‘EFFECT OF IRREGULARITIES IN R.C. FRAMED STRUCTURE UNDER SEISMIC CONDITION’

A PROJECT REPORT SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR AWARD OF THE DEGREE OF

MASTER OF ENGINEERING
IN
STRUCTURAL ENGINEERING

BY

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CERTIFICATE

This is to certify that the project entitled **"EFFECT OF IRREGULARITIES IN R.C. FRAMED STRUCTURE UNDER SEISMIC CONDITION"** being submitted by me, is a bonafide record of my own work carried by me under the guidance of Shri. Alok Verma and Dr. Anil Kumar Sahu in partial fulfillment of requirements for the award of the Degree of Master of Engineering (Structural Engineering) in Civil Engineering, Delhi University, Delhi.

The matter embodied in this project has not been submitted for the award of any other degree**.**

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Roll No: 10311
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CERTIFICATE

This is to certify that the above statement made by the candidate is correct to the best of our knowledge.

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Acknowledgement

It is a matter of great pleasure to express my deep sense of gratitude and indebtness to Shri. Alok Verma and Dr. Anil Kumar Sahu for their valuable guidance without which completion of this project would not have been possible.

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Last but not the least; I am thankful to my parents and friends for their forbearance, patience, encouragement and guidance.

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Abbreviations

Abbreviation	Description
ABS	Absolute sum
ATC	APPLIED Technological Council
BIS	Bureau of Indian Standards
CM	Center of mass
CP	Collapse prevention
CQC	Complete Quadratic Combination
CR	Center of rigidity
CS	Center of stiffness
DBE	Design basis earthquake
DI	Damage Index
DCR	Damage Capacity Ratio
FEMA	Federal emergency management agency
FVC	Field Visit Check
IS	Indian Standard
LDP	Linear Dynamic Process
LS	Life Safety
MCE	Maximum Considered Earthquake
RSM	Rapid Screening Method
RVA	Rapid Visual Assessment
RAM	Rapid Assessment Method
SAM	Simplified Assessment Method
E.CO.C.	Extreme corner column
E.MI.C.	Extreme middle column
E.CE.C.	Extreme centre column
E.CO.B.	Extreme corner beam
E.MI.B	Extreme middle beam
E.CE.B.	Extreme centre beam

ABSTRACT

This study summarizes state-of-the-art knowledge in the seismic response of vertical and plan irregularity of building frames. There is an urgent need to assess the seismic vulnerability of buildings in urban areas of India as an essential component of a comprehensive earthquake disaster risk management policy.

Seismic Vulnerability Assessment of the Building stock is an important activity. Rapid Visual Assessment Method is generally used for the Assessment of Seismic Vulnerability as a first step to have an idea of the requirement of the application of more detailed methods.

Detailed seismic vulnerability evaluation is a technically complex and expensive procedure and can only be performed on a limited number of buildings. It is therefore very important to use simpler procedures that can help to rapidly evaluate the vulnerability profile of different types of buildings, so that the more complex evaluation procedures can be limited to the most critical buildings. Though existing rapid screening approaches consider the effect of vertical and plan irregularity in seismic vulnerability assessment; they fail to distinguish different cases of vertical and plan irregularity. Buildings having different degrees of irregularity may have varied seismic performances. If this aspect is ingrained in the rapid seismic assessment procedure, the assessment procedure may be more accurate. It is with this view that the effect of different degrees of vertical and plan Irregularities and the seismic performance of RC Buildings (Mid rise and High rise) has been examined in this project work. For comparison, same storey stiffness and loads have been maintained & variations of Time period, Story drift, Member forces, Base shears and Drifts have been considered.

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1. INTRODUCTION :

Traditionally, India has been vulnerable to various natural hazards on account of its unique geoclimatic conditions especially earthquakes, which is considered to be among the most destructive with the potential of inflicting huge losses to life and property.

India has experienced several devastating earthquakes in the past resulting in a large number of deaths and severe property damage. In recent times, damaging earthquakes experienced in our country include, (1) 1993 Latur-Killari earthquake, (2) 1997 Jabalpur earthquake, (3) 1999 Chamoli earthquake and (4) 2001 Bhuj earthquake.

During the last century,4 great earthquakes struck different parts of the country: (1) 1897 Great Assam earthquake, (2) 1905 Kangra earthquake (3)1934 Bihar-Nepal earthquake and (4) 1950 Assam earthquake. The frequent occurrence of damaging earthquakes clearly demonstrates the high seismic hazard in India and highlights the need for a comprehensive earthquake disaster risk management policy. (ref.1)

A study carried based on the building data in the vulnerability atlas of India 1997shows that only in the seismic zone V of India covering an area of 12% of the total land area of the country, there are 11.1 million vulnerable housing units as per census of India 1991. If one accounts for similar vulnerable buildings in seismic zone IV also, the number will at least be 50 million. (ref.3)

The urban areas have experienced very rapid population growth during the last few decades. The rapid urbanization has led to proliferation of slums and has severely strained the resources in our urban areas. A big portion of the construction in the urban areas consists of poorly designed and constructed buildings. The older buildings, even if constructed in compliance with relevant standards. Until the 2001 Bhuj earthquake, our country was fortunate not to experience a large earthquake in an urban area. During this earthquake, a large number of recently constructed concrete buildings in Ahmedabad were also badly damaged even though the city is located over 200 km from the epicenter and these buildings should have suffered only minor damage if properly designed and constructed.

It is therefore urgent need to assess the seismic vulnerability of buildings in urban areas of India as an essential component of a comprehensive earthquake disaster risk management policy.

1.1 OBJECTIVE OF THE STUDY

1. To study the rapid seismic vulnerability assessment method.

2. To study the effect of presence of vertical and plan irregularity on total score, in different heights of building.

3. To study the effect of different degrees of vertical and plan irregularity on seismic performance of RC MR framed buildings of different heights, for same storey stiffness and loads in terms of variations of time period, story drift, member forces, base shears and drifts.

1.2 VULNERABILITY ASSESSMENT

The Indian cities are dotted with all kinds of buildings and infrastructural facilities comprising of very good construction to poorly designed & constructed ones. The most challenging task is to evaluate seismic safety of these constructions and take necessary steps for their retrofitting so as to protect them from future earthquakes. Assessment of seismic vulnerability of existing building stock in urban areas would help in disaster mitigation and management by planning mitigation measures before an earthquake strikes.

A vulnerability assessment considers the building's functions, systems, and physical characteristics to determine possible areas of weakness. The goal of vulnerability assessment is to identify mitigative or corrective actions that can be applied to structure to reduce vulnerability.

Seismic vulnerability is a measure of the seismic strength or capacity of a structure, and hence it is found to be the main component of seismic risk assessment. The review of the built environment for seismic vulnerability estimation is normally carried out in the light of earthquake resistance of buildings, past earthquake damage history & repair thereof, construction practices being adopted, building typology, seismic zoning of the area, building samples, detailed survey of selected buildings, and creation of database and its quantitative and qualitative analysis. The quantitative approach covers demand-capacity (DCR) computation, while qualitative procedure estimates structural scores for buildings and is known as Rapid Screening Procedure (RSP). (ref. 2)

Quantitative Approach: Demand-Capacity Ratio

The approach is a comparison between some measures of demand at the earthquake places on a structure to a measure of capacity of building to resist. The Demand/capacity ratio (DCR), thus evaluated measure of earthquake resistance of a building. The DCR less than unity indicate the building is safe for respective stresses under consideration. However, any DCR exceeding one indicates that building is vulnerable to earthquake loads as defined in IS: 1893-2002. DCR computation for masonry and RC buildings are discussed hereunder.

The general procedures for seismic vulnerability estimation of existing buildings proposed are site visit & data collection; selection & review of evaluation statements; follow-up fieldwork; and analysis of buildings by quantitative and qualitative approach.

2. LITERATURE REVIEW:

2.1 RAPID VISUAL SCREENING (RVS):

The building profile for different construction types that is developed on the basis of application of the first procedure (rapid visual screening) will be useful to short-list the buildings to which simplified vulnerability assessment procedure should be applied. This RVS procedure, even though originally developed for typical constructions in the US have been widely used in many other countries after suitable modifications. The most important feature of this procedure is that it permits vulnerability assessment based on walk-around of the building by a trained evaluator. The rapid visual screening will be useful for all buildings except critical structures where detailed vulnerability assessment is always required.

2.2 RVS Procedure, Objectives and Scope:

The rapid visual screening method is designed to be implemented without performing any structural calculations. The procedure utilizes a scoring system that requires the evaluator to

1. The primary structural lateral load- resisting system.

2. Identify building attributes that modify the seismic performance expected for this lateral load-resisting system.

The inspection, data collection and decision-making process typically occurs at the building site, and is expected to take around 30 minutes for each building. The screening is based on numerical seismic hazard and vulnerability score. The scores are based on the expected ground shaking levels in the region as well as the seismic design and construction practices for the city or region. The scores use probability concepts and are consistent with the advanced assessment methods.

The RVS methodology can be implemented in both rural and urban areas. However, the variation in construction practice is more easily quantifiable for urban areas and the reliability of the RVS results for rural areas may be very low. It is therefore preferable that the RVS methodology be used for non-standard (or non-government) constructions in rural areas only with adequate caution. The RVS methodology is also not intended for structures other than buildings. For important structures such as bridges and lifeline facilities, the use of detailed evaluation methods is recommended. (ref.1)

2.3 Building Types Considered:

The existing building stock of Indian cities is a rich mix of several different building types & construction technologies. The most commonly used building typology are reinforced concrete frame building with infill brick walls; brick masonry buildings with reinforced concrete roofs and using cement mortar in most of the case and mud/lime mortar in few of buildings; buildings made of GI sheets, thatch and other light weight and cheaper materials.

Vulnerability class of a building type is based on the average expected seismic performance for that building type. All buildings have been divided into six vulnerability class, denoted as Class A to Class F based on the European Macroseismic Scale (EMS-98) recommendations. The buildings in Class A have the highest seismic vulnerability while the buildings in Class F have lowest seismic vulnerability. The vulnerability ranges and the basic vulnerability class of different building types are given in Table A. The basic class is denoted by O in Table 1, while the brackets specify the likely range of vulnerability of the buildings.

The RVS procedure has considered 10 different building types, based on the building materials and construction types that are most commonly found in urban areas. These included both engineered constructions (designed and constructed by following the specifications) and non-engineered constructions (designed or constructed without following the specifications). Some masonry building types constructed using local materials are prevalent in urban areas but are not included in this methodology since their seismic vulnerability is known to be very high (vulnerability class A and B) and do not require visual screening to provide any additional information regarding their expected structural performance. These include all constructions using random rubble masonry in mud mortar, earthen walls, adobe and tin sheet constructions.

Table B. provides guidance regarding likely performance of the building in the event of design-level earthquake. This information can be used to decide the necessity of further evaluation of the building using higher level procedures. It can also be used to identify need for retrofitting, and to recommend simple retrofitting techniques for ordinary buildings where more detailed evaluation is not feasible. Generally, the score $S < 0.7$ indicates high vulnerability requiring further evaluation and retrofitting of the building. (ref. 2)

Table A. Seismic vulnerability classification for different structural types.

All buildings can be divided into the following primary categories: (1) masonry buildings, (2) RCC buildings, (3) steel buildings, and (4) timber buildings. These can be further divided into various sub-categories. Based on their seismic resistance the following vulnerability classification has been proposed based on the European Macroseismic Scale (EMS-98) and modified during development of World Housing Encyclopaedia.

Material	Type of Load Bearing Structure	Sub-Types	Vulnerability Class					
			A	B	C	D	E	F
Masonry	Stone Masonry Walls	Rubble stone (field stone) in mud/lime mortar or without mortar (usually with timber roof)	O					
		Massive stone masonry (in lime/cement mortar)	|		O	-|		
	Earthen/Mud/ Adobe/Rammed Earthen Walls	Mud walls	O					
		Mud walls with horizontal wood elements	|	O	-|			
		Adobe block walls	O	-|				
		Rammed earth/Pise construction	O	-|				
	Burnt clay brick/block masonry walls	Unreinforced brick masonry in mud mortar	|	O	-|			
		Unreinforced brick masonry in mud mortar with vertical posts	|	O		-|		
		Unreinforced brick masonry in lime mortar	|	O		-|		
		Unreinforced brick masonry in cement mortar with reinforced concrete floor/roof slabs		|	O	-|		
		Unreinforced brick masonry in cement mortar with lintel bands (various floor/roof systems)		|	O	-|		
		Confined brick/block masonry with concrete posts/tie columns and beams			|	O	-|	
	Concrete block masonry	Unreinforced, in lime/cement mortar (various floor/roof systems)		|	O	-|		
		Reinforced, in cement mortar (various floor/roof systems)			|	O	-|	
Structural concrete	Moment resisting frame	Designed for gravity loads only (predating seismic codes i.e. no seismic features)	|		O	-|		
		Designed with seismic features (various ages)			|		O	-|
		Frame with unreinforced masonry infill walls						
		Flat slab structure		|	O		-|	
		Precast frame structure		|	O	-|		
		Frame with concrete shear walls (dual system)			|		O	-|
	Shear wall structure	Walls cast in-situ				|	O	-|
		Precast wall panel structure		|	O	-|		
Steel	Moment-resisting frame	With brick masonry partitions			|	O		-|
		With cast in-situ concrete walls			|			
		With lightweight partitions				|	O	-|
	Braced frame	With various floor/roof systems				|	O	-|
	Light metal frame	Single storey LM frame structure			|		O	-|
Wooden structures	Load-bearing timber frame	Thatch roof	|		O	-|		
		Post and beam frame			|	O	-|	
		Walls with bamboo/reed mesh and post (Wattle and Daub)		|	O	-|		
		Frame with (stone/brick) masonry infill	|		O	-|		
		Frame with plywood/gypsum board sheathing		|	O	-|		
		Frame with stud walls				|	O	-|

O Most likely vulnerability class |- Most likely lower range
-| Most likely upper range

timber frame

Table B . Expected damage level as function of RVS score.

The probable damage can be estimated based on the RVS score and is given below. However, it should be realised that the actual damage will depend on a number of factors that are not included in the RVS procedure. As a result, this table should only be used as indicative to determine the necessity of carrying out simplified vulnerability assessment of the buildings. These results can also be used to determine the necessity of retrofitting buildings where more comprehensive vulnerability assessment may not be feasible.

RVS Score	Damage Potential
S < 0.3	High probability of Grade 5 damage; Very high probability of Grade 4 damage
0.3 < S < 0.7	High probability of Grade 4 damage; Very high probability of Grade 3 damage
0.7 < S < 2.0	High probability of Grade 3 damage; Very high probability of Grade 2 damage
2.0 < S < 3.0	High probability of Grade 2 damage; Very high probability of Grade 1 damage
S > 3.0	Probability of Grade 1 damage

2.4 Uses of RVS Results

The results from rapid visual screening can be used for a variety of applications that are an integral part of the earthquake disaster risk management program of a city or a region. The main uses of this procedure are: (ref. 3)

1. To identify if a particular building requires further evaluation for assessment of its seismic vulnerability.
2. To rank a cities or communities (or organization's) seismic rehabilitation needs.
3. To design seismic risk management program for a city or a community.
4. To plan post-earthquake building safety evaluation efforts.
5. To develop building-specific seismic vulnerability information for purposes such as regional rating, prioritization for redevelopment etc.
6. To identify simplified retrofitting requirements for a particular building (to collapse prevention level) where further evaluations are not feasible.
7. To increase awareness among city residents regarding seismic vulnerability of buildings.

2.5 Definitions of Irregular buildings-Plan Irregularities:
(ref. 4)

1 Torsion irregularity

To be considered when floor diaphragms are rigid in their own plan in relation to the vertical structural elements that resist the lateral forces. Torsional irregularity to be considered to exist when the maximum storey drift, computed with design eccentricity, at one end of the structures transfers to an axis is more than 1.2 times the average of the storey drifts at the two ends of the structures.

2. Re-entrant corners

Plan configurations of a structure and its lateral forces resisting systems contain re-entrant corners where both projections of the structures beyond the re-entrant corner are greater than 15 percent of its plan dimension in the given direction.

3. Diaphragm discontinuity

Diaphragm with abrupt discontinuities or variations in stiffness including those having cut-out or open areas greater than 50 percent of the gross enclosed diaphragm area, or changes in effective diaphragm stiffness of more than 50 percent from one storey to the next.

4. Out-of-plane offsets

Discontinuities in a lateral forces resistance path such as out of plane offsets of vertical elements.

2.6 Definitions of Irregular Buildings-Vertical Irregularities: (ref. 4)

1. Stiffness irregularity –soft storey:

A soft storey is one in which the lateral stiffness is less than 70 percent of that in the storey above or less than 80 percent of the average lateral stiffness of the three stories above.

1 a. Stiffness irregularity – extreme soft storey:

A extreme storey is one in which the lateral stiffness is less than 60 percent of that in the storey above or less than 70 percent of the average stiffness of the three stories above. For example building on STILTS will fall under this category.

2. Mass irregularity

Mass irregularity shall be considered to exist where the seismic weight of any storey is more than 200 percent of that of its adjacent stories. The irregularity need not be considered in case of roofs.

3. Vertical geometric irregularity

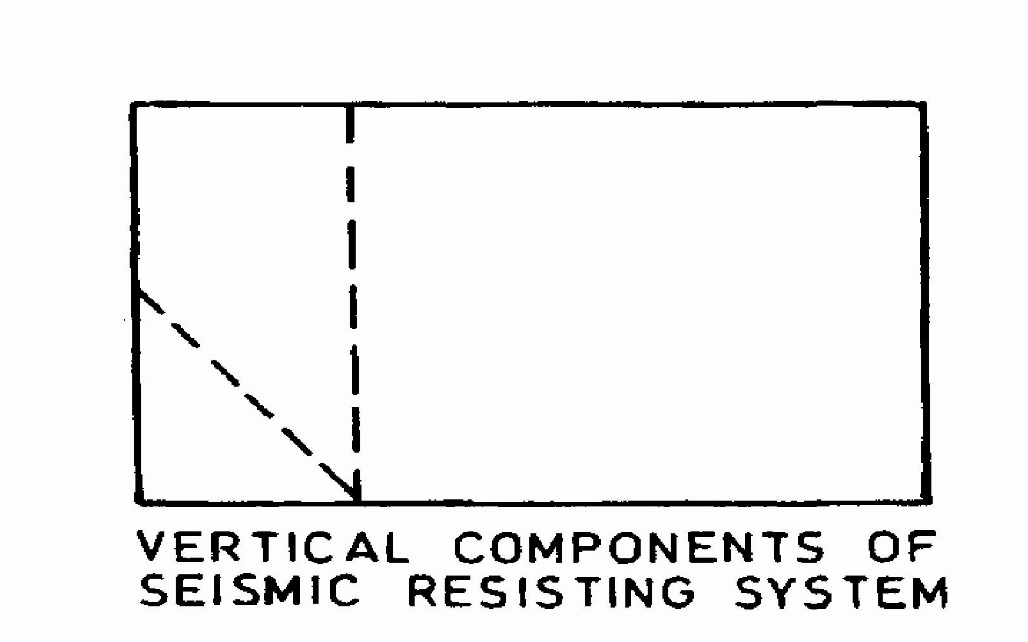
Vertical geometric irregularity shall be considered to exist where the horizontal dimension of the lateral force resisting system in any storey is more than 150 percent of that in its adjacent storey.

4. In plane discontinuity in vertical elements resisting lateral forces

A in – plane offset of the lateral force resisting elements greater than the length of those elements

5. Discontinuity in capacity-weak storey

A weak storey is one in which the storey lateral strength is less than 80 percent of that in the storey above. The storey lateral strength is the total strength of all seismic force resisting elements sharing the storey shear in the considered direction. (ref. 4)


VERTICAL COMPONENTS OF
SEISMIC RESISTING SYSTEM

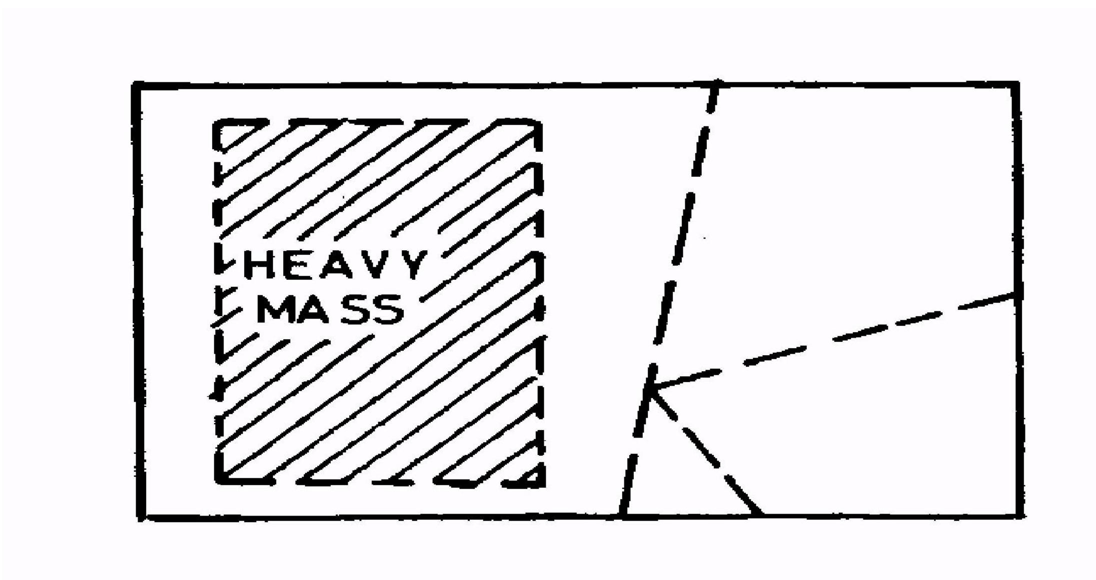

HEAVY
MASS

Fig. b

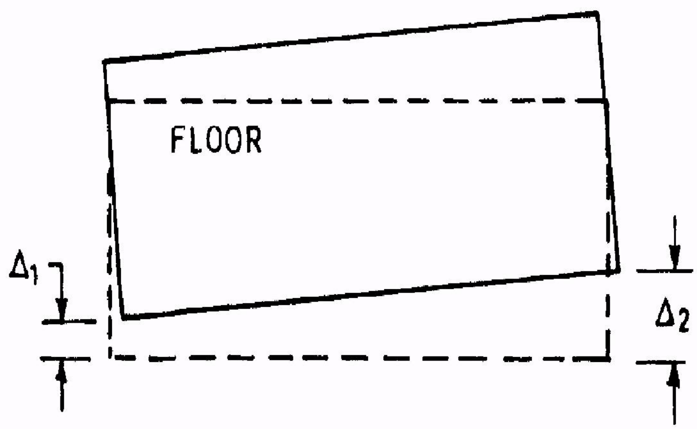


Fig. c Torsional Irregularity

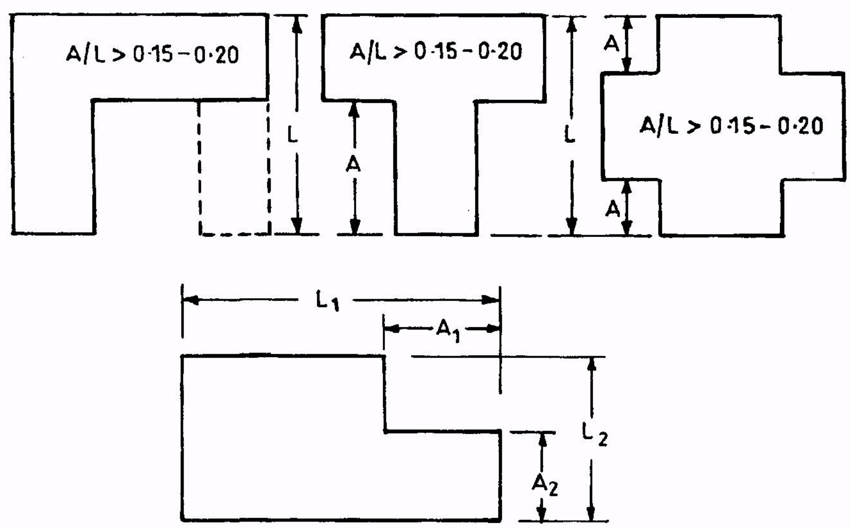


Fig. d Re-entrant Corner

PLAN IRREGULARITY (ref.4)

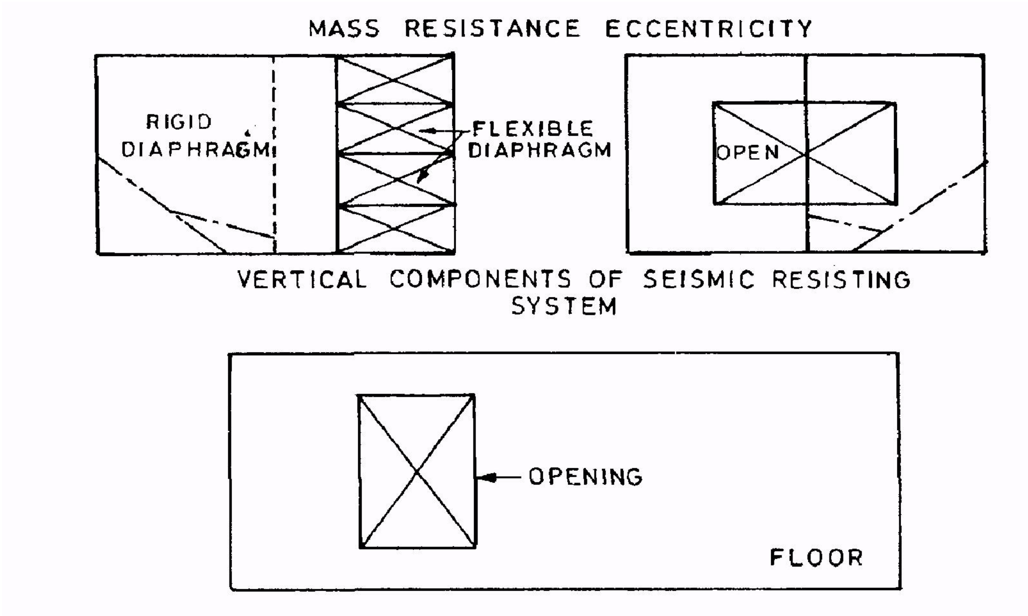


Fig. e Diaphragm Discontinuity

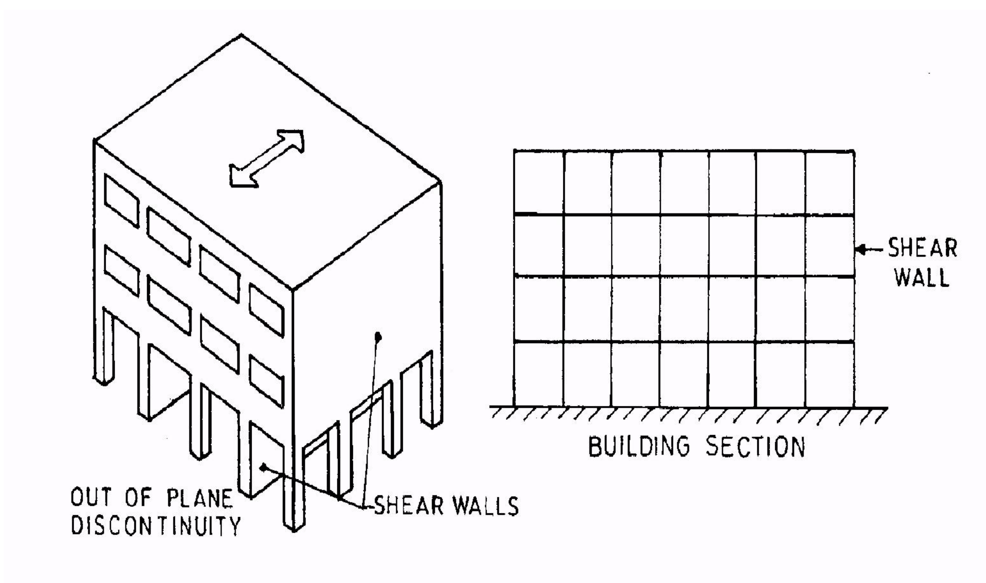


Fig. f Out-of-plan Offset

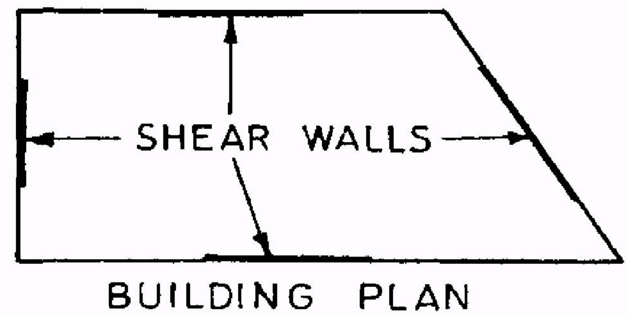


Fig. g Non-parallel System

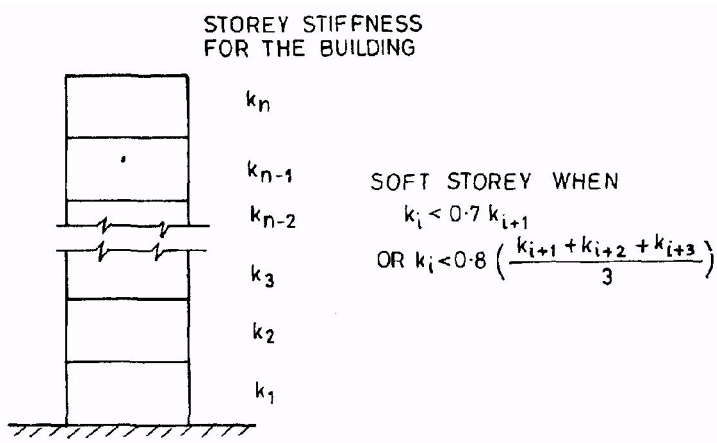


Fig. h Stiffness Irregularity

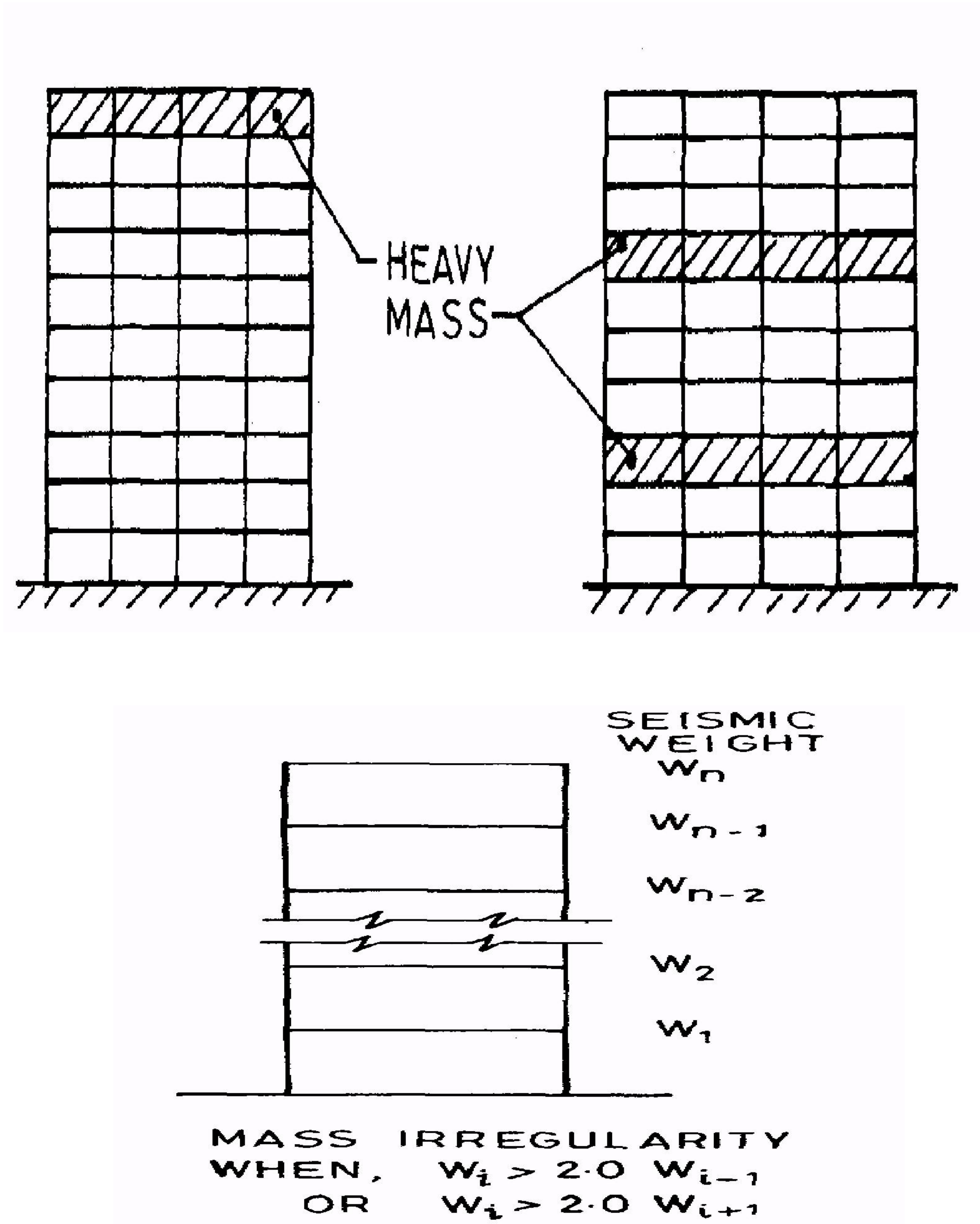


Fig. i Mass Irregularity

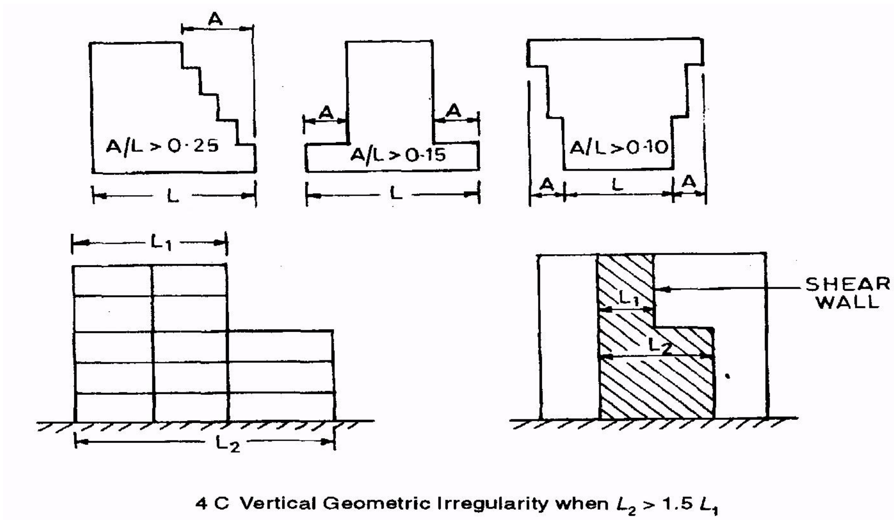


Fig. j a Vertical Geometric Irregularities

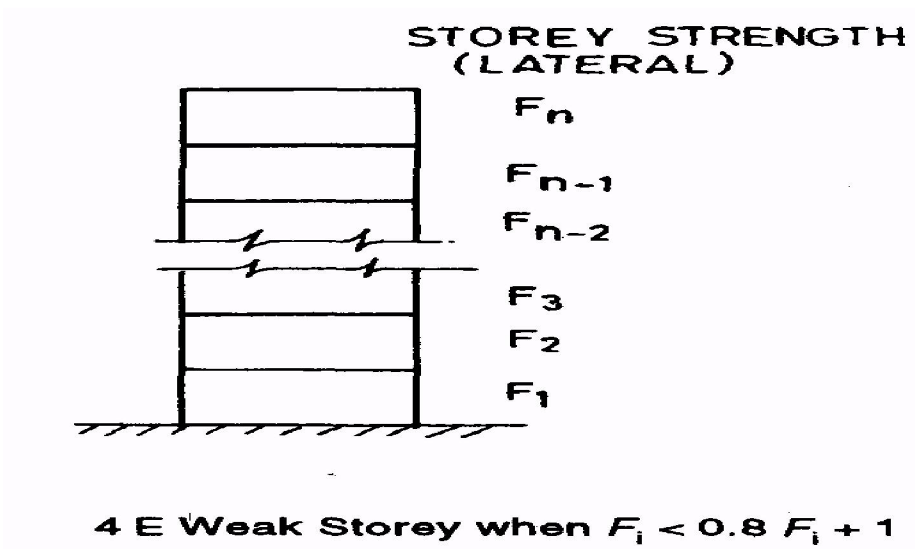
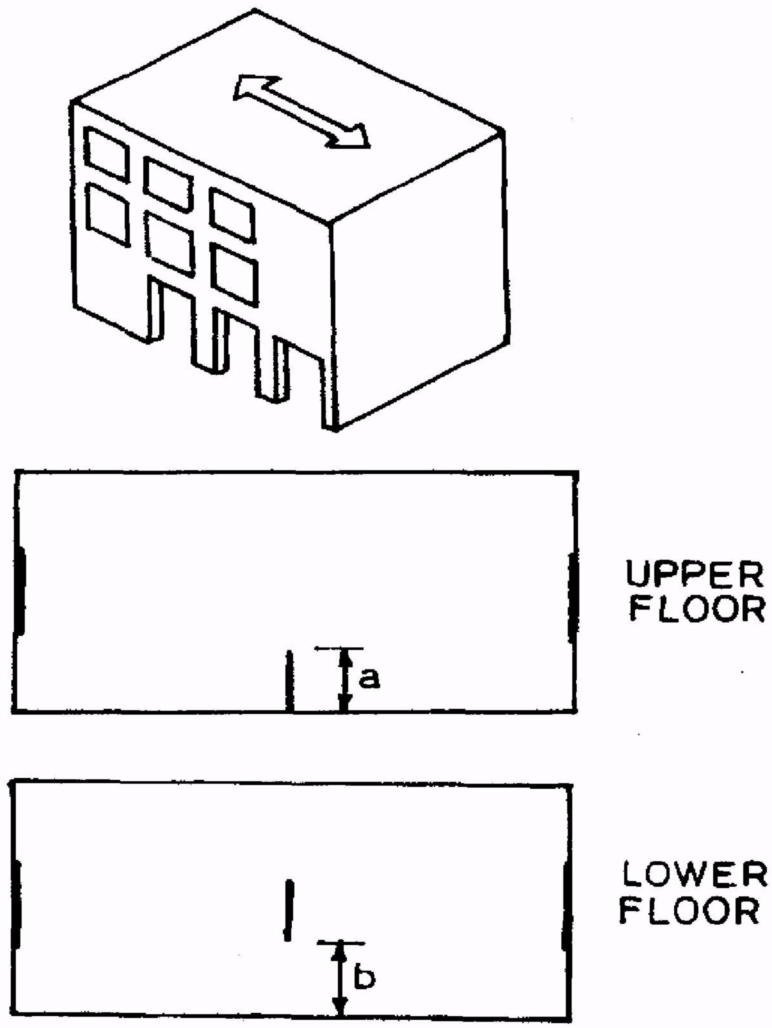


Fig. j b Vertical Geometric Irregularities



4 D In-Plane Discontinuity in Vertical Elements Resisting Lateral Force when *b* > *a*

Fig. j Vertical Geometric Irregularities (ref. 4)

3. OBSERVATIONS OF RVS METHOD BASED ON FEMA 154 COLLECTION FORM:

1. In the form for RVS provided in FEMA 154 the final score is a summation of the values provided for different parameters. Though the parameters are independent in nature, still one parameter affects the other ones and the final score which is used for assessing the seismic vulnerability of buildings for potential seismic hazards may not be a simple relation.

