iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 11 **Issue:** VII **Month of publication:** July 2023

DOI: https://doi.org/10.22214/ijraset.2023.55120

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 11 Issue VII Jul 2023- Available at www.ijraset.com

Tortional Effect in Vertically Mass Irregular RC Frame Structure under Response Spectrum Analysis

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Abstract: The structures having discontinuity like distribution of mass, stiffness and geometry of the structure are termed as Irregular structures. Irregular structures contribute a large portion of urban infrastructure. The past earthquakes have shown catastrophic effect on the buildings with irregularities. It was seen that the buildings with irregularities are more prone to earthquake then the regular building. In the present study a special case of vertical mass irregularity are discussed. Six different models including three basic cases of buildings models i.e. vertically regular structure, vertically irregular structure and vertically irregular structure with shear wall at different position are taken for analysis by Response spectrum. It has observed that, the torsion, base reaction, displacement and modal load participation ratio in structure. This study exhibits effect of mass variation aspect of RCC structure.
Keywords: Vertically irregular structure, mass irregularity, Response spectrum analysis, torsion, displacement

I. INTRODUCTION

In past, several major earthquakes have exposed the short comings in buildings, which leads to damage or collapse. It has been found that regular shaped buildings perform better during earthquakes. The structural irregularities cause non-uniform load distribution in various members of a building. There must be a continuous path for these inertial forces to be carried from the ground to the building weight locations. A gap in this transmission path results in damage of the structure at that location. The damage in a structure generally initiates at location of the structural weak planes present in the building systems. These weaknesses trigger further structural deterioration which leads to the structural collapse. These weaknesses often occur due to presence of the structural irregularities in stiffness, strength and mass in a building system. The structural irregularity can be broadly classified as plan and vertical irregularities. The structures having this discontinuity are termed as Irregular structures. Irregular structures contribute a large portion of urban infrastructure. Vertical irregularities are one of the major reasons of failures of structures during earthquakes. For example structures with vertical geometric change, soft storey and weak storey were the most notable structures which collapsed. So, the effect of vertically irregularities in the seismic performance of structures becomes really important. Height-wise changes in stiffness and mass render the dynamic characteristics of these buildings different from the regular building, when such buildings are constructed in high seismic zones, the analysis and design becomes more complicated.

II. DEFINITION OF VERTICALLY IRREGULAR STRUCTURES

A. IS 1893 definition of Vertically Irregular structures:

There are two types of irregularities

1) Plan Irregularities
2) Vertical Irregularities

Vertical Irregularities are mainly of five types-

a) *Stiffness Irregularity*

- *Stiffness Irregularity:* Soft Storey-A soft storey is one in which the lateral stiffness is less than 70 per cent of the storey above or less than 80 per cent of the average lateral stiffness of the three storeys above.
- *Stiffness Irregularity:* Extreme Soft Storey-An extreme soft storey is one in which the lateral stiffness is less than 60 per cent of that in the storey above or less than 70 per cent of the average stiffness of the three storeys above.

b) *Mass Irregularity:* Mass irregularity shall be considered to exist where the seismic weight of any storey is more than 200 per cent of that of its adjacent storeys. In case of roofs irregularity need not be considered.

c) *Vertical Geometric Irregularity:* A structure is considered to be Vertical geometric irregular when the horizontal dimension of the lateral force resisting system in any storey is more than 150 per cent of that in its adjacent storey.

d) *In-Plane Discontinuity in Vertical Elements Resisting Lateral Force:* An in-plane offset of the lateral force resisting elements greater than the length of those elements.

e) *Discontinuity in Capacity:* Weak Storey-A weak storey is one in which the storey lateral strength is less than 80 per cent of that in the storey above.

III.RESPONSE OF VERTICALLY IRREGULAR STRUCTURE

A building structure may collapse or suffer severe damage under the action of seismic forces due to sudden change in mass, stiffness and strength along vertical plane. Presence of structural irregularities triggers the structural collapse. The some author gives literature reviews of building performance that have occurred during the past earthquakes due to presence of different vertical structural irregularities.

