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Analysis the Effect of Structural Irregularities in Multistorey Earthquake Resistant Building

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ABSTRACT

Irregular structures, especially those in seismic areas, are a concern. Structures often have a network of discontinuities, and identification of individual discontinuities may not accurately predict the seismic response.

The movement of the ground during an earthquake does not damage the building by impact or any other force, but affects the building by creating inertial forces resulting from the vibration of the large building. The size of the seismic lateral force mainly depends on the inertial mass of the building, ground acceleration and dynamic properties. To characterize the soil and its behavior, the model provides response spectra.

Facade and planning irregularities are one of the most common types of irregularities in modern architecture. Functionality and beauty are the main reasons why this model is appreciated. These houses are very useful in big cities because the houses are close to each other. Buildings in these areas also have adequate sunlight and ventilation to enter the ground; Use of Indian Standard Code IS: 1893-2002 for Irregularities. Due to position of CG goes down, after providing the irregularity, the stability of building increases. After providing the irregularity, due to descreasement in loading, the value of maximum bending moment is decreases, so failure chances decreases.

***KEYWORDS**: Structural irregularity, earthquake resistant building, Fundamental time period, model analysis*

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1. INTRODUCTION

Behavior of a multi-storey building amid solid seismic tremor movement depends on basic arrangement. Sporadic setup either in arrange or in height is recognized as one of the major causes of disappointment amid earthquakes.

The choice of sort, degree and area of inconsistencies within the plan of structures is imperative because it makes a difference in progressing the utility as well as aesthetics of structures. Thus, the show think about addresses the seismic reaction of strengthenedconcrete structures having different combinations of irregularities.

Introduction

The behavior of any building depends on the course of action of auxiliary components display in it. The critical viewpoints on which the basic setup depends are geometry, shape and measure of the building. When a building is subjected to energetic loads, idleness strengths are created and gets concentrated at the center of mass of the structure. As a rule, the vertical individuals such as columns and shear dividers stand up to the even idleness strengths and the resultant of these powers gets firmness.

METHODOLOGY

The steps undertaken in the present study to achieve the above-mentioned objectivesare as follows:

1. Select the set of irregularity building frame models heights (6storey,30 storeys), different irregularities (limit to 4 irregularity building models).
2. Calculation of data like CG, maximum moment, maximum displacement, stability index Qsi, storey drift.
3. Analysing the results.

Select the set of irregularity building frame models heights (6 storey, 30 storeys), different

irregularities (limit to 4 irregularity building models)

This study presents the design models found for this building group. Almost all major international design standards recommend a good analysis for the construction of regular buildings using the main shear force of the foundation corresponding to the main period, as the standard clearly shows.

However, the equations for critical moments as a function of building height in these codes are not clear for normal buildings.

It can be seen from the analysis that when the configuration of the building changes, the main moment of the building changes constantly, although the overall height remains constant.

In our study, we chose 6-storey and 30-storey normal buildings and also provided three different types of rules.

Table 1.1: List of selected building with different types of irregularity

	No of storey	Height of building	Types of irregularity	Notation
1.	**6**	18 Meter	Regular building	R-1-6
2.	**6**	18 Meter	Irregularity type -1	S-1-6
3.	**6**	18 Meter	Irregularity type -2	S-2-6
4.	**6**	18 Meter	irregularity type -3	S-3-6
5.	**30**	90 Meter	Regular building	R-1-30
6.	**30**	90 Meter	Irregularity type -1	S-1-30
7.	**30**	90 Meter	Irregularity type -2	S-2-30
8.	**30**	90 Meter	Irregularity type -3	S-3-30

Calculation of data like cg, maximum moment, maximum displacement,stability index Qsi, storey drift

Center of gravity:
The center of gravity (CG) is the center of all weight of an object. The center of gravityis the balance point of an object and is also specified as the point at which all the masslies.

Centroids have several special properties:
- ➢ Objects in space revolve around their centroids.
- ➢ A force applied to the center of gravity causes a net translation.

Therefore, the position of the center of gravity is an important parameter for determining the flight characteristics of an object.

Controlling the flight of an object requires a good knowledge of the location of its centerof gravity.

