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Comparison of seismic performance of steel Frames with regularity and irregularity in Elevation

M. A. Shayanfar[1], M. Ghanooni-Bagha[2], Y. Khalaj-zadeh[3]

[1] *The Centre of Excellence for* Fundamental *Studies in Structural Engineering, Iran University of Science and Technology, P.O.BOX: 16765-163; Narmak, Tehran, Iran*

[2] *Department of civil Engineering, East Tehran Branch, Islamic Azad University, Tehran, Iran*

[3] *School of Civil Engineering, Iran University of Science and Technology, P.O. Box 16765-163, Narmak, Tehran, Iran*

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**Corresponding Author. E-mail: ykhalaj1990@yahoo.com*

Abstract

Irregularities instruments, as a result of the limitations of architectural, performance and finance, are one of the issues considered unavoidable in many urban structures. This study examines the seismic behavior of steel structure with vertical irregularities, including mass, strength and stiffness irregularities. Structural steel moment frames as 2D models were Designed, and using nonlinear static and dynamic analyses, seismic demand frames are calculated. Columns of the middle storey in a regular state have attracted less energy, while irregular structures columns of middle- storey absorb almost 2 times higher energy. If irregular floor is at a higher storey, acceleration in control point is higher. Existence of soft and weak storey, increases the higher mode effect on mass participation ratio.

Keywords: Steel Frames, Irregularities in Height, Pushover Analysis, Time History Analysis

1. Introduction

In the early decades of the twentieth century terms resistance and performance were synonymous from around 25 years ago, the difference between these two terms were determined and it was found that increase in strength is not necessarily increase safety and less failures. The researchers showed that the distribution of structural resistance components is more important criterion of strength. Collins & Chen [1] carried out a research on seismic performance of steel buildings asymmetric double height using nonlinear static and dynamic analysis, concluded that the effect of soil type and level of earthquake risk is more effective than the winding. Bugeja et al. [2] examined the effect of resistance on the response of nonlinear structures eccentricity and dynamic parameters in terms of their structure and concluded that the eccentricity of the resistance of eccentricity affects the stiffness for nonlinear response. Moghadam & Tso [3] study on a seven storey building asymmetric concluded that the effects of torsion in asymmetrical buildings are important, instead of using three-dimensional analysis Pushover be the first to use linear dynamic analyzing several target displacement, each corresponding to one of the side panels open is also determined.

Faella and Killar [4] examined seismic behavior of asymmetric triangular using analysis of structures pushover. In this method for consider the effects of torsional loading on the location of the construction work was performed in 4 points and was nonlinear dynamic analysis of similarity of the results. Lopez-Menjivar and Pinho [5] in the same building as the three-dimensional model under both constant load and was staggered by pushover analysis, nonlinear behavior of concrete materials, respectively. G.W and Outinen [6] showed that the results of static analysis, where the output of the centrality of design shear distance from the center rigidity of the center of mass is not ensure and the effect of storey and mass moments of inertia caused by the creation of

the dynamic behavior of torsional twisting moments is larger than the static torsional moment.
M.n.bugzha et al. (1999), have done some experiments on the effect of eccentricity tough resistance on nonlinear response of asymmetric structures and by providing an analytical model that considers key parameters and dynamic characteristics of the actual structures concluded that more eccentricity hardly affects the nonlinear response of asymmetric structures. Moghadam and Tessu studies pointed out they proposed a modified method for considering the effect of twisting the asymmetrical structure.
Goyle and Chopra [9] to study the behavior of asymmetric models with resisting elements in both directions perpendicular to the earthquake and concluded that elements are effective in decreasing the maximum ductility demand and have maximum displacement. Ghanoonibagha et al. [10] investigate interaction of soil adjacent to the walls of basement using Gap elements with nonlinear static analysis method.
According to the above mentioned research study to investigate irregularities in the height and shortcomings of researches in this research try to consider the effect of irregularities in the large constructions and the effects of this irregularity must be considered in the seismic behavior of structures and the impact of irregularities in height compared to conventional structures.

2. Research Method

In this study, using the software Perform3D the analysis and design of structures discussed above, and finally using the output of the software to compare the performance of different scenarios irregularities in the structure of short and long has been a regular mode.
Nonlinear static method (Pushover) is an easy nonlinear analysis method to work on design guidelines based on performance [3, 11]. In nonlinear static analysis lateral forces as a certain load pattern as step increases the structural members are gradually. This operation will continue until the structure becomes unstable or failure mechanism happened. Thus graph structure as capacity building in front of the base shear displacement curve for a particular point of the structure (e.g. roof) is obtained. The performance levels of a structure pushover analysis by FEMA to the non-stop service (Operational), usability of uninterrupted (Immediate Occupancy) life safety level (Life Safety) level of the threshold of collapse. (Collapse Prevention) is classified [11~ 14].
In order to perform nonlinear dynamic analysis on the frames, also modal increased load analysis of a system with one degree of freedom seven pairs of registered acceleration mapping consist of: Northridge, El Centro, Cape Mendocino, Loma Prieta, Morgan Hill, San Fernando, Whittier Narrows are used; all of these mappings are held on type II (according to Iranian standard) as time history of earth drastic movement. Regarding Iranian Standard, all of these acceleration mappings should be tantamount. In this study, the average spectrum from seven pair of acceleration mapping is coordinated with design spectrum for soil type II by using Seismosignal software [15]. After that, nonlinear dynamic analysis of principal structure is held by means of selected acceleration mappings [16, 17].

3. Case Study

First two steel frames 5 and 20 floors with [16, 17], are designed so that the mass and frame stiffness and strength of floors at evenly distributed. Frames of the hospital building (with high importance) and in an area with high seismic risk is specially modeled frames. 3.2 m height and size of all spans is shown in Figs (1,2).
In the next stage by creating irregularities in mass and stiffness and resistance in the initial frames of new models is achieved. These new models include frames that according to the reference 17 Regulations and irregularities in their frames have been created at different heights. Then, PERFORM 3D modeling software every frame and nonlinear static analysis (pushover) and nonlinear dynamic analysis (time history) [18]. Capacity of the structure and dynamic parameters of structural elements derived models and impact analysis study on the seismic behavior of frame considered irregularities in height (tables 1 and 2).

4. The results of pushover analysis

At this stage some of the graphs of linear static analysis models as capacity curve (pushover) as well as their performance levels are provided.

