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Study & Analysis of G+10 Building in M25grade Concrete for Earthquake & Wind Resistance

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Abstract:

The present study focuses on the structural analysis and design of a G+10 (Ground plus Ten stories) reinforced concrete building using M25 grade concrete, with particular emphasis on its performance under seismic and wind loads. In high-rise structures, lateral forces due to earthquakes and wind play a crucial role in the overall stability and safety of the building. This research aims to evaluate the structural behavior of a multi-storey building located in a seismically active region, ensuring compliance with IS codes such as IS 1893:2016 for earthquake load and IS 875 (Part 3):2015 for wind load analysis.The building model is analyzed using finite element software (e.g., ETABS or STAAD Pro) considering load combinations, material properties, and boundary conditions as per relevant standards. The study incorporates dynamic analysis methods, including Response Spectrum Analysis and Wind Load Analysis, to determine the building's response under lateral loading conditions. Key parameters such as story drift, base shear, displacement, and bending moments are examined to ensure that the structure performs within permissible limits.The results reveal the critical elements and stories that are most affected by lateral forces, offering insights for design optimization. The study concludes with recommendations for improving earthquake and wind resistance in similar high-rise concrete structures through design detailing, material selection, and structural configuration.

Keywords: G+10 building, M25 grade concrete, structural analysis, earthquake load, wind load, seismic resistance, wind resistance, lateral forces, IS 1893:2016, IS 875 (Part 3):2015, finite element analysis, ETABS, STAAD Pro, response spectrum analysis.

1. Introduction

The demand for residential and commercial buildings increased drastically day by day in the constructional sector. The multi storied building should be economical and should have less building components for architectural point of view. Due to this reason flat slab construction would be preferred. A slab which does not have beam component and it directly transfers its load to the foundation through vertical columns called flat slab. Slabs are generally of two types which are R.C.C slab and Flat slab. Required more headroom for the architectural purpose the flat slab should preferred in a multi storied building. (Jamle & Giri, 2018) The construction of flat slab is generally used with drop panel or column head and vice versa depends upon the loading condition. If loading is less than a simple flat slab is used, otherwise, the rest of three types of the flat slab will be considered.

1.1 Flat Slab

In the Johnson-Bovey Building (1905) in Minneapolis, Minnesota, the American engineer C.A.P. Turner employed concrete floor slabs without beams (called flat slabs or flat plates) that used diagonal and orthogonal patterns of reinforcing bars. The system still used today—which divides the bays between columns into column strips and middle strips and uses only an orthogonal arrangement of bars—was devised in 1912 by the Swiss engineer Robert Maillart. A reinforced concrete flat slab, also called a beamless slab, is a slab supported directly by columns without beams. A part of the slab bound on each of the four sides by centre lines of columns is called a panel. The flat slab is usually thickened almost supporting columns to supply adequate strength in shear and to scale back the number of negative reinforcements within the support regions. The thickened portion meets the ground slab, or a drop panel is enlarged, therefore, to extend primarily the perimeter of the crucial section, for shear and hence, Increasing the capability of the slab for resisting two-way shear and to cut back a negative bending moment at the support.

1.1.1 Advantages of Flat Slab

Flat-slab building structures possess major advantages over traditional slab beam column structures:

1. It is a beamless slab, directly supported on the column.
2. Lesser construction time.
3. Simple formwork is required for construction
4. Flat slab structures have the minimum structural depth
5. A flat slab structure generally does not require shear reinforcement at columns.
6. The flat-slab structural system is significantly more flexible for lateral loads than a traditional RC frame system

1.1.2 Types of Flat Slab

Flat slab is usually differentiating supported drop and column head. Flat slab is employed with the sole drop, only column head or without drop and column head, these are used as per loading requirements. If loading is a smaller amount, then using normal flat slab which has no drop and no head. If loading is far above at the junction of column and slab a shear phenomenon has occurred this is often called punching shear it'll be developed near the support because of high moment.

