Determination of seismic upgradation requirements of RC framed structures

A DISSERTATION

SUBMITTED IN THE PARTIAL FULFILLMENT OF REQUIREMENTS
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Submitted by:
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CANDIDATE'S DECLARATION

I, Sanjeet, Roll No 2k16/STE/17 student of M. Tech. (Structural Engineering), hereby declare that the project Dissertation titled "**Determination of seismic upgradtion requirements of RC framed structures**" which is submitted by me to the department of civil engineering, Delhi technological university, Delhi in partial fulfillment of the requirement for the award of degree of Master Of Technology is original and not copied from any source without proper citation. This work has not previously formed the basis for the award of any Degree, Diploma Associate ship, Fellowship or other similar title or recognition.

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Date: (2K16/STE/17)

CERTIFICATE

I hereby certify that the Project Dissertation titled "**Determination of seismic upgradtion requirements of RC framed structures**" which is submitted by Sanjeet, 2K16/STE/17 Department of Civil Engineering (Structural Engineering), Delhi Technological University, Delhi in partial fulfilment of the requirement for the award of the degree of Master of Technology, is a record of the project work carried out by the student under my supervision. To the best of my knowledge this work has not been submitted in part or full for any Degree or Diploma to this University or elsewhere.

Place: Delhi **Dr. ALOK VERMA**

Date: **(SUPERVISOR)**

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ABSTRACT

Building codes are revised from time to time and the revision necessitates checking the adequacy of existing building for the demand as per the latest codes of practice. The code for criteria for earthquake resistant design of structures IS: 1893, was introduced in 1962. This standard was subsequently revised in 1966, 1970, 1975, 1984, 2002 and 2016. Conventional earthquake resistant design of buildings was aimed to provide minimum amount of lateral resistance to buildings and the methods for the estimation of base shear (seismic coefficient method) were modified with respect to the revisions.

The present study is carried out under two major heads (1) codal study and (2) analytical study.

In the codal study, a thorough study of different codes of IS: 1893 has been done. Seismic base shear and lateral load are computed using static method i.e. seismic coefficient method as per various versions of IS code 1893, in an MS Excel worksheet.

In the analytical study, a frame building having a plan dimension of 25m x 18m and height of 16m has been modelled. The building frame is modelled in STAAD PRO. the building is subjected to lateral forces as per various codes of previous times, calculated in codal study above. Various types of load combinations are applied according to latest available code for earthquake resistant design of buildings. Results of the building model, subjected to forces as per previous codes, are analyzed and compared to understand the effect of revision of seismic code on the adequacy of the buildings to sustain the earthquake forces and to appreciate upgradation requirements in them.

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LIST OF SYMBOLS

SYMBOLS	MEANING
Z	Zone factor
I	Importance factor
R	Response reduction factor
d	Base dimension of building at plinth level
Q_i	Design lateral force
S	Number of storeys
N	Number of storeys above the one under consideration
C	Coefficient defining the flexibility of structure with the increase in number of storey
W	Total dead load + appropriate amount of live load
α_h	Horizontal seismic coefficient
β	Coefficient depending upon the soil foundation system
n	Number of storey including basement storey
h	Height of building in m
α_0	Basic horizontal seismic coefficient
F_o	Seismic zone factor
K	Performance factor
$\sum W$	Seismic Weight of building
A_h	Horizontal seismic coefficient
V_B	Seismic base shear
$\frac{s_a}{g}$	Average response acceleration coefficient

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CHAPTER 1

INTRODUCTION

1.1 GENERAL

Literature reveals that construction remains vulnerable to seismic force due to many reasons like lack of integral action between brick and mortar, low shear strength of masonry, heavy mass and varying construction practices. It is essential to enhance seismic improvement structure using different retrofitting measures. Past earthquakes in India and other countries reveals low seismic resistance of URM structure and extensive damage caused due to this reason. Reconstruction of damaged structure may be very costly and time consuming therefore retrofitting is a best alternative to enhance the seismic performance of damaged structures. Many conventional and non-conventional techniques like, ferrocement, shotcrete, steel elements application, grout injection, FRP, post-tensioning is available around the world for retrofitting of structure.

Figure1.1: **Failure of unreinforced masonary**

While preparation of seismic codes, many things are considered like structure typologies seismology of country, construction methods, accepted level of seismic risk, properties of construction materials. The data and clauses given in seismic codes are based on the observations, analytical case studies, experiments made during last earthquakes in particular region. In India, IS 1893 (Part1) Criteria for Earthquake Resistant Design of Structures is used as code of practice for analysis & designing of earthquake resistant buildings. Up-to now, six times seismic code have been revised. For First time, IS: 1893-1962 came in 1962. First, second, third, fourth, fifth, sixth revision of seismic code came in 1966, 1970, 1975, 1984, 2002, 2016 respectively.

1.2Major earthquakes in India

1.2.1 BHUJ EARTHQUAKE

Bhuj earthquake of magnitude 7.6 in 26th Jan 2001 caused lots of destruction in Gujarat. Nearly 20,000 people were dead and more than 60,000 were injured in that earthquake. There was a loss of Rs 10,000 crores. Epicenter of Bhuj earthquake was located at a distance of 10kms northeast of bachau city, district kutch of Gujarat. The United States Geological Survey estimated that focal depth of earthquake was 25kms. The waves of earthquake were sensed up to Kashmir in north direction, kanyakumari in the south direction, Nepal and Calcutta in the northeast direction. Bachau, Bhuj, Anjar, Rapar, Gandhidham and kandla cities were most affected by the earthquake.

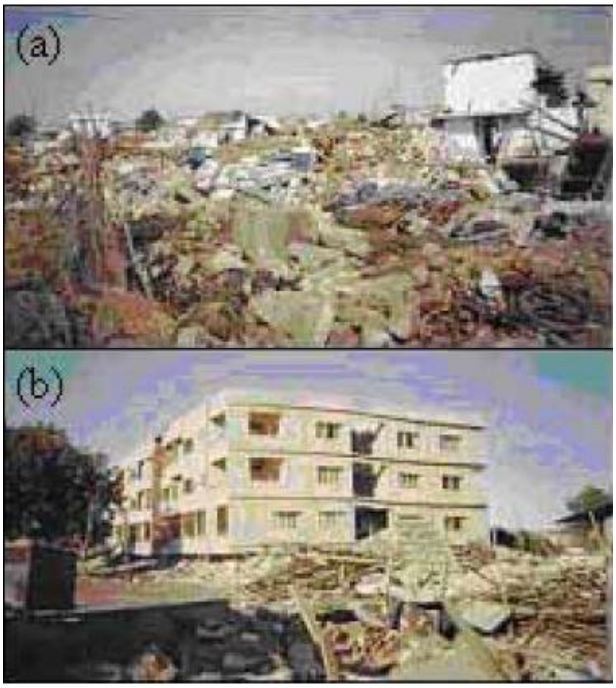


Fig1.2 (a) Ratnal Village was destroyed due to bhuj earthquake and (b) Ground Floor of RC building was collapsed in Bachau (*iitk.ac.in*)

Fig1.3: left image-crack in road due to bhuj earthquake (*newsnation.com*) and right image building collapse in bhuj earthquake (*civildigital.com*)

1.2.2 CUTCH EARTHQUAKE OF 1819

Cutch earthquake took place on west coast on 16th June 1819, which had a magnitude of 8.3. This earthquake caused a ground failure in the form of scrap of 16 mile long and 18 foot high named as: "Allah Bund".

1.2.3 ASSAM EARTHQUAKE (1897)

Assam earthquake of magnitude 8.7 took place on 12th June 1897. This earthquake had a impact of about 500 km radius. These earthquakes caused up throw of object due to shaking. It was found that during the earthquake, maximum vertical acceleration exceed 1.0g. Rail tracks and bridges were extremely damaged. In Shillong, buildings were classified into three classes:
1) Stone building
2) Ekra build building
3) Timber plank

Stone building were extremely damaged and got levelled to the ground. Ekra building were less damaged as compared to the stone building and partially damaged. Timber plank were undamaged.

1.2.4 BIHAR NEPAL EARTHQUAKE (1934)

Bihar Nepal earthquake took place on the northern part of the Bihar and Nepal on 15th June 1934. It had a magnitude of 8.4. 7253 and 3400 peoples were died in India and Nepal respectively. This earthquake had a impact over 300 km mean radius. It was found that 6 foot high embankment was levelled with the ground surface and also, depth of lakes and ponds became lower.

1.2.5 KOYNA EARTHQUAKE OF 1967

This earthquake took place in Koyna close to 103 m concrete gravity dam. Before this earthquake occurred, this place assumes to be non-seismic. However, after the construction of the dam in 1982, this area became prone to earthquake.

1.2.6 KILLARI (LATUR) EARTHQUAKE OF 1993

This earthquake took place the area near village Killari in Latur district on September 30, 1993. This earthquake had a magnitude of 6.4. The maximum intensity of shaking was about VIII to IX. This area was considered as the non-seismic zone as per IS: 1893-1984 and assumed to be in the lowest seismic zone i.e. zone 1. Killari earthquake always remember for the operation of rescue, relief and rehabilitation. That was carried out for any earthquake in recent Indian history.

CHAPTER 2
LITERATURE REVIEW

2.1 Research efforts in the past

Urunkar et al. (2018) presented the comparative study of codal provision in IS 1893(PART 1):2002 & IS 1893(PART 1):2016. In this paper, they have studied sixth revised code of IS 1893(PART 1) published in 2016 and changes made in IS 1893(PART 1):2016 from IS 1893(PART 1):2002 are deeply studied.

S.K. Ahirwar et al. (2008) studied seismic loads acting on 4 multi-storey RC framed buildings varying from three to nine storeyed as per IS 1893(PART 1)-1984 & IS 1893(PART 1)-2002. In this paper, two methods (response spectrum and modal analysis methods) were used to calculate seismic forces acting on these building. The conclusion presented comparison of lateral load and base shear for these building computed as per above mentioned IS codes.

S.V. Itti et al. studied seismic provision made in Indian Codes and international codes. In this paper, they have modelled 22.5mX45m plan of building having 30m elevation. Equivalent static methods were used. The conclusion includes comparison of base shear, lateral loads, displacement for this building computed as per above mentioned IS codes.

Pujan Neupane et al. (2008) presented comparative study and analysis of Indian Seismic code and Nepal Seismic code. In this paper, they have used response spectrum method for analysis purposes. The conclusion involves comparison of base shear coefficient and factored storey shear coefficient calculated as per above mentioned codes provision.

Azhar et al. presented the response of industrial structure as per IS:1893-1984 and IS:1893(part 4)-2005. In this paper, a building of plan area 16mX30m, height of column=3m is modelled under the combined load (dead load, live load , earthquake load, wind load). The result includes comparison of base shear, storey drift calculated as per IS:1893-1984 and IS:1893(part 4)-2005.

K Rama Raju et al. (2012) performed seismic evaluation of existing structures designed according to past seismic codes. Building of plan area 22.5mX22.5m and elevation of building = 32.2 is modelled under according to seismic code IS:1893-1966, IS:1893-1984 and IS:1893-2002. The result includes comparison of base shear, roof displacement, capacity spectra, nodal displacement which are calculated as per IS: 1893-1966, IS: 1893-1984 and IS: 1893-2002

Dhiman Basu et al. performed seismic analysis of building with flexible floor diaphragms. Two models named as model 1, model 2. Model 1 includes flexible floor under torsion loading and Model 2 includes flexible floor without torsion loading. The result includes comparison of the Contribution of Torsion and Diaphragm Flexibility to Design Response.

Syed Saif Uddin at al. preformed analysis of liquid storage tanks under seismic loading. An intz tank is modelled in FEM based software (SAP 2000) under the seismic loading as per IS: 1893-2002. The result include that there is increase of 15 % in hydrodynamic pressure in elevated tank and 25 % in ground supported tank.

Dr. H Sudarshan Rao et al, has done a comparative study of lateral force computed from IS: 1893-1984 & IS: 1893-2002. Seismic coefficient method and response spectrum method were used to determine the lateral load acting on the two cases of building model.

Mayur R. Rethaliya et al. (2018) presented the comparative study of codal provision in IS 1893(PART 1):2002 & IS 1893(PART 1):2016. In this paper, they have studied sixth revised code of IS 1893(PART 1) published in 2016 and changes made in IS 1893(PART 1):2016 from IS 1893(PART 1):2002 are deeply studied.

CHAPTER 3
PROGRAMME OF STUDY

Building codes are revised from time to time and the revision necessitates checking the adequacy of existing building for the demand as per the latest codes of practice. The code for criteria for earthquake resistant design of structures IS: 1893, was introduced in 1962. This standard was subsequently revised in 1966, 1970, 1975, 1984, 2002 and 2016. Conventional earthquake resistant design of buildings was aimed to provide minimum amount of lateral resistance to buildings and the methods for the estimation of base shear (seismic coefficient method) were modified with respect to the revisions.