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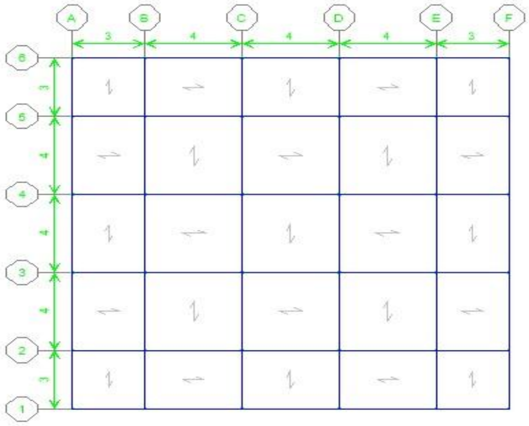

Figur1 Building plan of 20 storey structure

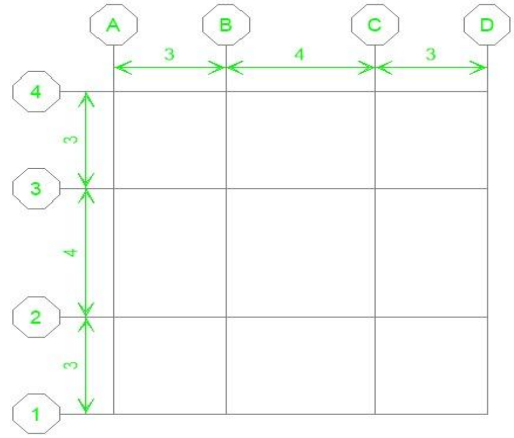

Figure2. Building plan 5 storey structure

Table 1. Five story building and irregularity causes

Case	Factors of irregularities	Irregular-type of irregularity
A_1	—	regular
A_2	1.5 times increase in loads	150% mass disorder in middle class
A_3	1.5 times increase in loads	150% mass disorder on the top floor
A_4	Increasing height of 4.2 m	70% reduction in hardness on the ground floor
A_5	Increase of 1.8 times of the height of floors	80% of middle class resistance

Table 2. 20story building on the causes of irregular

Case	Factors of irregularities	Irregular-type of irregularity
B_1	—	regular
B_2	1.5 times increase in loads	150% mass disorder in middle class
3_3	1.5 times increase in loads	150% mass disorder on the top floor
B_4	Increasing height of 4.2 m	70% reduction in hardness on the ground floor
B_5	Reduction of lateral resistant	80% of middle class resistance

In this diagram, the vertical axis cutting the base (ton) and the horizontal axis shows the percentage of storey drift. Marks indicated on the envelope graph performance levels IO, LS, CP show; that red color represents the IO performance level and performance level LS and yellow-green color indicates the level of performance CP, is. Vertical line, base-shear off the tops graph target displacement for the IO performance shows, pushover and graph linear approximation using two coefficients method according to FEMA 356 is obtained
Figs. 3 and 4 show incorporated push over of structures in regular and irregular conditions.

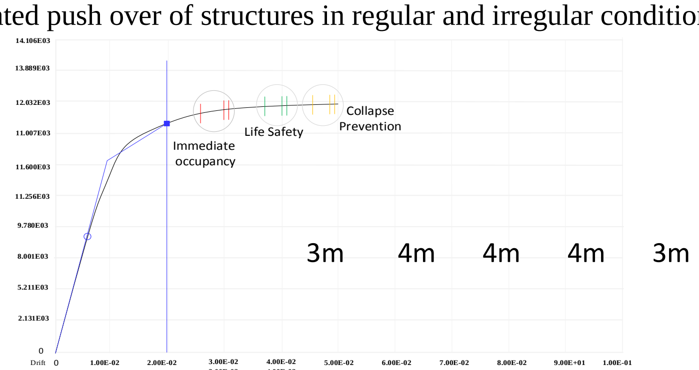

Figure 3 – pushover curve of 5-storey regular building

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Figure 3 showed Pushover diagram (base shear-target displacement) for the regular 5-story frame. As can be seen because of the uniform distribution of mass and stiffness and strength target displacement against the base shear is applied in small steps pushover analysis and also considering that the IO performance level after target displacement, structure is capable IO performance.

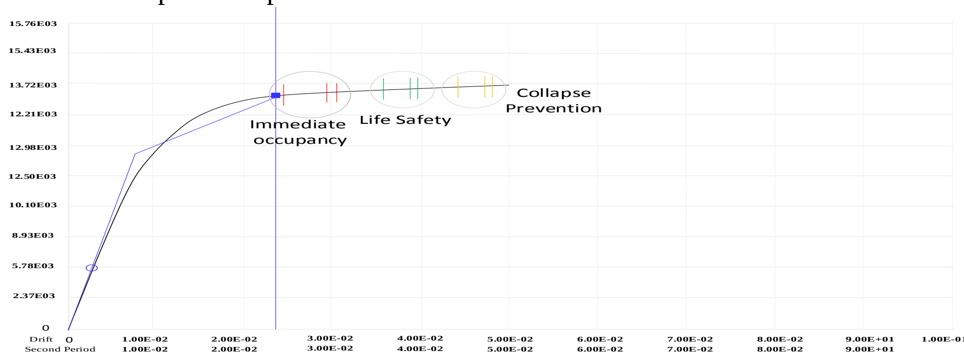

Figure 4 – pushover curve of regular 20-storey building

Pushover diagram (Base shear- Displacement in target point) Figure 4 shows a regular 20-storey frame structure. As can be seen because of the uniform distribution of mass and stiffness and strength target displacement against the base shear is applied in small steps pushover analysis and also the performance level of IO is before than target displacement, thus the structure is capable of IO performance.

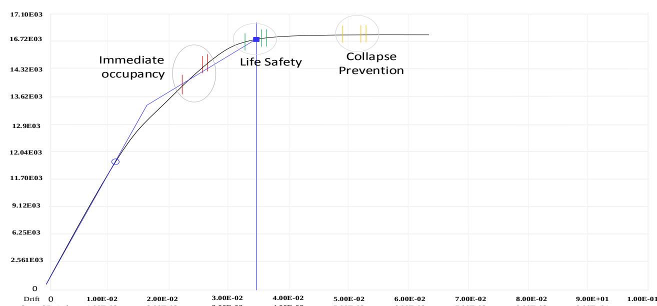

Figure 5- pushover curve of 5 storey building with 150% mass irregularity in middle storey

Figure 5 shows pushover curve of 5-storey frame with 150% irregularities mass on the third floor. As can be seen due to non-uniform distribution of mass target displacement the increased base shear is applied in the analysis steps and also considering that the performance level of IO is less than target displacement, the performance level of IO is lost and it means that the structures before they reach the target displacement more of its member passed the displacement level of IO.

