Parametric Study on Seismic Behaviour of Multi-Storey Flat Slab Building Incorporated with Mass Irregularity with and without Shear Walls.

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Abstract – *The present study focuses on study on seismic performance of mass irregular flat slab models. In our surroundings we may observe certain mass irregular buildings like an academic building which has got library at one storey or has got store room installed. Also factories having bulk machines installed or apartments with swimming pool installed at one storey level. These structures may also exist in seismic zones. Hence the present study tries to summarize the effect of mass irregularity and also the most optimal position for placement of shear wall. Firstly a 15 storey regular 9x5 bay building is modeled & mass irregularity is incorporated at various storey levels and shear wall is placed at different locations like at corner, central periphery, core & at both core & centre .Then accordingly all the models are analyzed by using response spectrum analysis which is a linear dynamic analysis method. The analysis outcome furnishes a more realistic behavior of structure response.*

Key Words: *Mass irregularity, Shear wall, Flat slab, Response spectrum method, Drift, Displacement, Mode period*

1. INTRODUCTION

In this investigation seismic performance of a regular 9x5 bay flat slab building with an opening exactly at the centre(of size 5x5m) is modeled .Span of each bay is 5m & for each storey height of 3m is adopted. Loads are applied as per the codal provisions. Then vertical mass irregularity is incorporated at different floor levels & models are framed. For each model with mass irregularity at certain floor level shear wall at different location is placed & the modeling is done .This is the procedure adopted for modeling. In the present work a total of 28 models are done. Etabs 2016 is the software used for analysis in the study.

1.1 Mass Irregularity

Occurrence of large bulky mass on a floor results in mass irregularity. Dynamic response of the structure is largely affected by mass irregularity occurrence this condition is observed in factories where heavy and bulky machineries are installed. It also can occur in buildings that has large storage rooms(mechanical rooms), Swimming pools, library, Store rooms of shopping malls and so on. Mass irregularity mass exist as vertical mass irregularity or plan mass irregularity. IS 1893(2002) states that mass irregularity intend to exist where the seismic weight of a floor is more than 200 % of that of its next floor. In case of roofs the irregularity shall be neglected. Seismic Weight of a storey is calculated as its full dead load + applicable amount of live load.

1.2 Flat slab

Flat slab is a RCC slab sustained on concrete columns, here the use of beams is almost eliminated. It is also referred as beamless slab. Flat slab system is a floor system which is uncomplicated to construct & is efficient in terms of functionality. For a given number of stories, it needs minimal building height. Usually four types of flat slabs are constructed; Simple flat slab, Flat slab with drop panels ,Flat slab with column heads, Flat slab with both drop panels &column heads. Adoption of flat slabs requires less time for construction when compared to other flooring system. Also these floor system is preferably easy to install. The major noticeable disadvantages of flat slab system are the thickness of flat slab is slightly on the higher side when compared to ordinary floor slabs, it is not possible to have large spans in case of flat slab

1.3 Shear walls

It is a structural system comprising of parallel walls which opposes lateral loads acting on a building. Shear walls are mostly designed to carry wind & seismic loads these are easy to construct & extra plastering or finishing is also not needed as the wall itself gives a high level of precision if longitudinal & transverse reinforcement are properly provided the shear wall can achieve the necessary strength to avoid the structural damage under earthquakes. Hence Shear wall is an effective lateral load resisting system. Studies shows that it is economical up to 35 stories

2. Modelling

The whole study is divided into 2 streams so that the analysis results becomes easily comparable and one gets better picture of the project. In the first course a total of 13 models were prepared with varying % of vertical mass irregularity.4 models were created with 150% vertical mass irregularity enforced at 5th storey ,at 10th storey at 15th storey and at all the 3 storeys (i.e at 5th ,10th and 15th storey levels). 4

models were created with 200 % vertical mass irregularity enforced at 5th storey ,at 10th storey at 15th storey and at all the 3 storeys (i.e at 5th ,10th and 15th storey levels). 4 models were created with 250 % vertical mass irregularity enforced at 5th storey ,at 10th storey at 15th storey and at all the 3 storeys (i.e at 5th ,10th and 15th storey levels).For all the models analysis was carried out and results are extracted and tabulated. The purpose was to examine the effect of seismic performance of the building with the increase in magnitude of mass irregularity and also to check the variation in performance as mass irregularity is introduced at various levels .All the 13 models framed the below mentioned input data were used .For incorporating mass irregularity of 150% and 200% the live load is suitably increased so that seismic weight of the structure is increased .In case of 250% of vertical mass irregularity a part of thickness of slab and drop is increased and a part of live load is also increased so that the slab does not fail in punching shear. Analysis is done by Response spectrum method.

Table -1: Input data of all the building models

No. of storey	15
Storey height	3m
Plinth beam	1.5m
Foundation height	1. 5kN/m^2
Column	600x600mm of M25
Grade of steel	HYSD 500
Density of concrete	25kN/m^3
Density of brick	22kN/m^3
Wall load	2kN/m^2
Floor finishes	750x750 mm of M30

Zone	IV
Zone factor, Z (Table 2)	0.24
Importance factor, I (Table 6)	1
Response reduction factor, R (Table 7)	5
Damping ratio	5% (for RC framed buildings)
Soil type &case	Type-2 medium
Natural Period of Building Ta = 0.075 h0.75	1.27s
Type of frames	SMRF

Description of the mass irregular models with varying % of Mass irregularity (All the other parameters are same as specified in the above tables).

Model 1-Regular flat slab building in which a flat slab of thickness 200 mm & drop of 150mm is used. Imposed load of 5kN/m^2 and floor finishes of 3.5kN/m^2

Model 2- Irregular flat slab building with 150% of vertical mass irregularity incorporated at 5th floor in which a regular flat slab of thickness 200 mm &drop of 150mm is used & a live load of 5kN/m^2 for all floors & live load of 10 kN/m^2 is incorporated at the 5th floor.

Model 3 - Irregular flat slab building with 150% of vertical mass irregularity incorporated at 10th floor in which a regular flat slab of thickness 200 mm & drop of 150mm is used live load of 5kN/m^2 for all floors & live load of 10 kN/m^2 is imposed at the 10th floor

Model 4 - Irregular flat slab building with 150% of vertical mass irregularity incorporated at 15th floor in which a regular flat slab of thickness 200 mm &drop of 150mm is used live load of 5kN/m^2 for all other floors &live load of 10 kN/m^2 is incorporated at the 15th floor.

Model 5- Irregular flat slab building with 150% vertical mass irregularity incorporated at 5th, 10th & at 15th storey levels in which a regular flat slab of thickness 200 mm &drop of 150mm is used live load of 5kN/m^2 for all floors &live load of 10 kN/m^2 is incorporated at all the 3 floor levels .i.e at 5th, 10th & at 15th floor level.

Model 6- Irregular flat slab building with 200% of vertical mass irregularity incorporated at 5th floor in which a regular flat slab of thickness 200 mm &drop of 150mm is used live load of 5kN/m^2 for all floors & live load of 17. 5kN/m^2 is incorporated at the 5th floor.

Model 7 - Irregular flat slab building with 200% of vertical mass irregularity incorporated at 10th floor in which a regular flat slab of thickness 200 mm & drop of 150 mm is used live load of 5kN/m^2 for all floors & live load of 17. 5kN/m^2 is imposed at the 10th floor.