Following are the objective of the study as discussed below:

3.1 Objective of the study

1. To explore the availability of different seismic codes available from time to time i.e. different version of IS: 1893 and their procurement.
2. To study these version of codes and different specifications for calculation of various seismic parameters.
3. To develop excel based format for calculation of different seismic parameters, for e.g. base shear and its distribution on different floor of RC framed building.
4. To study the use of commercial analysis and design software STAAD Pro. and development of an RC framed building model.
5. To calculate base shear and its distribution in the model made, in the above objective.
6. To apply seismic forces calculated in the above objective, as per the different versions of code, one by one on the developed model and analyze the model for all such forces
7. To see variations in response parameters such as top displacement, storey drifts and forces in selected beam and columns and also reinforcement requirement in selected members.
8. To analyze and discuss the results, documentation of results in the form of graphs and exploring the further scopes for the study.

3.2 INTRODUCTION OF VARIOUS CODES

In the codal study, a thorough study of different codes of IS: 1893 has been done. Criterion for determining seismic base shear and lateral load using static method i.e. seismic coefficient method as per previous versions of IS code 1893 are discussed below. And various seismic parameters which are involved in calculation of seismic base shear and lateral load as per various codes are discussed.

3.2.1 IS CODE: 1893-1962

Key features of IS: 1893 – 1962 code are as given below:

1. Indian standard was adopted by the Indian Standards Institution on 7 August 1962

2. Permissible increase in stresses(3.3.2 clause)

TABLE 3.1: Permissible increases in stress according to IS: 1893-1962

Nature of soil	Permissible Increase in Bearing Pressure (percent)
Hard soils having a bearing capacity greater than 45 tonnes/m^2	50
Average soils having a bearing capacity greater 20 tonnes/m^2 and equal to or less than 45 tonnes/m^2	30
Soft soils having a bearing capacity greater 10 tonnes/m^2 and equal to or less than 20 tonnes/m^2	0 to 30

3. Country is divided in seven zones(3.4 clause)

TABLE 3.2: Value of horizontal seismic coefficient according to IS: 1893-1962

Zone	HORIZONTAL SEISMIC COEFICIENT		
	Hard soil	Average Soil	Soft Soil
VI	0.08	0.1	0.12
V	0.06	0.08	0.1
IV	0.05	0.06	0.08
III	0.04	0.05	0.06
II	0.02	0.03	0.04
I	0	0.01	0.02
0	0	0	0

4. Design Factors for Different types of building(4.2 clause)

TABLE 3.3: Design factors for different type of building as per IS: 1893-1962

Type of building	Load Combination
Residential building	1.0 DL + 0.50 LL
community building, such as schools, offices, cinema, houses, etc	1.0 DL + 0.67 LL
industrial building	1.0 DL + 10 LL

5. For Multi storeyed building, the seismic coefficient may be decreased by a factor 'K'

$$K = \frac{0.35\,S}{N+0.9\,(S-8)} \leq 1$$

6. Seismic Shear

$$V = K.\alpha_h.(W_r+NW_f)$$

7. Important buildings should be designed for 1 and half times the seismic coefficient.

3.2.2 IS CODE: 1893-1966

Key features of IS: 1893 – 1966 code are as given below:

1. Indian standard was adopted by the Indian Standards Institution on 19 Oct 1966.

2. Permissible increase in stresses(3.3.2 clause)

TABLE 3.4: Permissible increases in stress according to IS: 1893-1966

Nature of soil	**Permissible Increase in Bearing Pressure (percent)**
Soils Type I having a bearing capacity greater than 45 tonnes/m^2	50
Soils Type II having a bearing capacity greater 20 tonnes/m^2 and equal to or less than 45 tonnes/m^2	30
Soils Type III having a bearing capacity greater 10 tonnes/m^2 and equal to or less than 20 tonnes/m^2	30

3. Country is divided in seven zones(3.4 clause)

TABLE 3.5: Value of horizontal seismic coefficient according to IS: 1893-1966

Zone	**HORIZONTAL SEISMIC COEFICIENT**		
	Soil Type I	**Soil Type II**	**Soil Type III**
VI	0.08	0.1	0.12
V	0.06	0.08	0.1
IV	0.05	0.06	0.08
III	0.04	0.05	0.06
II	0.02	0.03	0.04
I	0	0.01	0.02
0	0	0	0

4. Important buildings should be designed for 1 and half times the seismic coefficient.

5. Design Live Loads (4.1 clause)

TABLE 3.6: Design live loads according to IS: 1893-1966

Load Class	**Percentage of Design Vertical Live Load**
200, 250, 300, Stairs and balconies	25
400, 500, 750, and 1000, Garage, light and heavy	50

6. For Important building, the seismic coefficient will be 1.5 times $\alpha_{h.}$

7. Live load on roof may not be considered.

8. $\alpha_v = 0.5\ \alpha_h$

9. If H≤40m, static method can be used

10. H≥40m and up to 30 storeys, model analysis is recommended

11. Base Shear, V_B

$$V_B = \alpha_h CW$$

$$C = \frac{9}{n+5} \leq 1.0 \text{ – framed building}$$
$$\leq 1.33 \text{ – load bearing walls in building}$$

12. Lateral Force, Q_i

$$Q_i = V_B \frac{Wh^2}{\sum Wh^2}$$

3.2.3 IS CODE: 1893-1970

Key features of IS: 1893 – 1970 code are as given below

1. Indian standard was adopted by the Indian Standards Institution on 1970.

2. For static design, α_h is given.

3. For dynamic design, $\frac{\text{Sa}}{g}$ and F (multiplying factor) shall be used.

4. Depending on soil foundation system, α_h and F multiplied by a factor β.

5. Importance factor I=1.5
6. $\alpha_v = 0.5\ \alpha_h$

7. N<15 , liquefaction can occur

8. Live load on roof is assumed to be zero.

9. If H≤40m, static method can be used.

10. H≥40m and up to 30 storeys, model analysis is recommended.

11. H≥90m in zone other than I and II, dynamic analysis shall be made.

12. H≥40m, check for drift and torsion should be made.

13. Base shear, V_B

$$V_B = C\ \alpha_h\ \beta\ W$$

14. For determining T,

(a) For moment resisting frames without bracing/ shear walls for resisting the lateral load

$$T = 0.1\ n$$

(b) For all other buildings,

$$T = \frac{0.09\ H}{d^{0.5}}$$

15. Lateral Force, Q_i

$$Q_i = V_B \frac{Wh^2}{\sum Wh^2}$$

3.2.4 IS CODE: 1893-1975

Key features of IS: 1893 – 1975 code are as given below:

1. Seismic zone factors are incorporated.

2. Country is classified in to five zones.

3. Method to determine seismic forces:
3.1 Seismic Coefficient Method
3.2 Response Spectrum Method

4. Seismic Coefficient Method

$$\alpha_h = \beta\ I\ \alpha_0$$

5. Response Spectrum Method

$$\alpha_h = \beta\ I\ F_o\ \frac{Sa}{g}$$

6. $\alpha_v = 0.5\ \alpha_h$

7. Base shear is calculated as

$$V_B = C\ \alpha_h\ W$$

8. For determining T

(a) For moment resisting frames without bracing/ shear walls for resisting the lateral load

$$T = 0.1\ n$$

(b) For all other buildings,

$$T_a = \frac{0.09}{\sqrt{d}} h$$

9. Design lateral force, Q_i

$$Q_i = V_B \frac{Wh^2}{\sum Wh^2}$$

3.2.5 IS CODE: 1893-1984

Key features of IS 1893-1984 code are as given below:

1. India was divided into 5 seismic zones.

2. Horizontal Seismic Coefficient can be computed as given below:

2.1.Seismic coefficient method

$$\alpha_h = \beta\ I\ \alpha_0$$

2.2. Response Spectrum Method

$$\alpha_h = \beta\ I\ F_o\ \frac{Sa}{g}$$

3. Base Shear is calculated as given below:

$$V_B = K\ C\ \alpha_h\ W$$

4. Design lateral force, Q_i

$$Q_i = V_B \frac{Wh^2}{\sum Wh^2}$$

3.2.6 IS CODE: 1893-2002

Key features of IS 1893-2002 code are as given below:

1. Load combinations:

1.1 for steel structures

a) 1.7 (DL + IL)
b) 1.7 (DL $\pm$ EL)
c) 1.3 (DL + IL $\pm$ EL)

1.2 for reinforced concrete and prestressed structure

a) 1.5 (DL + IL)
b) 1.2 (DL + IL $\pm$ EL)
c) 1.5 (DL $\pm$ EL)
d) 0.9 DL $\pm$ 1.5 EL

2. Design horizontal seismic coefficient A_h is computed as,

$$A_h = \frac{Z\ I\ Sa}{2\ R\ g}$$

3. Zone factor table

Table 3.7: Zone factor for different zones of India according to IS 1893-2002

Seismic zone	**II**	**III**	**IV**	**V**
Seismic Intensity	Low	Moderate	Severe	Very Severe
Z	0.10	0.16	0.24	0.36

4. Importance Factor I

TABLE 3.8: Importance factor for various building

S. No.	**Structure**	**Importance factor**
1	Important service and community building such as schools, hospital, monument structures etc	1.5
2	All other buildings	1.0

5. Response acceleration coefficient

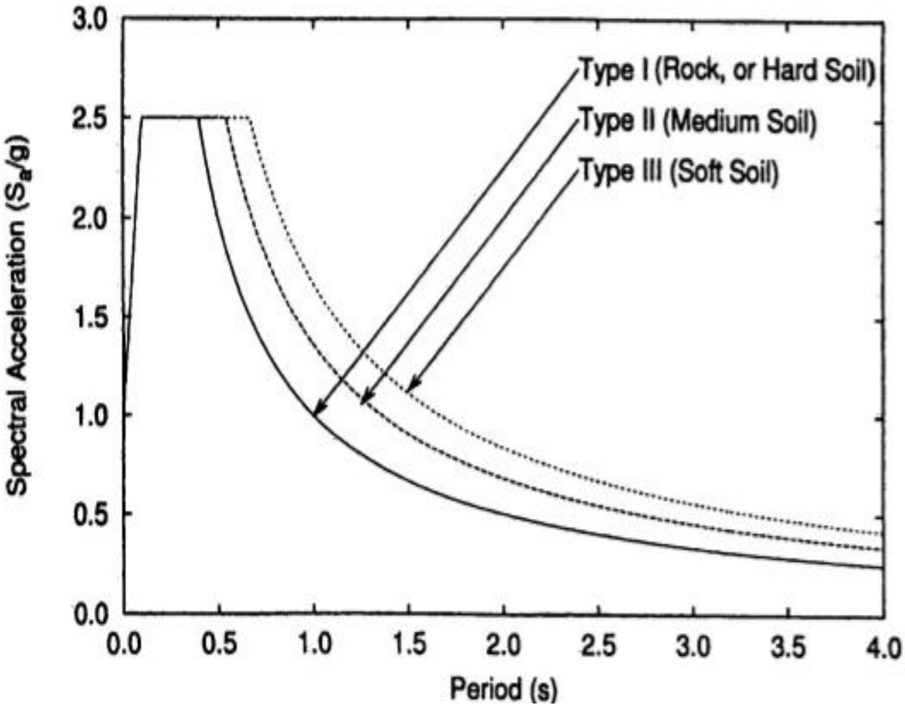


Fig. 3.1: Spectral acceleration v/s period (taken from IS 1893-2002)

6. Response Reduction Factor, R

6.1 Ordinary RC moment resisting frame (OMRF)	3.0
6.2 Special RC moment resisting frame (SMRF)	5.0

7. Percentage of Imposed load to be considered in seismic weight

7.1	Up to 3.0 N/mm^2	25 %
7.2	Above 3.0 N/mm^2	50 %

8. Seismic base shear is calculated as

$$V_B = A_h W$$

9. Fundamental Natural Period for building without brick infill panel

$$T_a = 0.075\, h^{0.75} \text{ for rcc frame building}$$
$$T_a = 0.085\, h^{0.75} \text{ for steel frame building}$$

10. Approximate fundamental Natural Period for building with brick infill panel

$$T_a = \frac{0.09}{\sqrt{d}} h$$

11. Design lateral force, Q_i

$$Q_i = V_B \frac{Wh^2}{\sum Wh^2}$$

3.2.7 IS CODE: 1893-2016

Key features of IS 1893-2016 code are as given below:

1. Load Combinations:

1.1 When Structural Elements are placed along two mutually orthogonal horizontal directions. Then Structure will design for fully design load in one horizontal direction

1.2 When Structural Elements are not placed along two mutually orthogonal horizontal directions. Then structure will design for full 100 % EQ in one direction + 30% EQ in other direction.