The flat slab is especially of 4 types:

- Simple Flat slab
- Flat slab attached with drop
- Flat slab attached with column capital
- Flat slab attached with drop and column capital

1.2 Shear Wall

- A shear wall is a structural system composed of parallel walls that counter the consequences of lateral hundreds working on a structure. Wind and seismic loadsmare the foremost common loads that shear walls are designed to hold.
- They are made of concrete and masonry and are used to resist lateral loads acting on a building. They are continued down to the base to which they are rigidly attached and act as a vertical cantilever in the form of separate planar walls.
- These walls are relatively thin and deep and are subjected to axial forces. Shear walls are important parts of mid and high-rise residential buildings.
- As a part of earthquake-resistant building design, these walls are placed on building plans for reducing lateral displacements under earthquake loads.
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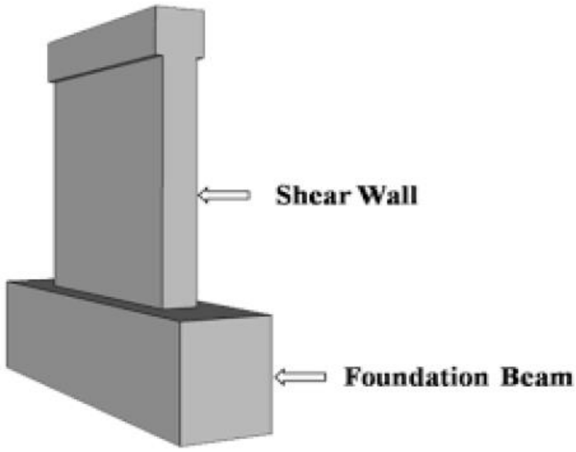


Figure 1.1: Shear Wall

1.3 Effect of Earthquake on Structure

During an earthquake, the failure of the structure starts at points of weakness. This weakness arises because of discontinuities in mass, stiffness and geometry of the structure. The structures having this discontinuity are termed as Irregular structures. Irregular structures contribute an outsized portion of urban infrastructure. Vertical irregularities are one among the main reasons for failures of structures during earthquakes. the impact of vertical irregularities within the seismic performance of structures becomes extremely necessary. Height-wise changes in stiffness and mass render the dynamic characteristics of those buildings completely different from the regular building. The irregularity within the building structures is also due to irregular distributions in their mass, strength and stiffness beside the peak of the building. Once such buildings are constructed in high seismic zones, the analysis and design become more difficult.

1.4 Earthquake & Its Causes

There are many natural hazards in the world, but earthquakes are one of the most destructive natural hazards that can result in severe social and economic impact. The devastating potential of an earthquake can have major consequences on infrastructure and lifelines. Roughly, 11,000 people die each year due to earthquakes, while annual economic losses run into billions of dollars, taking a major toll on the world economy. Earthquake defined as any sudden vibration or movement of a part of the earth's crust caused by natural con man-made stress, resulting in shaking and trembling called as an earthquake. (Prof. C. Valenti Planet Earth Earthquake Notes 1) An Earthquake may be defined as a wavelike motion generated by forces in constant turmoil (confusion (or) disturbance) under the surface layer of the earth-crust or lithosphere.

1.5 Aim Objectives and Scope:

- Analysis the behaviour of the flat slab system in the vertical irregular multi-storied building against different forces acting on it during the earthquake which is carried out using STAAD Pro software. Conventional R.C.C structure, i.e. Flat slab, shear wall, the column for vertical irregularity are modelled and analysed for the dynamic loading.
- The analysis is made between the conventional R.C.C flat slab structure of G+10 building, 200 % vertical irregular building and 300% vertical irregular building without shear wall and with the shear wall with the different seismic zone.
- Analysis the structural behaviour of the shear wall – flat slab interaction
- To find out the effect of Geometric irregularity on the shape (vertical geometric) irregular building the geometry is changed by reducing the no. Of bays in X direction vertically downward, as per the IS 1893:2016 (part-1).

2.Literature Review

- To analyses and design of flat slab for a different shape such as rectangular and square with and without the drop, pushover analysis (statics analysis) and earthquake analysis (seismic co-efficient method) with the help of ETABS software. After the evaluation of the result, the maximum strip moment was almost same for rectangular and square slab and the value of base shear was higher in square flat slab without the drop. The storey displacement seems to be higher in rectangular slab and the storey drift value for rectangular and square was also the same, the natural period value was almost the same for both shapes. **(Kaulkhere R.V, Prof. G.N Shete, (2017).[1]**

- In this work, to analyze and model of G+3 regular frame structure with shear wall and G+3 flat slab with the shear wall in Seismic Zone 3 done with SAP-2000. The plan area is (24 x 24) m, the height of plinth 1.8 m and floor height is 3.6 m. After the result comparison regular frame building has better performance as compared to the flat slab. To enhance the performance of flat slab building, shear wall can be provided. **(Imran Mohammed, et.al 2017).[2]**