Model 8 - Irregular flat slab building with 200% of vertical mass irregularity incorporated at 15th floor in which a regular flat slab of thickness 200 mm &drop of 150mm is used live load of 5kN/m^2 for all other floors & live load of 17. 5kN/m^2 is incorporated at the 15th floor.

Model 9- Irregular flat slab building with 200% of vertical mass irregularity incorporated at 5th, 10th floor ad at 15th storey levels in which a regular flat slab of thickness 200 mm &drop of 150mm is used live load of 5kN/m^2 for all floors &live load of 17. 5kN/m^2 is incorporated at all the 3 floor levels .i.e at 5th, 10th &at 15th floor level..

Model 10- Irregular flat slab building with 250% of vertical mass irregularity incorporated at 5th floor -IN this model a regular flat slab of thickness 300 mm & drop of 250mm is used live load of 5kN/m^2 for all floors & live load of 20 kN/m^2 is incorporated at the 5th floor..

Model 11 - Irregular flat slab building with 250% of vertical mass irregularity incorporated at 10th floor in which a regular flat slab of thickness 300 mm & drop of 250mm is used live load of 5kN/m^2 for all floors & live load of 20 kN/m^2 is imposed at the 10th floor.

Model 12 - Irregular flat slab building with 250% of vertical mass irregularity incorporated at 15th floor in which a regular flat slab of thickness 300 mm &drop of 250mm is used live load of 5kN/m² for all other floors &live load of 20 kN/m² is incorporated at the 15th floor.

Model 13- Irregular flat slab building with 250% of mass irregularity incorporated at 5th, 10th floor ad at 15th storey levels in which a regular flat slab of thickness 300 mm &drop of 250mm is used live load of 5kN/m² for all floors &live load of 20kN/m² is incorporated at all the 3 floor levels .i.e at 5th, 10th &at 15th floor level.

Calculation of floor mass ratios:

For mass irregularity of 150%-For 150% of mass irregularity to exist the floor mass ratio(the ratio of considered floor to its adjacent floor) should be more than 1.5

Slab dimensions-200mm

Drop dimensions-150 mm of 2X2m

Imposed load = 5kN/ m² for regular building and 10kN/ m² for mass irregular storey.

Seismic weight of regular storey-

DL of slab=0.2x25=5kN/ m²

Super imposed load(wall+floor finishes)=3.5kN/ m²

Live load=5kN/ m²

Area of the slab=1100 m²

Total load from the drop=60x2x2x0.15x25=900kN

Total load from column=60x0.75x0.75x3x25=2531.25

Total seismic weight of a floor=15531.25kN

Seismic weight of mass irregular regular storey-

DL of slab=0.2x25=5kN/ m²

Super imposed load(wall+floor finishes)=3.5kN/ m²

Live load=10 kN/ m²

Area of the slab=1100 m²

Total load from the drop=60x2x2x0.15x25=900kN

Total load from column=60x0.75x0.75x3x25=2531.25

Total sesmic weight of a floor=23781.25kN

Floor mass ratio=Semic weight of mass irregular storey/ Semic weight of regular storey=23781.25 / 15531.25=1.53>1.5

Hence mass irregularity of 150% exists.

For mass irregularity of 200%-For 200% of mass irregularity to exist the floor mass ratio(the ratio of considered floor to its adjacent floor) should be more than 2.

Slab dimensions-200mm

Drop dimensions-150 mm of 2X2m

Imposed load =5kN/ m² for regular building and 17.5 kN/ m² for mass irregular storey

Seismic weight of regular storey-

DL of slab=0.2x25=5kN/ m²

Super imposed load(wall+floor finishes)=3.5kN/ m²

Live load=5kN/ m²

Area of the slab=1100 m²

Total load from the drop=60x2x2x0.15x25=900kN

Total load from column=60x0.75x0.75x3x25=2531.25

Total seismic weight of a floor=15531.25kN

Seismic weight of mass irregular regular storey-

DL of slab=0.2x25=5kN/ m²

Super imposed load(wall+floor finishes)=3.5kN/ m²

Live load=17.5kN/ m²

Area of the slab=1100 m²

Total load from the drop=60x2x2x0.15x25=900kN

Total load from column=60x0.75x0.75x3x25=2531.25

Total seismic weight of a floor=32031.25kN

Floor mass ratio=Seismic weight of mass irregular storey/

Seismic weight of regular storey=32031.5/15531.25==2.06>2

Hence mass irregularity of 200% exists.

For mass irregularity of 250%-For 250% of mass irregularity to exist the floor mass ratio(the ratio of considered floor to its adjacent floor) should be more than 2.5

Slab dimensions- 200 mm for regular storey and 300mm for mass irregular storey

Drop dimensions-150 mm and 2 X 2m for regular storey and 250 mm of 2.5 X2.5m for mass irregular storey

Imposed load =5kN/ m² for regular building and 20 kN/ m² for mass irregular storey

Seismic weight of regular storey-

DL of slab=0.2x25=5kN/ m²

Super imposed load(wall+floor finishes)=3.5kN/ m²

Live load=5kN/ m²

Area of the slab=1100 m²

Total load from the drop=60x2x2x0.15x25=900kN

Total load from column=60x0.75x0.75x3x25=2531.25

Total seismic weight of a floor=15531.25kN

Seismic weight of mass irregular regular storey-

DL of slab=0.3x25=7.5 kN/ m^2

Super imposed load(wall+floor finishes)=3.5kN/ m^2

Live load=20 kN/ m^2

Area of the slab=1100 m^2

Total load from the drop=60x 2.5 x 2.5 x0.25x25=2343.75 kN

Total load from column=60x0.75x0.75x3x25=2531.25

Total seismic weight of a floor=38975 kN

Floor mass ratio=Seismic weight of mass irregular storey/ Seismic weight of regular storey=38975/15531.25==2.51 >2.5

Hence mass irregularity of 250% exists

Steps involved in modeling of 200% mass irregular models with and without shear wall

In the second course of work since it is observed that most prevailing mass irregular structure are of 200% mass irregularity .A detailed study on this % was decided.200% mass irregularity was enforced at various floor levels and for each floor level shear wall was placed at 4 different locations namely at core, corner, central periphery and at both core and central periphery was placed and models were framed. And then a comparison was made in terms of seismic parameters like storey drift, displacements, modal period and storey shear. Then a suitable position of shear wall for effective lateral load resistance is found out.

Description of the 200% mass irregular models with shear wall placed at different positions:

Model 14 - Irregular flat slab building with 200% mass irregularity incorporated at 5th floor & core shear wall in which a regular flat slab of thickness 200 mm &drop of 150mm is used live load of 5kN/m^2 for all floors &live load of 17. 5 kN/$m^{2\ is}$ incorporated at the 5th floor. All the other parameters are same as specified in the above tables. A shear wall of 200mm size is placed at the core of the building.

Model 15 - Irregular flat slab building with mass irregularity incorporated at 5th floor & shear wall at placed at central periphery -in which a regular flat slab of thickness 200 mm &drop of 150mm is used live load of 5kN/m^2 for all floors &live load of 17. 5kN/m^2 is incorporated at the 5th floor .All the other parameters are same as specified in the above tables .A shear wall of 200mm size is placed at the central periphery of the building

Model 16 - Irregular flat slab building with 200% of mass irregularity incorporated at 5th floor & shear wall placed at corner -in which a regular flat slab of thickness 200 mm &drop of 150mm is used live load of 5kN/m^2 for all floors &live load of 17. 5kN/m^2 is incorporated at the 5th floor .All the other parameters are same as specified in the above tables. A shear wall of 200mm size is placed at the corner of the building.