12. Design horizontal seismic coefficient A_h is computed as

$$A_h = \frac{Z\ I\ Sa}{2\ R\ g}$$

13. Zone factor table

TABLE 3.9: Zone factors for different zones as per IS: 1893-2016

Seismic zone	**II**	**III**	**IV**	**V**
Seismic Intensity	Low	Moderate	Severe	Very Severe
Z	0.10	0.16	0.24	0.36

14. Importance Factor I

TABLE 3.10: Importance factor for different buildings according to IS: 1893-2016

S. No.	**Structure**	**Importance factor**
1	Important service and community building such as schools, hospital, monument structures etc	1.5
2	All other buildings	1.0
3	Commercial building or residential building	1.2

15. Response acceleration coefficient

TABLE 3.11: Response acceleration Coefficient for different types if soils according to IS: 1893-2016

Type of soil	Static analysis	
	S_a/g	Range of T
Rocky/Hard soil sites	2.5	0 < T < 0.40s
	1/T	0.40s < T < 4.0s
	0.25	T > 4.0s
Medium stiff soil sites	2.5	0 < T < 0.55s
	1.36/T	0.55 < T < 4.0s
	0.34	T > 4.0s
Soft soil sites	2.5	0 < T < 0.67s
	1.67/T	0.67 < T < 4.0s
	0.42	T > 4.0s

16. Response Reduction Factor, F
6.1 Ordinary RC moment resisting frame (OMRF) 3.0
6.2 Special RC moment resisting frame (SMRF) 5.0

17. Percentage of Imposed load to be considered in seismic weight
17.1 Up to 3.0 N/mm^2 25 %
17.2 Above 3.0 N/mm^2 50 %

18. Seismic base shear is calculated as,

$$V_B = A_h W$$

19. Fundamental Natural Period for building without brick infill panel

$$T_a = 0.075\, h^{0.75} \text{ for rcc frame building}$$

$$T_a = 0.080\, h^{0.75} \text{ for steel frame building}$$

20. Approximate fundamental Natural Period for building with brick infill panel

$$T_a = \frac{0.09}{\sqrt{d}} h$$

21. Design lateral force, Q_i

$$Q_i = V_B \frac{Wh^2}{\sum Wh^2}$$

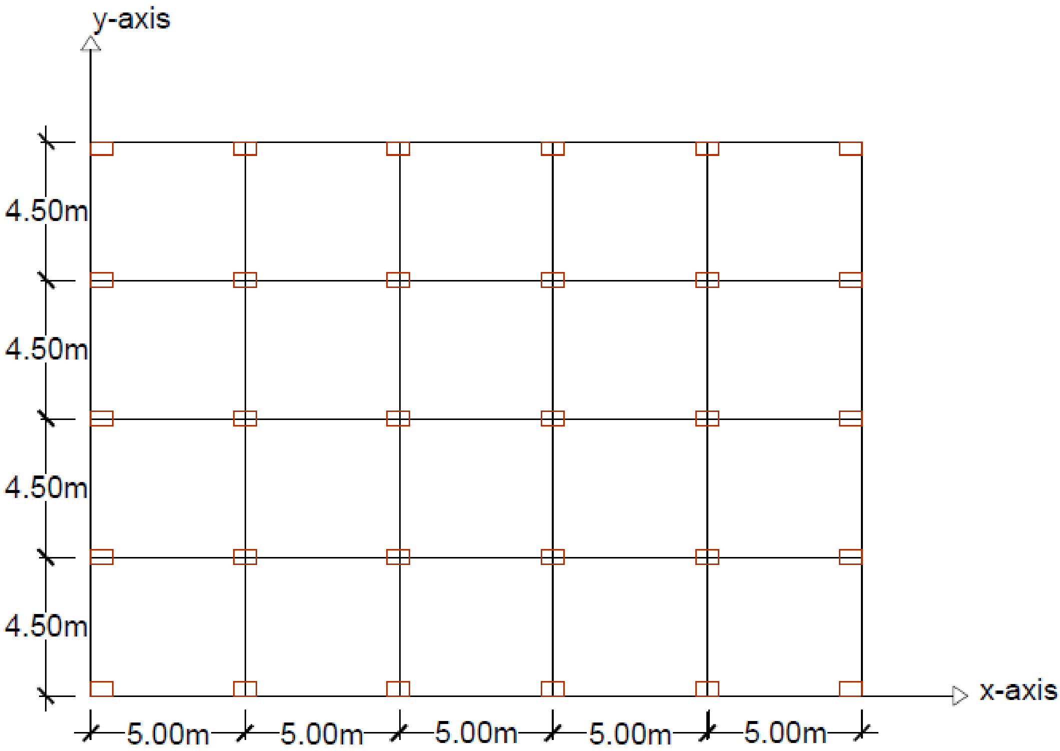
CHAPTER 4
MODELLING

A building is modelled to compute the lateral load and seismic base shear as per various codes for earthquake resistant design of building. A frame is needed for the study of various codes, which would help in analyzing and comparison, to understand the effect of revisions of seismic codes. Following are the details of the building modelled as mentioned below:

Plan and elevation details of building:

TABLE 4.1: Description of frame element and building

S.NO.	PARTICULARS	DETAILS
1	Height of the building	16m
2	Plan dimension	25m X 18m
3	Type of structure	Multi-storey rigid plane frame (OMRF)
4	Seismic zone (selected)	3, 4 and 5
5	Number of stories	G+4
6	Floor height	3.2m
7	Live load (floor)	4 kN/m^2
8	Live load (roof)	1.5 kN/m^2
9	Material	Fe 415 & M20
10	Size of columns	300mm X 500mm
11	Size of beams	300mm X 400mm
12	Depth of slab	150mm (3.75 kN/m^2)
13	Slab load including finishes	4 kN/m^2
14	Partition wall loads	2 kN/m^2
15	Unit weight of RCC	25 kN/m^3
16	Unit weight of wall	20 kN/m^3
17	Type of soil condition	Medium (average soil)
18	Foundation	Isolated without tie beams



PLAN (25m X 18m)

FIG. 4.1: Plan of the building

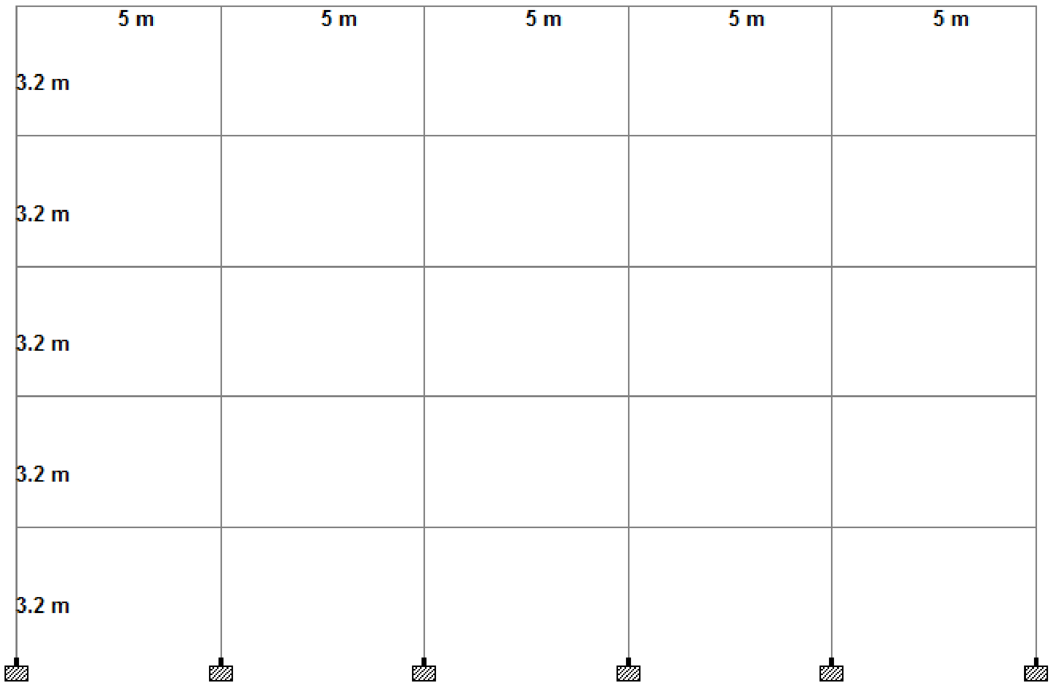


Fig. 4.2: Elevation of the building

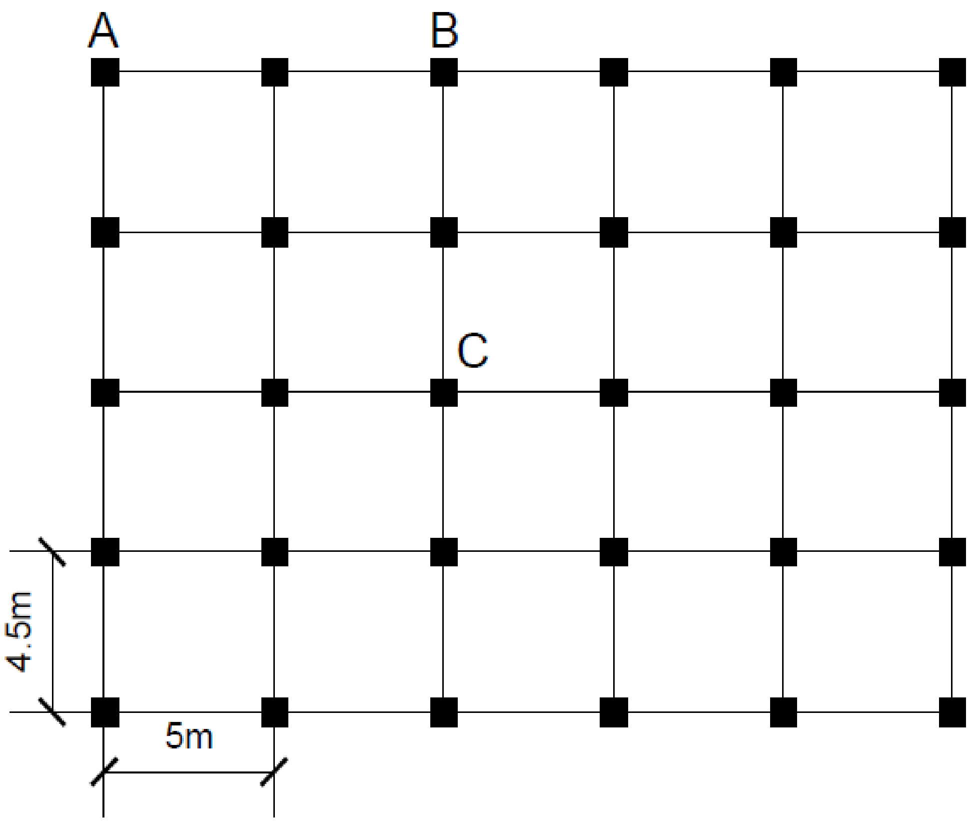


Fig. 4.3: Location of selected columns A, B & C in plan of the building

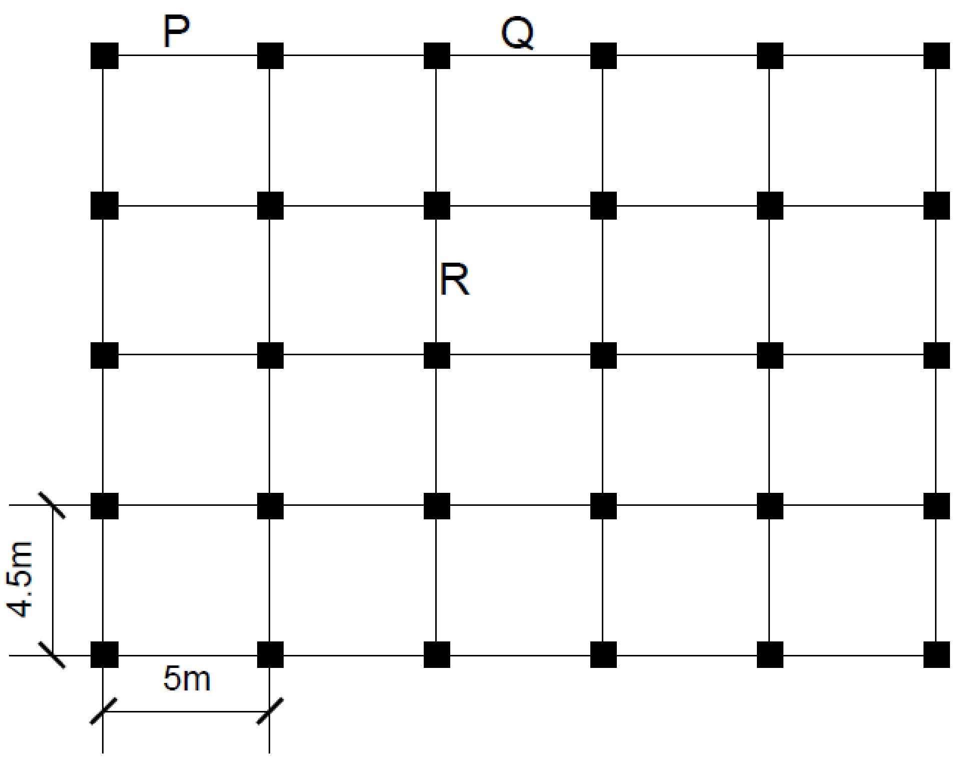


Fig. 4.4: Location of selected beams P, Q & R in the plan of the building

CHAPTER 5
EXCEL PROGRAMME

In this chapter, calculation is made in EXCEL sheet, to compute the lateral load as per various codes of earthquake resistant design of building. A programme has been developed in EXCEL sheet to calculate the seismic shear and lateral load as per various codes available for earthquake resistant design of building. Seismic shear and lateral load are calculated for building located in zone 3, zone 4 and zone 5. Graphs are also plotted for understanding the behavior of variation of seismic shear, lateral load and variation of seismic base shear with various iterations of code IS: 1893.

