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Study of Seismic Responses of Multistoried RCC Building with Mass Irregularity and column stiffness Variation

Harshakunj Y. Sangore[1], S. T. Sanap[2], U. S. Ansari[3]

PG Student, Department of Civil Engineering, SND College of Engineering & Research Center, Nashik, India[1]

Professor, Department of Civil Engineering, SND College of Engineering & Research Center, Nashik, India[2]

Professor & Head, Department of Civil Engineering, SND College of Engineering & Research Center, Nashik, India[3]

Abstract: From recent earthquakes it is proved that many of structure are totally or partially damaged due to earthquake. So, it is necessary to determine seismic responses of such buildings. Also presence of mass irregularity in the structure may lead structure to the failure if not taken into account. There are different techniques of analysis of structure. Response spectrum analysis is one of the important dynamic method of analysis which will be used in this project work. This paper is concerned with the effects of various Mass and column stiffness Irregularity on the seismic response of a structure. The primary objective of the project is to carry out Response spectrum analysis (RSA) of vertically Mass irregular RC frames with column stiffness variation. Comparison of the results of analysis of irregular structures with regular structure will be done. Comparison of mass irregular buildings having different column stiffness will also be done. The scope of the project also includes the evaluation of response of structures for axial force, base shear, time period, storey drift and storey displacement.

Keyword: Response spectrum analysis (RSA).

I. INTRODUCTION

Earthquakes are occasional forces on structures that may occur rarely during the lifetime of buildings. It is also likely that a structure may not be subjected to severe earthquake forces during its design lifetime. Reinforced Concrete Multi-Storied buildings (RCMS) are supposed to be of engineered construction in the sense that they might have been analyzed and designed to meet the provisions of the relevant codes of practice and building bye-laws; the construction might have been supervised by trained persons. In such cases, even if earthquake forces have not been considered precisely, the structures would have adequate in-built strength and ductility to withstand some level of earthquake intensity. During the past 50 years, only two events- Jabalpur Earthquake of May 1997, and Kutch earthquake of January 2001 have caused significant damages to RCMC buildings with some spectacular damages during latter event. Compared to the large number of RCMS buildings in existence in the country, the number of damaged structures due to earthquakes is indeed very small. It is usually assumed that damage is due to poor quality of construction, and builders are usually blamed for greed. However, it is possible that codes might have been inadequate in some cases.

II. LITERATURE REVIEW

A. Himanshu Bansal (1999), In this research work, the storey shear is found to be maximum for the first storey and it decreases to a minimum value in the top storey in all cases. It is found that mass irregular building frames experience larger base shear than that of similar regular building frames. Base shear for the stiffness irregular building is lesser as compared to that of regular frame.

B. Md. Arman Chowdhury (1999), In this literature study the dynamic behavior of the structure is studied, dynamic analysis is performed on regular and irregular structure with and without isolators. Dynamic analysis may be linear response spectrum analysis or time history analysis. Isolator increases the time period of the structure which reduces the possibilities of resonance of the structure.

C. A. S. Patil, This research paper shows a similar variations pattern in Seismic responses such as base shear and storey displacements in horizontal directions with intensities V to X. Based on the study it is concluded that for multistoried RC frame structure, Time History method of analysis becomes necessary to ensure the safety of structure against earthquake forces.

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D. **P. P. Chandurkar**, This literature deals with the seismic design of buildings, shear walls act as major earthquake resisting members. Structural walls provide an effective bracing system and offer great strength to resist lateral loads. The installation of these seismic shear walls helps to reduce the response of the structure, and hence, it becomes important task to evaluate the seismic response of the walls accurately.

III. OBJECTIVE OF WORK

The primary objective of this work is to study the seismic response of multistoried RC framed building by Response spectrum analysis (RSA) Using ETABS software. This work also includes secondary objectives such as;

A. To analyse a multistoried RC framed building with mass irregularity

B. To compare behaviour of multistoried RC framed building for different mass irregularities & same column stiffness in terms of various responses such as lateral displacements, base shear, and drift.