Model 17 - Irregular flat slab building with 200% mass irregularity incorporated at 5th floor & shear wall at both core &central periphery. In which a regular flat slab of thickness 200 mm &drop of 150mm is used live load of 5kN/m^2 for all floors &live load of 17. 5kN/m^2 is incorporated at the 5th floor all the other parameters are same as specified in the above tables. A shear wall of 200mm size is placed at both core & at the central periphery. Both the shear walls are connected by a connecting beam of size 230x230mm at an interval of 5 storeys. Here size is limited to 230 x 230 mm since it only does the job of connecting not load bearing.

Model 18 - Irregular flat slab building with 200% mass irregularity incorporated at 10th floor &core shear wall -in which a regular flat slab of thickness 200 mm &drop of 150mm is used live load of 5kN/m^2 for all floors &live load of 17. 5kN/m^2 is incorporated at the 10th floor .All the other parameters are same as specified in the above tables .A shear wall of 200mm size is placed at the core of the building

Model 19 - Irregular flat slab building with 200% mass irregularity incorporated at 10th floor & shear wall at central periphery in which a regular flat slab of thickness 200 mm &drop of 150mm is used live load of 5kN/m^2 for all other floors &live load of 17. 5kN/m^2 All the other parameters are same as specified in the above tables..A shear wall of 200mm size is placed at the central periphery of the building

Model 20 - Irregular flat slab building with 200% mass irregularity incorporated at 10th floor & corner shear wall in which a regular flat slab of thickness 200 mm & drop of 150mm is used live load of 5kN/m^2 for all floors &live load of 17. 5kN/m^2 is incorporated at the 10th floor. All the other parameters are same as specified in the above tables. A shear wall of 200mm size is placed at the corner of the building.

Model 21- Irregular flat slab building with 200% mass irregularity incorporated at 10th floor & shear wall at both core &central periphery-in which a regular flat slab of thickness 200 mm &drop of 150mm is used live load of 5kN/m^2 for all floors &live load of 17. 5kN/m^2 is incorporated at the 10th floor all the other parameters are same as specified in the above tables .A shear wall of 200mm size is placed at both core of the building &at the central periphery. Both the shear walls are connected by a connecting beam of size 230x230mm connected at an interval of 5 storeys. Here size is limited to 230 x 230 mm since it only does the job of connecting not load bearing

Model 22- Irregular flat slab building with 200% mass irregularity incorporated at 15th floor & core shear wall in which a regular flat slab of thickness 200 mm &drop of 150mm is used live load of 5kN/m² for all floors & live load of 17. 5kN/m² m² is incorporated at the 15th floor all the other parameters are same as specified in the above tables. A shear wall of 200mm size is placed at the core of the building

Model 23- Irregular flat slab building with 200% mass irregularity incorporated at 15th floor & shear wall at central periphery in which a regular flat slab of thickness 200 mm &drop of 150mm is used live load of 5kN/m² for all floors &live load of 17. 5kN/m² m² is incorporated at the 15th floor. All the other parameters are same as specified in the above tables. A shear wall of 200mm size is placed at the central periphery of the building

Model 24- Irregular flat slab building with mass irregularity incorporated at 15th floor &corner shear wall in which a regular flat slab of thickness 200 mm &drop of 150mm is used live load of 5kN/m² for all floors &live load of 17. 5kN/m² m² is incorporated at the 15th floor. All the other parameters are same as specified in the above tables .A shear wall of 200mm size is placed at the corner of the building.

Model 25 - Irregular flat slab building with 200% mass irregularity incorporated at 15th floor & shear wall at both core &central periphery-IN this model a regular flat slab of thickness 200 mm &drop of 150mm is used live load of 5kN/m² for all floors &live load of 17. 5kN/m² m² is incorporated at the 15th floor .All the other parameters are same as specified in the above tables. A shear wall of 200mm size is placed at both core of the building &at the central periphery. Both the shear walls are connected by a connecting beam of size 230x230mm connected at an interval of 5 storeys. Here size is limited to 230 x 230 mm since it only does the job of connecting not load bearing.

Model 26 - Irregular flat slab building with 200% mass irregularity incorporated at 5th, 10th floor &15th storey level &core shear wall -in which a regular flat slab of thickness 200 mm &drop of 150mm is used live load of 5kN/m² for all other floors &live load of 17. 5kN/m² is incorporated at all the 3 floor levels .i.e at 5th ,10th &at 15th floor level All the other parameters are same as specified in the above tables A shear wall of 200mm size is placed at the core of the building

Model 27 - Irregular flat slab building with 200% mass irregularity incorporated at 5th, 10th &at 15th storey level & shear wall at central periphery in which a regular flat slab of thickness 200 mm &drop of 150mm is used live load of 5kN/m² for all other floors &live load of 17. 5kN/m² is incorporated at all the 3 floor levels .i.e at 5th ,10th &at 15th floor level All the other parameters are same as specified in the above tables. A shear wall of 200mm size is placed at the central periphery of the building

Model 28- Irregular flat slab building with mass irregularity incorporated at 5th , 10th &15th floor &corner shear wall - IN this model a regular flat slab of thickness 200 mm &drop of 150mm is used live load of 5kN/m² for all other floors &live load of 17. 5kN/m² is incorporated at all the 3 floor levels .i.e at 5th ,10th &at 15th floor level All the other parameters are same as specified in the above tables .A shear wall of 200mm size is placed at the corner of the building.

Model 29 - Irregular flat slab building with mass irregularity incorporated at 5th , 10th &15th floor &shear wall at both core &central periphery-IN this model a regular flat slab of thickness 200 mm &drop of 150mm is used live load of 5kN/m² for all other floors &live load of 17. 5kN/m² is incorporated at all the 3 floor levels .i.e at 5th ,10th &at 15th floor level All the other parameters are same as specified in the above tables .A shear wall of 200mm size is placed at both core of the building &at the central periphery. Both the shear walls are connected by a connecting beam of size 230x230mm connected at an interval of 5 storeys. Here size is limited to 230 x 230 mm since it only does the job of connecting not load bearing.

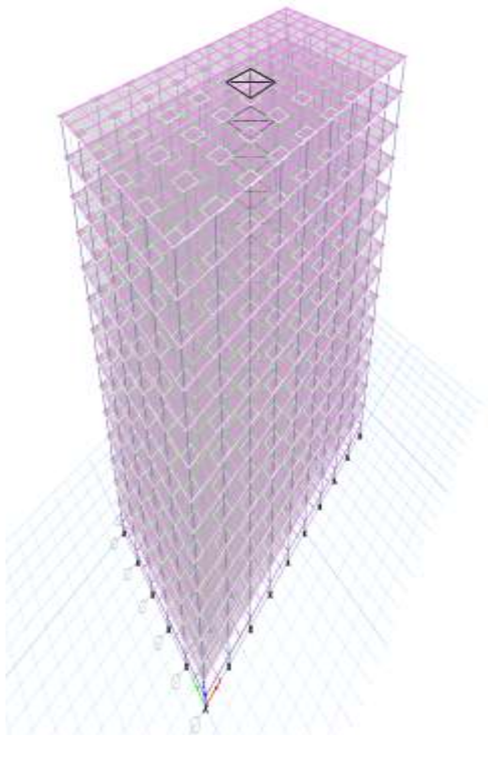

Figure-1: Regular flat slab building

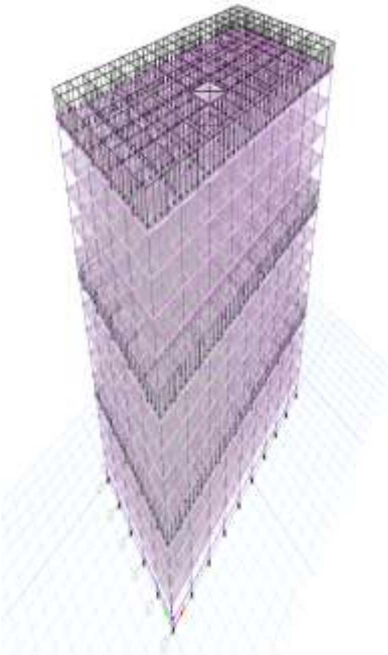

Figure-2: Irregular flat slab building with 200% mass irregularity at the 5th,10th & 15th floor.

