Comparative Analysis of Moment Resisting RC Frames for Seismic Performance in Various Building Configurations

Shashank Verma[1], Prof. Satyendra Dubey[2], Prof. Anubhav Rai [3]
[1]Dept of Civil Engineering
[2]Assistant Professor, Dept of Civil Engineering
[3]HOD, Dept of Civil Engineering
[1, 2, 3,]GGITS JABALPUR

Abstract- *This thesis investigates the seismic performance of Ordinary Moment Resisting Frames (OMRF) and Special Moment Resisting Frames (SMRF) across all four seismic zones, focusing on regular and irregular building configurations. The study evaluates three building types – a regular bare-frame block structure, an irregular stepped structure, and an irregular plaza structure – with identical plan area (15m x 15m) and height (G+8 storeys, 27m). Using STAAD.Pro software and Indian Standards, analysis employs the Equivalent Static Code Method, considering thirteen load combinations from IS 456:2000 and referencing IS 1893 (PART 1):2002, IS 875 (PART 1):1987, IS 875 (PART2):1987, and IS 13920:1993.*

Comparisons of shear force, bending moment, maximum deformation, and storey deformation reveal competitive performance between regular bare-frame and irregular stepped-frame structures, with irregular plaza frames exhibiting higher values. Notably, OMRF displays higher values compared to SMRF across the configurations. This study provides insights into the adoptability of suitable moment resisting frames and building configurations for seismic resilience.

I. INTRODUCTION

The choice of a particular kind of framing system is influenced by two key factors: the zone's seismic risk and the budget. However, as earthquake threats rise, it becomes insufficient, necessitating the use of SMRF frames. MRFs are in general understood as beams and columns rigidly coupled to shear, reinforcement, and other factors. Because of their superior deformation and energy absorption characteristics. A moment frame's components should be able to withstand both gravity and lateral loads. The flexural stiffness for every component determines how lateral forces are distributed.

Under seismic loads, regular buildings are thought to perform far better than irregular buildings. This is what the codes have been urging us to do all along. In the construction of buildings, irregularities are unavoidable. As competition has intensified, so have aesthetic demands. It is preferable to combine strength and beauty. As a result, a thorough investigation into the structural behaviour performance of structures with irregularities under seismic loading is required for proper design and improved.

Table 2 Zone Factor, Z
(*Clause* 6.4.2)

Seismic Zone	II	III	IV	V
Seismic Intensity	Low	Moderate	Severe	Very Severe
Z	0.10	0.16	0.24	0.36

Ground shaking is a symptom of an earthquake triggered by a sudden outpouring of energy in the Earth's crust. This energy can come from various places, including crustal dislocations, volcanic eruptions, artificial explosions, and the collapse of underground holes like mines or karsts. While seismic activity is defined as an environmental phenomenon, there are other types of earthquakes: crack rupture, volcanoes, mining-induced, and massive water source earthquakes. As seen in the flow graphic before, Ritcher (1958) offered a list of important earth disturbances documented by seismographs. For structural engineers, tectonic earthquakes are particularly interesting. An earthquake, thus, is literally described as an episode of intense seismic energy generation. Richter scales are commonly employed as magnitudes scales. Trace deformation of surface-wave seismograms is the most important parameter in determining the magnitude of an earthquake. Magnitudes estimated from body wave components of seismograms are widely used to refine magnitude estimations due to this property. But, for the purposes of reporting, the outcome is almost always reported as equivalent Richter magnitude. When it comes to measuring the magnitude of an earthquake, there is a direct correlation between the quantity of energy emitted (E) and the Richter magnitude (M).

STRUCTURAL SYSTEMS FOR SEISMIC RESISTANCE

1. Structural Frame Systems – Frames are commonly used in multi-story reinforced concrete buildings. In nature, beams, supporting floors, and columns are all continuous. They come together at nodes, which are also known as "stiff" joints. Such structures can easily support gravity loads while also resisting horizontal forces acting in any direction.

2. Structural Wall Systems – When functional requirements allow, lateral force resistance can be attributed solely to structural walls made of reinforced concrete or masonry. The effects of gravity loads on such walls are rarely considerable, and they have little bearing on the design. There are usually other elements within such a structure that are only assigned to carry gravity loads. Their, if any, contribution to lateral force resistance is frequently overlooked.

3. Dual System – Reinforced concrete frames interact with reinforced concrete or masonry walls to give the required lateral force resistance, while each system bears its fair share of the gravity load. The words dual, hybrid, and wall-frame systems are all used to describe these forms.