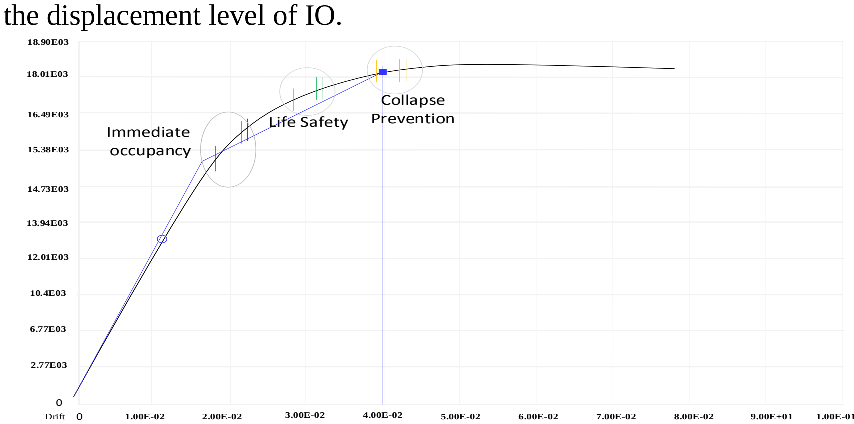

Figure 6 - pushover curve of 5-storey building with 150% mass irregularity on the top floor

Figure 6 shows 5-storey building with 150% frame pushover diagram mass irregularity on the top floor. As can be seen due to non-uniform mass distribution target displacement against the base shear is applied in the high cover analysis steps and also considering that the performance level IO is before than displacement target, performance level IO is lost and it means that the structures before they reach the target changed to displacement more of its lateral extent that the level of its IO performance satisfy. A comparison of pushover diagram of 5-storey with mass irregularity that irregularity in the middle storey of the height and in the highest storey, can be adverse impact of the increase in mass that is greater at higher stories, and this increase in mass in the higher stories, creating more demand in the structure.

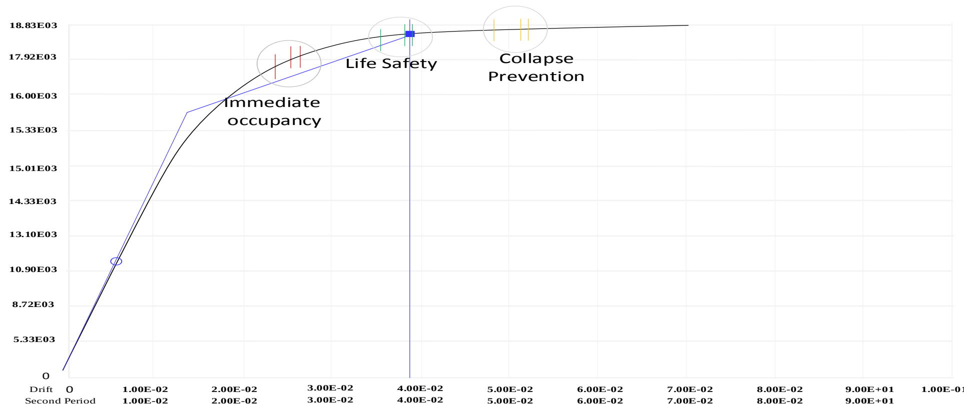

Figure 7- Pushover curve of 20 storey- structure with 150% mass irregularity in middle storey

Figure 7 shown, pushover diagram of 20 storey structure with 150% charge of mass in middle storey. As can be seen due to non-uniform distribution of mass target displacement the increased base shear is applied in the analysis steps and also considering that the performance level of IO to target displacement performance level IO is lost.

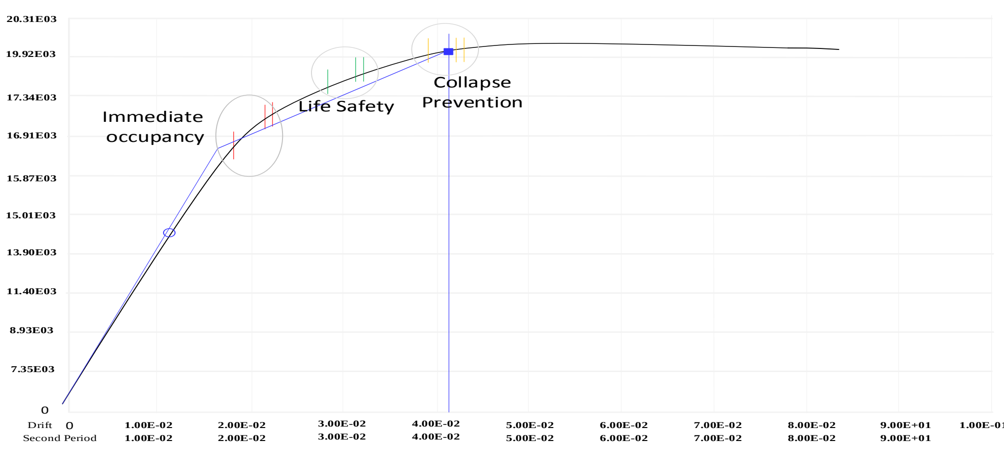

Figure 8 - Pushover diagram of 20-storiey structure with 150% mass irregularity on the top floor

Figure 8, shows pushover curve of 20-storey structure with 150% mass irregularity on the top floor. As can be seen due to non-uniform mass distribution target displacement against the base shear is applied in the high cover analysis steps and also considering that the targeted performance level of IO to target displacement, the performance level of IO is lost. Compare tops diagram in the mid-height of 20-storey structure is disorganized mass tops diagram with 20-storey structures that mass irregularity was on the top floor, can be adverse impact of the increase in mass that is greater at higher stories, and this increase in mass in the higher stories, creating more demand in the structure (Figs. 9-12).