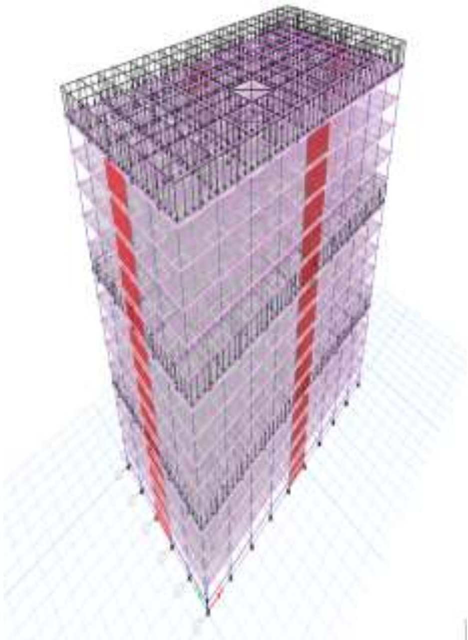

Figure -4: Irregular flat slab building with 200% mass irregularity at the 5th, 10th & 15th floor and shear wall at central periphery.

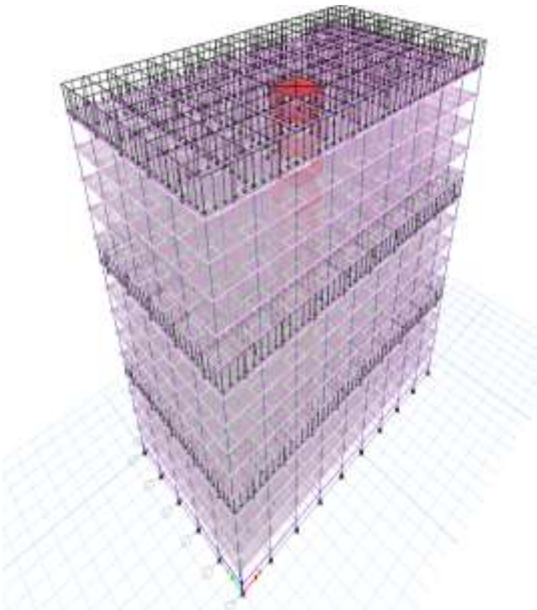

Figure-3: Irregular flat slab building with 200% mass irregularity at the 5th, 10th & 15th floor and shear wall at core

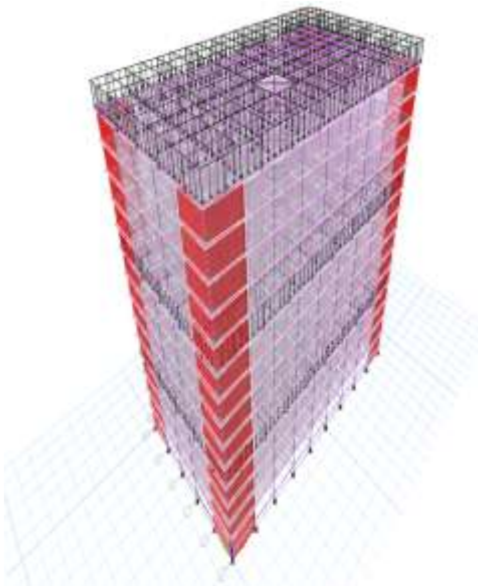

Figure-5: Irregular flat slab building with 200% mass irregularity at the 5th, 10th & 15th floor and shear wall at core

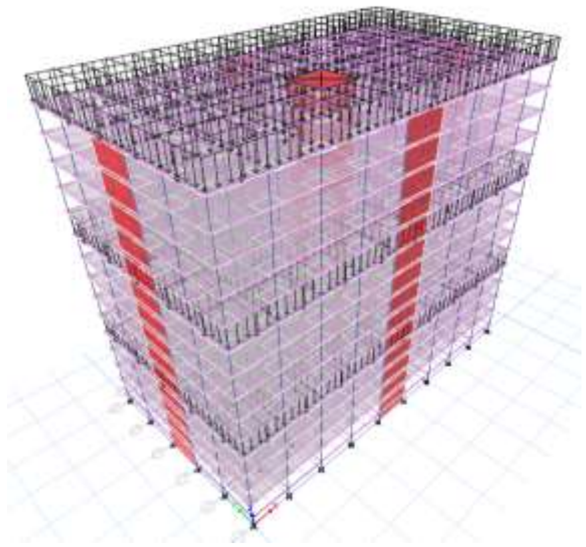

Figure-6: Irregular flat slab building with 200% mass irregularity at the 5th, 10th & 15th floor and shear wall at core & central periphery.

Analysis

After suitably modeling and loading the model the next step is to analyze the structure after the analysis a deformed shape of model appears on the screen. Cursor when placed at a node gives displacement of that node. After analysis we need to check some important parameters prior to design. The model is checked for base shear to validate the fact that the Etabs model prepared is accurate under applied loading. Then the slabs are checked for punching shear failure. Once check is done the next step is to extract the seismic parameters to the spreadsheet filter the parameter for critical load combination of the load.

Base shear check-This is done to check whether the models prepared by Etabs produces satisfactory results or not. For this manual calculation is done and compared with the results obtained from Etabs.

Manual calculations of a 15-storey reinforced concrete commercial building

Computation of Seismic weights:

Ground floor:

- DL due to self weight of columns =0.75 x 0.75 x 25x 60 x0.75 = 632.82 kN/m^2

First floor:

- Self weight of beam per unit length = 0.6 x 0.6 x 25 = 9 kN/m
- Total length = 520m
- DL due to self weight of beams = 520x 9 = 4680kN
- DL due to self-weight of columns (60 No.s) = 2531.25 N
- DL due to self weight of wall +floor finishes=3.5kN/m^2 x area=15271.25kN

Second floor-

- DL due to self weight of slab = 0.2x25=5kN//m^2
- DL due to wall + FF= 3.5 kN//m^2
- LL=5kN//m^2
- DL due to self weight of drop=900kN
- DL due to self-weight of columns (60 No.s) = 2531.25 N
- Total seismic weight of the structure = 15531.25 kN

Roof

- DL due to self weight of slab = 0.2x25=5kN//m^2
- DL due to wall + FF= 3.5 kN//m^2
- LL=5kN//m^2
- DL due to self weight of drop=900kN
- DL due to self-weight of columns (60 No.s) = 1265.625 N
- Total seismic weight of the structure = 14265.625kN

Total load=15531.5x13+14265.5+11061.5N=230559.3kN

Fundamental period:

Natural period, $T_a = 0.075h^{0.75} = 0.075\ (43.5)^{0.75} = 1.27$sec

(Moment resisting frame without in-fill walls)

Spectral acceleration:

- Type of soil: medium Soil
- For T_a=1.27 sec
- Sa/g = 1.07

Zone factor: For Zone IV, Z = 0.24

Importance Factor: I = 1.0

Response Reduction Factor: R = 5.0 (SMRF)

- Horizontal acceleration coefficient $A_h = (ZIS_a) / (2Rg) = 0.025$

Base shear $V_{B} = A_{h} X W$ = 5613.938 kN

From Etabs software base shear calculated = 5763.97kN (due to equivalent static load)

% of error = 2.67%<5 % Hence acceptable.

