Scrutinizing the Structural Response of Regular and Irregular Structure (With and Without Shear Wall) Subjected to Seismic and Wind Loading

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Abstract— The spectacular increase in population, living in urban areas and their demands leads to housing problem in India. This results in the rise of multi-storey and high-rise building with irregular configuration. Past earthquake occurrences in India reveals that the buildings with irregular configuration are prone to earthquake damage. Therefore, it is obligatory to identify the seismic and wind response of structures with irregular shape in different zones of India. Shear Wall system is one of the most common systems used for lateral load resistance. It is necessary to identify the response of structure in different zones of India with and without Shear Wall. In the present study the main focus is to thoroughly examine and have a comparative study of the behavior of regular and irregular R.C building with and without shear wall for seismic and wind load activities in different zones of India. Analysis has been done in CYPE Software.

Keywords- *Seismic behaviour, plan irregular, vertical irregular, response spectrum, re-entrant corner, seismic zone, shear wall, lateral loading, ecccentricity, drift, forces, CYPECAD.*

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I. INTRODUCTION

In the modern-era major buildings are irregular in both plan and vertical configuration. Irregularities in plan and vertical configuration leads to notable eccentricity between mass and stiffness center and forms lateral response due to which damage occurs. Therefore, careful structural analysis is needed for irregular structure to reach suitable behavior during earthquake and wind load. For same region, earthquake and same configuration damages in structures are not equal hence lots of care should be taken for structures.

However from past earthquake occurrences most of the damages are related to architectural and structural configuration in plan and elevation. The effect of seismic force in irregular structures were observed in many past earthquakes. Most of the literature gives an approximate detail and the prevention of effect are briefly described. Therefore it is necessary to conduct a large and broad investigation.

Lateral force resisting system is a component of the building to resist seismic force. There may be different types of lateral force resisting system but shear wall is one of the most common lateral load resisting system. In a buildings damage initially occurs in a structurally weak plane. These weaknesses further leads to structural collapse. These weakness is mainly because of structural irregularities in a building system.

Earthquake and wind load causes a dynamic action, but the design for wind and earthquake are totally different. Earthquake ground motion effects the base initially but in case of wind pressure the effect will be on exposed area. Hence the loading due to earthquake is known as displacement-type loading and the loading due to wind load is known as force-type loading.

The main objective of this study is to analyze R.C structures (regular and irregular structure) with and without shear wall by response spectrum analysis and wind analysis using CYPE software. Parameter such as time period, center of mass and center of stiffness, base shear, mode shapes and drifts are calculated and compared. Comparing quantity analysis for different models is also done. The model analysis is conducted to know the response of a structure with shear wall.

II. EARLIER RESEARCH

Amin Alavi and P.Srinivasa Rao (2013) have carried out an analytical study on effect of plan irregularity for R.C Buildings in high seismic zone. The result of analysis have revealed that building with severe irregularity are more vulnerable than those with less irregularity and the center of mass and resistance has a significant impact on seismic response of structure especially in high seismic zones.

M.C.G Pastor and C.F Fernandez (2011) have done an analytical investigation with different international standards of buildings subjected to seismic loads. This paper concludes that the structural reinforcement not only depends on the forces produced by the action to which the structure is subjected, but also depends on seismic requirement for reinforcement specified by the standards codes.

Ashraf et al. (2008) conducted a study to determine the optimum configuration of a multi-story building by change in shear wall location that it is very fruitful against seismic induced torsion. It was concluded from the study that non-uniform placement of stiff elements cause the structure more harm than good by introducing torsion besides increase in beam and column moments due to their off-center locations.

Ehsan Salimi Firoozabad et al. (2012) have done an analytical study on the effect of shear wall configuration on RCC Building taking seismic load into consideration. This paper conclude that position of shear wall can reduce the drift of building and that the quantity of shear wall does not guarantee a better seismic behavior for R.C buildings.

S. Varadharajan et al. (2013) reviewed past research work on different structural irregularities in buildings Review of research works with respect to plan irregularities are done in this paper. Single story building model, multi-story plan asymmetric structures and vertical irregularity are also discussed. Chandler Hutchison (1992) said that different codes of practice yielded different results. De-La Colina (1999) described that for stiff-torsionally unbalanced element the ductility demand increases with time period and for flexible-torsionally unbalanced element the ductility demand decreases with time period. Dutta das (2002) said that the strength and stiffness irregularities are interdependent. In case of multistory plan asymmetric structures Chopra Goel (2004) said that the accuracy decreases with the increase in magnitude of torsional coupling. Stefano et al. (2006) said that the seismic response is influenced by over-strength factor. In case of vertical irregularity Ruiz and Diedrich (1989) said that the infill wall behavior is mainly influenced by time period of seismic excitation. Chintanpakdee Chopra (2004) concludes that irregularities in lower story has high displacement compared to upper story. Fragiadakis (2006) concluded his paper by saying that the seismic response depends on the type of structural irregularities. Further in his paper, the author has summarized the list and listed the advantages and disadvantages based on different researchers. The structural irregularity and the change the seismic response has also discussed. On comparing research work large number of research has done for plan irregularity then vertical irregularities.