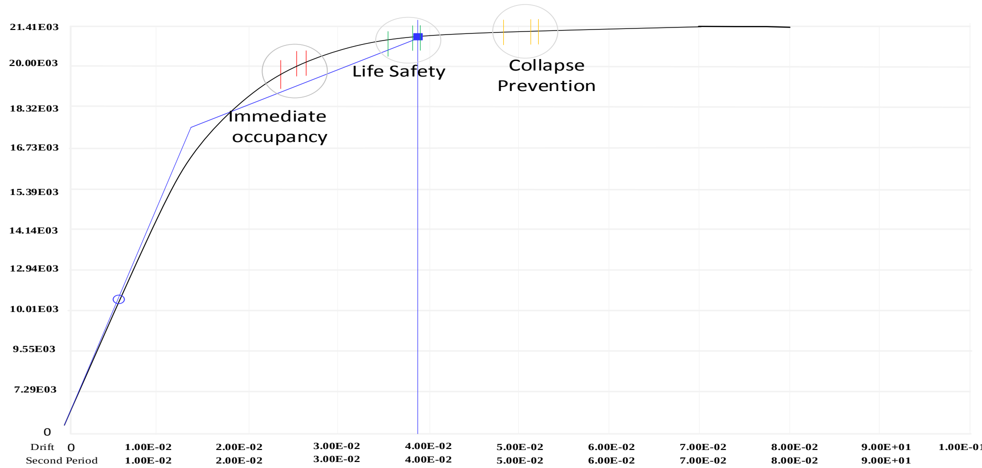

Figure 9- pushover diagram of 5-story irregularity structure decreased by 70% stiffness in ground floor

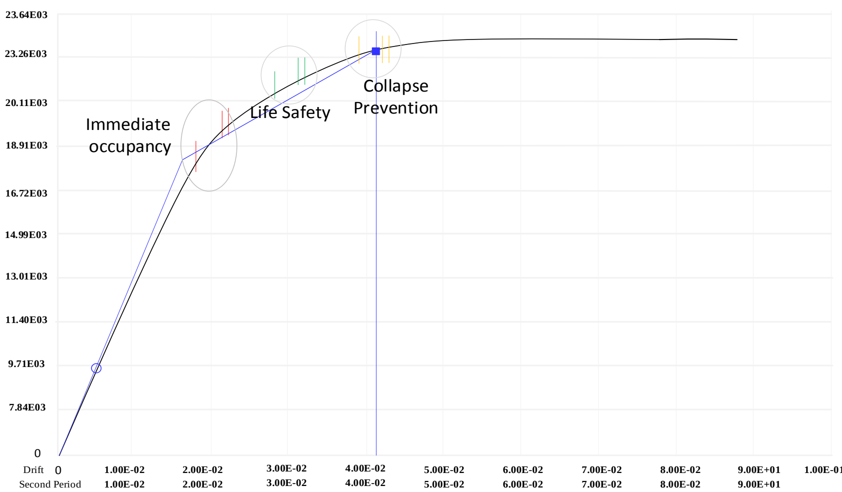

Figure 10 - pushover diagram of 20-storey irregularity structure decreased by 70% stiffness in ground floor.

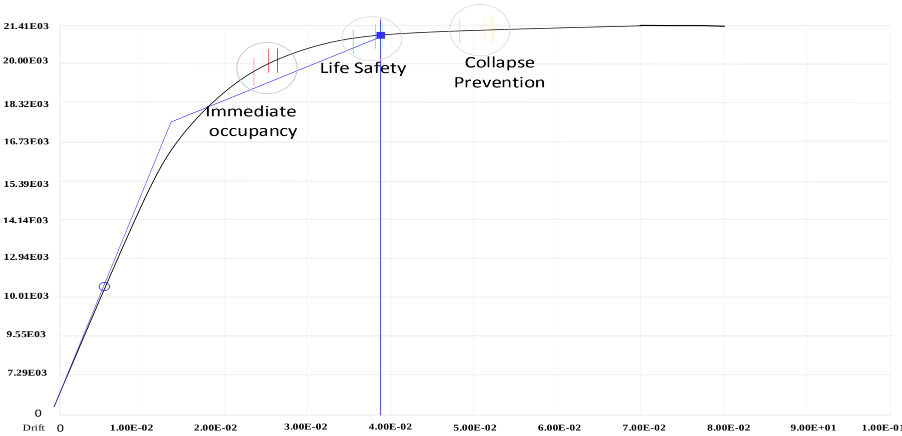

Figure 11 - pushover curve of 5-storey structure with the irregularity 80% resistance reduction in the middle storey

Figure 12 - pushover curve of 20-storey structure with the irregularity 80% resistance reduction in the middle storey

Table 3. Levels of 5 story structure performance in different scenarios

Level of performance	
IO	Regular 5 story structures
LS	5 story building with 150 percent irregularity in the middle floor
CP	5-storey building with 150% of the mass irregularities in the highest story
LS	5-storey structures with irregularities due to 80% reduction in middle-class resistance
LS	5-story structure with a 70 percent reduction in hardness on the ground floor

Table 4. Performance of levels 20-story structures in different states

Level of performance	
IO	Regular 20 story structures
LS	20 story building with 150 percent irregularity in the middle floor
CP	20 storey building with 150% of the mass irregularities in the highest story
CP	20-storey structure with irregularities due to 70% reduction in hardness of the ground floor
CP	20-storey structure with irregularities due to 80% reduction in middle-story resistance

In a moment frame to the energy induced by the earthquake to construct more beams to be absorbed and therefore less power to impose structural columns and beams fail in later columns. One of the outputs of the time history analysis software charts related to the energy balance structure, in which the four have a modeling stage. For example, if inductive energy absorption beams on the first floor of the building to assess, should be modeled in the first floor beams will be organized in a group (Tables 3 and 4) .
Energy balance energy absorption in the diagram vertical axis shows the percentage of members and the horizontal axis when members begin to absorb their energy in terms of seconds. The yellow curve energy absorption induced by the earthquake by members who consider us to show and red curve shows the amount of energy absorption of constructions.
In following figures, diagrams and energy balance models in different states of regular and irregular construction is provided. In this forms of energy balance by comparing the graphs of regular and irregular 5-storey structures can be seen that when the structure is one of the columns of the middle storey has attracted less energy.

But while mass is irregular structures, columns of the middle storey is almost 2 times higher than the energy to have a negative impact on the seismic behavior of structures that time.
Figures 13 to 20 show level of absorption column of structures in different states.