- Flat-slab building structures possess major advantages over traditional slab-beam column structures because of the free design of space, shorter construction time, architectural –functional and economical aspects. Because of the absence of deep beams and shear walls, the flat-slab structural system is significantly more flexible for lateral loads then traditional RC frame system and that make the system more vulnerable under seismic events. This fact has resulted in to ensure safety against earthquake forces of tall structures hence, there's got to determine seismic responses of such building for designing earth quake resistant structures. Response spectrographic analysis is one among the important techniques for structural seismic analysis. In the present work, dynamic analysis of 15 models of multi-storied RCC Flat slab structure is administered by response spectroscopic analysis. **(Renuka Ramteke 2017) [3]**

• STAAD pro has a very interactive user interface which allows the users to draw the frame and load the input

values and dimensions. Then consistent with the desired

criteria allotted it analyses the structure and styles the

members with reinforcement details for RCC frames.

(Bhatia Navjot Kaur., Golait Tushar,2016).[4]

• In this study, for the strengthening of flat slab against punching shear, the use of postinstalled shear reinforcement after the completion of construction work. It is also known as post shear reinforcement, used to improvement of punching shear strength of flat slab. The critical shear crack theory has used to design the post-installed shear reinforcement. The main conclusion of this work was that the inclined shear reinforcement was simpler to enhance punching shear strength. **(Devtale M. K. et.al 2016).[5]**

• The work is done in this kind of approach, the analysis of flat slab in earthquake loading condition has drawn out. In this research, the flat slab is designed with the help of direct design method, equivalent frame method (for gravity load only) and finite element method (for irregular geometry and irregular layout). Contrasting the result, it has been found that in IS Code 456-2000, there aren't any provisions related to the flat slab for seismic loading, it is only based on the gravity loading conditions. If the designing has not done properly, then cracks are evolved near the support which concluding the drastic results when any structure considered during construction. **(Srinivasulu P., Dattatreya Kumar A 2015).[6]**

• The storey shear value seems comparatively high on the bottom floor and less at the top floor. Hence

concluding this, the flat slab with drop and shear wall is a better option to overcome the displacement in the X direction, also base shear increased when weight increases. If the drop has provided in the interior panel then punching shear gets reduced by 25%. **(More R. S., Sawant V. S. (2015).[7]**

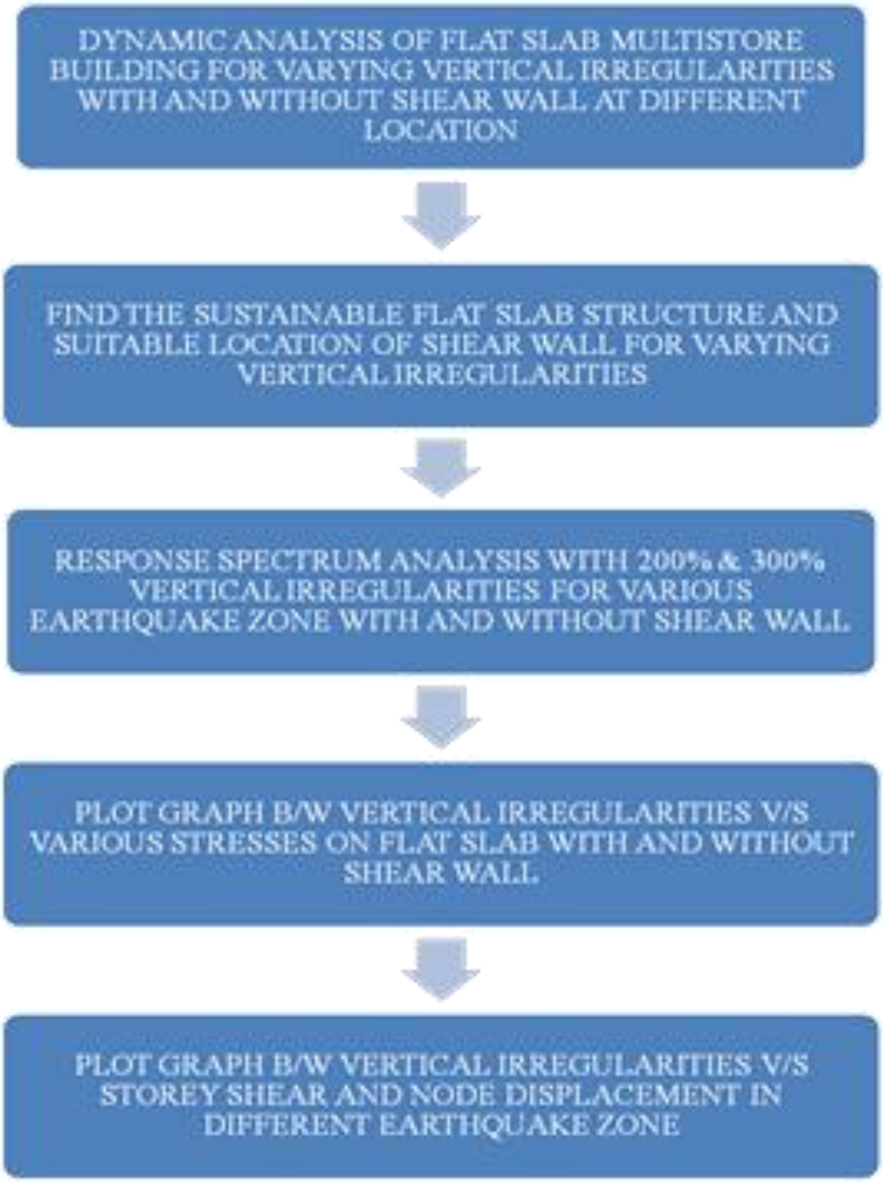
• The effect of with and without the shear wall of flat slab building on the seismic behaviour of high rise building with different position of shear wall studied. For that, 15 story models are selected. To study the effect of different location of the shear wall on high rise structure, linear dynamic analysis (Response spectrum analysis) in software ETABs is carried out. Seismic parameters like period of time, base shear, storey displacement and storey drift are verified. **(Walvekar Anuja, Jadhav H.S. 2015).[8]**