III. IRREGULARITIES IN INDIAN CODE(1893)

The irregularities is classified as horizontal and vertical irregularities as shown in Fig 1.

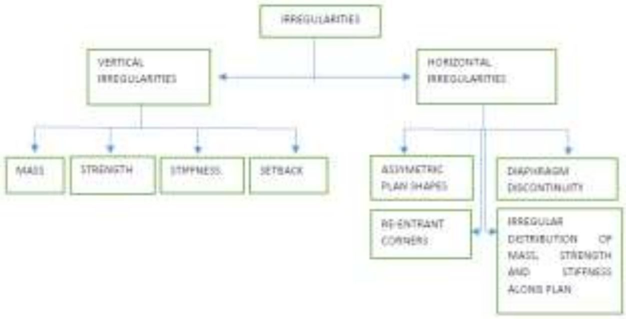

Fig 1: Irregularities Classification

The structure is considered as irregular as the structure exceeds the limits prescribed in codes. Irregularity limits by IS 1893:2002 is shown in Table 1.

Table 1: Irregularity limits by IS 1893:2002

Types of Irregularities		**IS 1893:2002**
	Horizontal	
a)	Re-entrant corners	Re-entrant corners <= 15%
b)	Torsional irregularity	Maximum drift computed at a particular storey <= 1.2(Average of drifts computed at both sides of a structures)
c)	Diaphragm Discontinuity	Open area in diaphragm > 50% Diaphragm stiffness > 50%
	Vertical	
a)	Mass	Mass of i^{th} storey < 2*(Mass of storey adjacent to i^{th} storey)
b)	Stiffness	Stiffness of i^{th} storey < 0.7(Stiffness of $i+1^{th}$ storey) Stiffness of i^{th} storey < 0.7(Stiffness of $i+1^{th}$ storey) Stiffness of i^{th} storey < 0.8(Stiffness of $i+1^{th}$ storey)
c)	Setback	Setback of i^{th} storey < 1.5(Stiffness of adjacent storey)

IV. METHODOLOGY

Analysis of a structure can be done by linear and non-linear method which includes dynamic and static method. If a structural loading is small, linear dynamic and static analysis is considered for analysis. The main difference between this analyses lies in the magnitude and distribution of lateral forces over the height of a structure. In the dynamic analysis the lateral forces are found from the properties of the natural vibration modes of the building, which are determined by the distribution of mass and stiffness over height. In the equivalent lateral force procedure the magnitude of forces is based on an estimation of the fundamental period and on the distribution of forces as given by a simple formula given in the codes.

The analysis of structure is done by using CYPECAD software. The different configuration position of shear wall in Reinforced Concrete building were analyzed for under seismic and wind analysis. The data used is as per Seismic definition (IS: 1983-2002) and Wind definition (IS: 875 Part 3).

V. LOCATION OF SHEAR WALL

Location of Shear Wall is an important part which effects the response of a structure. Shear wall is a good mechanism for lateral loads resisting, but the placement of shear walls should be made judiciously. In case of regular structure, shear walls at mid-sides perform better in major number of cases (Anshul Sud et at.,2014). Incorporation of shear walls improves the seismic performance of the building with re-entrant corner i.e. plan irregularity buildings and strengthening the inner notch was found to be much efficient compared to strengthening outer notch (Divyashree M et at. (2014)). In case of vertical irregularity, placement of shear wall mainly depends on the location of centre of mass and centre of rigidity.

VI. STRUCTURAL PROPERTIES

Six-storey RC office structure is assumed to be located in seismic zone-II, zone-III, and zone-IV on medium soil with each storey being of height of 3m. Grade of concrete considered for all structure is M25 and grade of steel as Fe415 and thickness of slab as 150mm. It is designed as ordinary moment-resisting frame. With shear wall and without shear wall structure are considered. These frames are subjected to dead load of 1.5 kN/m^2, live load of 2 kN/m^2 on all floors, wall load of 12 kN/m^2, parapet load of 5kN/m^2 on roof (as per IS 875-part-2) earthquake loads as per IS 1893:2002 and wind load as per IS 875 Part 3. These structures are analysed for more than 45 load combinations.