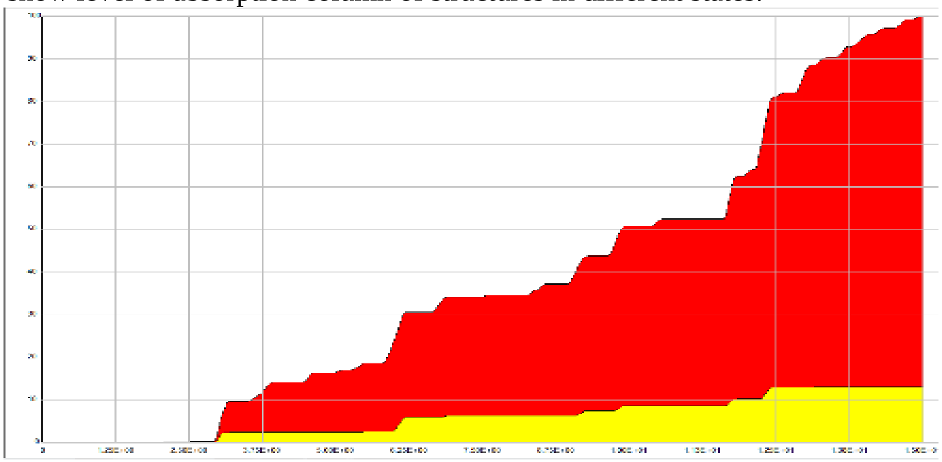

Figure 13 - Energy balance diagram of columns in the top storey of 5-storey regular structure

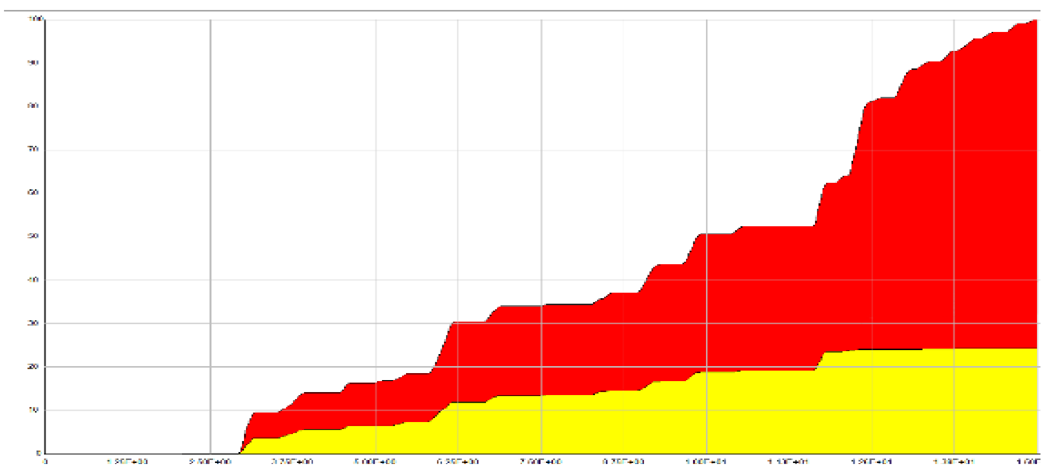

Figure 14 - Energy balance diagram of columns in the middle storey of 5-storey regular structure

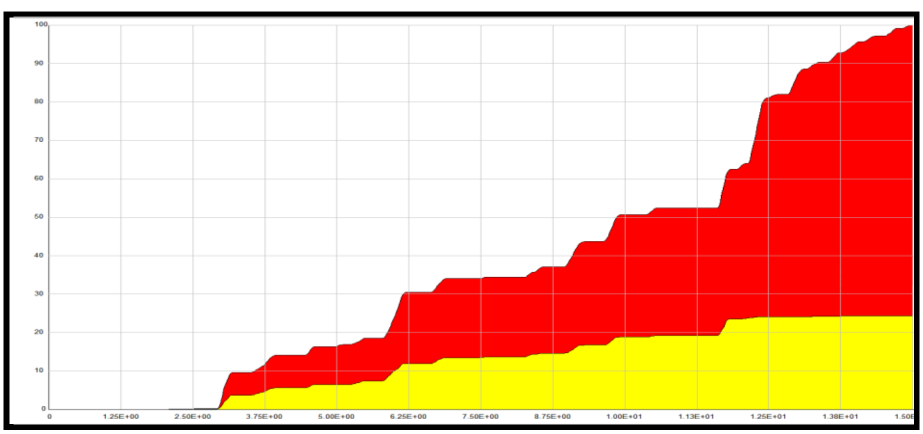

Figure 15 - Energy balance diagram of columns on the ground floor in regular 5-storey structure

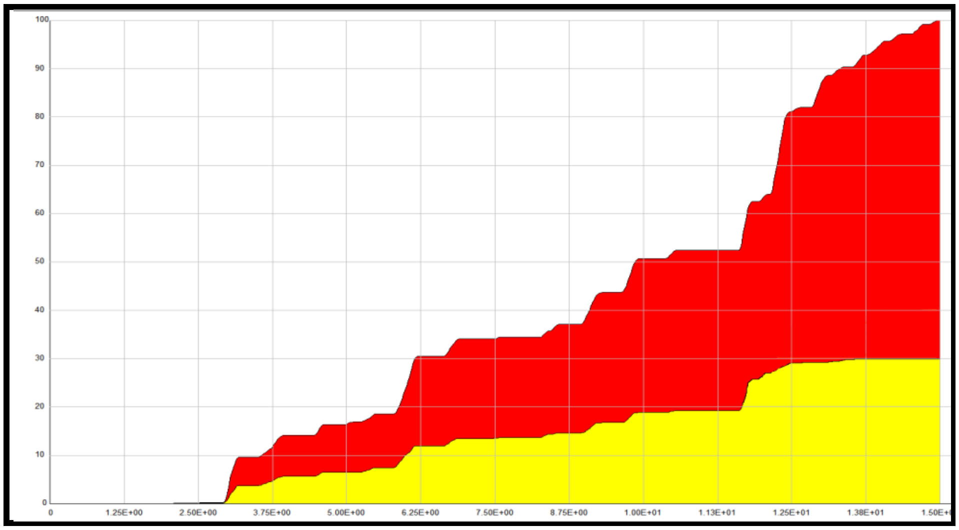

Figure 16 - Energy Balance diagram of columns at the fifth floor of 5-storey building with 150% mass irregularities in roof

