SEISMIC VULNERABILITY ASSESSMENT OF BUILDINGS

Submitted in Partial Fulfillment for the Award of the Degree of

Master of Engineering
in
Civil Engineering

With specialization in

STRUCTURAL ENGINEERING
by
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2007

Department of Civil & Environmental Engineering
Delhi College of Engineering, Delhi-110042

CERTIFICATE

This is to certify that the project entitled "SEISMIC VULNERABILITY ASSESSMENT OF BUILDINGS" being submitted by me, is a bonafide record of my own work carried by me under the guidance and supervision of Prof. P.R.Bose and Mr. Alok Verma in partial fulfillment of requirements for the award of the Degree of Master of Engineering (Structural Engineering) in Civil Engineering, from University of Delhi, Delhi.

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

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Enroll No: 05/Str/05
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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

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I also express my sincere gratitude to the faculty of Civil Engineering Department, Computer Centre & Library Delhi college of Engineering. I also express my indebtedness to many sources, including those specially mentioned in the references, at the end of the text for using their literature for the preparation of this report.

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

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05/Stru/05

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SEISMIC VULNERABILITY ASSESSMENT OF BUILDINGS

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
ESDOF	Equivalent single degree of Freedom
FEMA	Federal emergency management agency
FVC	Field Visit Check
IS	Indian Standard
JI	Journal
LDP	Linear Dynamic Process
LS	Life Safety
LSP	Linear Static Process
MCE	Maximum Considered Earthquake
MDOF	Multi Degree of Freedom
MMPOA	Multi Modal pushover analysis
MPOA	Modal pushover analysis
NDP	Nonlinear Dynamic Process
NSP	Nonlinear Static process
POA	Push Over Analysis
POC	Push Over Curve
RSM	Rapid Screening Method
RVA	Rapid Visual Assessment
SDOF	Single Degree of Freedom
SPOA	Static Push over analysis
RAM	Rapid Assessment Method
SAM	Simplified Assessment Method
DAM	Detailed Assessment Method
DI	Damage Index
DCR	Damage Capacity Ratio
RSI	Reserve Strength Index

ABSTRACT

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.

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 an the seismic performance of RC Buildings has been examined in this project work. For comparison, same storey stiffness and loads have been maintained & variations of member forces, base shears and drifts have been considered.

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1.0 INTRODUCTION :

Experience in the recent past earthquakes in India, like 1993 Killari earthquake in Maharashtra, 1997 Jabalpur earthquake in Madhya Pradesh, 1999 Chamoli earthquake in Uttaranchal in 2001 Kachchh earthquake in Gujrat, have clearly indicated the fragility of the building stock in the country, in practically all the states to the same extent.

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.1)

India has experienced several devastating earthquakes in past resulting in a large number of deaths and severe property damages. The urban areas have experienced very rapid population growth during the last few decades due to economic factors such as decrease in economic opportunities in the rural areas and consequent migration to the urban areas. 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. The very high vulnerability of urban India was starkly demonstrated during the Bhuj earthquake, in which the urban centers of Bhuj, Anjar and Bhachau experienced extreme damages and losses to both new and old constructions. During this earthquake, a large number of recently constructed concrete buildings in Ahmedabad were also badly damaged even though the city is located over 200km from the epicenter and these buildings should have suffered only minor damage if properly designed and constructed.

Seeing to a large number of building structures in the country, it is necessary to have a means of determining the seismic vulnerability of building structures in a short time so that appropriate steps can be taken to retrofit vulnerable structures.

1.1 OBJECTIVE OF THE STUDY

1. To study the rapid seismic vulnerability assessment method and the effect of presence of vertical and plan Irregularity on total scores.

2. To study the effect of different of degrees of vertical and plan Irregularity on seismic performance of RC MR framed buildings.

1.2 NEED OF VULNERABILITY ASSESSMENT

Vulnerability is the existence of weaknesses that makes an entity susceptible to attack. When applied to existing structures, vulnerability is the susceptibility to damage from natural and manmade hazards. Design and mitigation for natural hazard is incorporated into existing building codes .The guidelines and techniques in the building codes are well established. However, the Oklahoma City Bombing and the World Trade Center attacks have demonstrated that building regulations and standards are not sufficient to protect against manmade hazards (ref. 6).

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 reduce vulnerability. Vulnerability assessment procedures use a screening process to examine the physical properties of a facility.

PHASE 1 (ref. 6)

Seismic vulnerability assessment in phase 1 belongs to **qualitative type of assessment** where method relies on general seismic response and observed strength and weakness of different structures under seismic actions Based on some seismic properties of structures and type of structures etc. seismic vulnerability are assessed in qualitative terms. Several of field surveys based on screening method surfaced due to efforts of researchers working in their area; seismic vulnerability assessment was mainly comparing the existing structure in the light of new seismic codal provisions and identifying the seismic strength and weakness.

Qualitative methods use information gathered from past earthquakes, various laboratory tests and visual inspections. These methods are based on the seismic behavior of structure and different materials under earthquake load. Qualitative methodology try to identify weakness and strengths of a particular structure and material at element as well as global levels and then assign a score to such findings in away to find total score for the structures. Finally, a ranking system is devised to palace the structure in different predetermined damage classes. Hence, local considerations prevail in the scoring pattern. Again, scoring exercise depends on personal judgment also. Hence these methods cannot be universally adopted uniformly.

PHASE-2:

Seismic evaluation is moving towards analytical base and hence development of quantitative stream of methodology. Simplified analytical approaches such as SDOF representing MDOF system for seismic analysis equivalent linear analysis for considering non-linear actions and development of related damage indices and damage models. Damage models got maturity under this phase and there use paved way of their importance so that better calibrations can be made.

Seismic vulnerability assessment in phase 2 belongs to **quantative metholodigies** are comparison of capacity of structure with seismic demand on the structure, consistent with the performance objectives decided for the structure. Hence any assessment methodology requires capacity been calculated with actual values (strength, stiffness, geometry and other mechanical properties) demand of earthquake been determined (ground motion characteristics assessed for a non linear structures) and performance objective be decided. For comparison damage descriptors (required structural response parameters) damage states and damage indices are also very important parts of a seismic vulnerability assessment scheme. The final step in seismic vulnerability assessment scheme is development of economic damage index. In seismic analysis analytical techniques may be broadly categorized as linear procedure (LSP), Linear Dynamic Procedure (LDP), Non-linear Static Procedure (NSP) and Non-linear Dynamic Procedure (NDP). The choice of analytical method used for seismic vulnerability assessment depends upon building type, performance objectives, geometry and degree of expected inelastic response.

PHASE-3

There is always an effort to modify the existing methods and include complex behavior of structure under strong ground motion. Push over analysis has been used to find seismic vulnerability of asymmetric buildings. Non-linear Static analysis came in to pictures prominently. Seismic vulnerability assessment suited the graphical representation of capacity and demand for regular buildings a planner analysis provides sufficiently accurate results. Hence this phase can be attributed to the push over analysis and its development for the seismic vulnerability assessment. Analytical treatment for structures with infill as well as asymmetry is under tremendous improvement.

The vulnerability assessment is typically only a portion of a broader evaluation.

FEMA 452 has the following five-step approach for vulnerability assessment.

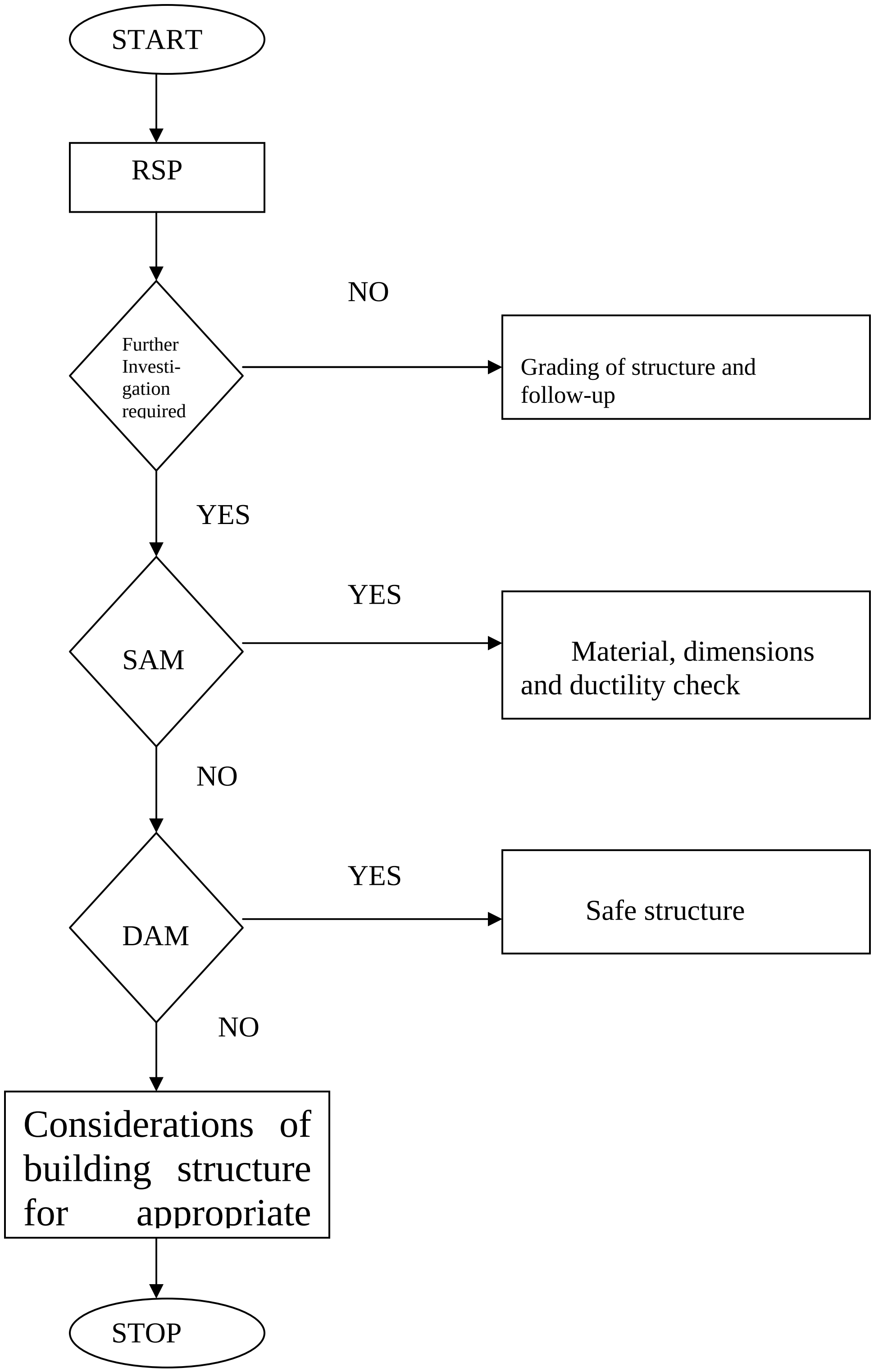
1. Asset value assessment
2. Threat/hazard assessment
3. Vulnerability assessment
4. Risk assessment
5. Mitigation identification

Although other agencies and organizations may use a slightly different approach, most vulnerability assessments cover the same topics.

Table. 1 General assessment factors and their corresponding criteria

Assessment Factors	Criteria
Site Characteristics	Standoff distance, perimeter parking roadways, surrounding buildings
Architectural Elements	Building laysout, entrances, windows, doors, mailroom roof access, mounted architectural components
Structural Systems	Type of construction, building overhangs, redundant load paths, progressive collapse avoidance, structural isolation
Electrical Systems	System controls, electrical distribution panels, utility routing, redundant utilities, emergency backup systems, lighting
Mechanical Systems	Air intakes, heating, ventilating, and air-conditioning (HVAC) systems, ventilation
Utility Systems	Water supply, sewer systems, fuel supply, emergency power
Security Systems	Security cameras, alarms, x-ray equipment, photo identification system, asset tracking system, access control

FLOW CHART OF SEISMIC VULNERABITITY ASSESSMENT PROCEDURE



2. LITERATURE REVIEW

2.1 RAPID VISUAL SCREENING (RVS): (ref. 7)

Introduction:

A procedure for rapid visual screening (RVS) was first proposed in the US in 1988, which was further modified in 2002 to incorporate latest technological advancements and lessons from earthquake disasters in the 1990s. 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 evaluation procedure and system is compatible with GIS-based city database, and also permits use of the collected building information for a variety of other planning and mitigation purposes.

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:

1. To identify if a particular building requires further evaluation for assessment of its seismic vulnerability.
2. To rank a city's or community's (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.

2.2 RVS Objectives and Scope

Rapid visual screening (RVS) was first proposed in the US in 1988, which was further modified in 2002 to incorporate latest technological advancements and lessons from earthquake disasters in the 1990s. 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 method is designed to be implemented without performing any structural calculations. The procedure utilizes a scoring system that requires the evaluator to:

- Identify the primary structural lateral load-resisting system, and
- 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 RVS procedure can be integrated with GIS-based city planning database and can also be used with advanced risk analysis software. The methodology also permits easy and rapid reassessment of risk of buildings already surveyed based on availability of new knowledge that may become available in future due to scientific or technological.

2.3 Procedure

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 procedure can be integrated with GIS-based city planning database and can also be used with advanced risk analysis software. The methodology also permits easy and rapid reassessment of risk of buildings already surveyed based on availability of new knowledge that may become available in future due to scientific or technological advancements.

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. Even in urban areas, some very weak forms of non-engineered buildings are well-known for their low seismic vulnerability and do not require RVS to estimate their vulnerability. These building types are also not included in the RVS procedure.

2.4 Building Types Considered in RVS Procedure

A wide variety of construction types and building materials are used in urban areas of India. These include local materials such as mud and straw, semi-engineered materials such as burnt brick and stone masonry and engineered materials such as concrete and steel. The seismic vulnerability of the different building types depends on the choice of building materials. The building vulnerability is generally highest with the use of local materials without engineering inputs and lowest with the use of engineered materials.

The basic 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 Macro seismic Scale (EMS-98) recommendations. The buildings in Class-A have the highest seismic vulnerability while the buildings in Class-F have lowest seismic vulnerability. A building of a given type, however, may have its vulnerability different from the basic class defined for that type depending on the condition of the building, presence of earthquake resistance features, architectural features etc. It is therefore possible to assign a vulnerability range for each building type to encompass the expected vulnerability considering the different factors affecting its likely performance. The vulnerability ranges and the basic vulnerability class of different building types are given in Table 1. O in Table 1 denotes the basic class, 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, and adobe and tin sheet constructions.

The likely damage to structures has been categorized in different grades depending on their impact on the seismic strength of the building. The different damage levels that have been recommended by European Macroseismic Scale (EMS-98) are described in Table 2. Table 3 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.

Different types of buildings may have different extents of dificiencienceis. Some of them are described below :

2.5 LOCAL DEFICIENCIES

Local deficiencies lead to the failure of individual elements of the building. The observed deficiencies of the elements are summarized below (ref.5).

2.6 COLUMNS

a. Inadequate shear capacity
b. Lack of confinement of column core
c. Faulty location of splice just above the floor, with inadequate tension splice length
d. Inadequate capacity of corner columns under bi-axial seismic loads
e. Existence of short and stiff columns due to infill walls of partial height

2.7 BEAMS AND BEAM- TO-COLUMN JOINTS

a. Inadequate shear reinforcement
b. Inadequate anchorage of re-bar
c. Inadequate plastic hinge rotation capability due to lack of confinement
d. Inadequate lap length for re-bars

2.8 SLAB AND SLAB-TO-BEAM CONNECTIONS

a. Absence of drag and chord reinforcement
b. Inadequate negative reinforcement at the slab –to-beam connections

2.9 STRUCTURAL WALLS

a. Lack of adequate boundary elements
b. Inadequate reinforcement at the slab-to-wall or beam-to-wall connections

2.10 UNREINFORCED MASONRY WALL

Lack of out of plane bending capacity

2.11 PRECAST ELEMENTS

Lack of tie reinforcements

2.12 DEFICIENT CONSTRUCTIONS

a. Bad workmanship and use of poor mixes
b. Inadequate compaction and curing of concrete
c. Top 100-200 mm of column cast separately
d. Inadequate side face cover, leading to re-bar corrosion
e. Poor quality control

2.13 GLOBAL DEFICIENCIES

Global deficiencies are those deficiencies, which affect the behaviour of structure on a higher scale. Global deficiencies can be broadly classified as plan irregularities and vertical irregularities (ref.3)

2.14 Definitions of Irregular buildings-Plan Irregularities

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

5.Non-parallel systems

The vertical elements resisting the lateral force are not parallel to or symmetric about the major orthogonal axis or the lateral force resisting elements.

2.15 Definitions of Irregular Buildings-Vertical Irregularities

(a) 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.

(b) 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

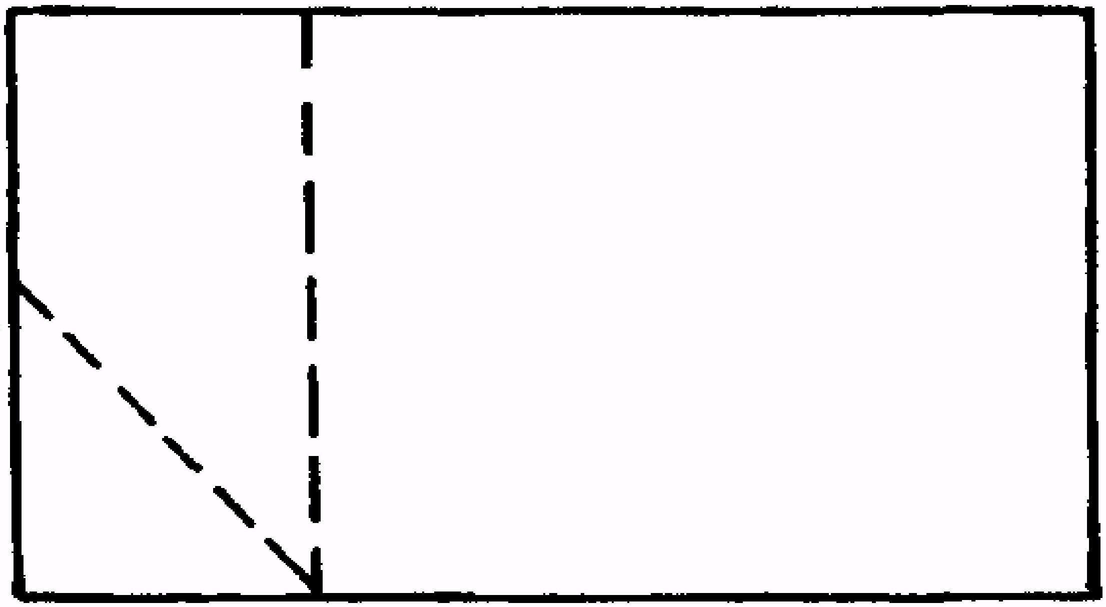
5. Discontinuity in capacity-weak storey

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.

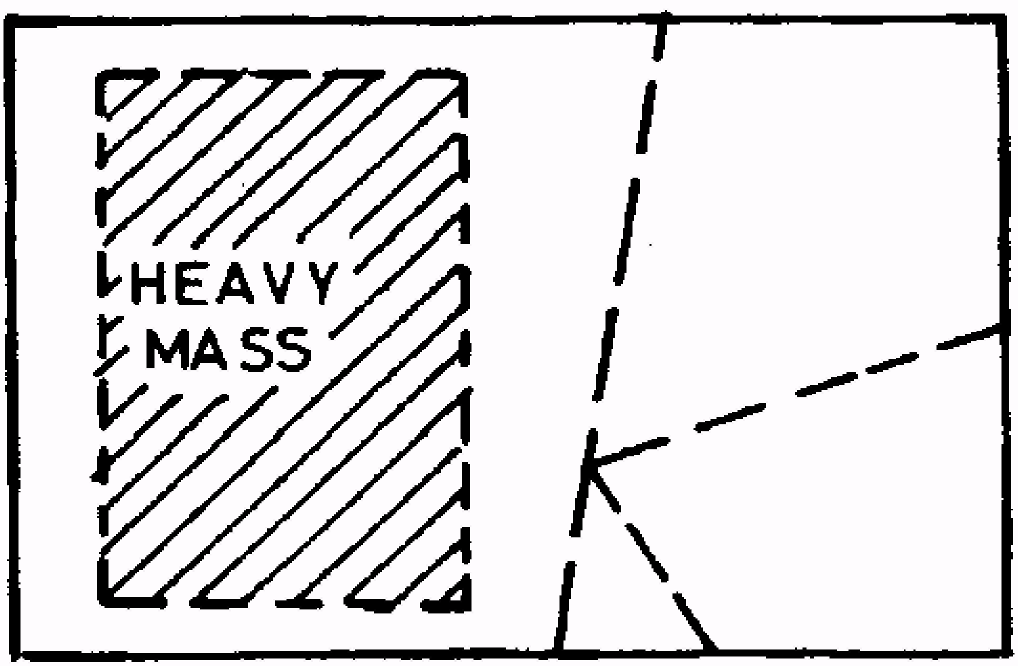
2.16 Uses of RVS Results

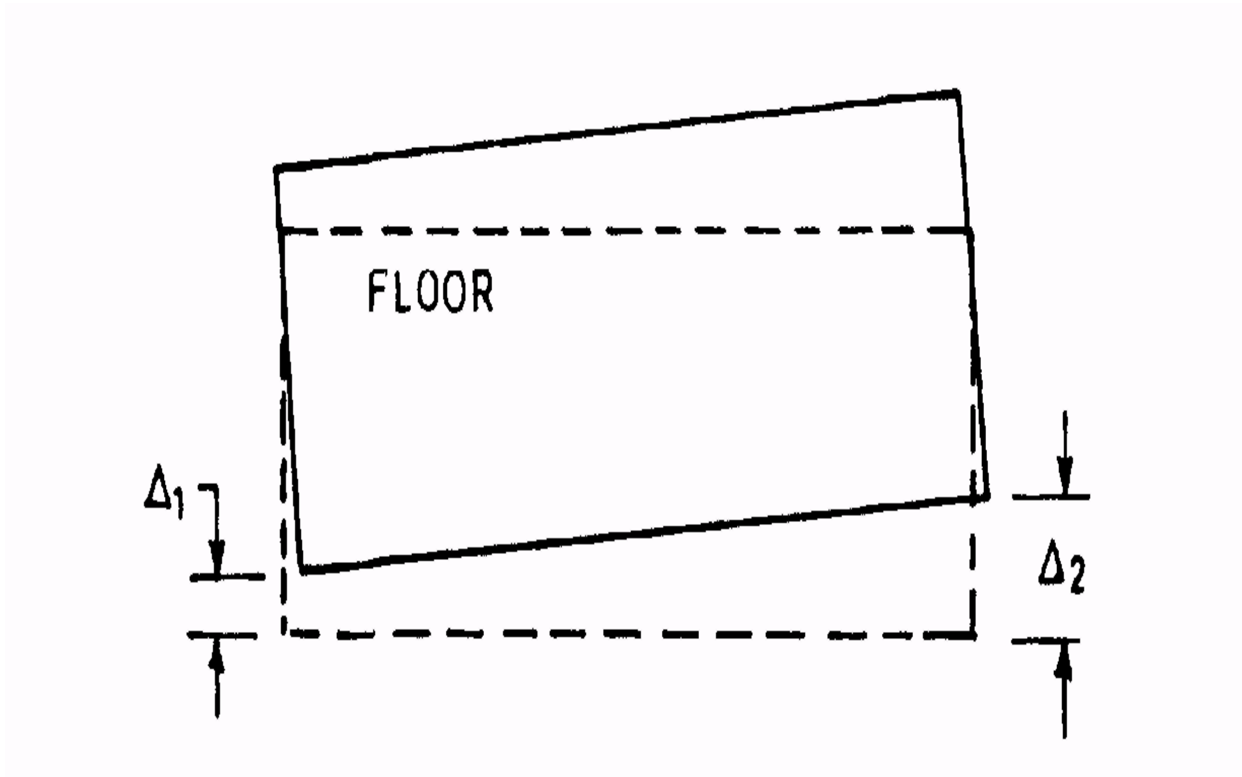
The results from rapid visual screening can be used for a variety of applications that are an integral part of the earthquake disaster risk management program of a city or a region. The main uses of this procedure are:

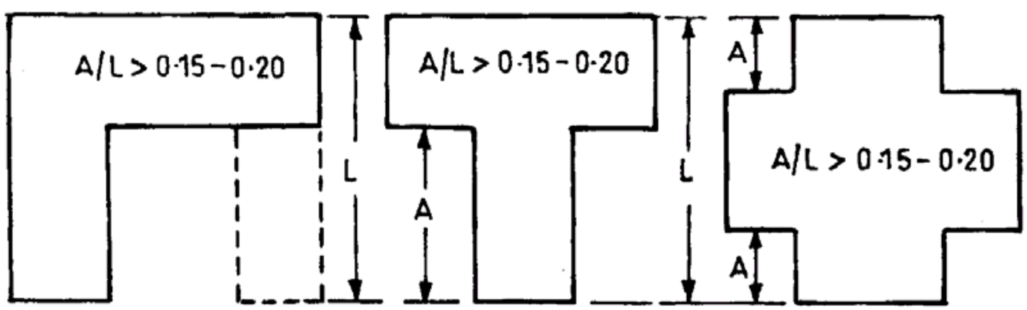
1. To identify if a particular building requires further evaluation for assessment of its seismic vulnerability.
2. To rank a city's or community's (or organization's) seismic rehabilitation needs.
3. To design seismic risk management program for a city or a community.
4. To plan post-earthquake building 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.