C. To compare behaviour of multistoried RC framed building for same mass irregularity & different column stiffness in terms of various responses such as lateral displacements, base shear, and drift.

IV. METHODOLOGY

A. Literature survey by referring books, research papers carried out to understand basic concept of topic.
B. Identification of need of research.
C. Formulation problem statement.
D. Selection of plan for study.
E. Analytical work of modelling is to be carried out
F. Using software.
G. Analysis of the various models by using ETABS analysis package.
H. Interpretation of results & conclusion.

V. MODELLING AND ANALYSIS

At the starting of any project some preliminary study is required. These preliminary studies are required to know the exact behavior of the structure, to know the property of the structure and various load conditions of the structure.

Name of parameter	Value	Unit
Number of stories	20	Nos.
Height of Building	60	M
Floor to floor height	3	M
Length in long direction	29.4	M
Length in short direction	20.2	M
Size of the columns for case I	230X1000	MM
Size of the columns for case II	300X1000	MM
Size of the beams	230X450	MM
Thickness of internal wall	0.15	M
Thickness of external wall	0.23	M
Live load on slab	2	KN/M
Floor finish load	1.5	KN/M
Grade of concrete	M30	-
Density of concrete	25	KN/cubic meter
Unit weight of water	9.81	KN/cubic meter
Damping	5	%
Seismic Zone	V	-
Importance factor (I)	1	-
Responded reduction factor	5	-
Soil type	Medium soil	-
Time period (X)	0.996	Sec
Time period (Y)	1.202	Sec

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The primary focus of this thesis is to evaluate the response of building with various mass irregularities and subjected to column stiffness variation. The variation of seismic response of mass irregular building for different column stiffness are calculated by Response spectrum method. The comparison of various irregularities for two different column stiffness present in the building are studied in subsequent chapter.

A. Method of analysis:

Linear dynamic analysis i.e., response spectrum analysis is performed on all above models using ETABS analysis package.

B. Response Spectra Analysis:

Response spectrum method is a procedure for computing the statistical maximum response of a structure to a base excitation. The functions are defined to describe how the load varies as a function of period, time or frequency. Each of the vibration modes that are considered may be assumed to respond independently as a single degree of freedom system. Design codes specify response spectra which determine the base acceleration applied to each mode according to its period. Having determined the response of each vibration mode to the excitation it is necessary to obtain the response of structure by combining the effect of each vibration mode because the maximum response of each mode will not be necessarily occur at the same instant. Undammed free vibration analysis of entire building shall be performed using appropriate masses and elastic stiffness of the structural system to obtained natural period and mode shapes of those of its mode of vibration. The modes to be considered in the analysis should be such that the sum total of masses of all modes considered is at least 90% of total seismic weight.

For caring out response spectra analysis the building is may be considered as system of masses lumped at floor level with each mass having one degree of freedom and various quantities are computed based on following expressions.

1. Modal Masses

$$Mk = \frac{[\sum_{i=1}^{n} Wi\ \phi ik]^2}{g \sum_{i=1}^{n} Wi(\phi ik)^2}$$

Where

g = Acceleration due to gravity

ϕik = Mode shape coefficient at floor i in mode k

Wi = Seismic weight of floor i

2. Modal Participation Factor

$$Pk = \frac{\sum_{i=1}^{n} Wi\ \phi ik}{\sum_{i=1}^{n} Wi(\phi ik)^2}$$

3. Design Lateral Force at Each Floor In Each Mode

The peak lateral force at floor i in mode k is given by

$$Qik = Ak\ \phi ik\ Pk\ Wi$$

$$Qik = Ak\ \phi ik\ Pk\ Wi$$

Ak = Design horizontal acceleration spectrum value using natural period of vibration of mode k

4. Modal Combination

The peak response quantities shall be combined as per complete quadratic combination method as follows

$$\lambda = \sqrt{\sum_{i=1}^{r}\sum_{j=1}^{r} \lambda i\ Pij\ \lambda j}$$

Where,

r = Number of modes being considered

Pij = Cross modal coefficient

λi = Response quantity in mode i

λj = Response quantity in mode j

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$$Pij = \frac{8\zeta^2(1+\beta)\beta^{1.5}}{(1+\beta^2)^2 + 4\zeta^2\beta(1+\beta)^2}$$