5.1 Seismic weight of the building

Calculate the seismic weight of the different floors:

TABLE 5.1: Dead load calculation for different component of buildings

ELEMENT	Length (m)	Width (m)	Thickness (m)	No./Floor	Unit Weight (kN/m^3)/udl (kN/m^2)	DL (kN)
Beam	233	0.3	0.4	1	25	699.0
Column	2.9	0.3	0.5	30	25	326.3
Slab DL	25	18	1	1	4	1800.0
P. wall	25	18	1	1	1.5	675.0
LL(floor)	25	18	1	1	4	1800.0
LL (roof)	25	18	1	1	1.5	675.0

TABLE 5.2: Seismic weight calculation of different floors

FLOORS	TOTAL DL (kN)	% LL (kN)	SEISMIC WEIGHT (kN)
ROOF	2662.13	0	2662.13
OTHER FLOOR	3500.25	900	4400.25
Seismic weight of building (∑W)			20263.13

5.2 Seismic base shear as per various codes of IS: 1893 for zones 3, 4 & 5

In this section, seismic base shear is calculated in tabular form as per various codes of IS: 1893. Seismic coefficient method is used to calculate the seismic base shear for each zone taken into consideration i.e. zone 3, zone 4 and zone 5.

TABLE 5.3: Calculation of seismic base shear as per various codes of IS: 1893 for zones 3, 4 & 5

SEISMIC CODE	SEISMIC BASE SHEAR		
	ZONE 3	ZONE 4	ZONE 5
IS: 1893-1966	C = $\frac{9}{n+5}$ = 9/10 = 0.9 $V_B = \alpha_h CW$ = 0.05 x 0.9 x 20263.13 = 911.84 Kn	C = $\frac{9}{n+5}$ = 9/10 = 0.9 $V_B = \alpha_h CW$ = 0.06 x 0.9 x 20263.13 = 1094.21 kN	C = $\frac{9}{n+5}$ = 9/10 = 0.9 $V_B = \alpha_h CW$ = 0.08 x 0.9 x 20263.13 = 1458.95 kN
IS: 1893-1970	T = 0.1n = 0.1 x 5 = 0.5s C = $\frac{0.5}{T^{1/3}}$ = 0.63 $V_B = \alpha_h C\beta W$ = 0.04 x 0.63 x 1.2 x 20263.13 = 612.76 KN	T = 0.1n = 0.1 x 5 = 0.5s C = $\frac{0.5}{T^{1/3}}$ = 0.63 $V_B = \alpha_h C\beta W$ = 0.05 x 0.63 x 1.2 x 20263.13 = 765.95 kN	T = 0.1n = 0.1 x 5 = 0.5s C = $\frac{0.5}{T^{1/3}}$ = 0.63 $V_B = \alpha_h C\beta W$ = 0.08 x 0.63 x 1.2 x 20263.13 = 1225.51 kN
IS: 1893-1975	T = 0.1n = 0.1 x 5 = 0.5s From graph, C = 0.8 $\alpha_h = \beta I\alpha_0$ =1.2 x 1 x 0.04 = 0.048 $V_B = \alpha_h CW$ = 0.048 x 0.8 x 20263.13 = 778.1 kN	T = 0.1n = 0.1 x 5 = 0.5s From graph, C = 0.8 $\alpha_h = \beta I\alpha_0$ =1.2 x 1 x 0.05 = 0.06 $V_B = \alpha_h CW$ = 0.06 x 0.8 x 20263.13 = 972.63 kN	T = 0.1n = 0.1 x 5 = 0.5s From graph, C = 0.8 $\alpha_h = \beta I\alpha_0$ =1.2 x 1 x 0.08 = 0.096 $V_B = \alpha_h CW$ = 0.096 x 0.8 x 20263.13 = 1556.21 kN

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IS: 1893-1984	$T = 0.1n = 0.1 \times 5 = 0.5s$ From graph, C = 0.8 $\alpha_h = \beta I \alpha_0 = 1.2 \times 1 \times 0.04 = 0.048$ $V_B = k\alpha_h CW$ $= 1 \times 0.048 \times 0.8 \times 20263.13$ $= 778.1$ kN	$T = 0.1n = 0.1 \times 5 = 0.5s$ From graph, C = 0.8 $\alpha_h = \beta I \alpha_0 = 1.2 \times 1 \times 0.05 = 0.06$ $V_B = k\alpha_h CW$ $= 1 \times 0.06 \times 0.8 \times 20263.13$ $= 972.63$ kN	$T = 0.1n = 0.1 \times 5 = 0.5s$ From graph, C = 0.8 $\alpha_h = \beta I \alpha_0 = 1.2 \times 1 \times 0.08 = 0.096$ $V_B = k\alpha_h CW$ $= 1 \times 0.096 \times 0.8 \times 20263.13$ $= 1556.21$ kN
IS: 1893-2002	$T_a = 0.075(H)^{0.75}$ $= 0.075(16)^{0.75} = 0.6s$ From table, $\frac{Sa}{g} = \frac{1.36}{T} = 2.267$ $A_h = \frac{Z}{2}\frac{I}{R}\frac{Sa}{g} = \frac{0.16}{2}\frac{1}{3}x2.267$ $= 0.06045$ $V_B = A_h W$ $= 0.06045 \times 20263.13$ $= 1224.97$ kN	$T_a = 0.075(H)^{0.75}$ $= 0.075(16)^{0.75} = 0.6s$ From table, $\frac{Sa}{g} = \frac{1.36}{T} = 2.267$ $A_h = \frac{Z}{2}\frac{I}{R}\frac{Sa}{g} = \frac{0.24}{2}\frac{1}{3}x2.267$ $= 0.09068$ $V_B = A_h W$ $= 0.09068 \times 20263.13$ $= 1837.46$ kN	$T_a = 0.075(H)^{0.75}$ $= 0.075(16)^{0.75} = 0.6s$ From table, $\frac{Sa}{g} = \frac{1.36}{T} = 2.267$ $A_h = \frac{Z}{2}\frac{I}{R}\frac{Sa}{g} = \frac{0.36}{2}\frac{1}{3}x2.267$ $= 0.13602$ $V_B = A_h W$ $= 0.13602 \times 20263.13$ $= 2756.19$ kN
IS: 1893-2016	$T_a = 0.075(H)^{0.75}$ $= 0.075(16)^{0.75} = 0.6s$	$T_a = 0.075(H)^{0.75}$ $= 0.075(16)^{0.75} = 0.6s$	$T_a = 0.075(H)^{0.75}$ $= 0.075(16)^{0.75} = 0.6s$

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IS: 1893-2016	From table, $\frac{Sa}{g} = \frac{1.36}{T}$ = 2.267 $A_h = \frac{Z}{2}\frac{I}{R}\frac{Sa}{g} = \frac{0.16}{2}\frac{1.2}{3}$x2.267 = 0.072544 $V_B = A_hW$ = 0.072544 x 20263.13 = 1469.97 kN	From table, $\frac{Sa}{g} = \frac{1.36}{T}$ = 2.267 $A_h = \frac{Z}{2}\frac{I}{R}\frac{Sa}{g} = \frac{0.24}{2}\frac{1.2}{3}$x2.267 = 0.108816 $V_B = A_hW$ = 0.108816 x 20263.13 = 2204.95 kN	From table, $\frac{Sa}{g} = \frac{1.36}{T}$ = 2.267 $A_h = \frac{Z}{2}\frac{I}{R}\frac{Sa}{g} = \frac{0.36}{2}\frac{1.2}{3}$x2.267 = 0.163224 $V_B = A_hW$ = 0.163224 x 20263.13 = 3307.43 kN

5.3 Excel sheet for zone 3

In the table given below, seismic lateral load and shear at floors of the building are calculated as per various iterations of IS: 1893 code. In this excel sheet, lateral load and seismic shear are calculated for the building located in zone 3.

TABLE 5.4: Excel sheet for calculation of lateral load and seismic shear for zone 3 as per various iterations of IS: 1893 (Part 1)

Seismic shear and lateral load as per IS: 1893-1962 for zone 3

Floors	N	Factor 'K'	Seismic coefficient	Weight of roof	Weight of floor	Seismic base shear	Q (kN)
Roof	0	1	0.05	0	0	0	133.11
4 Floor	0	1	0.05	2662.13	0	133.11	121.79
3 Floor	1	0.83	0.05	2662.13	3500.25	254.90	83.29
2 Floor	2	0.70	0.05	2662.13	3500.25	338.19	61.08
1 Floor	3	0.61	0.05	2662.13	3500.25	399.27	46.71
0 Floor	4	0.54	0.05	2662.13	3500.25	445.98	0.00

Seismic shear and lateral load as per IS: 1893-1966 for zone 3

Floors	Floors weight (kN)	h	h^2	Wh^2	Lateral load coefficient	Base shear (kN)	Q (kN)	Seismic shear (kN)
Roof	2662.13	16	256	681504	0.33518	911.84	305.63	305.63
4 Floor	4400.25	12.8	163.84	720936.96	0.35457	911.84	323.31	628.94
3 Floor	4400.25	9.6	92.16	405527.04	0.19945	911.84	181.86	810.81
2 Floor	4400.25	6.4	40.96	180234.24	0.08864	911.84	80.83	891.63
1 Floor	4400.25	3.2	10.24	45058.56	0.02216	911.84	20.21	911.84
$\sum Wh^2$				2033260.8				

Seismic shear and lateral load as per IS: 1893-1970 for zone 3

Floors	Floors weight (kN)	h	h^2	Wh^2	Lateral load coefficient	Base shear (kN)	Q (kN)	Seismic shear (kN)
Roof	2662.13	16	256	681504	0.33518	612.76	205.38	205.38
4 Floor	4400.25	12.8	163.84	720936.96	0.35457	612.76	217.27	422.65
3 Floor	4400.25	9.6	92.16	405527.04	0.19945	612.76	122.21	544.86
2 Floor	4400.25	6.4	40.96	180234.24	0.08864	612.76	54.32	599.18
1 Floor	4400.25	3.2	10.24	45058.56	0.02216	612.76	13.58	612.76
$\sum Wh^2$				2033260.8				

Cont…

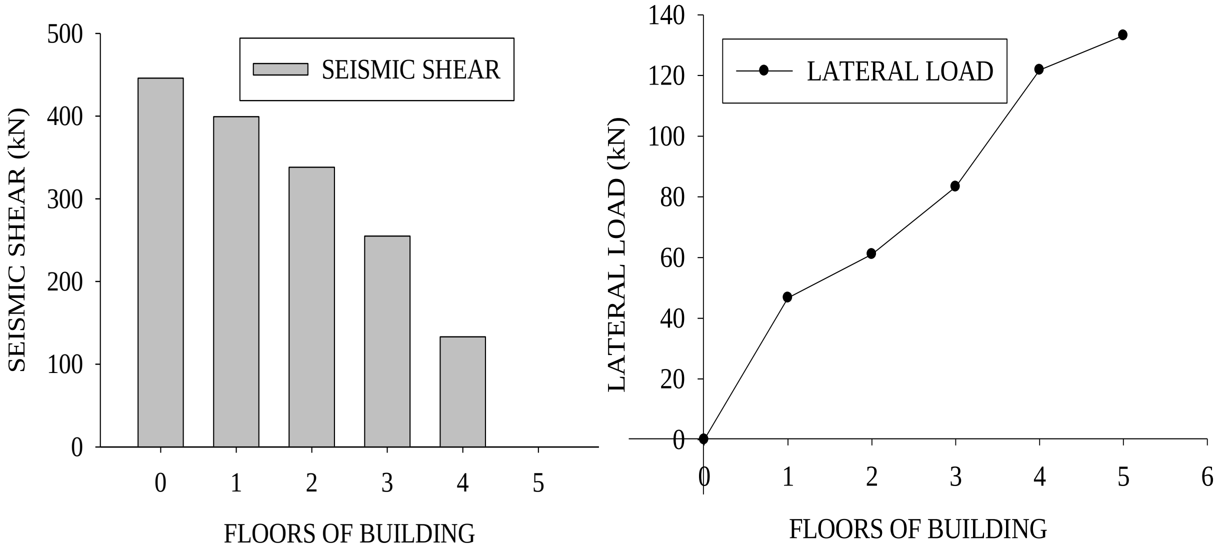
Seismic shear and lateral load as per IS: 1893-1975 for zone 3								
Floors	**Floors weight (kN)**	**h**	**h^2**	**Wh^2**	**Lateral load coefficient**	**Base shear (kN)**	**Q (kN)**	**Seismic shear (kN)**
Roof	2662.13	16	256	681504	0.33518	778.10	260.80	260.80
4 Floor	4400.25	12.8	163.84	720936.96	0.35457	778.10	275.89	536.70
3 Floor	4400.25	9.6	92.16	405527.04	0.19945	778.10	155.19	691.89
2 Floor	4400.25	6.4	40.96	180234.24	0.08864	778.10	68.97	760.86
1 Floor	4400.25	3.2	10.24	45058.56	0.02216	778.10	17.24	778.10
$\sum Wh^2$				2033260.8				