SPECIAL MOMENT RESISTING FRAMES (SMRF)	ORDINARY MOMENT RESISTING FRAMES (OMRF)
It is a moment-resisting frame specially detailed to provide ductile behavior and comply with the requirements given in IS 13920.	It is a moment-resisting frame not meeting the special detailing requirements for ductile behavior.
Used under moderate or high earthquakes.	Used in low earthquakes.
Response Reduction Factor, R=5	Response Reduction Factor, R=3
Low design base shear.	High design base shear.
It is safe to design a structure with ductile detailing.	It is not safe to design a structure without ductile detailing.

REGULAR AND IRREGULAR BUILDINGS

PLAN IRREGULARITY

As per Indian Standards i.e., IS 1893:2002 plan irregularities can be categorized into the following types-

Torsion Irregularity

When the maximum storey drift with eccentricity on one side of the structure exceeds 1.2 times its transverse axis, and the floor diaphragms are deemed stiff in their own plan to withstand vertical and lateral loads, it must be considered.

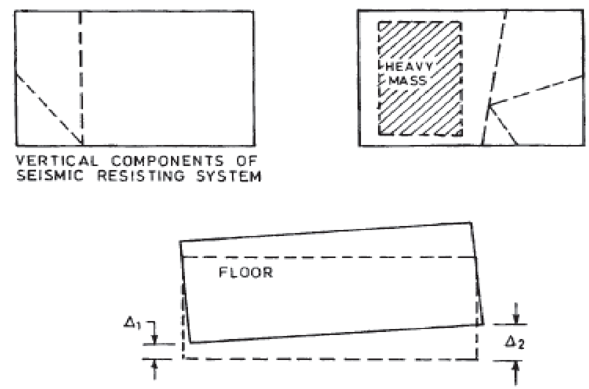


FIGURE: 8 TORSIONAL IRREGULARITY
(Ref- IS 1893:2002,Page 19-20)

Re-entrant Corners

This are found in framework layouts of a structure and its lateral force resisting system when the projections of a framework over the re-entrant corner exceed 15% of the structure's plan dimension in the given direction.

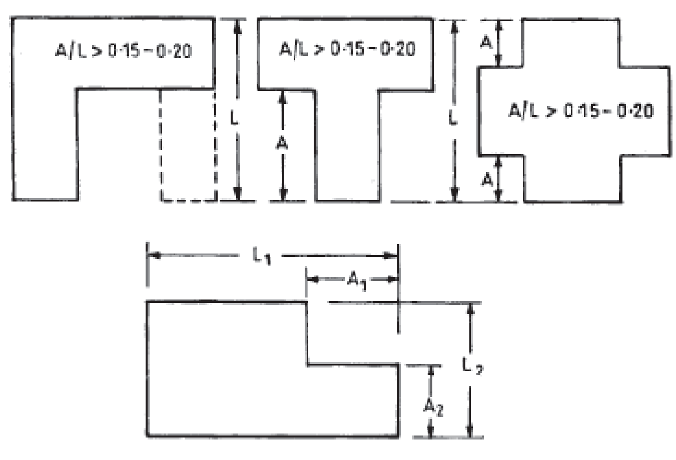


FIGURE 9: RE-ENTRANT CORNERS
(Ref- IS 1893:2002,Page 19-20)

Diaphragm Discontinuity

Diaphragms with abrupt discontinuities or stiffness fluctuations.

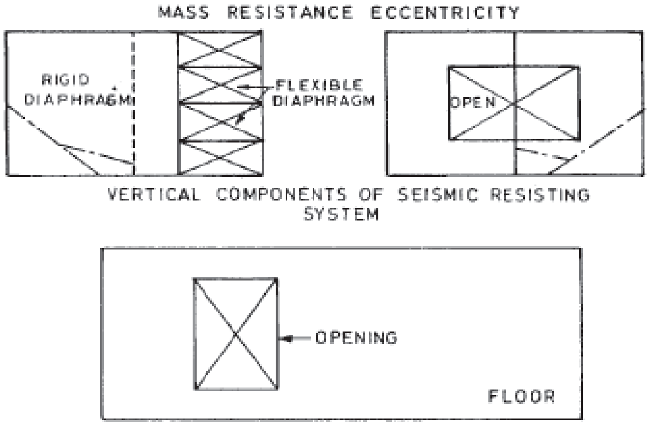


FIGURE 10: DIAPHRAGM DISCONTINUITY
(Ref- IS 1893:2002,Page 19-20)

Non-Parallel Systems

The lateral force opposing on vertical components are not aligned to or symmetric around the principal orthogonal directions or the laterally force resisting components.