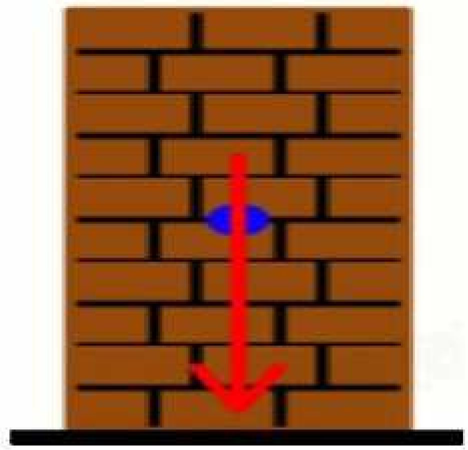

Figure 3.1: A Building shows position and direction of CG

Bending moment:
The bending moment (BM) is a measure of the bending effect that can occur when an external force (or moment) is applied to the material. This concept is important in building construction because it can be used to calculate where and how much bending will occur when force is applied.

The structure most affected by bending moments is the beam, which will bend when loaded at any point along its length.

Bending failure occurs when the tensile force equals or exceeds the ultimate strength (or stress) of the member. However, despite the different methods, the beams will collapse due to the sheer force before bending.

If the beam is not well constrained, the bending force will cause it to rotate at the pivotpoint.

To calculate the bending moment, the magnitude of the force is divided by the distanceof the force from the fulcrum.

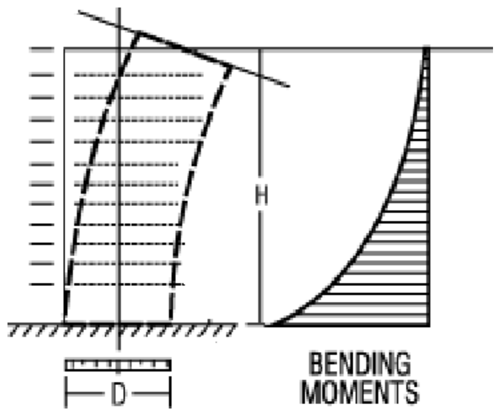

Figure 3.2: A Building and bending moment diagram

Displacement:
In engineering, deflection is the degree of displacement of a structure under load. It canrefer to an angle or distance..

The deflection distance of an element under load is directly related to the slope of the deflection quality of the element under load and can be calculated by integrating a function that mathematically describes the deflection of the element under load. Deflections can be calculated from the standard model (it only gives the deviations for different beams and loads at different locations) or methods such as virtual work, direct integration, Castiglioni method, Macaulay method, or solid method.

Deflections of beam elements are usually calculated according to the Euler-Bernoulli beam equation, while deflections of plate or shell elements are calculated using plate orshell theory.

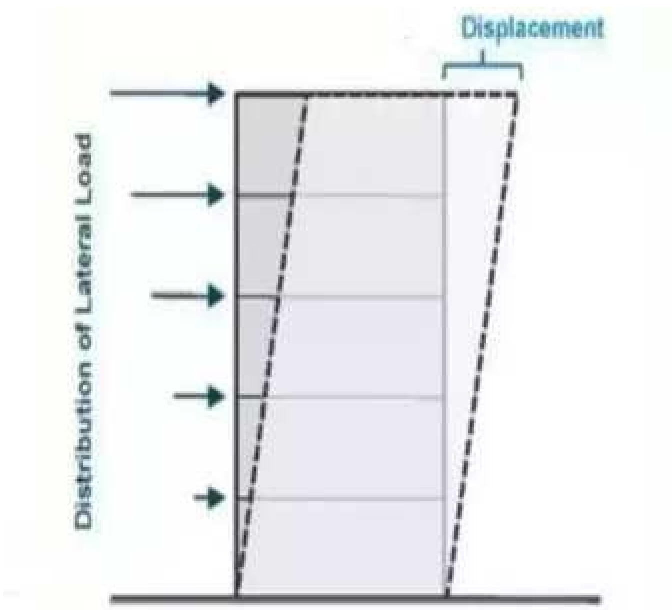

Figure 3.3: Horizontal displacement in building

Stability index:
As per Annex E of IS 456:2000 for all storey to classify the columns in a given storeyas non-sway or sway columns. The stability index Qsi of a storey is given by

$$Q_{si} = \frac{\sum P_u \Delta_u}{H_u h_s}$$

Qsi = stability index of building storey

∑Pu = sum of axial loads on all columns in the each storey Uu = elastically computed first order lateral deflection

Hu = total lateral force acting within the storeyhs = height of the storey.