• The effect of RC flat slab with shear wall at a different location for various heights of the building. Shear wall with flat slab provides stability to structure further because it improves lateral load resistance. The effectiveness of RC flat slab and shear wall building is studied with the help of three different models. Model one is a conventional building with regular slabs, beams & column framing. Model two is a conventional building with various shear wall location and model three with flat slab and shear wall. Time history analysis is carried out for the structure using ETABs software**.** **(Patwari K. G. L. G. Kalurkar 2016), [9]**

- As per IS code 1893:2002 analysis carried out by considering regular and irregular buildings with brick infill and modified building with strong column and shear wall at the corner of the soft storey. For linear and nonlinear analysis five, 10, and 15 storey buildings modelled by using ETABS software considering Response reduction factor, Importance factor, Zone factor, damping ratio, loads as per code Lateral displacement, base shear and hinge reactions were obtained consistent with code provision. **(Ravindra B N, Mallikarjun S. Bhandiwad 2015).[10]**

3. Methodology

3.1 Work Methodology



3.2 General

The presence of structural irregularity in a building has a significant impact on its seismic response. The structural irregularity aspect has not been adequately addressed by the codes in formulating the seismic design methodologies. The past earthquake records show that the irregular buildings exhibit a poor seismic performance which shows the inadequacy of the seismic design codes based on which these buildings were designed. Therefore, the structural irregularity aspect needs to be incorporated in formulating the seismic design methodologies. Moreover, the code procedures of seismic design are based on elastic analysis and single degree of freedom system which is unrealistic. In this Chapter, the building models with different types, magnitude and location of irregularity have been described at first. Secondly, different analysis methods available to obtain the seismic response have been discussed and based on a review of analysis methods a suitable method has been adopted for analysis of irregular building models.

3.3 Code-Based Procedure for Seismic Analysis

Main features of seismic method of analysis based on Indian standard 1893(Part 1): 2002 are described as follows

- Linear Static Method **(**Equivalent static lateral force)
- Linear Dynamic Method (Response spectrum Analysis)
- Nonlinear Static (Pushover Analysis)
- Nonlinear Dynamic (Time History Analysis)

3.4 Analysis of Response Spectrum Method

RSA (Response Spectrum Analysis) may be a linear dynamic statistical analysis method which measures the contribution from each natural mode of vibration to point the likely seismic response of an essentially elastic structure. (Kota Tejaswi & Kadiyla Rajesh,2015) In Response Spectra Method, Response spectra curves are plotted between the utmost response of SDOF system subjected to specified earthquake ground motion and its period of time (or frequency). Response spectrum can be interpreted as the locus of maximum response of an SDOF system for given damping ratio. Response spectra thus help in obtaining the height structural responses under linear range, which can be used for obtaining lateral forces developed in structure due to earthquake thus facilitates in the earthquake-resistant design of structures. Usually, the response of an SDOF system is decided by time domain or frequency domain analysis, and for a given period of time of the system, the utmost response is picked.

