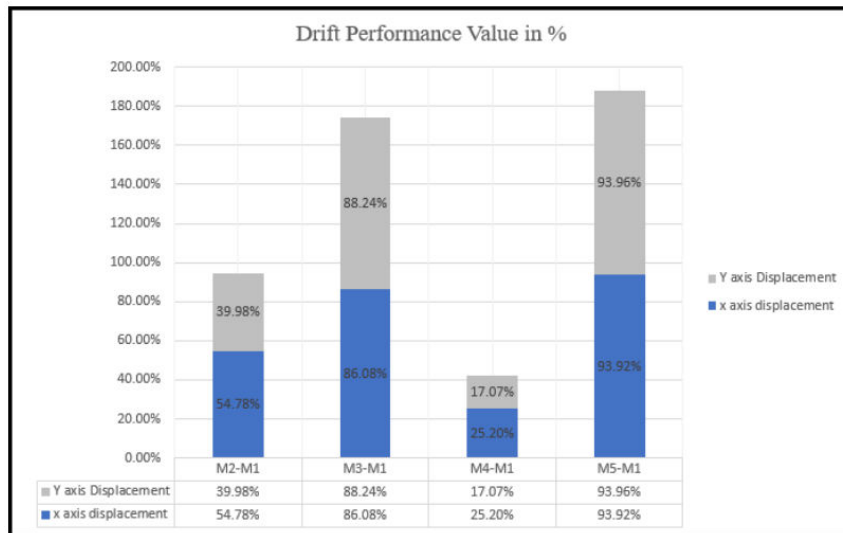


(b)



**Drift Unity Check:**

In Fig. 4. The regular model has shown a max drift value 0.02 mm in X-Axis and 0.016mm in Y-Axis due to the Regular shape of Structure without any eccentricities & Irregularities in Plan. Whereas IRM(M2) L-Shaped plan with installation of lateral force resisting system in this Re-entrant corner irregularity obtained max drift value of 0.00941mm in X-Axis & 0.0103mm in Y axis respectively with help of eccentric braced frame along with shear wall resisting system(M4) & IRM(M5) has shown a maximum drift value of 0.01557mm,0.00102mm in X & Y Axis respectively. The performance of the irregular model number has shown a better result even though it has a Horizontal & Vertical Irregularity, as can be seen from the stacked graph above. The drift value for Model 5, or IRM(M5), has significantly decreased to a greater extent of 93.92% in X-Direction and 93.96% in Y direction, respectively. While IRM(M4) WITH A 25.20% In X-Axis and 17.07% In Y-Direction shows the least reduction in Drift value, this is because there is a greater extent of re-entrant corner irregularity. However, it can be shown that this IRM (M5) has demonstrated a better outcome when compared to other Analysed Models while using a Lateral System at a Desired Location under the highest earthquake/Wind Force regulating Condition



(a)

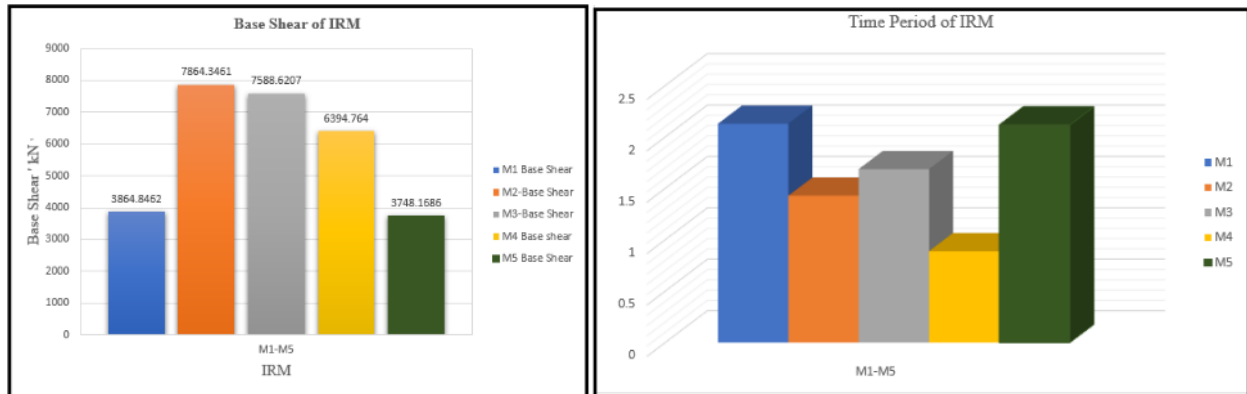
**Base Shear and Time Period:**

When an earthquake causes ground motion at a structure's base, base shear an approximated calculation of the greatest anticipated lateral force occurs., is a significant factor in predicting the behavior of the building in analysis. As can be seen from the bar graph and table, it is defined as the total of the lateral loads operating on the structure from peak to foot. As the estimated model's time period matches the FEM software's output.

Table 1 Base Shear and Time Period

STORY	RM1	IRM2-L	IRM3-Plus	IRM4	IRM5
BASE SHEAR	3864.84	7864.34	7588.62	6394.76	3748.16
TIME PERIOD	2.13	1.43	1.68	1.09	2.12

From Table 1and Fig. 5.It is observed that the least base shear is obtained in a Regular Plan model(RM) of 3864.84 kN whereas The greatest base shear is seen in a IRM(L-Shaped model) of 7864.34 kN.The reason for this increase in base shear values is due to presence of Horizontal Irregularity in IRM2-L shaped model i.e. Re-entrant corner at a percentage value 54.5% on side (A )and 75.7 % on adjacent side (B) of plan configuration.



(a)

(b)

From Table 1 and Fig. 5. It is observed that the least base shear is obtained in a Regular Plan model (RM) of 3864.84 kN whereas the greatest base shear is seen in a IRM (L-Shaped model) of 7864.34 kN. The reason for this increase in base shear values is due to presence of Horizontal Irregularity in IRM2-L shaped model i.e., Re-entrant corner at a percentage value 54.5% on side (A) and 75.7% on adjacent side (B) of plan configuration

## V. CONCLUSION

It was found that with the aid of the model response spectrum, a three-dimensional analysis is performed for all the structures under study that exhibit any type of horizontal or vertical irregularity. Rotation about the vertical axis and translation in two orthogonal directions count as the minimum three degrees of freedom.

1. Dynamic Seismic Response Spectrum Analysis performed for model -2 which is a L-shaped plan has projections at both minor axis and major axis. It has Type -2 re-entrant Irregularity with 75.7% along X-axis & 54.5% projection along Y-axis of plan configuration.
2. Maximum Drift of all Irregular models IRM2, IRM3, IRM4, IRM5 has reduced by a value 54.78%, 86.08%, 25.20%, 93.92% respectively along X direction when compared with Regular Base Model.
3. Diaphragm Centre of Mass Displacement of all Irregular models IRM2, IRM3, IRM4, IRM5 has reduced by a value 79.10%, 99.73%, 65.57%, 96.38% respectively along X direction when compared with Regular Base Model.

Further Research can be carried out by using Non-Parallel Lateral Force Resisting System in Irregularly shaped buildings based upon their Complexity of modelling, Analysis & Design. Typical Connections Can be assessed with the help of CBFEM to study stresses and strain capacity behavior. Further research can be carried by using the same Lateral force resisting system with soil structure interaction properties in designing footings and retaining walls.

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