Although irregular buildings are preferred due to their functional and aesthetic considerations is evident from examples of realistic existing irregular buildings. The past earthquake records show poor seismic performance of these structures during earthquakes as discussed in the next section.

The effect of increased mass at the top or bottom of the structure tended to increase the median peak forces demands compared to regular structures for the record suite considered. When the increased mass is present at the mid-height, the structures generally tended to produce lesser forces demands in between than the corresponding regular structures. A simple equation was developed to estimate the increase in interstorey forces demand due to mass irregularity. This can be used to set irregularity limits.

IV.TYPES OF CASES USED FOR ANALYSIS OF STRUCTURE

A. Type of Case

There are six different cases considered to analysis 10-storey structure.

1) *Model 1:* Vertically Irregular Building Model, Building model has four flats on each floor up to 10 storeys including garden floor at 3rd storey and fire exit area floor at 6th storey which gives mass irregularity to the building.
2) *Model 2:* Vertically Regular Building Models, Building model is same as considered in building Model I but there is no extra amenities provided on upper floor which gives regular flats to the building.
3) *Model 3:* Vertically Irregular Building model with 230mm Shear Wall at position 1(Lift position), Building model has four flats on each floor up to 10 storeys, including garden floor at 3rd storey and fire exit area floor at 6th storey (same as considered in Model I).Further incorporated shear wall at position 1 of the building.
4) *Model 4:* Vertically Irregular Building model with 230mm Shear Wall at position 2, Building model has four flats on each floor up to 10 storeys, including garden floor at 3rd storey and fire exit area floor at 6th storey (same as considered in Model I).Further incorporated shear wall at position 2 of the building.
5) *Model 5:* Vertically Irregular Building model with 230mm Shear Wall at position 3, Building model has four flats on each floor up to 10 storeys, including garden floor at 3rd storey and fire exit area floor at 6th storey (same as considered in Model I).Further incorporated shear wall at position 3 of the building.
6) *Model 6:* Vertically Irregular Building model with 230mm Shear Wall at position 4, Building model has four flats on each floor up to 10 storeys, including garden floor at 3rd storey and fire exit area floor at 6th storey (same as considered in Model I).Further incorporated shear wall at position 4 of the building.

B. Structural Data

Building consists of 19 m in short direction and 19 m in long direction, Brick masonry wall is provided with 230 mm thickness for all models. And 1.5m height parapet wall is also considered. Storey height is kept as 3m for bottom storey and all upper floors. Grade Fe-500 hot rolled deformed steel is used. Concrete having M-30 (E=5000√fck as per IS456) strength for columns, beams and slabs is to be employed. Columns were kept of 9”x32” (230x810mm) size for overall structure. All beams are of uniform size of 9″ × 24″ (230 × 600mm) having 5″ (125 mm) thick slab for all the spans. And 230 mm thick shear walls are used for different building models.

ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
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1) Gravity loading

Gravity loading consists of dead and live loading. Dead loading can be predicted reasonably accurately from the designed member sizes and material densities. Dead load due to structural self-weights and superimposed dead loads are as follows:

Dead Load (DL):

Intensity of wall (External & Internal wall)	= 12.34 KN /m (for 3m height)	
Intensity of parapet wall	= 7.71 KN /m (for 1.5m height)	
Intensity of floor finish load	=1 KN /m2	
	=2.7 KN /m2	(150mm sunk)
	=3 KN /m2	(Staircase slab)
Intensity of amenities	= 5 KN /m2	(Garden floor slab)
	= 1 KN /m2	(Fire exit floor slab)

Live load (LL):

Intensity of live load	=3 KN /m2	
	=5 KN /m2	(Staircase slab)

2) Lateral loading

Lateral loading consists of earthquake loading. Earthquake loading has been calculated by the program and it has been applied to the mass centre of the building. Since the building under consideration has in ZonesV with standard occupancy so the total base shear was computed as follows:

Load Case:

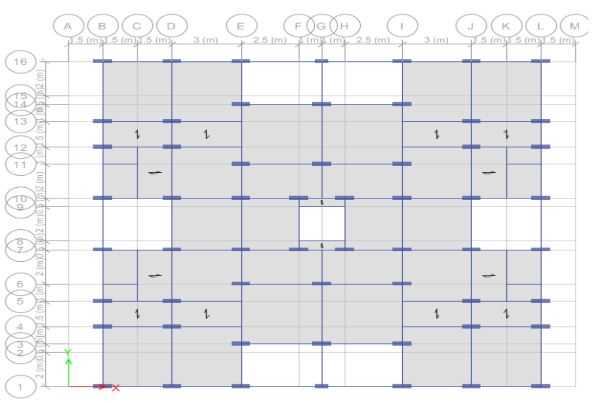
- SPECX
- SPECY

Period Calculation: Program Calculated

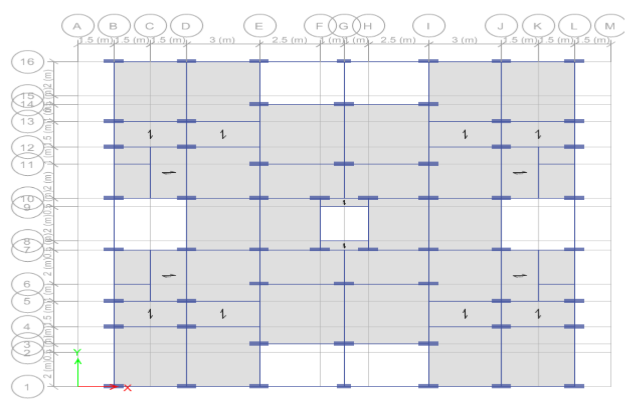
Top Storey: Storey- 10
Fire exit area: Storey -6
Garden area: Storey - 3
Bottom Storey: Base
Response reduction factor, R = 5
Importance factor, I = 1
Building Height H = 30 m
Soil Type = II (Medium Soil)

3) Building under Consideration

The building under consideration is a 10 storied of residential building, as shown in following figures with all considered cases.



Model 1



Model 2

Fig. 1 Plan of considered basic Model 1& Model 2

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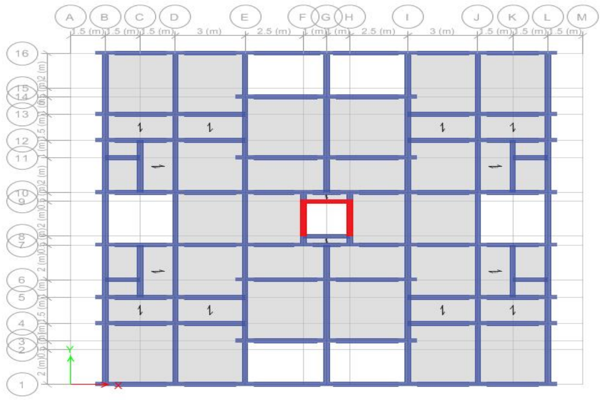
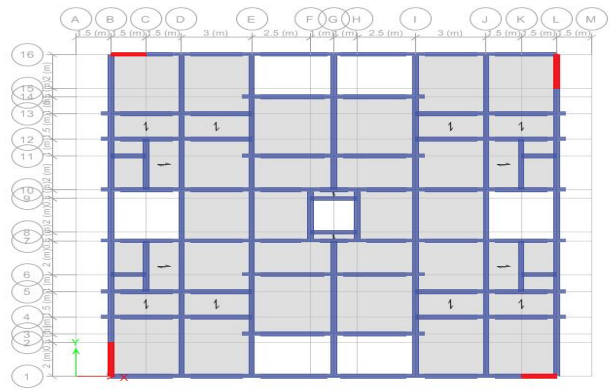
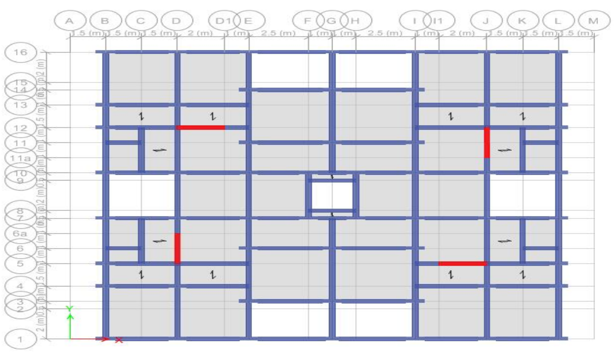