ζ = Modal damping ratio
β = Frequency ratio = ωj/ ωi
ωi = Circular frequency in i th mode
ωj = Circular frequency in j th mode

VI. RESULTS AND FINDINGS

A Comparision of results of case I & case II

For the purpose of comparision of various results obtained, seven groups are made namely 1,2,3....6. The purpose of making the group is to compare the models of same mass irregularities but having different column stiffnesses.

In group 1, model 11 from case 1 is compared with model 21 in case 2, both being the regular structures with different column sizes. Likewise all grouping is done so we can show 6 comparisions in a single graph.

Copmarision includes Lateral displacements in X & Y directions, time periods, storey drifts, base shear and axial forces of columns selected for study shown in fig.

B Lateral displacements in X direction:

Graph 1. lateral displacements in X direction (Case I & II)

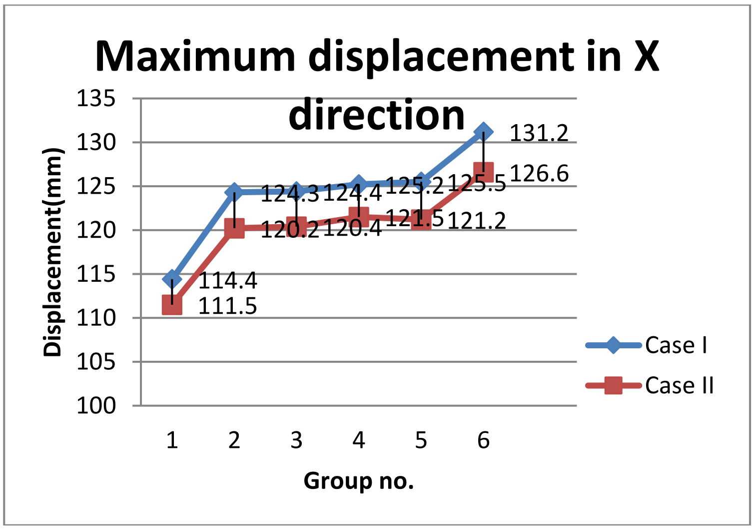

Table 1. Lateral displacement in X direction for case I & II

MODEL	Case I X displacement	Case II X displacement
M1	114.4	111.5
M2	124.3	120.2
M3	124.4	120.4
M4	125.2	121.5
M5	125.5	121.2
M6	131.2	126.6

C Lateral displacements in Y direction:

Graph 2. lateral displacements in Y direction (Case I & II) Table 2. Lateral displacement in Y direction for case I & II

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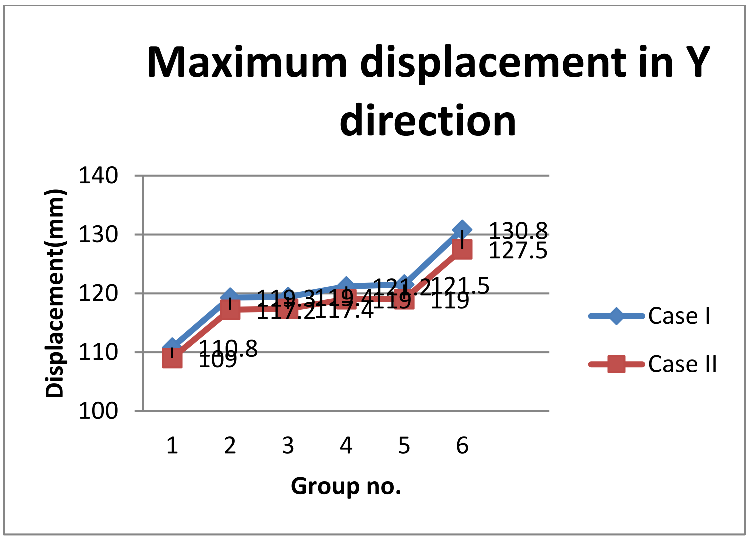