Punching shear check-Punching shear results are presented as a ratio of maximum calculated shear with respect to capacity. A ratio above 1.0 illustrates that the capacity was out striped somewhere along the critical section. The ratio is exhibited. For each column &each point load. A notation of N/C means the value was not calculated by the program. For all the flat slabs his check is done

Results and discussions

The whole study conducted was divided into 2 segments in the 1st segment models were prepared by incorporating 150%,200% and 250% of MI at various floor levels. And in the second segment detailed study was made on models with MI 200% applied at various storey levels and placing shear wall at 4 different locations to reduce the lateral forces. From the analysis the following notes were made

In this chapter the result values of all the models are tabulated after analysis is completed and deliberated in detail..The seismic parameters used for study are storey drift, storey shear, time period, storey displacement and base shear.

Study on Mass irregular models with varying % of mass irregularity.

Storey drift-

The storey drift values of mass irregular models in X direction are tabulated and compared as shown below.

Table-2: Storey drift (mm) values for 150% mass irregular models in X direction

Storey	**Regular building**	**MI at 5th floor**	**MI at 10th floor**	**MI at 15th floor**	**MI at 5th,10th and 15th floor**
15	0.74	0.75	0.75	0.90	0.927
14	0.99	1.00	1.01	1.15	1.184
13	1.25	1.26	1.26	1.39	1.433
12	1.43	1.47	1.45	1.6	1.649
11	1.66	1.69	1.69	1.77	1.84
10	1.82	1.85	1.88	1.93	2.02
9	1.96	1.99	2.05	2.06	2.18
8	2.09	2.12	2.19	2.19	2.32
7	2.20	2.23	2.31	2.31	2.44
6	2.30	2.34	2.41	2.40	2.54
5	2.36	2.42	2.46	2.46	2.61
4	2.32	2.39	2.40	2.40	2.568
3	2.04	2.11	2.12	2.12	2.262
2	1.28	1.33	1.33	1.33	1.421
1	0.35	0.36	0.36	0.36	0.39

Table-3: Storey drift(mm) values for 200% mass irregular models in both X direction.

Storey	**Regular building**	**MI at 5th floor**	**MI at 10th floor**	**MI at 15th floor**	**MI at 5th,10th and 15th floor**
15	0.748	0.756	0.767	1.049	1.096
14	0.997	1.013	1.023	1.3	1.364
13	1.251	1.28	1.284	1.527	1.609
12	1.473	1.517	1.516	1.721	1.822
11	1.663	1.717	1.73	1.89	2.019
10	1.824	1.884	1.951	2.038	2.228
9	1.963	2.025	2.138	2.171	2.41
8	2.091	2.151	2.289	2.296	2.559
7	2.209	2.269	2.415	2.41	2.681
6	2.309	2.381	2.512	2.504	2.785
5	2.365	2.481	2.559	2.552	2.863
4	2.32	2.463	2.497	2.493	2.813
3	2.047	2.181	2.194	2.192	2.474
2	1.288	1.374	1.378	1.377	1.552
1	0.356	0.379	0.38	0.38	0.428

Table-4: Storey drift(mm) values for 250% mass irregular models in both X and Y direction

Storey	Regular building	MI at 5th floor	MI at 10th floor	MI at 15th floor	MI at all 3 floors
15	0.748	0.737	0.734	0.762	0.767
14	0.997	0.994	0.962	1.23	1.224
13	1.251	1.268	1.157	1.555	1.497
12	1.473	1.511	1.24	1.787	1.578
11	1.663	1.71	1.128	1.967	1.393
10	1.824	1.861	1.385	2.116	1.611
9	1.963	1.989	1.94	2.246	2.168
8	2.091	1.987	2.26	2.366	2.396
7	2.209	1.897	2.459	2.478	2.354
6	2.309	1.565	2.584	2.785	1.945
5	2.365	1.691	2.637	2.616	2.051
4	2.32	2.145	2.57	2.554	2.561
3	2.047	2.075	2.254	2.245	2.455
2	1.288	1.354	1.414	1.411	1.593
1	0.356	0.38	0.39	0.389	0.446

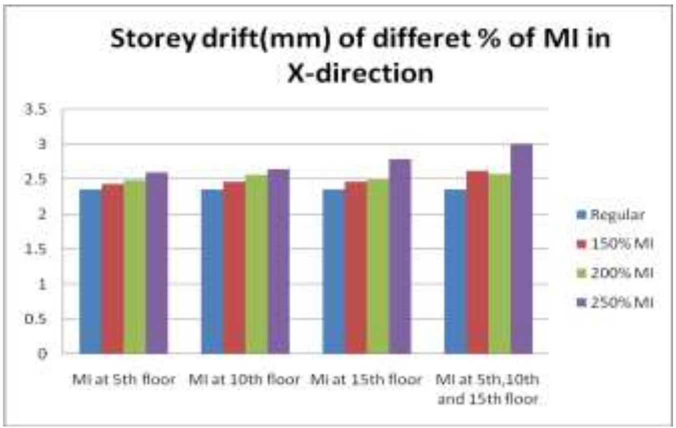

Figure-7: Graph of storey drift of different % MI along the various height mass irregularity incorporation

Obervations-The following are the inferences drawn.

- The drift increases with magnitude of mass irregularity
- Also it is to be noted that there is no drastic change i drift values between 200% and 250% .this is because we have increased the slab and drop thickness to incorporate 250% of MI without punching shear of the slab, there by the stiffness also increases,
- The regular flat slab structure has the least drift and the irregular flat slab structure with mass irregularity at all 3 floor levels that is at 5th , 10th , 15th floors has the highest values of storey drift among the considered models for X direction.
- A small percentage of increase in drift values are seen as height of mass irregularity incorporation increase.
- Drift values are found to increase only in the mid height whereas in the top and bottom it is same as that of regular building.

Mode period- The modal period values for 150%, 200% and 250% of mass irregular models in both X and Y direction are tabulated and compared as shown below

Table -5:Modal time period(sec)of different % of MI

Type of building	150% MI	200% MI	250% MI
Regular building	2.134	2.134	2.134
MI at 5th floor	2.144	2.15	2.153
MI at 10th floor	2.183	2.201	2.231
MI at 15th floor	2.213	2.342	2.29
MI at 5th , 10th and 15th floor	2.268	2.35	2.394

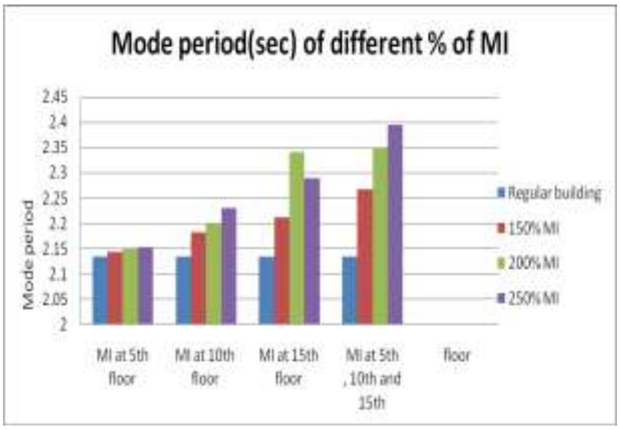

Figure-8: Variation of modal period of different % of MI along the height of the model.