3.5 Storey Drift

Storey drift considers as the displacement of a storey with respect to its adjacent storey above and below it. When lateral forces occur in the building the building starts lateral moments, its move from its original position and came back. This lateral deformation of storey with a floor height called drift of a storey. As per IS 1893-2002 part-I this storey drift should not exceed 0.004 times of the total building height when it's subjected to lateral pressure as per IS 1893-2002. The factor is defined as the ratio of the story shear force when story collapse occurs to the story shear force when total collapse occurs.

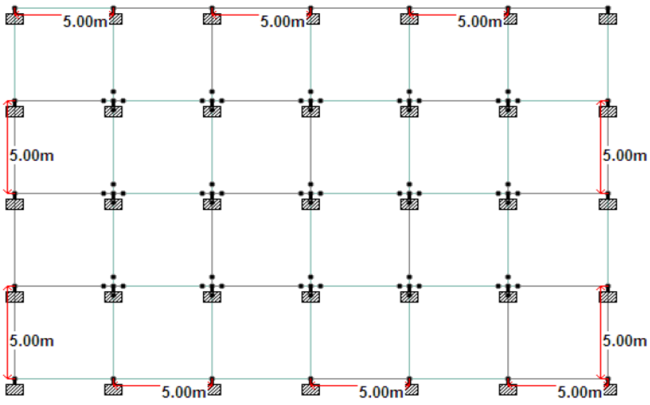


Figure 3.1: Plan of Flat Slab Structure

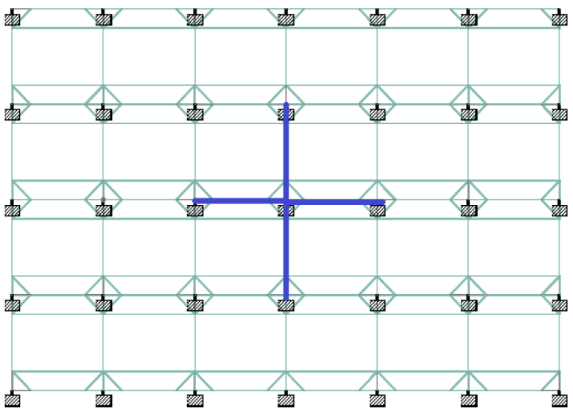


Figure 3.2: Position of Shear Wall

4. Results

4.1 CENTER SHEAR STRESSES

4.1.1 Center Shear Stresses Regular Buildings

Table 4.1: Center Shear Stresses in G+10 Regular Building without Shear Wall

CENTER STRESSES	NOTATION	ZONE III	ZONE IV	ZONE V
SHEAR (KN/M2)	SQX	298	353	530
	SQY	293	493	659

Table 4.2: Center Shear Stresses in G+10 Regular Building with Shear Wall

CENTER STRESSES	NOTATION	ZONE III	ZONE IV	ZONE V
7SHEAR (KN/M2)	SQX	1444	2304	3248
	SQY	1751	2293	3939

4.2 Discussion for Plate Center Shear Stress in Regular Building:

The plate Center shear stresses increases with seismic zone. The plate Center shear stress along X axis i.e. (SQX) increase by 79%, 84% and 85% and along Y axis i.e (SQY) increase by 83%,78%, and 83% when shear wall is provided in G+10 regular multi storied building at center in seismic zone III, IV and V respectively.

4.2.1 Discussion for Plate Center Shear Stress in 200% Irregular Building:

The plate Center shear stresses increases with seismic zone. The plate Center shear stress along X axis i.e. (SQX) decreases by 3%, 1% and 3% and along Y axis i.e (SQY) decreases by 1%,2%, and 1% when shear wall is provided in G+10 200% irregular multi storied building at center in seismic zone III, IV and V respectively.

4.2.2 Discussion for Plate Center Shear Stress in 300% Irregular Building:

The plate Center shear stresses increases with seismic zone. The plate Center shear stress along X axis i.e. (SQX) increase by 79%, 84% and 85% and along Y axis i.e (SQY) increase by 83%,78%, and 83% when shear wall is provided in G+10 300% irregular multi storied building at center in seismic zone III, IV and V respectively.

4.3 Discussion for Peak Storey Shear in Regular Building

- Peak storey Shear by Square root of sum of square method increases by an average 95%, 50% & 95% when shear wall provided at centre in G+10 regular building in seismic zone III, IV & V respectively.
- Peak storey Shear by Square root of sum of square method increases by an average 95%, 90% & 87% when shear wall provided at centre in G+10 regular building in seismic zone III, IV & V respectively.
- Peak storey Shear by Square root of sum of square method increases by an average 85%, 80% & 75% when shear wall provided at centre in G+10 regular building in seismic zone III, IV & V respectively.