MODEL	Case I Y displacement	Case II Y displacement
M1	110.8	109
M2	119.3	117.2
M3	119.4	117.4
M4	121.2	119
M5	121.5	119
M6	130.8	127.5

D Storey drifts in X direction

Graph 3. Storey drift in X direction (Case I & II)

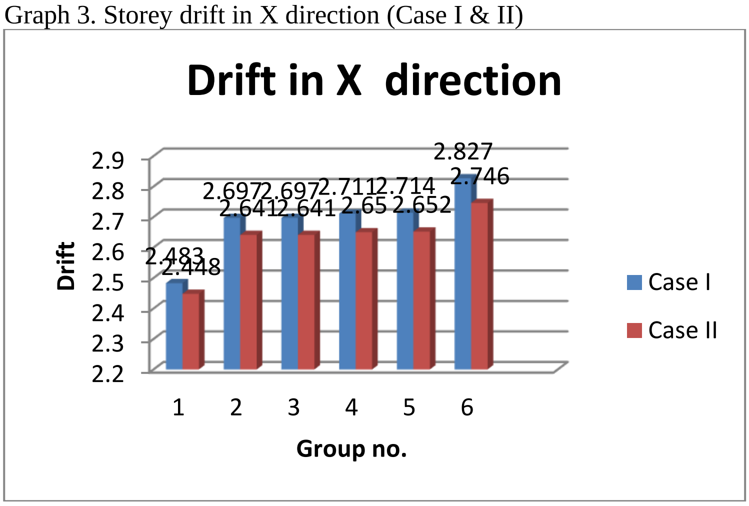

Table 3. Storey drift in X direction for case I & II

MODEL	Case I X Drift	Case II X Drift
M1	2.483	2.448
M2	2.697	2.641
M3	2.697	2.641
M4	2.711	2.65
M5	2.714	2.652
M6	2.827	2.746

E Storey drifts in Y direction.

Graph 4. Storey drift in Y direction (Case I & II)

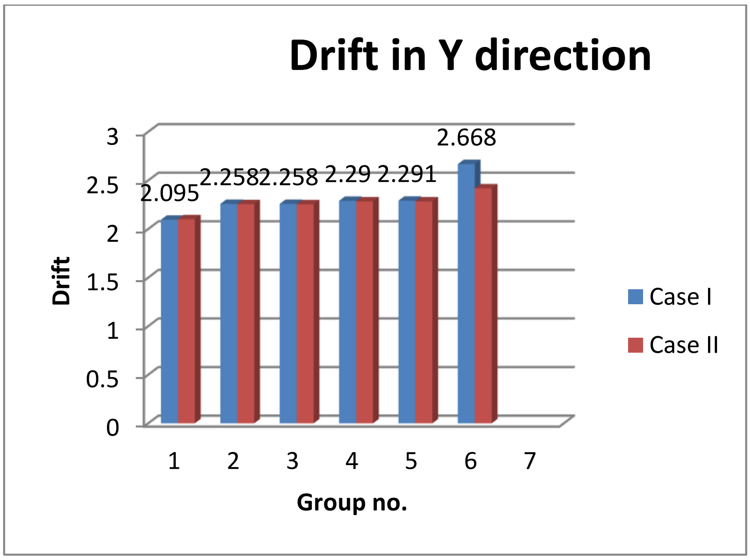

Table 4. Stoey drift in Y direction for case I & II

MODEL	Case I Y Drift	Case II Y Drift
M1	2.095	2.1
M2	2.258	2.255
M3	2.258	2.254
M4	2.29	2.284
M5	2.291	2.284
M6	2.668	2.418