As per IS 456:2000, the column is classified as non-sway if Qsi ≤ 0.04, otherwise, it isa sway column.

Storey drift:
As per Clause no. 7.11.1 of IS 1893 (Part 1): 2002, the storey drift in anystorey due tospecified design lateral force with partial load factor of 1.0, shall not exceed 0.004 timesthe storey height.

Sometimes it may so happen that the requirement of storey drift is not satisfied. However, as per Clause 7.11.1, IS: 1893 (Part 1): 2002; "For the purpose of displacement requirements only, it is permissible to use seismic force obtained from the computed fundamental period (T) of the building without the lower bound limit on design seismic force." In such cases one may check storey drifts by using the relatively lower magnitude seismic forces obtained from a dynamic analysis.

Analysing the results
After selecting the building and different types of irregularity, we calculate and analysisThe given value and find the conclusion of project work.

DESIGN AND CALCULATIONS
In this chapter include analysis of RCC buildings representing vertically irregular multi-storeyed irregularity buildings.

Result of the dynamic analysis
1. COMPARISON OF CG POSITION.
2. MAXIMUM DISPLACEMENT.
3. BENDING MOMENT CALCULATION.
4. STABILITY INDICES (STABILITY INDEX QSI).
5. THE STOREY DRIFT

Dimensions of beams and columns for different buildings

Table 4.1: List of Dimensions of beams and columns

Building Type according tonumber to stories	Column dimension	Beam dimension
Six-storey building	400 mm × 400 mm	300 mm × 450 mm
Thirty-storey building	1200mm ×1200mm	600 mm × 750 mm

Height and Fundamental time period for irregularity buildings

Table 4.2: List of Height and Fundamental time period for irregularity buildings

Building Designation	Height (m)	T(sec)
R-6	18	1.1
IR1-6	18	1.02
IR2-6	18	1.02
IR3-6	18	0.9
R-30	90	2.82
IR1-30	90	2.57
IR2-30	90	2.71
IR3-30	90	2.37

The design data

1. Live load: 4.0 kN/m^2 at typical floor: 1.5 kN/m^2
2. Wind load: As per IS: 875-Not designed for wind load, since earthquake loadsexceed the wind loads.
3. Earthquake load: As per IS-1893 (Part 1) - 2002
4. Storey height: floor: 3m

Material Properties

Concrete

1. All components unless specified in design: M25 grade all

E_c= 5 000 N/mm^2, f_{ck}= 5 000N/mm^2

Steel HYSD reinforcement of grade Fe 415 confirming to IS: 1786 is used throughout

Section-1: Calculation of cg position from bottom

6 storey buildings:

For Regular type -1 building:

Position of C.G = H/2=18/2 =9 M

Building C.G lies at 9m from the bottom

For Irregularity type -1 building:

$$\text{Position of C.G} = \frac{(V1*y1)+(V2*y2)}{V1+V2}$$

$$= 6.819M$$

Building C.G lies at 6.819 m from the bottom

For Irregularity type -2 building:

$$\text{Position of C.G} = \frac{(V1*y1)+(V2*y2)+(V3*y3)}{V1+ V2+V3}$$

$$= 4.935M$$

Building C.G lies at 4.935 m from the bottom

For Irregularity type -3building:

$$\text{Position of C.G} = \frac{(V1*y1)+(V2*y2)+(V3*y3)+V4*y4)}{V1+V2+V3+V4}$$

Building C.G lies at 2.875m from the bottom

30 STOREY BUILDINGS

For Regular type -1 building:

Position of C.G = H/2 =90/2=45M Building C.G lies at 45m from the bottom

For Irregularity type -1 building:

$$\text{Position of C.G} = \frac{(V1*y1)+(V2*y2)}{V1+V2}$$

$$= 34.095M$$

Building C.G lies at 34.095 m from the bottom

For Irregularity type -2building:

$$\text{Position of C.G} = \frac{(V1*y1)+(V2*y2)+(V3*y3)}{V1+V2+V3}$$

$$= 24.675M$$

Building C.G lies at 24.675 m from the bottom

For Irregularity type -3 building:

$$\text{Position of C.G} = \frac{(V1*y1)+(V2*y2)+(V3*y3)+V4*y4)}{V1+V2+V3+V4}$$

$$= 17.19M$$

Building C.G lies at 17.19 m from the bottom

Table 4.3: Calculation of centre of gravity position

S NO	TYPES OFBUILDING	STOREYHEIGHT	POSITION OF CG
1.	R1 -6storey	18m	AT 09m FROM BOTTOM
2.	IR1 -6storey	18m	AT 6.819m FROM BOTTOM
3.	IR2 -6storey	18m	AT 4.9635m FROM BOTTOM
4.	IR3 -6storey	18m	AT 2.8756mFROM BOTTOM
5.	R1 -30storey	90m	AT 45m FROM BOTTOM
6.	IR1 -30storey	90m	AT 34.095m FROM BOTTOM
7.	IR2 -30storey	90m	AT 24.675m FROM BOTTOM
8.	IR3 -30storey	90m	AT 17.198mFROM BOTTOM

Section-2 Comparision of maximum displacement

The building configuration is same in both the directions, the displacement values aresame in either direction:

Table 4.4: List of maximum displacement

S N	TYPES OF BUILDING	NO. OF STOREY	MAXMIMUM DISPLACEMENT (IN MM) (IN X-X DIRECTION)	POSITION
1.	R1	6	76.43	FROM THE TOP OF BUILDING
2.	IR1	6	69.60	FROM THE TOP OF BUILDING
3.	IR2	6	67.35	FROM THE TOP OF BUILDING
4.	IR3	6	66.42	FROM THE TOP OF BUILDING
5.	R1	30	317.34	FROM THE TOP OF BUILDING
6.	IR1	30	313.24	FROM THE TOP OF BUILDING
7.	IR2	30	307.36	FROM THE TOP OF BUILDING
8.	IR3	30	257.32	FROM THE TOP OF BUILDING

Section-3 Comparision of the max, bending moment

Table 4.5: List of comparison of the maximum bending moment

S N	TYPES OF BUILDING	STOREY	MAX BENDINGMOMENT (IN KN-M) INX-X DIRECTION	POSITION
1.	R1	6	540.00	At the centre of mass of top floor
2.	IR1	6	536.00	At the centre of mass of top floor
3.	IR2	6	516.00	At the centre of mass of top floor
4.	IR3	6	506.00	At the centre of mass of top floor
5.	R1	30	2056.63	At the centre of mass of top floor
6.	IR1	30	2023.56	At the centre of mass of top floor
7.	IR2	30	2012.24	At the centre of mass of top floor
8.	IR3	30	1996.65	At the centre of mass of top floor

Section-4 Calculation of the stability index QSI

It is necessary to check the stability indices as per Annex E of IS 456:2000 for allstoreys to classify the columns in a given storey as non-sway or sway columns.

The stability index Q_{si} of a storey is given by:

$$Q_{si} = \frac{\sum P_u U_u}{H_u h_s}$$

Q_{si} = stability index of building storey

$\sum P_u$ = sum of axial loads on all columns in the nth storey

U_u = elastically computed first order lateral deflection

H_u = total lateral force acting within the storey

h_s = height of the storey.

As per IS 456:2000, the column is classified as:
1. Non-sway column if $Q_{si} \leq 0.04$
2. Sway column if $Q_{si} > 0.04$

Table 4.6: List of the value of stability index

SN	Types of Building	Storey	∑Pu (In KN)	Hu (In KN)	MAX. Displacement(U)	Hs (in mm)	$Q_{si} = \frac{\sum P_{uu}}{H_u h_s}$	Remark
1.	R1	6	5 597	480	76.43	3000	0.0162≤ 0.04	No-sway
2.	IR1	6	5028	480	69.60	3000	0.0149≤ 0.04	No-sway
3.	IR2	6	4800	480	67.35	3000	0.0310≤ 0.04	No-sway
4.	IR3	6	4562	480	66.42	3000	0.0186≤ 0.04	No-sway
5.	R1	30	5 597	480	317.34	3000	0.0162≤ 0.04	No-sway
6.	IR1	30	5028	480	313.24	3000	0.0149≤ 0.04	No-sway
7.	IR2	30	4800	480	307.36	3000	0.0310≤ 0.04	No-sway
8.	IR3	30	4562	480	257.32	3000	0.0286≤ 0.04	No-sway

Section-5 Calculation of storey drift

As per Clause no. 7.11.1 of IS 1893 (Part 1): 2002, the storey drift in anystorey due tospecified design lateral force with partial load factor of 1.0, shall not exceed 0.004 timesthe storey height.