2. Exact values have been provided to different parameters such as vertical irregularity, plan irregularity etc. depending on the expertise of the assessor, it may sometimes be difficult to determine whether a building has appreciable extent of irregularity. Different extents of irregularity in a building shall affect the vulnerability of a building to different degrees.

3. Different types of soil conditions have been specified in the data collection form. The type of soil may sometimes be difficult to determine, especially under mixed soil conditions.

4. The occupancy types given in the data collection form are not explicitly used in the calculation of the final score of buildings.

5. Exact values have been provided for mid rise and high rise categories provided in the data collection form. The nature of buildings of different number of stories, especially when the difference in height of buildings in terms of number of stories is large, may be very different.

6. The conclusion of the data collection form in deciding the need of a detailed assessment is not explicitly connected to the final score. Based only on the information collected in the data collection form it may be difficult for a person to determine whether a detailed investigation is really needed. (ref.5)

Rapid Visual Screening of Buildings for Potential Seismic Vulnerability

FEMA-154/ATC-21 Based Data Collection Form **(Seismic Zone II)**

Address: ____________________

____________________ Pin ________

Other Identifiers ____________________

GPS Coordinates (if available) ____________________

No. Stories ____________ Year Built ________

Surveyor ____________ Date ________

Total Floor Area (sq. ft./sq. m) ____________________

Building Name ____________________

Use ____________________

Current Visual Condition: Excellent ☐ / Good ☐ / Damaged ☐ / Distressed ☐

Building on Stilts / Open Ground Floor: Yes ☐ / No ☐

Construction Drawings Available: Yes ☐ / No ☐

PHOTOGRAPH

(OR SPECIFY PHOTOGRAPH NUMBERS)

Plan and Elevation Scale:

OCCUPANCY					SOIL TYPE (IS 1893:2002)			FALLING HAZARDS			
Assembly	Govt.	Office	Max. Number of Persons		**Type I**	**Type II**	**Type III**	☐	☐	☐	☐
Commercial	Historic	Residential	0 - 10	11 - 100	Hard Soil	Medium Soil	Soft Soil	Chimneys	Parapets	Cladding	Other:
Emer.Service	Industrial	School	101 - 1000	1000+							

BASIC SCORE, MODIFIERS, AND FINAL SCORE, S

BUILDING TYPE	Wood	S1 (FRAME)	S2 (LM)	C1 (MRF)	C2 (SW)	C3 (INF)	URM1 (BAND+RD)	URM2 (BAND+FD)	URM3	URM4
Basic Score	**6.0**	**4.6**	**4.6**	**4.4**	**4.8**	**4.4**	**4.6**	**4.8**	**4.6**	**3.6**
Mid Rise (4 to 7 stories)	N/A	+0.2	N/A	+0.4	-0.2	-0.4	-0.2	-0.4	-0.6	-0.6
High Rise (>7 stories)	N/A	+1.0	N/A	+1.0	0.0	-0.4	N/A	N/A	N/A	N/A
Vertical Irregularity	-3.0	-2.0	N/A	-1.5	-2.0	-2.0	-1.5	-2.0	-1.5	-1.5
Plan Irregularity	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8
Code Detailing	N/A	+0.4	N/A	+0.6	+0.4	N/A	N/A	N/A	N/A	N/A
Soil Type II	-0.4	-0.8	-0.4	-0.6	-0.4	-0.4	-0.2	-0.4	-0.4	-0.4
Soil Type III	-0.8	-1.4	-1.0	-1.4	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8
Liquifiable Soil	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0	-1.6	-1.4	-1.4	-1.4

FINAL SCORE, *S*

Result Interpretation (*Likely building performance*)

S < 0.3	High probability of Grade 5 damage; Very high probability of Grade 4 damage
0.3 < S < 0.7	High probability of Grade 4 damage; Very high probability of Grade 3 damage
0.7 < S < 2.0	High probability of Grade 3 damage; Very high probability of Grade 2 damage
2.0 < S < 3.0	High probability of Grade 2 damage; Very high probability of Grade 1 damage
S > 3.0	Probability of Grade 1 damage

Further Evaluation Recommended

YES NO

* = Estimated, subjective, or unreliable data
DNK = Do Not Know

FRAME = Steel Frame
SW = Shear Wall
URM3 = Unreinforced burnt brick or stone masonry (cem mortar)
INF = Burnt Brick Masonry Infill Wall
LM = Light Metal
MRF = Moment-Resisting Frame
BAND = Seismic Band
RD = Rigid diaphragm
FD = Flexible Diaphragm
URM4 = Unreinforced masonry (lime mortar)

Rapid Visual Screening of Buildings for Potential Seismic Vulnerability

FEMA-154/ATC-21 Based Data Collection Form **(Seismic Zone III)**

Address: ____________________

Pin ______

Other Identifiers ____________________

GPS Coordinates (if available) ____________________

No. Stories __________ Year Built __________

Surveyor __________ Date __________

Total Floor Area (sq. ft./sq. m) ____________________

Building Name ____________________

Use ____________________

Current Visual Condition: Excellent ☐/ Good ☐/ Damaged ☐/ Distressed ☐

Building on Stilts / Open Ground Floor: Yes ☐ / No ☐

Construction Drawings Available: Yes ☐ / No ☐

Plan and Elevation Scale:

PHOTOGRAPH

(OR SPECIFY PHOTOGRAPH NUMBERS)

OCCUPANCY

			Max. Number of Persons	
Assembly	Govt.	Office	0 - 10	11 - 100
Commercial	Historic	Residential	101 - 1000	1000+
Emer.Service	Industrial	School		

SOIL TYPE (IS 1893:2002)

Type I	**Type II**	**Type III**
Hard Soil	Medium Soil	Soft Soil

FALLING HAZARDS

☐ Chimneys ☐ Parapets ☐ Cladding ☐ Other:

BASIC SCORE, MODIFIERS, AND FINAL SCORE, S

BUILDING TYPE	Wood	S1 (FRAME)	S2 (LM)	C1 (MRF)	C2 (SW)	C3 (INF)	URM1 (BAND+RD)	URM2 (BAND+FD)	URM3	URM4
Basic Score	**4.4**	**3.6**	**3.8**	**3.0**	**3.6**	**3.2**	**3.4**	**3.6**	**3.0**	**2.4**
Mid Rise (4 to 7 stories)	N/A	+0.4	N/A	+0.2	+0.4	+0.2	+0.4	+0.4	-0.4	-0.4
High Rise (>7 stories)	N/A	+0.8	N/A	+0.5	+0.8	+0.4	N/A	N/A	N/A	N/A
Vertical Irregularity	-3.0	-2.0	N/A	-2.0	-2.0	-2.0	-2.0	-2.0	-1.5	-1.5
Plan Irregularity	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
Code Detailing	N/A	+1.4	N/A	+1.2	+1.6	+1.2	+2.0	+2.0	N/A	N/A
Soil Type II	-0.2	-0.6	-0.6	-0.6	-0.8	-0.6	-0.8	-0.8	-0.4	-0.4
Soil Type III	-0.6	-1.2	-1.0	-1.0	-1.2	-1.0	-1.2	-1.2	-0.8	-0.8
Liquifiable Soil	-1.2	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6

FINAL SCORE, *S*

Result Interpretation (*Likely building performance*)

S < 0.3	High probability of Grade 5 damage; Very high probability of Grade 4 damage
0.3 < S < 0.7	High probability of Grade 4 damage; Very high probability of Grade 3 damage
0.7 < S < 2.0	High probability of Grade 3 damage; Very high probability of Grade 2 damage
2.0 < S < 3.0	High probability of Grade 2 damage; Very high probability of Grade 1 damage
S > 3.0	Probability of Grade 1 damage

Further Evaluation Recommended

YES NO

* = Estimated, subjective, or unreliable data
DNK = Do Not Know

FRAME = Steel Frame
SW = Shear Wall
URM3 = Unreinforced burnt brick or stone masonry (cem mortar)
INF = Burnt Brick Masonry Infill Wall
LM = Light Metal
MRF = Moment-Resisting Frame
BAND = Seismic Band
RD = Rigid diaphragm
FD = Flexible Diaphragm
URM4 = Unreinforced masonry (lime mortar)

Rapid Visual Screening of Buildings for Potential Seismic Vulnerability

FEMA-154/ATC-21 Based Data Collection Form **(Seismic Zones IV & V)**

Address: ____________________
____________________ Pin ______
Other Identifiers ____________________
GPS Coordinates (if available) ____________________
No. Stories ______ Year Built ______
Surveyor ______ Date ______
Total Floor Area (sq. ft./sq. m) ______
Building Name ____________________
Use ____________________
Current Visual Condition: Excellent ☐/ Good ☐/ Damaged ☐/ Distressed ☐
Building on Stilts / Open Ground Floor: Yes ☐ / No ☐
Construction Drawings Available: Yes ☐ / No ☐

Plan and Elevation Scale:

PHOTOGRAPH

(OR SPECIFY PHOTOGRAPH NUMBERS)

OCCUPANCY					**SOIL TYPE (IS 1893:2002)**			**FALLING HAZARDS**			
Assembly	Govt.	Office	Max. Number of Persons		**Type I**	**Type II**	**Type III**	☐	☐	☐	☐
Commercial	Historic	Residential	0 - 10	11 - 100	Hard Soil	Medium Soil	Soft Soil	Chimneys	Parapets	Cladding	Other:
Emer.Service	Industrial	School	101 - 1000	1000+							

BASIC SCORE, MODIFIERS, AND FINAL SCORE, S

BUILDING TYPE	Wood	S1 (FRAME)	S2 (LM)	C1 (MRF)	C2 (SW)	C3 (INF)	URM1 (BAND+RD)	URM2 (BAND+FD)	URM3	URM4
Basic Score	**3.8**	**2.8**	**3.2**	**2.5**	**2.8**	**2.6**	**2.8**	**2.8**	**1.8**	**1.4**
Mid Rise (4 to 7 stories)	N/A	+0.2	N/A	+0.4	+0.4	+0.2	+0.4	+0.4	-0.2	-0.4
High Rise (>7 stories)	N/A	+0.6	N/A	+0.6	+0.8	+0.3	N/A	N/A	N/A	N/A
Vertical Irregularity	-2.0	-1.0	N/A	-1.5	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0
Plan Irregularity	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
Code Detailing	N/A	+0.4	N/A	+0.2	+1.4	+0.2	N/A	N/A	N/A	N/A
Soil Type II	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4
Soil Type III	-0.8	-0.6	-0.6	-0.6	-0.6	-0.4	-0.6	-0.6	-0.6	-0.6
Liquifiable Soil	-0.8	-1.2	-1.0	-1.2	-0.8	-0.8	-0.6	-0.6	-0.8	-0.8

FINAL SCORE, *S*

Result Interpretation (*Likely building performance*)

S < 0.3	High probability of Grade 5 damage; Very high probability of Grade 4 damage
0.3 < S < 0.7	High probability of Grade 4 damage; Very high probability of Grade 3 damage
0.7 < S < 2.0	High probability of Grade 3 damage; Very high probability of Grade 2 damage
2.0 < S < 3.0	High probability of Grade 2 damage; Very high probability of Grade 1 damage
S > 3.0	Probability of Grade 1 damage

Further Evaluation Recommended

YES NO

* = Estimated, subjective, or unreliable data
DNK = Do Not Know
FRAME = Steel Frame
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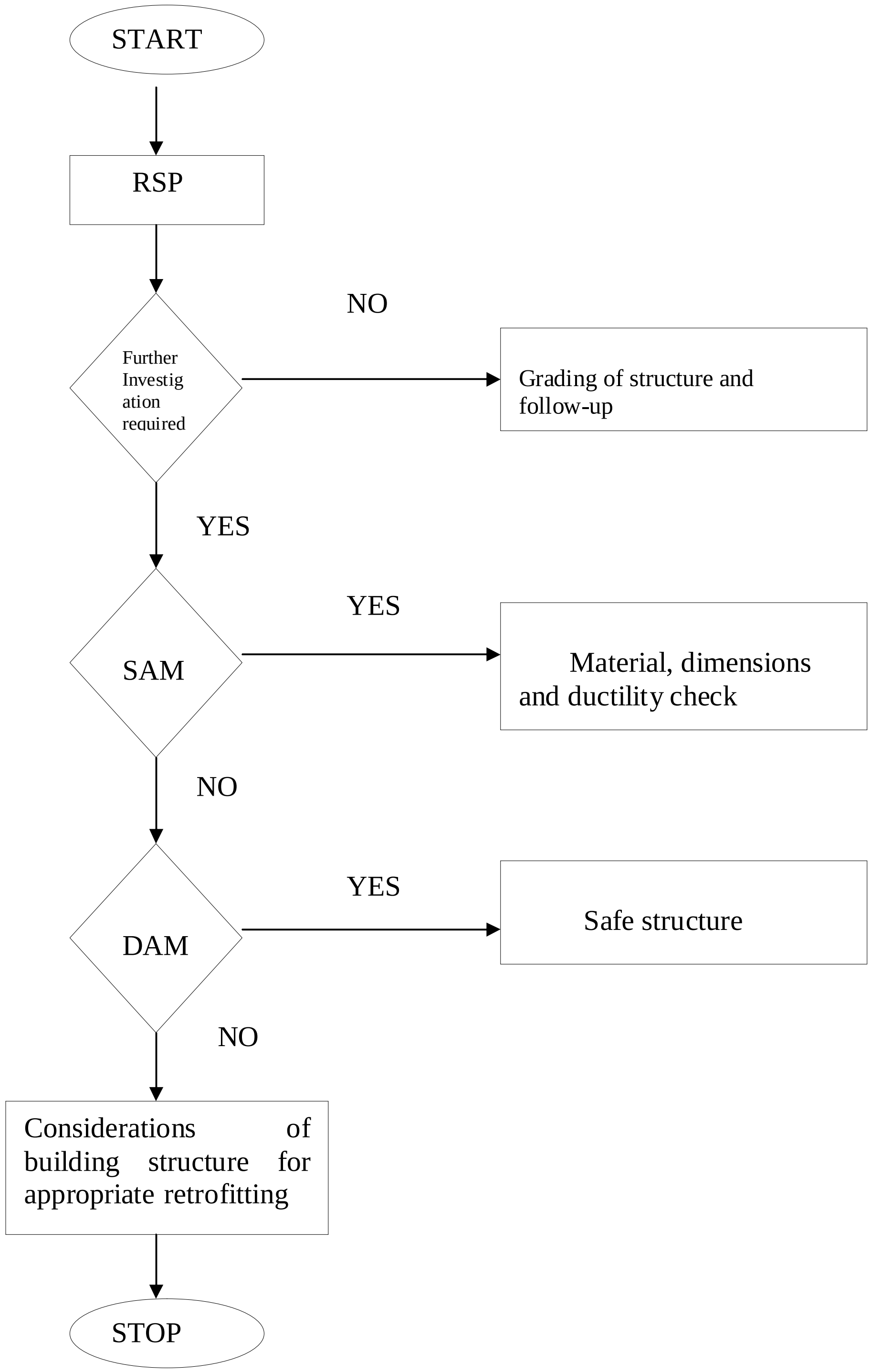
LM = Light Metal
MRF = Moment-Resisting Frame
BAND = Seismic Band
RD = Rigid diaphragm
FD = Flexible Diaphragm
URM4 = Unreinforced masonry (lime mortar)

FLOW CHART OF SEISMIC VULNERABITITY ASSESSMENT PROCEDURE



4. PROGRAMME OF STUDY:

1 Considering the observations a project study was undertaken with a view to determine the extent of possible changes in the seismic performance of Mid Rise and High Rise RC framed buildings having different degrees of vertical & plan irregularity.

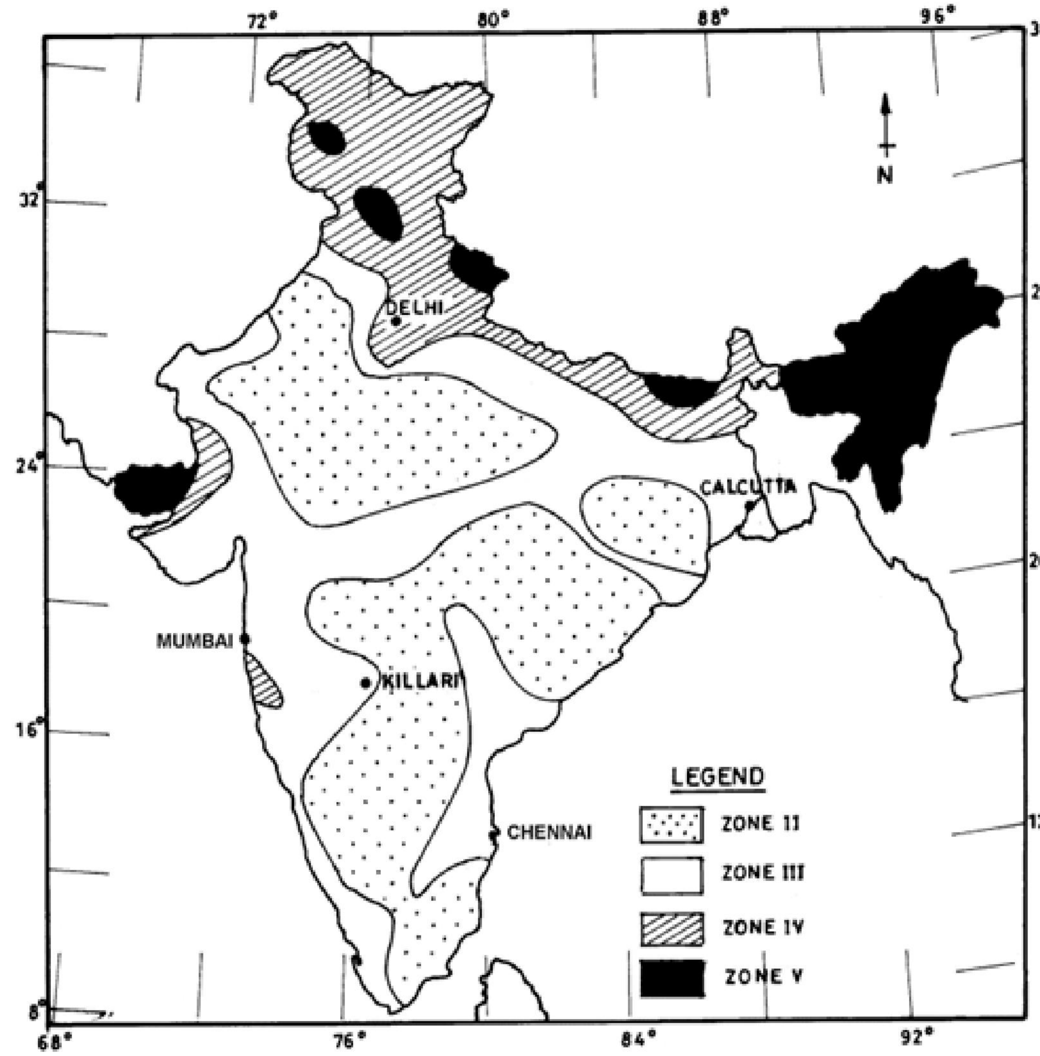
2. RC framed buildings are firstly designed for minimum area of column and beam and then irregularities are created in the structures.

3. For this the seismic performance of a different height RC framed building has been considered with changes in the following parameters:
   (a) Vertical Irregularity
   (b) Plan Irregularity

4. As the effect of only plan & vertical irregularity in different heights of RC framed buildings is considered, the loading and storey stiffness have been maintained constant. Different configurations of such buildings taken for study are provided hence after this topic.

5. The effect of vertical and plan irregularity in these buildings in terms of variations in Time Period, Storey Drift, Member forces, Base shears and Drifts have been considered.

The results in the form of graphs and tables with the different case of buildings analysed in STAAD 2006 are given hereafter.
Building Shapes with different forms of vertical and plan irregularity have also been shown only for the high rise type.



Picture.1

Seismic zoning map of India (IS 1893-2002 Part I) ref.4

Vertical irregular Buildings

Picture. 2

Building in North Delhi Showing vertical irregularity

Picture. 3

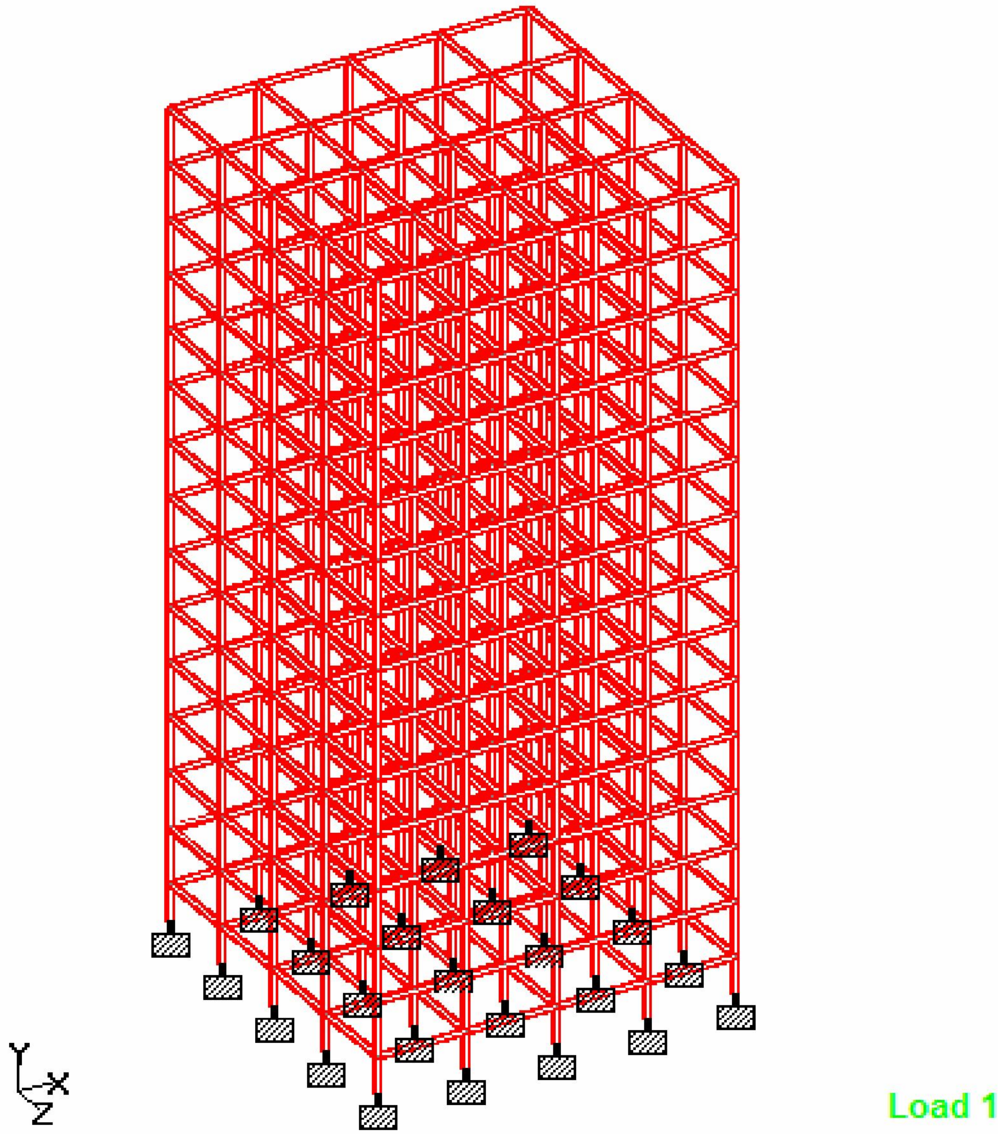
Building in North Delhi Showing vertical irregularity

Picture. 4

Building in North Delhi Showing vertical irregularity

Picture. 5

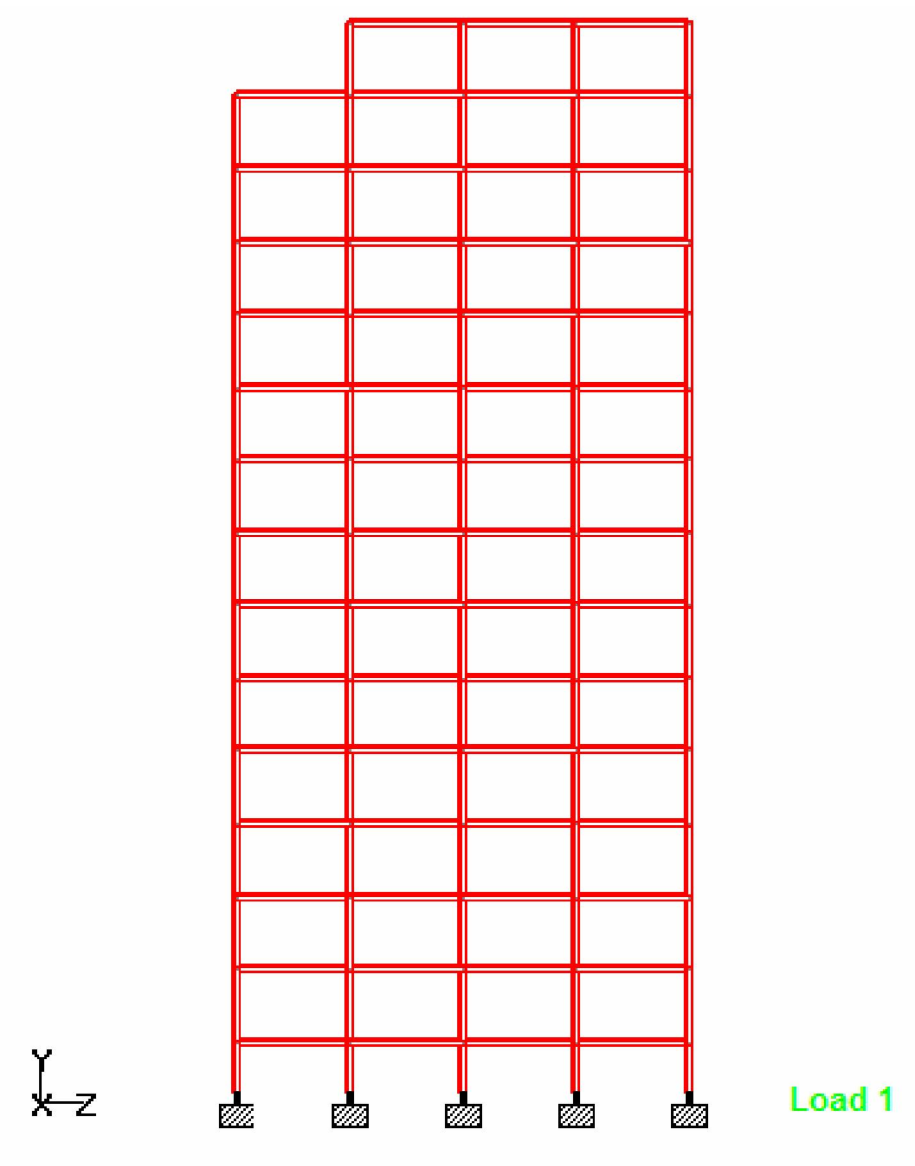
Building in North Delhi Showing vertical irregularity