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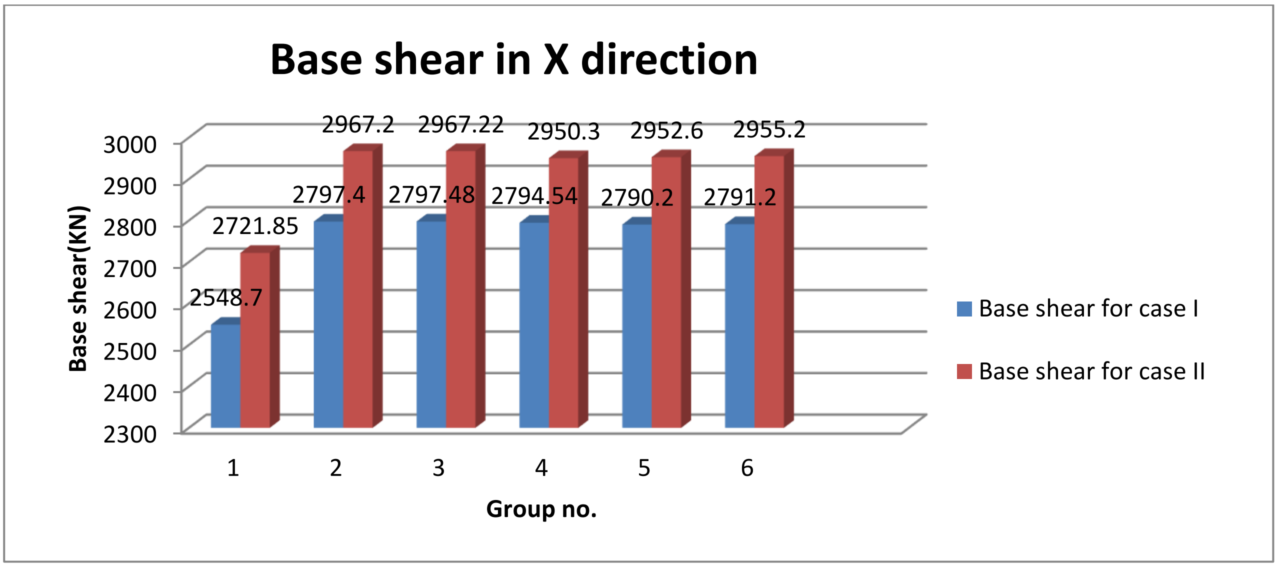
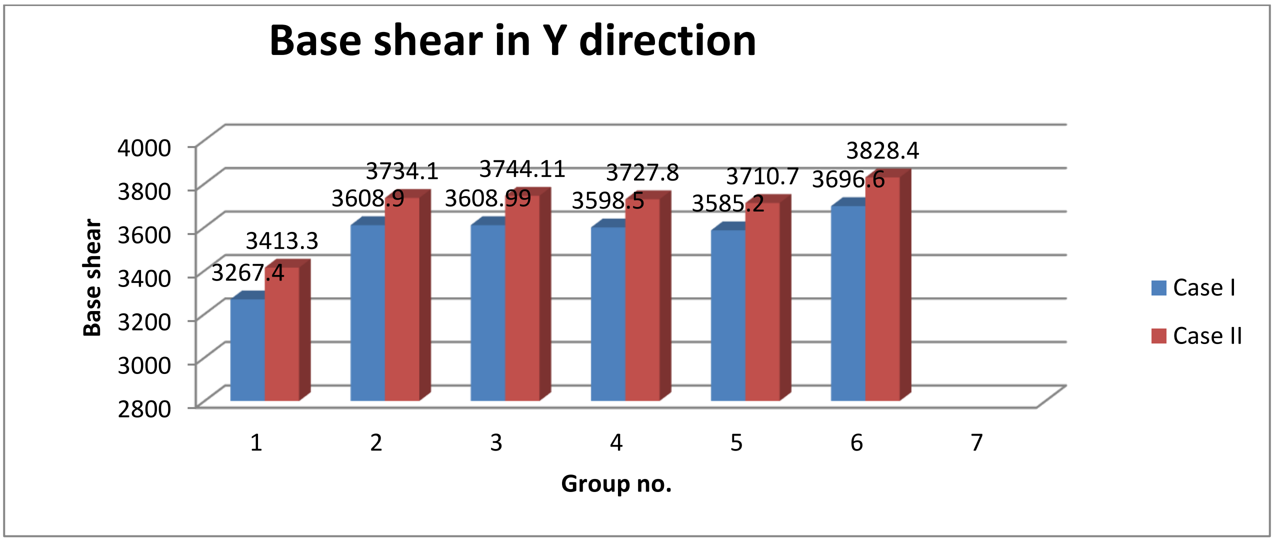
F Base shear in X direction