Sometimes it may so happen that the requirement of storey drift is not satisfied. However, as per Clause 7.11.1, IS: 1893 (Part 1): 2002; "For the purpose of displacement requirements only, it is permissible to use seismic force obtained from the computed fundamental period (T) of the building without the lower bound limit ondesign seismic force." In such cases one may check storey drifts by using the relativelylower magnitude seismic forces obtained from a dynamic analysis.

6 storey buildings

For Regular type -1 building

Storey drift (mm) =Δnth-Δ(n-1) th(mm)

=79.43- 68.26 =11.17 mm

Maximum drift permitted = 0.004 x 3000 = 12mm Hence, ok

For Irregularity type -1 building

Storey drift (mm) =Δnth-Δ(n-1) th(mm)

=72.60-61.10=21.36=11.05 mm

Maximum drift permitted = 0.004 x 3000 = 12mm Hence, ok

For Irregularity type -3 building

Storey drift (mm) =Δnth-Δ(n-1) th(mm)

=70.35-60.11=10.24mm

Maximum drift permitted = 0.004 x 3000 = 12mm Hence, ok

For Irregularity type -4 building
Storey drift (mm) =Δnth-Δ(n-1) th(mm)
=69.42 -58.48=10.94mm
Maximum drift permitted = 0.004 x 3000 = 12mm Hence, ok

30 Storey buildings
For Regular type -1 building
Storey drift (mm) =Δnth-Δ(n-1) th(mm)
=326.34-316.96=9.38mm
Maximum drift permitted = 0.004 x 3000 = 12mm Hence, ok

For Irregularity type -1 building
Storey drift (mm) =Δnth-Δ(n-1) th(mm)
=316.24-308.06=8.18 mm
Maximum drift permitted = 0.004 x 3000 = 12mm Hence, ok

For Irregularity type -3 building
Storey drift (mm) =Δnth-Δ(n-1) th(mm)
=310.36-302.36=8.00 mm
Maximum drift permitted = 0.004 x 3000 = 12mm Hence, ok

For Irregularity type -4 building
Storey drift (mm) =Δnth-Δ(n-1) th(mm)
=306.32-298.56=7.76 mm
Maximum drift permitted = 0.004 x 3000 = 12mm Hence, ok

Table 4.7: The value of storey drift

S NO.	Type of Building	Storey	Height of Building (m)	Storey drift(mm) Δ =Δnth-Δ(n-1)th(mm)	Maximum value of storey drift(mm)
1.	R1	6	18	79.43 - 68.26 =11.17	12
2.	IR1	6	18	72.60- 61.10 =11.50	12
3.	IR2	6	18	70.35-60.11=10.24	12
4.	IR3	6	18	69.42 -58.48=10.94	12
5.	R1	30	90	326.34-316.96=9.38	12
6.	IR1	30	90	316.24-308.06=8.18	12
7.	IR2	30	90	310.36-302.36=8.00	12
8.	IR3	30	90	306.32-298.56=7.76	12

RESULTS AND DISCUSSION
Result of cg position in multi storey building with different irregularity
In all the types of buildings the cg position changes, from bottom of building the position just like building become more stable then compared to the regular type of building.

Table 5.1: List of Position of CG for different building

S NO	TYPES OFBUILDING	STOREYHEIGHT	POSITION OF CG
1.	R1	18m	AT 09m FROM BOTTOM
2.	IR1	18m	AT 6.819m FROM BOTTOM
3.	IR2	18m	AT 4.9635m FROM BOTTOM
4.	IR3	18m	AT 2.8756mFROM BOTTOM
5.	R1	90m	AT 45m FROM BOTTOM
6.	IR1	90m	AT 34.095m FROM BOTTOM
7.	IR2	90m	AT 24.675m FROM BOTTOM
8.	IR3	90m	AT 17.198mFROM BOTTOM

Result comparison of maximum displacement
The displacement due to considered load in a fundamental period show that in theirregularity Building the value of maximum displacement is less compared to the ordinary building.