Building Type: High Rise Building

Structure No. 1

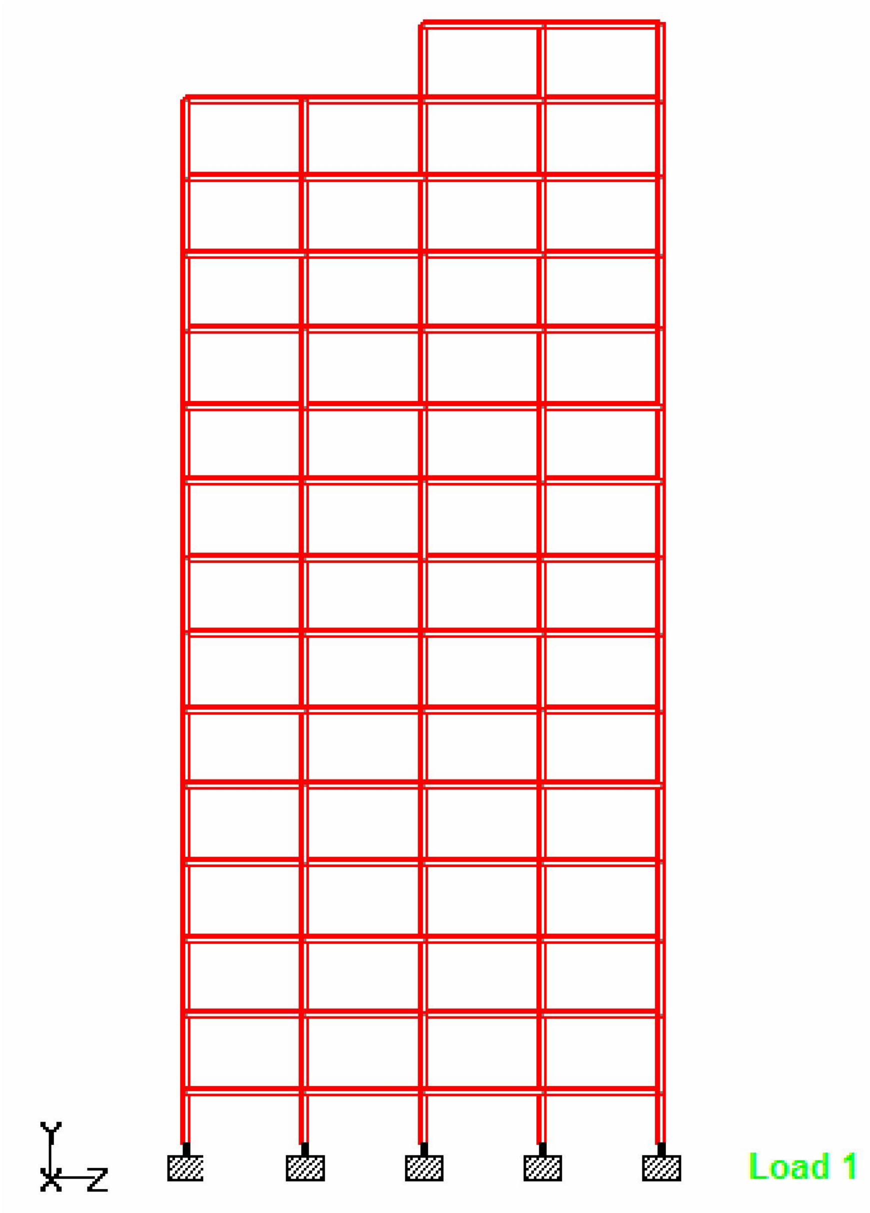
No. Storey: 16



Building Type: High Rise Building

Structure No. 2

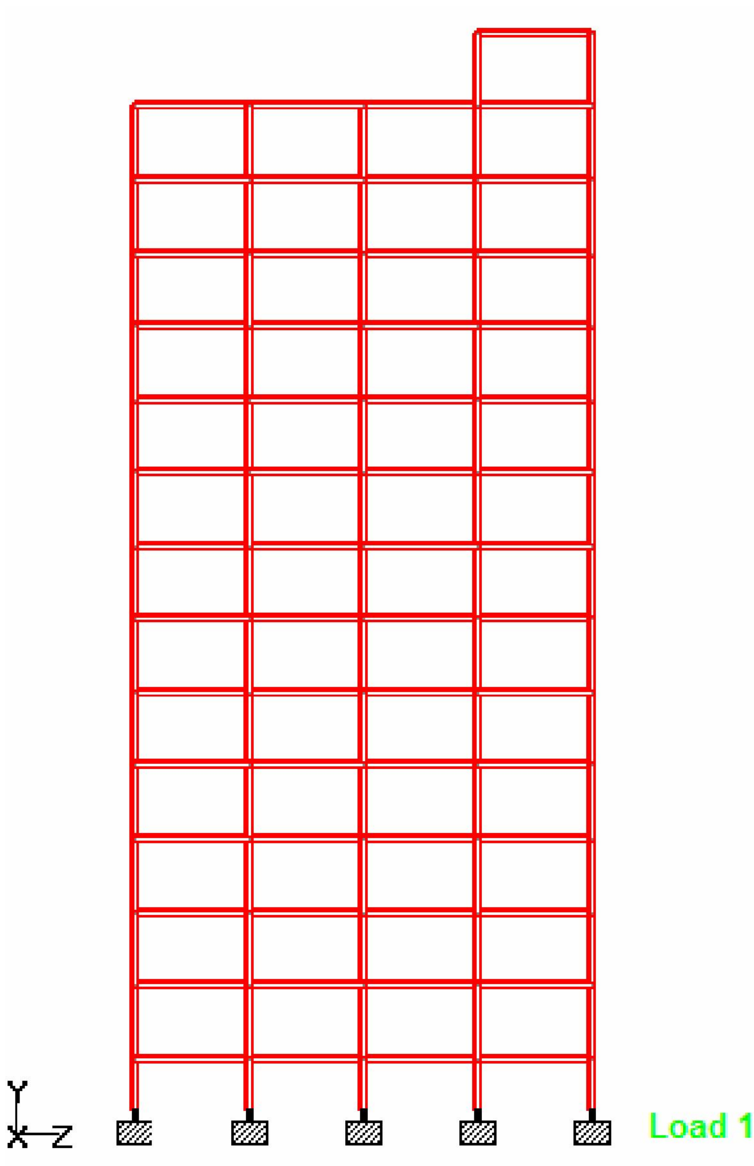
No. Storey: 16



Building Type: High Rise Building

Structure No. 3

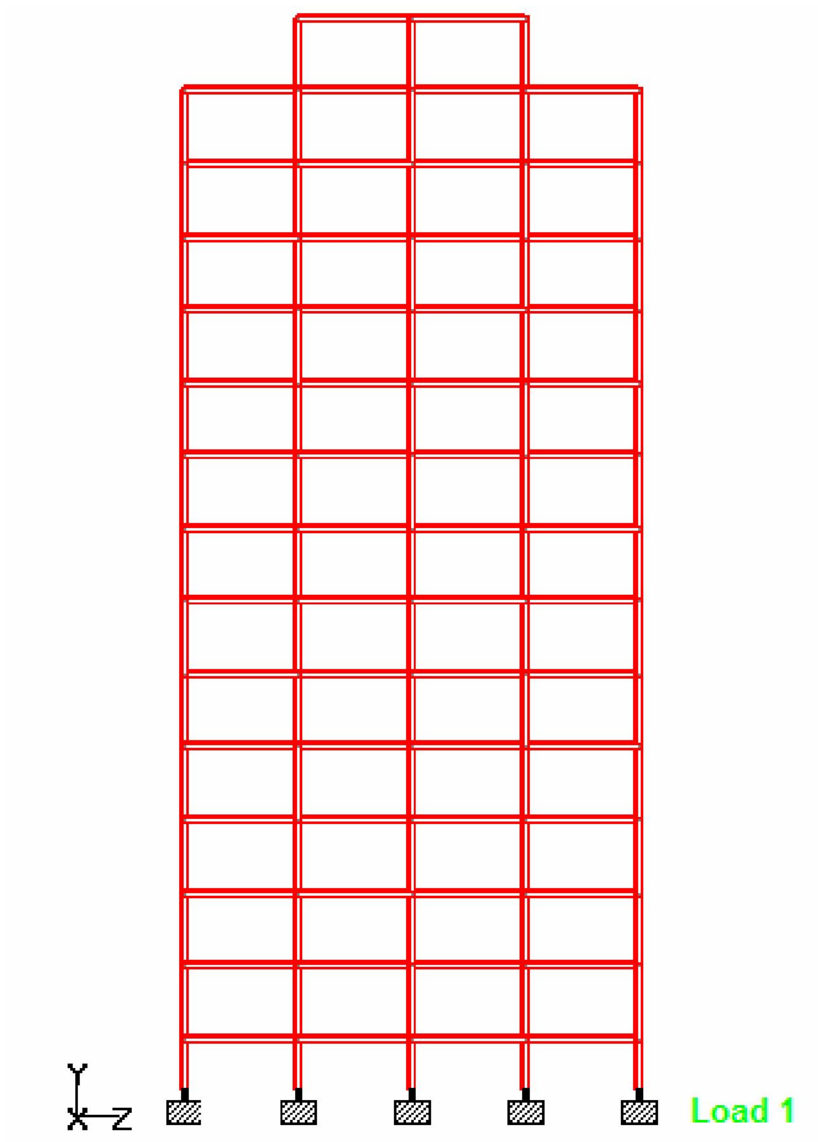
No. Storey: 16



Building Type: High Rise Building

Structure No. 4

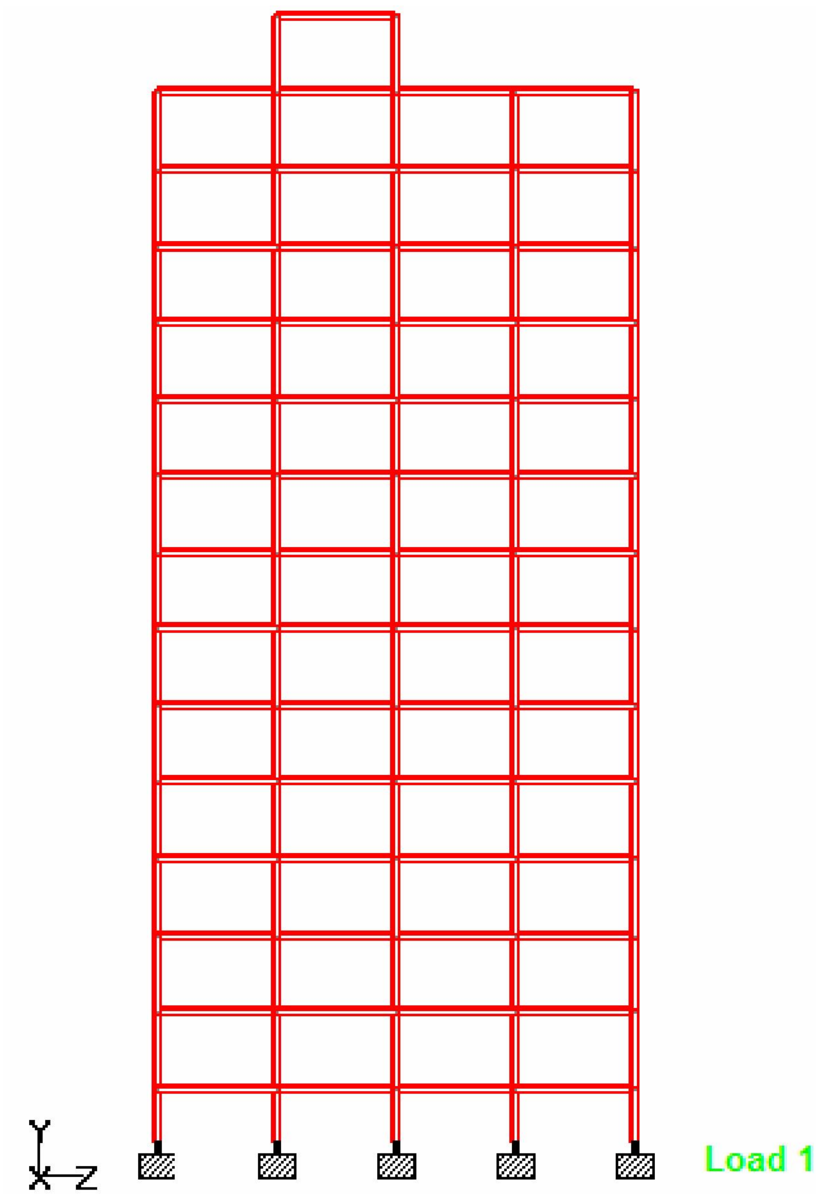
No. Storey: 16



Building Type: High Rise Building

Structure No. 5

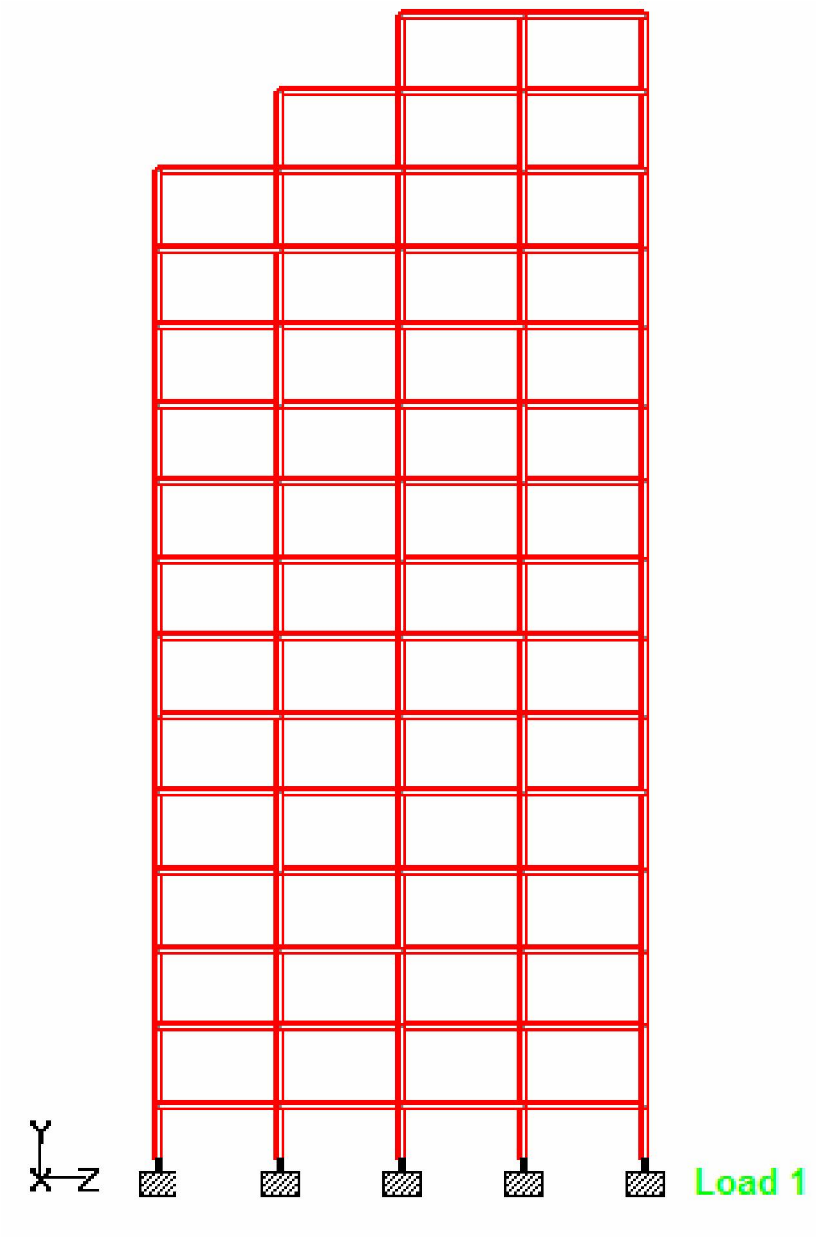
No. Storey: 16



Building Type: High Rise Building

Structure No. 6

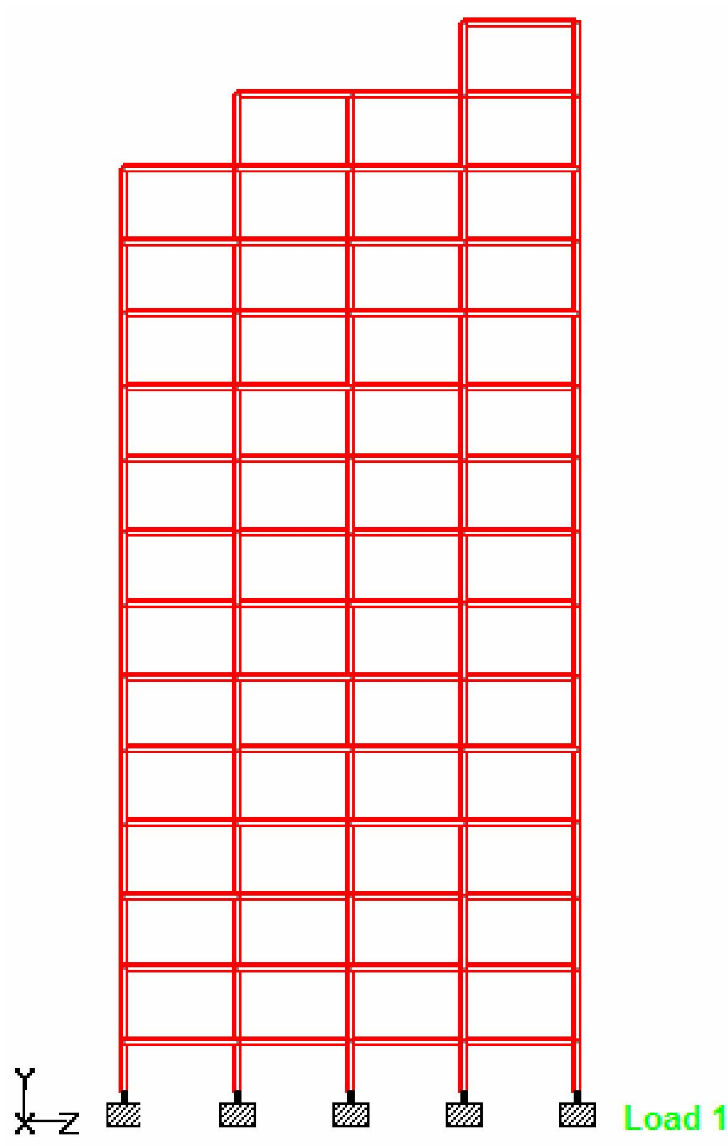
No. Storey: 16



Building Type: High Rise Building

Structure No. 7

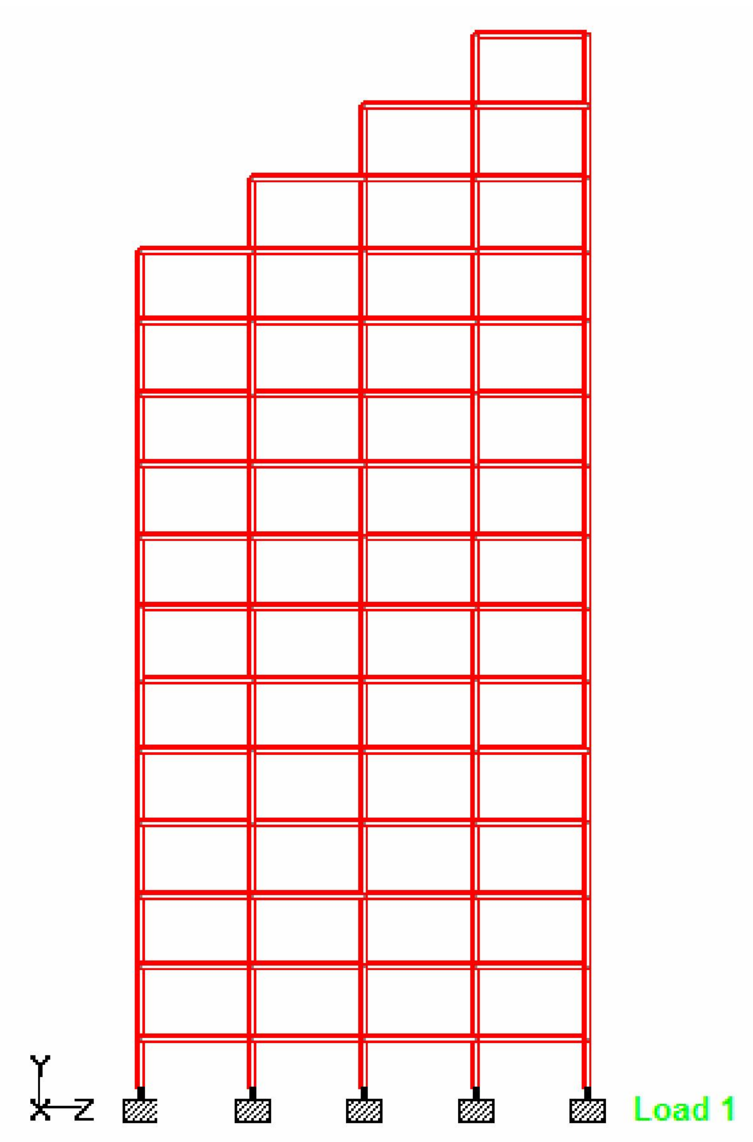
No. Storey: 16



Building Type: High Rise Building

Structure No. 8

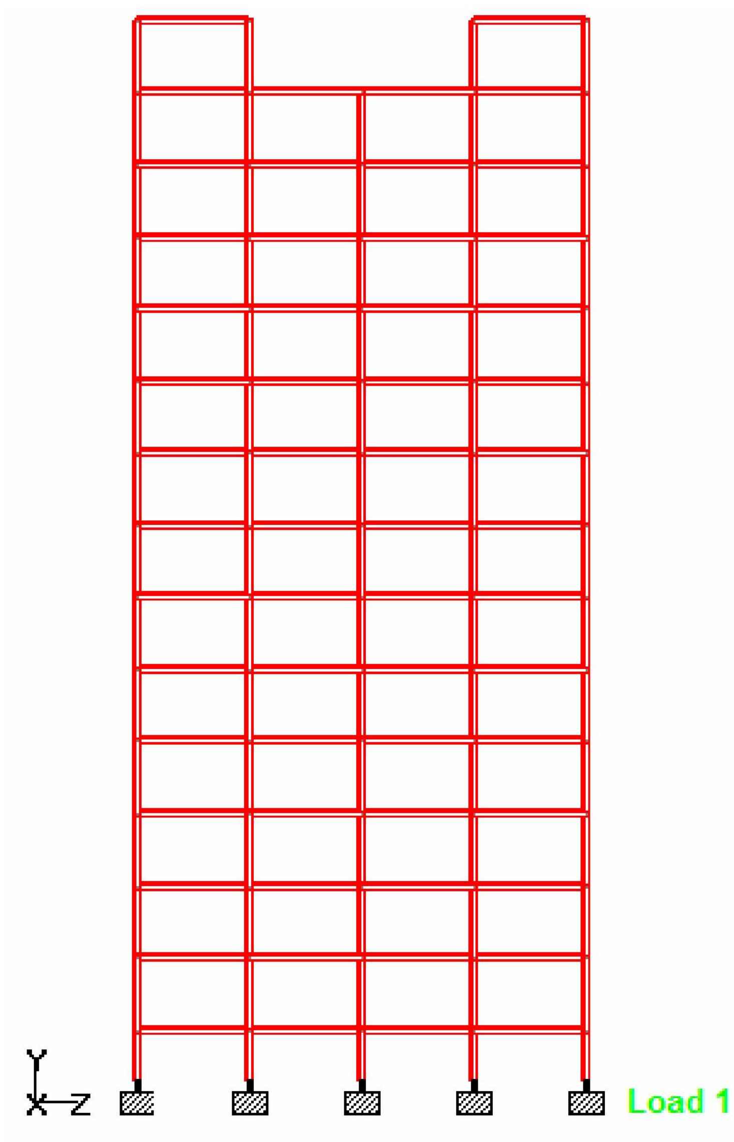
No. Storey: 16



Building Type: High Rise Building

Structure No. 9

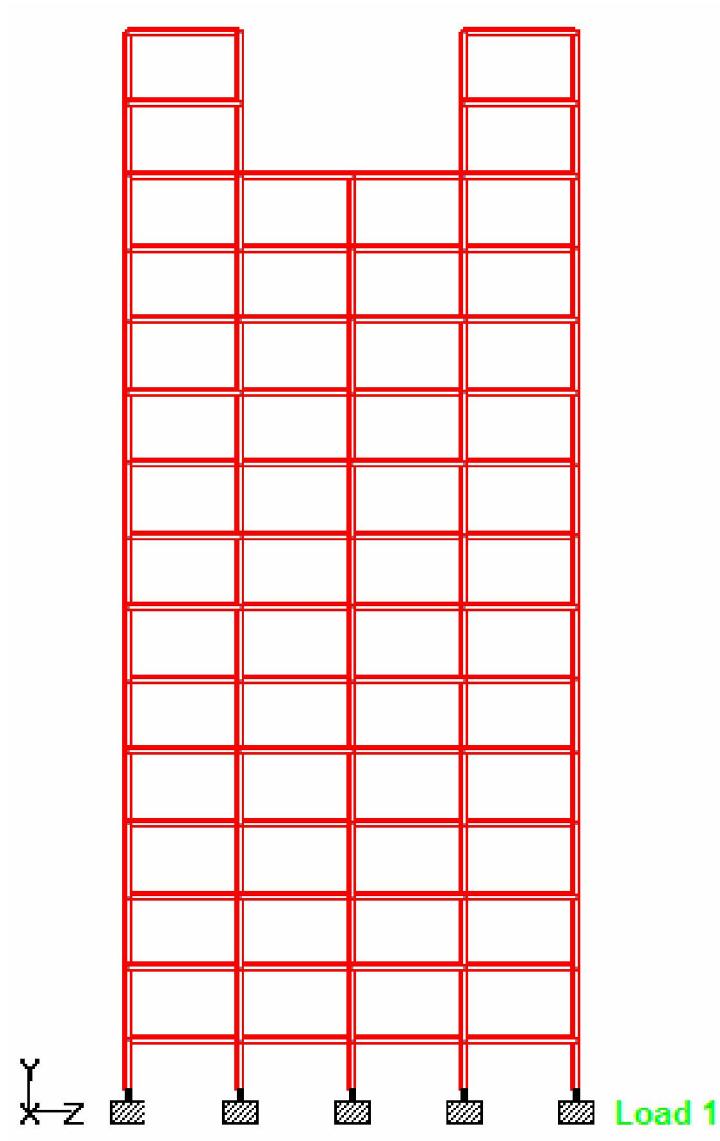
No. Storey: 16



Building Type: High Rise Building

Structure No. 10

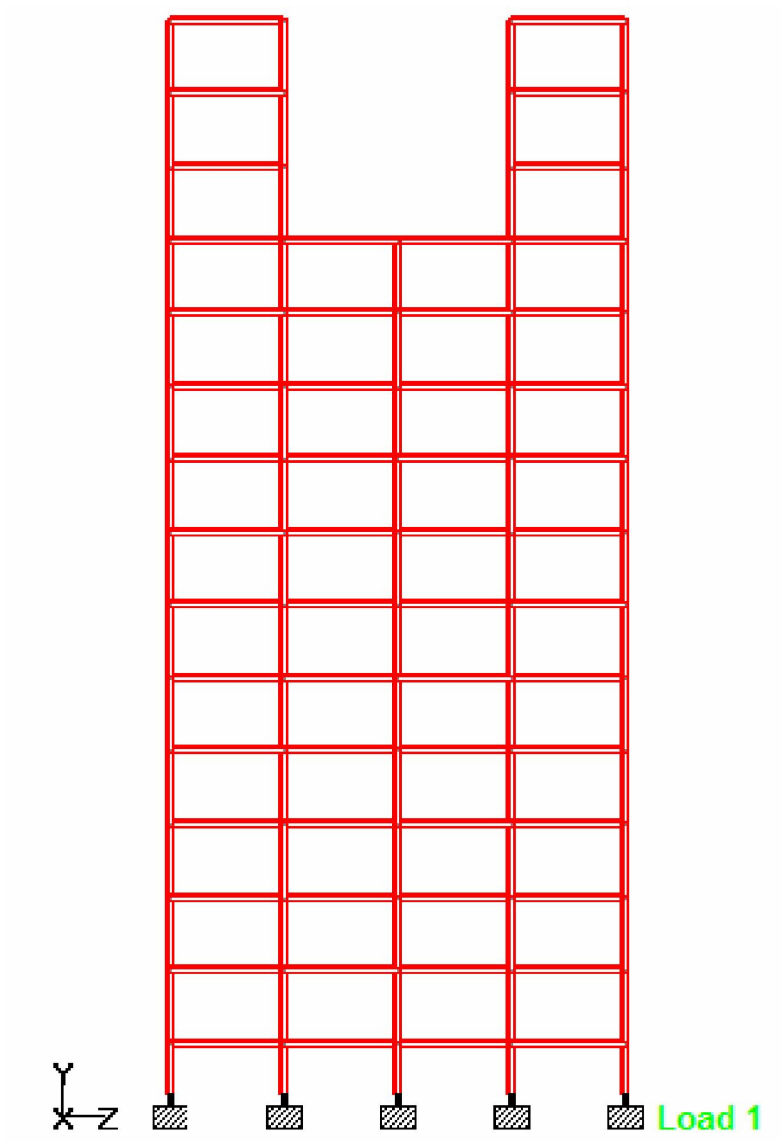
No. Storey: 16



Building Type: High Rise Building

Structure No. 11

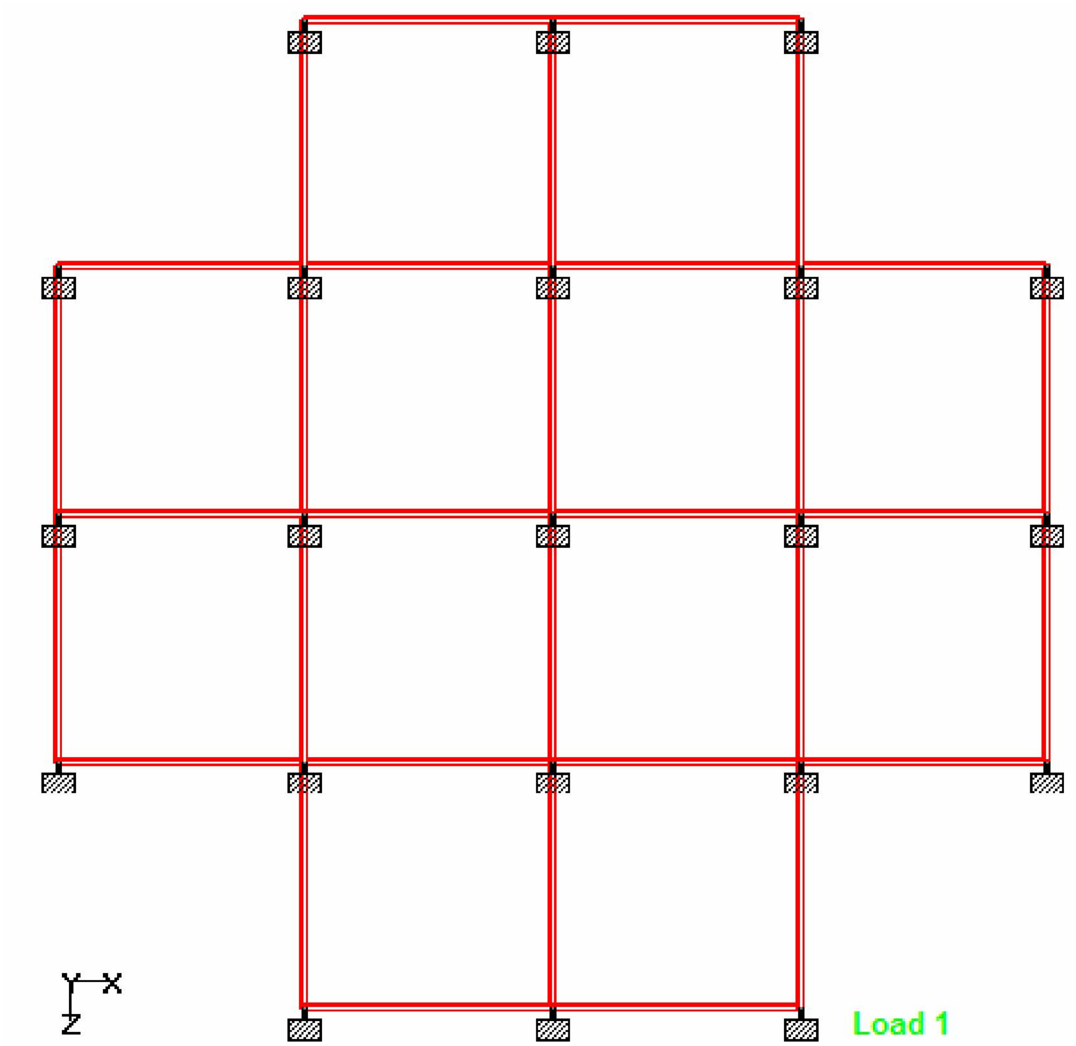
No. Storey: 16



Building Type: High Rise Building

Structure No. 12

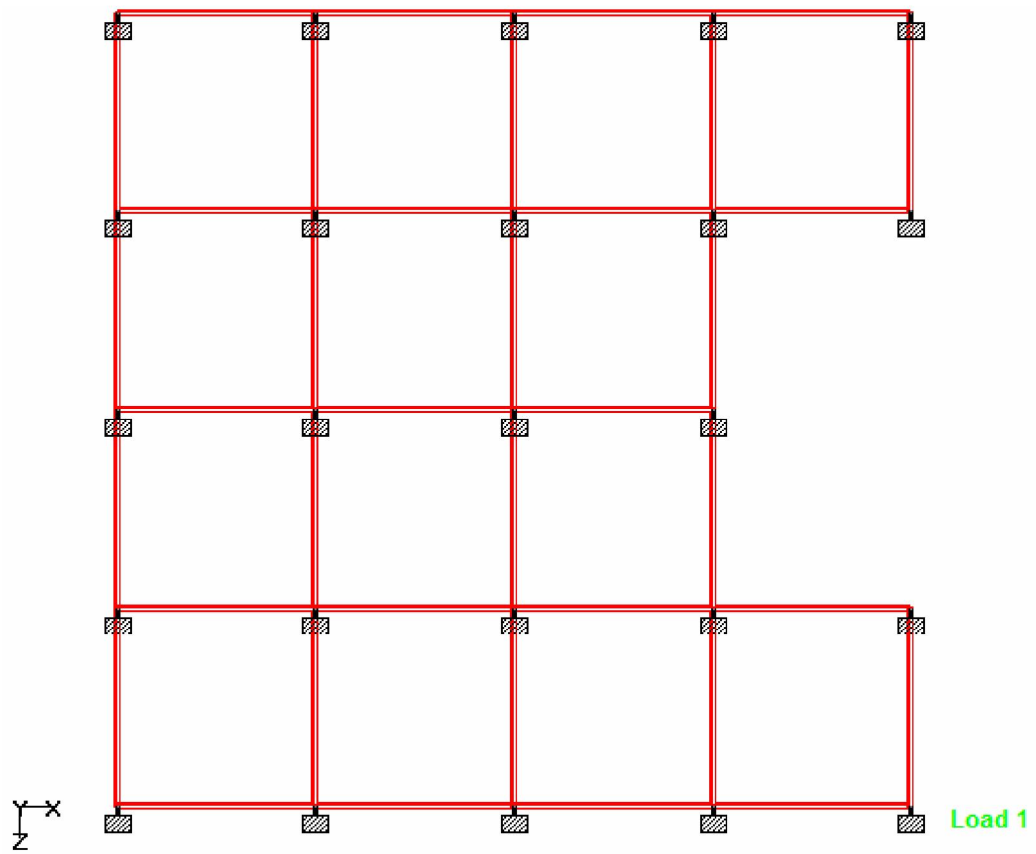
No. Storey: 16



Building Type: High Rise Building

Structure No. 13

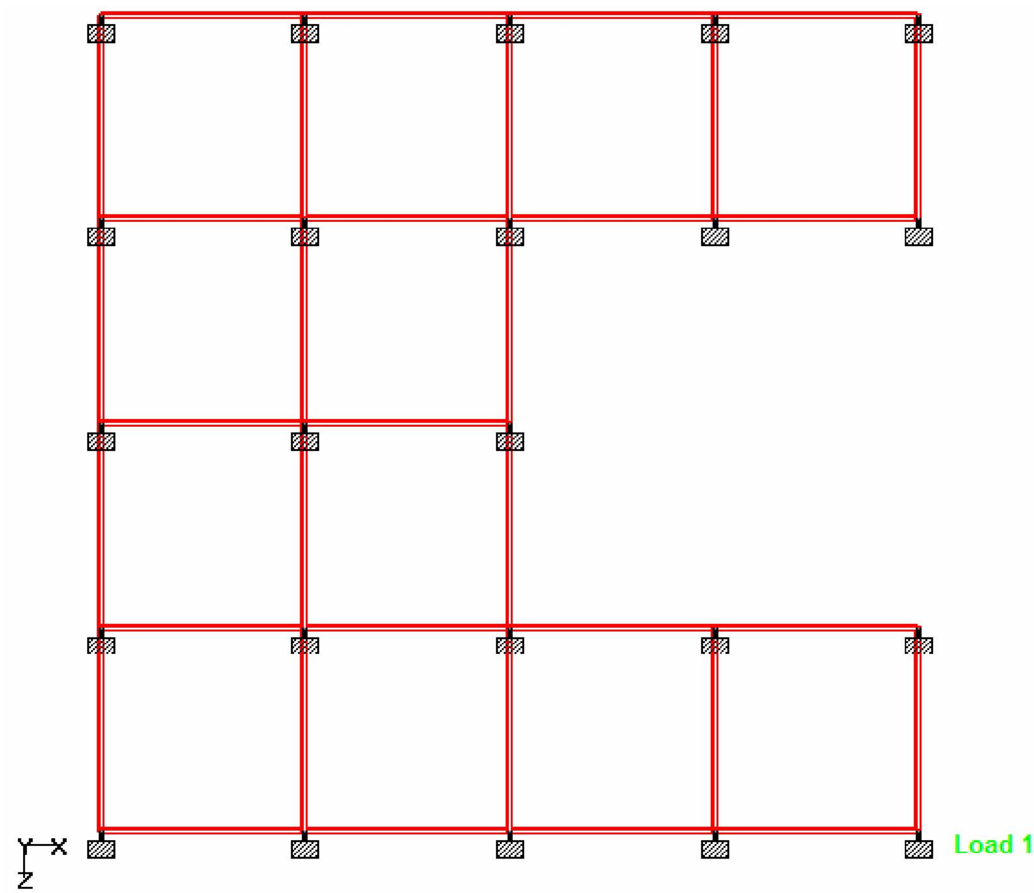
No. Storey: 16



Building Type: High Rise Building

Structure No. 14

No. Storey: 16



Building Type: High Rise Building

Structure No. 15

No. Storey: 16

Modal Time period variation for Six Storey building

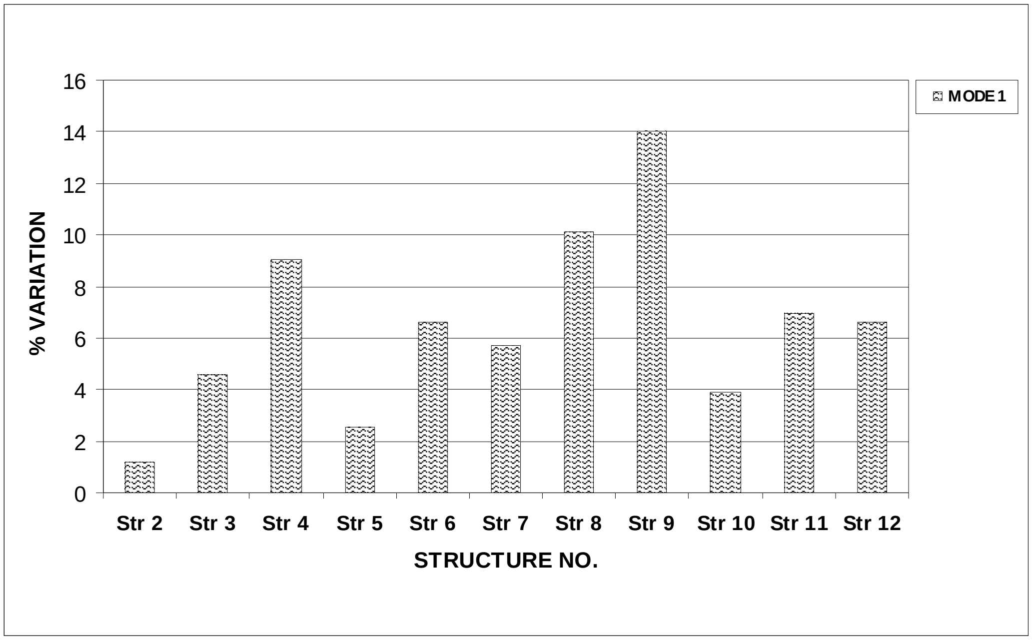


Fig.1 Percent Variation in time period in different structures due to change in V.I.