4.4 Discussion for Peak Storey Shear for 200% Irregular Building

- Peak storey Shear by Square root of sum of square method increases by an average 40%, 40% & 45% when shear wall provided at centre in G+10 regular building in seismic zone III, IV & V respectively.
- Peak storey Shear by Square root of sum of square method increases by an average 98%, 97% & 94% when shear wall provided at centre in G+10 regular building in seismic zone III, IV & V respectively.
- Peak storey Shear by Square root of sum of square method increases by an average 90%, 93% & 86% when shear wall provided at centre in G+10 regular building in seismic zone III, IV & V respectively.

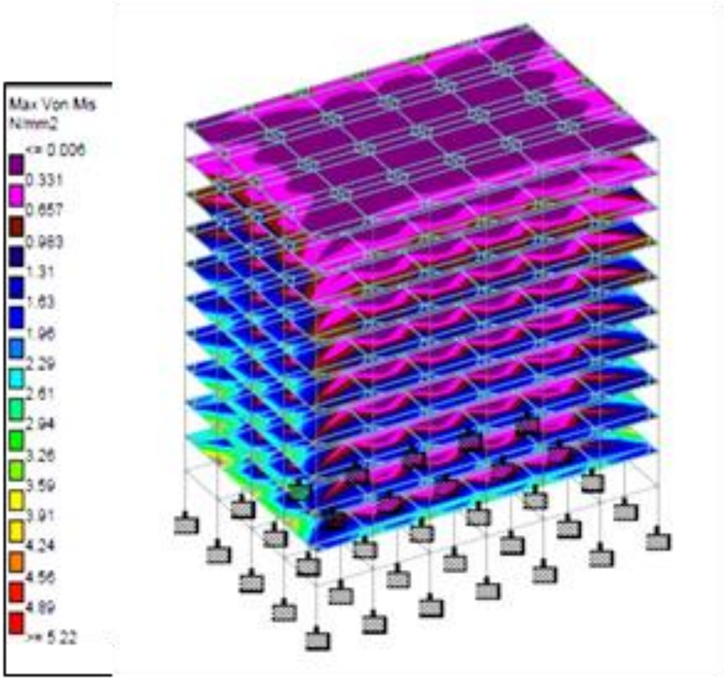


Figure 4.1: Stress diagram of regular Building without Shear wall (Ref. Staad output)

5. Conclusion

A structure will be classified as irregular if it contains irregular distributions of mass, strength and stiffness. The structural irregularity will be any classified as horizontal and vertical irregularity. Several existing buildings contain irregularity, and some of them are designed ab initio to be irregular to satisfy completely different functions e.g. basements for business functions created by eliminating central columns, and reduction of sizes of beams and columns within the higher stories to satisfy user requirements and for alternative business functions like storing significant mechanical appliances etc, and the following conclusions are drawn from the study:

- Effect on Flat slab center shear stresses SQX and SQY more increase when shear wall provided at the core in Regular & 300% irregular building and decreases in 200% irregular multi-storied building.
- The flat slab Von Mis top and bottom stresses increases when shear wall provided at the center in Regular building and decreasing in 200% irregular & 300% irregular multi-storied building.
- The flat slab Principal top and bottom stress increases when shear wall provided at the center in Regular building and decreasing in 200% irregular & 300% irregular multi-storied building.
- Total base shear increases when shear wall provides at the central periphery in 200% & 300% irregular multi-storey building. Mass of a building that is effective in lateral oscillation during earthquake shaking is called the seismic mass of the building. It is the total of its unstable lots at totally different floor levels. An increase in the mass of a building increases its natural period.
- Node displacement in the X direction will be more restricted when shear wall provides at the central periphery in all type of model i.e. regular & irregular building. As the height of the building increases, its mass increases but its overall stiffness decreases. Hence, the natural period of a building increases with an increase in height. Buildings.

- The values of storey drift are found to be within permissible limit i.e. not more than 0.004 times the storey height as per norms according to IS 1893:2002 Part-1.
- It concluded that the Structure with shear at the center is not suitable for the effect of Dynamic load on the performance of the building.
- As the height of building increases, its mass increases but its overall stiffness decreases. Hence, the natural period of a building increases with increase in height.

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