Seismic shear and lateral load as per IS: 1893-1984 for zone 3								
Floors	**Floors weight (kN)**	**h**	**h^2**	**Wh^2**	**Lateral load coefficient**	**Base shear (kN)**	**Q (kN)**	**Seismic shear (kN)**
Roof	2662.13	16	256	681504	0.33518	778.10	260.80	260.80
4 Floor	4400.25	12.8	163.84	720936.96	0.35457	778.10	275.89	536.70
3 Floor	4400.25	9.6	92.16	405527.04	0.19945	778.10	155.19	691.89
2 Floor	4400.25	6.4	40.96	180234.24	0.08864	778.10	68.97	760.86
1 Floor	4400.25	3.2	10.24	45058.56	0.02216	778.10	17.24	778.10
$\sum Wh^2$				2033260.8				

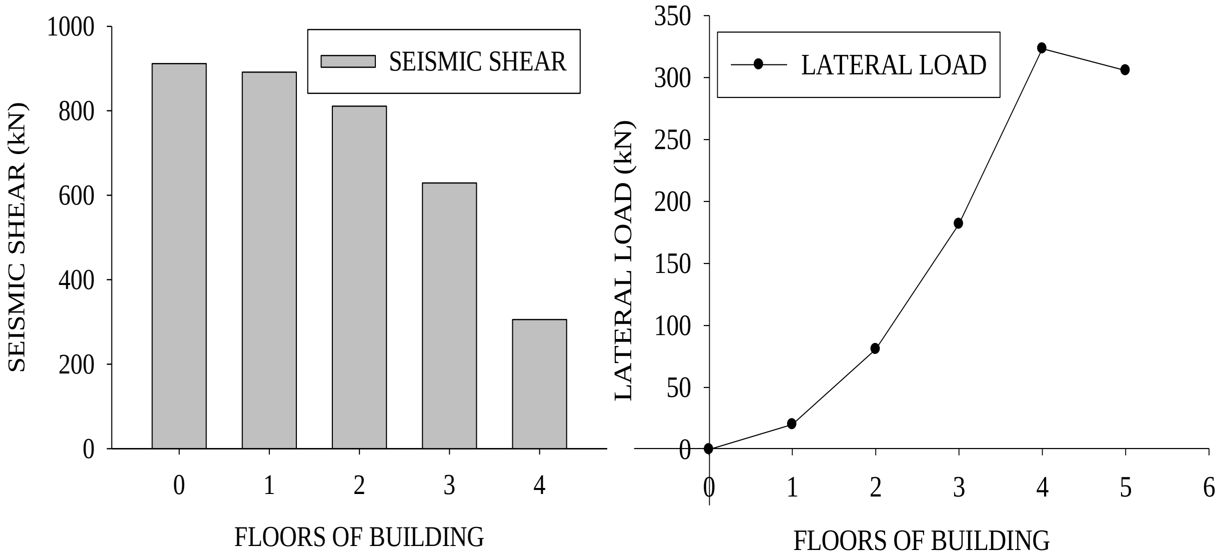
Seismic shear and lateral load as per IS: 1893-2002 for zone 3								
Floors	**Floors weight (kN)**	**h**	**h^2**	**Wh^2**	**Lateral load coefficient**	**Base shear (kN)**	**Q (kN)**	**Seismic shear (kN)**
Roof	2662.13	16	256	681504	0.33518	1224.97	410.58	410.58
4 Floor	4400.25	12.8	163.84	720936.96	0.35457	1224.97	434.34	844.93
3 Floor	4400.25	9.6	92.16	405527.04	0.19945	1224.97	244.32	1089.24
2 Floor	4400.25	6.4	40.96	180234.24	0.08864	1224.97	108.59	1197.83
1 Floor	4400.25	3.2	10.24	45058.56	0.02216	1224.97	27.15	1224.97
$\sum Wh^2$				2033260.8				

Seismic shear and lateral load as per IS: 1893-2016 for zone 3								
Floors	**Floors weight (kN)**	**h**	**h^2**	**Wh^2**	**Lateral load coefficient**	**Base shear (kN)**	**Q (kN)**	**Seismic shear (kN)**
Roof	2662.13	16	256	681504	0.33518	1469.97	492.70	492.70
4 Floor	4400.25	12.8	163.84	720936.96	0.35457	1469.97	521.21	1013.91
3 Floor	4400.25	9.6	92.16	405527.04	0.19945	1469.97	293.18	1307.09
2 Floor	4400.25	6.4	40.96	180234.24	0.08864	1469.97	130.30	1437.39
1 Floor	4400.25	3.2	10.24	45058.56	0.02216	1469.97	32.58	1469.97
$\sum Wh^2$				2033260.8				

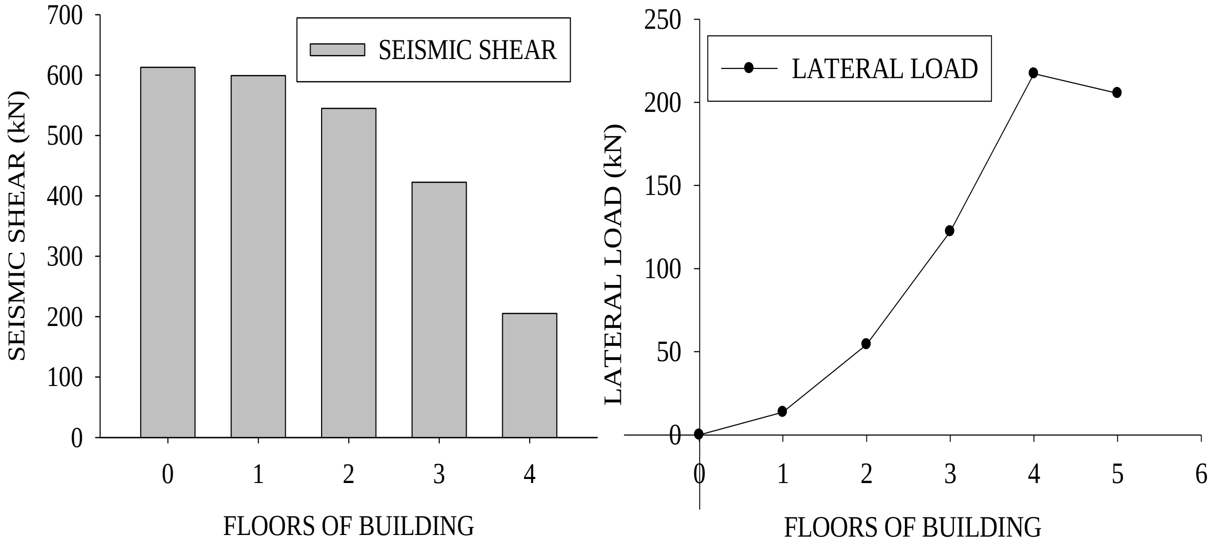
Following are the graphical representations for shear and lateral load variations in accordance with various version of IS: 1893 for zone 3.



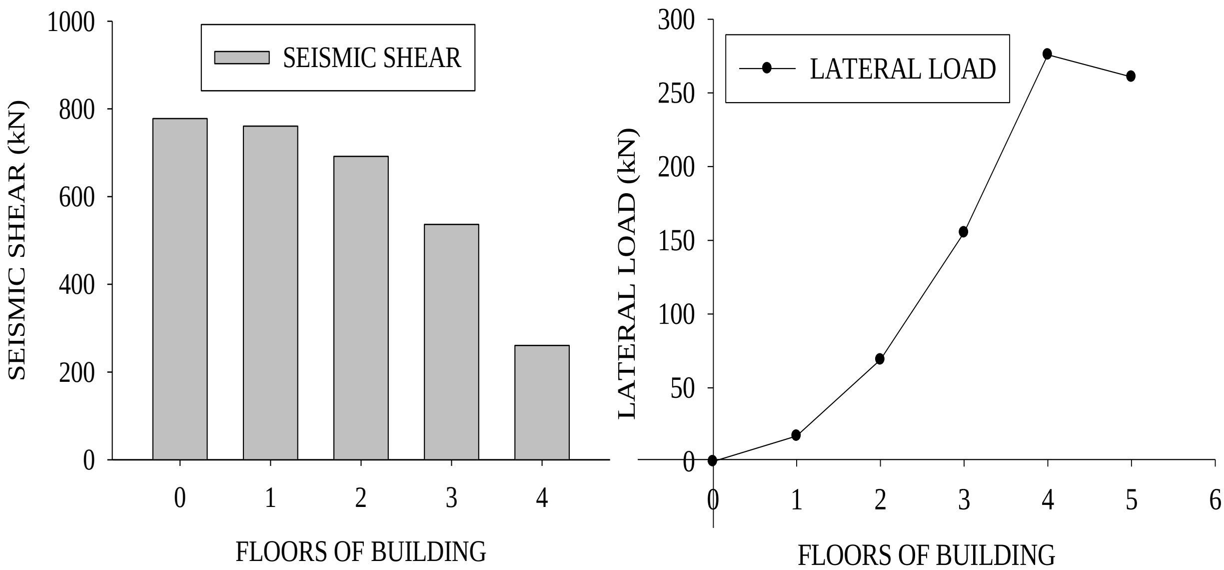
GRAPH 5.1: Variation of seismic shear and lateral load with floors of building for zone 3 as per IS: 1893-1962



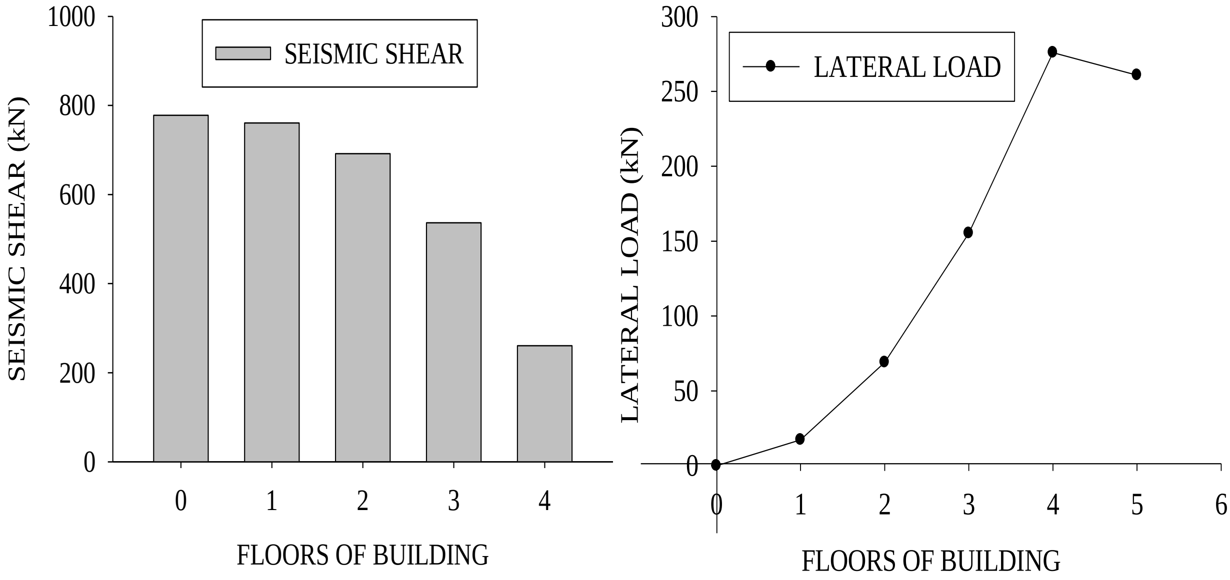
GRAPH 5.2: Variation of seismic shear and lateral load with floors of building for zone 3 as per IS: 1893-1966



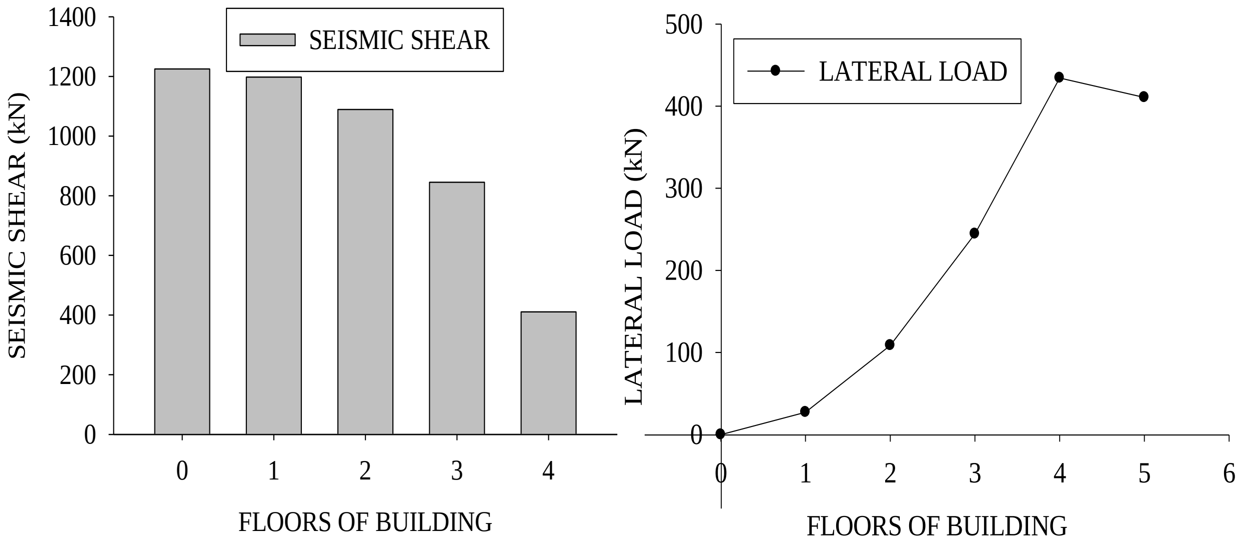
GRAPH 5.3: Variation of seismic shear and lateral load with floors of building for zone 3 as per IS: 1893-1970