Out-of-Plane Offsets

Out-of-plane deviations of vertical components, for example, are examples of discontinuities in a lateral load resistance pattern.

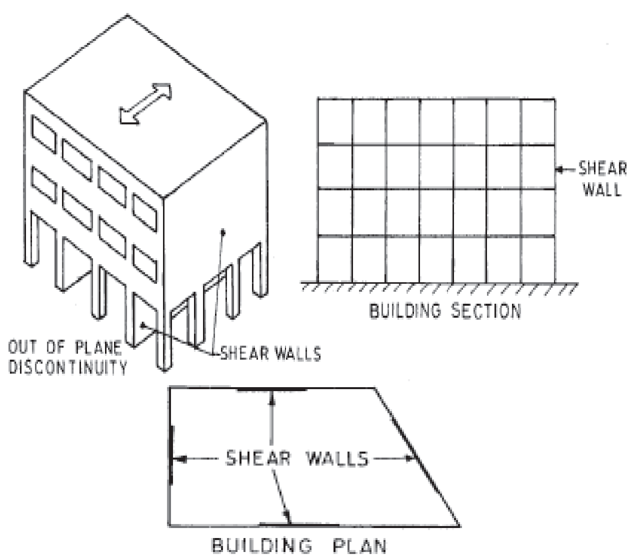


FIGURE : OUT-OF-PLANE OFFSETS
FIGURE : NON-PARALLEL SYSTEMS
(Ref- IS 1893:2002,Page 19-20)

VERTICAL IRREGULARITY

Stiffness Irregularity – Soft Storey

If the stiffness of the above stories is 70% or greater, or if the stiffness of the above three stories is 80%, then that narrative is classified as a soft storey.

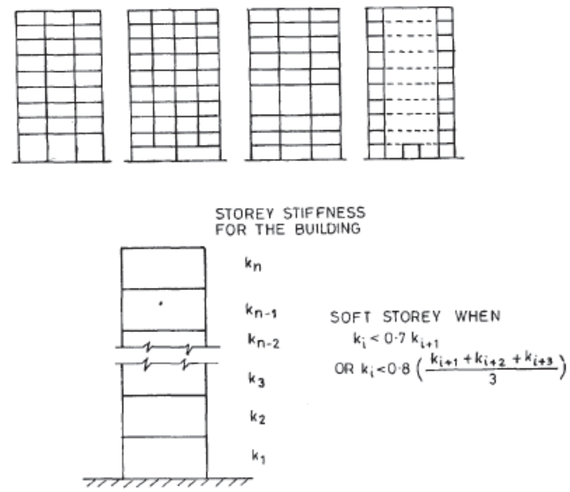


FIGURE : STIFFNESS IRREGULARITY
(Ref- IS 1893:2002,Page 20-21)

Mass Irregularity

When the seismic weight of one level exceeds 200 percent of the seismic weight of the neighbouring storey, mass irregularity is present. In the case of roofing, irregularity is not a factor to consider.