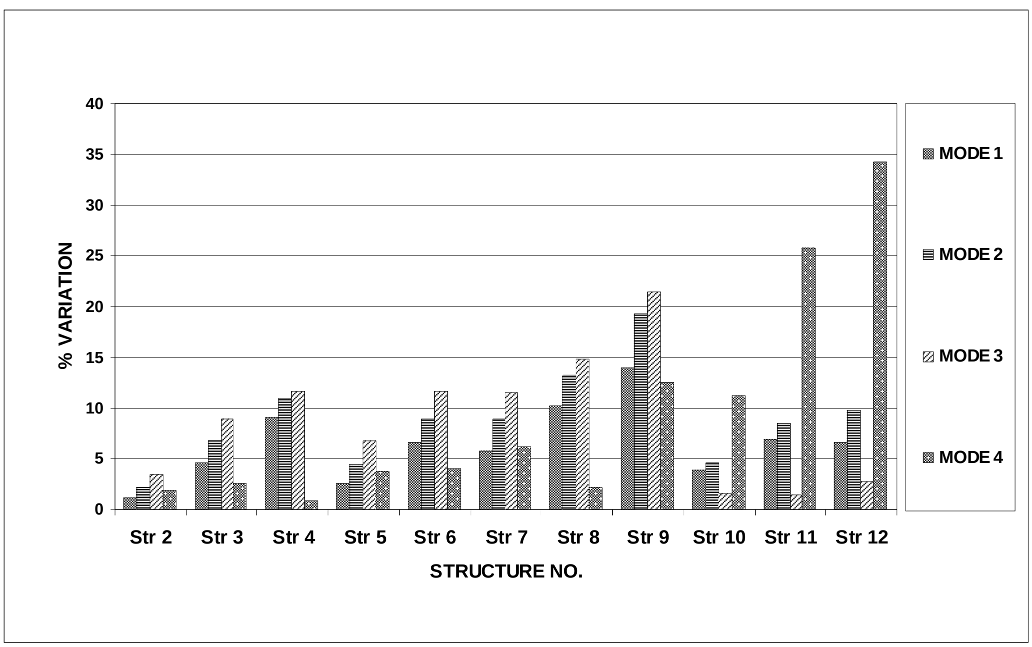


Fig.2 Percent Variation of modal time period in different structures due to change in V.I

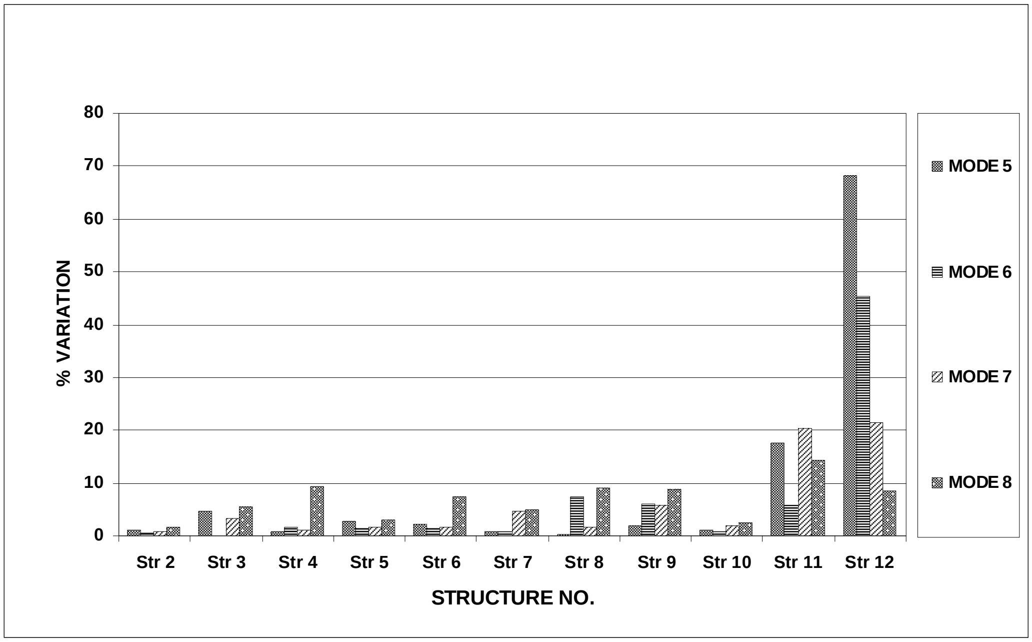


Fig. 3 Percent Variation of modal time period in different structures due to change in V.I

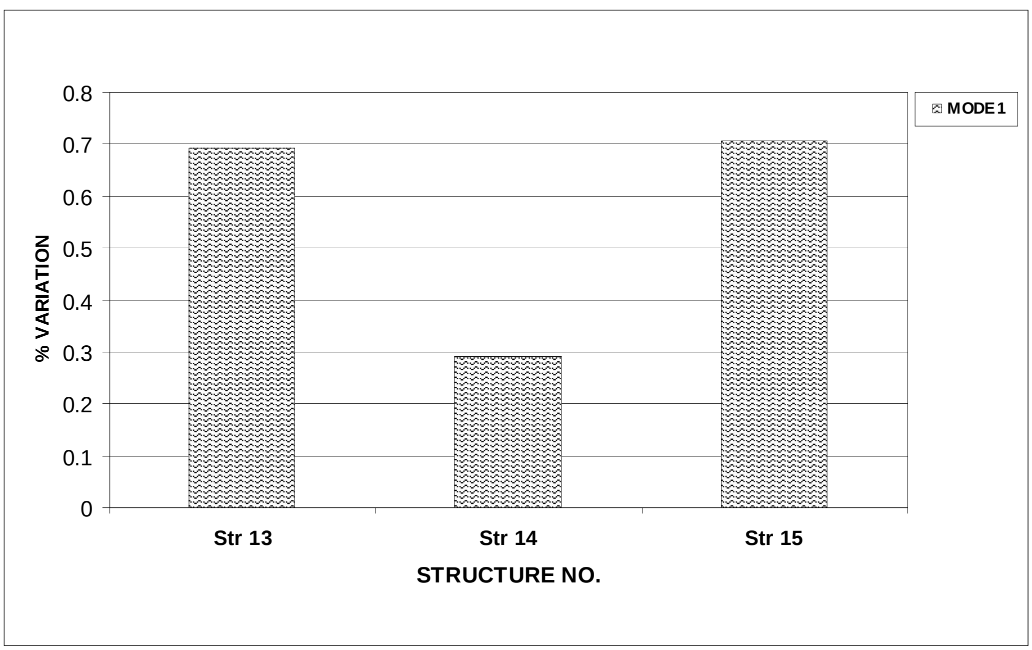


Fig.4 Percent Variation of modal time period in different structures due to change in P.I

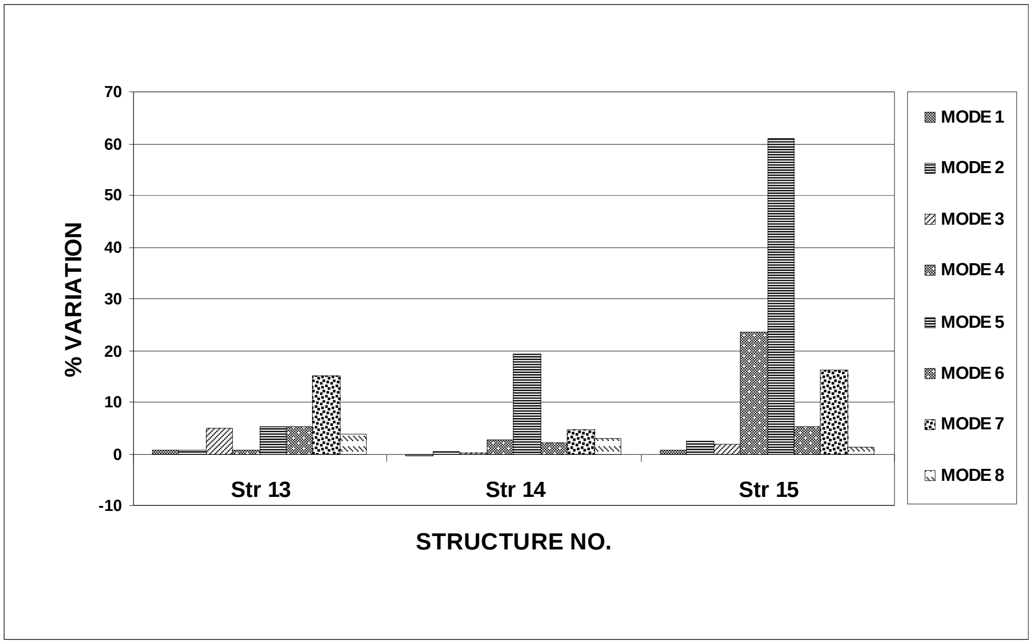


Fig.5 Percent Variation of modal time period in different structures due to change in P.I

Modal Time period variation for Eight Storey building

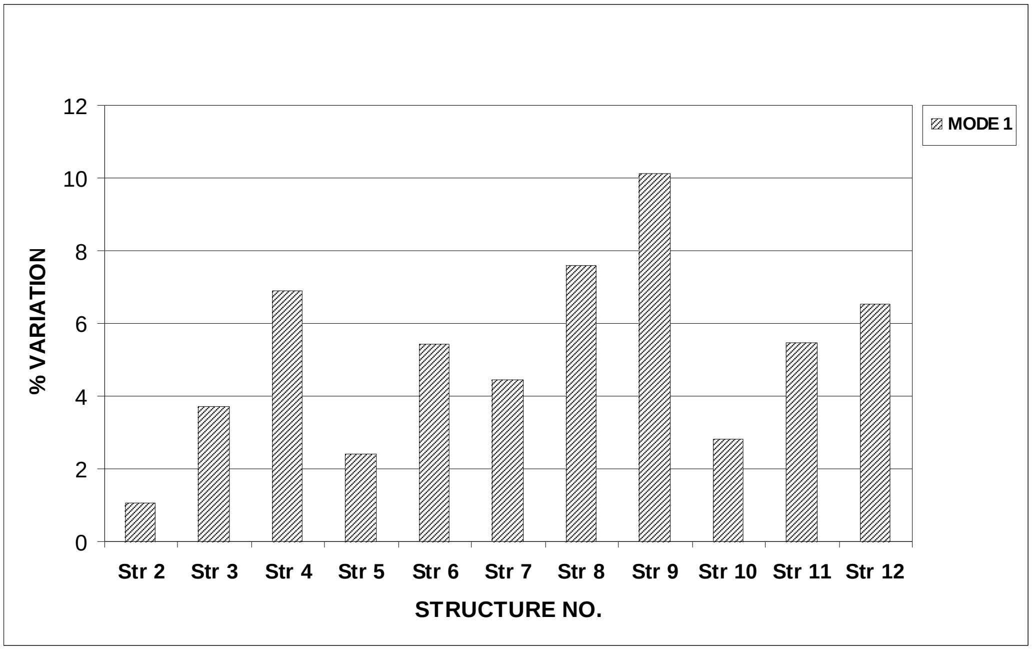


Fig.6 Percent Variation in time period in different structures due to change in V.I.

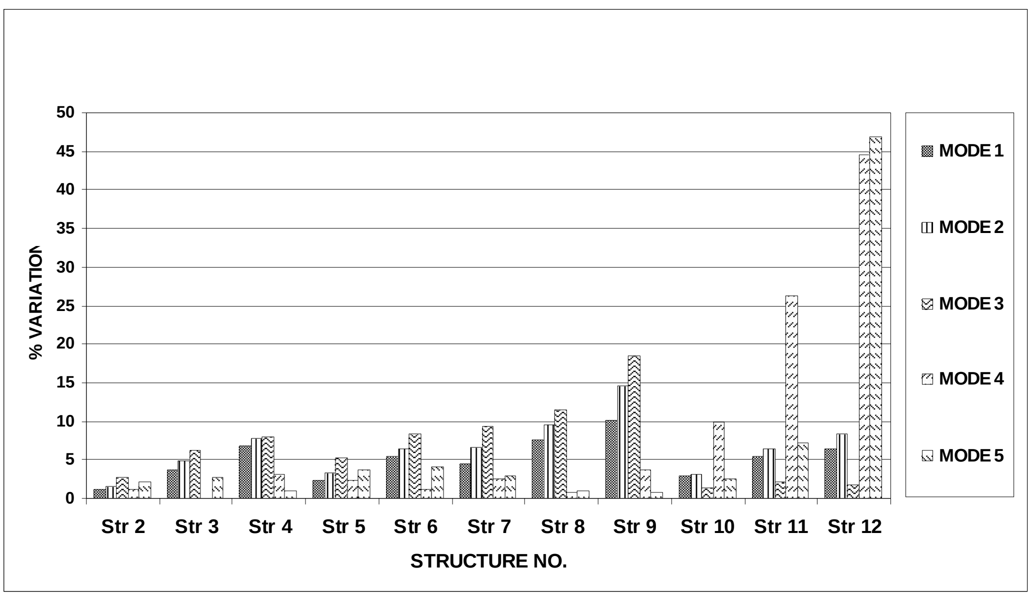


Fig.7 Percent Variation of modal time period in different structures due to change in V.I

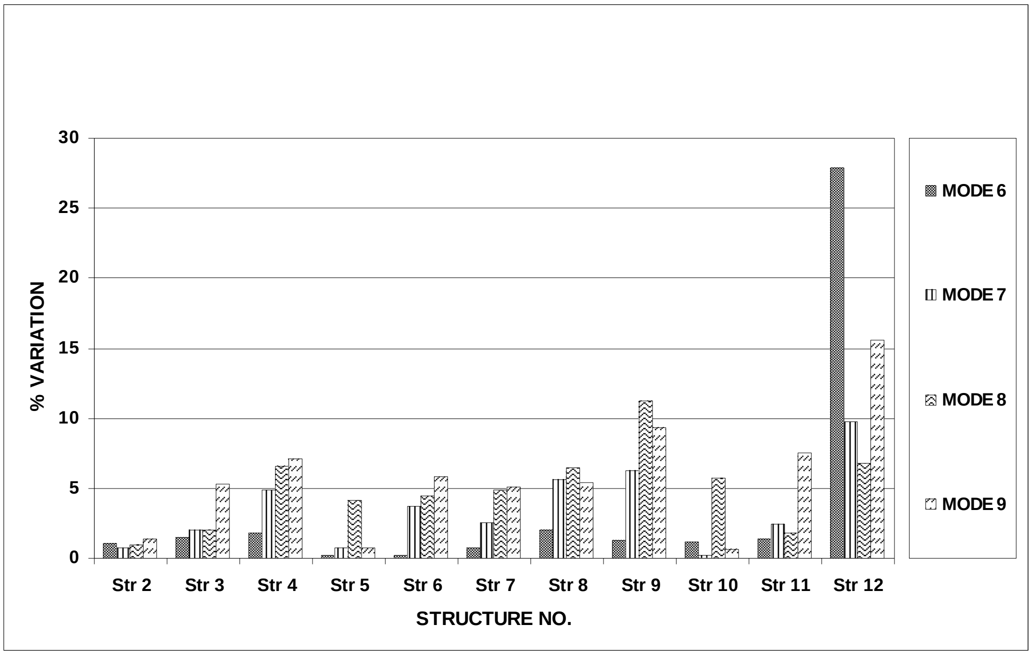


Fig.8 Percent Variation of modal time period in different structures due to change in V.I

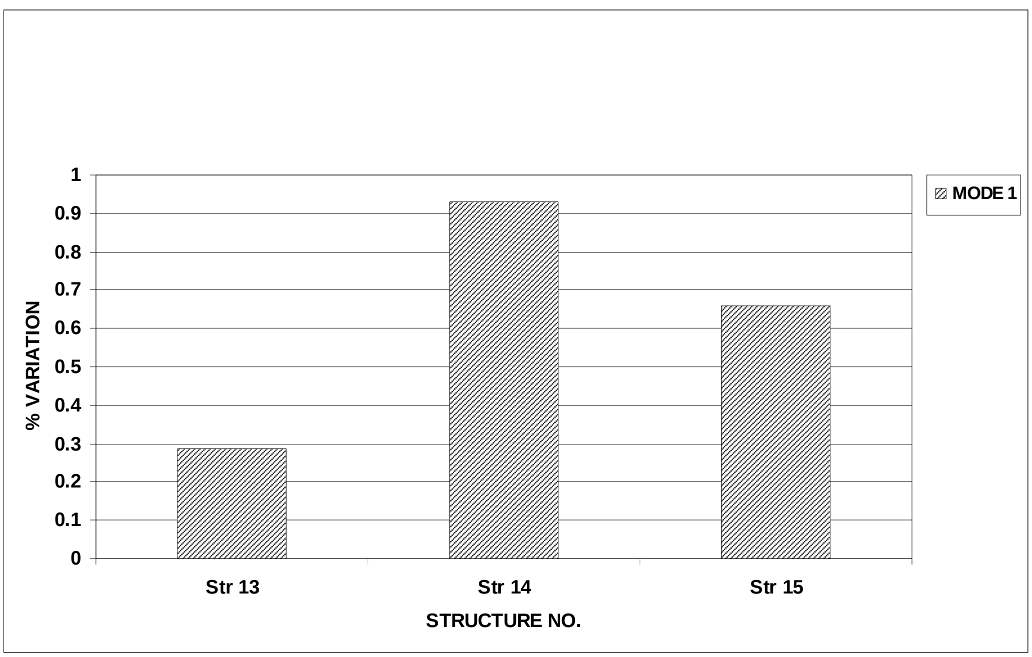


Fig.9 Percent Variation of modal time period in different structures due to change in P.I

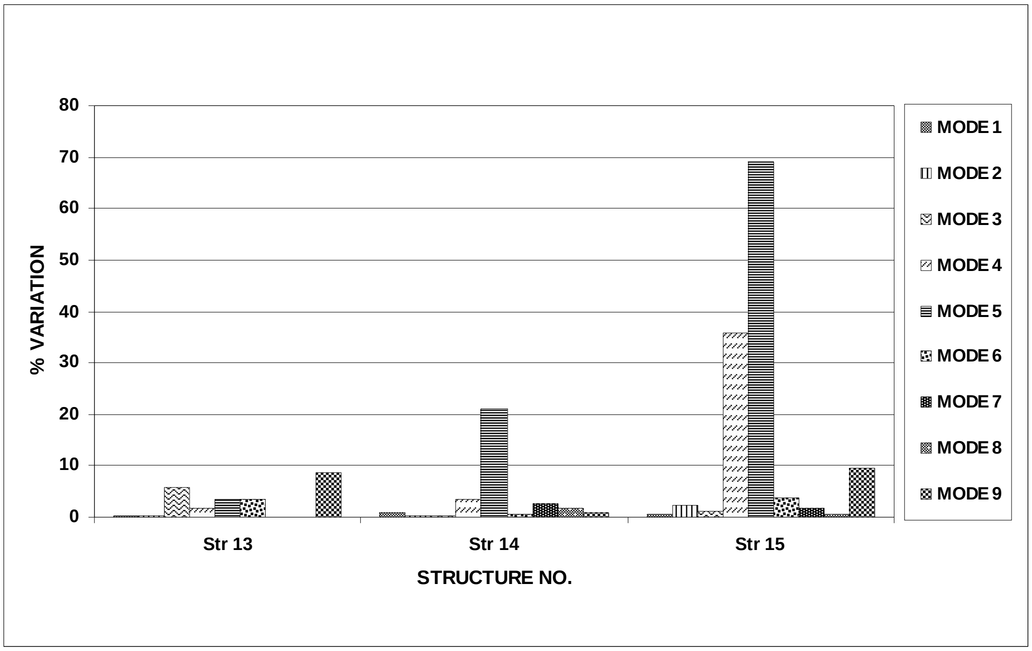


Fig.10 Percent Variation of modal time period in different structures due to change in P.I

Modal Time period variation for Sixteen Storey building

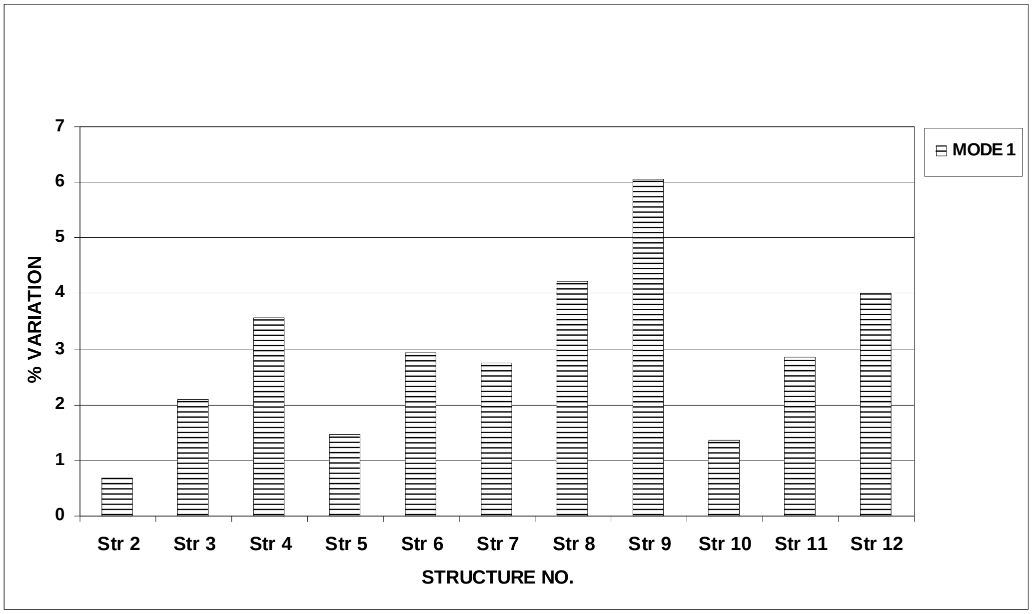


Fig.11 Percent Variation of time period in different structures due to change in V.I

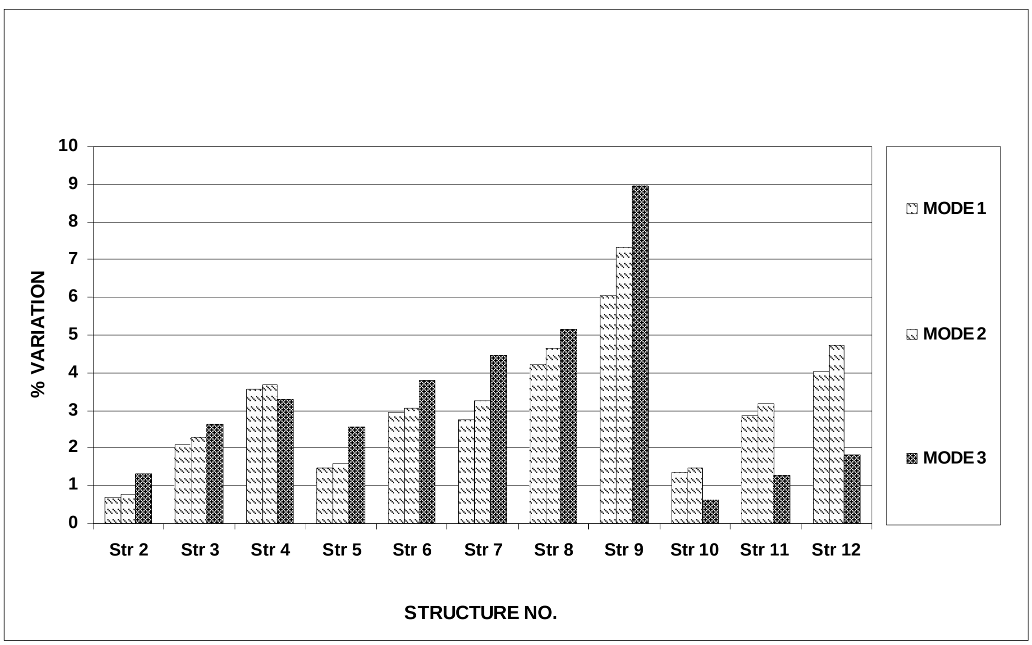


Fig.12 Percent Variation of modal time period in different structures due to change in V.I

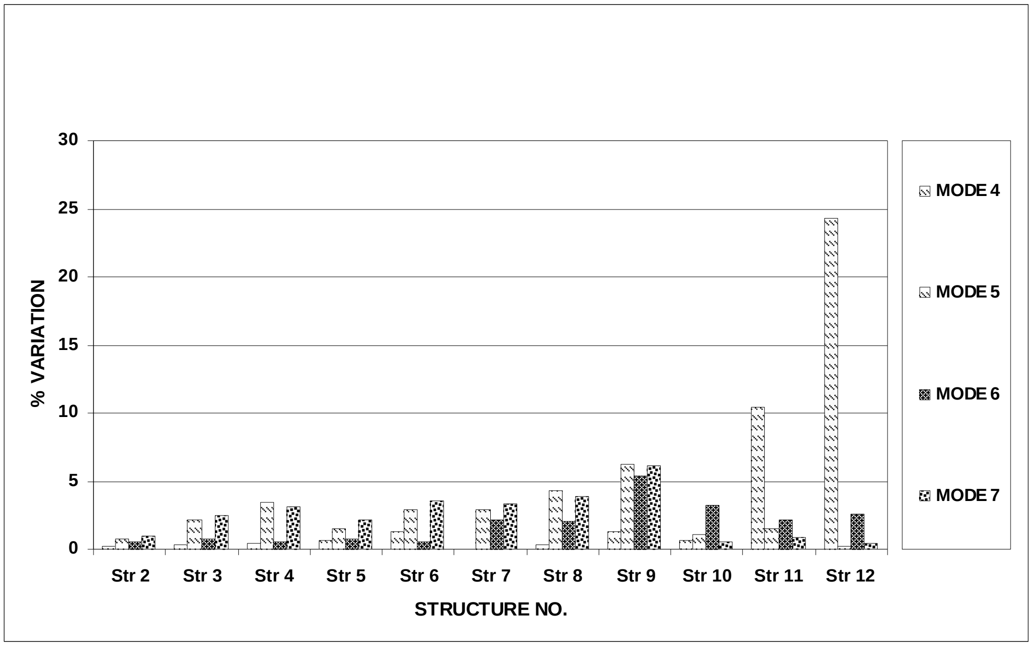


Fig.13 Percent Variation of modal time period in different structures due to change in V.I

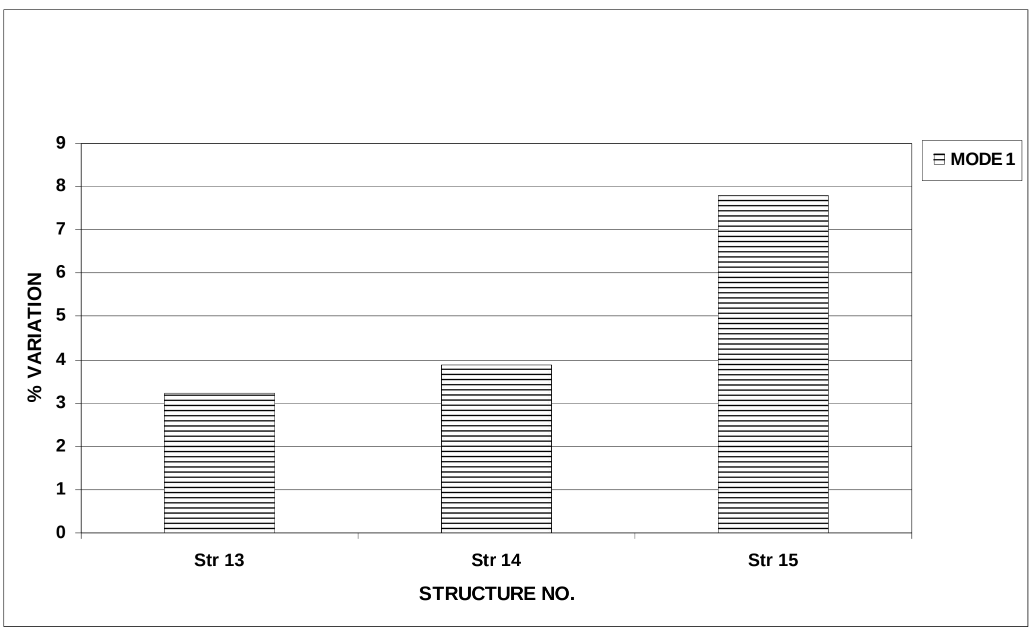


Fig.14 Percent Variation of time period in different structures due to change in P.I

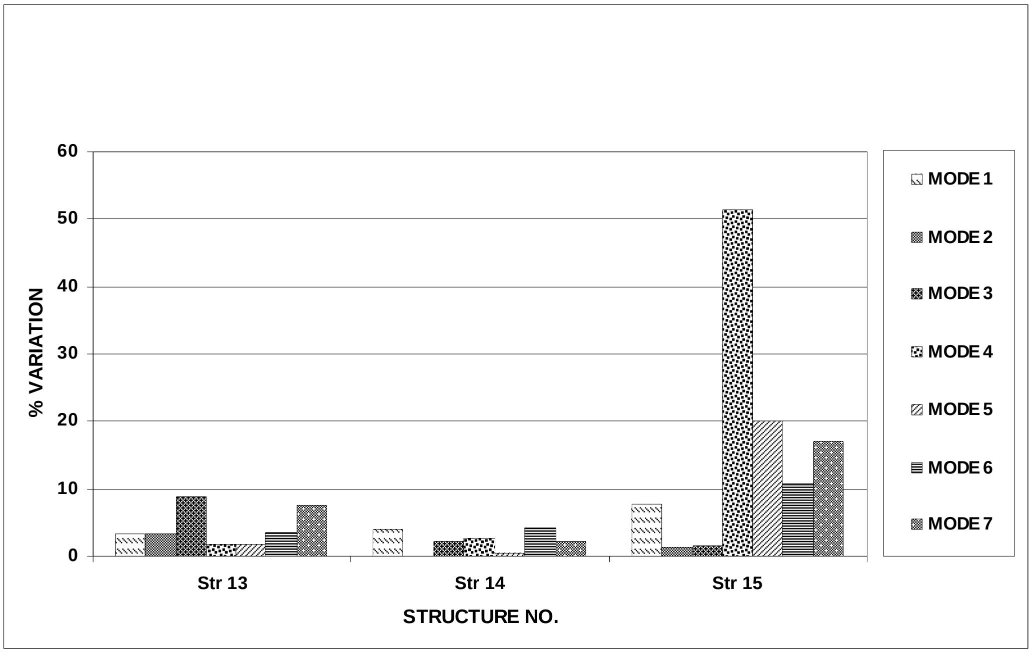


Fig.15 Percent Variation of modal time period in different structures due to change in P.I

Storey Drift variation for Six Storey building

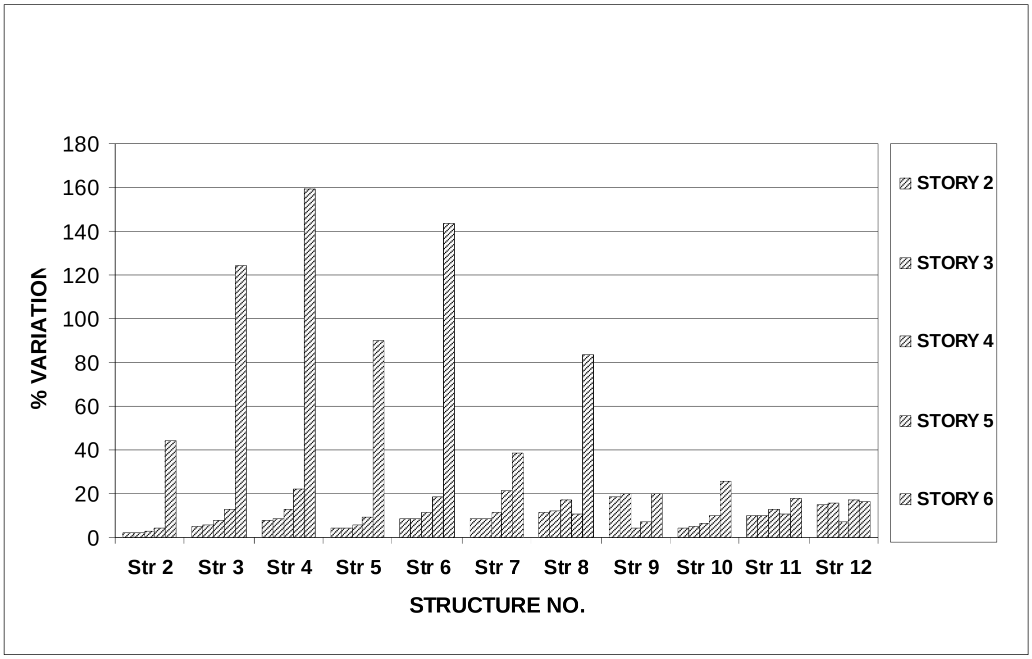


Fig.16 Percent Variation in storey drifts in X-direction in different structures due to change in V.I.

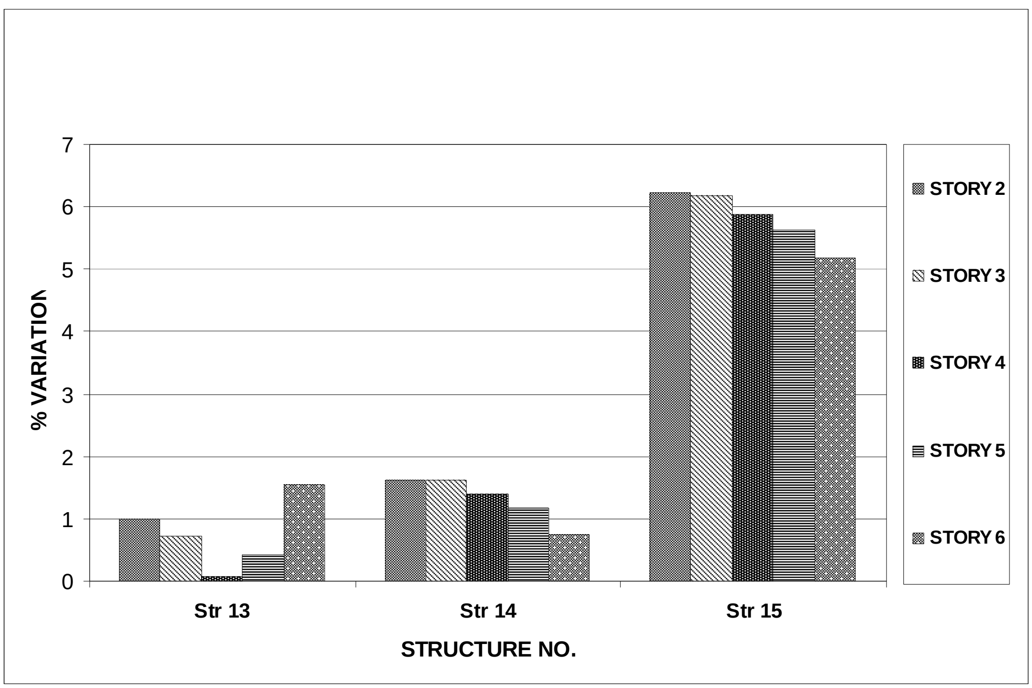


Fig.17 Percent Variation in storey drifts in X-direction in different structures due to change in P.I.