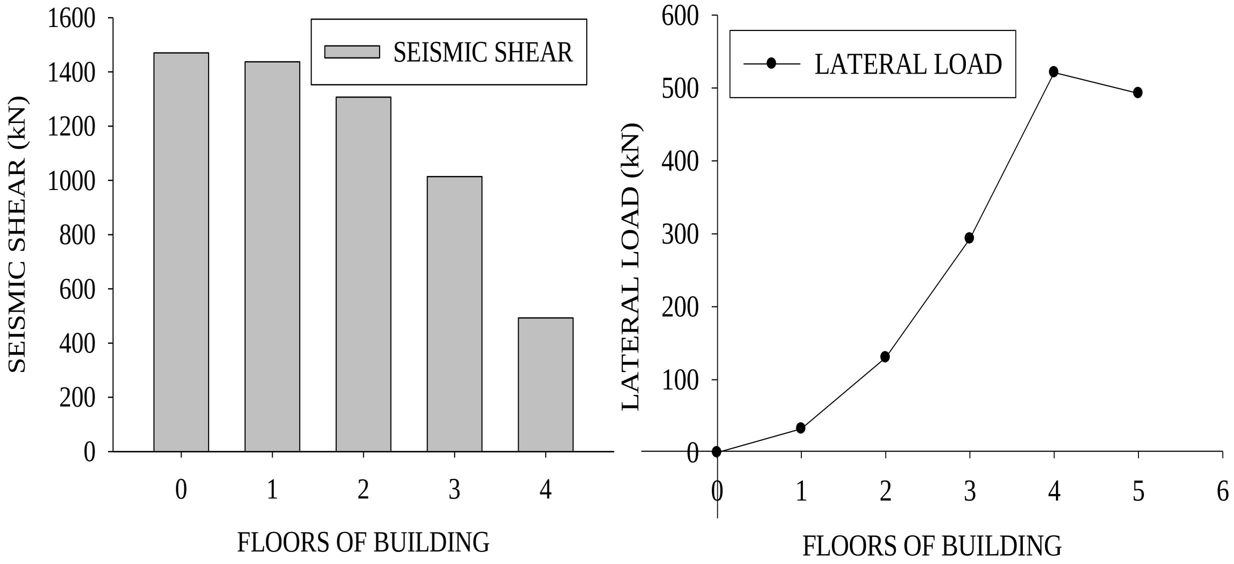
GRAPH 5.4: Variation of seismic shear and lateral load with floors of building for zone 3 as per IS: 1893-1975



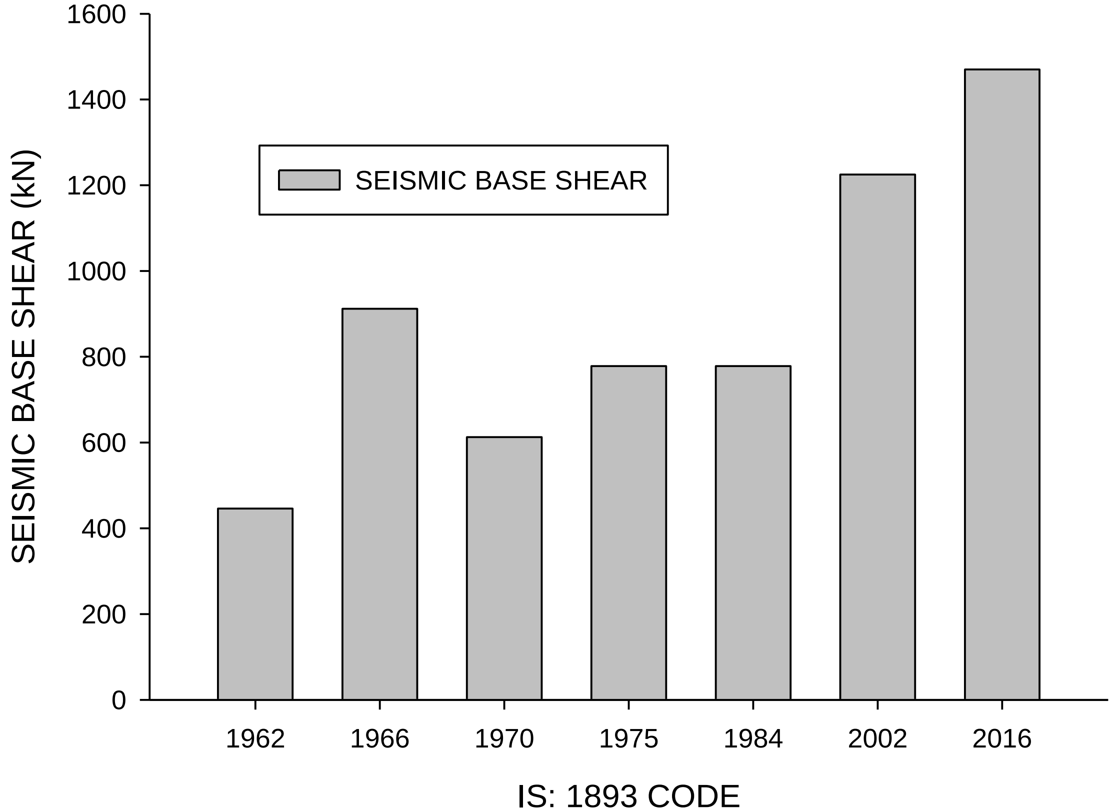
GRAPH 5.5: Variation of seismic shear and lateral load with floors of building for zone 3 as per IS: 1893-1984



GRAPH 5.6: Variation of seismic shear and lateral load with floors of building for zone 3 as per IS: 1893-2002



GRAPH 5.7: Variation of seismic shear and lateral load with floors of building for zone 3 as per IS: 1893-2016



Graph 5.8: Comparison of seismic base shear computed through various iterations of IS: 1893 code for zone 3

5.4 Excel sheet for zone 4

In the table given below, seismic lateral load and shear at floors of the building are calculated as per various iterations of IS: 1893 code. In this excel sheet, lateral load and seismic shear are calculated for the building located in zone 4.

TABLE 5.5: Excel sheet for calculation of lateral load and seismic shear for zone 4 as per various iterations of IS: 1893 (Part 1)

Seismic shear and lateral load as per IS: 1893-1962 for zone 4

Floors	N	Factor 'K'	Seismic coefficient	Weight of roof	Weight of floor	Seismic base shear	Q (kN)
Roof	0	1	0.06	0	0	0	159.73
4 Floor	0	1	0.06	2662.13	0	159.73	146.15
3 Floor	1	0.83	0.06	2662.13	3500.25	305.88	99.95
2 Floor	2	0.70	0.06	2662.13	3500.25	405.83	73.30
1 Floor	3	0.61	0.06	2662.13	3500.25	479.13	56.05
0 Floor	4	0.54	0.06	2662.13	3500.25	535.18	0.00

Seismic shear and lateral load as per IS: 1893-1966 for zone 4

Floors	Floors weight (kN)	h	h^2	Wh^2	Lateral load coefficient	Base shear (kN)	Q (kN)	Seismic shear (kN)
Roof	2662.13	16	256	681504	0.33518	1094.21	366.75	366.75
4 Floor	4400.25	12.8	163.84	720936.96	0.35457	1094.21	387.98	754.73
3 Floor	4400.25	9.6	92.16	405527.04	0.19945	1094.21	218.24	972.97
2 Floor	4400.25	6.4	40.96	180234.24	0.08864	1094.21	96.99	1069.96
1 Floor	4400.25	3.2	10.24	45058.56	0.02216	1094.21	24.25	1094.21
$\sum Wh^2$				2033260.8				

Seismic shear and lateral load as per IS: 1893-1970 for zone 4

Floors	Floors weight (kN)	h	h^2	Wh^2	Lateral load coefficient	Base shear (kN)	Q (kN)	Seismic shear (kN)
Roof	2662.13	16	256	681504	0.33518	765.95	256.73	256.73
4 Floor	4400.25	12.8	163.84	720936.96	0.35457	765.95	271.58	528.31
3 Floor	4400.25	9.6	92.16	405527.04	0.19945	765.95	152.77	681.08
2 Floor	4400.25	6.4	40.96	180234.24	0.08864	765.95	67.90	748.97
1 Floor	4400.25	3.2	10.24	45058.56	0.02216	765.95	16.97	765.95
$\sum Wh^2$				2033260.8				

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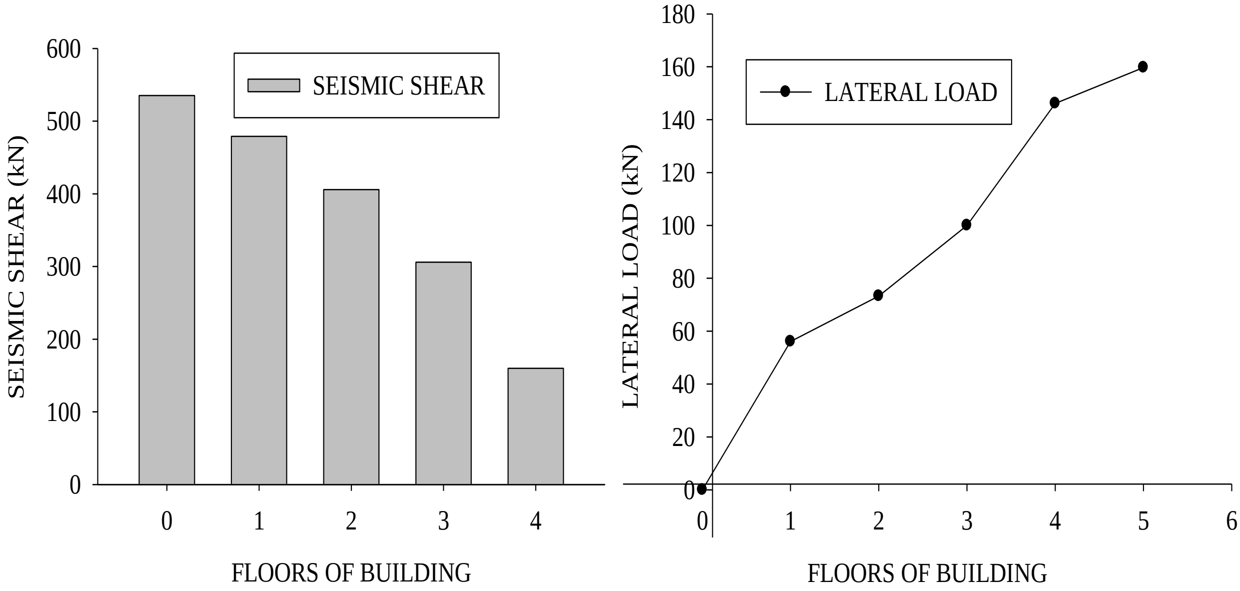
Seismic shear and lateral load as per IS: 1893-1975 for zone 4								
Floors	**Floors weight (kN)**	**h**	**h^2**	**Wh^2**	**Lateral load coefficient**	**Base shear (kN)**	**Q (kN)**	**Seismic shear (kN)**
Roof	2662.13	16	256	681504	0.33518	972.63	326.00	326.00
4 Floor	4400.25	12.8	163.84	720936.96	0.35457	972.63	344.87	670.87
3 Floor	4400.25	9.6	92.16	405527.04	0.19945	972.63	193.99	864.86
2 Floor	4400.25	6.4	40.96	180234.24	0.08864	972.63	86.22	951.08
1 Floor	4400.25	3.2	10.24	45058.56	0.02216	972.63	21.55	972.63
$\sum Wh^2$				2033260.8				

Seismic shear and lateral load as per IS: 1893-1984 for zone 4								
Floors	**Floors weight (kN)**	**h**	**h^2**	**Wh^2**	**Lateral load coefficient**	**Base shear (kN)**	**Q (kN)**	**Seismic shear (kN)**
Roof	2662.13	16	256	681504	0.33518	972.63	326.00	326.00
4 Floor	4400.25	12.8	163.84	720936.96	0.35457	972.63	344.87	670.87
3 Floor	4400.25	9.6	92.16	405527.04	0.19945	972.63	193.99	864.86
2 Floor	4400.25	6.4	40.96	180234.24	0.08864	972.63	86.22	951.08
1 Floor	4400.25	3.2	10.24	45058.56	0.02216	972.63	21.55	972.63
$\sum Wh^2$				2033260.8				