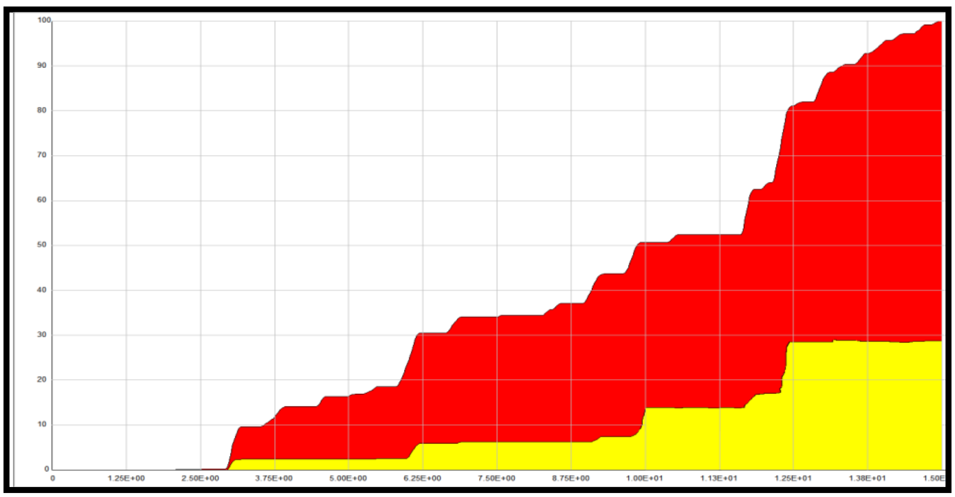

Figure 17 - Energy balance diagram of columns at twentieth floor in a regular 20-storey building

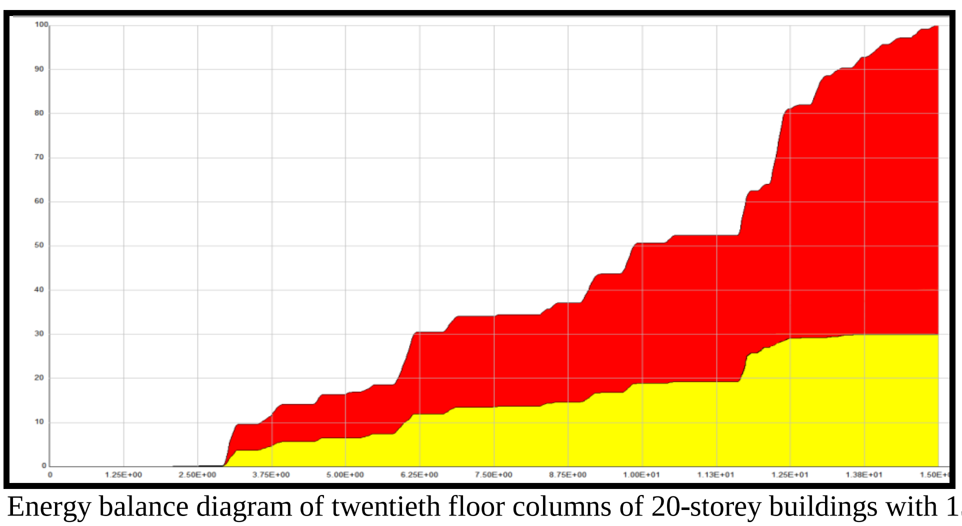

Figure 18- Energy balance diagram of twentieth floor columns of 20-storey buildings with 150% of the mass irregularity in roofing

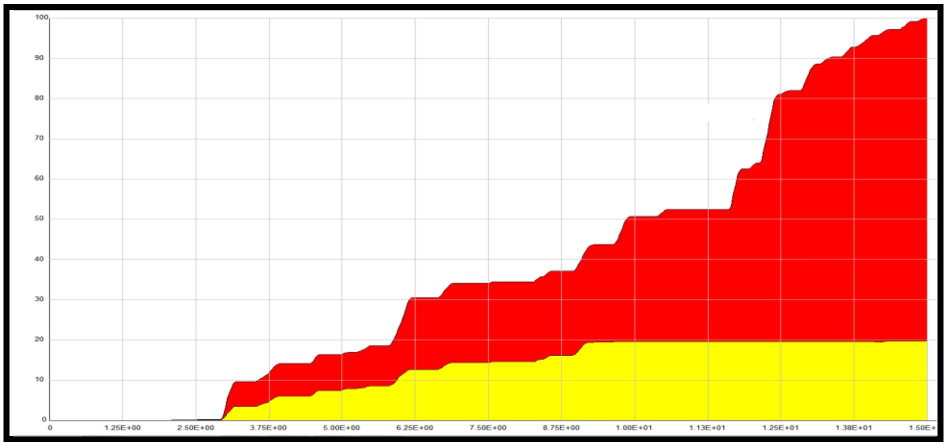

Figure 19 - Energy balance of ground floor columns in 5-storey building with the irregularities caused by 70% stiffness decreased

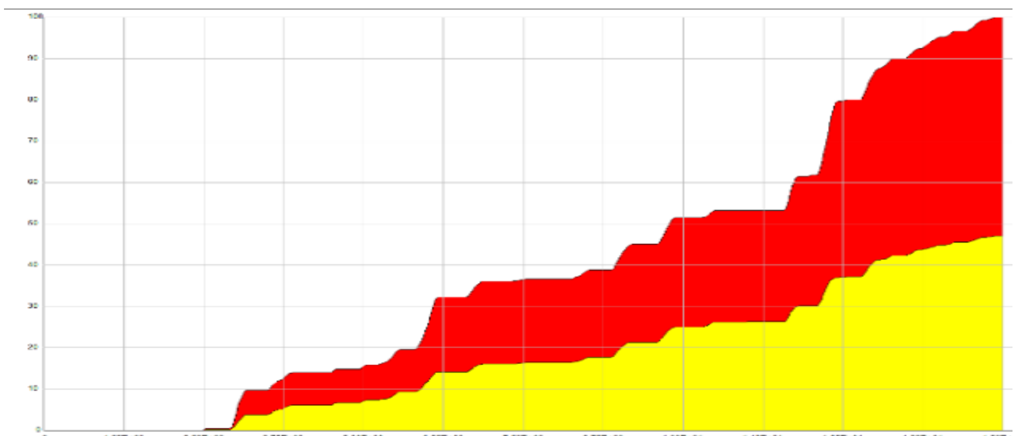

Figure 20 - Energy balance of ground floor columns in 5-storey building with the irregularities caused by 80% resistance decreased

Table 5. 5-story structures in different states of energy absorption

Energy absorption	
13	5-storey constructions regular column in the middle class
23	5-storey building with 150% of the mass of irregular in middle story
20	Regular columns on the fifth floor in 5 floor building
30	5-storey building with 150% of the mass of irregular in middle story
23	Ground floor columns of regular 5 story building
30	Columns of ground floor of 5 story building with 70 percent reduction in hardness

Table 6. energy absorption by 20 story bulding columns in different states

Energy absorption percant	
28	Columns of twentieth story of 20 story regular structure
33	Columns of twentieth floor of 20 story building with 150 percent irregular mass
15	Columns of middle story of 20 floor structure
24	Columns of middle story of 20 story building with 150 percent irregular mass

When instruments are affected by a particular earthquake, force structure, and subsequently to the force structure, accelerate. Check acceleration control point where the center of mass of the roof structure in good measure to evaluate the seismic performance of structures is taken. At this stage absolute acceleration curve control points have been presented models (Tables 5, 6).