For the calculation, Importance Factor ‘I’ equal to 1, Response reduction factor ‘R’ as 3 and Damping Ratio as 5 is considered for all structures. In case of wind analysis Terrain Category is taken as I (Exposed open terrain with few or no obstructions and in which the average height of any object surrounding the structure is less than 1.5 m) and Land Orography is taken as flat.

VII. MODELLING

Six structures have been considered with one regular and two irregular as shown in figure 2. Shear wall are considered for all buildings and analysed again. The buildings are considered in zone II, zone III and zone IV. The model has been analysed and designed based on Indian Standard Codes using CYPECAD software. For regular structural in x-direction there are 5 bays, each of 5 m width and in z-direction also there are 5 bays, each of 5 m width. For Plan irregular structure it has 64% re-entrant corner in L shape and in case of vertical irregular structure irregularity taken is 80 % as per IS 1893:2002

Zone 2:

Zone Area- Bangalore
Beam Dimension-230X450mm
Column Dimension-230X900mm
Basic Wind Speed-33 m/s

Zone 3:

Zone Area-Ahmedabad
Beam Dimension-230X650mm
Column Dimension-300X900mm
Basic Wind Speed-39 m/s

Zone 4:

Zone Area-Darjeeling
Beam Dimension-230X650mm
Column Dimension-300X900mm
Basic Wind Speed-47 m/s

Shear Wall:

Shear Wall has been taken with different shape depending on the type of structures. Number of shear wall provided also varies by structures as shown in fig 3.

Regular:

Shape- Normal
Number of shear wall provided- 4
Thickness-300mm
Length-5.3m

Plan irregular:

Shape- L shaped
Number of shear wall provided- 1
Thickness-300mm
Dimension-5.5X5.5m

Vertical irregular:

Shape- Normal
Number of shear wall provided- 1
Thickness-300mm
Length-15.3m

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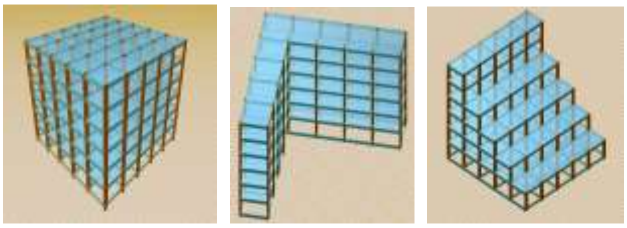
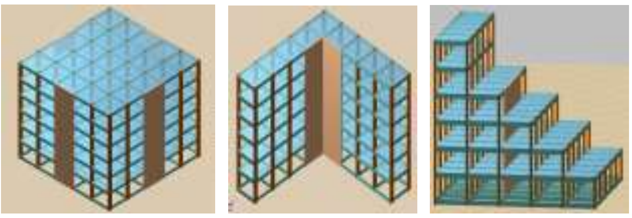


a) Regular b) Plan Irregular c) Vertical Irregular

Fig 2: Structures without shear-wall



a) Regular b) Plan Irregular c) Vertical Irregular

Fig 3: Structures with shear-wall

VIII. RESULTS AND DISCUSSIONS

The fundamental natural periods, base shear, center of mass and center of stiffness, roof top displacement, drifts, have been considered to identify the dynamic properties of the building analyzed. Wind load has also been considered to identify the response of a structures. A comparison of the quantities of reinforcement is done which is obtained from each structure by using the amount of reinforcing steel per meter square in CYPECAD. The analysis of the reinforcement amounts was calculated using groups based on geographical proximity as well as the concrete code used in the calculation.

Result obtain from the analysis are recorded in tabular form with respect to different zones for the following cases.

Case 1: Regular Structure
Case 2: Plan Irregular Structure
Case 3: Vertical Irregular Structure
Case 4: Regular Structure with Shear Wall
Case 5: Plan Irregular Structure with Shear Wall
Case 6: Vertical Irregular Structure with Shear Wall