VERTICAL COMPONENTS OF SEISMIC RESISTING SYSTEM




FLOOR
Δ1
Δ2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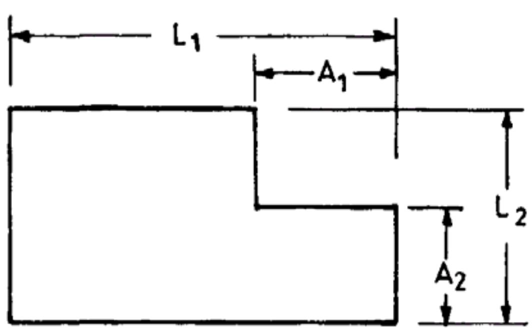
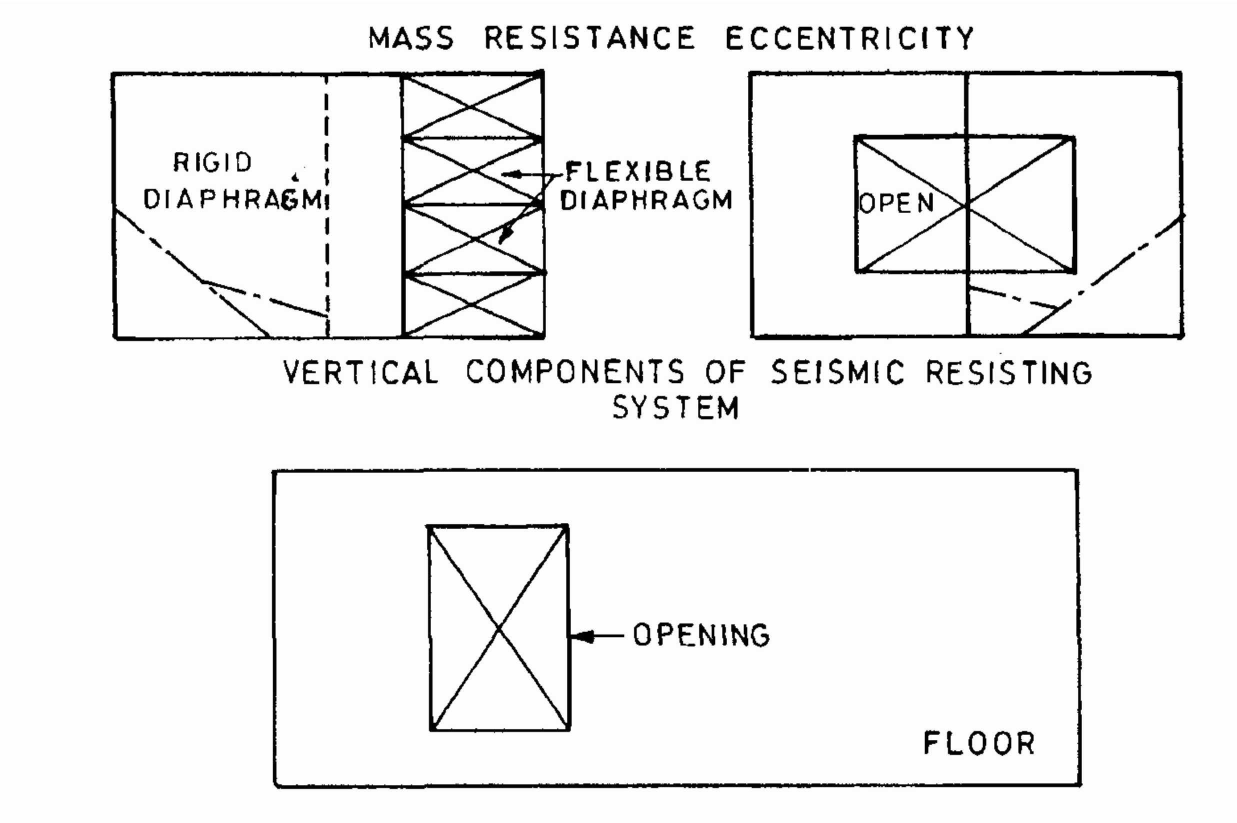
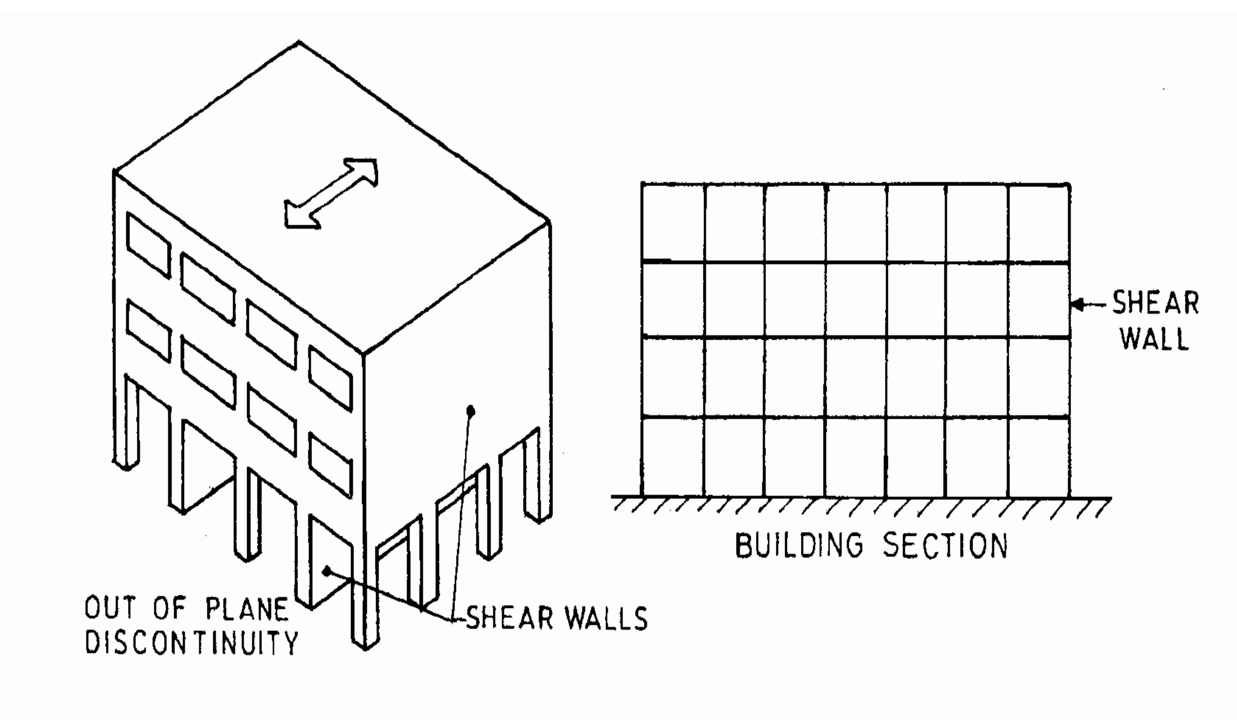
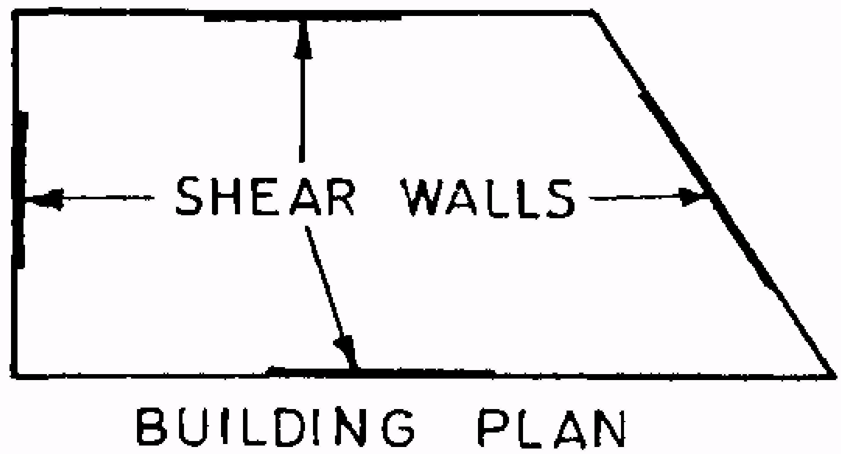
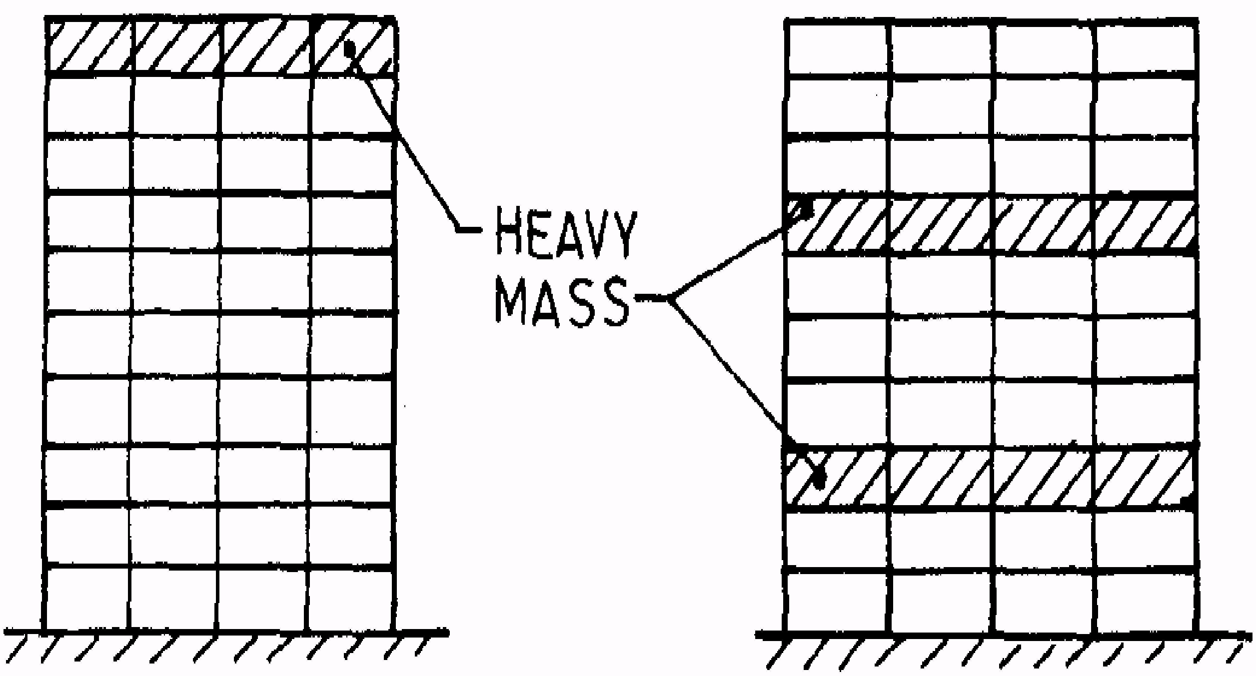
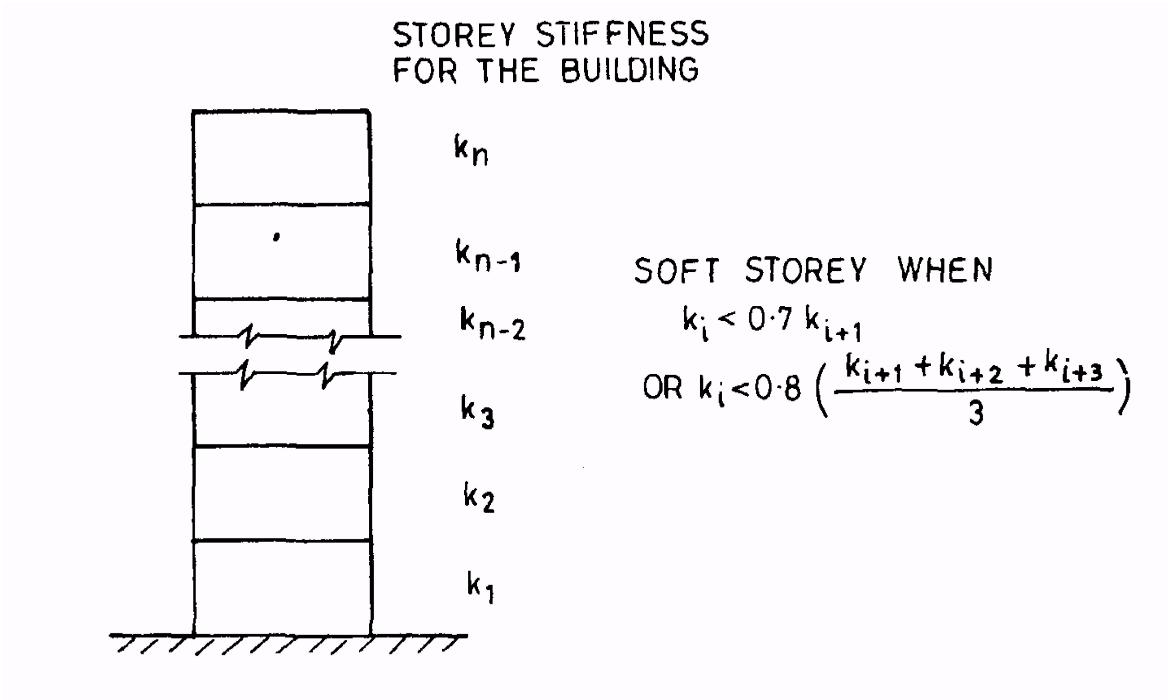

L1
A1
L2
A2

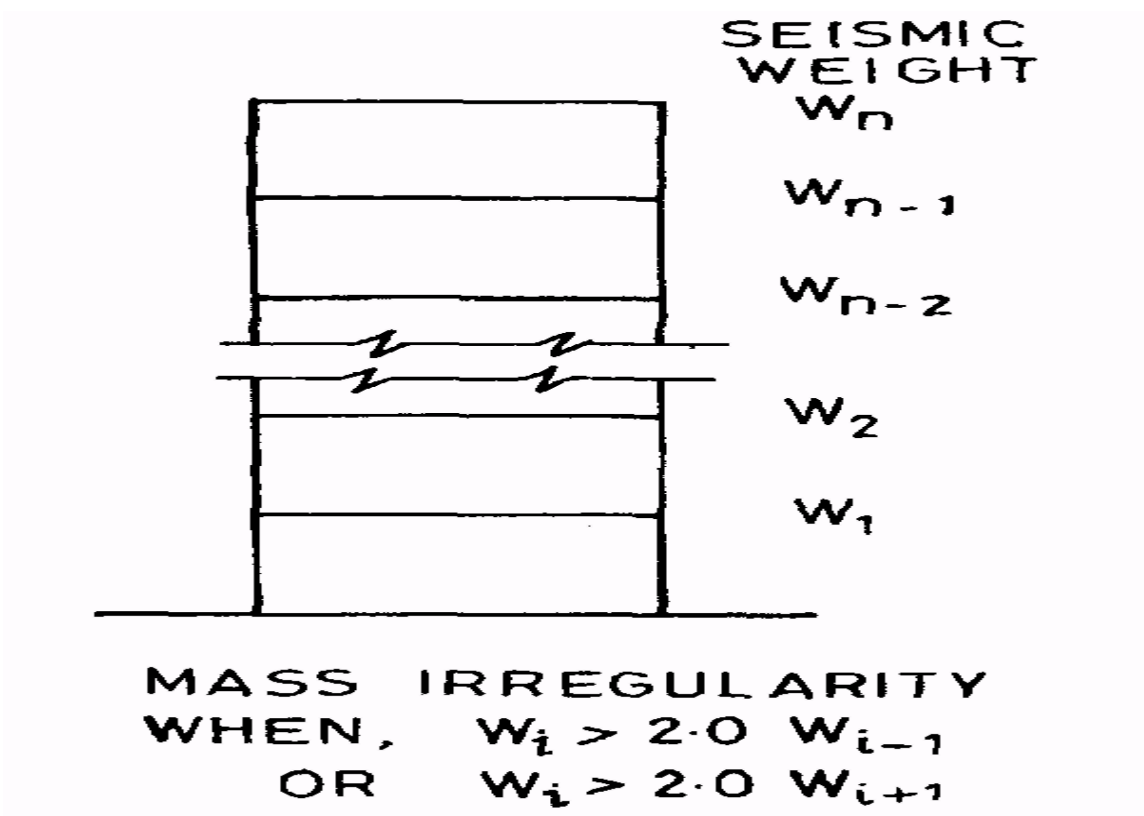

MASS RESISTANCE ECCENTRICITY
RIGID DIAPHRAGM
FLEXIBLE DIAPHRAGM
OPEN
VERTICAL COMPONENTS OF SEISMIC RESISTING SYSTEM
OPENING
FLOOR

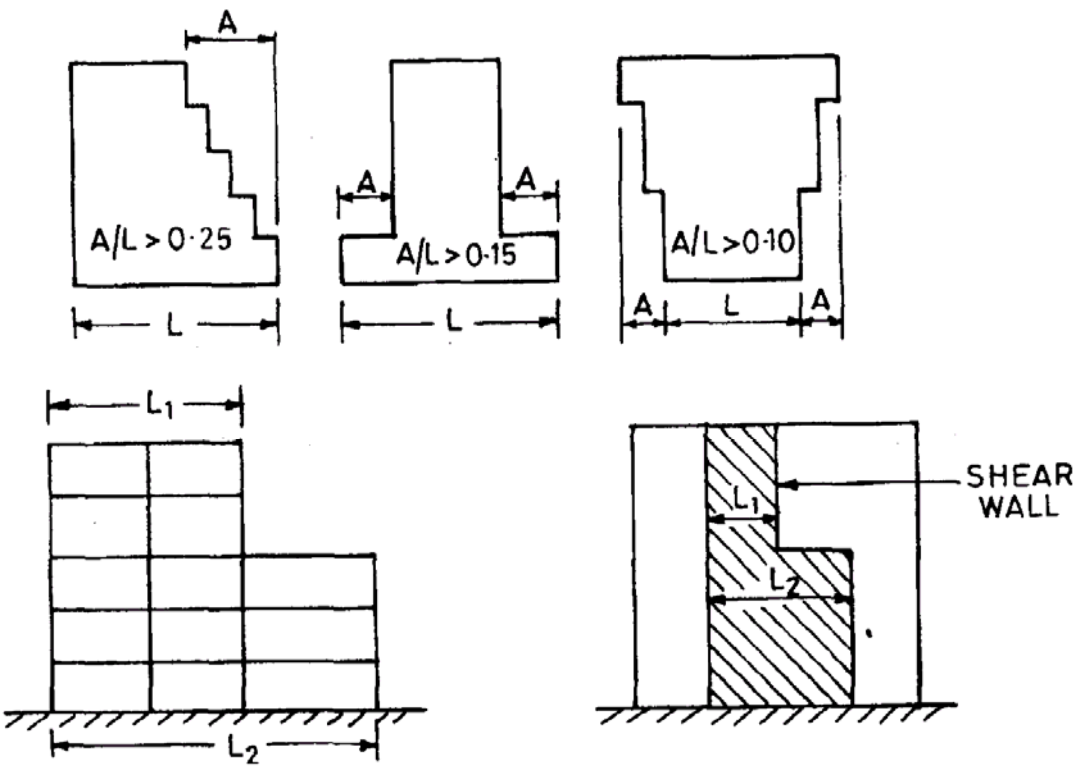

SHEAR WALL
BUILDING SECTION
OUT OF PLANE DISCONTINUITY
SHEAR WALLS


SHEAR WALLS
BUILDING PLAN

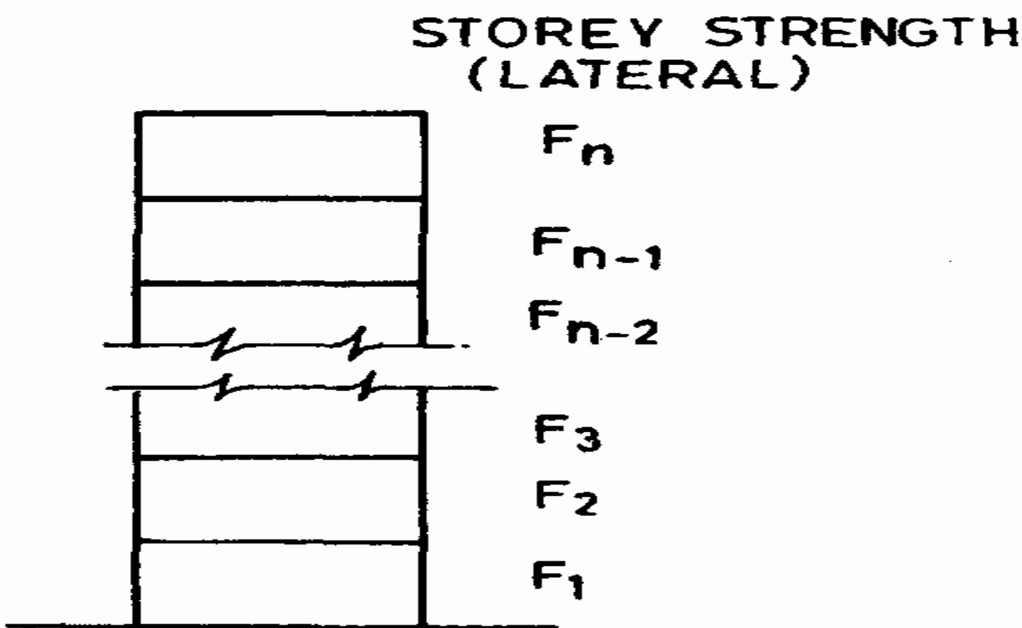

HEAVY
MASS


STOREY STIFFNESS
FOR THE BUILDING
k_n
k_{n-1}
k_{n-2}
k_3
k_2
k_1
SOFT STOREY WHEN
$k_i < 0.7\, k_{i+1}$
OR $k_i < 0.8 \left(\frac{k_{i+1} + k_{i+2} + k_{i+3}}{3} \right)$

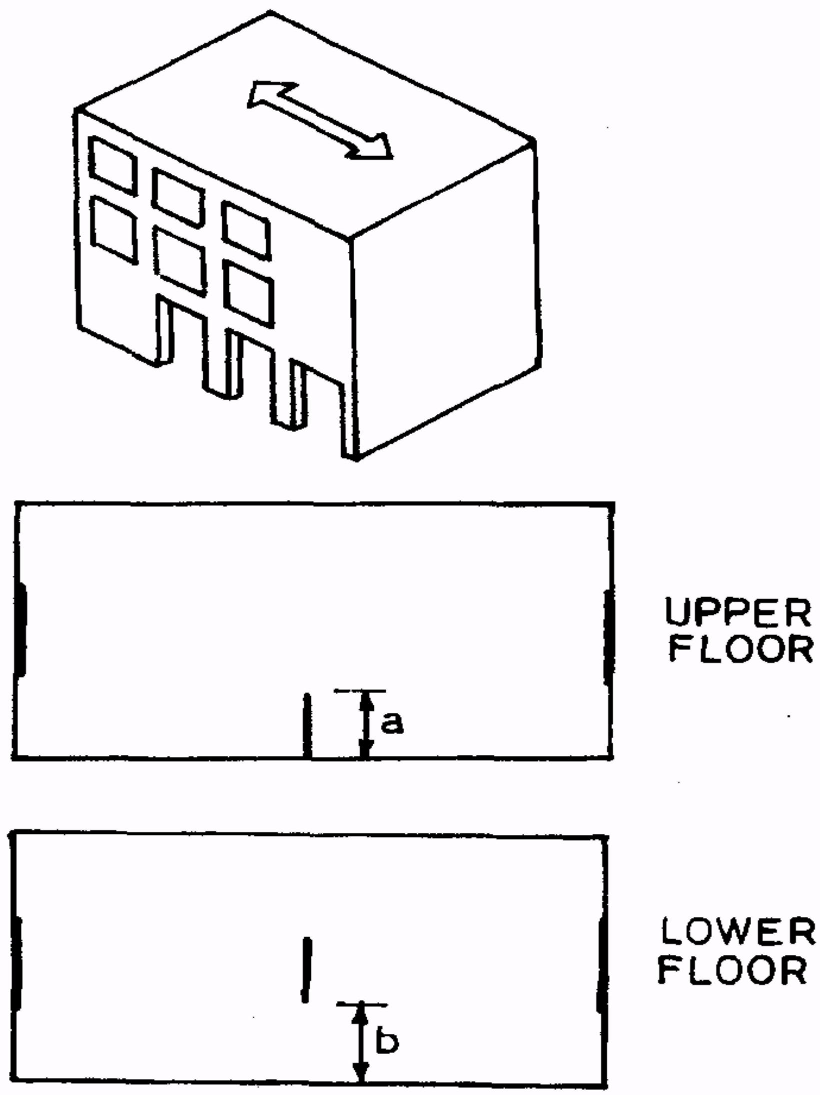

SEISMIC
WEIGHT
W_n
W_{n-1}
W_{n-2}
W_2
W_1
MASS IRREGULARITY
WHEN, $W_i > 2.0\, W_{i-1}$
OR $W_i > 2.0\, W_{i+1}$



4 C Vertical Geometric Irregularity when $L_2 > 1.5\ L_1$



4 E Weak Storey when $F_i < 0.8\ F_i + 1$



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

3. OBSERVATIONS TO METHODS FOR RAPID VISUAL SCREEING OF BUILDINGS FOR POTENTIAL SEISMIC HAZARDS 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.

7. No guidelines for possible performance of building has been provided in the form based on the final scores calculated. This attempt has been made in FEMA 154/ ATC 21 based form. But other points, enumerated above, are still valid for it also.

8. The comparative values of building score modifiers which are used to calculate the final scores may have to be looked into. For example, the values given to vertical irregularity are more than those given to plan irregularity. This uniform grading to all the buildings may not always be recommended as every building structure is different and a uniform yardstick to such cases may not work well always.

9. There are many parameters which are important but are not included in the RVS procedure. For example, the stiffness, nature of the joining of different structural elements, appropriate load path etc may be some of them which may not be considered in the RVS procedure to sustain the speed of operations.

Based on the above observation and a study (ref.8) the following points were observed.

1. Suitable relationships among various parameters are required to be established for the determination of total scores. Model studies on an appropriate scale shall be needed for it.
2. Total scores are sensitive to values of building parameters taken for a building under the RVS procedure.
3. The types of different types of buildings and the construction practices should be given appropriate weightage in the procedure for the calculation of the total scores under the RVS procedure.

4. PROGRAMME OF STUDY

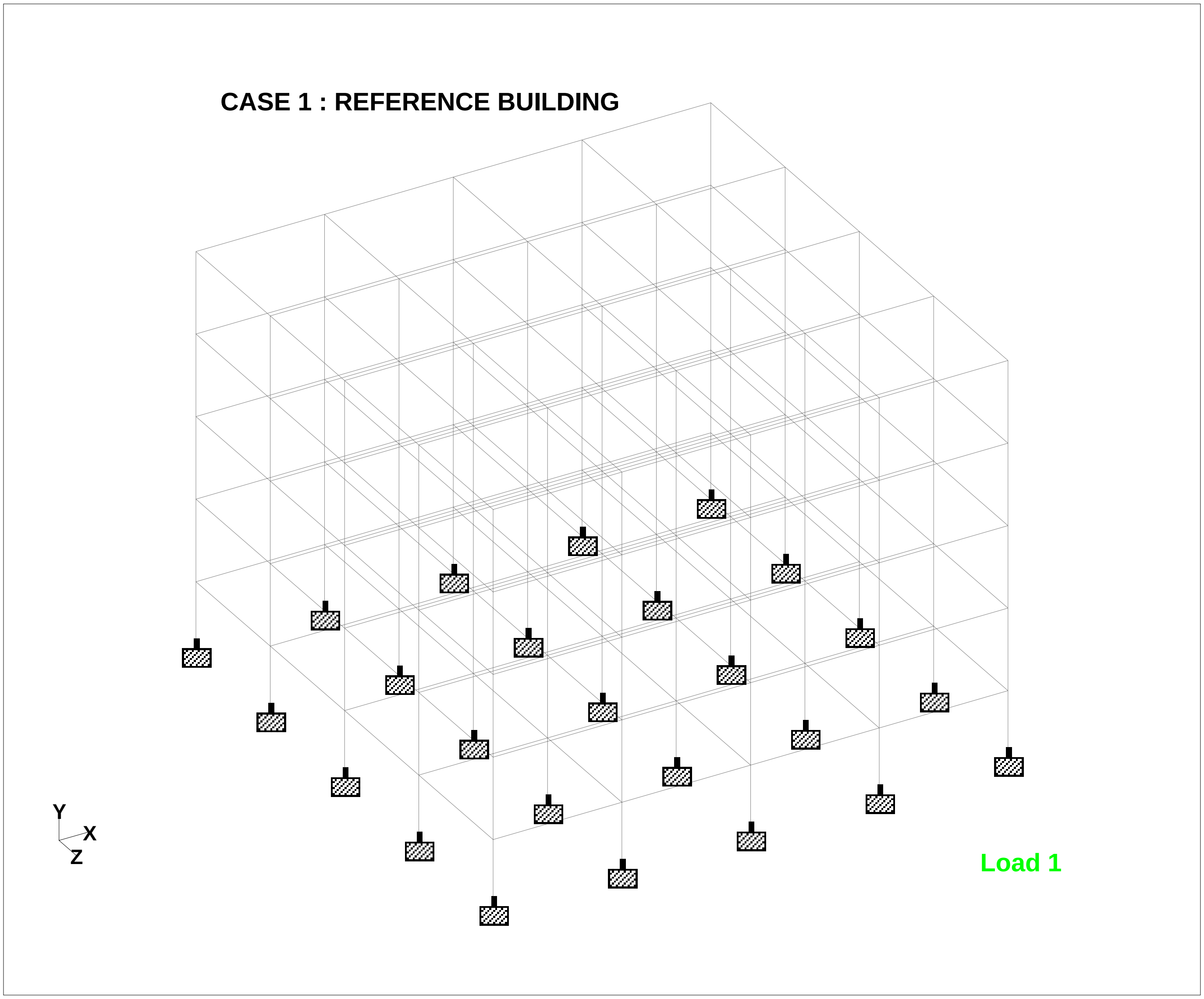
1 Considering the observations a project study was undertaken with a view to determine the extent of possible changes in the seismic performance of RC framed buildings having different degrees of vertical & plan irregularity .