Storey Drift variation for Eight Storey building

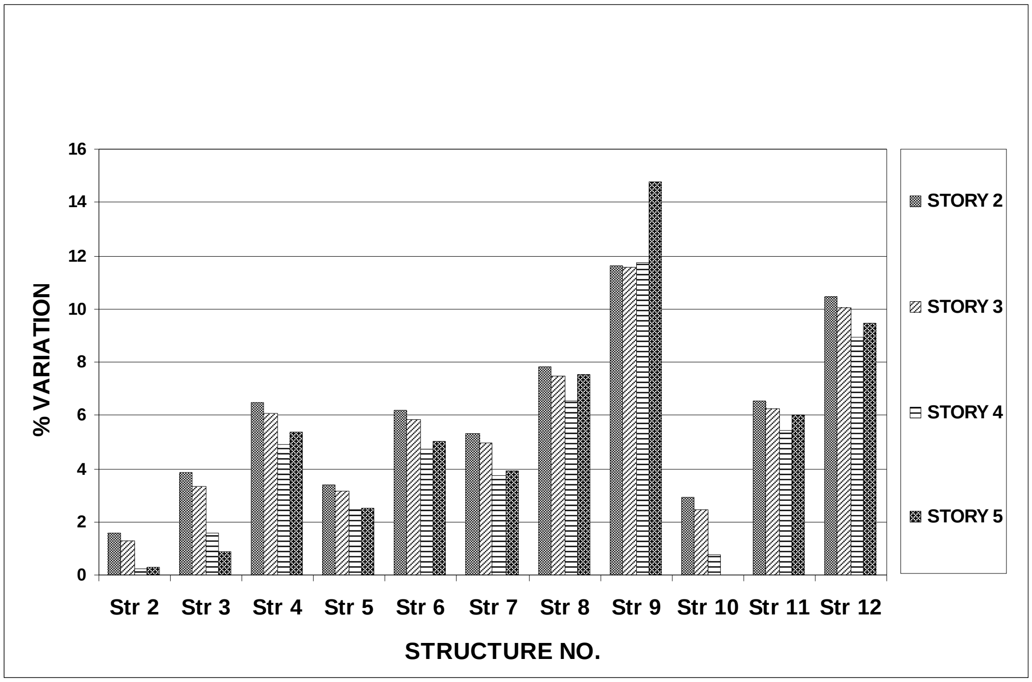


Fig.18 Percent Variation in storey drifts in X-direction in different structures due to change in V.I.

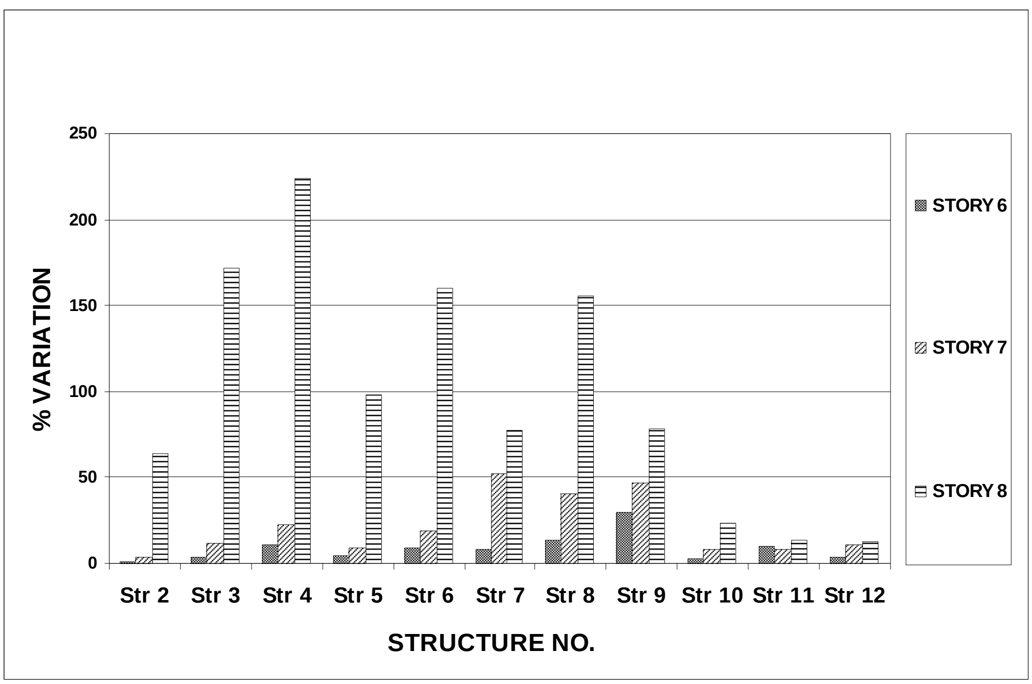


Fig.19 Percent Variation in storey drifts in X-direction in different structures due to change in V.I.

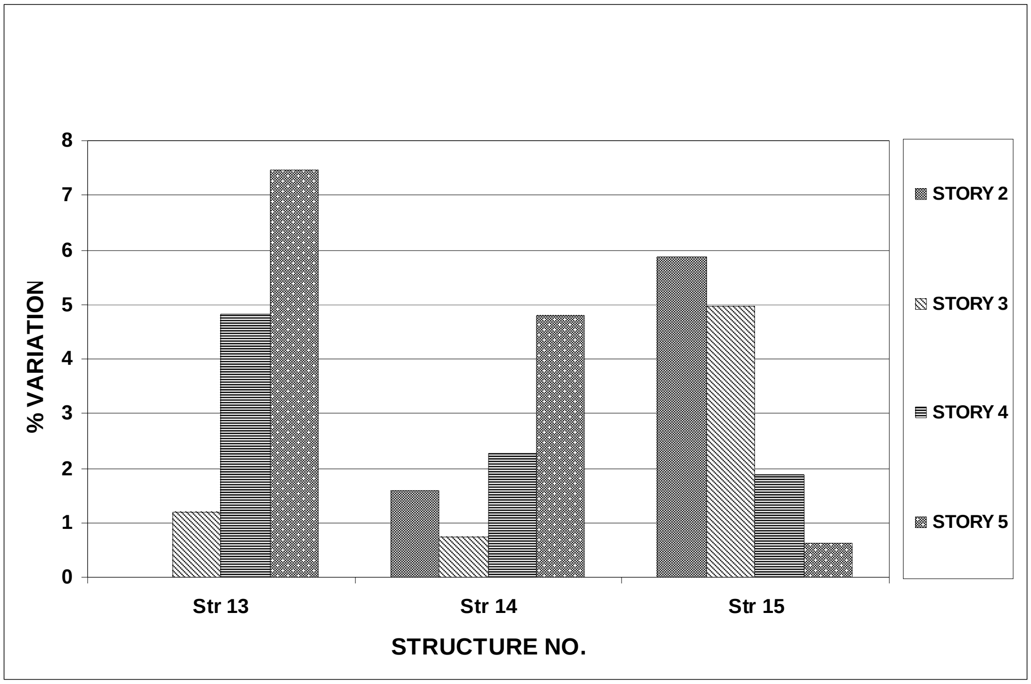


Fig.20 Percent Variation in storey drifts in X-direction in different structures due to change in P.I.

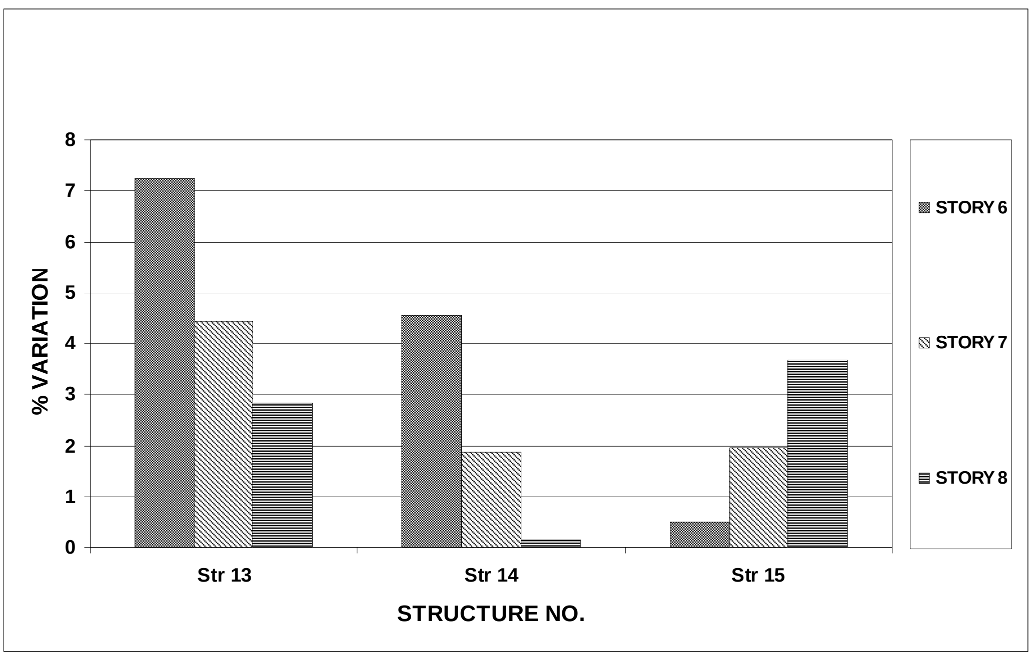


Fig. 21 Percent Variation in storey drifts in X-direction in different structures due to change in P.I.

Storey Drift variation for Sixteen Storey building

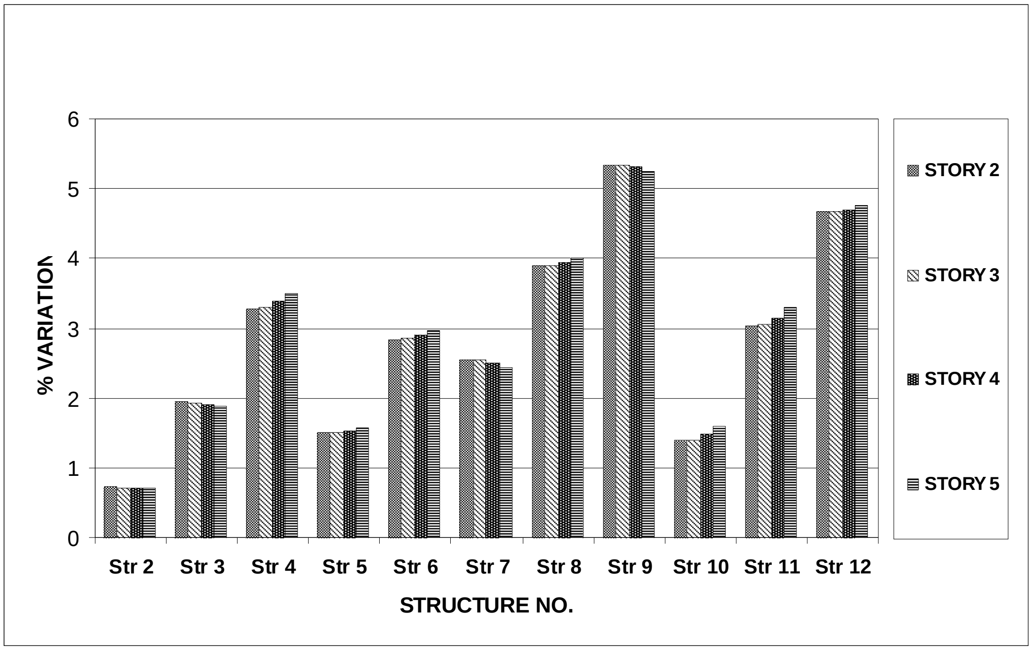


Fig.22 Percent Variation in storey drifts in X-direction in different structures due to change in V.I.

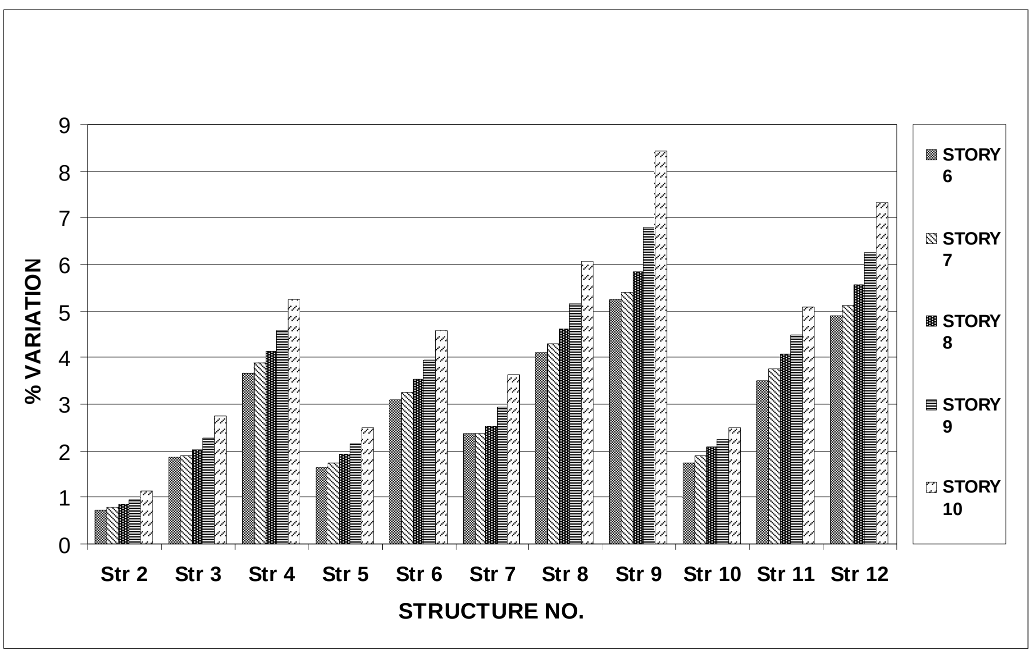


Fig.23 Percent Variation in storey drifts in X-direction in different structures due to change in V.I.

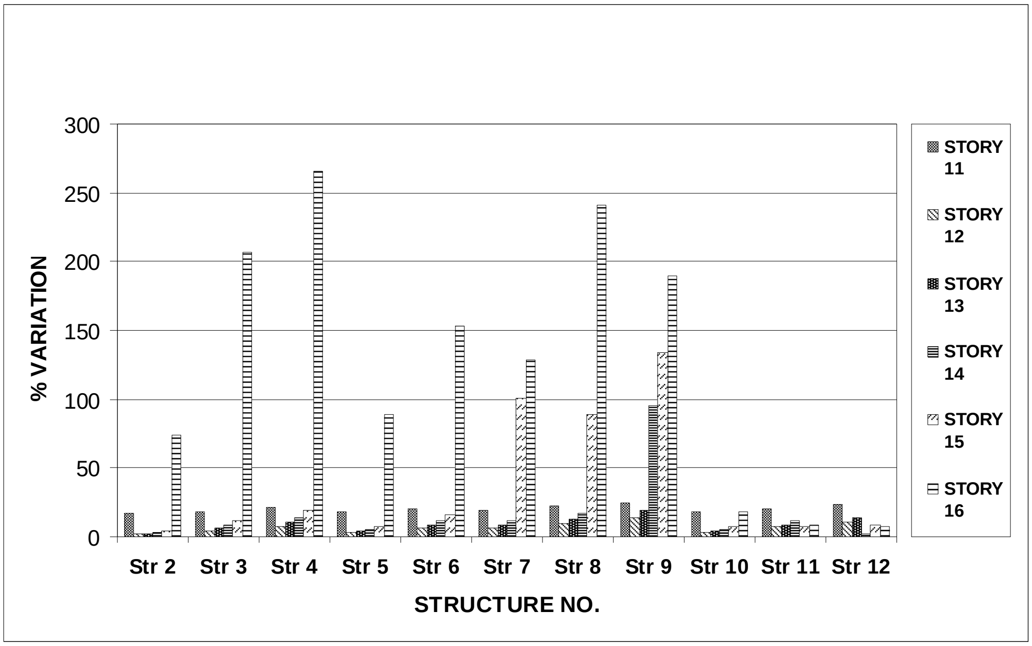


Fig. 24 Percent Variation in storey drifts in X-direction in different structures due to change in V.I.

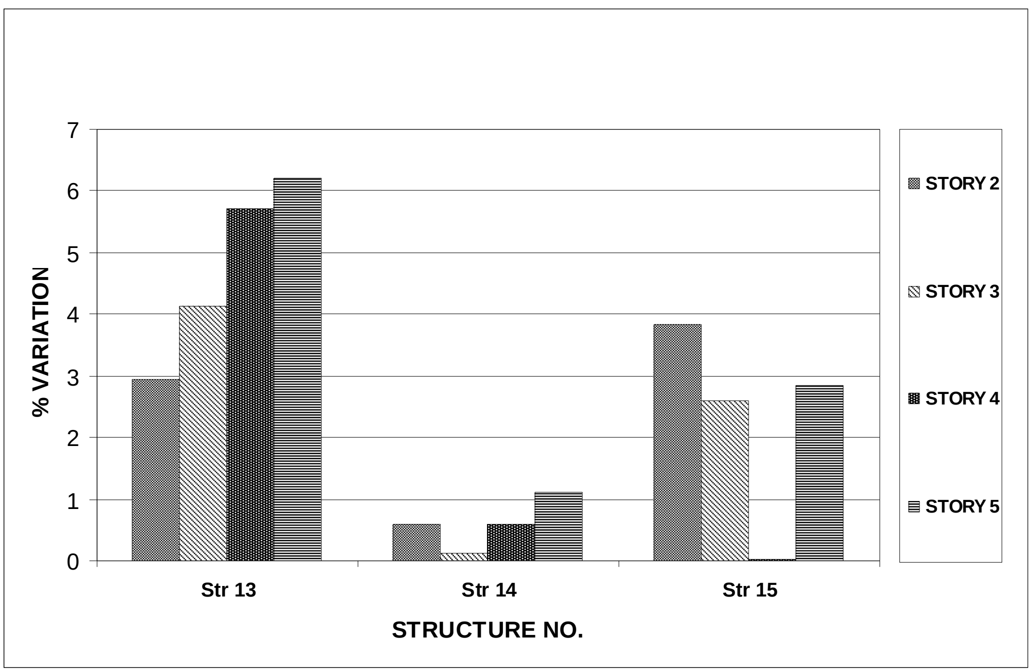


Fig.25 Percent Variation in storey drifts in X-direction in different structures due to change in P.I.

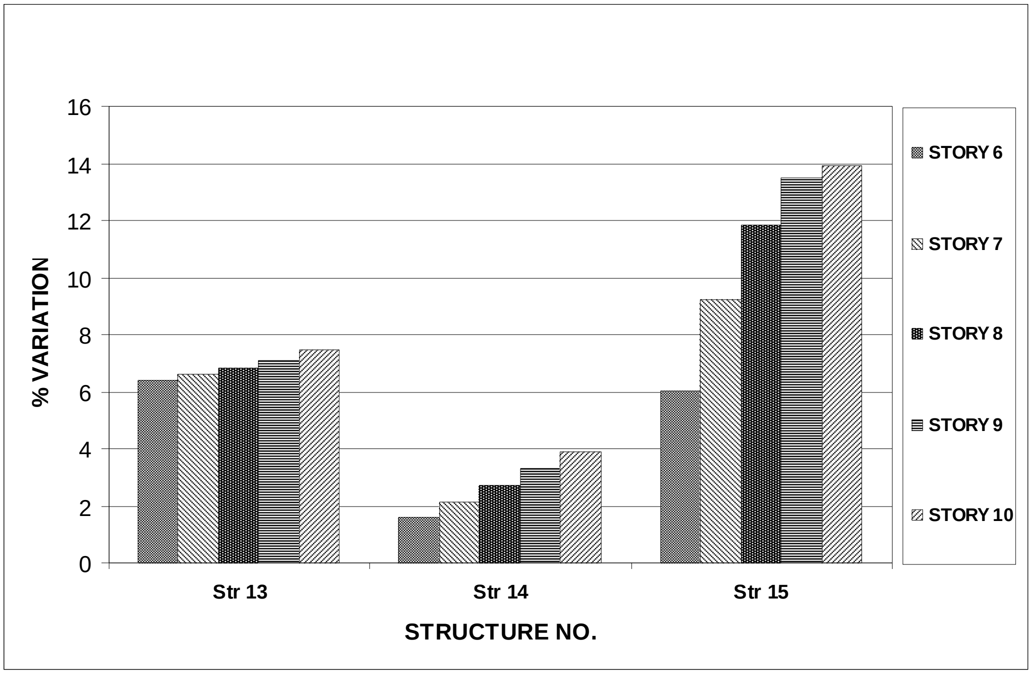


Fig. 26 Percent Variation in storey drifts in X-direction in different structures due to change in P.I.

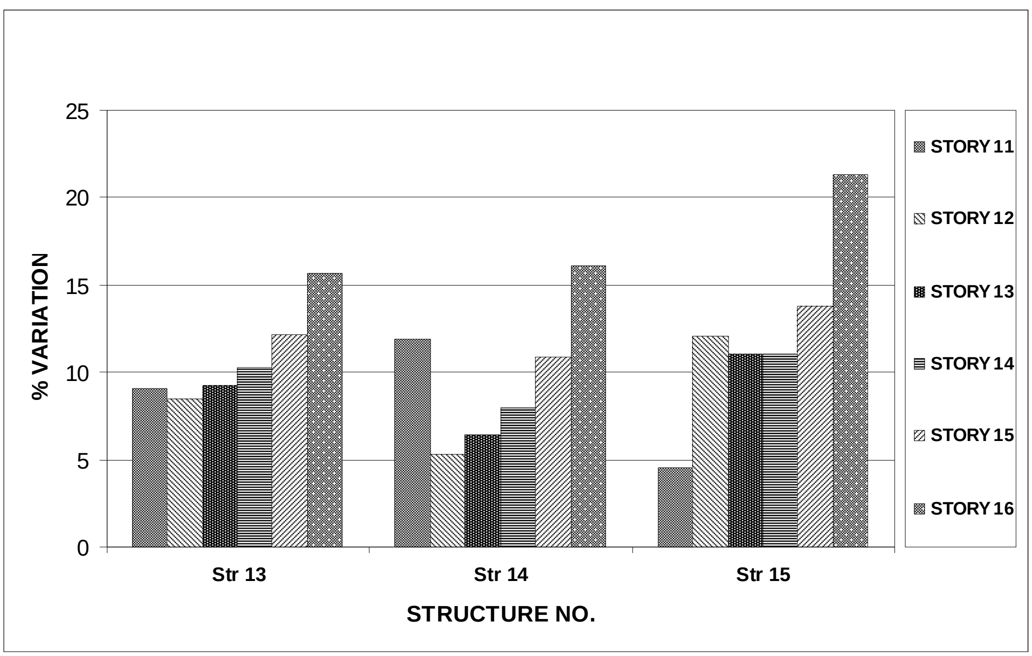


Fig.27 Percent Variation in storey drifts in X-direction in different structures due to change in P.I.

Base Shear variation in X-dir. for Six Storey building

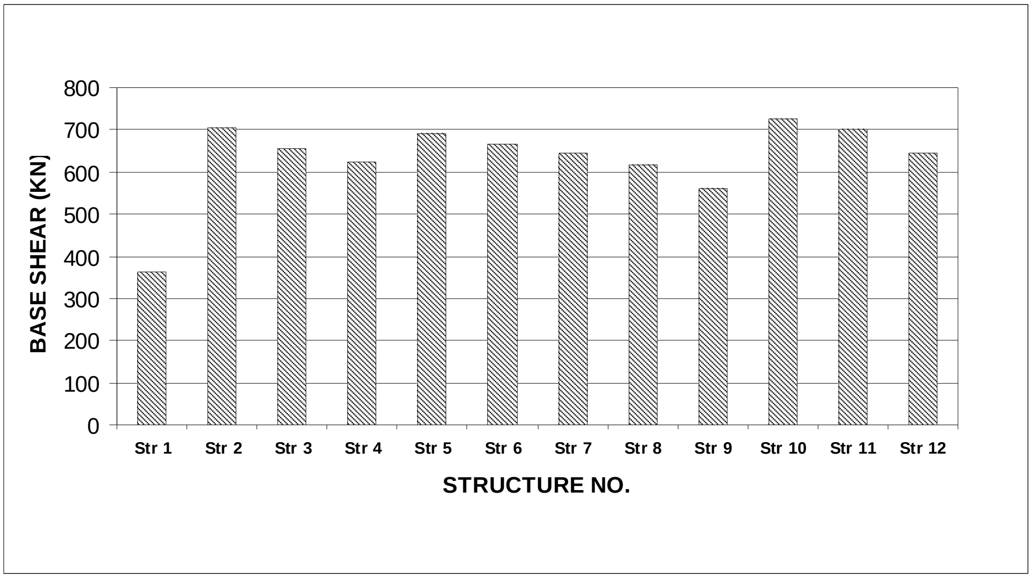


Fig.28 Base shears in mode 1 in different structures due to change in V.I.

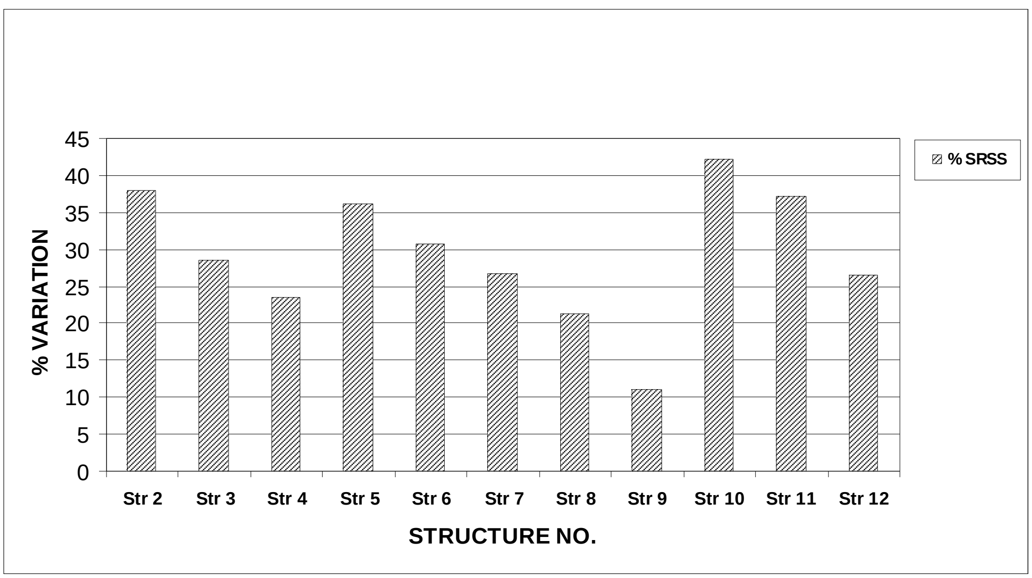


Fig.29 Percent variation in SRSS base shears in different structures due to change in V.I.

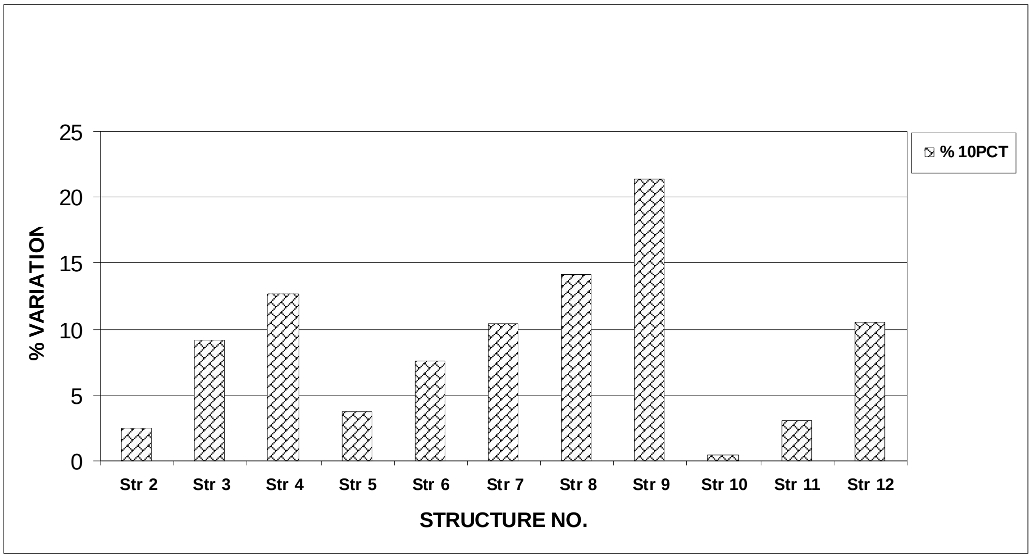


Fig.30 Percent variation in 10PCT base shears in different structures due to change in V.I.

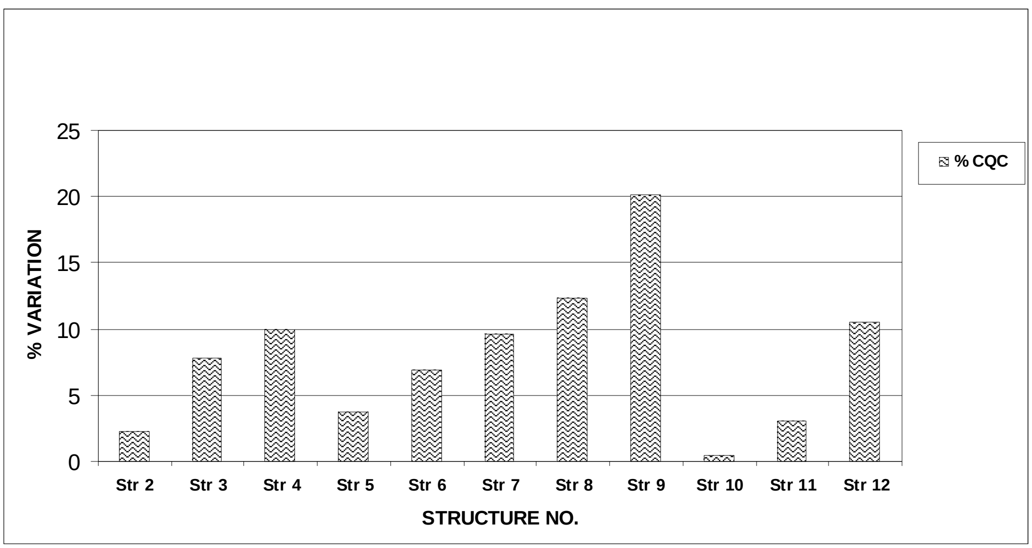


Fig.31 Percent variation in CQC base shears in different structures due to change in V.I.

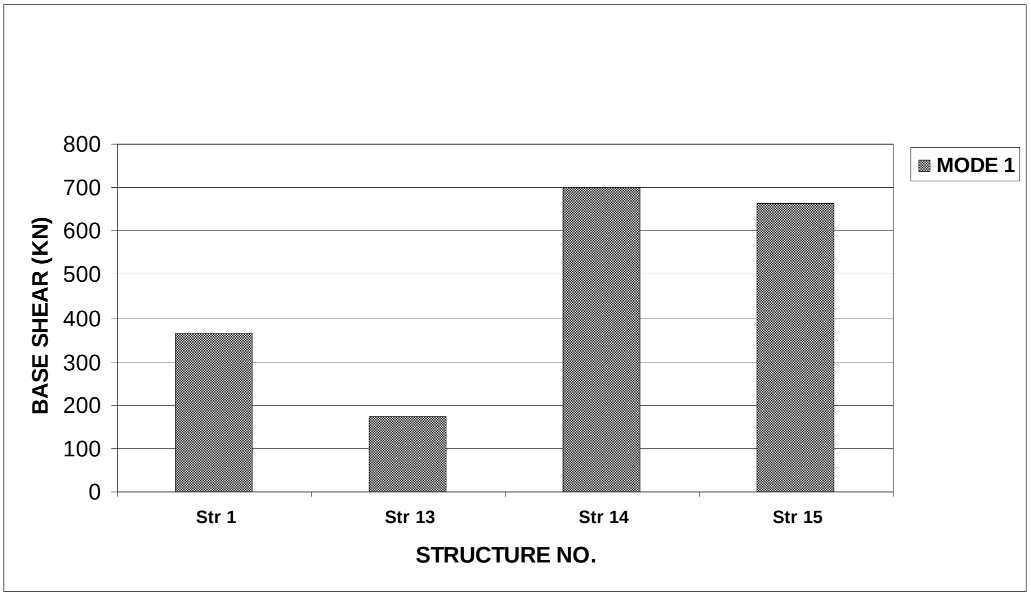


Fig.32 Base shears in mode 1 in different structures due to change in P.I

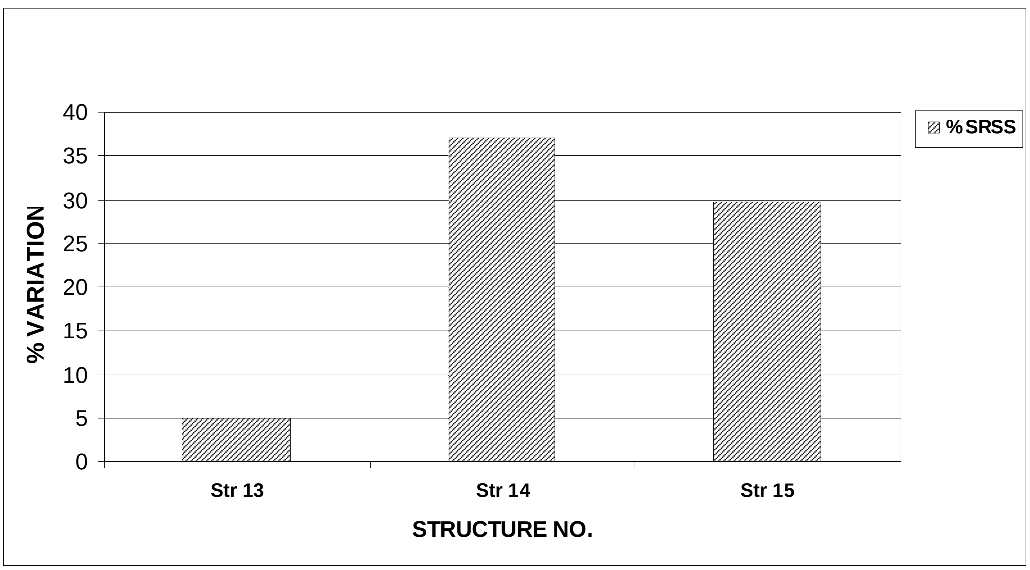


Fig.33 Percent variation in SRSS base shears in different structures due to change in P.I.

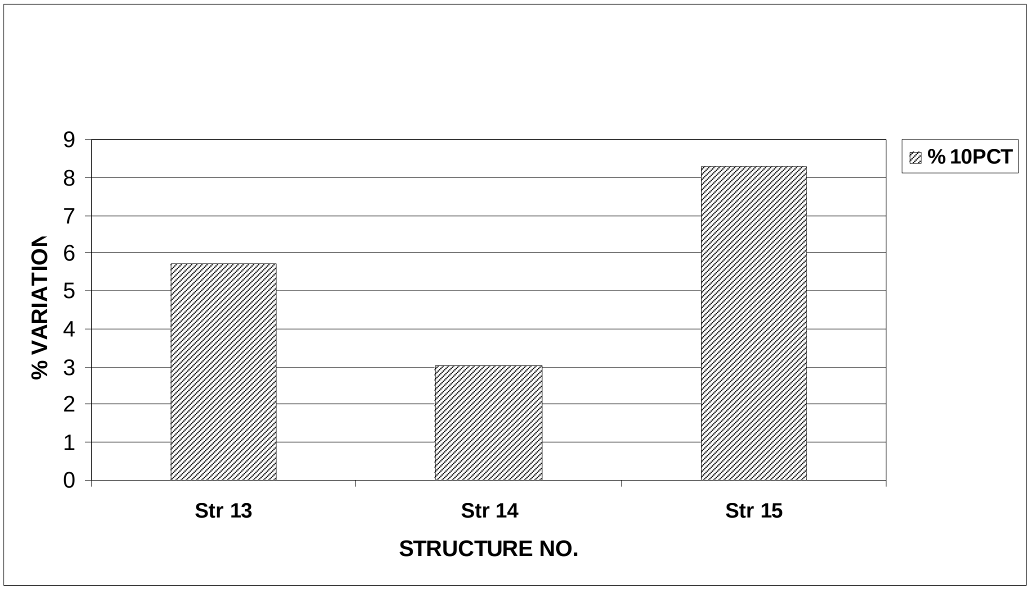


Fig.34 Percent variation in 10PCT base shears in different structures due to change in P.I.