Table 5.2: List of value of maximum displacement

S N	TYPES OF BUILDING	STOREY HEIGHT	NO. OF STOREY	MAXMIMUM DISPLACEMENT (IN MM) (IN X-X DIRECTION)
1.	R1	18m	6	79.43
2.	IR1	18m	6	72.60
3.	IR2	18m	6	70.35
4.	IR3	18m	6	69.42
5.	R1	90m	30	320.34
6.	IR1	90m	30	316.24
7.	IR2	90m	30	310.36
8.	IR3	90m	30	302.32

Result comparison of maximum bending moment

The value of maximum bending moment shows as in table

Table 5.3: List of value of maximum bending moment

SN	TYPES OF BUILDING	STOREY	MAX BENDING MOMENT (INKN-M) IN X-X DIRECTION
1.	R1	6	540.00
2.	IR1	6	536.00
3.	IR2	6	516.00
4.	IR3	6	506.00
5.	R1	30	2056.63
6.	IR1	30	2023.56
7.	IR2	30	2012.24
8.	IR3	30	1996.65

Result comparisons of the stability index QSI

The stability index value which is shows in table, show that building achieve more nonsway Property when we provide irregularity in building.

Table 5.4: List of value of the stability index

SN.	TYPES OFBUILDING	STOREY	$Q_{si} = \frac{\sum P_{uu}}{H_u h_s}$	REMARK
1.	R1	6	0.0162≤ 0.04	No-sway
2.	IR1	6	0.0149≤ 0.04	No-sway
3.	IR2	6	0.0310≤ 0.04	No-sway
4.	IR3	6	0.0186≤ 0.04	No-sway
5.	R1	30	0.0162≤ 0.04	No-sway
6.	IR1	30	0.0149≤ 0.04	No-sway
7.	IR2	30	0.0310≤ 0.04	No-sway
8.	IR3	30	0.0286≤ 0.04	No-sway

Result comparisons of the storey drift

The value of storey drift also calculated separately for each type of building, also theValue of the storey drift come under the safety limits.

Table 5.5: List of value of the value of storey drift

S NO.	Type of Building	Storey	Height of Building (m)	Storey drift(mm) $\Delta = \Delta nth - \Delta (n-1)$ th(mm)	Maximumvalue of storey drift (mm)
1.	R1	6	18	11.17	12
2.	IR1	6	18	11.50	12
3.	IR2	6	18	10.24	12
4.	IR3	6	18	10.94	12
5.	R1	30	90	9.38	12
6.	IR1	30	90	8.18	12
7.	IR2	30	90	8.00	12
8.	IR3	30	90	7.76	12

CONCLUSSIONS AND FUTURE SCOPE

Conclusion

After the research work some conclusions are made. The conclusions are givenbelow:

1. Due to position of CG goes down, after providing the irregularity, the stabilityof building increases.
2. After providing the irregularity, due to descreasement in loading, the value ofmaximum bending moment is decreases, so failure chances decreases.
3. The stability index in the description shows that when we put the roughness inthe house, the house takes more work to prevent shaking.
4. Lateral displacement also decrease, after providing the irregularitys.
5. The value of storey drift also calculated separately for each type of building, also the Value of the storey drift come under the safety limits.
6. The displacement due to considered load in a fundamental period show that inthe irregularity
7. Building the value of maximum displacement is less compared to the ordinarybuilding.
8. Finally building stability more increases at the same time when we provideirregularity in the building.

Future Scope

1. This study cannot determine the inappropriateness of defining the degree of inequality of three-dimensional multilayer inequality. There are many variables that can be examined, whether geometric or pattern, or both, to identify inconsistencies, other variables of inconsistencies will be explored in the future.
2. This study is limited to reinforced concrete (RC) multi-frame buildings without gaps in minor directions only. The scope of future research is 3D architectural models with irregularities in both horizontal and vertical directions.

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