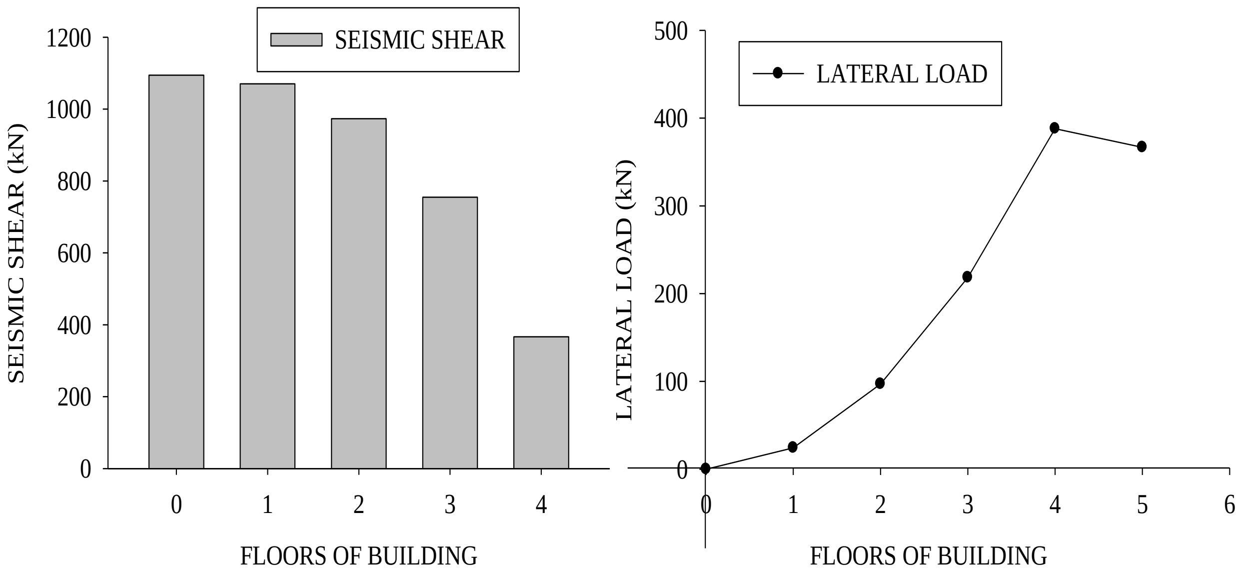
Seismic shear and lateral load as per IS: 1893-2002 for zone 4								
Floors	**Floors weight (kN)**	**h**	**h^2**	**Wh^2**	**Lateral load coefficient**	**Base shear (kN)**	**Q (kN)**	**Seismic shear (kN)**
Roof	2662.13	16	256	681504	0.33518	1837.46	615.88	615.88
4 Floor	4400.25	12.8	163.84	720936.96	0.35457	1837.46	651.51	1267.39
3 Floor	4400.25	9.6	92.16	405527.04	0.19945	1837.46	366.48	1633.86
2 Floor	4400.25	6.4	40.96	180234.24	0.08864	1837.46	162.88	1796.74
1 Floor	4400.25	3.2	10.24	45058.56	0.02216	1837.46	40.72	1837.46
$\sum Wh^2$				2033260.8				

Seismic shear and lateral load as per IS: 1893-2016 for zone 4								
Floors	**Floors weight (kN)**	**h**	**h^2**	**Wh^2**	**Lateral load coefficient**	**Base shear (kN)**	**Q (kN)**	**Seismic shear (kN)**
Roof	2662.13	16	256	681504	0.33518	2204.95	739.05	739.05
4 Floor	4400.25	12.8	163.84	720936.96	0.35457	2204.95	781.81	1520.87
3 Floor	4400.25	9.6	92.16	405527.04	0.19945	2204.95	439.77	1960.64
2 Floor	4400.25	6.4	40.96	180234.24	0.08864	2204.95	195.45	2156.09
1 Floor	4400.25	3.2	10.24	45058.56	0.02216	2204.95	48.86	2204.95
$\sum Wh^2$				2033260.8				

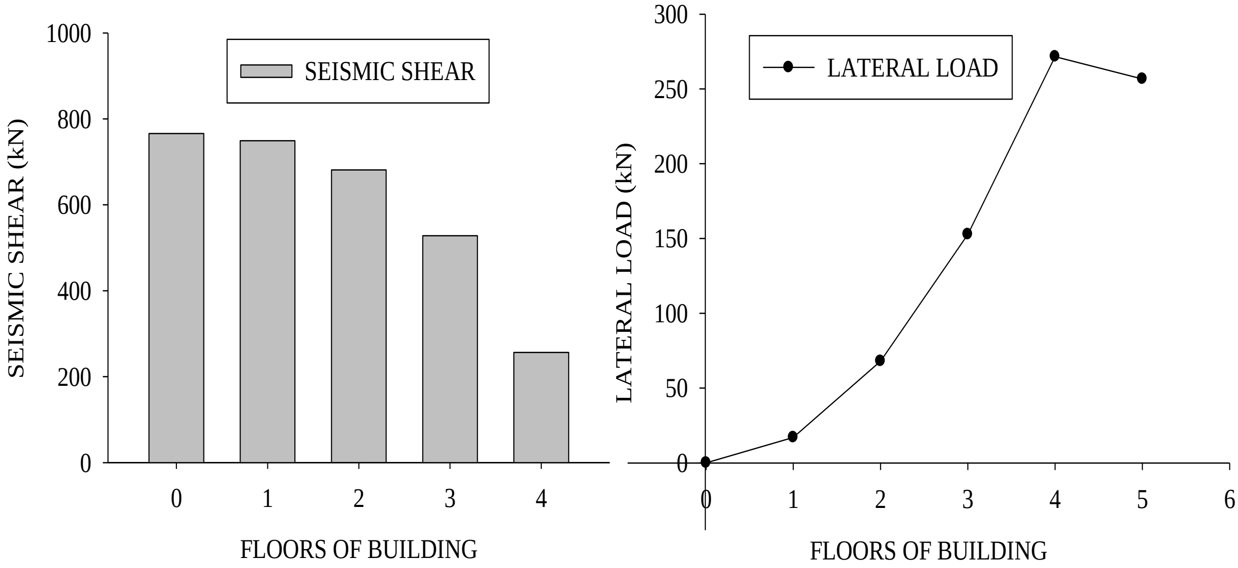
Following are the graphical representations for shear and lateral load variations in accordance with various version of IS: 1893 for zone 4.



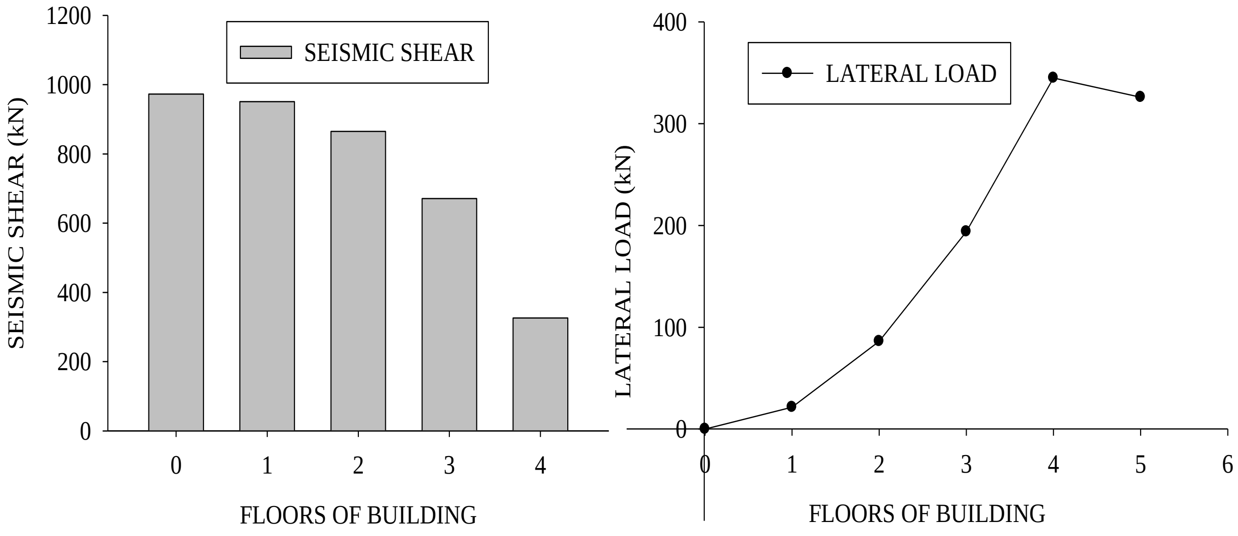
GRAPH 5.9: Variation of seismic shear and lateral load with floors of building for zone 4 as per IS: 1893-1962



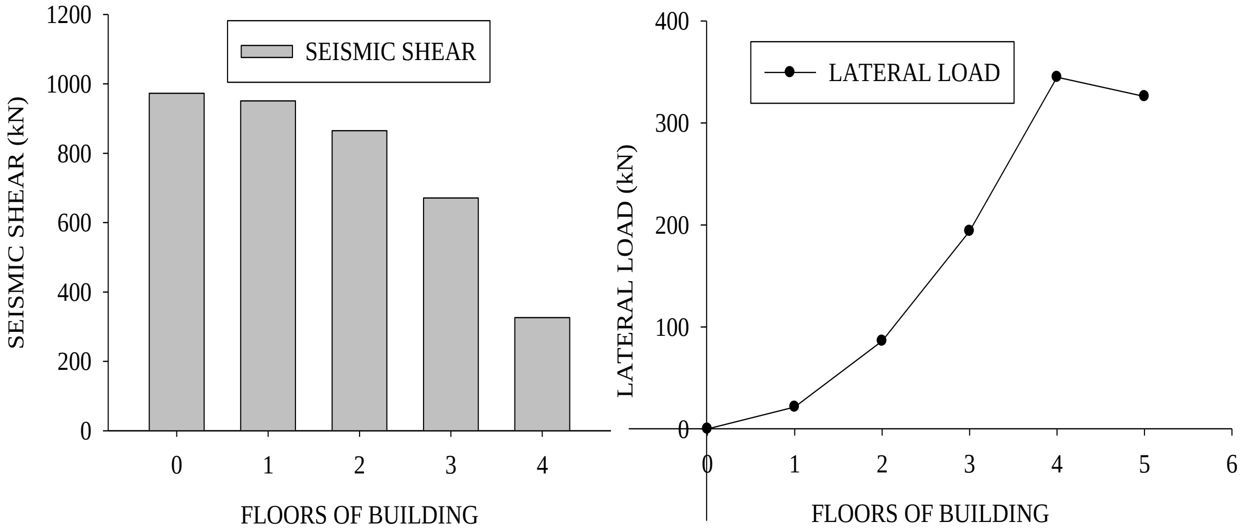
GRAPH 5.10: Variation of seismic shear and lateral load with floors of building for zone 4 as per IS: 1893-1966



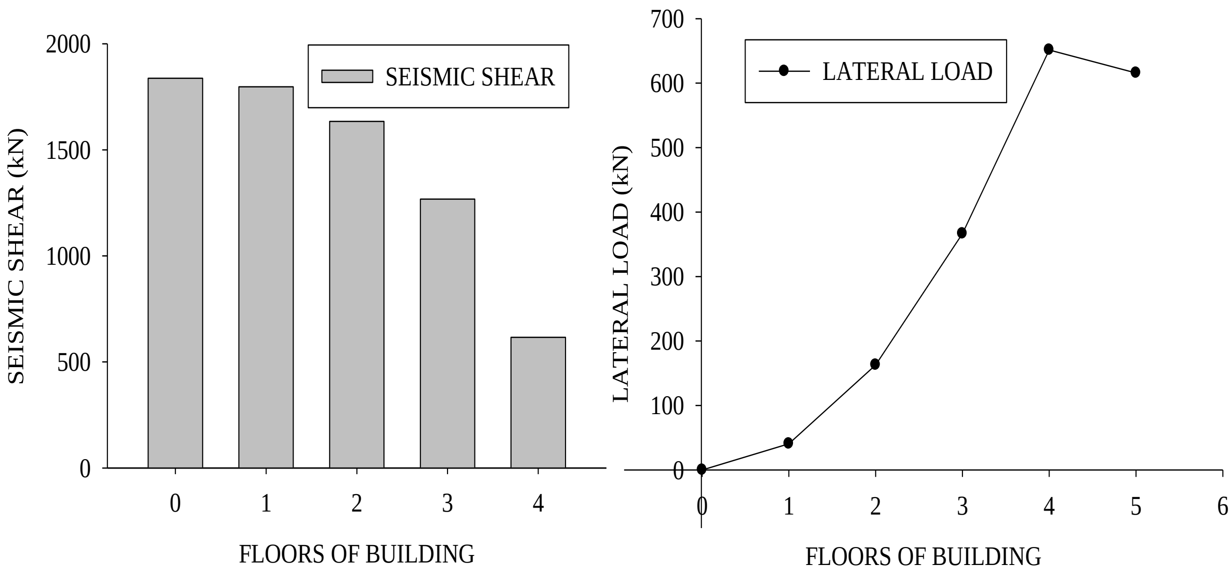
GRAPH 5.11: Variation of seismic shear and lateral load with floors of building for zone 4 as per IS: 1893-1970