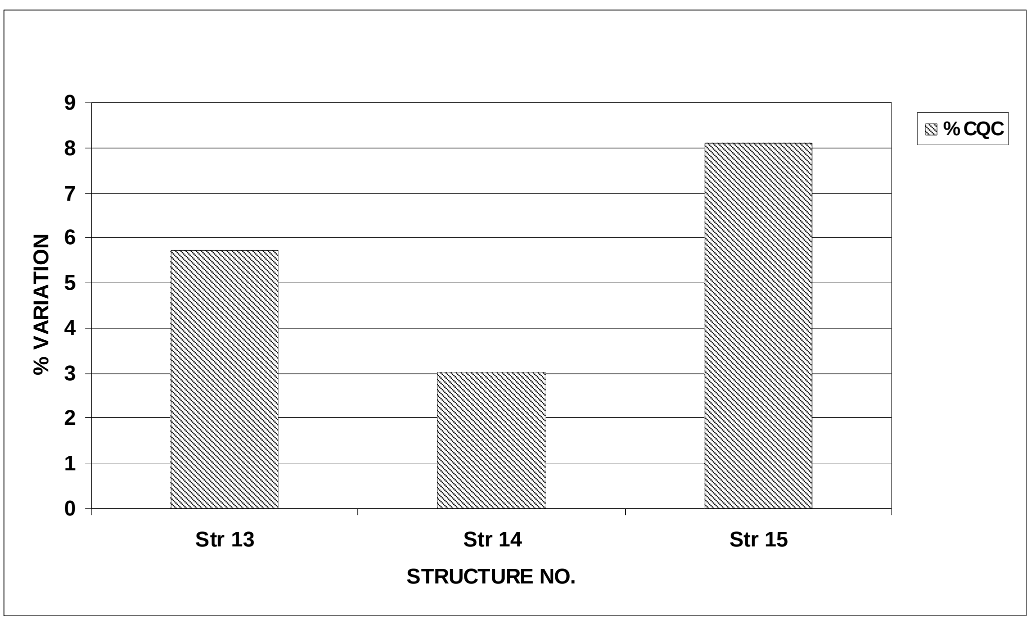


Fig.35 Percent variation in CQC base shears in different structures due to change in P.I.

Base Shear variation in X-dir. for Eight Storey building

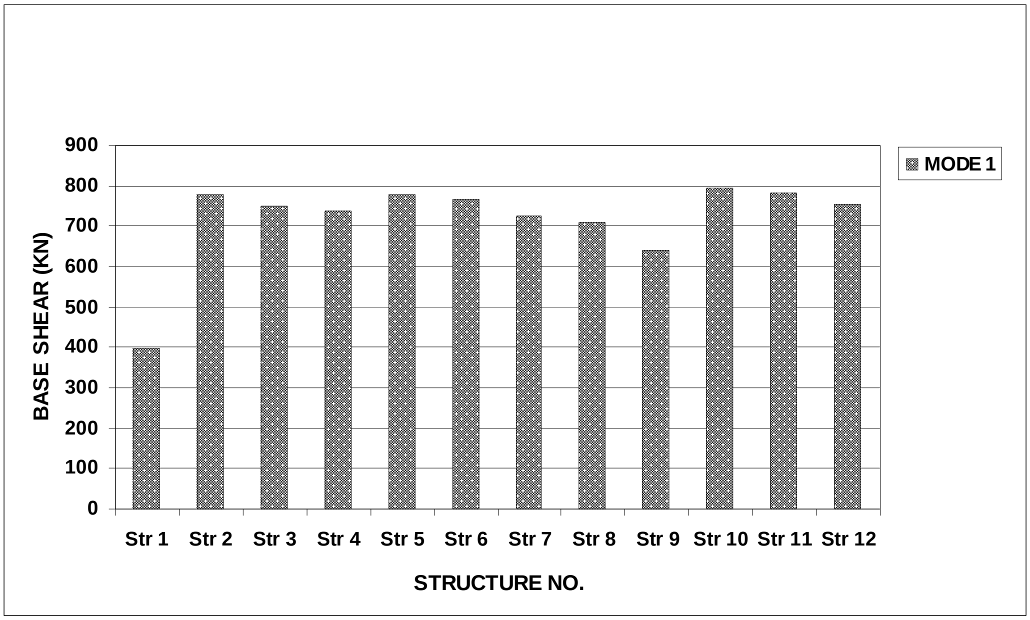


Fig. 36 Base shears in mode 1 in different structures due to change in V.I

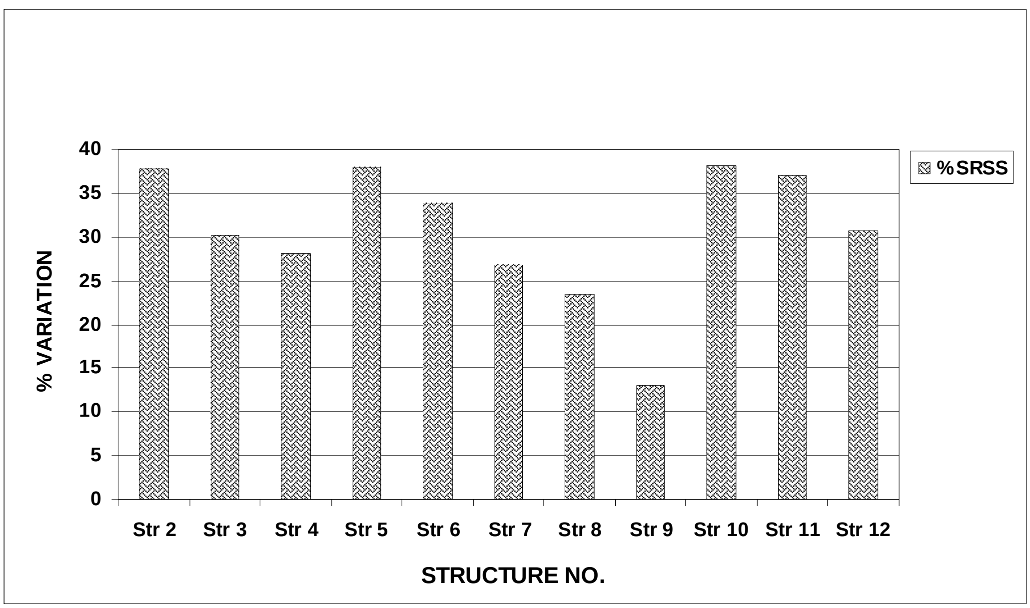


Fig.37 Percent variation in SRSS base shears in different structures due to change in V.I.

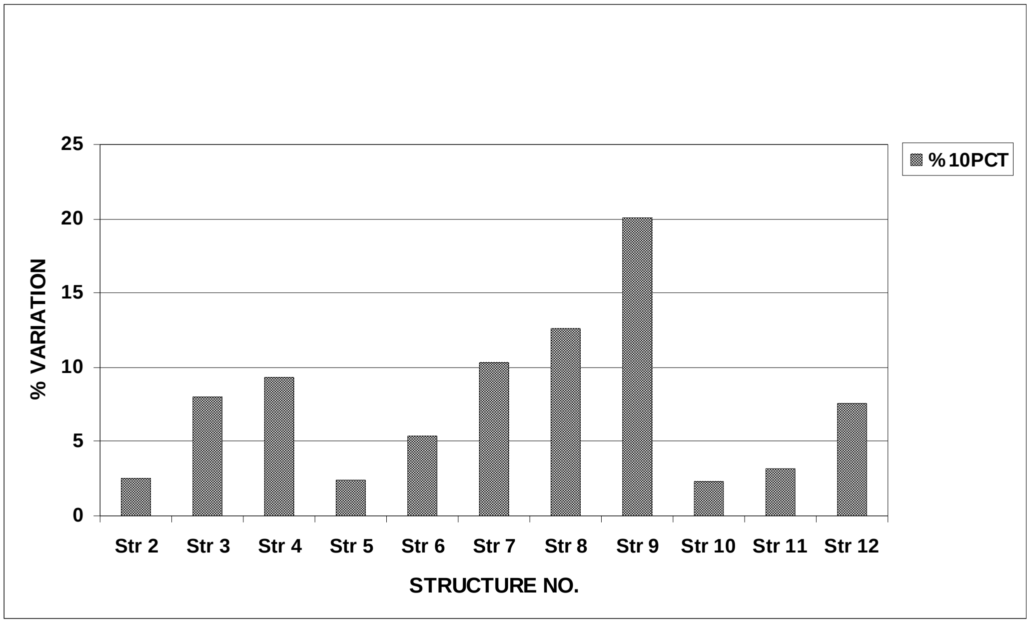


Fig.38 Percent variation in 10PCT base shears in different structures due to change in V.I.

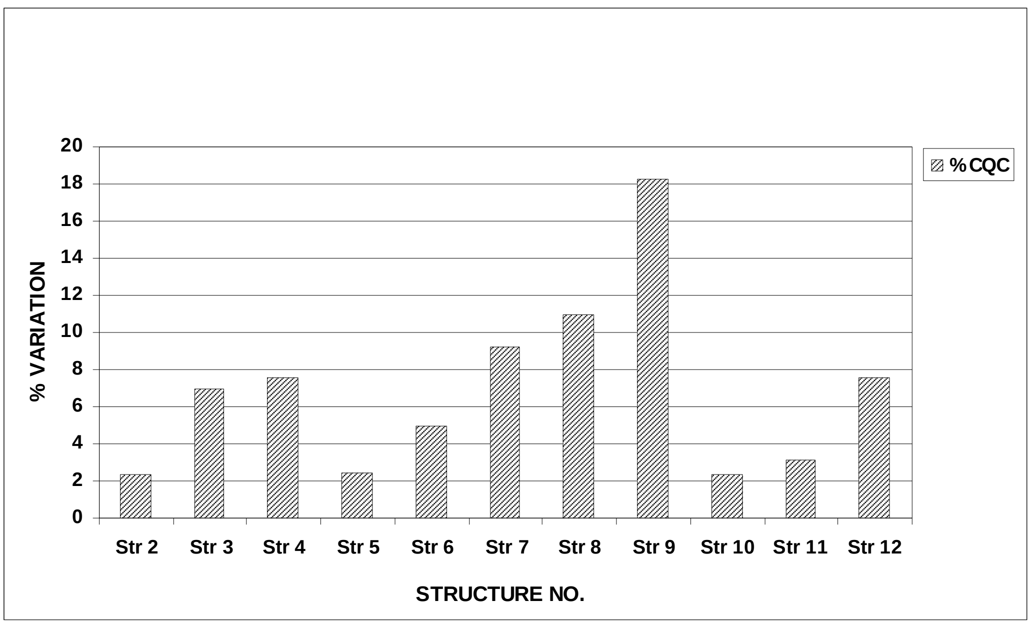


Fig.39 Percent variation in CQC base shears in different structures due to change in V.I.

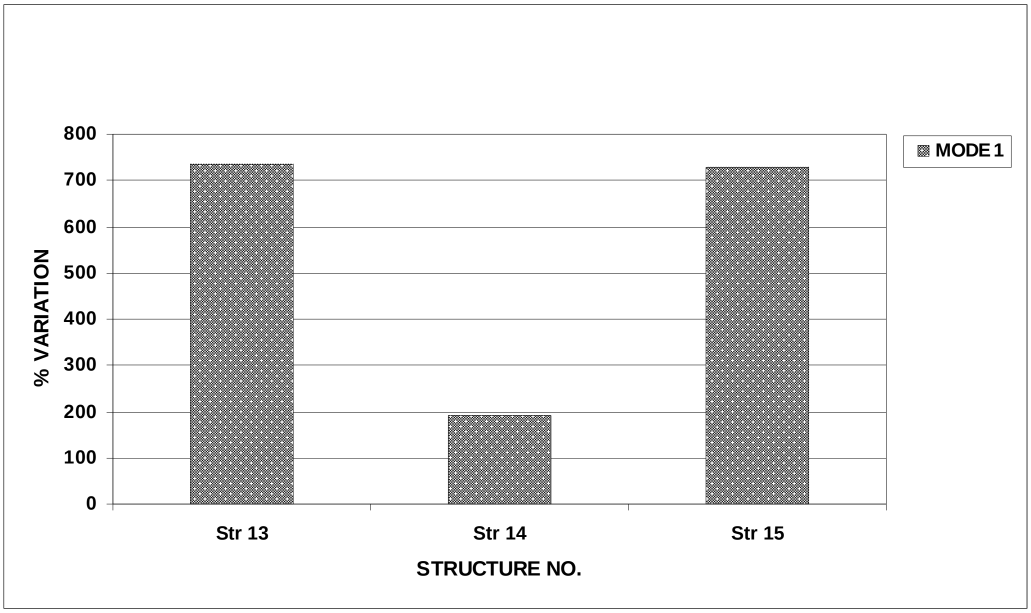


Fig.40 Base shears in mode 1 in different structures due to change in P.I

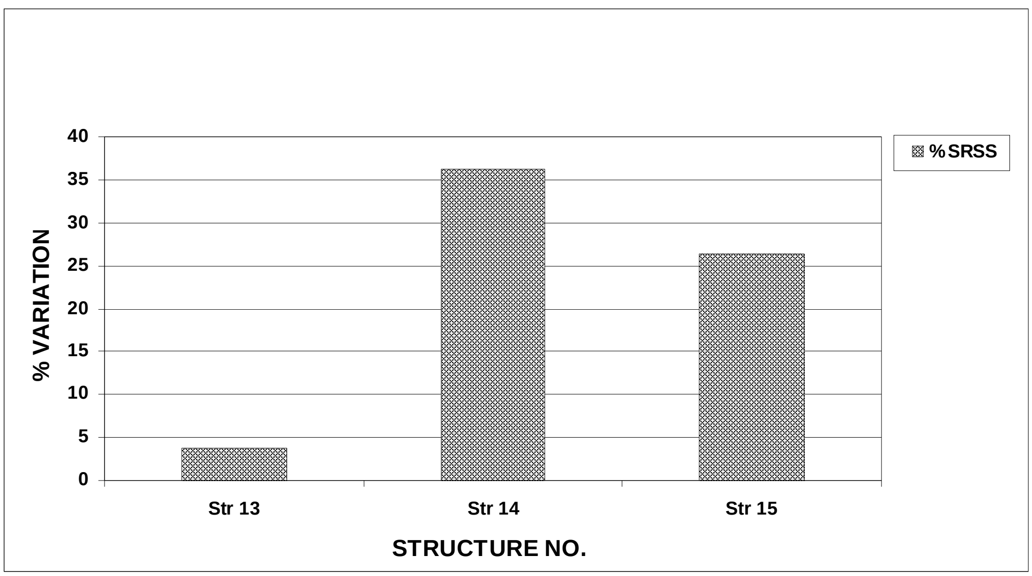


Fig.41 Percent variation in SRSS base shears in different structures due to change in P.I.

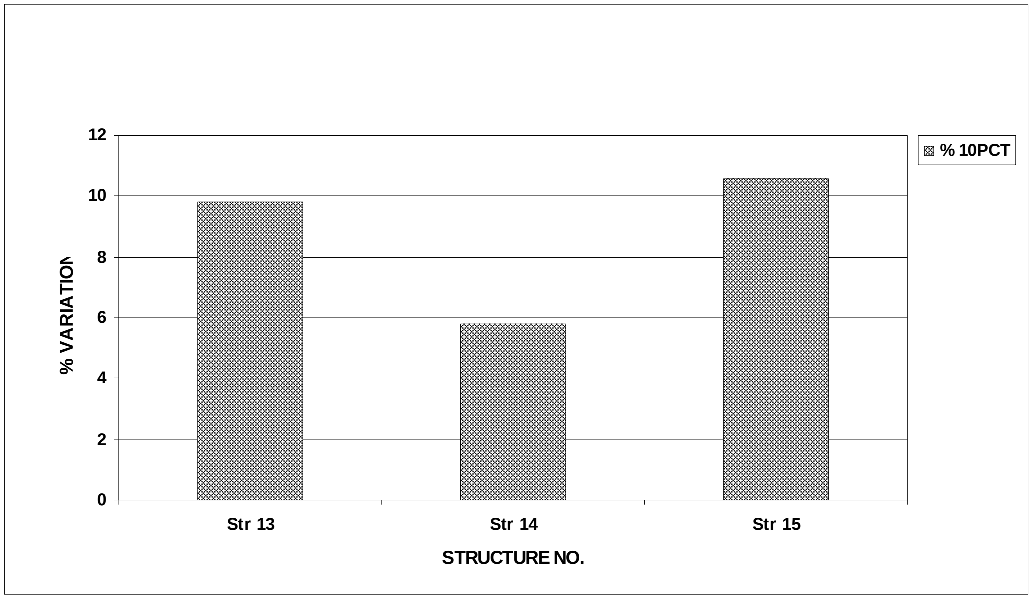


Fig.42 Percent variation in 10PCT base shears in different structures due to change in P.I.

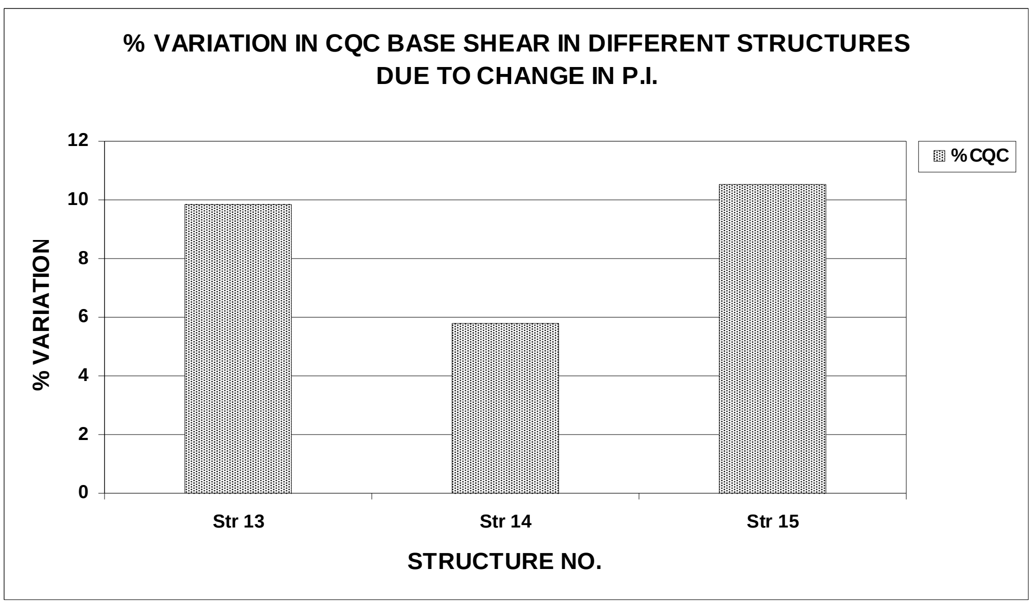


Fig.43 Percent variation in CQC base shears in different structures due to change in P.I.

Base Shear variation in X-dir. for Sixteen Storey building

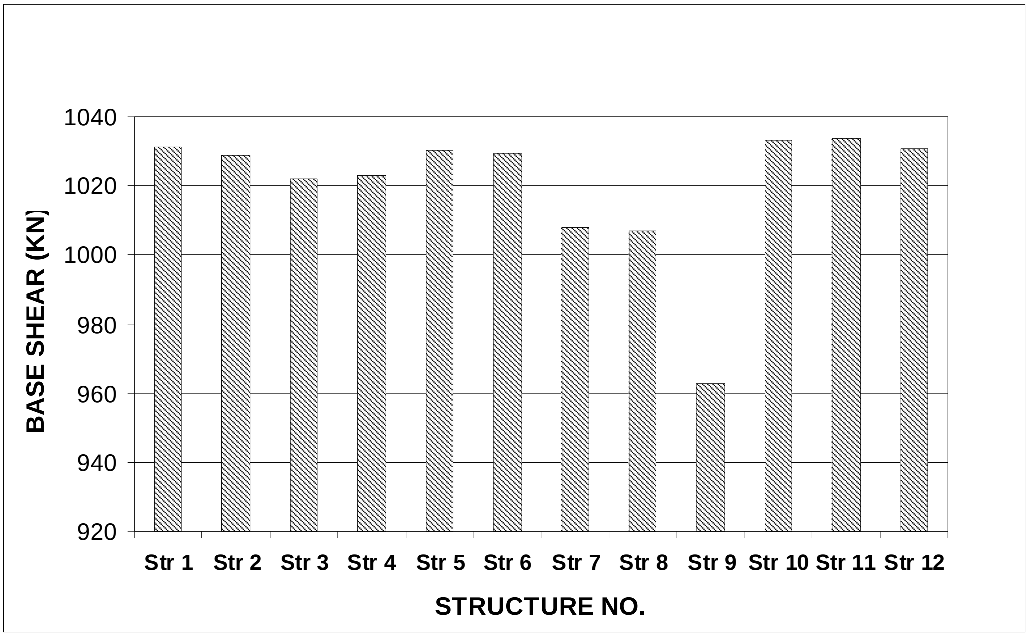


Fig. 44 Base shears in mode 1 in different structures due to change in V.I

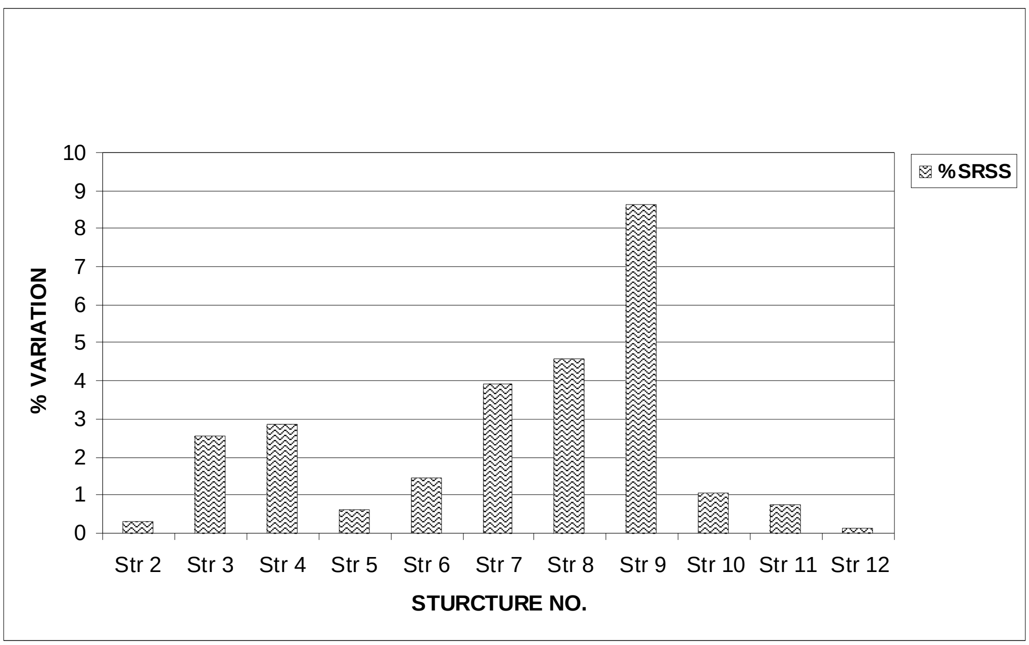


Fig.45 Percent variation in SRSS base shears in different structures due to change in V.I.

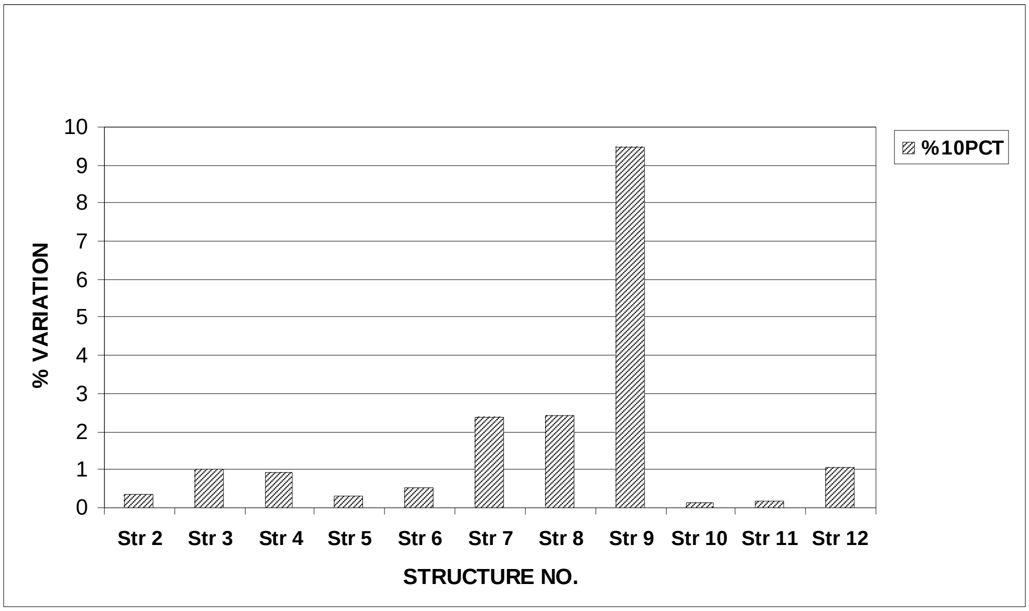


Fig.46 Percent variation in 10PCT base shears in different structures due to change in V.I.

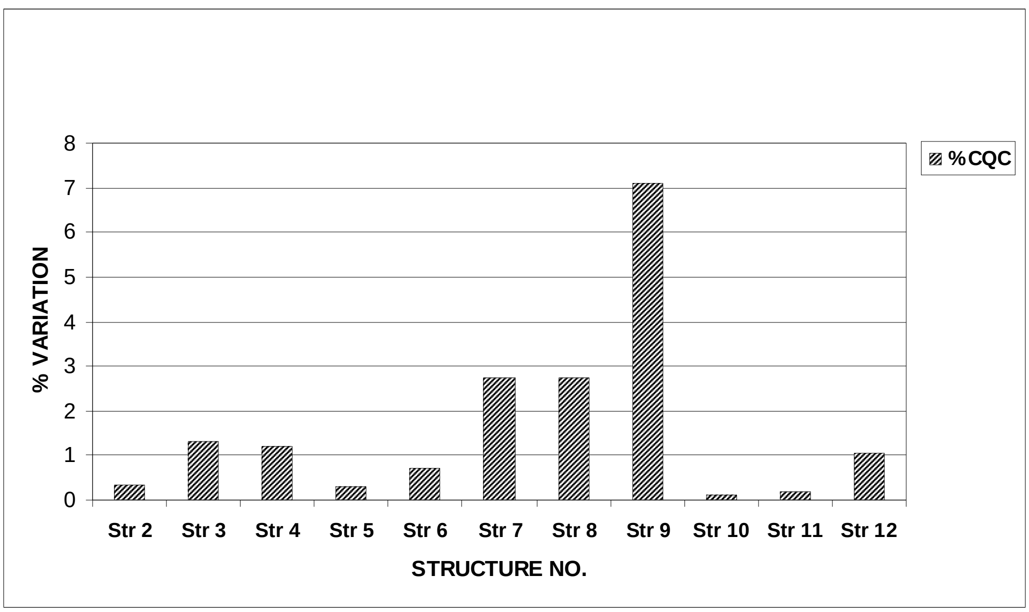


Fig.47 Percent variation in CQC base shears in different structures due to change in V.I.

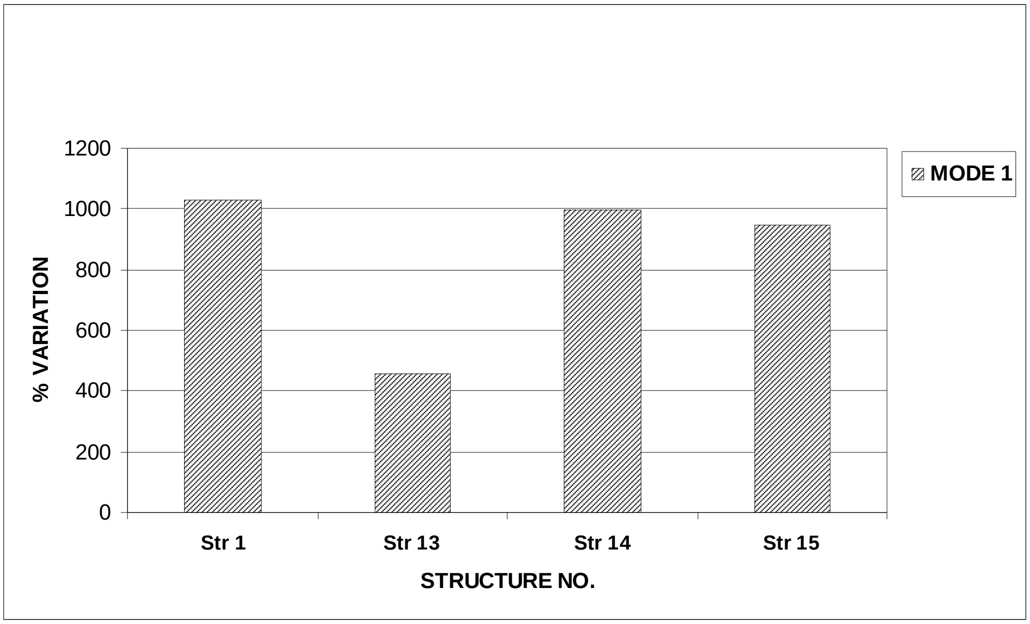


Fig.48 Base shears in mode 1 in different structures due to change in P.I

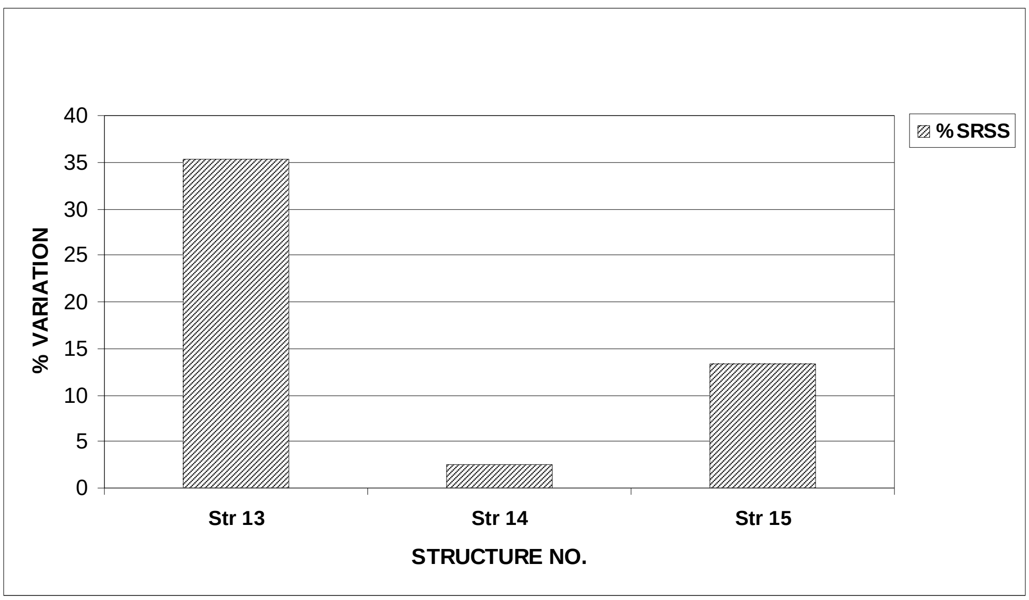


Fig.49 Percent variation in SRSS base shears in different structures due to change in P.I.

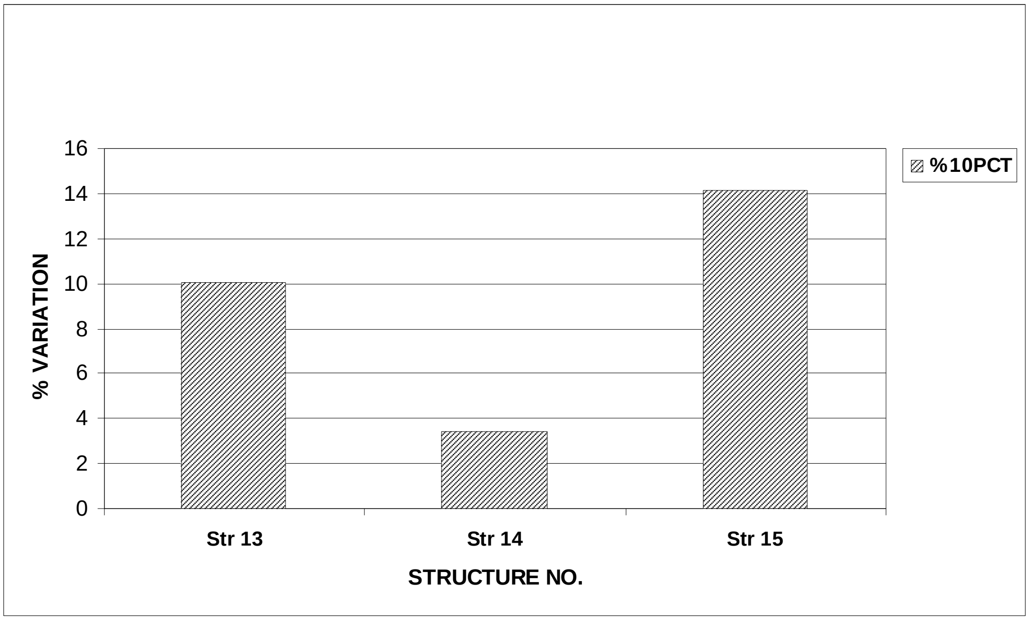


Fig.50 Percent variation in 10PCT base shears in different structures due to change in P.I.

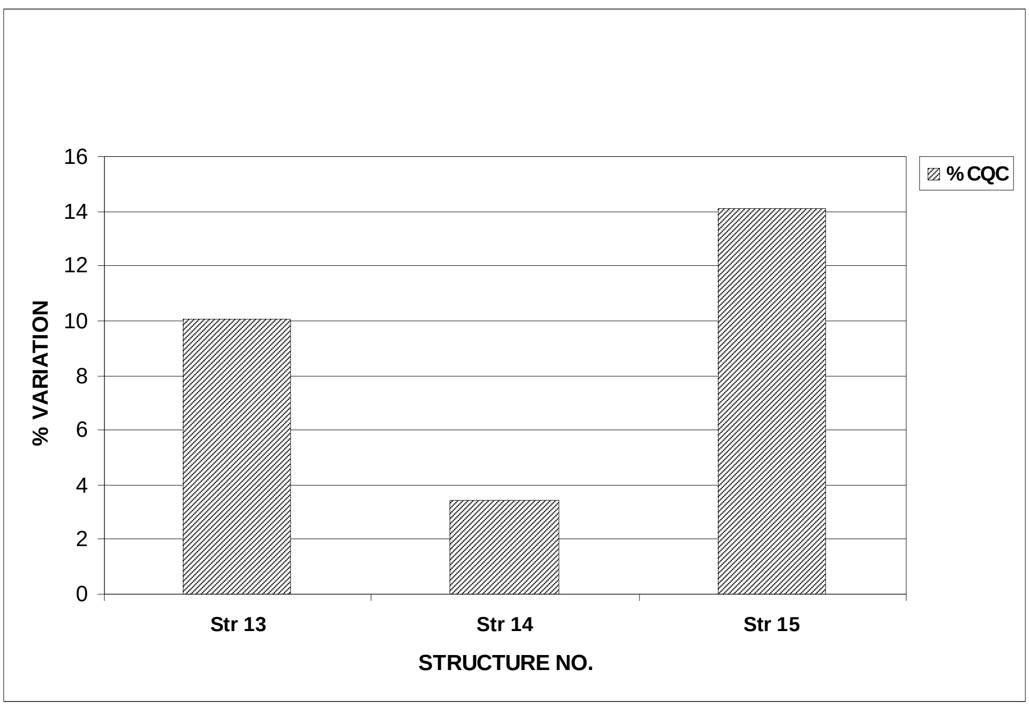


Fig.51 Percent variation in CQC base shears in different structures due to change in P.I.