Model 3

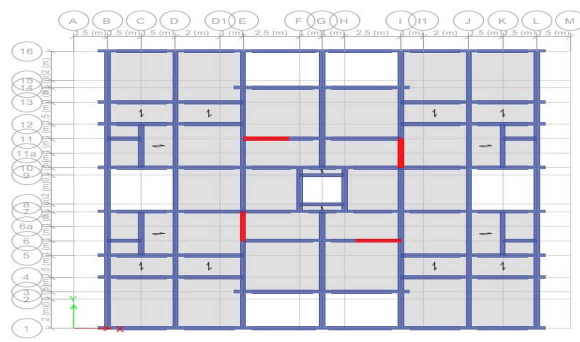


Model 4

Fig. 2 Plan of considered Model 3 & Model 4



Model 5



Model 6

Fig. 3 Plan of considered Model 5 & Model 6

V. RESULTS

A. Result obtained using Response Spectrum method

1) Torsion in Building Model.

TABLE I
COMPARISON OF TORSIONAL VALUES FOR SPECX

	Comparison of Torsion values (KNm) per storey for SPECX (Without & With 230mm SW)				
Storey	Model 1	Model 3	Model 4	Model 5	Model 6
10	5595.1432	6317.73	5749.1562	5654.652	5841.2663
9	13705.2572	15265.7827	14005.2772	13770.8676	13470.6991
8	20517.978	22642.7835	20897.9828	20586.449	20155.2723
7	26288.639	28880.9907	26727.9818	26379.03	25861.8255
6	29807.566	32709.5504	30297.1718	29934.5014	29445.0183
5	34028.3499	37217.0736	34548.602	34152.5934	33558.3286
4	37640.986	41031.6423	38172.1951	37722.5282	37046.0511
3	40283.403	43794.8296	40806.6637	40291.7343	39658.6682
2	42393.7323	45945.7958	42880.8714	42276.3951	41620.2772
1	43302.3336	46859.6923	43752.6371	43087.4235	42426.4062

ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
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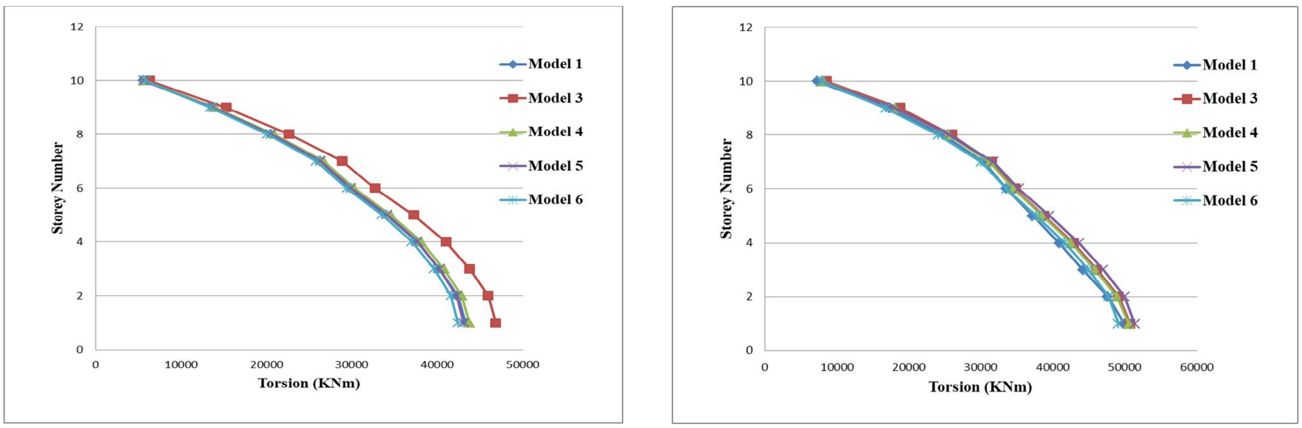
TABLE III. COMPARISON OF TORSIONAL VALUES FOR SPECY