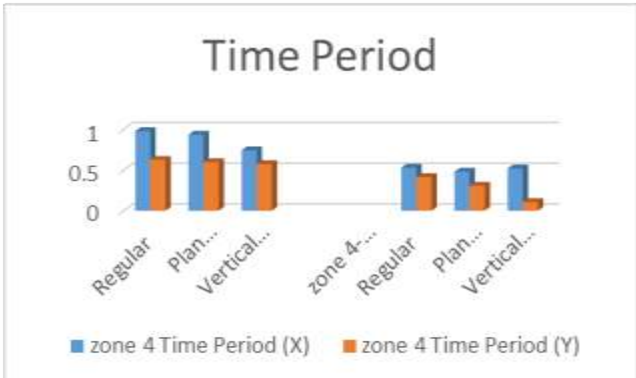


Fig 4: Comparison of Time Period

Fig 5: Comparison of Base Shear for zone 2

Fig 6: Comparison of Base Shear for zone 3

Fig 7: Comparison of Base Shear for zone 4

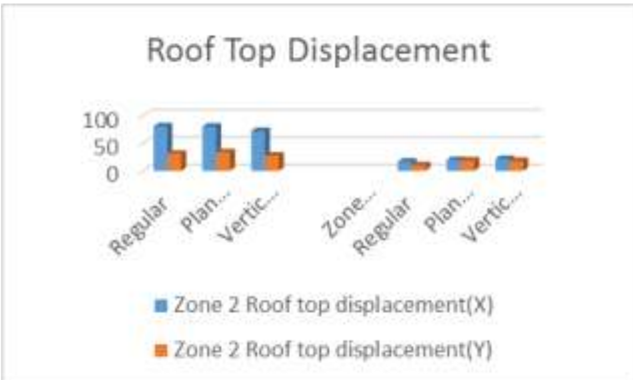


Fig 8: Comparison of Roof Top Displacement for zone 2

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Fig 9: Comparison of Roof Top Displacement for zone 3