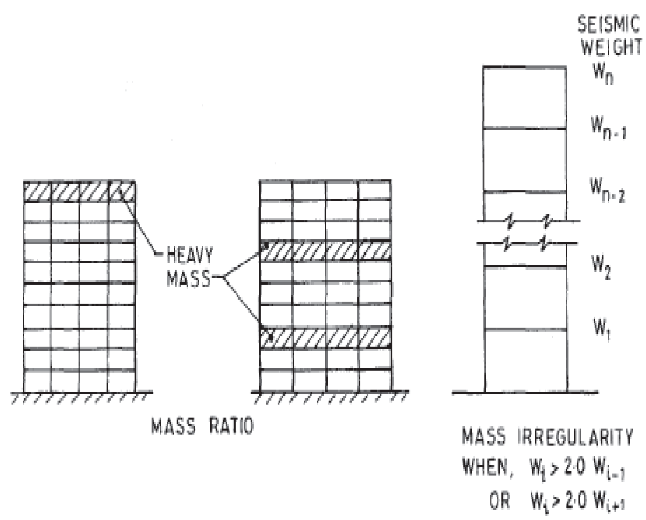


FIGURE : MASS IRREGULARITY
(Ref- IS 1893:2002,Page 20-21

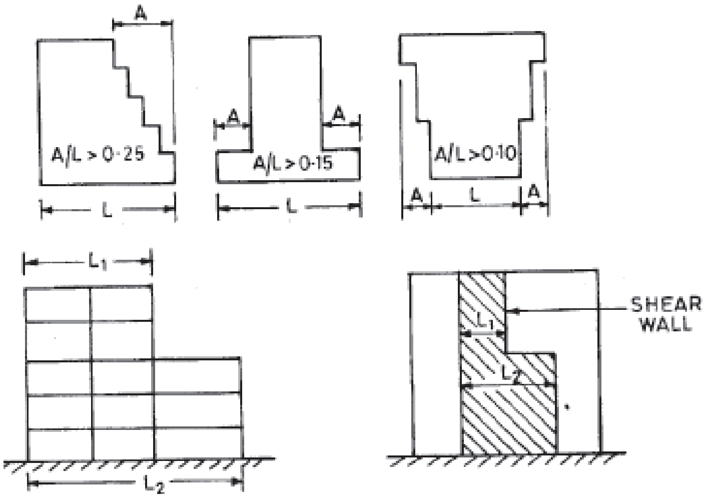


FIGURE : VERTICAL GEOMETRIC IRREGULARITY
(Ref- IS 1893:2002,Page 20-21

In-Plane Discontinuity in Vertical Elements Resisting Lateral Force

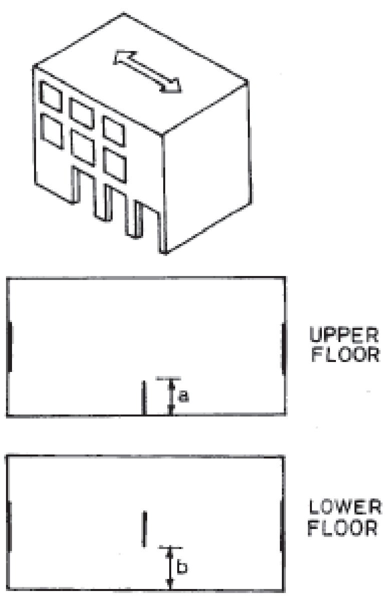


FIGURE : IN-PLAN DISCONTINUITY IN VERTICAL ELEMENTS
(Ref- IS 1893:2002,Page 20-21

In the work, the following technique is used.We looked at a number of different seismic analysis methodologies.

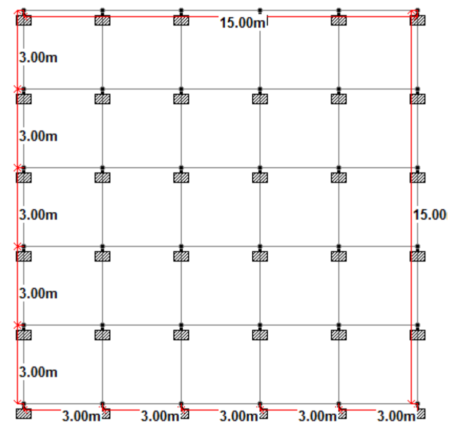
- Method of Dynamic Analysis
- Method of Static Analysis
- We prepared a G+8 storey building challenge.
- We use a reduced coding way to perform equivalent static analysis on the construction.
- In order to analyse the structures using the simplified code method, the following procedures were taken:
- Geometry, bays, and storeys of the building (3 geometries).
- Model selection for response reduction factors (OMRF and SMRF) according to IS 1893 (PART 1):2002 Table 7.
- Using Table 2 of IS 1893 (PART 1):2002, select four seismic zones (II, III, IV, and V).
- Importance factor selection according to IS 1893 (PART 1):2002 Table 6.
- Based on IS 456:2000 and IS 1893 (PART 1):2002, consider thirteen load combinations. Using STAAD.Pro tool to model structural systems.
- In this study, OMRF and SMRF models are used for distinct earthquake regions and 13 load combinations.
- This comparative analysis incorporates beam forces, deformation, and storey deformation to get the results.