Observations:

- From the graph it is pronounced that mode period of model with mass irregularity at all 3 floors is highest and regular building has the least mode period
- Also can be seen that mode period increases with the % increase of mass irregularity.

Base shear- The base shear values for 150%, 200% and 250% of mass irregular models in both X and Y direction are tabulated and compared as shown below

Table-6: The base shear values (kN) for 150%, 200% and 250% of mass irregular models in X direction

Type of building	Regular building	150% of MI	200% of MI	250% of MI
MI at 5th floor	8421.03	8718.73	8718.73	9958.71
MI at 10th floor	8421.03	8696.36	8696.36	9193.75
MI at 15th floor	8421.03	8696.15	8696.15	9173.75
MI at 5th,10th and 15th floor	8421.03	9247.3	9247.3	10739.65

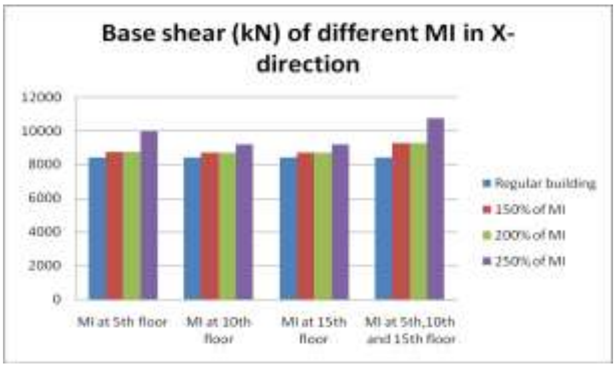

Figure-9: Graph of the base shear values for 150%, 200% and 250% of mass irregular models in both X-direction

Observations-

The following are the few observations made from the tabulated results & plotted graphs for regular and mass irregular models .Base shear is observed to be more at the base of the building and decreases towards the top.

- It is seen that the storey shear decreases as the height of incorporation of mass irregularity and no of stories of incorporation of mass irregularity increases.
- It is also seen that as % of mass irregularity increases ,base shear tends to increase

Displacements- The displacement values of mass irregular models in X direction are tabulated and compared as shown below.

Table-7: Storey displacements (mm) values for 150% mass irregular models in X direction.

Storey	No SW	SW at central periphery	SW at core and central periphery	SW at corner	SW at core
15	84.72	53.05	38.58	39.67	43.61
14	81.86	49.85	35.64	36.25	36.25
13	78.75	46.39	32.77	33.32	33.32
12	75.02	42.68	29.87	30.17	30.17
11	70.463	38.92	26.88	27.05	27.05
10	65.206	38	23.82	23.91	23.91
9	59.72	30.83	20.69	20.69	20.69
8	52.52	26.58	17.53	17.48	17.48
7	45.32	22.15	14.43	14.34	14.34
6	37.65	17.77	11.4	11.3	11.3
5	29.54	13.45	8.52	8.43	8.43
4	21.03	9.33	5.84	5.78	5.78
3	12.71	5.56	3.45	3.43	3.43
2	5.29	2.42	1.53	1.52	1.52
1	0.65	0.45	0.32	0.32	0.32

Figure-10: Graph of variation of storey displacement v/s storey levels in X-direction for 150% MI

The displacement values for 200% mass irregular models in X direction are tabulated and compared as shown below

Table-8: Storey displacement (mm) values for 200% mass irregular models in X direction.

Storey	Regular building	MI at 5th storey	MI at 10th storey	MI at 15th storey	MI at 5th,10th and 15th storey
15	68.58	70.91	73.7	77.09	84.72
14	66.81	68.89	71.91	74.36	81.86
13	64.46	66.68	69.53	71.35	78.75
12	61.45	63.59	66.44	67.72	75.02
11	57.79	59.85	62.74	63.36	70.463
10	53.53	55.5	58.27	58.52	65.206
9	48.82	50.57	53.5	53.06	59.72
8	43.46	45.13	47.17	46.95	52.52
7	37.47	39.31	40.68	40.58	45.32
6	31.23	32.86	33.6	33.62	37.65
5	24.4	25.87	26.28	26.27	29.54
4	17.42	18.55	18.69	18.67	21.03
3	10.53	11.22	11.27	11.26	12.71
2	4.41	4.71	4.72	4.71	5.29
1	0.54	0.58	0.58	0.59	0.65

Figure-11: Graph of Storey displacement v/s storey levels in X-direction for 200% MI

The displacement values for 250% mass irregular models in X direction are tabulated and compared as shown below

Table-9 : Storey displacement (mm) values for 250% mass irregular models in X direction

Storey	Regular building	MI at 5th floor	MI at 10th floor	MI at 15th floor	MI at 5th,10th and 15th floor
15	68.58	71.3	75.32	78.51	84.8
14	66.81	60.7	67.75	76.34	69.62
13	64.46	58.53	65.81	73.44	67.14
12	61.45	55.39	63.38	69.72	63.52
11	57.79	51.61	60.42	65.15	59.63
10	53.53	47.25	57.51	60.05	56.03
9	48.82	42.44	53.64	54.36	51.57
8	43.46	37.3	48.29	48.3	45.5
7	37.47	31.92	41.68	41.5	38.79
6	31.23	26.71	34.56	34.36	32.16
5	24.4	22.26	26.99	26.86	26.51
4	17.42	17.25	19.21	19.14	20.42
3	10.53	10.85	11.57	11.54	12.79
2	4.41	4.64	4.78	9.77	5.45
1	0.54	0.59	0.59	0.67	0.67

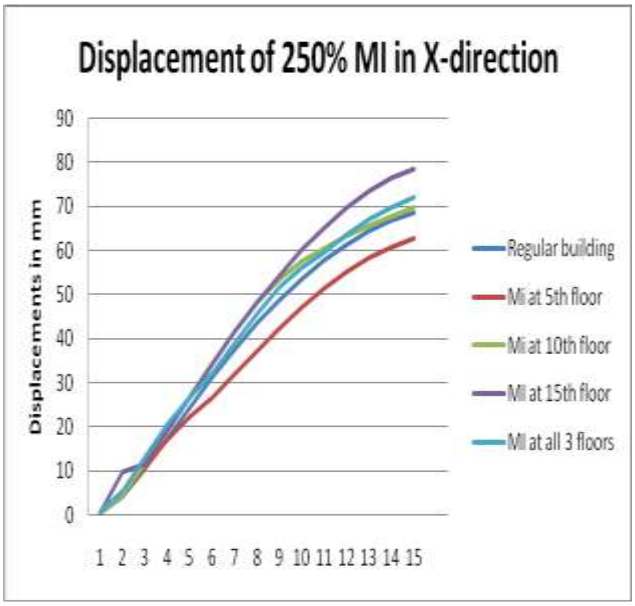

Figure-12 : Graph of Storey displacement v/s storey levels in X-direction for 250% MI

Comparison of models of 200% mass irregularity with and without shear wall:

In the second course of study a detailed study is made on MI of 200%.Mass irregularity of 200% is enforced on the slab at 4 different positions namely at 5th floor ,10th floor ,at 15th floor and at 5th,10th and 15th floor .For every model shear wall is placed at core ,corner, central periphery and at both core and central periphery .The seismic parameters of all models are tabulated and compared .Basically an attempt to made to find out the possible best location of shear wall under 200% of mass irregularity.