Graph 5. Base shear in X direction (Case I & II)



G Base shear in Y direction

Graph 6. Base shear in Y direction (Case I & II)



H Axial forces of selected columns

- **Column C6**

Graph 7. Axial force for column C6 (Case I & II)

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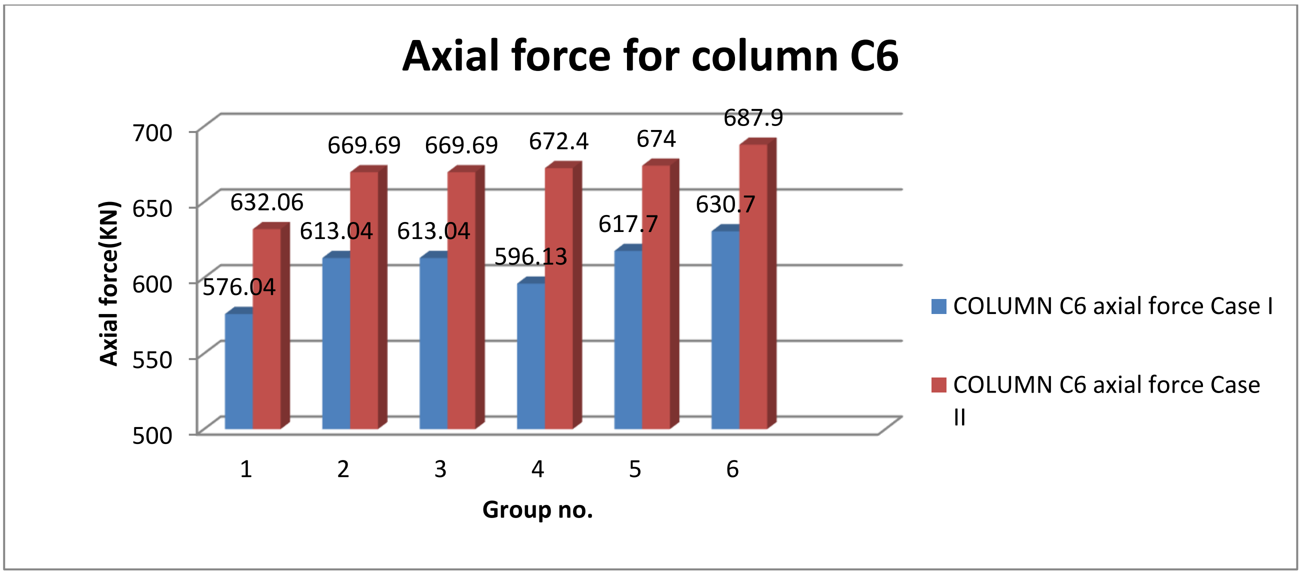
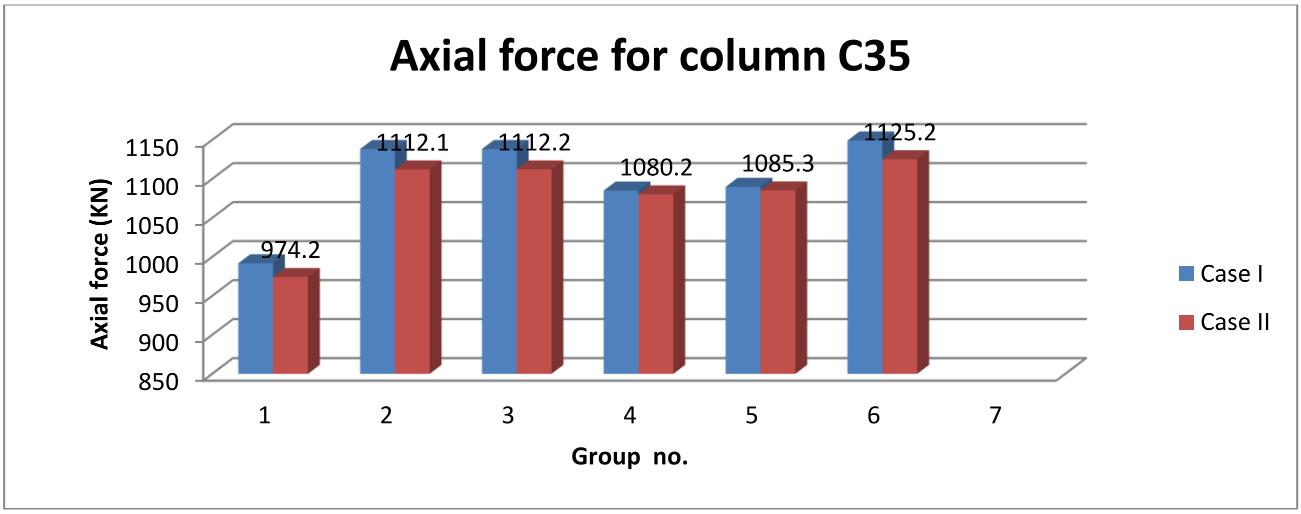