In all 24 models are made and analyzed. Following cases of building frames are considered –

CASES	**STRUCTURE**	**SEISMIC ZONE**	**RESPONSE REDUCTIO N FACTOR**
CASE 1	REGULAR (BARE FRAME)	ZONE - II	OMRF
CASE 2	REGULAR (BARE FRAME)	ZONE - III	OMRF
CASE 3	REGULAR (BARE FRAME)	ZONE -IV	OMRF
CASE 4	REGULAR (BARE FRAME)	ZONE - V	OMRF
CASE 5	REGULAR (BARE FRAME)	ZONE - II	SMRF
CASE 6	REGULAR (BARE FRAME)	ZONE - III	SMRF
CASE 7	REGULAR (BARE FRAME)	ZONE - IV	SMRF
CASE 8	REGULAR (BARE FRAME)	ZONE - V	SMRF
CASE 9	IRREGULAR (PLAZA FRAME)	ZONE - II	OMRF
CASE 10	IRREGULAR (PLAZA FRAME)	ZONE - III	OMRF
CASE 11	IRREGULAR (PLAZA FRAME)	ZONE - IV	OMRF

CASE 12	IRREGULAR (PLAZA FRAME)	ZONE - V	OMRF
CASE 13	IRREGULAR (PLAZA FRAME)	ZONE - II	SMRF
CASE 14	IRREGULAR (PLAZA FRAME)	ZONE - III	SMRF
CASE 15	IRREGULAR (PLAZA FRAME)	ZONE - IV	SMRF
CASE 16	IRREGULAR (PLAZA FRAME)	ZONE - V	SMRF
CASE 17	IRREGULAR (STEPPED FRAME)	ZONE - II	OMRF
CASE 18	IRREGULAR (STEPPED FRAME)	ZONE - III	OMRF
CASE 19	IRREGULAR (STEPPED FRAME)	ZONE - IV	OMRF
CASE 20	IRREGULAR (STEPPED FRAME)	ZONE - V	OMRF
CASE 21	IRREGULAR (STEPPED FRAME)	ZONE - II	SMRF
CASE 22	IRREGULAR (STEPPED FRAME)	ZONE - III	SMRF
CASE 23	IRREGULAR (STEPPED FRAME)	ZONE - IV	SMRF
CASE 24	IRREGULAR (STEPPED FRAME)	ZONE - V	SMRF

Below are structural models for various scenarios.



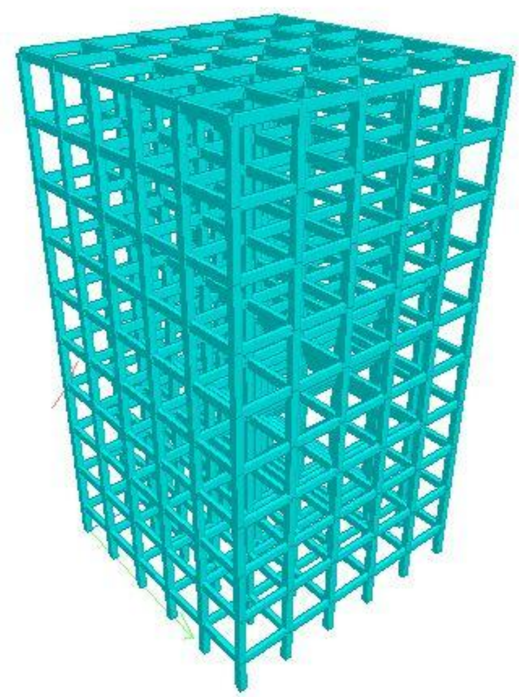


FIGURE : COMMON BASE PLANFIGURE : 3D VIEW OF REGULAR BARE-FRAME STRUCTURE

(Figures from StaadPro Software)

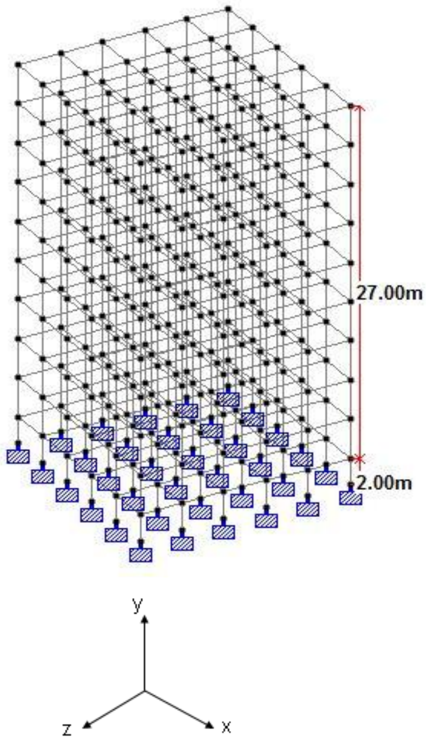
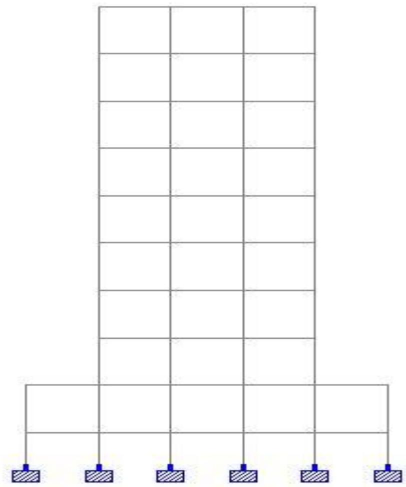