Storey drift- Drift values of all the Mass irregular models without shear wall & when shear wall is present at 4 different positions in X direction is extracted and tabulated. Graphs are plotted for variation of drift along the height of the structure.

Mass irregularity is incorporated at 5th storey:

Table-10: Drift values(mm) of all the models with mass irregularity at 5th, 10thand 15th floor without shear wall and when shear wall is present at 4 different positions in both X direction

Storey	No SW	SW at central periphery	SW at core and central periphery	SW at corner	SW at core
15	1.096	1.173	0.938	0.997	1.052
14	1.364	1.281	0.997	1.051	1.146
13	1.609	1.35	1.03	1.079	1.202
12	1.822	1.405	1.055	1.099	1.243
11	2.019	1.449	1.072	1.109	1.274
10	2.228	1.491	1.086	1.114	1.302
9	2.41	1.515	1.084	1.103	1.311
8	2.559	1.52	1.066	1.076	1.303
7	2.681	1.505	1.031	1.033	1.277
6	2.785	1.464	0.975	0.973	1.23
5	2.863	1.393	0.901	0.894	1.164
4	2.813	1.261	0.793	0.784	1.053
3	2.474	1.053	0.646	0.639	0.89
2	1.552	0.703	0.444	0.442	0.618
1	0.428	0.302	0.209	0.21	0.287

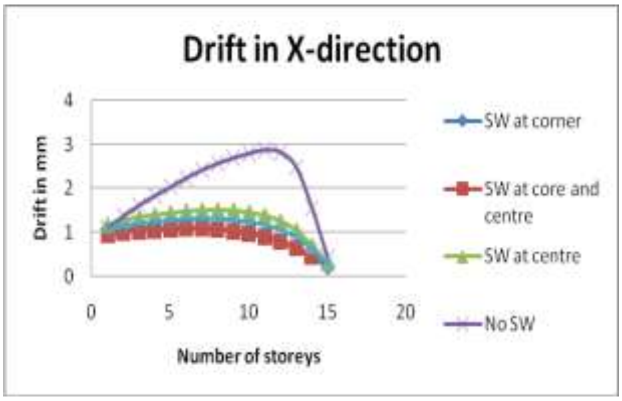

Figure-13: Graph of drift values of all the models with mass irregularity at 5th, 10th and 15th floor without shear wall an when shear wall is present at 4 different positions v/s storey level in X-direction.

Observations-From the tabulated results and plotted graphs of all mass irregular models with no shear wall and shear wall at 4 different positions the following notes are inferred

- The model of mass irregularity with no shear wall has the highest value of storey displacement and mass irregular model which has shear value at both core and central periphery has the least value of displacement among the models considered.
- For mass irregular models, shear wall when placed at corner reduces displacement by 60.5%, for core shear wall the displacement reduces by 53.8%, for shear wall placed at central periphery displacement reduces by 46.3% and when shear all is placed both at core and central periphery displacement is reduced by 61.7% in X-direction compared to mass irregular model with no shear wall.
- For mass irregular models, shear wall when placed at corner reduces displacement by 60.4%, for core shear wall the displacement reduces by 53.43%, for shear wall placed at central periphery displacement reduces by 45.96 % and when shear all is placed both at core and central periphery displacement is reduced by 61.5 % in X-direction compared to mass irregular model with no shear wall.

Storey shear-. Storey shear of all the Mass irregular models without shear wall an when shear wall is present at 4 different positions in both X and Y direction are extracted and tabulated. Graphs are plotted for variation of storey shear along the height of the building.

Table-11: Storey shear (kN) of all the models with mass irregularity at 5th, 10th and 15th floor without shear wall an when shear wall is present at 4 different positions in X direction.

Storey	No SW	SW at central periphery	SW at core and central periphery	SW at corner
15	2881.93	3177.53	3018.95	3019.34
14	4011.43	4361.62	4208.03	4208.23
13	4804.34	5130.75	5003.34	5003.13
12	5391.52	5618.30	5522.29	5521.42
11	5858.92	5894.85	5871.08	5869.37
10	6744.45	6393.57	6529.21	6525.78
9	7184.58	6724.63	6918.49	6914.36
8	7576.92	7068.37	7325.60	7321.10
7	7940.84	7461.31	7770.16	7765.74
6	8273.94	7911.18	8234.86	8230.90
5	9055.96	8969.07	9245.52	9242.87
4	9509.40	9518.42	9765.26	9763.40
3	9870.25	9952.617	10165.1	10164.31
2	10051.83	10202.49	10387.1	10387.57
1	10072.84	10237.69	10420.06	10420.92

Figure-14 : Graph of storey shear of all the models with mass irregularity at 5th ,10th and 15th floor without shear wall an when shear wall is present at 4 different positions V/s storey levels in X-direction

Observations-From the above tabulated results for storey shear and plotted graphs for mass irregular building with no shear wall & shear wall at 4 different positions it can be seen that

- Storey Shear is more for the mass irregular model with shear wall positioned at both core and central periphery and less for the mass irregular model without shear wall.
- With the increase in lateral stability of the structure with inclusion of shear wall it is found that storey shear tend to increase significantly.

Displacements- Displacements of all the Mass irregular models without shear wall an when shear wall is present at 4 different positions in both X and Y direction are extracted and tabulated. Graphs are plotted for variation of drift along the height of the structure.

Table-12: Displacement values(mm) of all the models with mass irregularity at 5th , 10th and 15th floor without shear wall an when shear wall is present at 4 different positions in both X and Y direction.

Storey	No SW	SW at central periphery	SW at core and central periphery	SW at corner	SW at core
15	84.72	53.05	38.58	39.67	43.61
14	81.86	49.85	35.64	36.25	36.25
13	78.75	46.39	32.77	33.32	33.32
12	75.02	42.68	29.87	30.17	30.17
11	70.463	38.92	26.88	27.05	27.05
10	65.206	38	23.82	23.91	23.91
9	59.72	30.83	20.69	20.69	20.69
8	52.52	26.58	17.53	17.48	17.48

7	45.32	22.15	14.43	14.34	14.34
6	37.65	17.77	11.4	11.3	11.3
5	29.54	13.45	8.52	8.43	8.43
4	21.03	9.33	5.84	5.78	5.78
3	12.71	5.56	3.45	3.43	3.43
2	5.29	2.42	1.53	1.52	1.52
1	0.65	0.45	0.32	0.32	0.32

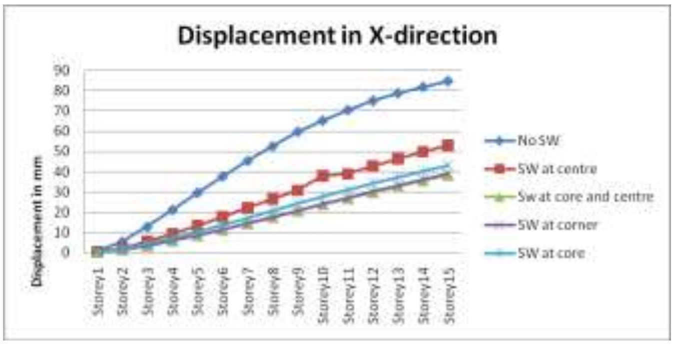

Figure-15: Graph of displacement values of all the models with mass irregularity at 5th ,10th and 15th floor without shear wall an when shear wall is present at 4 different positions v/s storey level in X - direction.