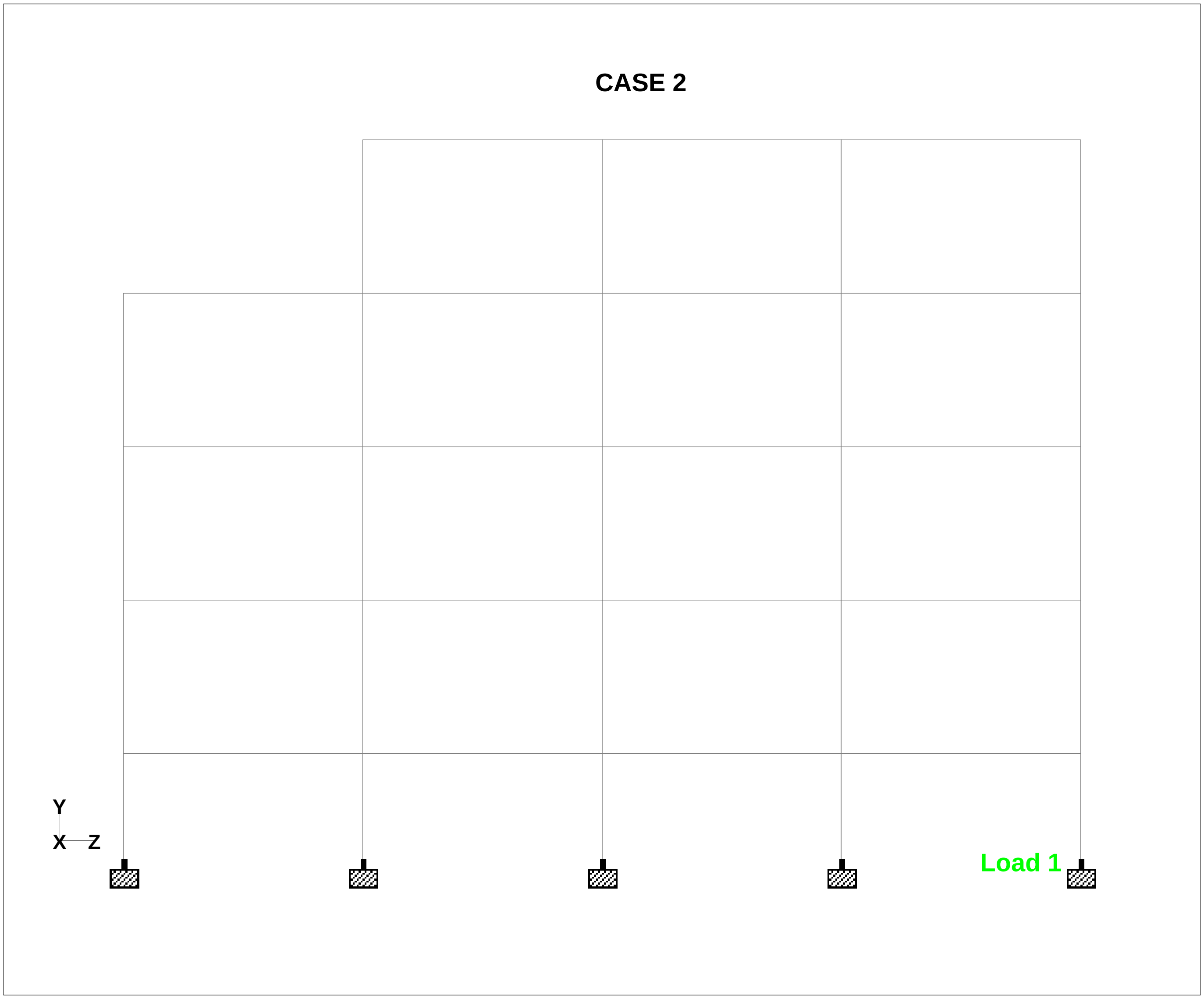
2. For this the seismic performance of an RC framed building has been considered with changes in the following parameters:
(a) Vertical Irregularity
(b) Plan Irregularity
(c) Seismic Zone

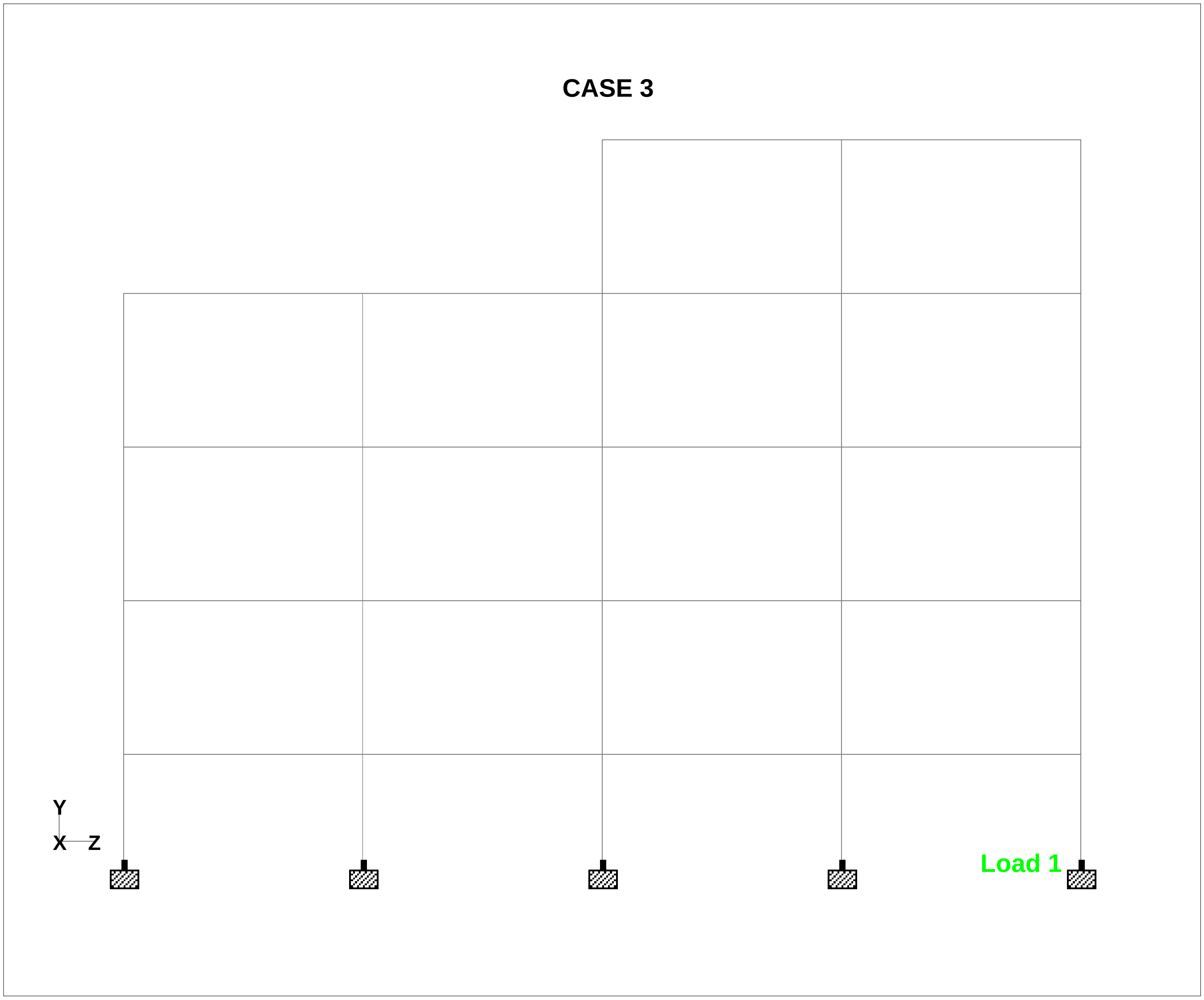
3. As the effect of only plan & vertical irregularity in RC framed buildings in different seismic zones is considered the loading and storey stiffness have been maintained constant. Different configurations of such buildings taken for study are provided hence after this topic.

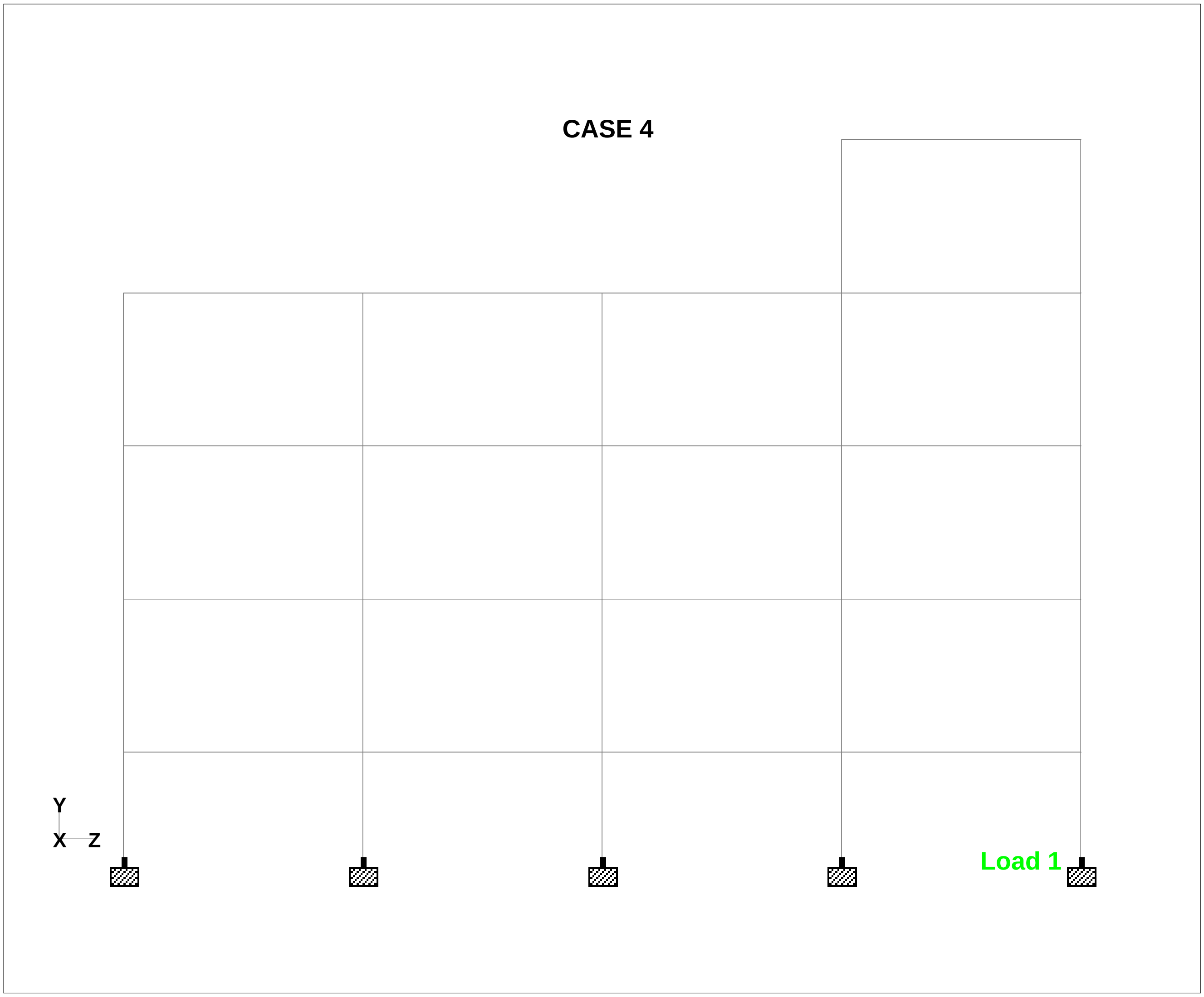
4. The effect of vertical and plan irregularity in these buildings in terms of variations in member forces , base shears and drifts have been considered.

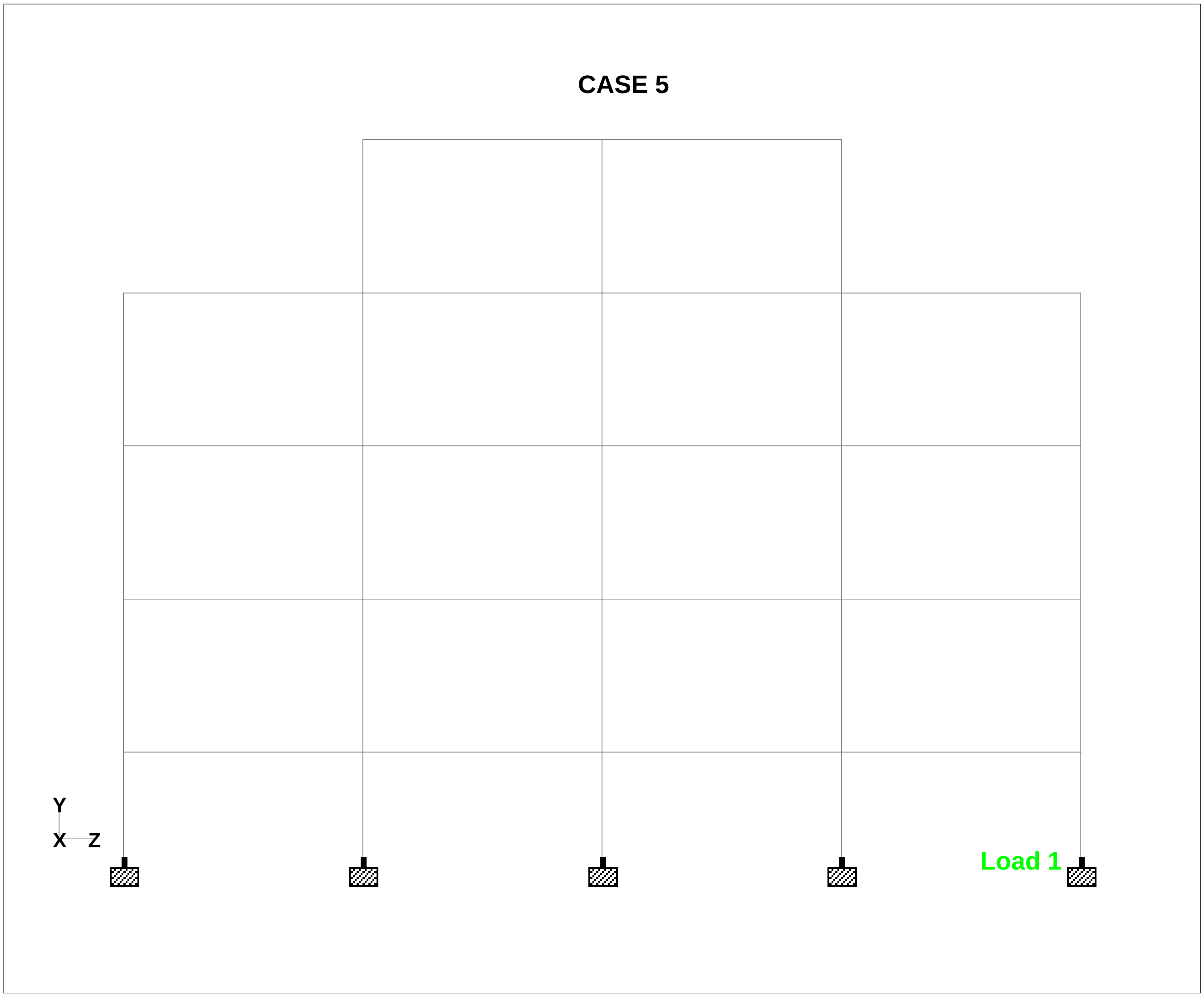
The results in the form of graphs and tables with the different case of buildings analysed in STAAD 2005 are given below.