FIGURE: ISOMETRIC VIEW OF REGULAR BARE-FRAME STRUCTURE



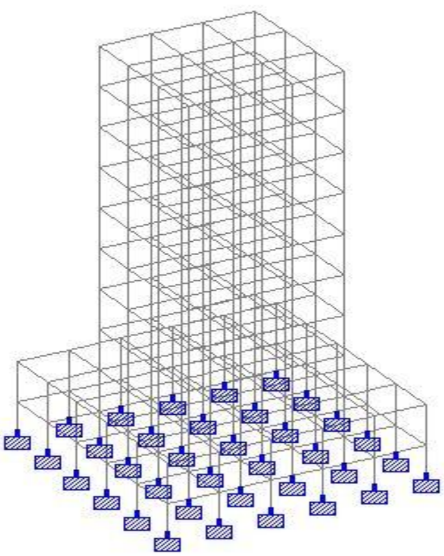
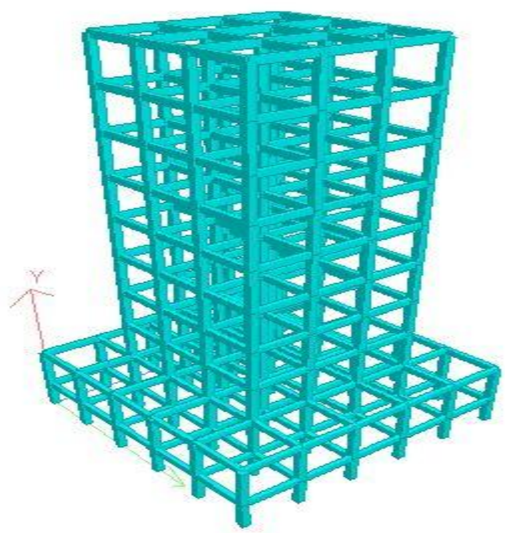


FIGURE : ISOMETRIC AND FRONT VIEW OF IRREGULAR PLAZA STRUCTURE

(Figures from StaadPro Software



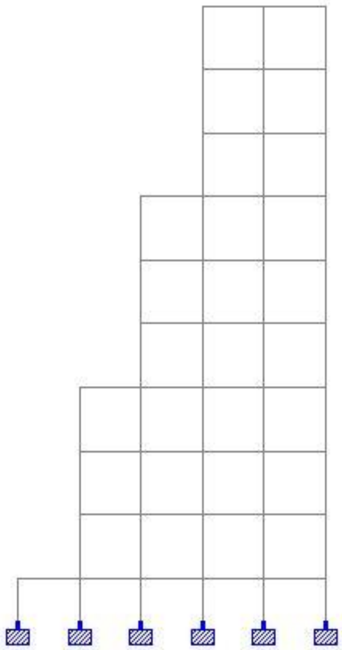
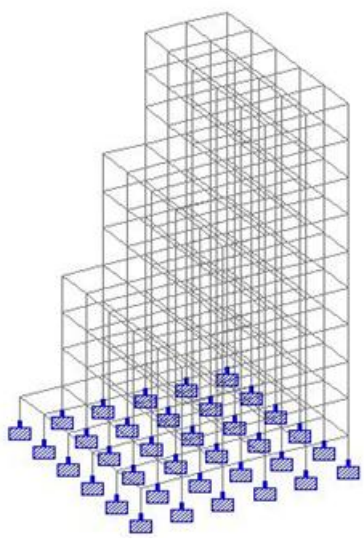