Drift variation in X-dir. for Six Storey building

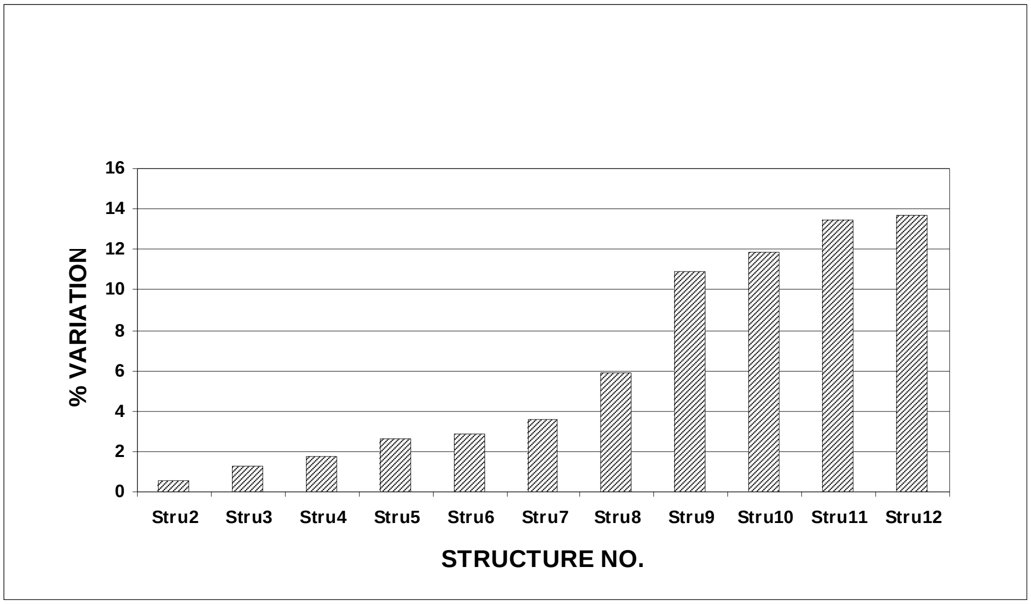


Fig.52 Percent variation in drift in different structures due to change in V.I.

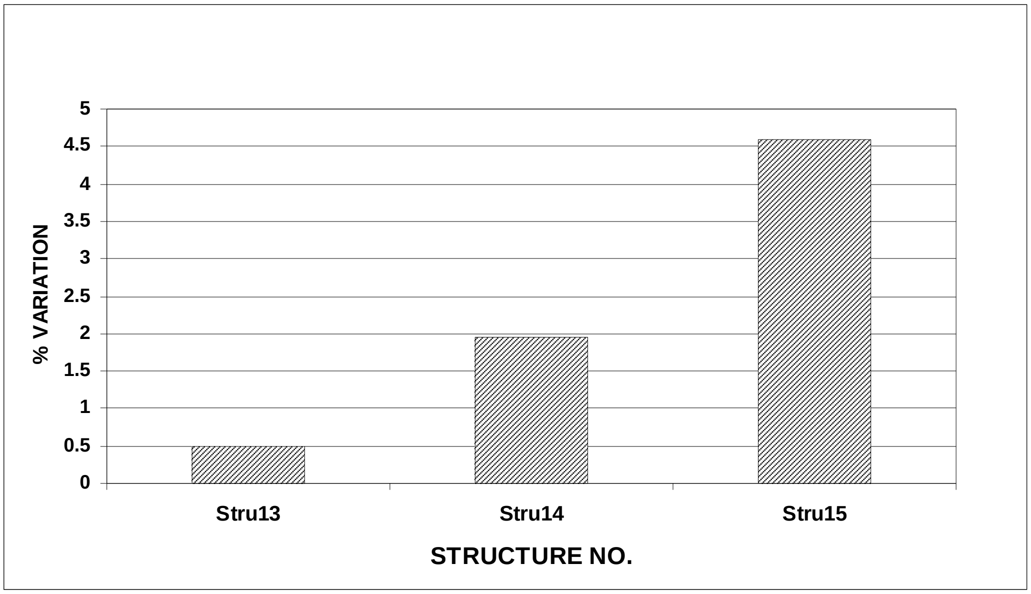


Fig.53 Percent variation in drift in different structures due to change in P.I.

Drift variation in X-dir. for Eight Storey building

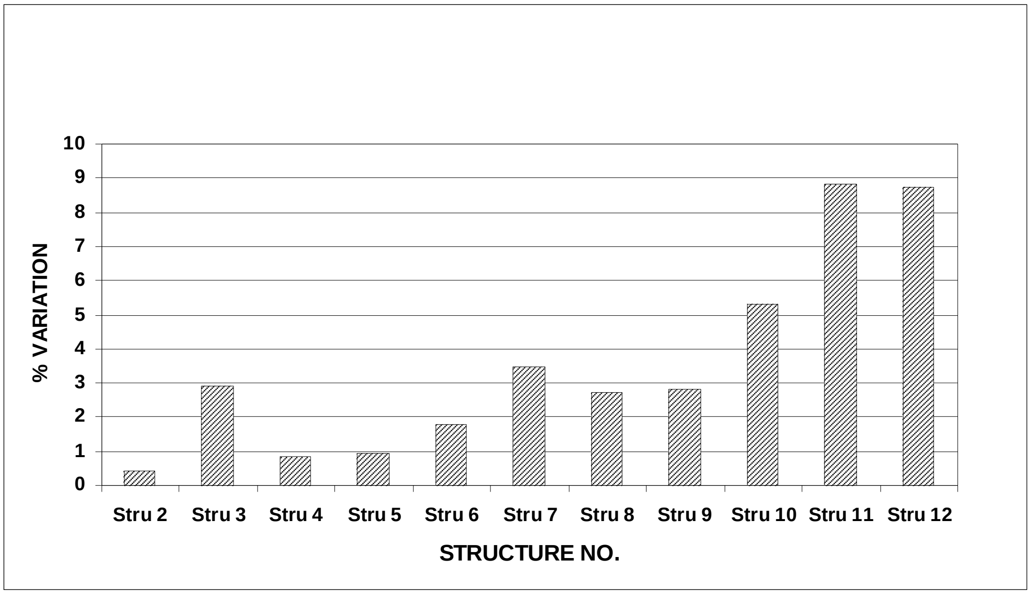


Fig.54 Percent variation in drift in different structures due to change in V.I.

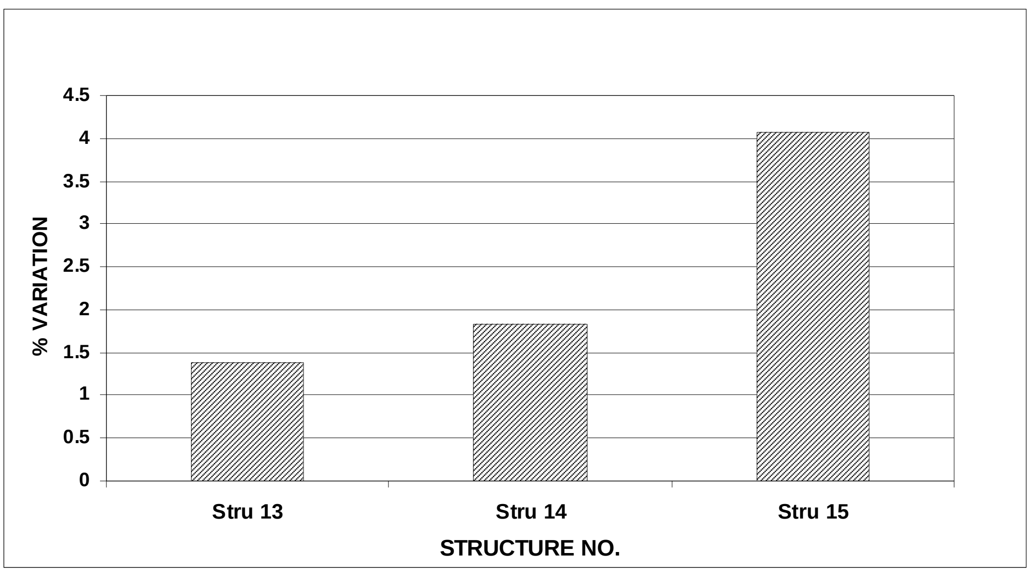


Fig.55 Percent variation in drift in different structures due to change in P.I.

Drift variation in X-dir. for Sixteen Storey building

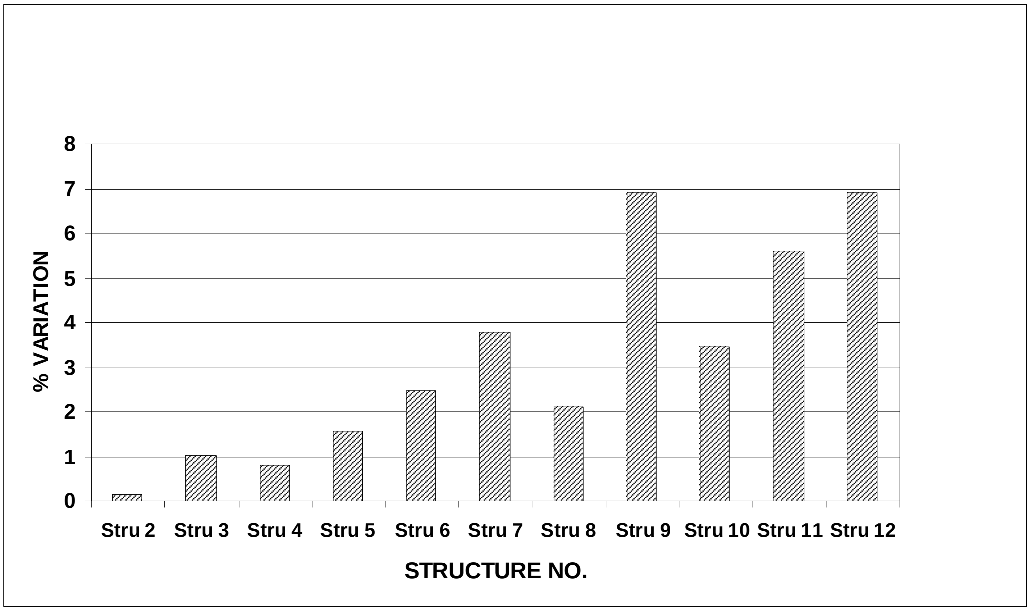


Fig.56 Percent variation in drift in different structures due to change in V.I.

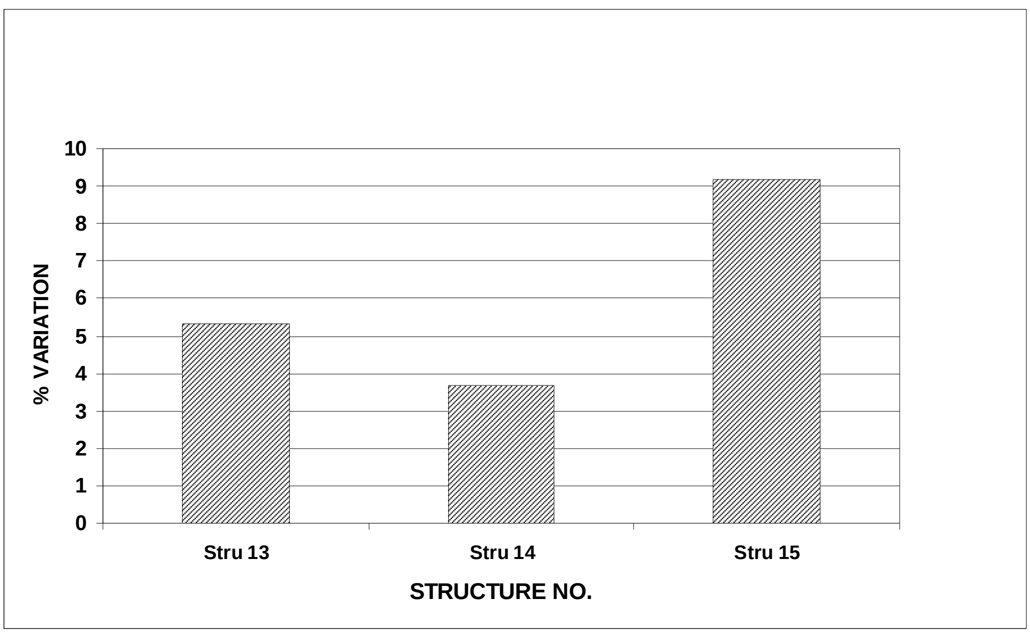


Fig.57 Percent variation in drift in different structures due to change in P.I.

Variation of Member forces in Column for Six Storey Building

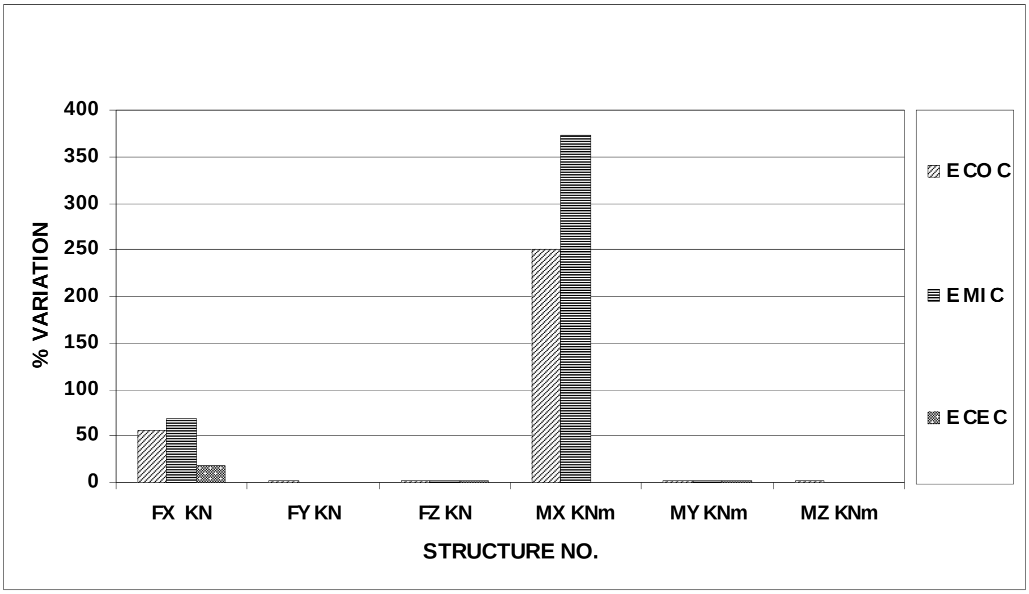


Fig.58 Maximum percent increase in member forces in G.F. column due to change in V.I.

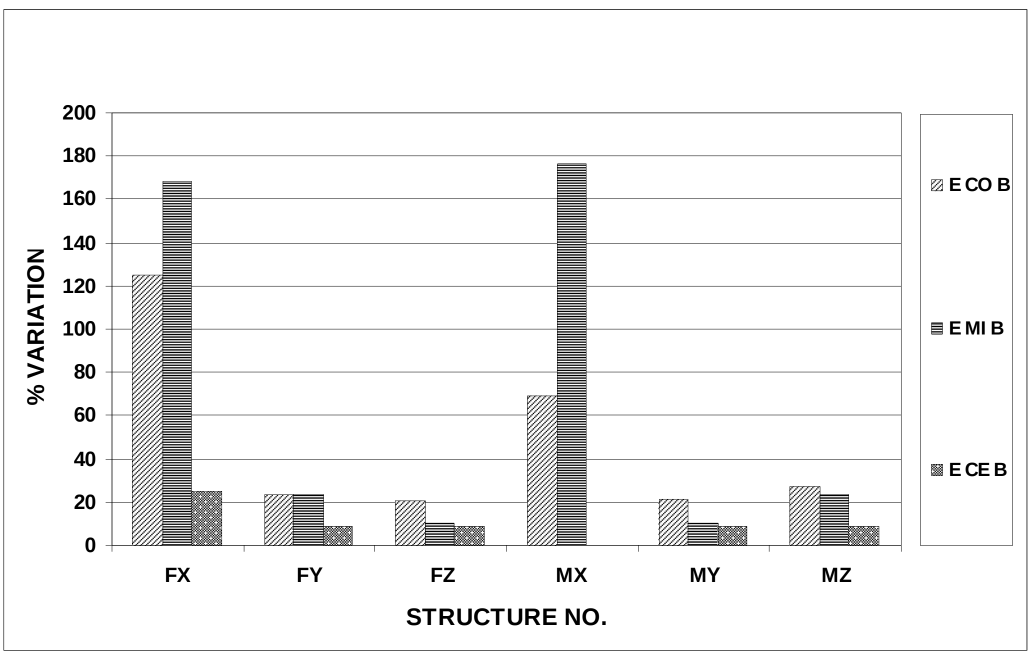


Fig.59 Maximum percent increase in member forces in G.F. column due to change in P.I.

Variation of Member forces in Column for Eight Storey Building

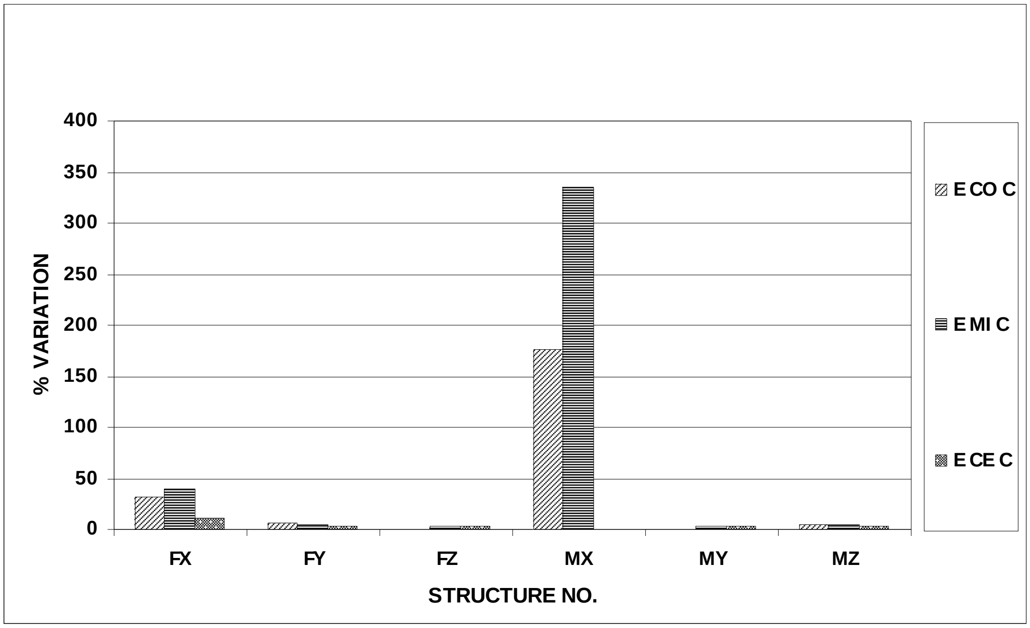


Fig.60 Maximum percent increase in member forces in G.F. column due to change in V.I.

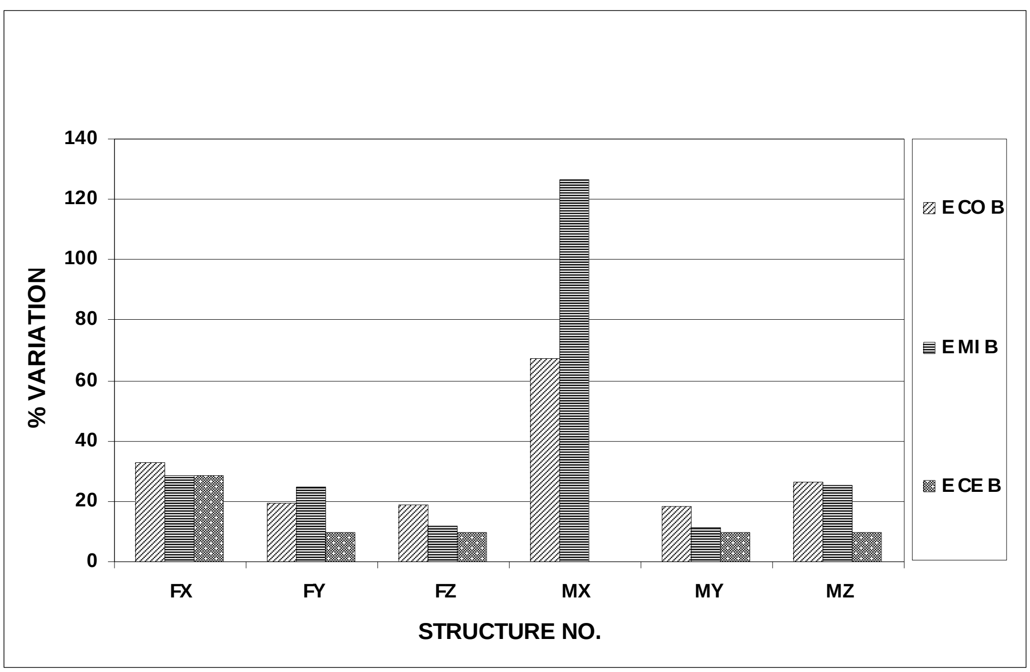


Fig.61 Maximum percent increase in member forces in G.F. column due to change in P.I.

Variation of Member forces in Column for Sixteen Storey Building

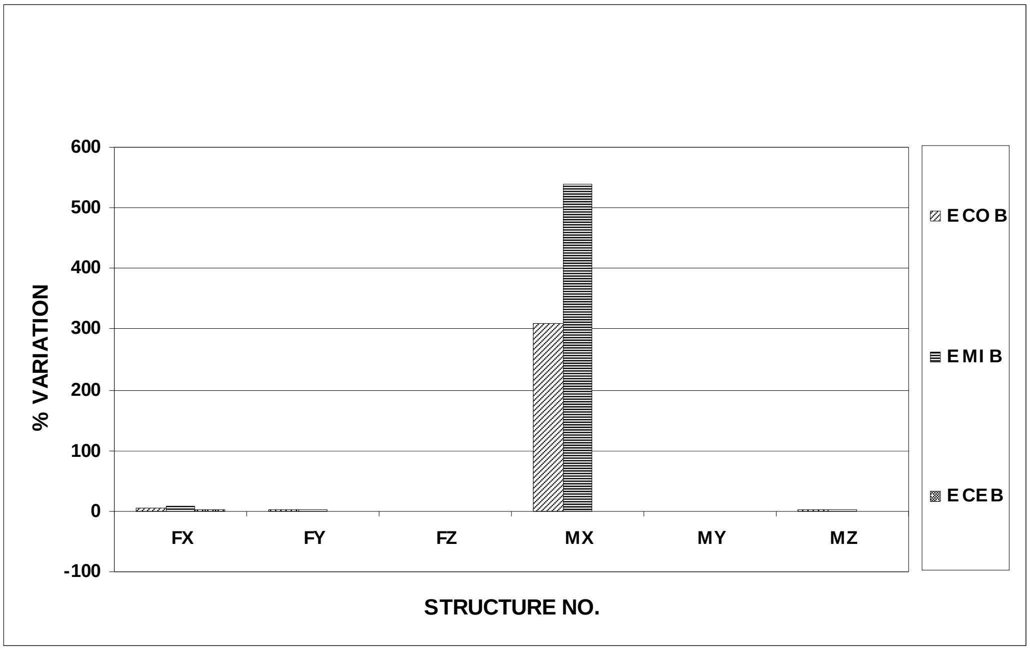


Fig.62 Maximum percent increase in member forces in G.F. column due to change in V.I.

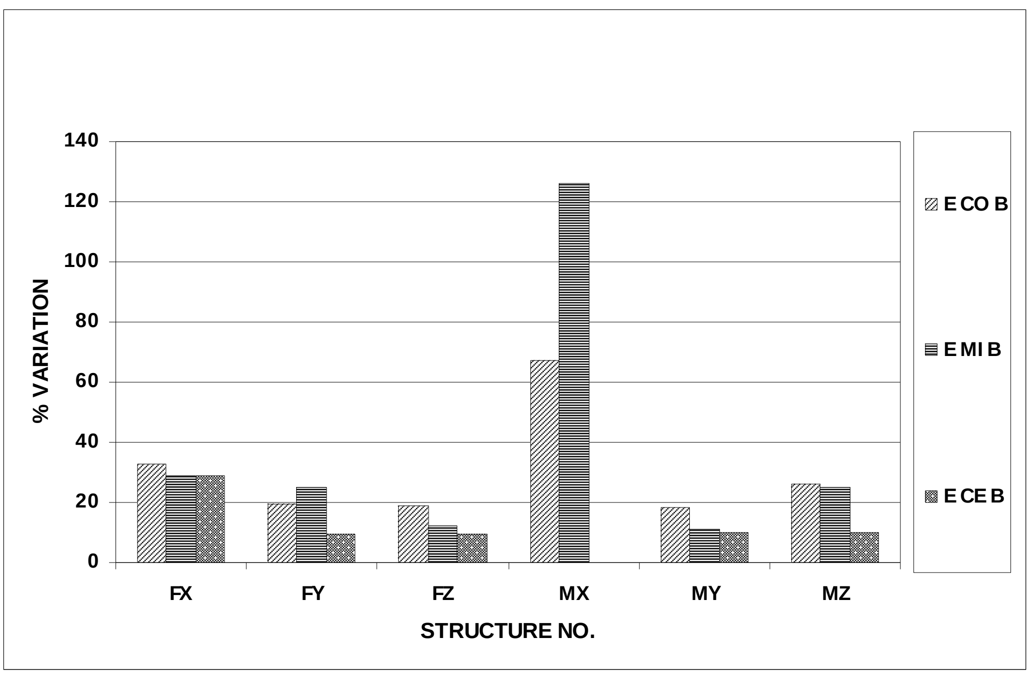


Fig.63 Maximum percent increase in member forces in G.F. column due to change in P.I.

Variation of Member forces in Beams for Six Storey Building

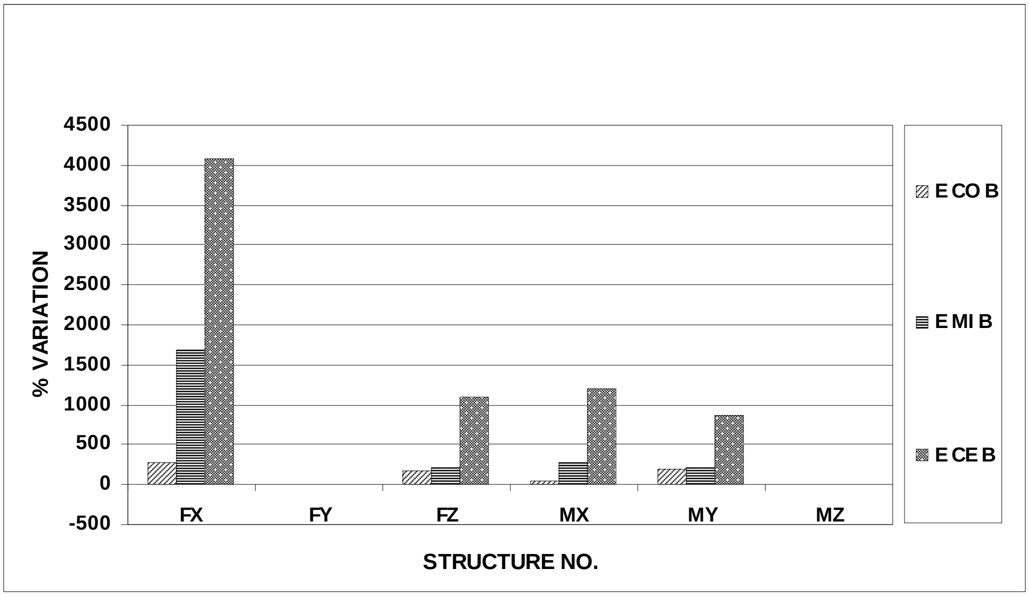


Fig.64 Maximum percent increase in member forces in G.F. beams due to change in V.I.

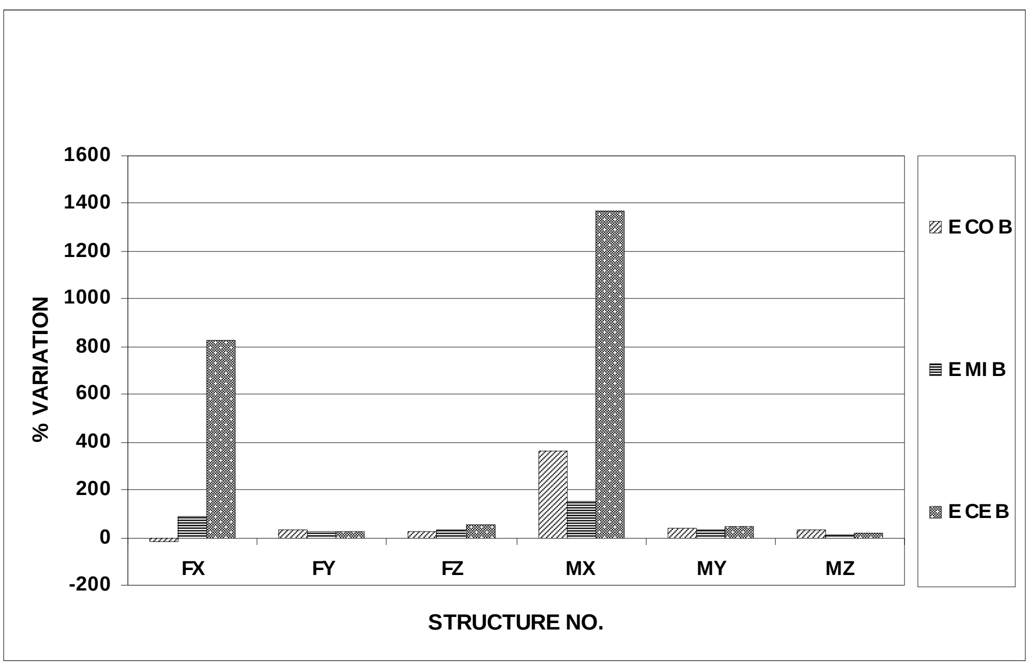


Fig.65 Maximum percent increase in member forces in G.F. beams due to change in P.I.

Variation of Member forces in Beams for Eight Storey Building

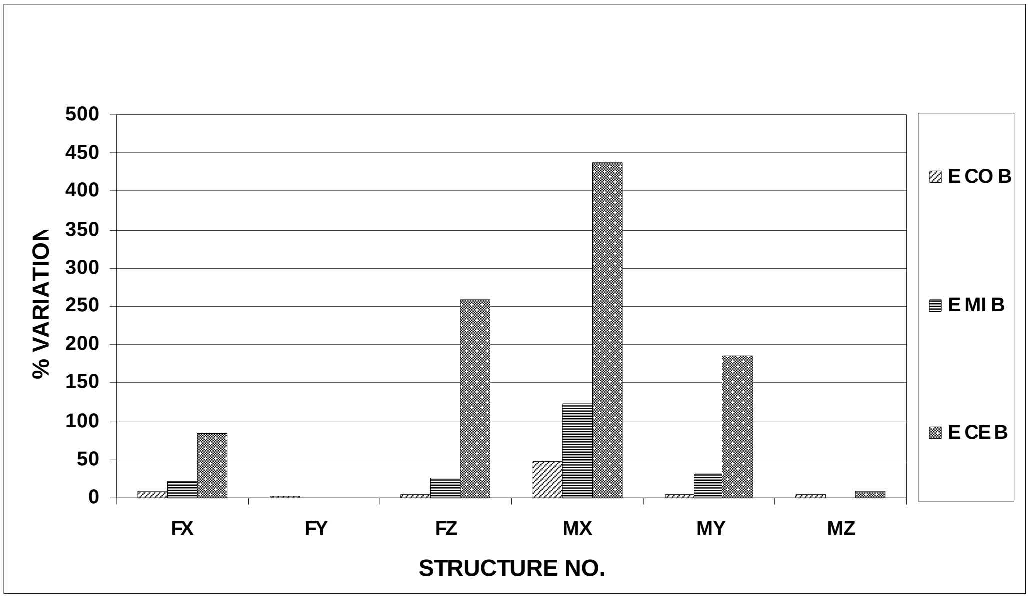


Fig.66 Maximum percent increase in member forces in G.F. beams due to change in V.I.

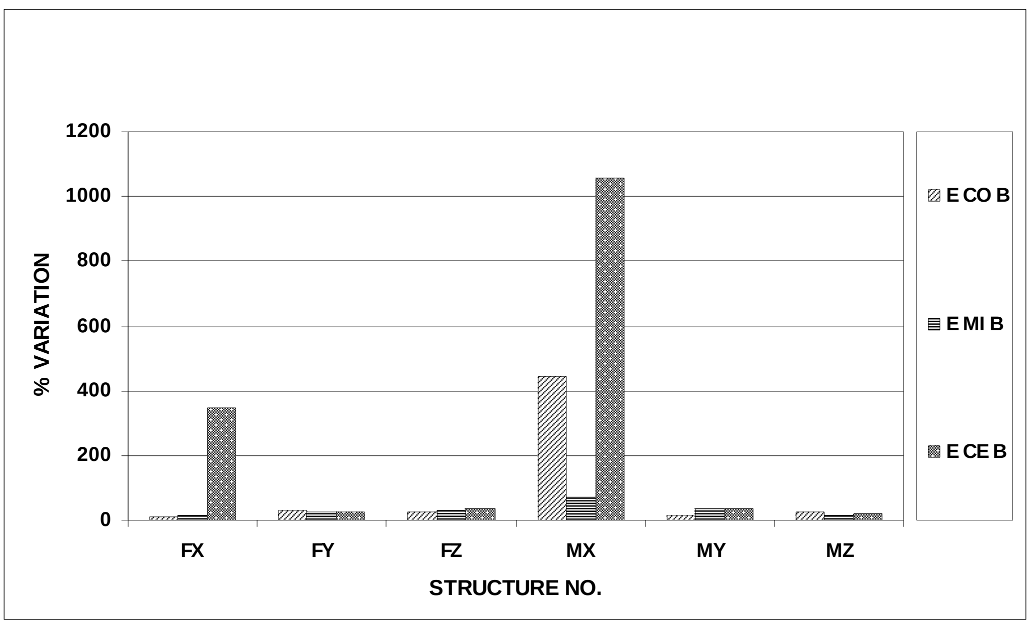


Fig.67 Maximum percent increase in member forces in G.F. beams due to change in P.I.

Variation of Member forces in Beams for Sixteen Storey Building

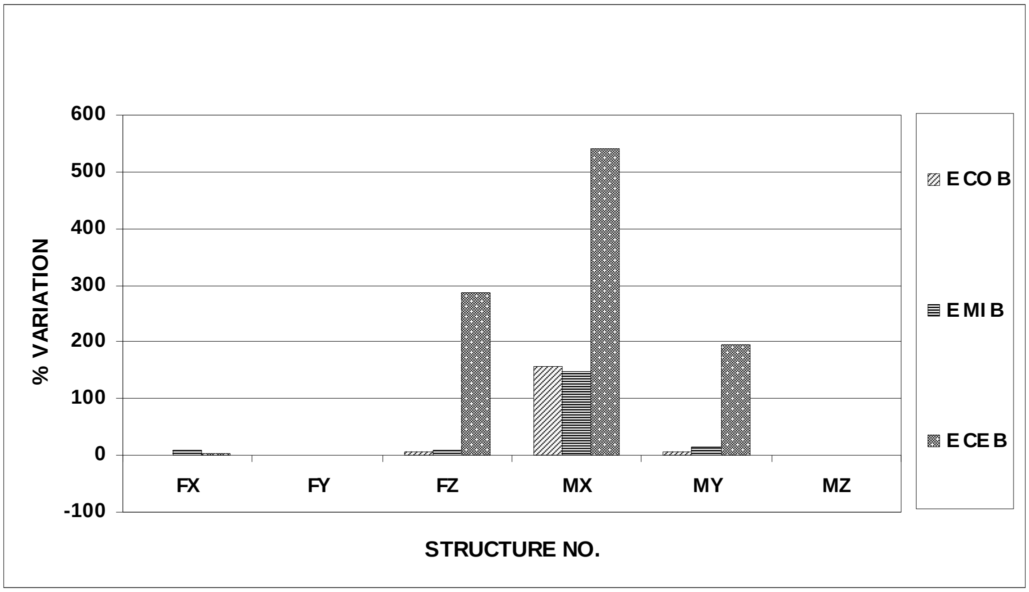


Fig.68 Maximum percent increase in member forces in G.F. beams due to change in V.I.