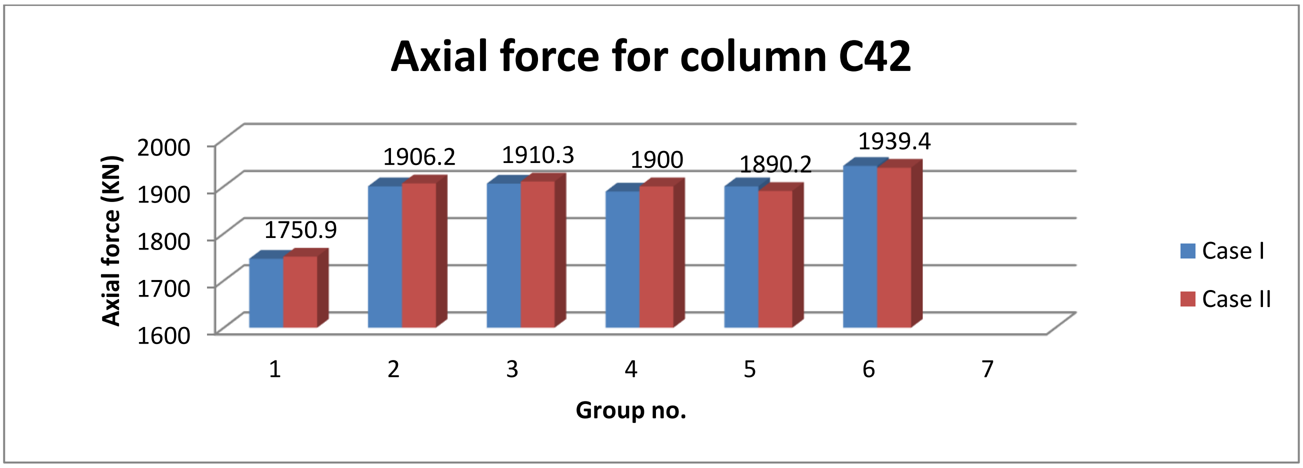
- **Column C35**

Graph 8. Axial force for column C6 (Case I & II)



- **Column C42**

Graph 9. Axial force for column C42 (Case I & II)



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VII. CONCLUSION

A. From discussions it can be concluded that, irregular structure shows critical responses as compared to regular structure.
B. Frames having irregular floors at larger height from the ground are critical. hence as far as possible, irregularity should be introduced on the floor close to the ground.
C. Most economical combination for irregular structure can be worked out using present study.
D. Displacements, drift and time periods can be reduced by adopting columns with higher stiffness.
E. As we increase the column stiffness, axial forces in columns and base shear increases.

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