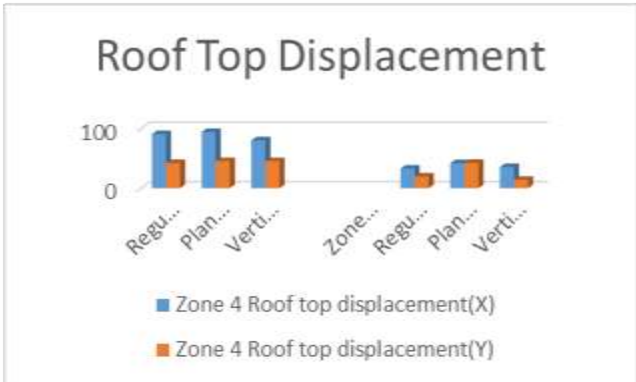

Fig 10: Comparison of Roof Top Displacement for zone 4

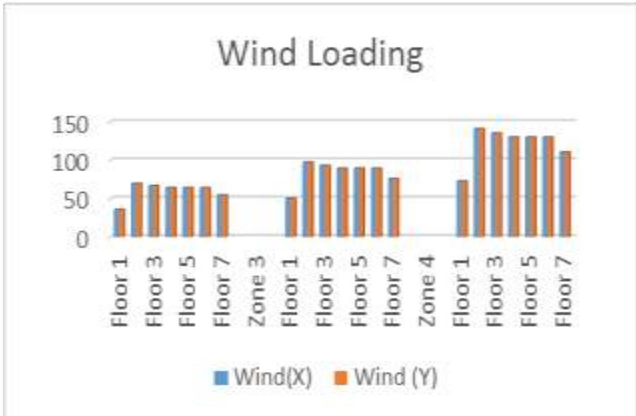

Fig 11: Comparison of Wind Load for different zone of India

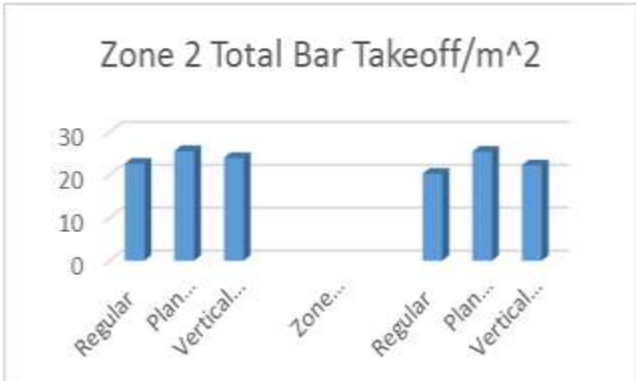

Fig 12: Comparison of Total reinforcement required/m^2 for zone 2

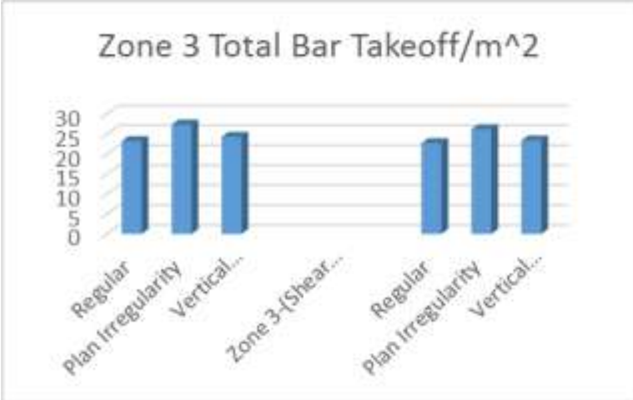

Fig 13: Comparison of Total reinforcement required/m^2 for zone 3

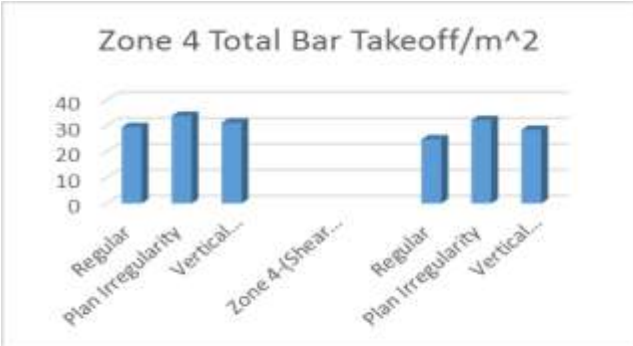

Fig 14: Comparison of Total reinforcement required/m^2 for zone 4

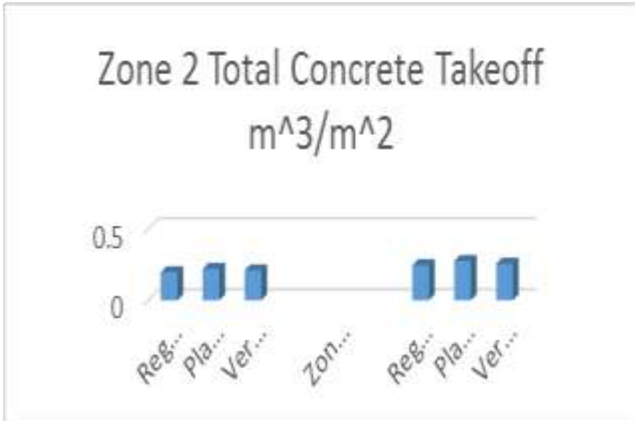

Fig 15: Comparison of Total Concrete quantity required for zone 2

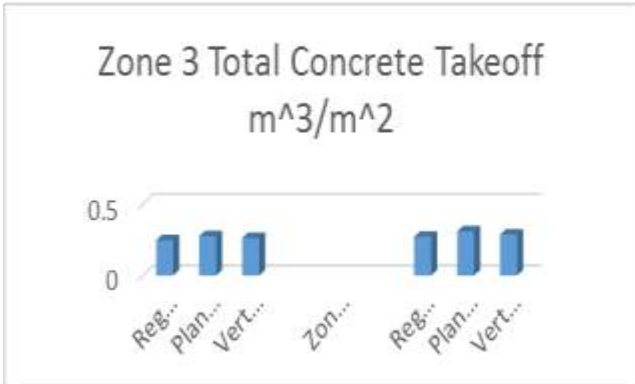

Fig 16: Comparison of Total Concrete quantity required for zone 3

Fig 17: Comparison of Total Concrete quantity required for zone 4

IX. CONCLUSION

For an accurate result, comparison has been done with respect to zones. The study of regular and irregular structure with and without shear wall in different zones of India leads to the following conclusions:

1. On structural capacity under earthquake and wind loading regular structure shows better performance as compared to irregular structure.
2. Regular structure will have 4-16 % higher time period as compared to irregular structure.
3. Regular structure will have 20-50 % higher base shear as compared to irregular structure.
4. Plan Irregular structure will have 4-14 % higher roof top displacement as compared to regular and vertical irregular structure.
5. Introduction of shear wall in regular and irregular structure shows good structural capacity under earthquake and wind loading.
6. Shear Wall can reduce the time period for regular as well as irregular structure and time period can be reduced by 45-50 %.
7. Shear Wall will increase the base shear for regular as well as irregular structure and the base shear is increased by 20-25%.
8. Shear Wall will reduce roof top displacement for regular as well as irregular structure by 70-80 %.
9. Total reinforcement required/m^2 for regular structure will be 5-15 % less as compared to irregular structure and the placement of shear wall can reduce the total reinforcement required/m^2 by 2-10%.
10. Total concrete quantity required/m^2 for regular structure will be 4-10 % less as compared to irregular structure and the placement of shear wall can increase the total concrete quantity required/m^2 by 10-15 %.

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