Observations-From the tabulated results of displacements of mass irregular models with and without shear walls following are the observations made

- Displacement is found to be more in the mass irregular model without shear wall and found to be least in the mass irregular models with shear wall positioned at both core and central periphery of the building among the considered models
- IT is also seen that displacement values tend to increase with the height of the building
- It is also noted that with the increase in lateral stability by placing shear wall displacement values tends to get decrease. By placing shear wall at central periphery the displacement values of mass irregular buildings are reduced by 36.23%,By placing shear wall at core displacement values decreases by 44%,By placing shear wall at corner displacement values decreases by 52.6%, and when shear wall is placed both at core and central periphery displacement values tend to decrease by 55.5% in X-direction compared to mass irregular model without shear wall
- By placing shear wall at central periphery the displacement values of mass irregular buildings are reduced by 35.72%,By placing shear wall at core displacement values decreases by 43.8%,By placing shear wall at corner displacement values decreases by 52.8 %, and when shear wall is placed both at core and central periphery displacement values tend to decrease by 54.7% in X-direction compared to mass irregular model without shear wall

Mode period-Comparison of mass irregular models with and without shear wall- A graph was plotted for mode period of mass irregular models with and without shear wall.

When mass irregularity is incorporated at 5th, 10th and 15th floor

Table-13: Mode period(sec) and natural time period(sec) of all mass irregular models(200% MI)with various positions of shear wall.

Models	Natural time period (sec)	Modal period (sec)
Regular flat slab building	1.27	2.134
MI at 5th,10th and 15th floor	1.27	2.394
MI at 5th,10th and 15th floor with SW at core	1.27	2.003
MI at 5th,10th and 15th floor with SW at corner	1.27	1.58
MI at 5th,10th and 15th floor with SW at central periphery	1.27	1.883
MI at 5th,10th and 15th floor with SW at both core and central periphery	1.27	1.554

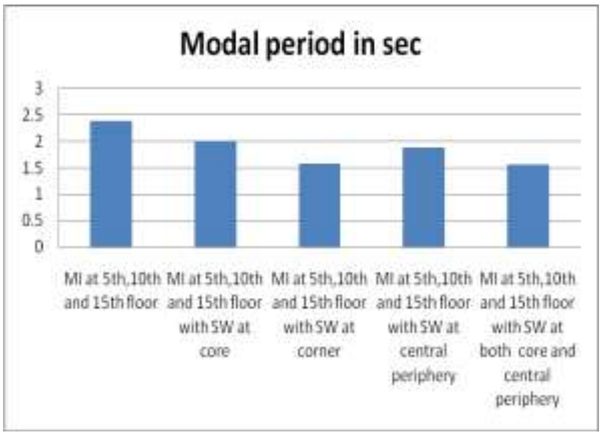

Figure-16 : Graph of variation of mode period for models with mass irregularity at all 3 floors with and without shear wall.

Observations-From the graph plotted above for mode period of mass irregular models with and without shear wall following points were observed.

- Mode period is more for mass irregular model without shear wall and least for mass irregular models with shear wall at with core and central periphery

CONCLUSIONS

- As the % of mass irregularity increases it demands higher size of structural members to effectively resist them.
- Seismic parameters like storey displacement ,storey drift ,modal time period tends to increase as the height of mass irregularity incorporation increase(i.e the model with mass irregularity at top exhibits more storey drift ,displacement values ,modal time period than the models with mass irregularity at mid height& bottom)
- Base shear is found to decrease as the height of mass irregularity inclusion increases.
- It is also concluded that as number of stories increases all the parameters like storey shear storey displacement base shear and modal period increases as magnitude of mass irregularity tends to increase with the increase in number of storeys.
- It is observed that flat slab (under loading specified in the above work) works effectively up to mass irregularity of 200% .Above 200% to resist the load and avoid punching shear we are supposed to increase the slab depth & drop thickness which seems quite economical .
- It is also seen that mass irregularity of 150% does not show much variation comparatively with regular building. Hence the code might have stipulated that for mass irregularity to exist the weight of adjacent store much be more than 200% of below or above storey .
- Also seen that when shear wall is placed both at core and central periphery connected by a connecting beam the lateral displacement and drift values tends to decrease tremendously
- From economy point of view it is seen that corner shear proves to be more efficient in resisting the lateral loads.
- Of all the shear wall positions, shear wall when placed at central periphery performs least effectively core shear wall proves somewhat better when compared to shear wall at central periphery.
- Shear wall proves to be an efficient lateral load resisting system in case of mass irregular structures .By inclusion of shear wall the lateral displacements and drifts end to occur well within the limits.
- At last it is consummated that for satisfactory performance of the building mass irregularity should to be avoided .In case of inevitable conditions it is advised to incorporate mass irregularity at bottom floors rather than top storeys accompanied with suitable lateral load resisting systems like shear walls and bracings.

6.2 Future scope-

- For the present work a regular 9 X 5 bay regular building has been chosen. One may also choose an existing plan or irregular plan and proceed with the study.

- This assessment was basically done for 3 varying % of mass irregularity like 150%,200% & 250%.Various other % of variation may be tried.

- Shear wall was placed at 4 positions .One may also preferentially change the position and analysis can be done

- To resist the huge lateral loads generated by incorporation of mass irregularity shear walls are used in present work .Other forms of lateral load resisting system may also be included.
- In this flat slab floor system drop panels are used .Also column heads may be included
- A linear dynamic method of analysis like Response spectrum method is selected .One may also go with time history analysis.

REFERENCES:

- Adarsh A, Rajeeva S.V-Seismic analysis of multi-storey reinforced concrete buildings having torsional irregularity -IJESC volume 6-issue

- Anshuman Nimade, Niraj Soni, Mahesh Patidar and Vikas Joshi -Dynamic Analysis of Flat Slab System in Vertical Irregular Building with & without Shear Wall -International Journal of Research and Scientific Innovation (IJRSI) ,Volume V, Issue I, January 2018

- Athira M. V 1, Sruthi K Chandran- Significance of shear wall in flat slab multi storied building - a review- International Research Journal of Engineering and Technology (IRJET) Volume: 04 Issue: 02,Feb -2017

- Bindu N Byadgi1, Vijayalaksmi R2, Dr.Jagadish Kori-" Behaviour of Flat Slab by Varying Stiffness in High Seismic Zone"- International Research Journal of Engineering and Technology (IRJET) Volume: 04 Issue: 08 Aug -2017

- Burugula Subrahmanya Prasanth and J. Simon-"Study on Behaviour of Asymmetric Building with Different Column Sections under Seismic Loading "-Indian Journal of Science and Technology, Vol 9(30), August 2016

- Chethan B N , Sanjay S -"Seismic analysis of multi-storey RC building with mass irregularity using etabs" International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056 Volume: 04 Issue: 07,July -2017

- Devesh P. Soni and Bharat B. Mistry "Qualitative review of seismic response of vertically irregular building frames"- ISET Journal of Earthquake Technology, Technical Note, Vol. 43, No. 4, December 2006

- Dipak M. Kolekar1, Mukund M. Pawar-" Study of Base Shear, Storey Shear and Base Moment on Multistory Building for Different Seismic Zones ”- International Journal of Engineering Science and Computing, June 2017 VOLUME 7 ISSUE 6