Figs 21 to 29 show absolute acceleration graphs in control point of structures in different modes.

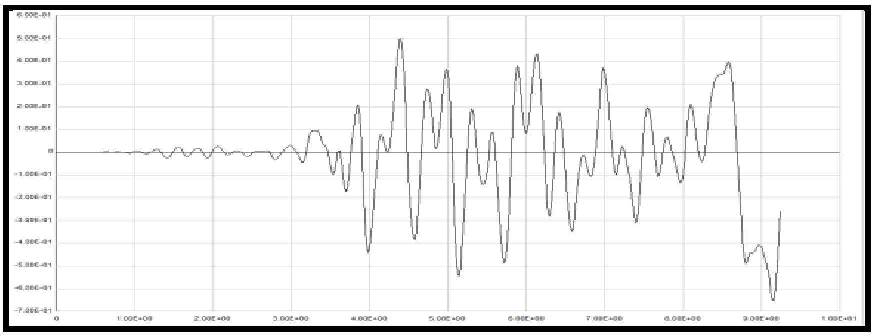

Figure 21 - Absolute acceleration at control point (center of gravity of roof) in regular 5-storey building

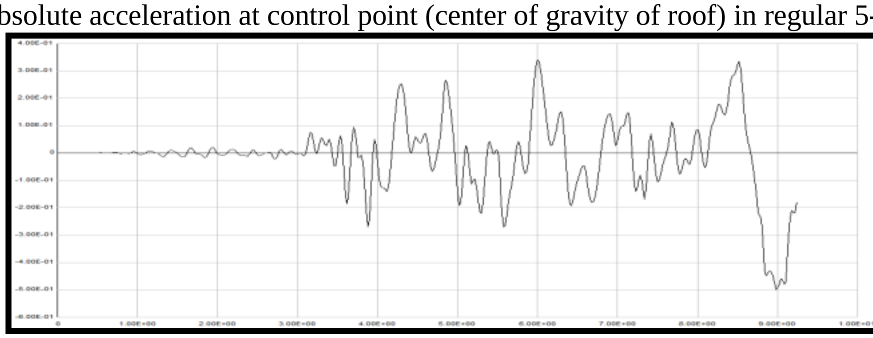

Figure 22 - Absolute acceleration at control point (the center of mass in the roof) 5-storey building with 150% mass irregularities in the middle storey

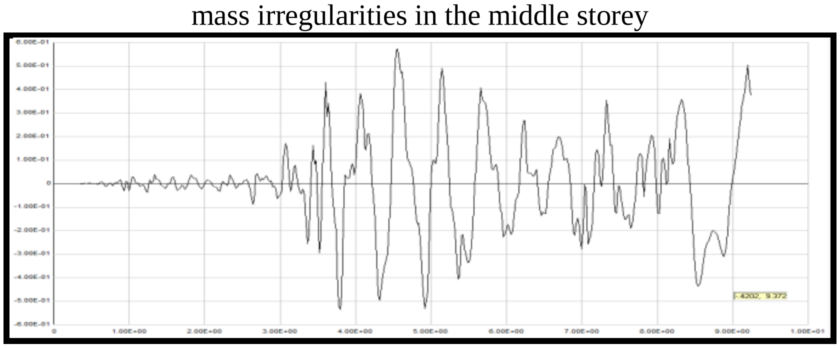

Figure 23 - Absolute acceleration at control point (target point) of 5-storey building with 150% of the of the mass irregularities on the top floor

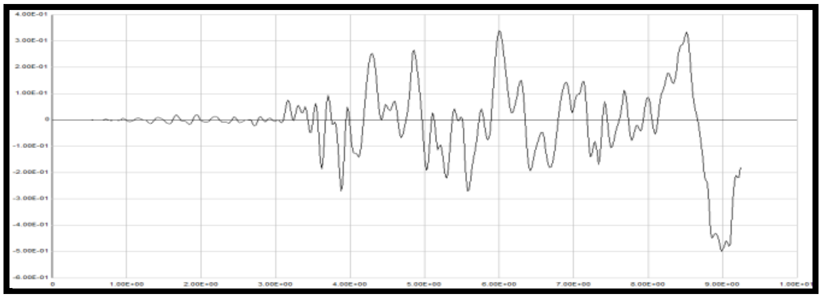

Figure 24 - Absolute acceleration at control point in regular 20-storey building

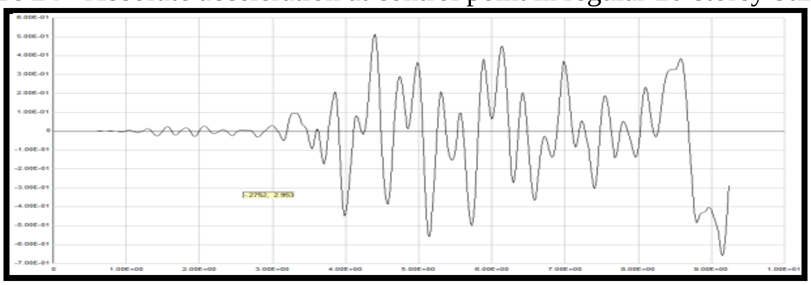

Figure 25 - Absolute acceleration at control point of 20-storey structure with 150% of the mass irregularities in roofing