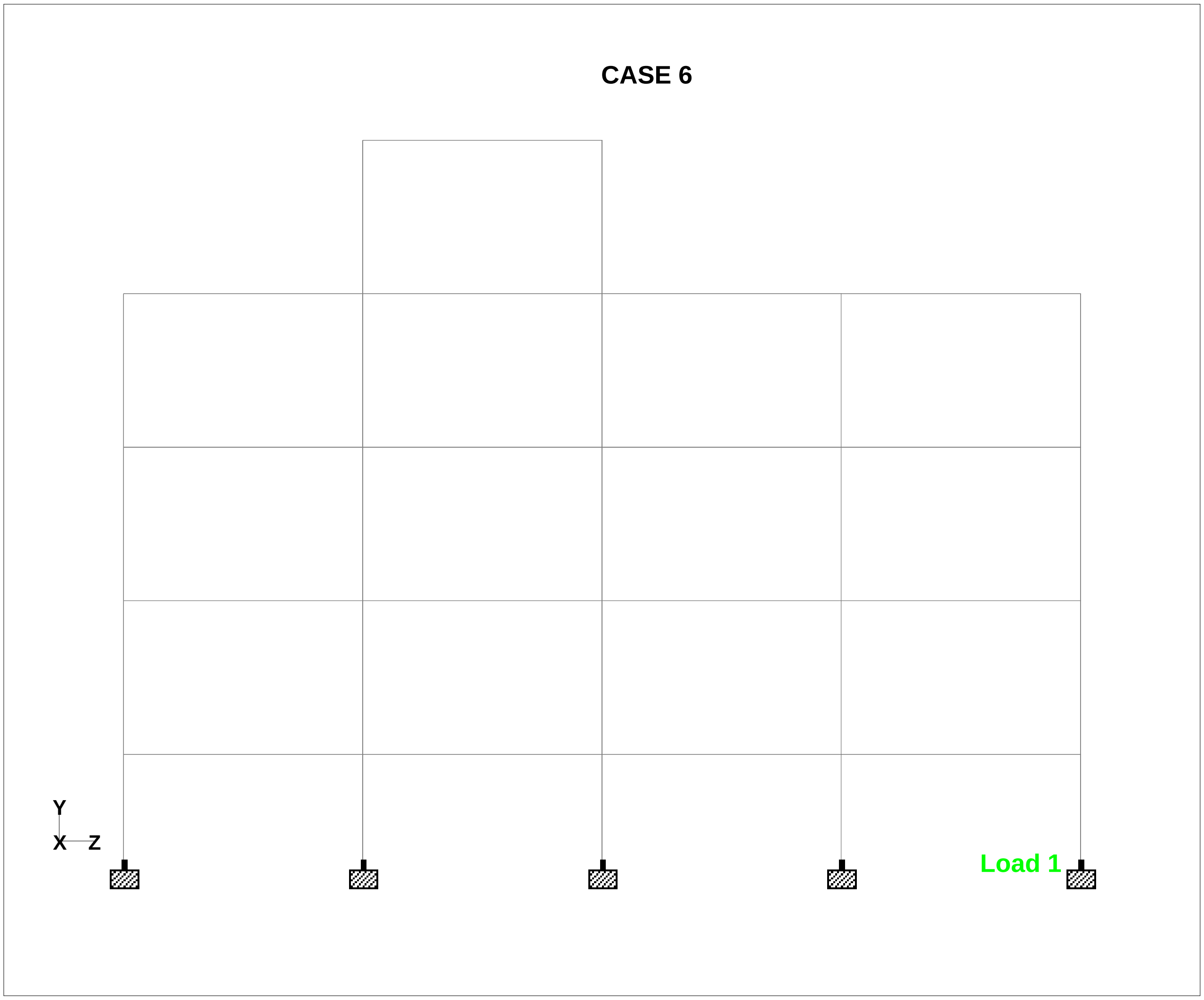

CASE 1 : REFERENCE BUILDING
Y
X
Z
Load 1


CASE 2
Y
X
Z
Load 1

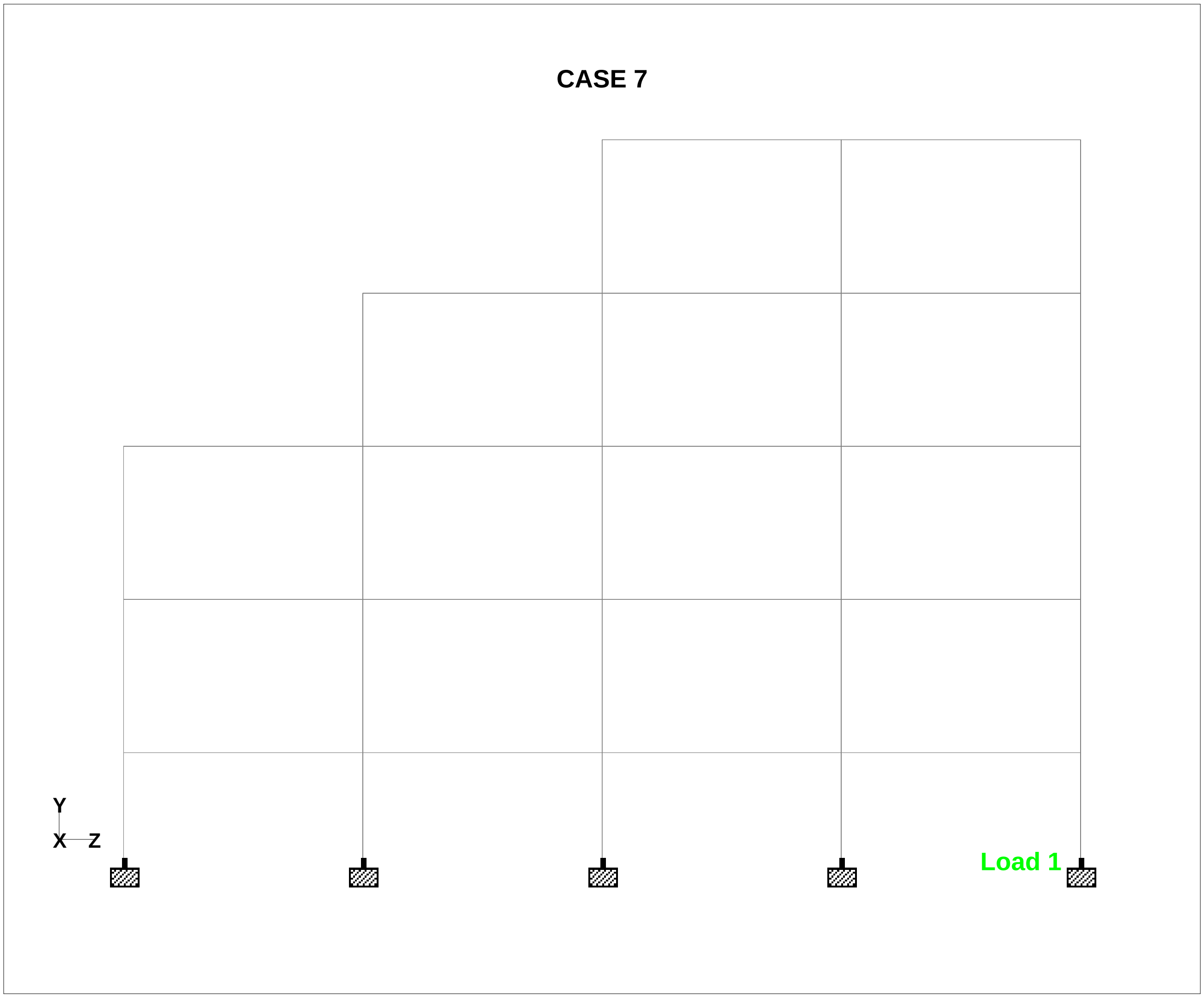

CASE 3
Y
X
Z
Load 1

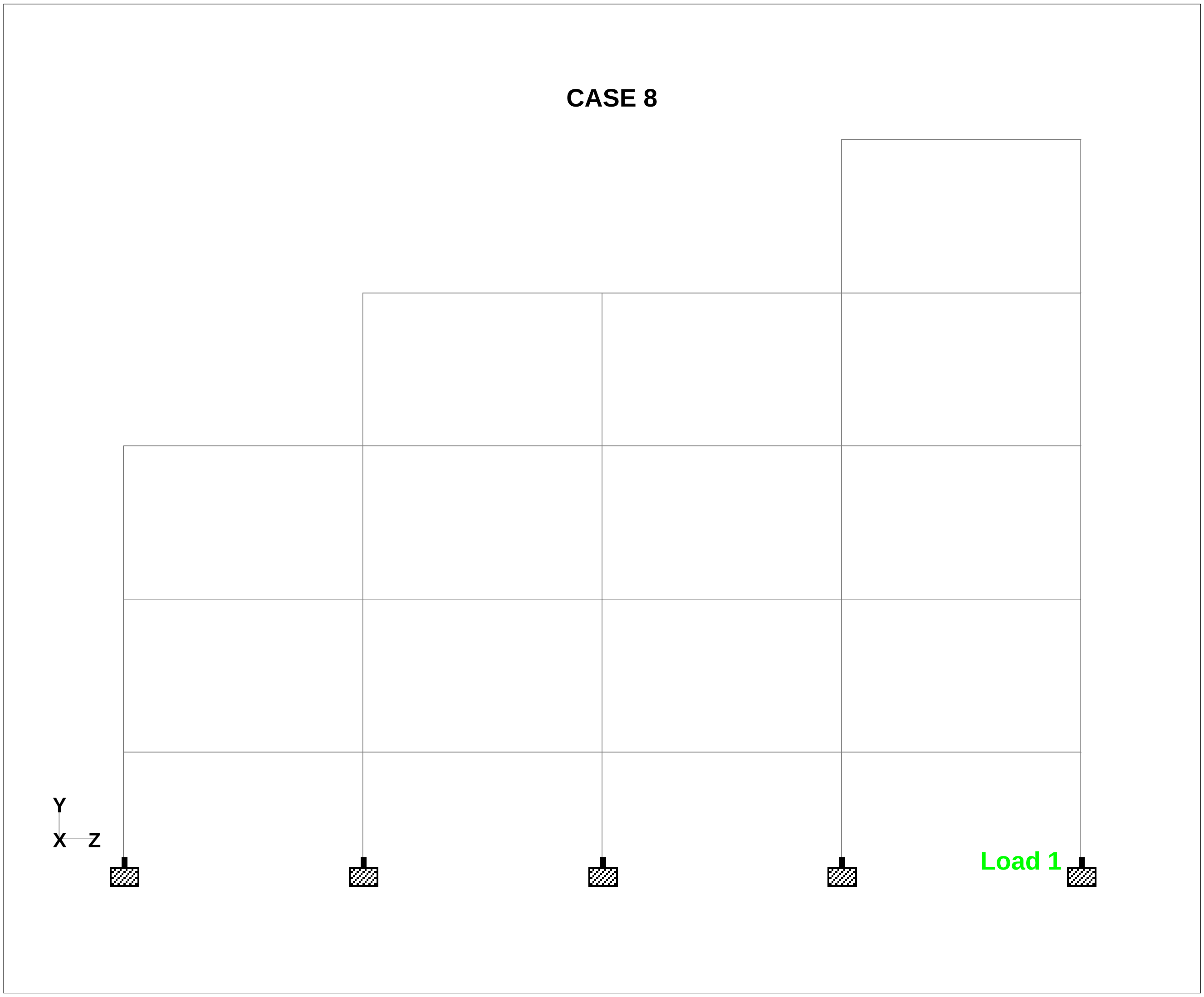

CASE 4
Y
X
Z
Load 1

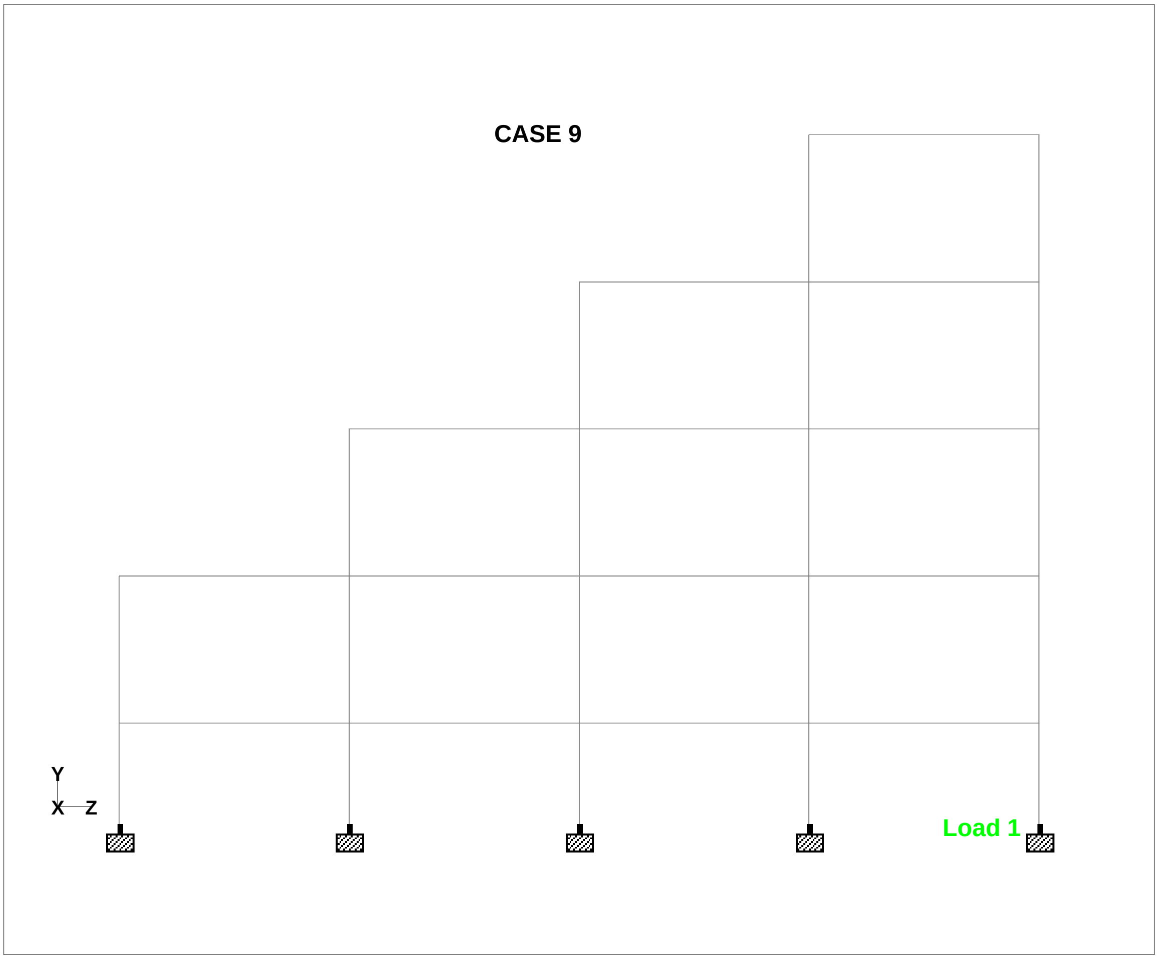

CASE 5
Y
X
Z
Load 1

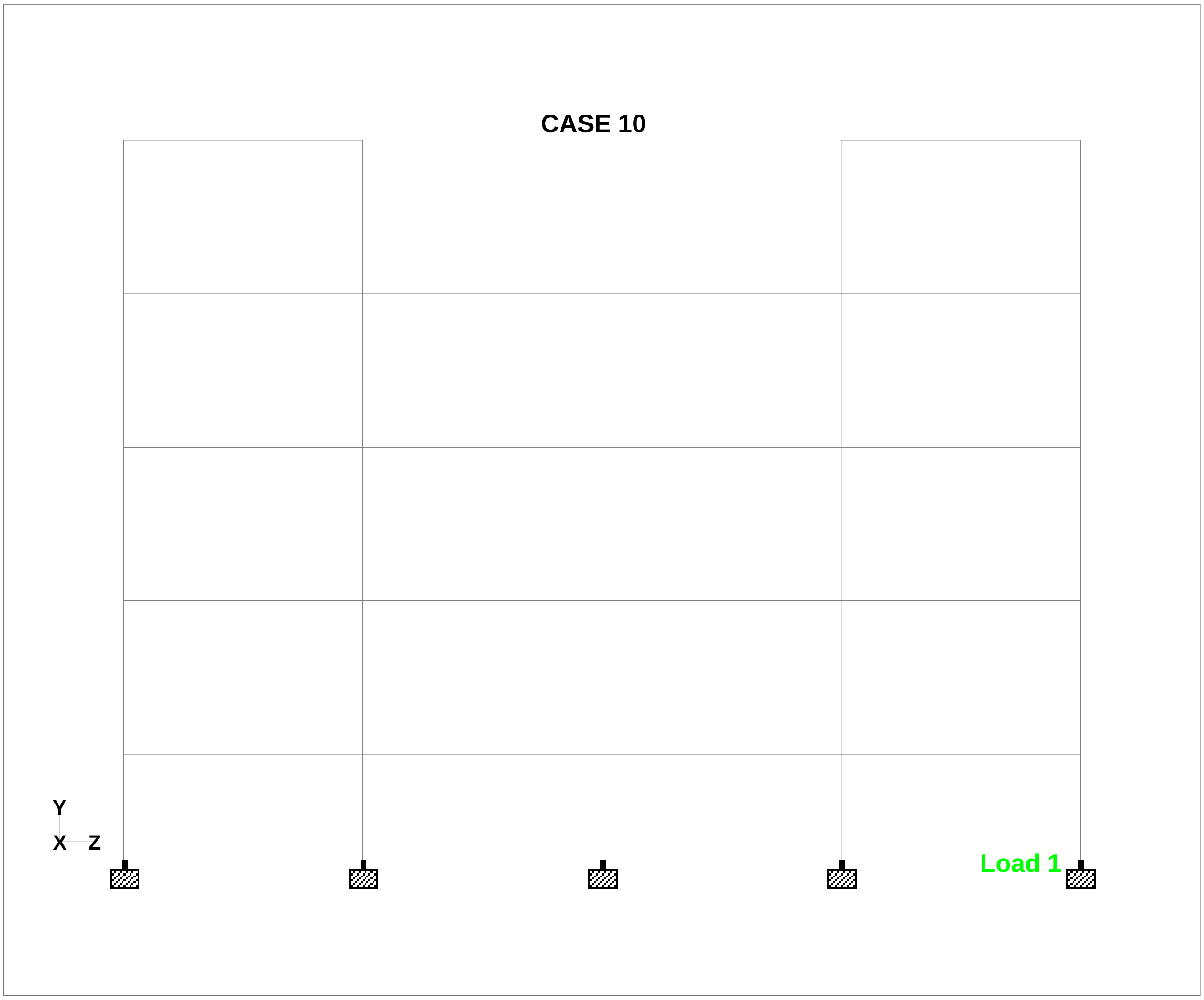


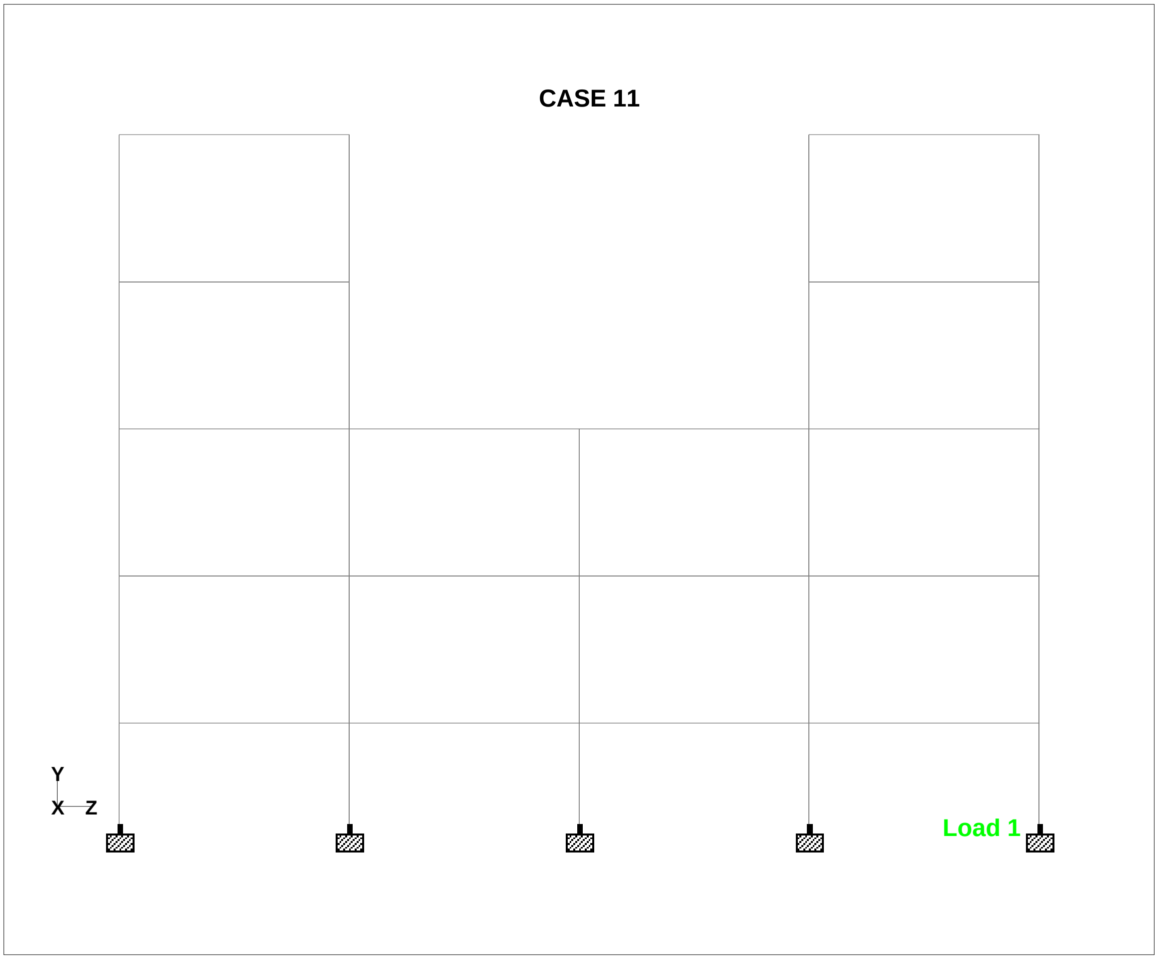
CASE 6
Y
X
Z
Load 1

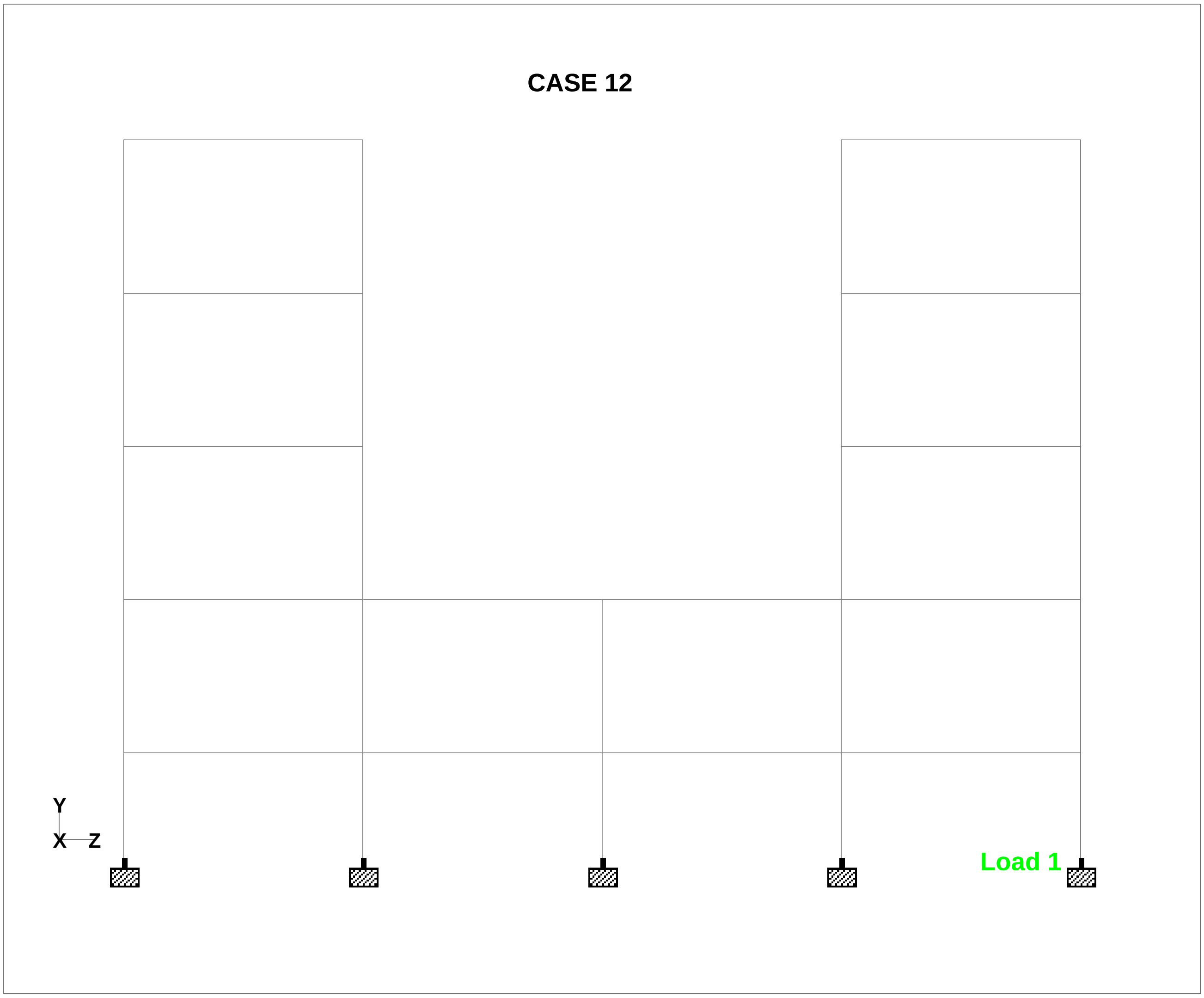

CASE 7
Y
X
Z
Load 1

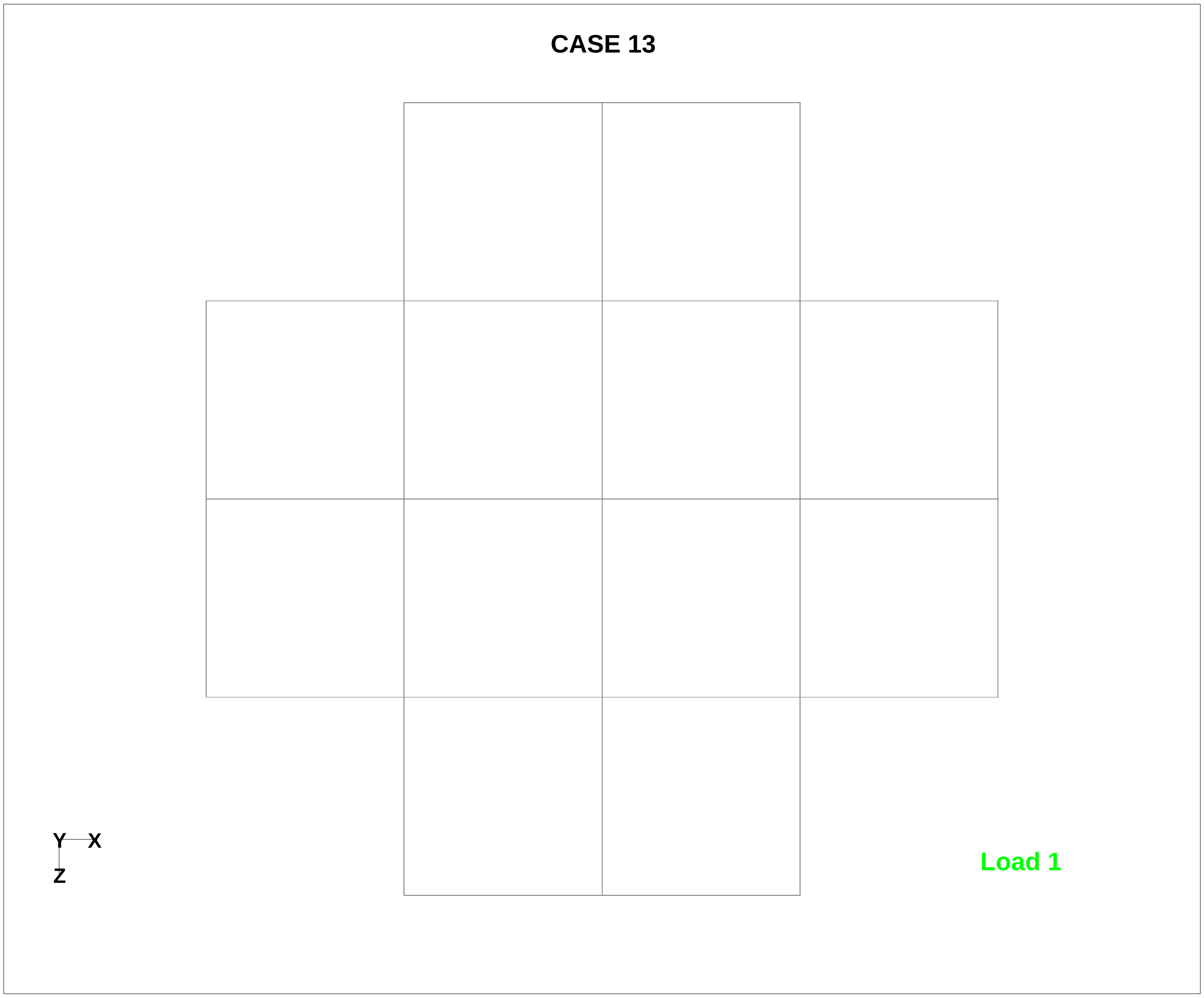

CASE 8
Y
X
Z
Load 1


CASE 9
Y
X
Z
Load 1

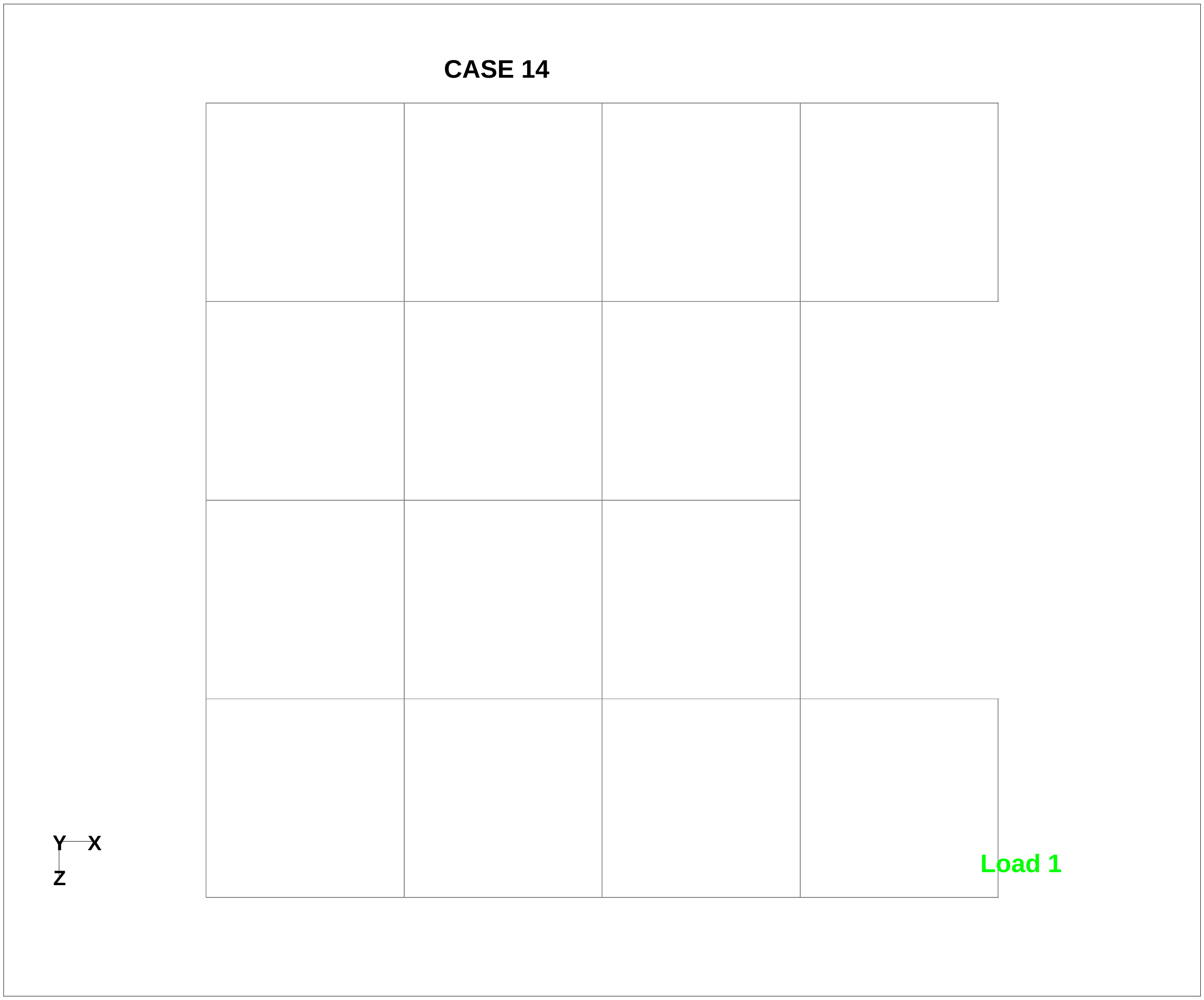

CASE 10
Y
X
Z
Load 1

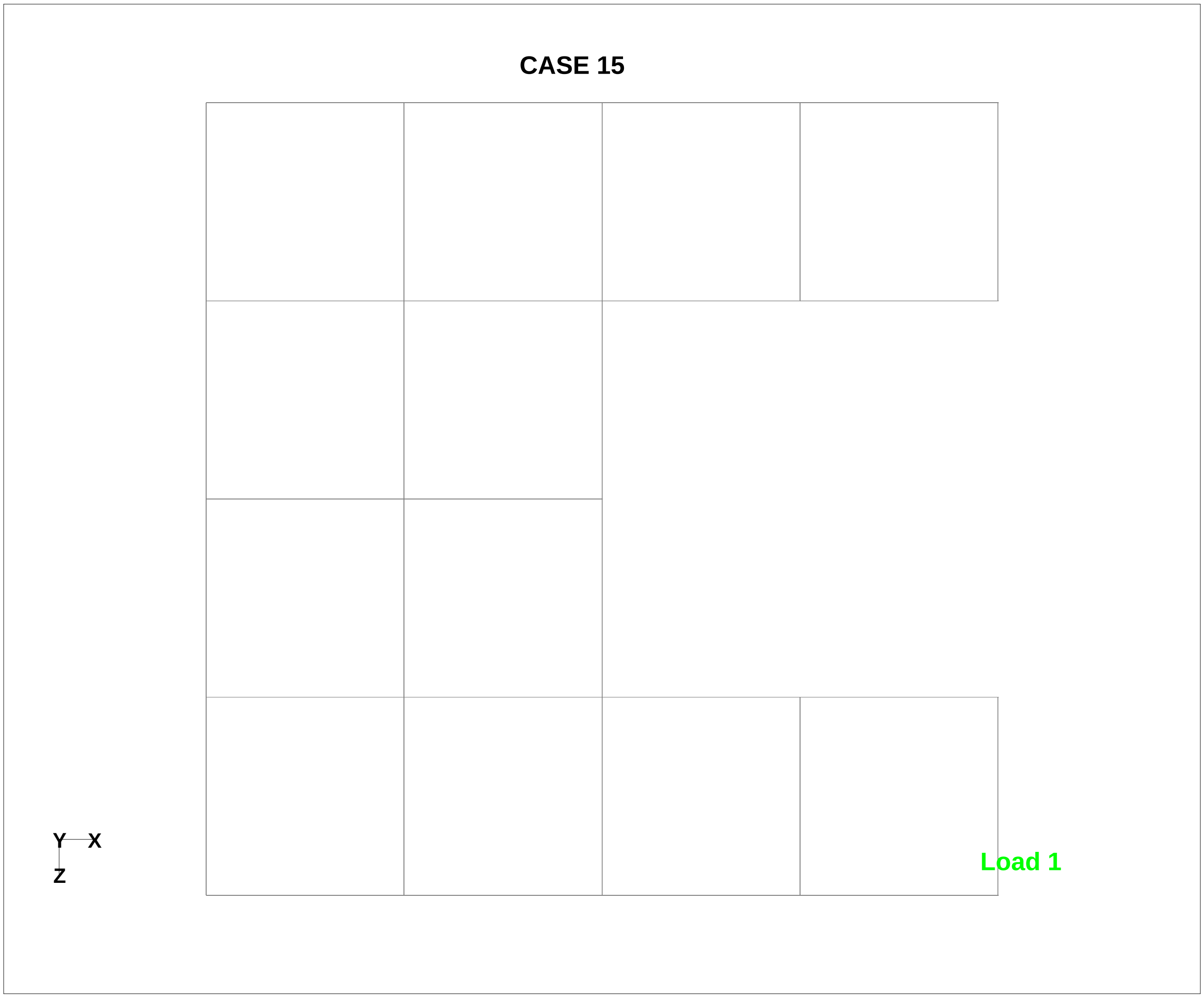

CASE 11
Y
X
Z
Load 1


CASE 12
Y
X
Z
Load 1

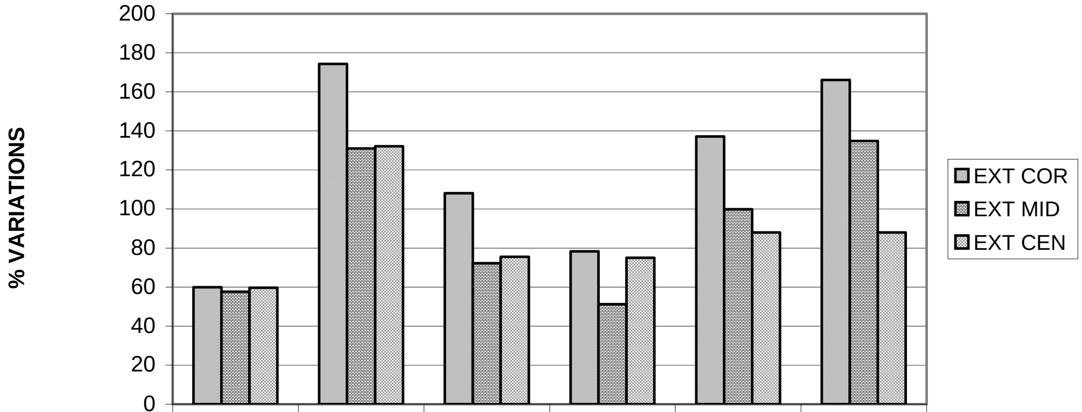


CASE 13
Y
X
Z
Load 1


CASE 14
Y
X
Z
Load 1


CASE 15
Y X
Z
Load 1

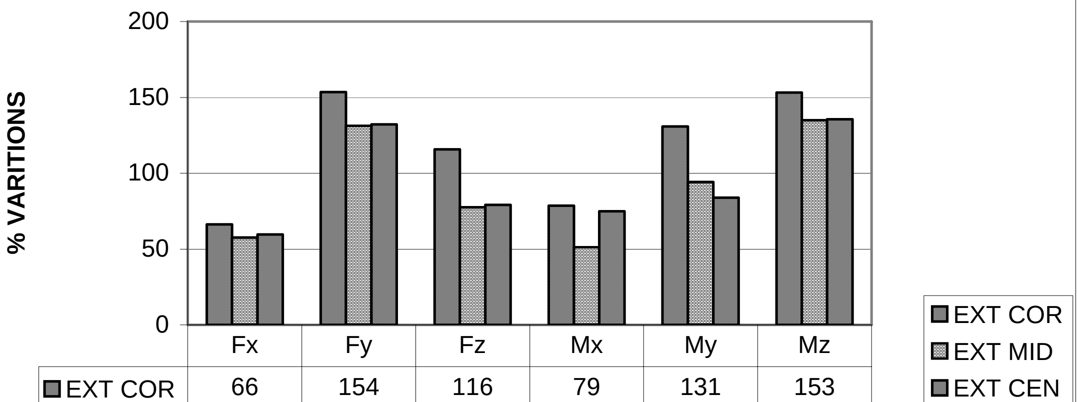
MAX INCREASE IN MEMBER FORCES IN DIFFERENT CASES OF GF COLUMNS DUE TO VERTICAL IRREGULARITY IN SEISMIC ZONE II



	Fx	Fy	Fz	Mx	My	Mz
EXT COR	60	174	108	78	137	166
EXT MID	58	131	72	51	100	135
EXT CEN	60	132	75	75	88	88