FIGURE : 3-DIMENSIONAL VIEW FIGURE : IRREGULAR STEPPED STRUCTURE



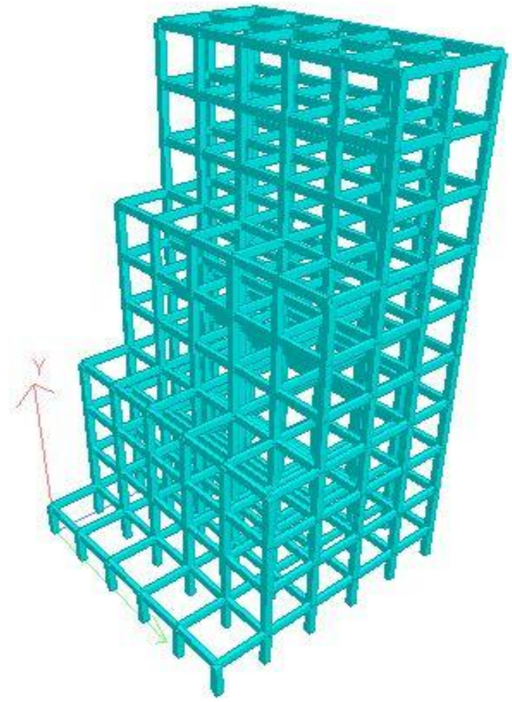


FIGURE: ISOMETRIC VIEW

FIGURE: 3D VIEW OF IRREGULAR STEPPED STRUCTURE

(Figures from StaadPro Software)

RESULTS AND CONCLUSION

***BENDING MOMENT* RESULTS**

- The irregular plaza building has the highest bending moment, while the standard bare frame building has the lowest.
- In case of bare frame structure and stepped building (irregular), the moments were nearly identical. On the other side, the moments were on the higher side in plaza building.
- On comparision of special moment resisting frame and ordinary moment resisting frame, we found that special moment resisting frame is more efficient. Also,it is economical over ordinary moment resisting frame
- As the seismic zone intensity rises, so does the rate of bending moment.

SHEAR FORCE

- The irregular plaza building has the most shear force, whereas the standard bare frame building has the lowest.

- Regardless of the type of frames, the shear forces of standard bare-frame and irregular stepped buildings were similar. In every case, however, the plaza building demonstrated stronger shear forces.
- The special moment resisting frame (SMRF) is more efficient than the ordinary moment resisting frame (OMRF), as it decreases shear forces and hence shear reinforcement, making it more cost effective.
- As the seismic zone intensity rises, the rate of shear forces rises as well.

MAXIMUM DEFORMATION

- In an irregular plaza building, the maximum deformation is noticed, while in a regular bare frame building, the smallest deformation is observed.
- As the seismic zone strength increases, the rate of deformation increases.
- In both directions, the maximum deformation is nearly the same (X and Z direction).
- Even when the type of structure is not taken into account, the regular bare frames structure and stepped structure were nearl identical and less when compared to that on plaza building structure.
- The SMRF is way more effective than the ordinary moment resisting frame, and because SMRF minimises deformation and hence section size, it is more cost effective than OMRF.

STOREY DEFORMATION

- The irregular plaza building has the most storey deformation , while the standard bare frame building has the least.
- As the seismic zone strength increases, the rate of increase in storey deformation accelerates.
- The special moment resisting frame is more efficient than the ordinary moment resisting frame, and because SMRF minimises storey deformation , it is possible to lower the size of the section, making it more cost effective for OMRF.
- Because the nature of the graph is the same in all seismic zones, it is apparent that bare frame, stepped frame, and plaza building are good options.

As can be seen from the graph and table above, SMRF with regular and irregular frames performs better than OMRF with regular and irregular frames in terms of bending moment, shear force, deformation , and storey deformation . The above results also show that the SMRF is a moment resistant frame that has been carefully designed to produce ductile behaviour, allowing the section size and reinforcing area to be reduced. This study is particularly valuable from a structural standpoint since SMRF offers designers more confidence when designing structures and it saves builders money.

FUTURE PERSPECTIVE OF THE WORK

- In this work static seismic analysis is perform and in future dynamic seismic analysis can also be performed for the same.
- Wind forces can be included in the future study.
- In this work supports are fixed and in further it can be pinned for analysis point of view.
- More parameters can be included as this is only analysis work, designing could be also done for the same.
- This work can be done with other soil conditions.
- This work is RC structure and it can also be analysed for steel structures.

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