	Comparison of Torsion values (KNm) per storey for SPECY (Without & With 230mm SW)				
Storey	Model 1	Model 3	Model 4	Model 5	Model 6
10	7260.2124	8555.763	8121.2101	7924.5729	7834.9997
9	17281.1345	18801.6616	18126.1362	18059.8088	16802.7715
8	24813.5624	25930.5264	25523.6552	25657.3448	24146.5008
7	30467.1012	31527.0807	31264.6133	31755.8759	30061.3282
6	33534.3603	34750.2064	34527.3937	35265.933	33580.0137
5	37181.1961	38757.7617	38525.5399	39519.1373	37694.7908
4	40864.2967	42822.3729	42532.681	43665.1079	41636.8169
3	44178.9496	46099.1864	45869.5919	46970.2725	44918.8281
2	47599.4928	49111.9	48908.3361	49943.62	47716.1137
1	49952.0656	50714.6461	50571.0903	51397.0845	49125.8166



FOR SPECX FOR SPECY

Fig. 4 Comparison of Torsion values of Models 1, 3, 4, 5 & 6 for SPECX & SPECY respt. with respect to storey numbers

2) Maximum Lateral Displacement

TABLE IIIII

COMPARISON MAXIMUM DISPLACEMENT FOR SPEC-X OF MODELS 1, 3, 4, 5 & 6

Maximum displacement in X-direction						
Storey	Storey Height (m)	Model 1 (mm)	Model 3 (mm)	Model 4 (mm)	Model 5 (mm)	Model 6 (mm)
10	30	22.778	22.676	22.286	20.674	21.56
9	27	21.843	21.523	21.221	19.749	20.52
8	24	20.468	19.934	19.835	18.447	19.096
7	21	18.622	17.924	18.002	16.73	17.261
6	18	16.369	15.55	15.777	14.649	15.061
5	15	13.809	12.907	13.241	12.285	12.579
4	12	10.971	10.046	10.447	9.676	9.862
3	9	7.919	7.071	7.462	6.891	6.986
2	6	4.768	4.144	4.402	4.055	4.092
1	3	1.787	1.521	1.531	1.46	1.472
Base	0	0	0	0	0	0

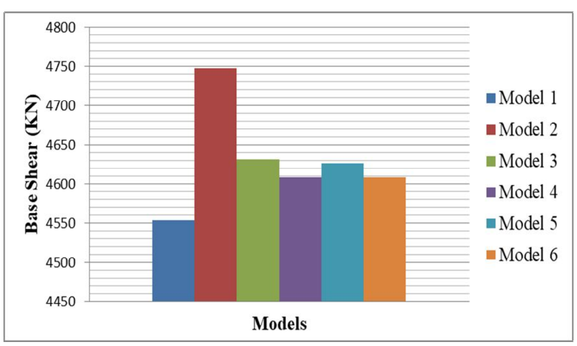
TABLE IVV
COMPARISON MAXIMUM DISPLACEMENT FOR SPEC-Y OF MODELS 1, 3, 4, 5 & 6

Maximum displacement in Y-direction						
Storey	Storey Height (m)	Model 1 (mm)	Model 3 (mm)	Model 4 (mm)	Model 5 (mm)	Model 6 (mm)
10	30	66.769	48.218	54.021	45.484	48.807
9	27	65.081	44.993	51.568	43.214	46.956
8	24	61.804	41.022	48.08	40.159	44.194
7	21	57.106	36.395	43.602	36.282	40.413
6	18	51.206	31.145	38.205	31.665	35.694
5	15	44.564	25.479	32.148	26.511	30.238
4	12	36.958	19.472	25.405	20.853	24.064
3	9	28.422	13.376	18.135	14.839	17.292
2	6	19.14	7.61	10.738	8.76	10.236
1	3	9.195	2.785	4.038	3.216	3.7
Base	0	0	0	0	0	0