MEMBER FORCES / MOMENTS

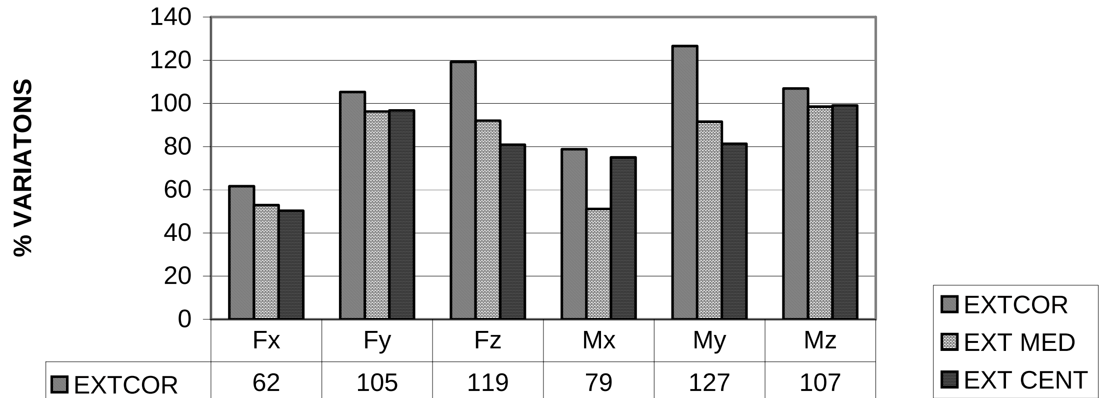
MAX INCREASE IN MEMBER FORCES IN DIFFERENT CASES OF GF COLUMNS DUE TO V. I. IN SEISMIC ZONE III



	Fx	Fy	Fz	Mx	My	Mz
EXT COR	66	154	116	79	131	153
EXT MID	58	131	78	51	94	135
EXT CEN	60	132	79	75	84	136

MEMBER FORCES / MOMENTS

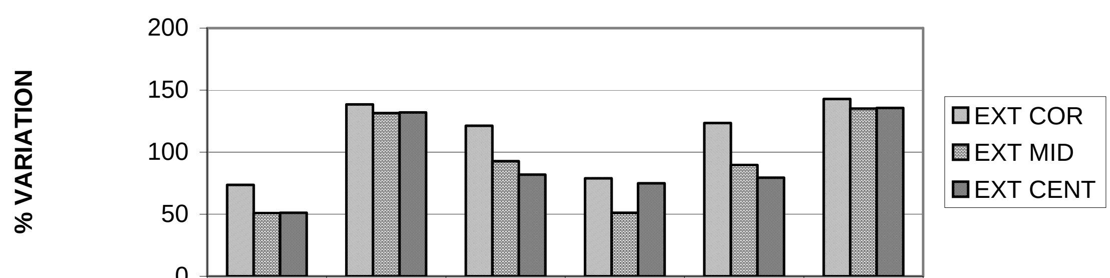
MAX INCREASE IN MEMBER FORCES IN DIFFERENT CASES OF GF COLUMNS DUE TO V. I. SEISMIC ZONE IV



	Fx	Fy	Fz	Mx	My	Mz
EXTCOR	62	105	119	79	127	107
EXT MED	53	96	92	51	92	99
EXT CENT	50	97	81	75	81	99

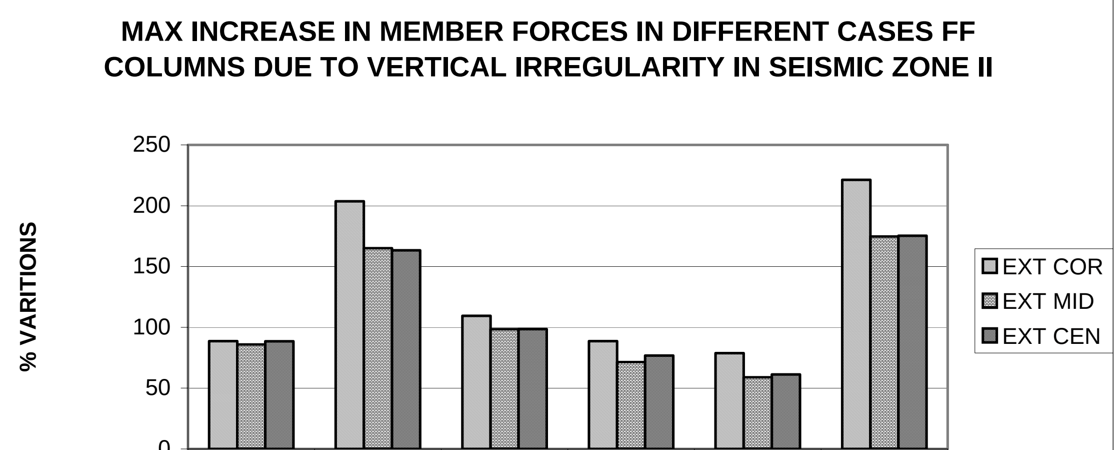
MEMBER FORCES / MOMENTS

MAX INCREASE IN MEMBER FORCES IN DIFFERENT CASES OFGF COLUMNS DUE TO CHANGE V. I. IN SEISMIC ZONE V



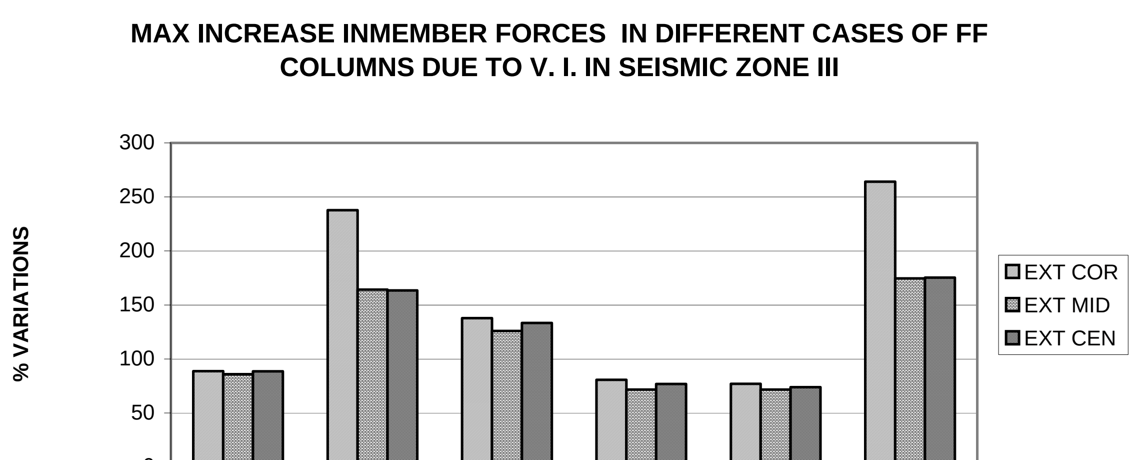
	Fx	Fy	Fz	Mx	My	Mz
EXT COR	74	138	121	79	124	143
EXT MID	51	132	93	51	90	135
EXT CENT	51	132	82	75	79	136

MEMBER FORCES / MOMENTS



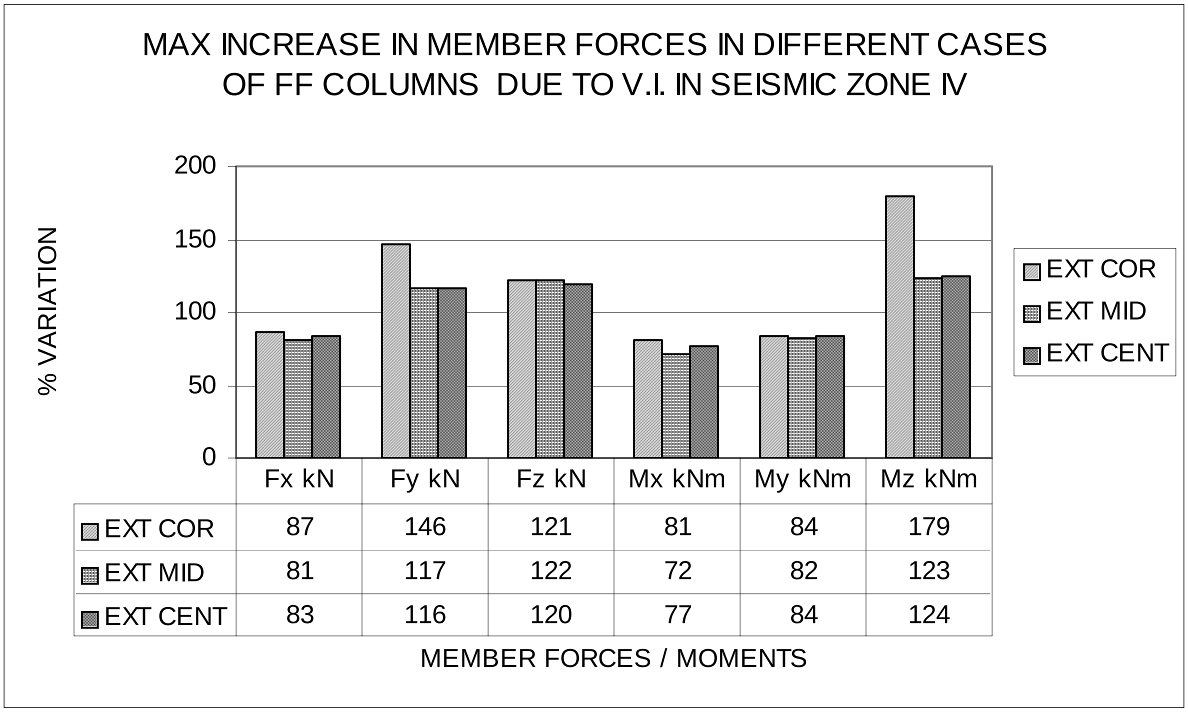
	Fx	Fy	Fz	Mx	My	Mz
EXT COR	89	204	109	89	79	221
EXT MID	86	165	98	71	59	175
EXT CEN	89	163	99	77	61	175

MEMBER FORCES / MOMENTS

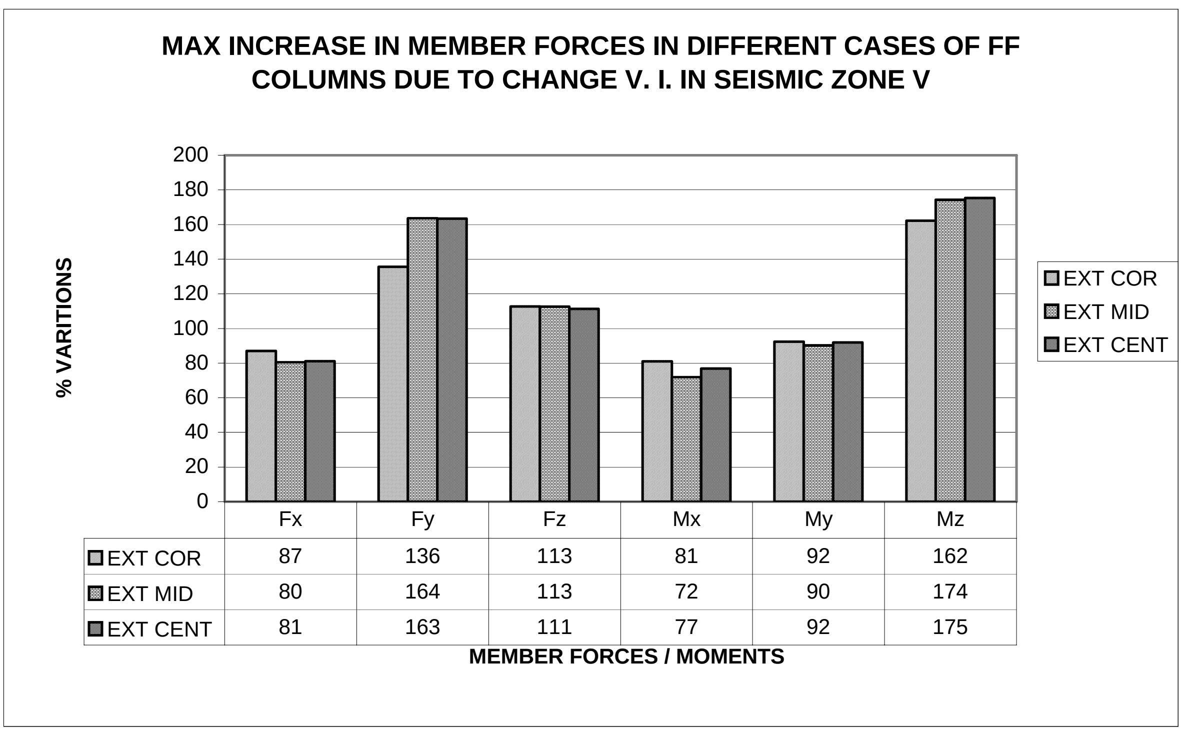


	Fx	Fy	Fz	Mx	My	Mz
EXT COR	89	238	138	81	77	264
EXT MID	86	164	126	72	72	174
EXT CEN	89	163	133	77	74	175

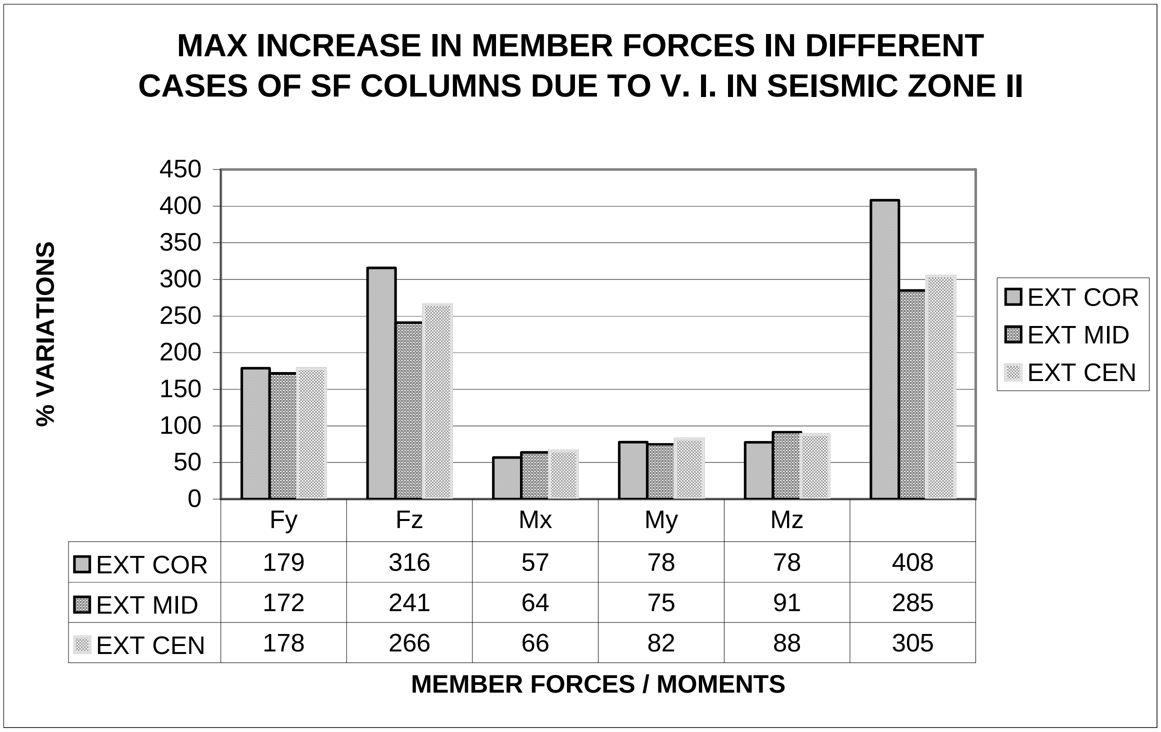
MEMBER FORCES / MOMENTS



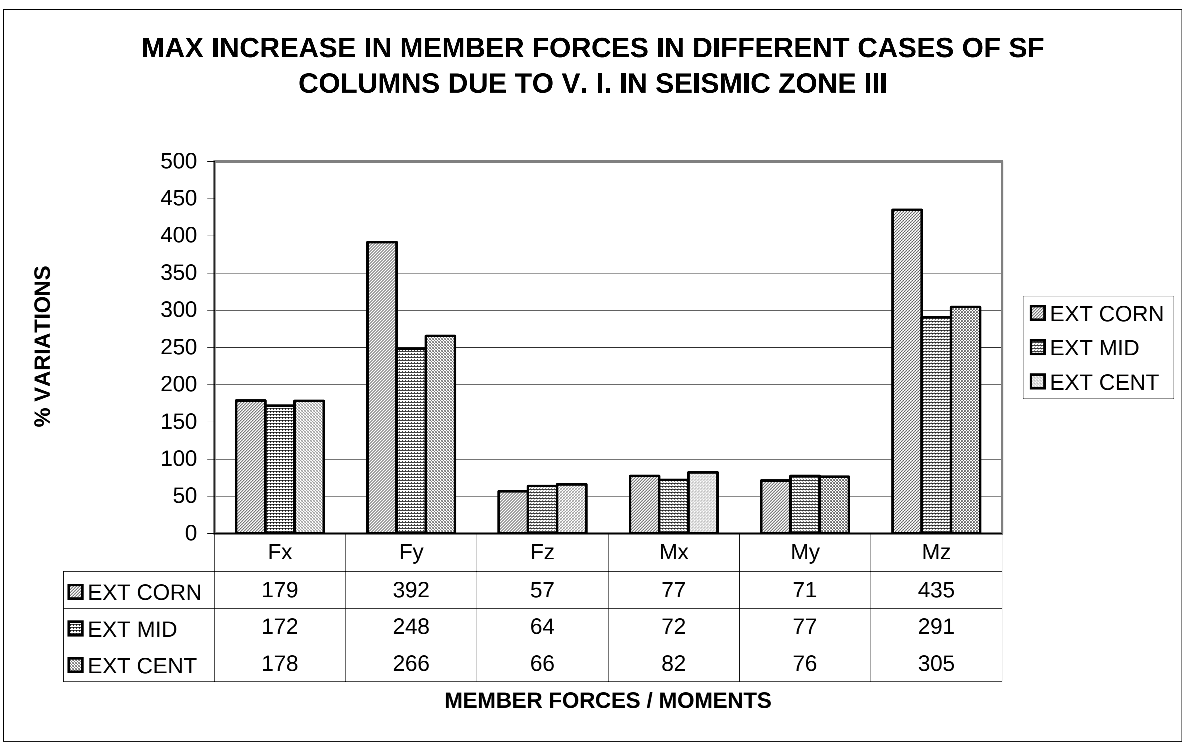
	Fx kN	Fy kN	Fz kN	Mx kNm	My kNm	Mz kNm
EXT COR	87	146	121	81	84	179
EXT MID	81	117	122	72	82	123
EXT CENT	83	116	120	77	84	124



	Fx	Fy	Fz	Mx	My	Mz
EXT COR	87	136	113	81	92	162
EXT MID	80	164	113	72	90	174
EXT CENT	81	163	111	77	92	175

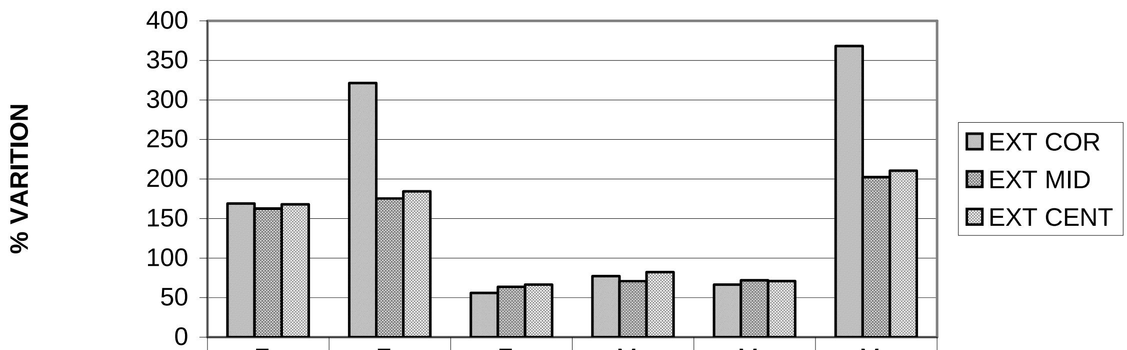


	Fy	Fz	Mx	My	Mz	
EXT COR	179	316	57	78	78	408
EXT MID	172	241	64	75	91	285
EXT CEN	178	266	66	82	88	305



	Fx	Fy	Fz	Mx	My	Mz
EXT CORN	179	392	57	77	71	435
EXT MID	172	248	64	72	77	291
EXT CENT	178	266	66	82	76	305

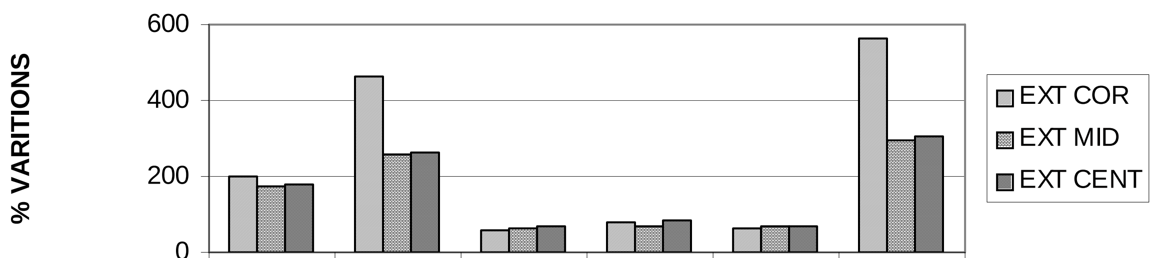
MAX INCREASE IN MEMBER FORCS IN DIFFERENT CASES OF SF COLUMNS DUE TO V. I. IN SEISMIC ZONE IV



	Fx	Fy	Fz	Mx	My	Mz
EXT COR	169	321	56	77	66	368
EXT MID	163	175	64	71	72	202
EXT CENT	168	184	66	82	71	211

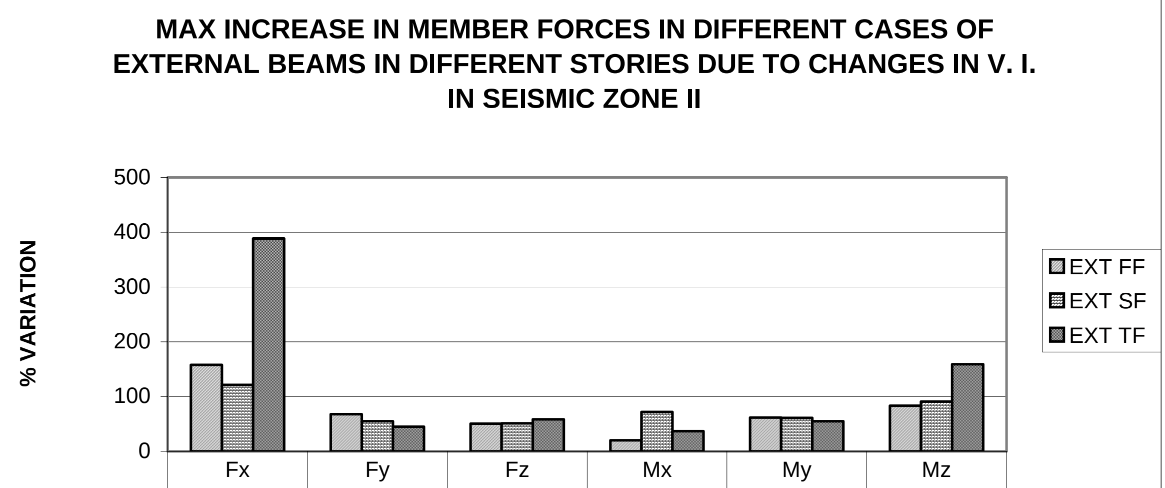
MEMBER FORCES / MOMENTS

MAX INCREASE IN MEMBER FORCES IN DIFFERENT CASES OF SF COLUMNS DUE TO CHANGE V. I. IN SEISMIC ZONE V

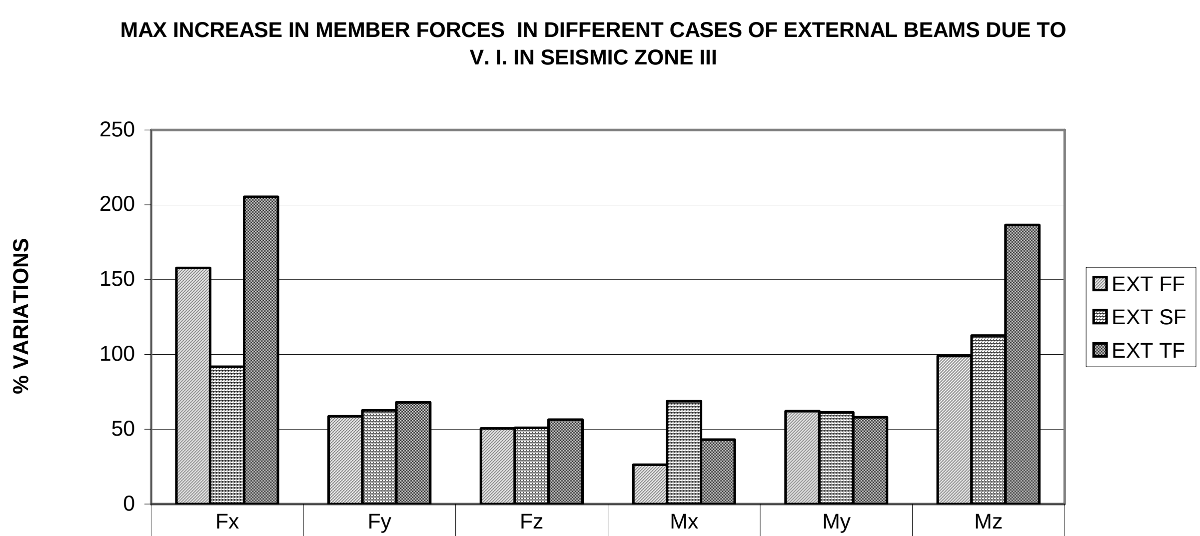


	Fx	Fy	Fz	Mx	My	Mz
EXT COR	198	465	56	77	63	561
EXT MID	172	255	64	70	67	296
EXT CENT	178	266	66	82	66	305

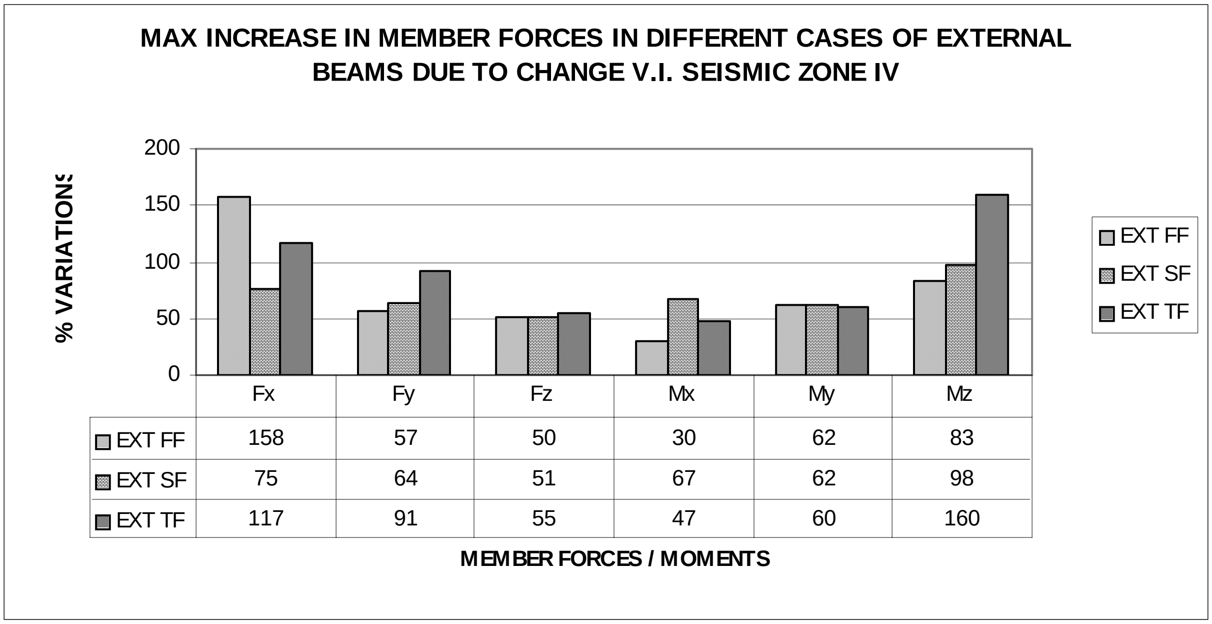
MEMBER FORCES / MOMENTS



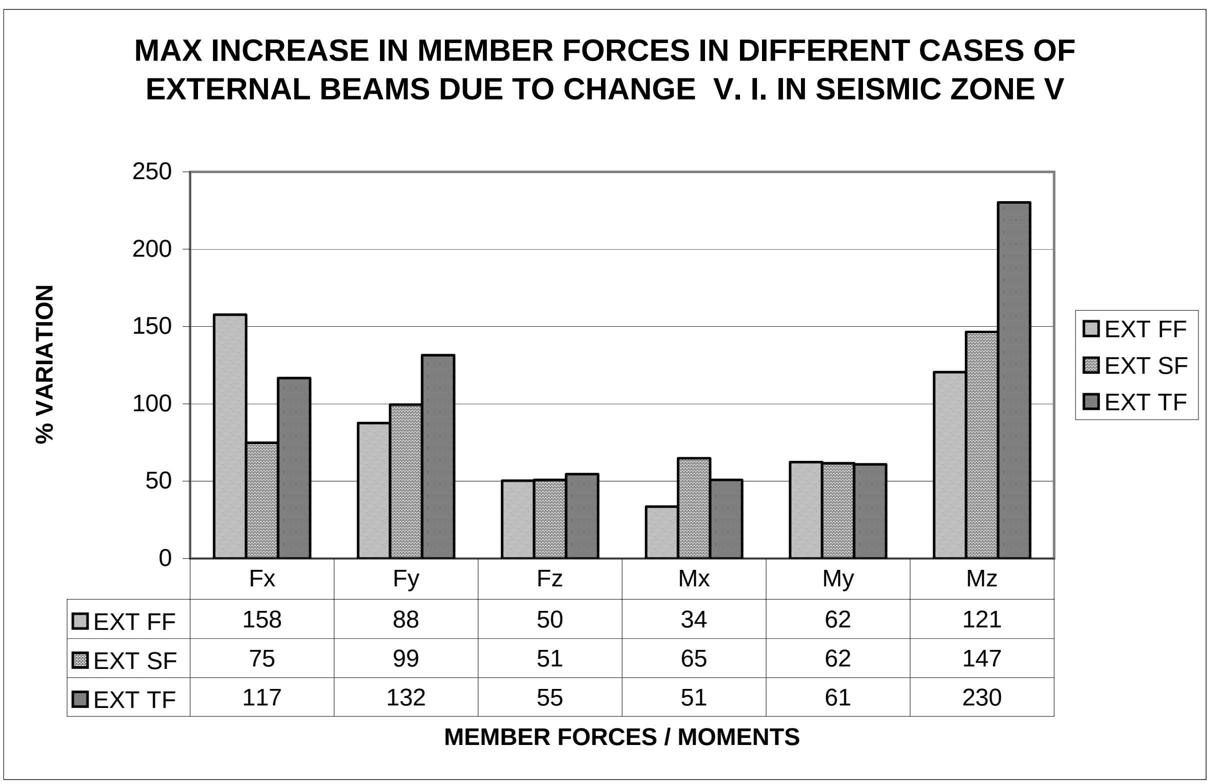
	Fx	Fy	Fz	Mx	My	Mz
EXT FF	158	68	51	20	62	83
EXT SF	121	55	51	72	61	91
EXT TF	389	45	58	37	55	159