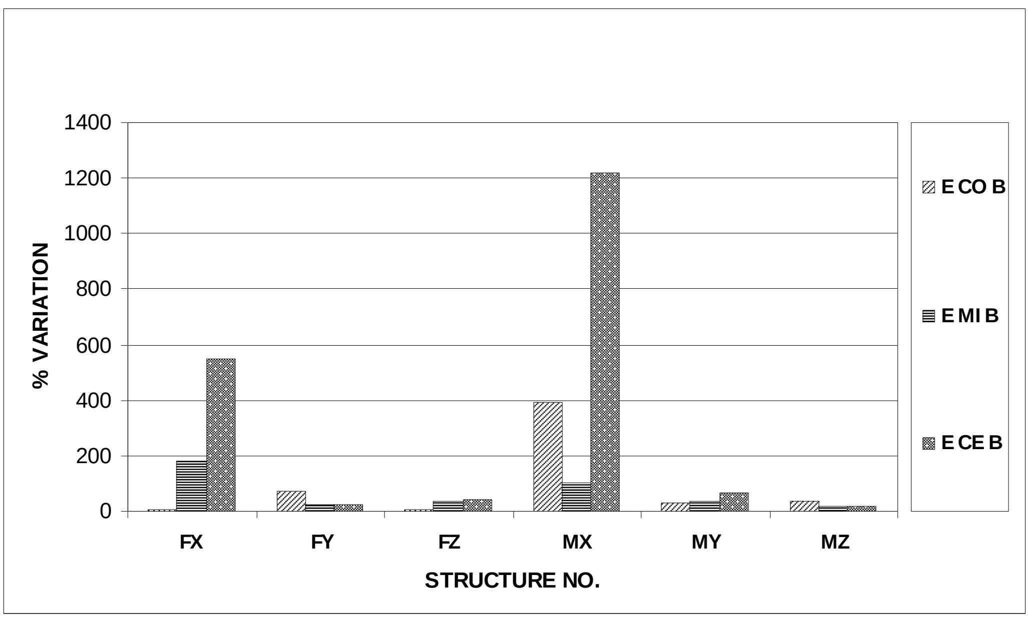


Fig.69 Maximum percent increase in member forces in G.F. beams due to change in P.I.

Table 1.

Modal Time periods (in Sec) in Six Storey Building.

Due to change in V.I.

	Str 1	Str 2	Str 3	Str 4	Str 5	Str 6	Str 7	Str 8	Str 9	Str 10	Str 11	Str 12	MAXIMUM
MODE 1	1.06	1.05	1.01	0.97	1.04	0.99	1.00	0.96	0.91	1.02	0.99	0.99	1.06
MODE 2	1.06	1.04	0.99	0.95	1.02	0.97	0.97	0.92	0.86	1.01	0.97	0.96	1.06
MODE 3	0.92	0.88	0.84	0.81	0.85	0.81	0.81	0.78	0.72	0.90	0.90	0.94	0.94
MODE 4	0.62	0.61	0.60	0.62	0.59	0.59	0.58	0.60	0.54	0.69	0.78	0.83	0.83
MODE 5	0.44	0.45	0.46	0.44	0.45	0.45	0.44	0.44	0.43	0.45	0.52	0.74	0.74
MODE 6	0.44	0.44	0.44	0.43	0.43	0.45	0.44	0.41	0.41	0.44	0.47	0.64	0.64
MODE 7	0.37	0.37	0.36	0.37	0.38	0.36	0.35	0.36	0.35	0.38	0.45	0.45	0.45
MODE 8	0.37	0.36	0.35	0.34	0.36	0.34	0.35	0.34	0.34	0.36	0.42	0.40	0.42

Due to change in P.I.

	Str 13	Str 14	Str 15	MAXIMUM
MODE 1	1.1	1.1	1.1	1.1
MODE 2	1.1	1.1	1.0	1.1
MODE 3	1.0	0.9	0.9	1.0
MODE 4	0.6	0.6	0.8	0.8
MODE 5	0.5	0.5	0.7	0.7
MODE 6	0.5	0.5	0.5	0.5
MODE 7	0.4	0.4	0.4	0.4
MODE 8	0.4	0.4	0.4	0.4

Table 2.

Modal Time periods (in Sec) in Eight Storey Building.

Due to change in V.I.

	Str 1	Str 2	Str 3	Str 4	Str 5	Str 6	Str 7	Str 8	Str 9	Str 10	Str 11	Str 12	MAXIMUM
MODE 1	1.4	1.4	1.4	1.3	1.4	1.3	1.3	1.3	1.3	1.4	1.3	1.3	1.4
MODE 2	1.4	1.4	1.3	1.3	1.4	1.3	1.3	1.3	1.2	1.4	1.3	1.3	1.4
MODE 3	1.2	1.2	1.1	1.1	1.1	1.1	1.1	1.1	1.0	1.2	1.2	1.2	1.2
MODE 4	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.9	1.0	1.0
MODE 5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.7	0.8
MODE 6	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.6	0.6
MODE 7	0.5	0.5	0.5	0.4	0.5	0.5	0.5	0.4	0.4	0.5	0.5	0.5	0.5
MODE 8	0.5	0.5	0.5	0.4	0.5	0.4	0.4	0.4	0.4	0.4	0.5	0.5	0.5
MODE 9	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.5	0.5	0.5

Due to change in P.I.

	Str 13	Str 14	Str 15	MAXIMUM
MODE 1	1.4	1.4	1.4	1.4
MODE 2	1.4	1.4	1.4	1.4
MODE 3	1.3	1.2	1.2	1.3
MODE 4	0.7	0.7	0.9	0.9
MODE 5	0.5	0.6	0.8	0.8
MODE 6	0.5	0.5	0.5	0.5
MODE 7	0.5	0.5	0.5	0.5
MODE 8	0.5	0.5	0.5	0.5
MODE 9	0.5	0.4	0.5	0.5

Table 3.

Modal Time periods (in Sec) in Sixteen Storey Building.

Due to change in V.I.

	Str 1	Str 2	Str 3	Str 4	Str 5	Str 6	Str 7	Str 8	Str 9	Str 10	Str 11	Str 12	MAXIMUM
MODE 1	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.3	2.3	2.4	2.4	2.3	2.4
MODE 2	2.4	2.4	2.4	2.3	2.4	2.4	2.4	2.3	2.3	2.4	2.4	2.3	2.4
MODE 3	2.1	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.9	2.0	2.0	2.0	2.1
MODE 4	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.9	1.0	1.0
MODE 5	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
MODE 6	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.7	0.8	0.8	0.8	0.8
MODE 7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.6	0.7	0.7	0.7	0.7

Due to change in P.I.

	Str 13	Str 14	Str 15	MAXIMUM
MODE 1	2.5	2.5	2.6	2.6
MODE 2	2.5	2.4	2.4	2.5
MODE 3	2.2	2.1	2.1	2.2
MODE 4	0.8	0.8	1.2	1.2
MODE 5	0.8	0.8	1.0	1.0
MODE 6	0.7	0.8	0.9	0.9
MODE 7	0.7	0.7	0.8	0.8

Table 4.

Storey Drift (in CM) in Six Storey Building.

Due to change in V.I.

STORY	Str 1	Str 2	Str 3	Str 4	Str 5	Str 6	Str 7	Str 8	Str 9	Str 10	Str 11	Str 12
STORY 1	**Negligible**											
STORY 2	0.6	0.6	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
STORY 3	1.7	1.6	1.6	1.5	1.6	1.5	1.5	1.5	1.3	1.6	1.5	1.4
STORY 4	1.5	1.4	1.4	1.3	1.4	1.3	1.3	1.2	1.4	1.4	1.3	1.4
STORY 5	1.1	1.0	0.9	0.8	1.0	0.9	1.3	1.2	1.1	1.0	1.0	0.9
STORY 6	0.5	0.8	1.2	1.4	1.0	1.3	0.7	1.0	0.6	0.4	0.4	0.5

Due to change in P.I.

STORY	Str 13	Str 14	Str 15
STORY 1	**Negligible**		
STORY 2	0.6	0.6	0.5
STORY 3	1.7	1.6	1.6
STORY 4	1.5	1.5	1.4
STORY 5	1.1	1.1	1.0
STORY 6	0.5	0.5	0.5

Table 5.

Storey Drift (in CM) in Eight Storey Building.

Due to change in V.I.

STORY	Str 1	Str 2	Str 3	Str 4	Str 5	Str 6	Str 7	Str 8	Str 9	Str 10	Str 11	Str 12
STORY 1	**Negligible**											
STORY 2	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
STORY 3	1.6	1.6	1.5	1.5	1.5	1.5	1.5	1.5	1.4	1.6	1.5	1.4
STORY 4	1.5	1.5	1.5	1.4	1.5	1.4	1.4	1.4	1.3	1.5	1.4	1.4
STORY 5	1.3	1.3	1.3	1.2	1.3	1.2	1.2	1.2	1.1	1.3	1.2	1.2
STORY 6	1.0	1.0	1.0	0.9	1.0	0.9	1.0	0.9	1.3	1.0	0.9	1.1
STORY 7	0.7	0.7	0.7	0.6	0.7	0.6	1.1	1.0	1.1	0.7	0.7	0.7
STORY 8	0.4	0.7	1.1	1.3	0.8	1.0	0.7	1.0	0.7	0.3	0.3	0.3

Due to change in P.I.

STORY	Str 13	Str 14	Str 15
STORY 1	**Negligible**		
STORY 2	0.5	0.5	0.5
STORY 3	1.6	1.6	1.5
STORY 4	1.6	1.5	1.5
STORY 5	1.4	1.4	1.3
STORY 6	1.1	1.1	1.0
STORY 7	0.8	0.8	0.7
STORY 8	0.4	0.4	0.4

Table 6.

Storey Drift (in CM) in Sixteen Storey Building.

Due to change in V.I.

STORY	Str 1	Str 2	Str 3	Str 4	Str 5	Str 6	Str 7	Str 8	Str 9	Str 10	Str 11	Str 12
STORY 1	**Negligible**											
STORY 2	0.4	0.4	0.4	0.3	0.4	0.4	0.4	0.3	0.3	0.4	0.3	0.3
STORY 3	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
STORY 4	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.1	1.2	1.2	1.1
STORY 5	1.2	1.2	1.2	1.1	1.2	1.1	1.1	1.1	1.1	1.2	1.1	1.1
STORY 6	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
STORY 7	1.1	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
STORY 8	1.0	1.0	1.0	0.9	1.0	1.0	1.0	0.9	0.9	1.0	0.9	0.9
STORY 9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
STORY 10	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
STORY 11	0.8	0.8	0.7	0.7	0.8	0.7	0.7	0.7	0.7	0.8	0.7	0.7
STORY 12	0.7	0.7	0.7	0.6	0.7	0.6	0.6	0.6	0.6	0.7	0.6	0.6
STORY 13	0.6	0.6	0.6	0.5	0.6	0.5	0.6	0.5	0.5	0.6	0.5	0.5
STORY 14	0.5	0.5	0.5	0.4	0.5	0.4	0.4	0.4	1.0	0.5	0.4	0.5
STORY 15	0.4	0.4	0.3	0.3	0.3	0.3	0.8	0.7	0.9	0.3	0.3	0.3
STORY 16	0.3	0.4	0.8	0.9	0.5	0.6	0.6	0.9	0.7	0.2	0.2	0.2

Table 7.

Storey Drift (in CM) in Sixteen Storey Building.

Due to change in P.I.

STORY	Str 13	Str 14	Str 15
STORY 1		**Negligible**	
STORY 2	0.4	0.4	0.3
STORY 3	1.2	1.1	1.1
STORY 4	1.3	1.2	1.2
STORY 5	1.2	1.2	1.2
STORY 6	1.2	1.1	1.2
STORY 7	1.1	1.1	1.2
STORY 8	1.1	1.0	1.1
STORY 9	1.0	0.9	1.0
STORY 10	0.9	0.9	1.0
STORY 11	0.8	0.8	0.9
STORY 12	0.8	0.7	0.8
STORY 13	0.7	0.6	0.7
STORY 14	0.5	0.5	0.6
STORY 15	0.4	0.4	0.4
STORY 16	0.3	0.3	0.3

Table 8.

Drift (in MM) in Six Storey Building.

Due to change in V.I.

	Stru1	Stru2	Stru3	Stru4	Stru5	Stru6	Stru7	Stru8	Stru9	Stru10	Stru11	Stru12
Drift X mm	57.78	57.0	58.1	56.3	56.8	56.1	55.7	54.4	50.9	51.5	49.9	50.0

Due to change in P.I.

	Stru13	Stru14	Stru15
Drift X mm	55.1	58.9	57.5

Table 9.

Drift (in MM) in Eight Storey Building.

Due to change in V.I.

	Stru1	Stru2	Stru3	Stru4	Stru5	Stru6	Stru7	Stru8	Stru9	Stru10	Stru11	Stru12
Drift X mm	74.45	74.8	76.6	75.1	73.7	73.1	77.0	76.5	76.5	70.5	67.9	67.9

Due to change in P.I.

	Stru13	Stru14	Stru15
Drift X mm	75.5	77.5	75.8

Table 10.

Drift (in MM) in Sixteen Storey Building.

Due to change in V.I.

	Stru1	Stru2	Stru3	Stru4	Stru5	Stru6	Stru7	Stru8	Stru9	Stru10	Stru11	Stru12
Drift X mm	122.16	122.0	123.4	121.2	120.2	119.1	126.8	124.8	130.6	117.9	115.3	113.7

Due to change in P.I.

	Stru13	Stru14	Stru15
Drift X mm	128.7	126.7	133.4

Table 11.

Base Shear (in KN) in Six Storey Building.

Due to change in V.I.

Base shear (KN)	Str 1	Str 2	Str 3	Str 4	Str 5	Str 6	Str 7	Str 8	Str 9	Str 10	Str 11	Str 12
MODE 1	363.29	704.1	654.2	624.9	692.3	665.6	644.5	616.3	561.1	726.1	700.9	646.3

Percentage change	Str 2	Str 3	Str 4	Str 5	Str 6	Str 7	Str 8	Str 9	Str 10	Str 11	Str 12
% SRSS	37.9	28.4	23.4	36.1	30.7	26.6	21.4	11.1	42.1	37.2	26.5

Percentage change	Str 2	Str 3	Str 4	Str 5	Str 6	Str 7	Str 8	Str 9	Str 10	Str 11	Str 12
% 10PCT	2.5	9.2	12.7	3.8	7.6	10.4	14.2	21.4	0.5	3.0	10.5

Percentage change	Str 2	Str 3	Str 4	Str 5	Str 6	Str 7	Str 8	Str 9	Str 10	Str 11	Str 12
% CQC	2.3	7.9	9.9	3.7	7.0	9.6	12.3	20.1	0.5	3.0	10.5

Due to change in P.I.

Base shear (KN)	Str 13	Str 14	Str 15
MODE 1	173.8	700.5	662.6

Percentage change	Str 13	Str 14	Str 15
% SRSS	5.0	37.1	29.7

Percentage change	Str 13	Str 14	Str 15
% 10PCT	5.7	3.0	8.3

Percentage change	Str 13	Str 14	Str 15
% CQC	5.7	3.0	8.1

Table 12.

Base Shear (in KN) in Eight Storey Building.

Due to change in V.I.

Base shear (KN)	Str 1	Str 2	Str 3	Str 4	Str 5	Str 6	Str 7	Str 8	Str 9	Str 10	Str 11	Str 12
MODE 1	395.32	778.5	748.1	737.3	777.4	765.3	724.3	709.0	642.5	792.6	783.2	753.4

Percentage change	Str 2	Str 3	Str 4	Str 5	Str 6	Str 7	Str 8	Str 9	Str 10	Str 11	Str 12
% SRSS	37.8	30.1	28.2	10.7	22.9	26.8	23.5	37.9	38.2	23.1	30.6

Percentage change	Str 2	Str 3	Str 4	Str 5	Str 6	Str 7	Str 8	Str 9	Str 10	Str 11	Str 12
% 10PCT	2.6	8.0	9.3	2.4	5.3	10.3	12.6	20.0	2.4	3.1	7.6

Percentage change	Str 2	Str 3	Str 4	Str 5	Str 6	Str 7	Str 8	Str 9	Str 10	Str 11	Str 12
% CQC	2.4	6.9	7.6	2.4	5.0	9.2	10.9	18.3	2.4	3.1	7.6

Due to change in P.I.

Base shear (KN)	Str 13	Str 14	Str 15
MODE 1	735.3	190.0	729.1

Percentage change	Str 13	Str 14	Str 15
% SRSS	3.7	36.2	26.4

Percentage change	Str 13	Str 14	Str 15
% 10PCT	9.8	5.8	10.6

Percentage change	Str 13	Str 14	Str 15
% CQC	9.8	5.8	10.5

Table 13.

Base Shear (in KN) in Sixteen Storey Building.

Due to change in V.I.

Base shear (KN)	Str 1	Str 2	Str 3	Str 4	Str 5	Str 6	Str 7	Str 8	Str 9	Str 10	Str 11	Str 12
MODE 1	1031.35	1028.6	1022.1	1023.0	1030.3	1029.2	1007.9	1007.2	962.7	1033.3	1033.5	1030.5

Percentage change	Str 2	Str 3	Str 4	Str 5	Str 6	Str 7	Str 8	Str 9	Str 10	Str 11	Str 12
% SRSS	0.29	2.57	2.87	0.61	1.46	3.94	4.56	8.65	1.05	0.74	0.13

Percentage change	Str 2	Str 3	Str 4	Str 5	Str 6	Str 7	Str 8	Str 9	Str 10	Str 11	Str 12
% 10PCT	0.34	1.03	0.95	0.31	0.52	2.38	2.41	9.49	0.11	0.19	1.05

Percentage change	Str 2	Str 3	Str 4	Str 5	Str 6	Str 7	Str 8	Str 9	Str 10	Str 11	Str 12
% CQC	0.36	1.32	1.20	0.31	0.71	2.74	2.75	7.08	0.11	0.19	1.05

Due to change in P.I.

Base shear (KN)	Str 13	Str 14	Str 15
MODE 1	457.5	997.7	947.3

Percentage change	Str 13	Str 14	Str 15
% SRSS	35.3	2.5	13.3

Percentage change	Str 13	Str 14	Str 15
% 10PCT	10.1	3.4	14.1

Percentage change	Str 13	Str 14	Str 15
% CQC	10.1	3.4	14.1

Table 14.

Member forces in different column due to change in V.I. & P.I. in Six Storey Building.

Due to change in V.I.

	FX KN	FY KN	FZ KN	MX KNm	MY KNm	MZ KNm
E CO C	56.53	1.41	2.36	251.00	2.17	1.09
E MI C	68.24	0.60	1.18	372.32	0.99	0.46
E CE C	18.62	0.09	1.74	0.00	0.96	0.11

Due to change in P.I.

	FX KN	FY KN	FZ KN	MX KNm	MY KNm	MZ KNm
E CO C	125.31	23.65	20.79	69.34	21.11	27.27
E MI C	168.26	23.35	10.32	176.23	10.13	23.47
E CE C	24.73	8.91	8.91	0.00	9.05	9.05

Table 15.

Member forces in different column due to change in V.I. & P.I. in Eight Storey Building.

Due to change in V.I.

	FX KN	FY KN	FZ KN	MX KNm	MY KNm	MZ KNm
E CO C	31.74	5.64	0.52	175.97	0.53	4.56
E MI C	39.26	4.86	2.74	334.55	3.01	4.82
E CE C	10.36	3.47	2.76	0.00	2.89	3.36

Due to change in P.I.

	FX KN	FY KN	FZ KN	MX KNm	MY KNm	MZ KNm
E CO C	32.96	19.54	18.72	67.47	18.24	26.23
E MI C	28.75	24.89	12.07	126.39	11.38	25.16
E CE C	28.79	9.47	9.48	0.00	9.90	9.89

Table 16.

Member forces in different column due to change in V.I. & P.I. in Sixteen Storey Building.

Due to change in V.I.

	FX KN	FY KN	FZ KN	MX KNm	MY KNm	MZ KNm
E CO C	6.50	1.32	-0.54	309.55	-0.36	1.17
E MI C	7.87	1.16	-0.34	540.43	-0.17	1.12
E CE C	2.82	-0.76	-0.65	0.00	-0.70	-0.75

Due to change in P.I.

	FX KN	FY KN	FZ KN	MX KNm	MY KNm	MZ KNm
E CO C	128.74	5.50	44.09	556.69	45.49	34.95
E MI C	140.41	17.60	16.08	861.11	14.83	18.80
E CE C	41.28	12.53	14.43	0.00	14.86	13.57

Table 17.

Member forces in different beams due to change in V.I. & P.I. in Six Storey Building.

Due to change in V.I.

	FX KN	FY KN	FZ KN	MX KNm	MY KNm	MZ KNm
E CO B	276.41	0.51	163.10	36.93	187.57	-0.16
E MI B	1690.01	0.23	215.34	275.74	216.96	-0.88
E CE B	4086.59	0.21	1102.98	1210.95	875.10	6.80

Due to change in P.I.

	FX KN	FY KN	FZ KN	MX KNm	MY KNm	MZ KNm
E CO B	-15.76	30.87	25.34	362.74	41.52	30.48
E MI B	87.77	22.54	34.73	148.73	34.49	10.24
E CE B	829.39	27.90	51.29	1367.91	46.79	20.16

Table 18.

Member forces in different beams due to change in V.I. & P.I. in Eight Storey Building.

Due to change in V.I.

	FX KN	FY KN	FZ KN	MX KNm	MY KNm	MZ KNm
E CO B	8.04	2.84	4.12	46.92	3.39	3.67
E MI B	21.42	0.33	25.97	123.11	31.35	0.40
E CE B	85.12	0.35	257.96	438.21	184.79	8.38

Due to change in P.I.

	FX KN	FY KN	FZ KN	MX KNm	MY KNm	MZ KNm
E CO B	12.40	28.89	22.99	443.04	16.48	27.66
E MI B	14.21	23.99	32.35	70.70	34.48	16.04
E CE B	345.27	27.55	37.88	1059.13	38.12	20.45

Table 19.

Member forces in different beams due to change in V.I. & P.I. in Sixteen Storey Building.

Due to change in V.I.

	FX KN	FY KN	FZ KN	MX KNm	MY KNm	MZ KNm
E CO B	1.00	0.80	5.44	157.91	5.34	0.96
E MI B	9.11	-0.17	8.07	148.16	14.18	-0.23
E CE B	3.42	-0.26	286.84	539.53	195.11	-0.38

Due to change in P.I.

	FX KN	FY KN	FZ KN	MX KNm	MY KNm	MZ KNm
E CO B	6.95	72.28	8.90	393.62	29.41	36.02
E MI B	178.74	22.52	37.80	105.23	33.24	15.36
E CE B	551.24	24.08	45.10	1221.22	68.70	20.84

5. **RESULT AND DISCUSSION**:

1. Maximum percentage increase in storey drift for different structures with different vertical and plan irregularities shows wide variation. As number of storey increases percentage variation in storey drift also increase. For example % variations in different storey building are.

For vertical irregularity

Building type	Maximum % variation	Average % variation	Minimum % variation
Six storey	159 %	69.3 %	2.0 %
Eight storey	233 %	97.07 %	0.25 %
Sixteen storey	266 %	125.9 %	0.7 %

For plan irregularity

Building type	Maximum % variation	Average % variation	Minimum % variation
Six storey	6.24 %	2.95 %	0.07 %
Eight storey	7.5 %	4.29 %	0.15 %
Sixteen storey	21.3 %	17.7 %	0.13 %

2. Increase in base shear in mode 1 in X-direction for different structures with different vertical and plan irregularities shows wide variations. For example,

For vertical irregularity

Building type	Maximum Base Shear	Average Base Shear	Minimum Base Shear
Six storey	726.1 KN	633.3 KN	363.29 KN
Eight storey	792.6 KN	717.2 KN	395.32 KN
Sixteen storey	1033.5 KN	1020 KN	962.7 KN

For plan irregularity

Building type	Maximum Base Shear	Average Base Shear	Minimum Base Shear
Six storey	700 KN	475.6 KN	173 KN
Eight storey	735 KN	551.48 KN	190 KN
Sixteen storey	997.8 KN	800.8 KN	457.5 KN

3. Percentage variation in SRSS base shear in different structures with different vertical and plan irregularities shows wide variation. For example

For vertical irregularity

Building type	Maximum % variation	Average % variation	Minimum % variation
Six storey	42.1 %	29.3 %	11.14 %
Eight storey	38.2 %	28.4 %	10.7 %
Sixteen storey	8.6 %	2.44 %	0.12 %

For plan irregularity

Building type	Maximum % variation	Average % variation	Minimum % variation
Six storey	37.11 %	23.9 %	4.96 %
Eight storey	36.19 %	22.12 %	3.17 %
Sixteen storey	35.3 %	17 %	2.5 %

4. Percentage variation in 10PCT base shear in different structures with different vertical and plan irregularities shows wide variation. For example

For vertical irregularity

Building type	Maximum % variation	Average % variation	Minimum % variation
Six storey	21.4 %	8.7 %	0.4 %
Eight storey	20 %	7.6 %	2.3 %
Sixteen storey	9.5 %	1.7 %	0.11 %

For plan irregularity

Building type	Maximum % variation	Average % variation	Minimum % variation
Six storey	8.7 %	5.68 %	3.04 %
Eight storey	10.5 %	8.7 %	5.8 %
Sixteen storey	14.12 %	9.20 %	3.4 %

5. Maximum percentage increase in CQC base shear in different structures with different vertical and plan irregularities shows wide variation. For example.

For vertical irregularity

Building type	Maximum % variation	Average % variation	Minimum % variation
Six storey	20.12 %	7.88 %	0.49 %
Eight storey	18.3%	6.91 %	2.35 %
Sixteen storey	7.08 %	1.62 %	0.11 %

For plan irregularity

Building type	Maximum % variation	Average % variation	Minimum % variation
Six storey	8.09 %	5.62 %	3.0 %
Eight storey	10.51%	8.71 %	5.80 %
Sixteen storey	14.11 %	9.20 %	3.41 %

6. Percentage variation in drift in x direction in different structures with different vertical and plan irregularity increases as structural irregularity increase. For example,

For vertical irregularity

Building type	Maximum % variation	Average % variation	Minimum % variation
Six storey	13.72 %	6.23 %	0.59 %
Eight storey	8.81%	3.52 %	0.43 %
Sixteen storey	6.9 %	3.16 %	0.13 %

For plan irregularity

Building type	Maximum % variation	Average % variation	Minimum % variation
Six storey	4.6 %	2.35 %	0.5 %
Eight storey	4.07%	2.43 %	1.38 %
Sixteen storey	9.17 %	6.06 %	3.70 %

7. Due to the different vertical and plan irregularity in different structures, there is a wide variation in time period in mode 1.

For vertical irregularity

Building type	Maximum % variation	Average % variation	Minimum % variation
Six storey	14 %	6.97%	1.24 %
Eight storey	10.12 %	5.14 %	1.1 %
Sixteen storey	6.1 %	2.91 %	0.70 %

For plan irregularity

Building type	Maximum % variation	Average % variation	Minimum % variation
Six storey	0.71 %	0.56 %	0.3 %
Eight storey	0.92%	0.63 %	0.3 %
Sixteen storey	7.9 %	5 %	3.2 %

8. Maximum percentage variation in modal time period in different structures with different vertical and plan irregularity shows wide variation. For example,

For vertical irregularity

Building type	Maximum % variation	Average % variation	Minimum % variation
Six storey	68.14 %	24 %	0.1 %
Eight storey	46.8 %	18 %	0.3 %
Sixteen storey	24 %	6.0 %	0.4 %

For plan irregularity

Building type	Maximum % variation	Average % variation	Minimum % variation
Six storey	61 %	14 %	0.3 %
Eight storey	68%	16 %	0.1 %
Sixteen storey	51 %	16 %	0.10 %

9. Due to changes in vertical and plan irregularity, the base shears in buildings change. The storey shears also changes with the variations in these parameters. As the irregularities have been introduced in the upper stories, the storey shears do not show the same large extent of variation as has been shown in the lower stories.

10. Due to different vertical and plan irregularity maximum percentage increase in member forces (FX) in different members of different structures were found to be nearly similar for extreme corner and extreme middle column as compared to the extreme center one.

11. In vertical irregularities shear force in x-direction in different column members varies with an order of 47.8%, 27.1%, & 5.7% in six, eight and sixteen storey building respectively. Similarly in plan irregularity cases it shows wide variation 106%, 103.5%, & 30.2% in six, eight and sixteen storey building respectively.

12. Due to different vertical and plan irregularity maximum percentage increase in member forces (FX) in different members of different structures were found to be nearly similar for extreme corner and extreme middle beam as compared to the extreme center one.

6. CONCLUSIONS:

1. Due to vertical and plan irregularity, time period of building for different structures shows wide variation and as number of storey increases variation in time period increases.

2. Due to vertical and plan irregularity, storey drifts of buildings have been found to vary and percentage increase in storey drift increase with number of storey.

3. Due to irregularities in buildings, base shears are also found to be varying. This aspect should be ingrained in the RVS procedure.

4. Due to irregularities in buildings, SRSS, 10PCT, CQC, base shears for different structures shows wide variation and SRSS base shear gives maximum percentage variation in different structures under consideration.

5. In different structures with different vertical and plan irregularity, variation of member forces shows wide extent and extreme corner and extreme middle column shows greater variation as compaired to extreme centre one.

6. Variation of member forces at G.F. beams shows wide extent for different structures with different vertical and plan irregularity.

7. Though the variations in member forces are different for different structures, and external columns and external beams are found to be subjected to greater variations.

8. Due to vertical and plan irregularity drift of buildings have been found to vary.

9. The rapid assessment procedure may be suitably modified based on the finding and allotting the scores for vertical and plan irregularity. A range of values may be arrived at; at the time of writing these scores for vertical and plan irregularity. The extent of these irregularities may be decided based on such studies. This may make the RVS procedure more accurate.

10. Use of computers having score cards in some suitable format such as MS Excel may be encouraged. These formats may be programmed to select the appropriate scores based on the extent of vertical and plan irregularity in buildings.

7. FUTHER SCOPE OF STUDY:

1. Some other aspects such as pounding of buildings may also be explored, especially in respect of the seismic vulnerability of building.

2. Different shapes and different heights of building may be considered.

3. Variation may be studied for different seismic zones and different soil conditions.

4. Different analysis method may be applied to see the applicability of these methods to different cases.

8. STAAD INPUT FILE:

STAAD SPACE
START JOB INFORMATION
ENGINEER DATE 21-May-07
END JOB INFORMATION
INPUT WIDTH 79
UNIT METER KN
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4091 TO 4130 4156 TO 4195 4221 TO 4260 4286 TO 4325 4351 TO 4390 -
4416 TO 4455 4481 TO 4520 4546 TO 4585 4611 TO 4650
_FL2 5 TO 20 50 TO 65 95 TO 110 140 TO 155 185 TO 200 231 TO 250 256 TO 275 -
281 TO 300 306 TO 325 4026 TO 4065 4091 TO 4130 4156 TO 4195 4221 TO 4260 -
4286 TO 4325 4351 TO 4390 4416 TO 4455 4481 TO 4520 4546 TO 4585
_FL3 4611 TO 4650
END GROUP DEFINITION
DEFINE MATERIAL START
ISOTROPIC CONCRETE
E 2.17185e+007
POISSON 0.17
DENSITY 23.5616
ALPHA 1e-005
DAMP 0.05
END DEFINE MATERIAL
CONSTANTS
MATERIAL CONCRETE ALL
MEMBER PROPERTY INDIAN
326 TO 350 1001 TO 1025 2001 TO 2025 3001 TO 3025 4001 TO 4025 4066 TO 4090 -
4131 TO 4155 4196 TO 4220 4261 TO 4285 4326 TO 4350 4391 TO 4415 -
4456 TO 4480 4521 TO 4545 4586 TO 4610 4651 TO 4675 PRIS YD 0.45 ZD 0.45
1 TO 20 46 TO 65 91 TO 110 136 TO 155 181 TO 200 226 TO 325 4026 TO 4065 4091 -
4092 TO 4130 4156 TO 4195 4221 TO 4260 4286 TO 4325 4351 TO 4390 4416 TO 4455 -
4481 TO 4520 4546 TO 4585 4611 TO 4650 PRIS YD 0.6 ZD 0.3
SUPPORTS
151 TO 175 FIXED
DEFINE 1893 LOAD
ZONE 0.24 RF 5 I 1.5 SS 2 ST 1 DT 2
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8 WEIGHT 103.778
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397 FX 145.598 FZ 145.598
398 FX 142.706 FZ 142.706
399 FX 145.598 FZ 145.598
400 FX 81.9 FZ 81.9
401 FX 62.42 FZ 62.42
402 FX 119.095 FZ 119.095

403 FX 113.523 FZ 113.523
404 FX 119.095 FZ 119.095
405 FX 62.42 FZ 62.42
406 FX 119.095 FZ 119.095
407 FX 226.203 FZ 226.203
408 FX 217.366 FZ 217.366
409 FX 226.203 FZ 226.203
410 FX 119.095 FZ 119.095
411 FX 113.523 FZ 113.523
412 FX 217.366 FZ 217.366
413 FX 208.258 FZ 208.258
414 FX 217.366 FZ 217.366
415 FX 113.523 FZ 113.523
416 FX 119.095 FZ 119.095
417 FX 226.203 FZ 226.203
418 FX 217.366 FZ 217.366
419 FX 226.203 FZ 226.203
420 FX 119.095 FZ 119.095
421 FX 62.42 FZ 62.42
422 FX 119.095 FZ 119.095
423 FX 113.523 FZ 113.523
424 FX 119.095 FZ 119.095
425 FX 62.42 FZ 62.42
SPECTRUM CQC 1893 X 0.036 ACC SCALE 1 DAMP 0.05
SOIL TYPE 2
LOAD 2 EQZ
SPECTRUM CQC 1893 Z 0.036 ACC SCALE 1 DAMP 0.05
SOIL TYPE 2
LOAD 3 LOADTYPE Dead TITLE LOAD DL
SELFWEIGHT Y -1
FLOOR LOAD
_FL1 FLOAD -5 GY
LOAD 4 LOADTYPE Live TITLE LOAD LL
FLOOR LOAD
_FL2 FLOAD -3 GY
_FL3 FLOAD -1.5 GY
LOAD COMBINATION 5
3 1.0 4 1.0
LOAD COMB 6 1.2*(+EQX + DL + LL)
1 1.2 3 1.2 4 1.2
LOAD COMB 7 1.2*(+EQZ + DL + LL)
2 1.2 3 1.2 4 1.2
LOAD COMB 8 1.2*(-EQX + DL + LL)
1 -1.2 3 1.2 4 1.2
LOAD COMB 9 1.2*(-EQZ + DL + LL)
2 -1.2 3 1.2 4 1.2
LOAD COMB 10 1.5*(EQX + DL)
1 1.5 3 1.5
LOAD COMB 11 1.5*(+EQZ + DL)
2 1.5 3 1.5
LOAD COMB 12 1.5*(-EQX + DL)
1 -1.5 3 1.5
LOAD COMB 13 1.5*(-EQZ+DL)
2 -1.5 3 1.5
LOAD COMB 14 (1.5*+EQX + 0.9 DL)
1 1.5 3 0.9
LOAD COMB 15 (1.5*+EQZ + 0.9 DL)
2 1.5 3 0.9
LOAD COMB 16 (1.5*-EQX + 0.9 DL)
1 -1.5 3 0.9

```
LOAD COMB 17 (1.5*-EQZ + 0.9 DL )
2 -1.5 3 0.9
LOAD COMB 18 1*(DL+LL) FOR FOUNDATION
3 1.0 4 1.0
PERFORM ANALYSIS
PRINT STORY DRIFT
FINISH.
```

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