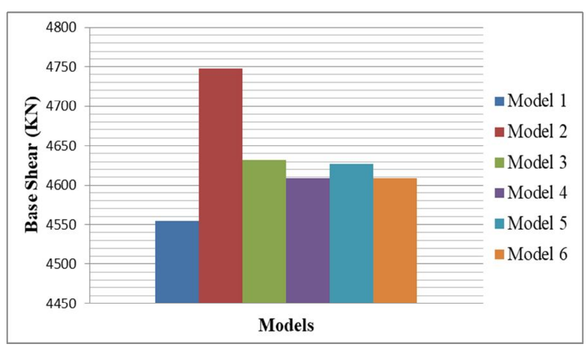
3) Base Shear

TABLE V
BASE SHEAR OF MODEL 1,2,3,4,5 &6

Model	SPECX (KN)	SPECY (KN)
Model 1	4553.9167	4553.917
Model 2	4747.9675	4747.9832
Model 3	4631.6142	4631.6142
Model 4	4608.2778	4608.2778
Model 5	4626.8977	4626.8977
Model 6	4608.2778	4608.2778



Along X-direction



Along Y-direction

Fig. 5 Comparison of Base Shear values of Models 1, 3, 4, 5 & 6 for SPECX & SPECY respt.

4) Fundamental Natural Period

TABLE VI
FUNDAMENTAL NATURAL PERIODS

Models	Fundamental Natural Period (sec)			
	X-direction		Y-direction	
	Code	Analysis	Code	Analysis
Model 1	0.61	1.523	0.61	1.523
Model 2	0.61	1.554	0.61	1.554
Model 3	0.61	1.203	0.61	1.203
Model 4	0.61	1.313	0.61	1.313
Model 5	0.61	1.191	0.61	1.191
Model 6	0.61	1.252	0.61	1.252

VI. CONCLUSION

A study has been carried out to determine the optimum configuration of an ten story building by changing shear walls location. Four different cases of shear wall position for an ten storey building have been analyzed by Response Spectrum analysis as a space frame system using a standard package ETAB subjected to lateral and gravity loading. The typical 230mm thickness of shear wall is also used in considered cases. This study leads to following conclusions:

For more simplified way to understand behavior of structure, also shown comparison of all models having same shear wall thickness with basic vertically irregular building model in Table I & Table II for SPECX-direction and SPECY-direction respectively. It can be seen from that in case of Model6 (230mm Shear Wall at position 4) has reduced torsional value globally by 2% & 1.65% respectively than the basic vertically irregular building Model 1. This is best location found to minimized torsion than other position of shear wall in building models

It is observed that, torsional values of structure for shear wall at lift is much greater than a structure without shear wall so the purpose of providing shear wall is not fulfilled. It increases torsional value in both directions. And instead of shear wall position at lift, shear wall at position 4 gives better results, it reduces significant torsional value. Hence the eccentricities due to shear wall location are more significant to the torsional behavior of structures during an earthquake.

It can be seen from maximum displacement Tables that in case of Model 5 (230mm Shear Wall at position 3) has minimum displacement value by 10% & 32% than the basic vertically irregular building Model 1 along X direction & Y direction respectively. Similarly Model 6 (230mm Shear wall at position 4) has also minimum displacement value than the other building models having same shear wall. Lateral displacement values obtained from analysis indicate that shear wall proper provision along longitudinal and transverse directions are effective in reducing the displacement values in the same directions.

Vertically irregular building models with shear wall have maximum base shear when compared to irregular building model where shear wall is absent. Indicating these models is stiffer than without shear wall model (Model 1).

From analysis, shorter fundamental periods is obtained in the form of seconds for shear wall building models that means to attract higher forces than the without shear wall model. So it concludes that these building models have more strength against the lateral loads to stable the structure.

VII. ACKNOWLEDGMENT

I would like to acknowledge my deep sense of gratitude to Prof. V. M. Sapate Sir, my Guide, Department of Civil Engineering, G H Raisoni University, Amravati for his guidance and encouragement. He gladly accepted all the pains in going through my work again and again and gave me opportunity to learn essential research skills. This study would not have been possible without his insightful and critical suggestions, his active participation in constructing right models and a very supportive attitude. I will always remain grateful to him forgiving right direction to my research study.

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