	Fx	Fy	Fz	Mx	My	Mz
EXT FF	158	59	51	26	62	99
EXT SF	92	63	51	69	61	113
EXT TF	205	68	56	43	58	186

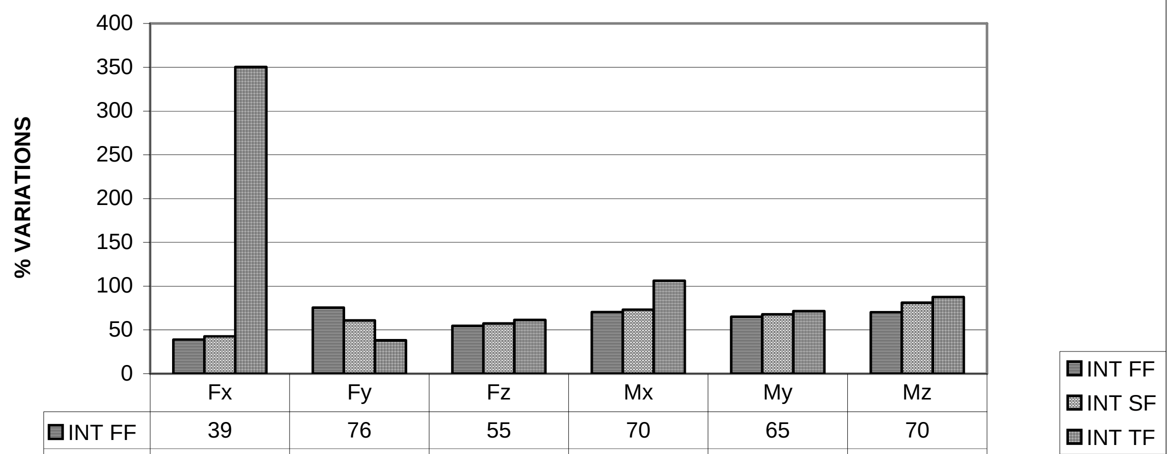


	Fx	Fy	Fz	Mx	My	Mz
EXT FF	158	57	50	30	62	83
EXT SF	75	64	51	67	62	98
EXT TF	117	91	55	47	60	160



	Fx	Fy	Fz	Mx	My	Mz
EXT FF	158	88	50	34	62	121
EXT SF	75	99	51	65	62	147
EXT TF	117	132	55	51	61	230

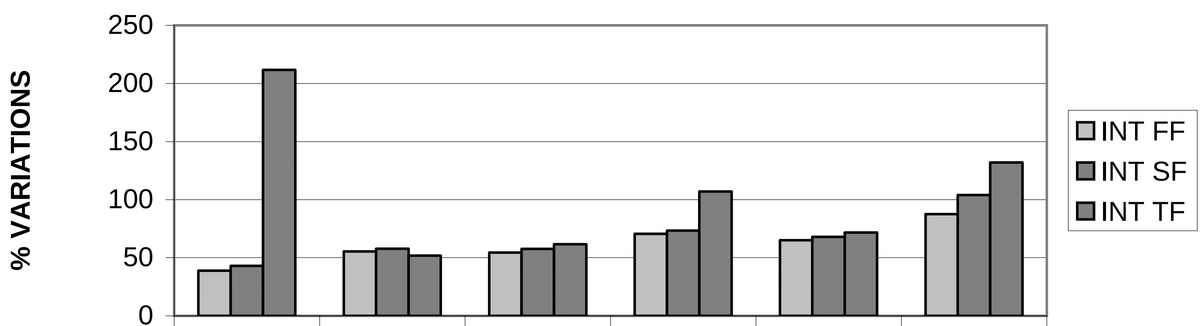
MAX INCREASE IN MEMBER FORCES IN DIFFERENT CASES OF INTERNAL BEAMS IN DIFFERENT STORIES DUE TO CHANGES IN V. I. IN SEISMIC ZONE II



	Fx	Fy	Fz	Mx	My	Mz
INT FF	39	76	55	70	65	70
INT SF	42	61	58	73	68	81
INT TF	350	38	62	106	72	88

MEMBER FORCES / MOMENTS

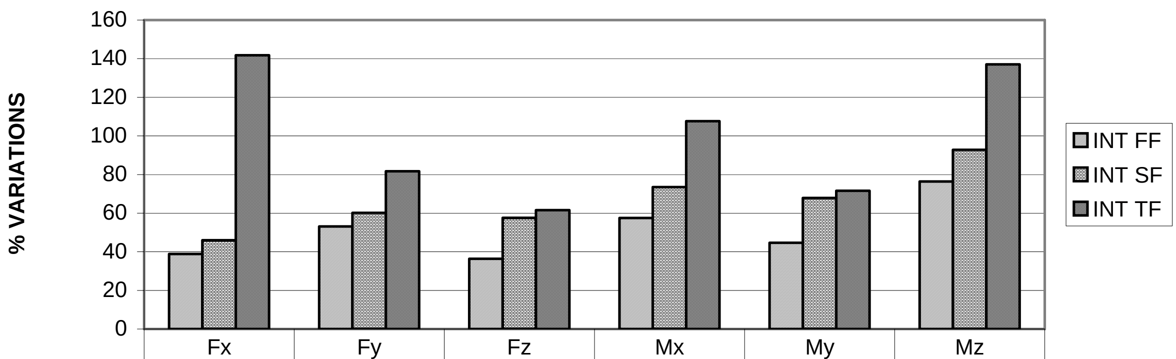
MAX INCREASE IN MEMBER FORCES IN DIFFERENT CASES OF INTERNAL FF BEAMS DUE TO V. I. IN SEISMIC ZONE III



	Fx	Fy	Fz	Mx	My	Mz
INT FF	39	55	54	71	65	88
INT SF	43	58	58	73	68	104
INT TF	212	52	62	107	72	132

MEMBER FORCES / MOMENTS

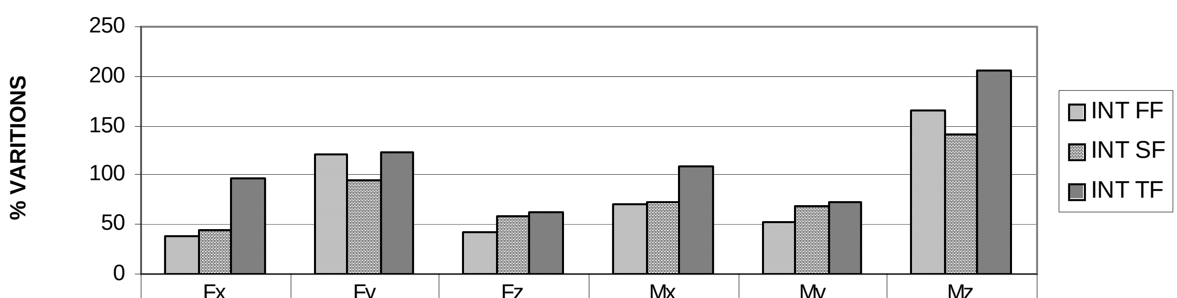
MAX INCREASE IN MEMBER FORCES IN DIFFERENT CASES OF INTERNAL BEAMS DUE TO CHANGE V. I. IN SEISMIC ZONE IV



	Fx	Fy	Fz	Mx	My	Mz
INT FF	39	53	36	58	45	76
INT SF	46	60	58	73	68	93
INT TF	142	82	62	108	72	137

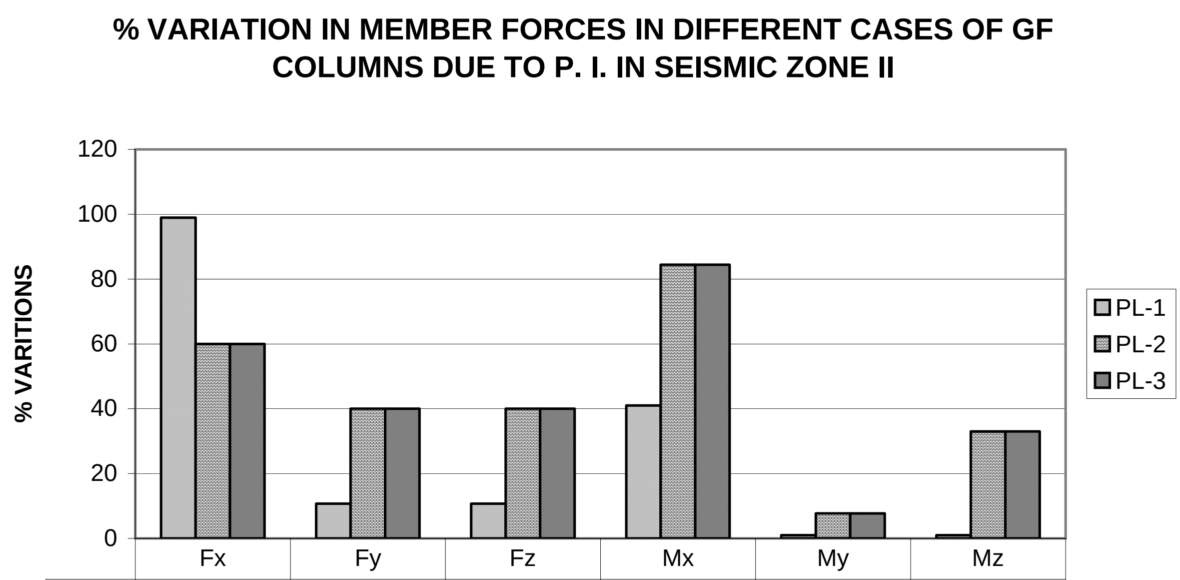
MEMBER FORCES / MOMENTS

MAX INCREASE IN MEMBER FORCES IN DIFFERENT CASES OF INTERNAL BEAMS DUE TO CHANGE V. I. IN SEISMIC ZONE V



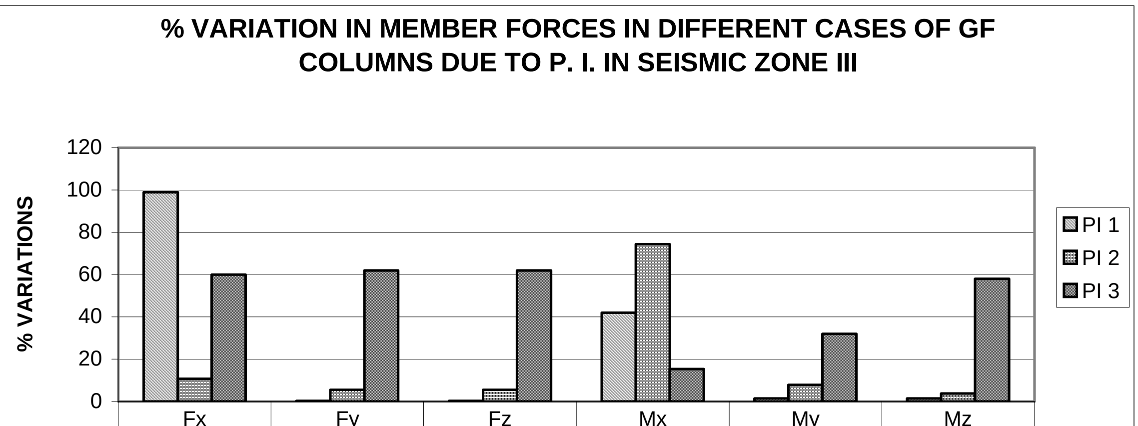
	Fx	Fy	Fz	Mx	My	Mz
INT FF	39	121	42	70	52	166
INT SF	45	95	58	74	68	141
INT TF	97	123	62	108	72	205

MEMBER FORCES / MOMENTS



	Fx	Fy	Fz	Mx	My	Mz
PL-1	99	11	11	41	1	1
PL-2	60	40	40	84	8	33
PL-3	60	40	40	84	8	33

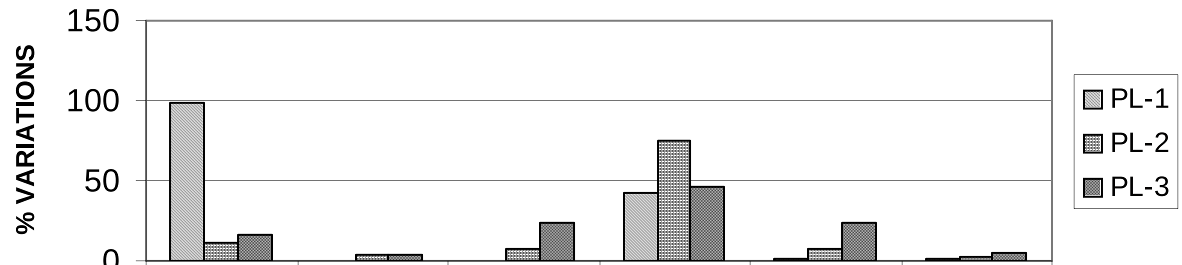
MEMBER FORCES / MOMENTS



	Fx	Fy	Fz	Mx	My	Mz
PI 1	99	0	0	42	1	1
PI 2	11	6	5	74	8	4
PI 3	60	62	62	15	32	58

MEMBER FORCES / MOMENNTS

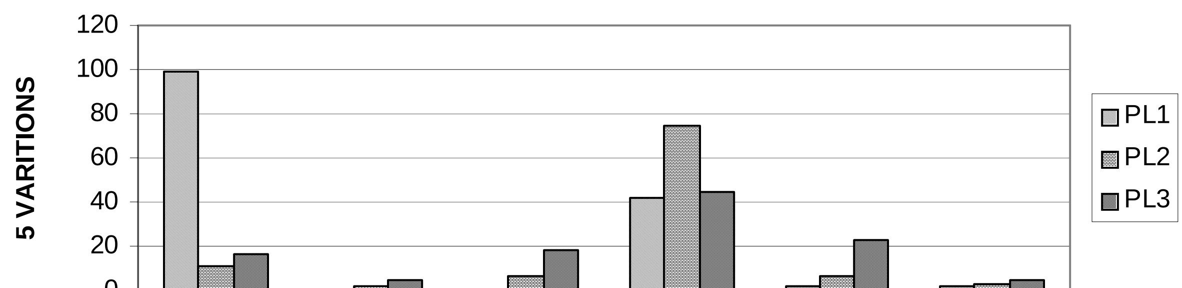
% VARITON IN MEMBER FORCES IN DIFFERENT CASES OF GF COLUMNS DUE TO CHANGE P. I. IN SEISMIC ZONE IV



	Fx	Fy	Fz	Mx	My	Mz
PL-1	99	0	0	42	2	2
PL-2	11	3	8	75	7	3
PL-3	16	4	23	46	23	5

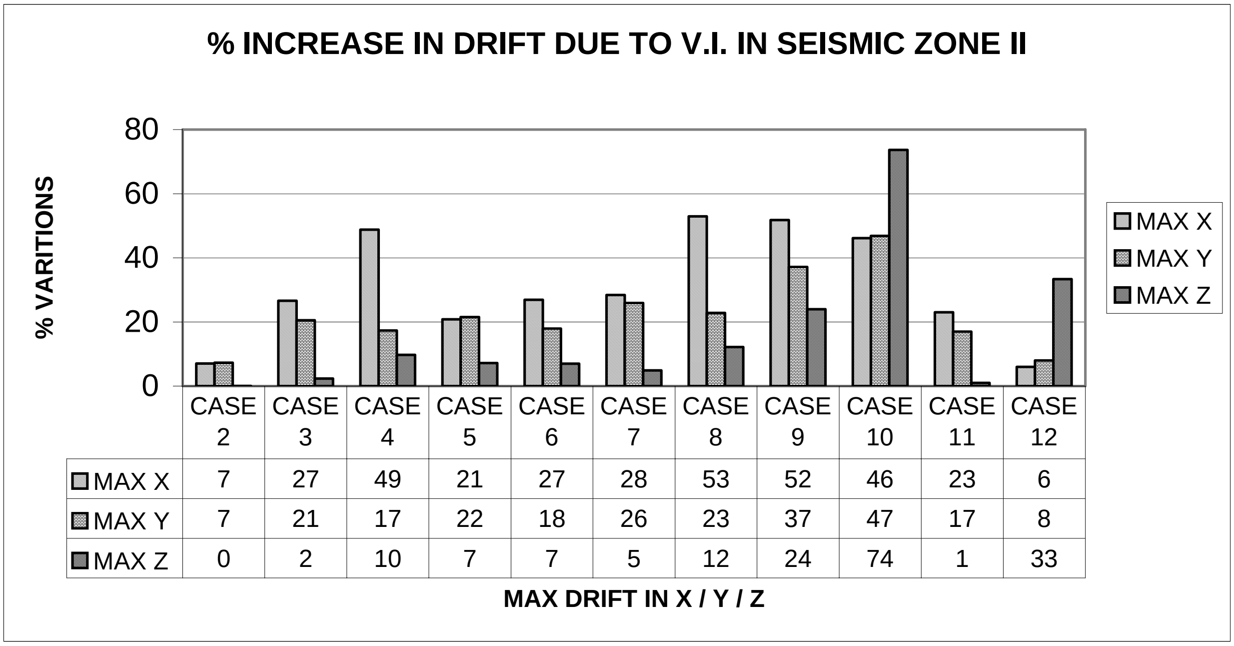
MEMBER FORCES / MOMENTS

% VARIATION IN MEMBER FORCES IN DIFFERENT CASES OF GF COLUMNS DUE TO CHANGE P. I. IN SEISMIC ZONE V

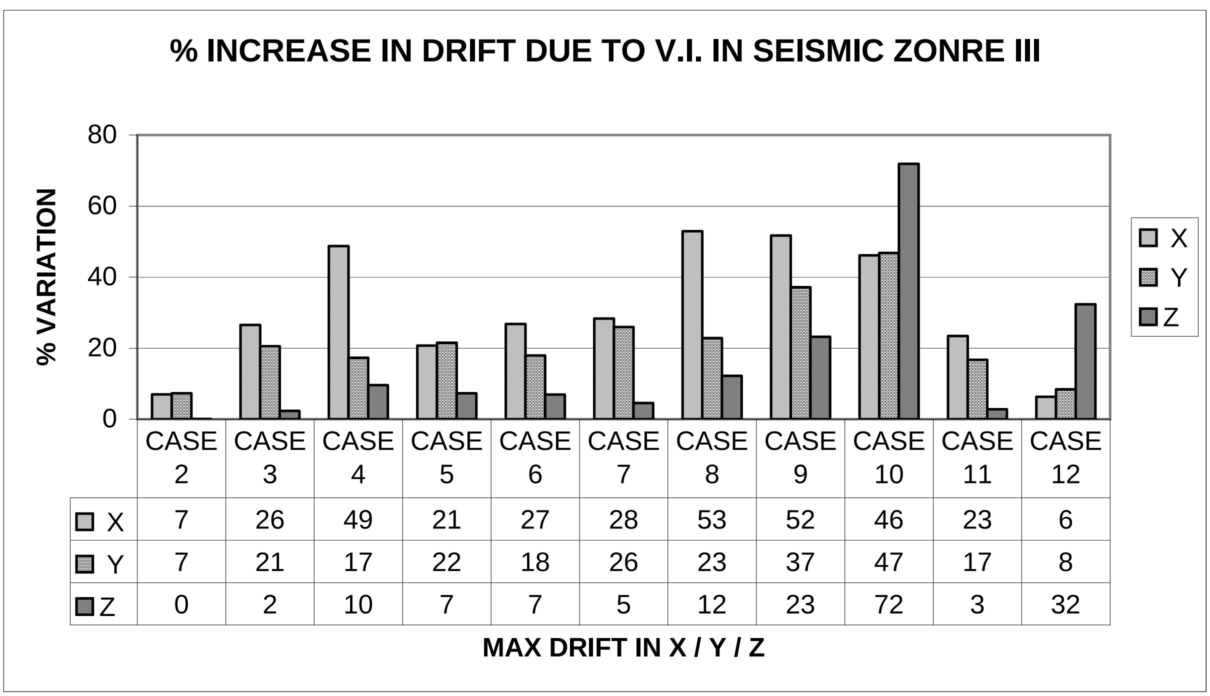


	Fx	Fy	Fz	Mx	My	Mz
PL1	99	0	0	42	2	2
PL2	11	2	7	75	7	2
PL3	16	4	18	45	23	5

MEMBER FORCES / MOMENTS

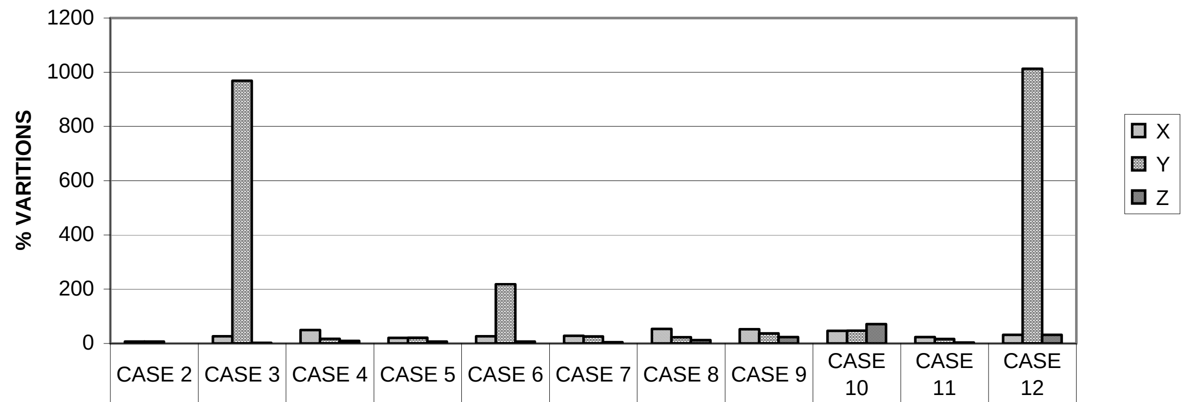


	CASE 2	CASE 3	CASE 4	CASE 5	CASE 6	CASE 7	CASE 8	CASE 9	CASE 10	CASE 11	CASE 12
MAX X	7	27	49	21	27	28	53	52	46	23	6
MAX Y	7	21	17	22	18	26	23	37	47	17	8
MAX Z	0	2	10	7	7	5	12	24	74	1	33



	CASE 2	CASE 3	CASE 4	CASE 5	CASE 6	CASE 7	CASE 8	CASE 9	CASE 10	CASE 11	CASE 12
X	7	26	49	21	27	28	53	52	46	23	6
Y	7	21	17	22	18	26	23	37	47	17	8
Z	0	2	10	7	7	5	12	23	72	3	32

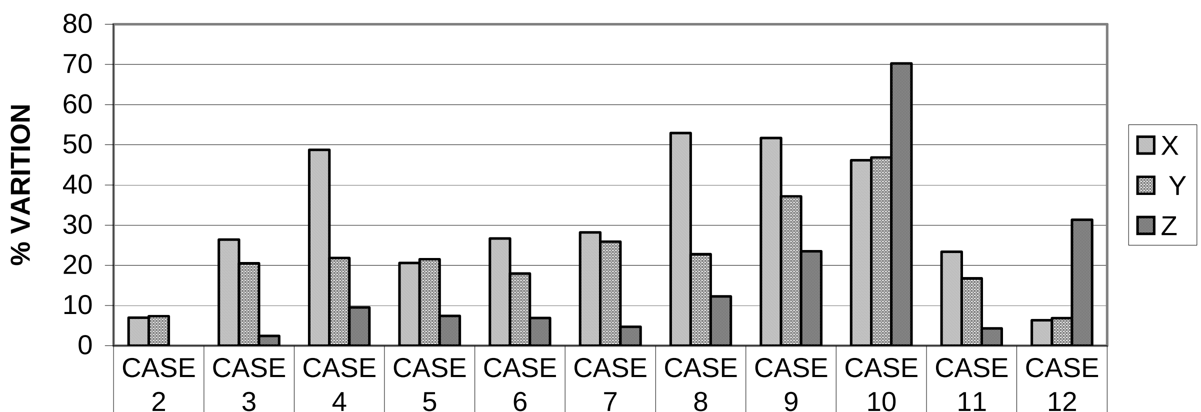
% INCREASE IN DRIFT DUE TO V.I. IN SEISMIC ZONE IV



	CASE 2	CASE 3	CASE 4	CASE 5	CASE 6	CASE 7	CASE 8	CASE 9	CASE 10	CASE 11	CASE 12
X	7	26	49	21	27	28	53	52	46	23	32
Y	7	968	17	22	218	26	23	37	47	17	1013
Z	0	2	10	7	7	5	12	23	71	4	32