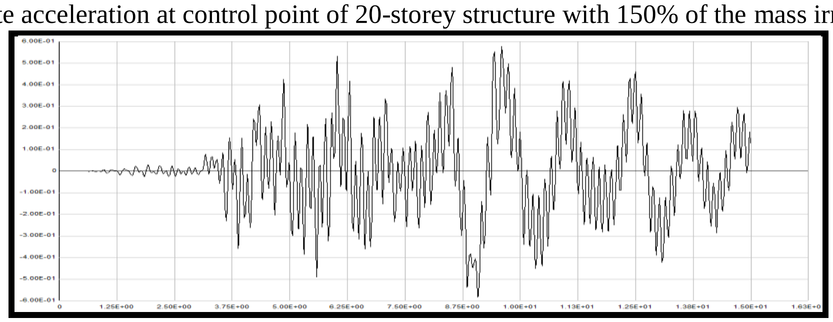

Figure 26 - Absolute acceleration at control point of 5-storey structures with irregularities 70% reduction in stiffness of the ground floor

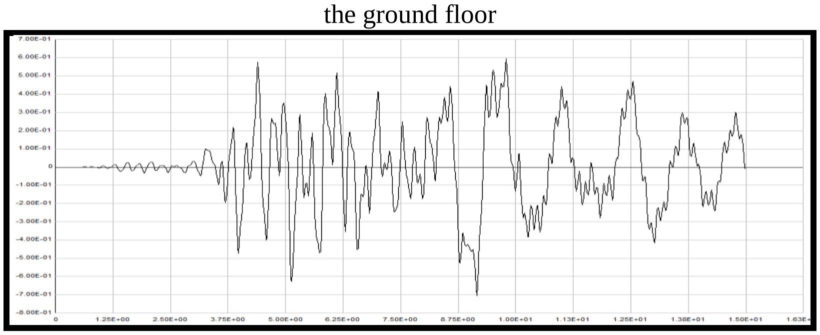

Figure 27 - Absolute acceleration at control point of 20-storey structure with irregularities by 70% stiffness decreased in the ground floor

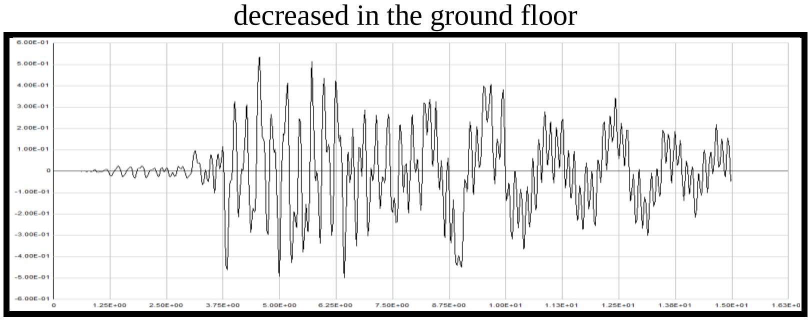

Figure 28- absolute acceleration at control point in 5-storey structures with irregularities of 80% resistance reduction of the middle storey

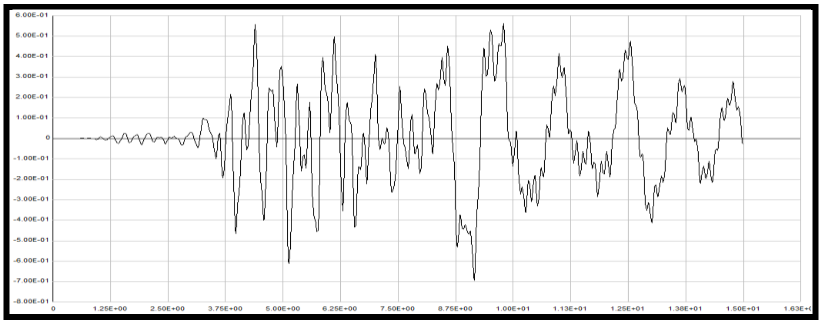

Figure 29 - absolute acceleration at control point in 20-storey structure with irregularities arising from 80% resistance reduction in middle storey

Mass participation frames per cent in the first case in various states (Tables 7, 8, 9)
Amount of first mode of mass participation of frames in different states

Table 7. Absolute acceleration of control point in 5 story building

Absolute acceleration of control point	Irregular-type of irregularity
4-E01	–
5-E 01	150% mass irregular in middle floor
5.8-E01	150% mass irregular in top floor
6-E01	70% reduction in hardness on the ground floor
5.3- E01	80% reduction in middle story

Table 8. Absolute acceleration of control point in 20 story structure

Absolute acceleration of control point	Irregular-type of irregularity
5-E01	–
5.5-E01	150% mass irregular in middle floor
6.3-E01	150% mass irregular in top floor
7-E01	70% reduction in hardness on the ground floor
7- E01	80% reduction in middle story

Table 9. First mode participation in different states

Structural features	5- story structure	20-strorey structure
in regular mode	94.31%	92.05%
with mass irregularities in roof	66.9%	63.34%
with irregular stiffness on the ground	53.47%	49.33%
with irregular resistance in the middle	56.39%	58.9%

Conclusion

- In both 5-storey and 20-storey respectively with the advent of mass irregularities and stiffness and resistance in height, to a large degree relative displacement of storey (storey drift) increased its poor performance on mobile. In addition, it was observed that irregularities stiffness and resistance to mass irregularities more unfavorable effects on seismic demand structure.

- Performance levels of structures calculated using non-linear static analysis. Studies show that regular frame that are designed to optimize, all performance levels of IO, LS and CP hold and frame to derive target displacement at IO performance is less base-shear in irregularity states, and with a variety of irregularities, the structure gradually loses its performance levels.
- An increase in mass in irregular floors increases the relative displacement and base-shear and earthquake forces of floors in irregular floor and around it. So, observed that the irregular mass, whatever frames come in the upper floors of the structure is critical. It is recommended to generally avoid the accumulation of mass in a storey and otherwise irregular floor mass, placed in the lowest height of the structure. It was observed that this is contrary to irregular stiffness and strength, and the emergence of soft or weak in the lower stories, structures performance is much worse than shown.
- By examining the energy balance diagram was observed which creates irregularities in a particular storey causes the irregular floor columns, attracted upper part of the structure from earthquake-induced energy, this causes premature plastic hinges in the main members of irregular storey.
- In structures with stiffness irregularities, energy absorption columns in irregularity storey is more than any other irregularities.
- By examining the amount of mass participation in the first mode of frame was found that the sudden change in mass of stories, increased the effect of participation of higher modes and structural response depends on to it.
- In short and high-rise structures, if irregular floor locate at a higher storey, the control point, its acceleration is higher and this makes it more floor force to impose structures.

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