MAX DRIFT IN X / Y / Z

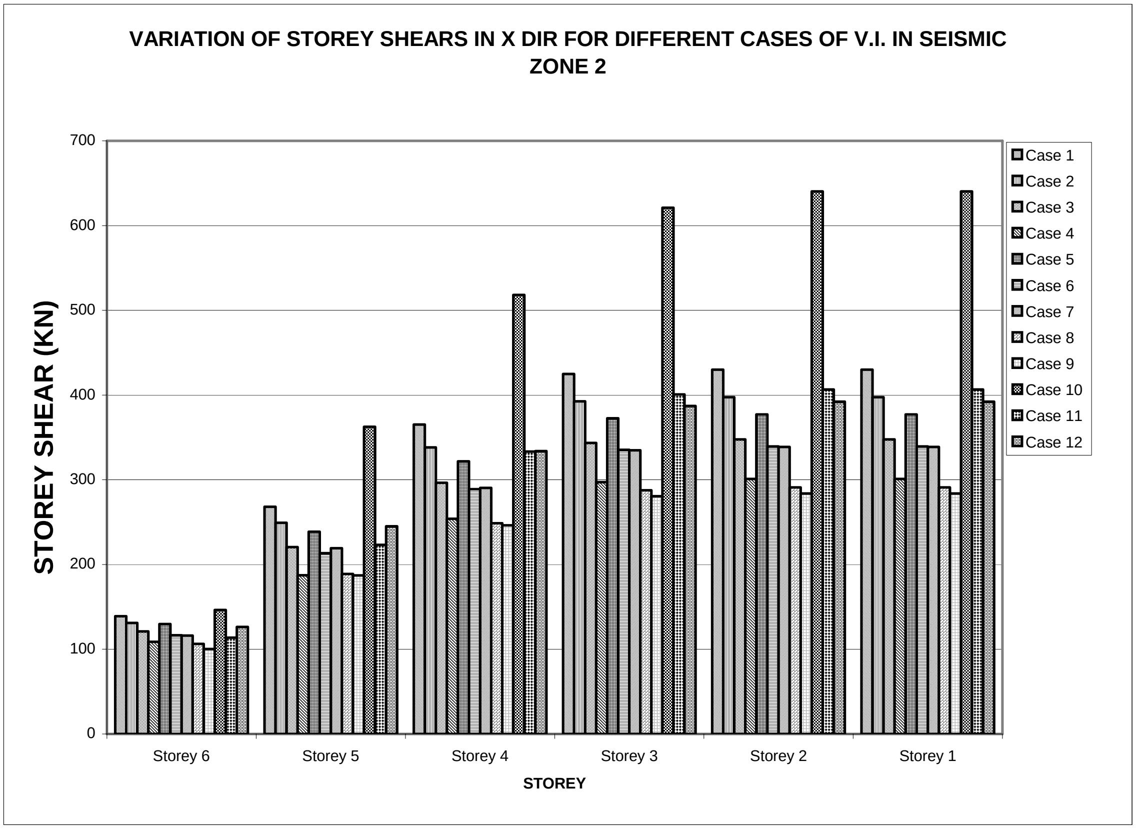
% INCREASE IN DRIFT DUE TO V.I. IN SEISMIC ZONE V



	CASE 2	CASE 3	CASE 4	CASE 5	CASE 6	CASE 7	CASE 8	CASE 9	CASE 10	CASE 11	CASE 12
X	7	26	49	21	27	28	53	52	46	23	6
Y	7	21	22	22	18	26	23	37	47	17	7
Z	0	2	9	7	7	5	12	24	70	4	31

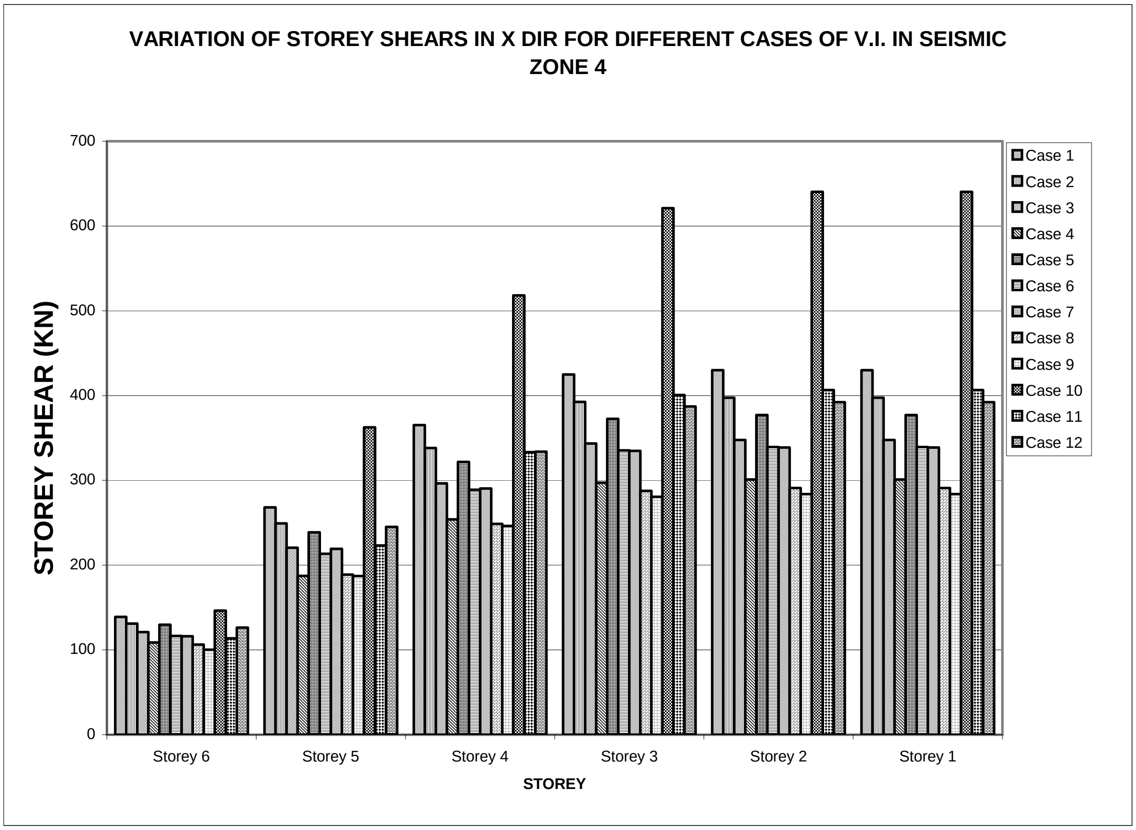
MAX DRIFT IN X / Y/ Z

[redacted]


VARIATION OF STOREY SHEARS IN X DIR FOR DIFFERENT CASES OF V.I. IN SEISMIC ZONE 2
STOREY SHEAR (KN)
0
100
200
300
400
500
600
700
Storey 6
Storey 5
Storey 4
Storey 3
Storey 2
Storey 1
STOREY
Case 1
Case 2
Case 3
Case 4
Case 5
Case 6
Case 7
Case 8
Case 9
Case 10
Case 11
Case 12

[redacted]

[redacted]



VARIATION OF STOREY SHEARS IN X DIR FOR DIFFERENT CASES OF V.I. IN SEISMIC ZONE 4
STOREY SHEAR (KN)
0
100
200
300
400
500
600
700
Storey 6
Storey 5
Storey 4
Storey 3
Storey 2
Storey 1
STOREY
Case 1
Case 2
Case 3
Case 4
Case 5
Case 6
Case 7
Case 8
Case 9
Case 10
Case 11
Case 12

[redacted]

TABLE-1: MEMBER FORCES IN GF EXTERNAL CORNER COLUMN FOR DIFFERENT VARIATIONS OF VERTICAL IRREGULARITY FOR SEISMIC ZONE II

Ground Floor External Corner Column															
Zone II Model Case No.	Column	Node	Env	Fx kN	Fy kN	Fz kN	Mx kNm	My kNm	Mz kNm	Comaprision in Percentage Due to change in V.I.					
										Fx	Fy	Fz	Mx	My	Mz
1	4021	126	+ve	531.62	18.96	18.96	1.52	51.09	36.05						
2	4021	126	+ve	557.17	24.47	18.22	1.62	50.38	45.87	4.81%	29.09%	-3.89%	6.99%	-1.39%	27.23%
3	4021	126	+ve	606.61	32.39	17.48	2.08	49.46	60.10	8.87%	32.37%	-4.05%	27.97%	-1.83%	31.03%
4	4021	126	+ve	738.69	40.57	16.94	3.45	47.84	75.26	21.77%	25.23%	-3.11%	65.86%	-3.28%	25.22%
5	4021	126	+ve	407.28	14.83	17.75	3.11	50.39	28.18	-44.86%	-63.43%	4.79%	-9.78%	5.34%	-62.56%
6	4021	126	+ve	398.25	12.06	17.13	2.43	47.24	23.11	-2.22%	-18.72%	-3.50%	-21.85%	-6.26%	-17.99%
7	4021	126	+ve	636.86	33.08	16.65	2.16	48.74	61.49	59.91%	174.32%	-2.81%	-11.20%	3.17%	166.11%
8	4021	126	+ve	769.13	42.69	16.08	3.85	47.06	79.25	20.77%	29.08%	-3.39%	78.30%	-3.44%	28.89%
9	4021	126	+ve	856.73	45.91	14.12	3.57	46.01	83.69	11.39%	7.52%	-12.21%	-7.23%	-2.24%	5.60%
10	4021	126	+ve	1134.46	34.30	29.38	2.46	109.08	64.38	32.42%	-25.28%	108.05%	-31.03%	137.10%	-23.07%
11	4021	126	+ve	600.40	21.23	15.19	1.47	43.33	40.18	-47.08%	-38.10%	-48.30%	-40.11%	-60.28%	-37.59%
12	4021	126	+ve	751.72	27.87	14.68	1.89	44.96	51.08	25.20%	31.28%	-3.31%	27.95%	3.78%	27.13%
									Max	59.91%	174.32%	108.05%	78.30%	137.10%	166.11%

TABLE-2: MEMBER FORCES IN GF EXTERNAL MIDDLE COLUMN FOR DIFFERENT VARIATIONS OF VERTICAL IRREGULARITY FOR SEISMIC ZONE II

Ground Floor External MIDDLE Column															
Zone II Model Case No.	Colum n	Node	Env	Fx kN	Fy kN	Fz kN	Mx kNm	My kNm	Mz kNm	Comaprision in Percentage Due to change in V.I.					
1	4022	127	+ve	877.61	37.10	23.83	1.69	66.84	62.03	Fx	Fy	Fz	Mx	My	Mz
2	4022	127	+ve	921.61	45.79	23.41	1.81	66.89	76.64	5.01%	23.42%	-1.76%	7.54%	0.08%	23.54%
3	4022	127	+ve	1009.52	58.29	23.00	1.96	66.89	97.74	9.54%	27.29%	-1.73%	8.17%	0.00%	27.54%
4	4022	127	+ve	1250.99	71.29	23.09	2.96	65.56	120.09	23.92%	22.31%	0.37%	51.22%	-1.99%	22.86%
5	4022	127	+ve	687.89	30.47	22.45	1.93	67.05	50.43	-45.01%	-57.26%	-2.78%	-35.05%	2.28%	-58.01%
6	4022	127	+ve	674.27	25.84	23.27	2.12	65.03	42.58	-1.98%	-15.21%	3.66%	10.23%	-3.02%	-15.55%
7	4022	127	+ve	1062.72	59.67	22.41	2.11	66.99	100.01	57.61%	130.94%	-3.70%	-0.57%	3.02%	134.85%
8	4022	127	+ve	1304.10	74.99	22.51	2.87	65.70	126.24	22.71%	25.68%	0.46%	36.11%	-1.92%	26.23%
9	4022	127	+ve	1304.10	74.99	22.51	2.87	65.70	126.24	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
10	4022	127	+ve	1730.77	75.99	38.77	2.81	131.27	126.96	32.72%	1.34%	72.25%	-2.05%	99.81%	0.57%
11	4022	127	+ve	1002.55	40.67	20.21	1.68	58.59	68.00	-42.07%	-46.48%	-47.87%	-40.31%	-55.37%	-46.44%
12	4022	127	+ve	1292.36	49.33	20.10	2.17	60.51	83.07	28.91%	21.30%	-0.58%	29.12%	3.27%	22.16%
									Max	57.61%	130.94%	72.25%	51.22%	99.81%	134.85%

TABLE-3: MEMBER FORCES IN GF EXTERNAL CENTER COLUMN FOR DIFFERENT VARIATIONS OF VERTICAL IRREGULARITY FOR SEISMIC ZONE II

Ground Floor External CEnter Column															
Zone II Model Case No.	Column	Node	Env	Fx kN	Fy kN	Fz kN	Mx kNm	My kNm	Mz kNm	Comaprision in Percentage Due to change in V.I.					
1	4023	128	+ve	884.16	36.55	26.84	0.98	72.18	61.17	Fx	Fy	Fz	Mx	My	Mz
2	4023	128	+ve	929.46	45.11	26.62	1.28	72.65	75.55	5.12%	23.40%	-0.82%	30.23%	0.65%	23.50%
3	4023	128	+ve	1019.82	57.44	26.46	2.23	73.12	96.37	9.72%	27.33%	-0.60%	75.06%	0.65%	27.56%
4	4023	128	+ve	1267.64	70.42	26.83	3.49	72.33	118.62	24.30%	22.61%	1.39%	56.18%	-1.08%	23.09%
5	4023	128	+ve	687.40	29.85	25.75	1.99	73.19	49.52	-45.77%	-57.62%	-4.03%	-42.94%	1.19%	-58.26%
6	4023	128	+ve	672.81	25.30	27.05	1.98	71.76	41.82	-2.12%	-15.22%	5.06%	-0.40%	-1.96%	-15.55%
7	4023	128	+ve	1074.28	58.73	26.05	1.87	73.62	98.55	59.67%	132.11%	-3.72%	-5.55%	2.60%	135.66%
8	4023	128	+ve	1321.91	73.97	26.48	3.13	72.95	124.594	23.05%	25.95%	1.64%	67.29%	-0.91%	26.42%
9	4023	128	+ve	1483.17	77.23	24.87	2.46	74.28	130.139	12.20%	4.40%	-6.08%	-21.37%	1.82%	4.45%
10	4023	128	+ve	1737.86	74.59	43.64	0.67	139.64	124.578	17.17%	-3.41%	75.50%	-72.86%	87.99%	-4.27%
11	4023	128	+ve	1011.91	40.06	23.30	0.37	64.00	67.063	-41.77%	-46.29%	-46.60%	-44.61%	-54.16%	-46.17%
12	4023	128	+ve	1306.33	49.09	23.28	0.25	66.60	82.479	29.10%	22.53%	-0.10%	-33.24%	4.06%	22.99%
									Max	59.67%	132.11%	75.50%	75.06%	87.99%	135.66%

TABLE-4: MEMBER FORCES IN FF EXTERNAL CORNER COLUMN FOR DIFFERENT VARIATIONS OF VERTICAL IRREGULARITY FOR SEISMIC ZONE II

FIRST Floor External Corner Column															
Zone II Model Case No.	Column	Node	Env	Fx kN	Fy kN	Fz kN	Mx kNm	My kNm	Mz kNm	Comaprision in Percentage Due to change in V.I.					
1	3021	131	+ve	397.32	12.61	12.61	1.47	47.04	18.18	Fx	Fy	Fz	Mx	My	Mz
2	3021	131	+ve	422.24	16.15	12.16	1.61	46.75	22.82	6.27%	28.04%	-3.58%	9.31%	-0.63%	25.54%
3	3021	131	+ve	470.86	22.89	11.69	2.11	46.20	32.76	11.51%	41.74%	-3.86%	31.47%	-1.16%	43.55%
4	3021	131	+ve	602.73	30.52	11.19	3.54	44.37	45.74	28.00%	33.34%	-4.29%	67.55%	-3.98%	39.63%
5	3021	131	+ve	272.64	9.69	12.78	3.34	48.59	13.05	-54.77%	-68.24%	14.24%	-5.65%	9.51%	-71.47%
6	3021	131	+ve	265.19		11.48	2.20	43.36	10.65	-2.73%	-16.84%	-10.19%	-34.08%	-10.75%	-18.39%
7	3021	131	+ve	500.29	24.48	11.12	2.31	46.37	34.21	88.65%	203.61%	-3.14%	5.04%	6.93%	221.22%
8	3021	131	+ve	717.54	33.49	11.70	4.37	51.55	46.34	43.42%	36.84%	5.23%	88.68%	11.18%	35.48%
9	3021	131	+ve	717.54	33.49	11.70	4.37	51.55	46.34	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
10	3021	131	+ve	857.36	25.76	22.44	2.26	92.16	37.36	19.49%	-23.10%	91.78%	-48.24%	78.78%	-19.40%
11	3021	131	+ve	466.55	14.28	9.05	1.42	39.00	20.47	-45.58%	-44.57%	-59.69%	-37.08%	-57.68%	-45.21%
12	3021	131	+ve	617.54	17.37	18.94	2.35	62.63	24.40	32.36%	21.64%	109.40%	65.05%	60.58%	19.23%
									Max	88.65%	203.61%	109.40%	88.68%	78.78%	221.22%

TABLE-5: MEMBER FORCES IN FF EXTERNAL MIDDLE COLUMN FOR DIFFERENT VARIATIONS OF VERTICAL IRREGULARITY FOR SEISMIC ZONE II

FIRST Floor External Middle Column															
Zone II Model Case No.	COLUMN	Node	Env	Fx kN	Fy kN	Fz kN	Mx kNm	My kNm	Mz kNm	Comaprision in Percentage Due to change in V.I.					
1	3022	132	+ve	651.916	32.754	16.397	1.631	68.19	50.414	Fx	Fy	Fz	Mx	My	Mz
2	3022	132	+ve	695.366	40.872	16.157	1.785	68.802	63.025	6.66%	24.78%	-1.46%	9.44%	0.90%	25.01%
3	3022	132	+ve	782.697	52.969	15.927	1.97	69.33	82.042	12.56%	29.60%	-1.42%	10.36%	0.77%	30.17%
4	3022	132	+ve	1026.59	67.016	15.678	3.01	67.501	104.838	31.16%	26.52%	-1.56%	52.79%	-2.64%	27.79%
5	3022	132	+ve	460.372	24.806	17.757	2.042	73.433	37.383	-55.16%	-62.98%	13.26%	-32.16%	8.79%	-64.34%
6	3022	132	+ve	449.131	20.316	16.122	2.11	66.211	30.414	-2.44%	-18.10%	-9.21%	3.33%	-9.83%	-18.64%
7	3022	132	+ve	834.963	53.836	15.494	2.22	70.659	83.526	85.91%	164.99%	-3.90%	5.21%	6.72%	174.63%
8	3022	132	+ve	1078.77	69.965	15.227	3.052	68.824	109.598	29.20%	29.96%	-1.72%	37.48%	-2.60%	31.21%
9	3022	132	+ve	1235.82	73.881	17.638	3.712	82.287	114.85	14.56%	5.60%	15.83%	21.63%	19.56%	4.79%
10	3022	132	+ve	1304.93	66.755	28.113	2.593	115.961	102.718	5.59%	-9.65%	59.39%	-30.15%	40.92%	-10.56%
11	3022	132	+ve	778.991	35.842	12.389	1.631	58.274	55.32	-40.30%	-46.31%	-55.93%	-37.10%	-49.75%	-46.14%
12	3022	132	+ve	1073.42	45.994	24.585	2.796	92.611	70.425	37.80%	28.32%	98.44%	71.43%	58.92%	27.30%
									Max	85.91%	164.99%	98.44%	71.43%	58.92%	174.63%

TABLE-6: MEMBER FORCES IN FF EXTERNAL CENTER COLUMN FOR DIFFERENT VARIATIONS OF VERTICAL IRREGULARITY FOR SEISMIC ZONE II

FIRST Floor External CENTER Column										Comaprision in Percentage Due to change in V.I.					
Zone II Model Case No.	COLUMN	Node	Env	Fx kN	Fy kN	Fz kN	Mx kNm	My kNm	Mz kNm	Fx	Fy	Fz	Mx	My	Mz
1	3023	133	+ve	658.67	32.49	17.99	0.95	71.96	49.73						
2	3023	133	+ve	703.19	40.46	17.87	1.26	72.88	62.11	6.76%	24.53%	-0.70%	32.77%	1.28%	24.89%
3	3023	133	+ve	792.56	52.37	17.78	2.22	73.77	80.84	12.71%	29.43%	-0.49%	76.75%	1.23%	30.16%
4	3023	133	+ve	1041.67	66.36	17.69	3.58	72.34	103.63	31.43%	26.72%	-0.47%	61.31%	-1.95%	28.19%
5	3023	133	+ve	460.70	24.70	19.83	2.18	78.51	36.80	-55.77%	-62.78%	12.09%	-39.26%	8.53%	-64.49%
6	3023	133	+ve	448.65	20.30	18.21	1.88	71.06	29.98	-2.62%	-17.82%	-8.19%	-13.75%	-9.48%	-18.53%
7	3023	133	+ve	845.93	53.47	17.42	1.94	75.44	82.55	88.55%	163.37%	-4.31%	3.36%	6.16%	175.35%
8	3023	133	+ve	1094.83	69.50	17.34	3.33	74.07	108.53	29.42%	29.99%	-0.49%	71.94%	-1.82%	31.47%
9	3023	133	+ve	1253.51	73.87	20.36	3.15	89.53	114.37	14.49%	6.28%	17.43%	-5.67%	20.88%	5.38%
10	3023	133	+ve	1312.36	66.04	30.52	0.54	121.46	101.21	4.69%	-10.60%	49.87%	-82.93%	35.66%	-11.50%
11	3023	133	+ve	788.07	35.74	13.83	0.38	61.83	54.81	-39.95%	-45.88%	-54.68%	-29.05%	-49.09%	-45.85%
12	3023	133	+ve	1084.62	46.10	27.46	0.46	99.68	70.30	37.63%	28.98%	98.53%	20.47%	61.21%	28.28%
									Max	88.55%	163.37%	98.53%	76.75%	61.21%	175.35%

TABLE-7: MEMBER FORCES IN SF EXTERNAL CORNER COLUMN FOR DIFFERENT VARIATIONS OF VERTICAL IRREGULARITY FOR SEISMIC ZONE II

Second Floor External Corner Column															
Zone II Model Case No.	**Column**	**Node**	**Env**	**Fx kN**	**Fy kN**	**Fz kN**	**Mx kNm**	**My kNm**	**Mz kNm**	**Comaprision in Percentage Due to change in V.I.**					
1	2021	136	+ve	259.46	9.20	9.20	1.20	36.44	11.34	**Fx**	**Fy**	**Fz**	**Mx**	**My**	**Mz**
2	2021	136	+ve	283.30	11.91	8.75	1.40	36.71	14.78	9.19%	29.46%	-4.92%	16.06%	0.74%	30.31%
3	2021	136	+ve	330.76	17.81	8.08	2.01	36.08	20.76	16.75%	49.50%	-7.66%	44.30%	-1.71%	40.46%
4	2021	136	+ve	461.95	27.84	6.26	3.21	31.55	32.92	39.66%	56.27%	-22.49%	59.51%	-12.56%	58.56%
5	2021	136	+ve	133.71	4.97	9.82	2.68	41.69	4.93	-71.05%	-82.13%	56.76%	-16.51%	32.14%	-85.03%
6	2021	136	+ve	128.55	3.91	7.93	1.39	34.70	3.78	-3.86%	-21.33%	-19.27%	-48.34%	-16.77%	-23.37%
7	2021	136	+ve	358.45	16.27	9.44	2.36	40.72	19.19	178.84%	315.72%	19.15%	70.69%	17.34%	408.08%
8	2021	136	+ve	489.86	27.06	7.40	4.21	35.81	29.31	36.66%	66.32%	-21.65%	77.88%	-12.05%	52.73%
9	2021	136	+ve	544.00	24.05	11.51	4.51	53.03	26.83	11.05%	-11.11%	55.58%	7.16%	48.07%	-8.46%
10	2021	136	+ve	585.69	19.61	14.53	1.82	69.11	24.72	7.66%	-18.45%	26.19%	-59.68%	30.33%	-7.85%
11	2021	136	+ve	330.82	10.24	10.51	1.31	35.94	11.68	-43.52%	-47.78%	-27.67%	-28.01%	-48.00%	-52.74%
12	2021	136	+ve	402.53	12.85	16.35	2.30	63.82	14.97	21.67%	25.43%	55.59%	75.84%	77.57%	28.12%
									Max	178.84%	315.72%	56.76%	77.88%	77.57%	408.08%

TABLE-8: MEMBER FORCES IN SF EXTERNAL MIDDLE COLUMN FOR DIFFERENT VARIATIONS OF VERTICAL IRREGULARITY FOR SEISMIC ZONE II

Second Floor External Middle Column															
Zone II Model Case No.	**COLUMN**	**Node**	**Env**	**Fx kN**	**Fy kN**	**Fz kN**	**Mx kNm**	**My kNm**	**Mz kNm**	**Comaprision in Percentage Due to change in V.I.**					
										Fx	**Fy**	**Fz**	**Mx**	**My**	**Mz**
1	2022	137	+ve	424.98	23.04	12.08	1.32	55.49	33.28						
2	2022	137	+ve	467.27	29.20	11.84	1.50	57.07	42.50	9.95%	26.77%	-2.02%	13.16%	2.85%	27.70%
3	2022	137	+ve	553.85	39.06	11.31	1.76	57.53	57.60	18.53%	33.76%	-4.49%	17.58%	0.81%	35.53%
4	2022	137	+ve	801.17	52.46	8.89	2.69	51.35	79.38	44.65%	34.30%	-21.38%	52.93%	-10.75%	37.79%
5	2022	137	+ve	230.46	15.24	14.29	1.74	66.10	19.89	-71.23%	-70.95%	60.79%	-35.50%	28.73%	-74.94%
6	2022	137	+ve	222.73	11.97	12.08	1.55	57.76	15.30	-3.36%	-21.43%	-15.48%	-10.43%	-12.62%	-23.10%
7	2022	137	+ve	605.47	40.82	13.86	2.25	65.92	58.86	171.85%	240.91%	14.75%	45.05%	14.13%	284.83%
8	2022	137	+ve	852.81	56.05	11.23	3.12	59.61	83.28	40.85%	37.29%	-18.98%	38.51%	-9.57%	41.48%
9	2022	137	+ve	954.57	57.76	18.39	4.40	91.19	82.19	11.93%	3.07%	63.77%	40.78%	52.97%	-1.30%
10	2022	137	+ve	879.07	47.47	18.55	2.14	88.13	69.45	-7.91%	-17.82%	0.85%	-51.33%	-3.36%	-15.50%
11	2022	137	+ve	558.92	26.10	14.25	1.57	54.45	36.86	-36.42%	-45.03%	-23.18%	-26.69%	-38.21%	-46.92%
12	2022	137	+ve	697.29	31.99	22.37	2.74	104.21	44.97	24.76%	22.61%	57.04%	74.68%	91.39%	22.00%
									Max	171.85%	240.91%	63.77%	74.68%	91.39%	284.83%

TABLE-9: MEMBER FORCES IN SF EXTERNAL CENTER COLUMN FOR DIFFERENT VARIATIONS OF VERTICAL IRREGULARITY FOR SEISMIC ZONE II

Second Floor External Center Column															
Zone II Model Case No.	Column	Node	Env	Fx kN	Fy kN	Fz kN	Mx kNm	My kNm	Mz kNm	Comaprision in Percentage Due to change in V.I.					
										Fx	Fy	Fz	Mx	My	Mz
1	2023	138	+ve	429.503	24.032	13.325	0.777	57.814	34.553						
2	2023	138	+ve	472.657	30.416	13.169	1.06	59.613	43.991	10.05%	26.56%	-1.17%	36.42%	3.11%	27.31%
3	2023	138	+ve	560.803	40.668	12.705	1.898	60.322	59.505	18.65%	33.71%	-3.52%	79.06%	1.19%	35.27%
4	2023	138	+ve	811.779	55.079	10.078	3.276	54.195	82.504	44.75%	35.44%	-20.68%	72.60%	-10.16%	38.65%
5	2023	138	+ve	228.478	15.027	16.121	1.908	69.425	19.729	-71.85%	-72.72%	59.96%	-41.76%	28.10%	-76.09%
6	2023	138	+ve	220.049	11.692	13.822	1.227	60.796	15.146	-3.69%	-22.19%	-14.26%	-35.69%	-12.43%	-23.23%
7	2023	138	+ve	612.501	42.746	15.717	1.925	69.734	61.276	178.35%	265.60%	13.71%	56.89%	14.70%	304.57%
8	2023	138	+ve	863.438	59.15	12.894	3.508	63.471	87.108	40.97%	38.38%	-17.96%	82.23%	-8.98%	42.16%
9	2023	138	+ve	965.85	61.623	21.398	3.536	97.908	87.277	11.86%	4.18%	65.95%	0.80%	54.26%	0.19%
10	2023	138	+ve	883.526	49.663	20.357	0.537	92.437	72.043	-8.52%	-19.41%	-4.86%	-84.81%	-5.59%	-17.45%
11	2023	138	+ve	564.549	27.498	15.967	0.574	58.04	38.736	-36.10%	-44.63%	-21.57%	6.89%	-37.21%	-46.23%
12	2023	138	+ve	705.482	33.854	25.072	0.492	109.21	47.416	24.96%	23.11%	57.02%	-14.29%	88.16%	22.41%
									Max	178.35%	265.60%	65.95%	82.23%	88.16%	304.57%

TABLE-10: MEMBER FORCES IN FF EXTERNAL CORNER BEAM FOR DIFFERENT VARIATIONS OF VERTICAL IRREGULARITY FOR SEISMIC ZONE II

First Floor External Corner Beam															
Zone II Model Case No.	Beam	Node	Env	Fx kN	Fy kN	Fz kN	Mx kNm	My kNm	Mz kNm	Comaprision in Percentage Due to change in V.I.					
										Fx	Fy	Fz	Mx	My	Mz
1	185	131	+ve	0.96	62.71	1.07	1.51	2.80	96.75						
2	185	131	+ve	1.19	68.41	1.18	1.58	3.31	111.71	24.14%	9.09%	10.33%	4.16%	18.11%	15.46%
3	185	131	+ve	1.54	76.82	1.26	1.67	3.54	133.75	28.92%	12.29%	6.89%	5.71%	7.08%	19.73%
4	185	131	+ve	1.96	86.51	1.26	1.72	3.29	159.06	27.11%	12.61%	0.00%	3.48%	-7.09%	18.92%
5	185	131	+ve	0.74	57.42	1.89	1.73	5.32	82.91	-61.94%	-33.62%	50.64%	0.12%	61.76%	-47.88%
6	185	131	+ve	0.81	54.38	1.40	1.76	3.84	74.38	8.60%	-5.30%	-25.79%	1.80%	-27.87%	-10.29%
7	185	131	+ve	1.16	77.81	1.37	1.72	3.90	136.37	43.81%	43.10%	-2.64%	-1.88%	1.64%	83.36%
8	185	131	+ve	1.50	88.98	1.31	1.80	3.76	165.58	29.26%	14.35%	-4.24%	4.18%	-3.54%	21.42%
9	185	131	+ve	2.65	91.62	1.32	1.98	3.68	172.21	76.43%	2.97%	1.07%	10.08%	-2.31%	4.00%
10	185	131	+ve	1.85	153.70	1.84	2.11	4.78	211.85	-30.19%	67.76%	39.23%	6.88%	30.05%	23.02%
11	185	131	+ve	0.75	65.07	1.05	1.48	2.78	102.92	-59.51%	-57.66%	-43.16%	-30.19%	-41.80%	-51.42%
12	185	131	+ve	1.93	72.50	1.21	1.77	3.20	122.43	157.81%	11.41%	15.38%	20.27%	14.91%	18.96%
									Max	157.81%	67.76%	50.64%	20.27%	61.76%	83.36%

TABLE-11: MEMBER FORCES IN SF EXTERNAL CORNER BEAM FOR DIFFERENT VARIATIONS OF VERTICAL IRREGULARITY FOR SEISMIC ZONE II

SECOND FLOOR ExternaL Corner Beam															
Zone II Model Case No.	**Beam**	**Node**	**Env**	**Fx kN**	**Fy kN**	**Fz kN**	**Mx kNm**	**My kNm**	**Mz kNm**	**Comaprision in Percentage Due to change in V.I.**					
1	189	136	+ve	1.824	59.744	1.836	1.3	4.667	89.058	**Fx**	**Fy**	**Fz**	**Mx**	**My**	**Mz**
2	189	136	+ve	2.383	64.828	1.97	1.354	5.422	102.353	30.65%	8.51%	7.30%	4.15%	16.18%	14.93%
3	189	136	+ve	3.069	72.785	2.093	1.462	5.791	123.171	28.79%	12.27%	6.24%	7.98%	6.81%	20.34%
4	189	136	+ve	5.036	83.645	2.196	1.539	5.705	151.537	64.09%	14.92%	4.92%	5.27%	-1.49%	23.03%
5	189	136	+ve	1.281	54.276	3.319	1.531	9.189	73.102	-74.56%	-35.11%	51.14%	-0.52%	61.07%	-51.76%
6	189	136	+ve	1.32	54.147	2.32	1.486	6.191	65.768	3.04%	-0.24%	-30.10%	-2.94%	-32.63%	-10.03%
7	189	136	+ve	1.339	73.756	2.297	1.534	6.623	125.602	1.44%	36.21%	-0.99%	3.23%	6.98%	90.98%
8	189	136	+ve	1.708	85.865	2.261	1.649	6.431	157.102	27.56%	16.42%	-1.57%	7.50%	-2.90%	25.08%
9	189	136	+ve	1.783	95.109	2.529	2.125	7.004	168.036	4.39%	10.77%	11.85%	28.87%	8.91%	6.96%
10	189	136	+ve	3.945	147.46	3.006	1.736	7.708	195.168	121.26%	55.05%	18.86%	-18.31%	10.05%	16.15%
11	189	136	+ve	1.139	62.144	1.799	1.323	4.62	95.322	-71.13%	-57.86%	-40.15%	-23.79%	-40.06%	-51.16%
12	189	136	+ve	1.625	95.772	2.555	2.275	6.255	132.448	42.67%	54.11%	42.02%	71.96%	35.39%	38.95%
									Max	121.26%	55.05%	51.14%	71.96%	61.07%	90.98%

TABLE-12: MEMBER FORCES IN TF EXTERNAL CORNER BEAM FOR DIFFERENT VARIATIONS OF VERTICAL IRREGULARITY FOR SEISMIC ZONE II

Third Floor External Corner Beam															
Zone II Model Case No.	Beam	Node	Env	Fx kN	Fy kN	Fz kN	Mx kNm	My kNm	Mz kNm	Comaprision in Percentage Due to change in V.I.					
1	193	141	+ve	1.371	55.746	2.365	1.065	6.082	73.163	Fx	Fy	Fz	Mx	My	Mz
2	193	141	+ve	1.503	57.827	2.526	1.098	7.227	83.571	9.63%	3.73%	6.81%	3.10%	18.83%	14.23%
3	193	141	+ve	1.986	64.044	2.696	1.2	7.864	100.738	32.14%	10.75%	6.73%	9.29%	8.81%	20.54%
4	193	141	+ve	4.305	74.94	2.855	1.365	8.057	129.138	116.77%	17.01%	5.90%	13.75%	2.45%	28.19%
5	193	141	+ve	21.033	50.908	4.525	1.767	12.496	46.716	388.57%	-32.07%	58.49%	29.45%	55.09%	-63.82%
6	193	141	+ve	21.624	50.639	3.199	1.623	7.98	42.089	2.81%	-0.53%	-29.30%	-8.15%	-36.14%	-9.90%
7	193	141	+ve	1.775	73.48	2.94	1.462	8.615	109.044	-91.79%	45.11%	-8.10%	-9.92%	7.96%	159.08%
8	193	141	+ve	3.495	83.801	3.157	1.604	8.915	139.439	96.90%	14.05%	7.38%	9.71%	3.48%	27.87%
9	193	141	+ve	2.929	103.532	3.856	2.179	10.894	155.14	-16.19%	23.55%	22.14%	35.85%	22.20%	11.26%
10	193	141	+ve	2.257	136.114	3.787	1.689	9.584	166.756	-22.94%	31.47%	-1.79%	-22.49%	-12.02%	7.49%
11	193	141	+ve	1.616	69.345	2.624	1.302	6.291	85.38	-28.40%	-49.05%	-30.71%	-22.91%	-34.36%	-48.80%
12	193	141	+ve	2.272	95.177	3.654	1.783	9.106	114.472	40.59%	37.25%	39.25%	36.94%	44.75%	34.07%
									Max	388.57%	45.11%	58.49%	36.94%	55.09%	159.08%

TABLE-13: MEMBER FORCES IN FF INTERNAL MIDDLE BEAM FOR DIFFERENT VARIATIONS OF VERTICAL IRREGULARITY FOR SEISMIC ZONE II

First Floor Internal MIDDLE Beam															
Zone II Model Case No.	Beam	Node	Env	Fx kN	Fy kN	Fz kN	Mx kNm	My kNm	Mz kNm	Comaprision in Percentage Due to change in V.I.					
										Fx	Fy	Fz	Mx	My	Mz
1	186	132	+ve	1.439	60.44	0.734	0.505	1.789	90.188						
2	186	132	+ve	1.538	65.462	0.848	0.544	2.066	102.687	6.88%	8.31%	15.53%	7.72%	15.48%	13.86%
3	186	132	+ve	1.664	72.809	1.08	0.854	2.801	120.969	8.19%	11.22%	27.36%	56.99%	35.58%	17.80%
4	186	132	+ve	1.845	80.942	1.472	1.294	4.054	141.162	10.88%	11.17%	36.30%	51.52%	44.73%	16.69%
5	186	132	+ve	1.635	56.075	1.47	0.625	3.587	79.266	-11.38%	-30.72%	-0.14%	-51.70%	-11.52%	-43.85%
6	186	132	+ve	1.781	53.774	1.175	0.669	2.957	72.107	8.93%	-4.10%	-20.07%	7.04%	-17.56%	-9.03%
7	186	132	+ve	1.771	73.557	1.077	0.662	2.724	122.812	-0.56%	36.79%	-8.34%	-1.05%	-7.88%	70.32%
8	186	132	+ve	1.979	82.99	1.664	1.128	4.497	146.237	11.74%	12.82%	54.50%	70.39%	65.09%	19.07%
9	186	132	+ve	2.35	85.155	1.394	0.863	3.752	151.653	18.75%	2.61%	-16.23%	-23.49%	-16.57%	3.70%
10	186	132	+ve	2.386	149.48	1	0.835	1.799	200.018	1.53%	75.54%	-28.26%	-3.24%	-52.05%	31.89%
11	186	132	+ve	1.464	62.354	0.536	0.501	0.922	94.933	-38.64%	-58.29%	-46.40%	-40.00%	-48.75%	-52.54%
12	186	132	+ve	2.032	67.994	0.706	0.728	1.323	108.893	38.80%	9.05%	31.72%	45.31%	43.49%	14.71%
									Max	38.80%	75.54%	54.50%	70.39%	65.09%	70.32%

TABLE-14: MEMBER FORCES IN SF INTERNAL MIDDLE BEAM FOR DIFFERENT VARIATIONS OF VERTICAL IRREGULARITY FOR SEISMIC ZONE II

Second Floor Internal Middle Beam										Comaprision in Percentage Due to change in V.I.					
Zone II Model Case No.	Beam	Node	Env	Fx kN	Fy kN	Fz kN	Mx kNm	My kNm	Mz kNm	Fx	Fy	Fz	Mx	My	Mz
1	190	137	+ve	2.863	56.965	1.21	0.433	2.962	81.461						
2	190	137	+ve	3.187	61.465	1.431	0.466	3.507	92.681	11.32%	7.90%	18.26%	7.62%	18.40%	13.77%
3	190	137	+ve	3.508	68.371	1.849	0.712	4.825	109.883	10.07%	11.24%	29.21%	52.79%	37.58%	18.56%
4	190	137	+ve	3.563	77.147	2.544	1.087	7.026	131.687	1.57%	12.84%	37.59%	52.67%	45.62%	19.84%
5	190	137	+ve	2.813	52.948	2.596	0.571	6.364	68.134	-21.05%	-31.37%	2.04%	-47.47%	-9.42%	-48.26%
6	190	137	+ve	2.923	52.922	1.924	0.579	4.868	61.671	3.91%	-0.05%	-25.89%	1.40%	-23.51%	-9.49%
7	190	137	+ve	2.945	69.098	1.867	0.585	4.745	111.72	0.75%	30.57%	-2.96%	1.04%	-2.53%	81.15%
8	190	137	+ve	3.37	79.121	2.941	1.013	7.968	136.675	14.43%	14.51%	57.53%	73.16%	67.92%	22.34%
9	190	137	+ve	3.922	88.656	2.471	0.926	6.706	149.296	16.38%	12.05%	-15.98%	-8.59%	-15.84%	9.23%
10	190	137	+ve	4.675	142.678	1.433	0.735	2.303	183.068	19.20%	60.93%	-42.01%	-20.63%	-65.66%	22.62%
11	190	137	+ve	2.478	58.725	0.82	0.486	1.311	85.837	-46.99%	-58.84%	-42.78%	-33.88%	-43.07%	-53.11%
12	190	137	+ve	3.53	92.376	1.229	0.78	2.076	123.448	42.45%	57.30%	49.88%	60.49%	58.35%	43.82%
									Max	42.45%	60.93%	57.53%	73.16%	67.92%	81.15%

TABLE-15: MEMBER FORCES IN TF INTERNAL MIDDLE BEAM FOR DIFFERENT VARIATIONS OF VERTICAL IRREGULARITY FOR SEISMIC ZONE II

Thrid Floor Internal Middle Column										Comaprision in Percentage Due to change in V.I.					
Zone II Model Case No.	Beam	Node	Env	Fx kN	Fy kN	Fz kN	Mx kNm	My kNm	Mz kNm	Fx kN	Fy kN	Fz kN	Mx kNm	My kNm	Mz kNm
1	194	142	+ve	2.994	52.92	1.569	0.351	3.85	66.058						
2	194	142	+ve	3.297	54.48	1.9	0.387	4.673	74.249	10.12%	2.95%	21.10%	10.26%	21.38%	12.40%
3	194	142	+ve	3.709	59.644	2.495	0.527	6.53	87.906	12.50%	9.48%	31.32%	36.18%	39.74%	18.39%
4	194	142	+ve	4.672	68.197	3.474	1.087	9.601	109.022	25.96%	14.34%	39.24%	106.26%	47.03%	24.02%
5	194	142	+ve	21.04	53.264	3.573	0.387	8.848	53.378	350.34%	-21.90%	2.85%	-64.40%	-7.84%	-51.04%
6	194	142	+ve	21.608	53.312	2.391	0.413	6.075	52.093	2.70%	0.09%	-33.08%	6.72%	-31.34%	-2.41%
7	194	142	+ve	3.93	69.382	2.525	0.548	6.471	97.753	-81.81%	30.14%	5.60%	32.69%	6.52%	87.65%
8	194	142	+ve	4.969	77.451	4.08	1.026	11.105	120.904	26.44%	11.63%	61.58%	87.23%	71.61%	23.68%
9	194	142	+ve	5.659	97.174	3.484	1.023	9.517	138.296	13.89%	25.47%	-14.61%	-0.29%	-14.30%	14.38%
10	194	142	+ve	4.965	130.568	1.748	0.718	2.717	152.383	-12.26%	34.37%	-49.83%	-29.81%	-71.45%	10.19%
11	194	142	+ve	3.507	65.349	1.104	0.47	1.691	77.687	-29.37%	-49.95%	-36.84%	-34.54%	-37.76%	-49.02%
12	194	142	+ve	4.957	90.224	1.671	0.7	2.642	104.524	41.35%	38.06%	51.36%	48.94%	56.24%	34.55%
									Max	350.34%	38.06%	61.58%	106.26%	71.61%	87.65%

TABLE-16: MEMBER FORCES IN GF EXTERNAL CORNER COLUMN FOR DIFFERENT VARIATIONS OF PLAN IRREGULARITY FOR SEISMIC ZONE II

Ground Floor External Corner Column DUE (S1) TO P.I. IN SEISMIC ZONE II									
Zone II Model Case No.	Column	Node	Env	Fx kN	Fy kN	Fz kN	Mx kNm	My kNm	Mz kNm
1	4001	6	+ve	531.617	18.958	31.407	1.517	36.05	36.051
2	4002	7	+ve	877.615	37.101	42.396	1.684	46.504	62.033
3	4003	8	+ve	884.156	36.554	45.521	0.979	51.767	61.171
4	4004	9	+ve	877.615	37.8	42.396	1.685	46.504	63.06
5	4005	10	+ve	531.616	31.407	31.407	1.517	36.05	51.087
6	4006	36	+ve	877.615	23.829	37.8	1.685	62.033	46.504
7	4007	37	+ve	1495.41	47.689	49.026	1.165	79.643	79.643
8	4008	38	+ve	1507.686	47.169	53.732	1.217	87.409	78.843
9	4009	39	+ve	1495.41	49.025	49.026	1.165	79.643	81.707
10	4010	40	+ve	877.614	42.396	37.8	1.684	62.033	66.839
11	4011	66	+ve	884.156	26.841	36.554	0.979	61.171	51.767
12	4012	67	+ve	1507.686	52.371	47.169	1.217	78.843	87.41
13	4013	68	+ve	1520.308	51.762	51.761	0	86.473	86.474
14	4014	69	+ve	1507.686	53.733	47.169	1.217	78.843	89.516
15	4015	70	+ve	884.155	45.522	36.554	0.979	61.171	72.182

16	**4016**	**96**	**+ve**	**877.615**	**23.829**	**37.101**	**1.684**	**63.06**	**46.504**
17	**4017**	**97**	**+ve**	**1495.41**	**47.689**	**47.689**	**1.165**	**81.707**	**79.643**
18	**4018**	**98**	**+ve**	**1507.686**	**47.169**	**52.371**	**1.217**	**89.515**	**78.843**
19	**4019**	**99**	**+ve**	**1495.411**	**49.025**	**47.689**	**1.165**	**81.707**	**81.707**
20	**4020**	**100**	**+ve**	**877.614**	**42.396**	**37.101**	**1.685**	**63.06**	**66.839**
21	**4021**	**126**	**+ve**	**531.616**	**18.958**	**18.958**	**1.517**	**51.086**	**36.051**
22	**4022**	**127**	**+ve**	**877.614**	**37.101**	**23.829**	**1.685**	**66.839**	**62.033**
23	**4023**	**128**	**+ve**	**884.155**	**36.554**	**26.841**	**0.979**	**72.181**	**61.171**
24	**4024**	**129**	**+ve**	**877.614**	**37.8**	**23.829**	**1.684**	**66.839**	**63.06**
25	**4025**	**130**	**+ve**	**531.616**	**31.407**	**18.958**	**1.517**	**51.086**	**51.087**
			MAX	1520.308	53.733	53.732	1.685	89.515	89.516

TABLE-17: MEMBER FORCES IN GF EXTERNAL CORNER COLUMN FOR DIFFERENT VARIATIONS OF PLAN IRREGULARITY FOR SEISMIC ZONE II

Ground Floor External Corner Column (S2) DUE TO P.I. IN SEISMIC ZONE II									
Zone II Model Case No.	Column	Node	Env	Fx kN	Fy kN	Fz kN	Mx kNm	My kNm	Mz kNm
1	4002	7	+ve	1531.977	23.37	51.417	0.992	51.906	49.699
2	4003	8	+ve	3024.523	50.834	42.04	0.229	52.798	84.997
3	4004	9	+ve	1531.978	59.485	51.417	0.958	51.906	88.511
4	4006	36	+ve	1531.977	23.702	59.485	0.958	49.699	51.906
5	4007	37	+ve	2283.088	54.018	52.205	0.248	90.388	90.388
6	4008	38	+ve	1968.283	47.049	49.058	0.232	89.801	78.738
7	4009	39	+ve	2283.088	52.205	52.205	0.248	90.388	90.024
8	4010	40	+ve	1531.977	51.417	59.485	0.992	49.698	78.771
9	4011	66	+ve	3024.522	27.444	50.834	0.229	84.997	52.798
10	4012	67	+ve	1968.283	54.789	47.049	0.232	78.738	89.801
11	4013	68	+ve	1871.36	50.285	50.285	0	83.986	83.986
12	4014	69	+ve	1968.283	49.058	47.049	0.232	78.738	82.798
13	4015	70	+ve	3024.522	42.04	50.834	0.229	84.997	66.119
14	4016	96	+ve	1531.978	23.702	23.37	0.992	88.511	51.906

15	4017	97	+ve	2283.088	54.018	54.018	0.248	90.024	90.388
16	4018	98	+ve	1968.283	47.049	54.789	0.232	82.798	78.738
17	4019	99	+ve	2283.088	52.205	54.018	0.248	90.024	90.024
18	4020	100	+ve	1531.977	51.417	23.37	0.958	88.511	78.771
19	4022	127	+ve	1531.977	23.37	23.702	0.958	78.771	49.698
20	4023	128	+ve	3024.522	50.834	27.444	0.229	66.119	84.997
21	4024	129	+ve	1531.977	59.485	23.702	0.992	78.771	88.511
			MAX	3024.523	59.485	59.485	0.992	90.388	90.388

TABLE-18: MEMBER FORCES IN GF EXTERNAL CORNER COLUMN FOR DIFFERENT VARIATIONS OF PLAN IRREGULARITY FOR SEISMIC ZONE II

Ground Floor External Corner Column (S3) DUE TO P.I. IN SEISMIC ZONE II									
Zone II Model Case No.	Column	Node	Env	Fx kN	Fy kN	Fz kN	Mx kNm	My kNm	Mz kNm
1	4001	126	+ve	531.62	18.96	18.96	1.52	51.09	36.05
2	4002	126	+ve	557.17	24.47	18.22	1.62	50.38	45.87
3	4003	126	+ve	606.61	32.39	17.48	2.08	49.46	60.10
4	4004	126	+ve	407.28	14.83	17.75	3.11	50.39	28.18
5	4005	126	+ve	75.87	-10.90	18.56	2.77	52.95	-18.91
6	4006	126	+ve	-255.54	-36.63	19.37	2.43	55.50	-66.00
7	4007	126	+ve	-586.95	-62.36	20.18	2.10	58.06	-113.09
8	4008	126	+ve	-918.36	-88.09	20.99	1.76	60.62	-160.17
9	4009	126	+ve	-1249.77	-113.82	21.81	1.42	63.17	-207.26
10	4010	126	+ve	-1581.18	-139.55	22.62	1.09	65.73	-254.35
11	4011	126	+ve	-1912.59	-165.28	23.43	0.75	68.28	-301.43
12	4012	126	+ve	-2244.00	-191.01	24.24	0.41	70.84	-348.52
13	4013	126	+ve	-2575.41	-216.75	25.05	0.07	73.40	-395.61
14	4014	126	+ve	-2906.81	-242.48	25.86	-0.26	75.95	-442.70

15	4016	126	+ve	-3569.63	-293.94	27.48	-0.94	81.06	-536.87
16	4017	126	+ve	-3901.04	-319.67	28.29	-1.27	83.62	-583.96
17	4018	127	+ve	-3901.04	-319.67	28.29	-1.27	83.62	-583.96
18	4019	128	+ve	-3901.04	-319.67	28.29	-1.27	83.62	-583.96
19	4020	129	+ve	-3901.04	-319.67	28.29	-1.27	83.62	-583.96
20	4021	130	+ve	-3901.04	-319.67	28.29	-1.27	83.62	-583.96
21	4022	131	+ve	-3901.04	-319.67	28.29	-1.27	83.62	-583.96
22	4023	126	+ve	-4895.27	-396.86	30.73	-2.28	91.29	-725.22
23	4024	126	+ve	-5226.68	-422.59	31.54	-2.62	93.84	-772.30
24	4025	126	+ve	-5558.09	-448.32	32.35	-2.96	96.40	-819.39
			MAX	606.61	32.39	32.35	3.11	96.40	60.10

TABLE-19: MEMBER FORCES IN GF EXTERNAL CORNER COLUMN FOR DIFFERENT VARIATIONS OF PLAN IRREGULARITY FOR SEISMIC ZONE II

Ground Floor External Corner Column (S4) DUE TO P.I. IN SEISMIC ZONE II									
Zone II Model Case No.	**Column**	**Node**	**Env**	**Fx kN**	**Fy kN**	**Fz kN**	**Mx kNm**	**My kNm**	**Mz kNm**
1	4001	126	+ve	531.62	18.96	18.96	1.52	51.09	36.05
2	4002	126	+ve	557.17	24.47	18.22	1.62	50.38	45.87
3	4003	126	+ve	606.61	32.39	17.48	2.08	49.46	60.10
4	4004	126	+ve	407.28	14.83	17.75	3.11	50.39	28.18
5	4005	126	+ve	75.87	-10.90	18.56	2.77	52.95	-18.91
6	4006	126	+ve	-255.54	-36.63	19.37	2.43	55.50	-66.00
7	4007	126	+ve	-586.95	-62.36	20.18	2.10	58.06	-113.09
8	4008	126	+ve	-918.36	-88.09	20.99	1.76	60.62	-160.17
9	4009	126	+ve	-1249.77	-113.82	21.81	1.42	63.17	-207.26
10	4010	126	+ve	-1581.18	-139.55	22.62	1.09	65.73	-254.35
11	4011	126	+ve	-1912.59	-165.28	23.43	0.75	68.28	-301.43
12	4012	126	+ve	-2244.00	-191.01	24.24	0.41	70.84	-348.52
13	4013	126	+ve	-2575.41	-216.75	25.05	0.07	73.40	-395.61
14	4016	126	+ve	-3569.63	-293.94	27.48	-0.94	81.06	-536.87

15	4017	126	+ve	-3901.04	-319.67	28.29	-1.27	83.62	-583.96
16	4018	127	+ve	-3901.04	-319.67	28.29	-1.27	83.62	-583.96
17	4019	128	+ve	-3901.04	-319.67	28.29	-1.27	83.62	-583.96
18	4020	129	+ve	-3901.04	-319.67	28.29	-1.27	83.62	-583.96
19	4021	130	+ve	-3901.04	-319.67	28.29	-1.27	83.62	-583.96
20	4022	131	+ve	-3901.04	-319.67	28.29	-1.27	83.62	-583.96
21	4023	126	+ve	-4895.27	-396.86	30.73	-2.28	91.29	-725.22
22	4024	126	+ve	-5226.68	-422.59	31.54	-2.62	93.84	-772.30
23	4025	126	+ve	-5558.09	-448.32	32.35	-2.96	96.40	-819.39
			MAX	606.61	32.39	32.35	3.11	96.40	60.10

TABLE-20 MAX DRIFTS FOR DIFFERENT VARIATIONS OF VERTICAL IRREGULARITY FOR SEISMIC ZONE II

CASE NO.	MAX X	MAX Y	MAX Z	%VARIATION OF DRIFT IN V.I. IN SEISMIC ZONE II		
				MAX X	MAX Y	MAX Z
CASE1	9.919	2.806	9.919			
CASE2	10.615	3.011	9.925	7.0	7.3	0.1
CASE3	12.557	3.382	10.154	26.6	20.5	2.4
CASE4	14.756	3.292	10.885	48.8	17.3	9.7
CASE5	11.984	3.41	10.632	20.8	21.5	7.2
CASE6	12.591	3.309	10.611	26.9	17.9	7.0
CASE7	12.737	3.533	10.406	28.4	25.9	4.9
CASE8	15.171	3.446	11.13	52.9	22.8	12.2
CASE9	15.054	3.849	12.299	51.8	37.2	24.0
CASE10	14.495	4.12	17.224	46.1	46.8	73.6

5 Result & discussion:

1. In all seismic zones the variations of member forces were found to be maximum for external corner column in all the floor. The average variation were 65%, 143%, 117%, 79%, 130%, 143% respectively Fx, Fy, Fz, Mx, My and Mz.

2. Nearly same shear force variations were found for the middle and central columns. The Torsional moment variation is found to be minimum for external middle column.

3. The variations of member forces were found to be more similar for external, middle & central columns compared to the external column. The average variation for first floor, middle & central for example were 85%, 115 %,74 %,76 %&162 % respectively for Fx, Fy, Fz, Mx, My and Mz.

4. Drifts in all the cases increases due to vertical irregularity in all the directions. For example maximum percentage increase in drift in x- direction &z- direction in seismic zone –II were respectively found to be of an order of 53 %& 74 %.

5. Due to vertical irregularity member forces in different beams also increase. The variation was found to be of higher order in external beams. For example in seismic zone II the average variation in external beams were of an order of 389 %, 45 %, 37 %, 55% and 159% for Fx, Fy, Fz, Mx, MY & MZ in external third floor beams. This pattern is visible for all the seismic zones.

6. Due to the plan irregularity also there is a wide variation in member forces in the buildings.

7. Due to changes in vertical and plan irregularity, the base shear in buildings change. The storey shears also have varied 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.

6. CONCLUSIONS

1. Due to vertical irregularity there may be wide variation in member forces in structures. Though the variations in member forces are different for different zones; external columns and external beams are found to be subjected to greater variations.

2. Due to plan irregularity also building elements may be subjected to a wide variation of member forces.

3. Due to vertical and plan irregularity drifts of buildings have been found to vary. Some other aspects such as pounding of buildings may also be explored, especially in respect of the seismic vulnerability of building.

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

5. The rapid assessment procedure may be suitably modified based on the finding in 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.

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

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