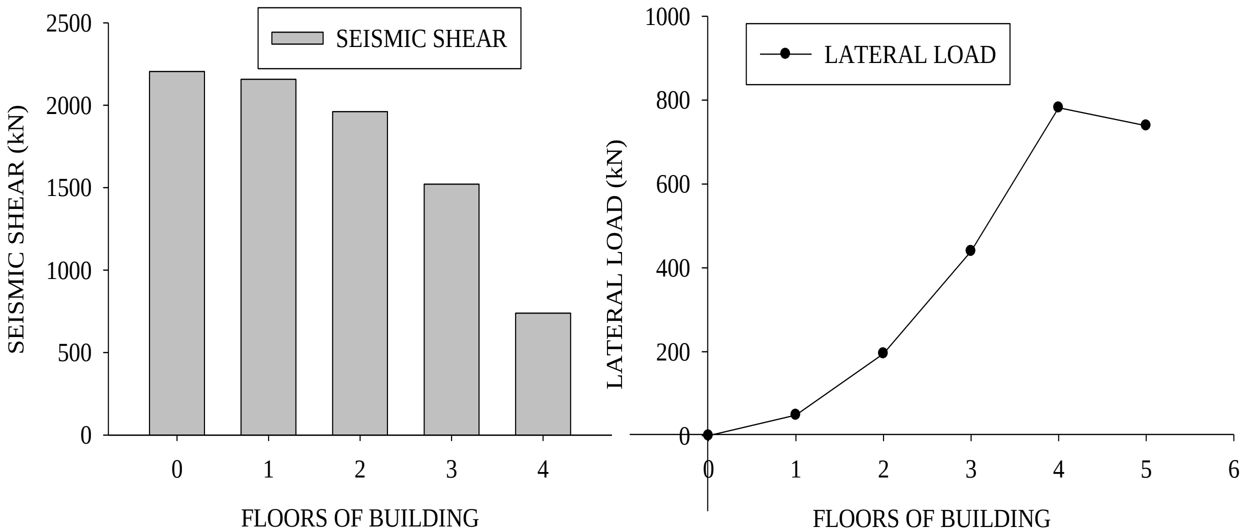
GRAPH 5.12: Variation of seismic shear and lateral load with floors of building for zone 4 as per IS: 1893-1975



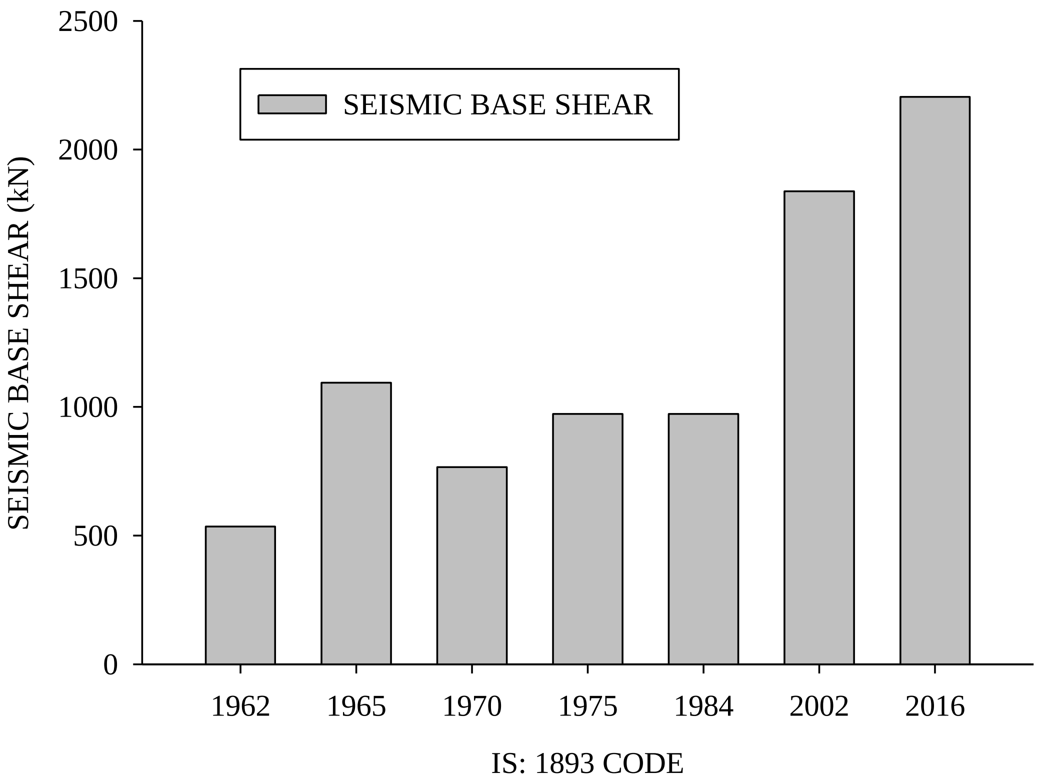
GRAPH 5.13: Variation of seismic shear and lateral load with floors of building for zone 4 as per IS: 1893-1984



GRAPH 5.14: Variation of seismic shear and lateral load with floors of building for zone 4 as per IS: 1893-2002



GRAPH 5.15: Variation of seismic shear and lateral load with floors of building for zone 4 as per IS: 1893-2016



Graph 5.16: Comparison of seismic base shear computed through various iterations of IS: 1893 code for zone 4

5.5 Excel sheet for zone 5

In the table given below, seismic lateral load and shear at floors of the building are calculated as per various iterations of IS: 1893 code. In this excel sheet, lateral load and seismic shear are calculated for the building located in zone 5.

TABLE 5.6: Excel sheet for calculation of lateral load and seismic shear for zone 5 as per various iterations of IS: 1893 (Part 1)

Seismic shear and lateral load as per IS: 1893-1962 for zone 5

Floors	N	Factor 'K'	Seismic coefficient	Weight of roof	Weight of floor	Seismic base shear	Q (kN)
Roof	0	1	0.08	0	0	0	212.97
4 Floor	0	1	0.08	2662.13	0	212.97	194.87
3 Floor	1	0.83	0.08	2662.13	3500.25	407.84	133.27
2 Floor	2	0.70	0.08	2662.13	3500.25	541.11	97.73
1 Floor	3	0.61	0.08	2662.13	3500.25	638.84	74.74
0 Floor	4	0.54	0.08	2662.13	3500.25	713.57	0.00

Seismic shear and lateral load as per IS: 1893-1966 for zone 5

Floors	Floors weight (kN)	h	h^2	Wh^2	Lateral load coefficient	Base shear (kN)	Q (kN)	Seismic shear (kN)
Roof	2662.13	16	256	681504	0.33518	1458.95	489.01	489.01
4 Floor	4400.25	12.8	163.84	720936.96	0.35457	1458.95	517.30	1006.31
3 Floor	4400.25	9.6	92.16	405527.04	0.19945	1458.95	290.98	1297.29
2 Floor	4400.25	6.4	40.96	180234.24	0.08864	1458.95	129.33	1426.61
1 Floor	4400.25	3.2	10.24	45058.56	0.02216	1458.95	32.33	1458.95
$\sum Wh^2$				2033260.8				

Seismic shear and lateral load as per IS: 1893-1970 for zone 5

Floors	Floors weight (kN)	h	h^2	Wh^2	Lateral load coefficient	Base shear (kN)	Q (kN)	Seismic shear (kN)
Roof	2662.13	16	256	681504	0.33518	1225.51	410.77	410.77
4 Floor	4400.25	12.8	163.84	720936.96	0.35457	1225.51	434.53	845.30
3 Floor	4400.25	9.6	92.16	405527.04	0.19945	1225.51	244.42	1089.72
2 Floor	4400.25	6.4	40.96	180234.24	0.08864	1225.51	108.63	1198.36
1 Floor	4400.25	3.2	10.24	45058.56	0.02216	1225.51	27.16	1225.51
$\sum Wh^2$				2033260.8				

Cont…

Seismic shear and lateral load as per IS: 1893-1975 for zone 5

Floors	Floors weight (kN)	h	h^2	Wh^2	Lateral load coefficient	Base shear (kN)	Q (kN)	Seismic shear (kN)
Roof	2662.13	16	256	681504	0.33518	1556.21	521.61	521.61
4 Floor	4400.25	12.8	163.84	720936.96	0.35457	1556.21	551.79	1073.39
3 Floor	4400.25	9.6	92.16	405527.04	0.19945	1556.21	310.38	1383.77
2 Floor	4400.25	6.4	40.96	180234.24	0.08864	1556.21	137.95	1521.72
1 Floor	4400.25	3.2	10.24	45058.56	0.02216	1556.21	34.49	1556.21
$\sum Wh^2$				2033260.8				

Seismic shear and lateral load as per IS: 1893-1984 for zone 5

Floors	Floors weight (kN)	h	h^2	Wh^2	Lateral load coefficient	Base shear (kN)	Q (kN)	Seismic shear (kN)
Roof	2662.13	16	256	681504	0.33518	1556.21	521.61	521.61
4 Floor	4400.25	12.8	163.84	720936.96	0.35457	1556.21	551.79	1073.39
3 Floor	4400.25	9.6	92.16	405527.04	0.19945	1556.21	310.38	1383.77
2 Floor	4400.25	6.4	40.96	180234.24	0.08864	1556.21	137.95	1521.72
1 Floor	4400.25	3.2	10.24	45058.56	0.02216	1556.21	34.49	1556.21
$\sum Wh^2$				2033260.8				

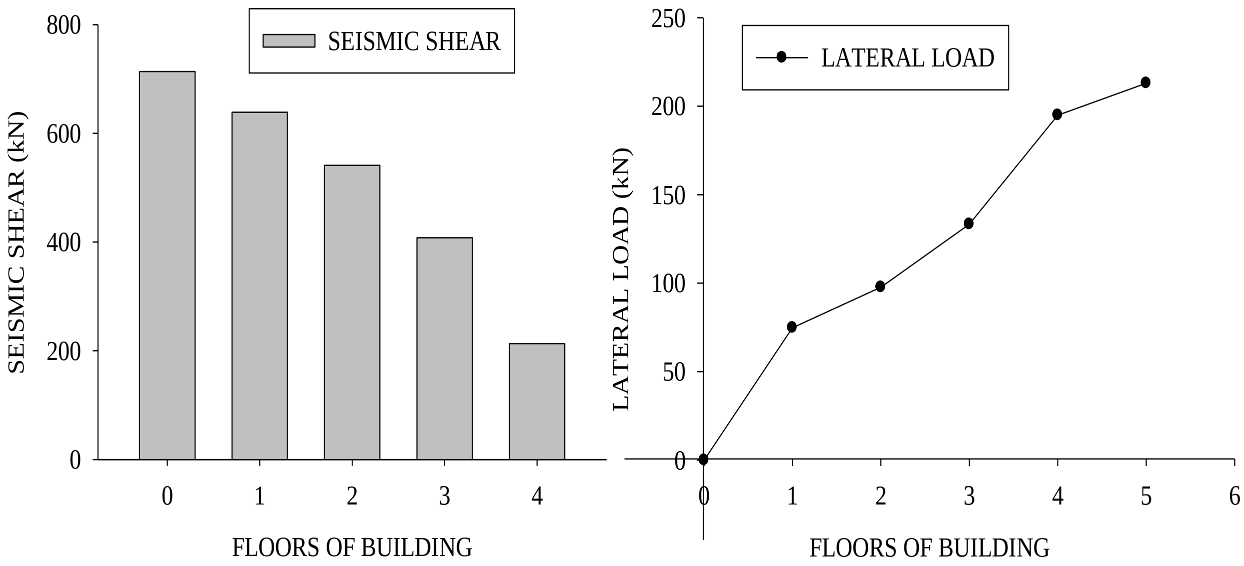
Seismic shear and lateral load as per IS: 1893-2002 for zone 5

Floors	Floors weight (kN)	h	h^2	Wh^2	Lateral load coefficient	Base shear (kN)	Q (kN)	Seismic shear (kN)
Roof	2662.13	16	256	681504	0.33518	2756.19	923.81	923.81
4 Floor	4400.25	12.8	163.84	720936.96	0.35457	2756.19	977.27	1901.08
3 Floor	4400.25	9.6	92.16	405527.04	0.19945	2756.19	549.71	2450.79
2 Floor	4400.25	6.4	40.96	180234.24	0.08864	2756.19	244.32	2695.11
1 Floor	4400.25	3.2	10.24	45058.56	0.02216	2756.19	61.08	2756.19
$\sum Wh^2$				2033260.8				

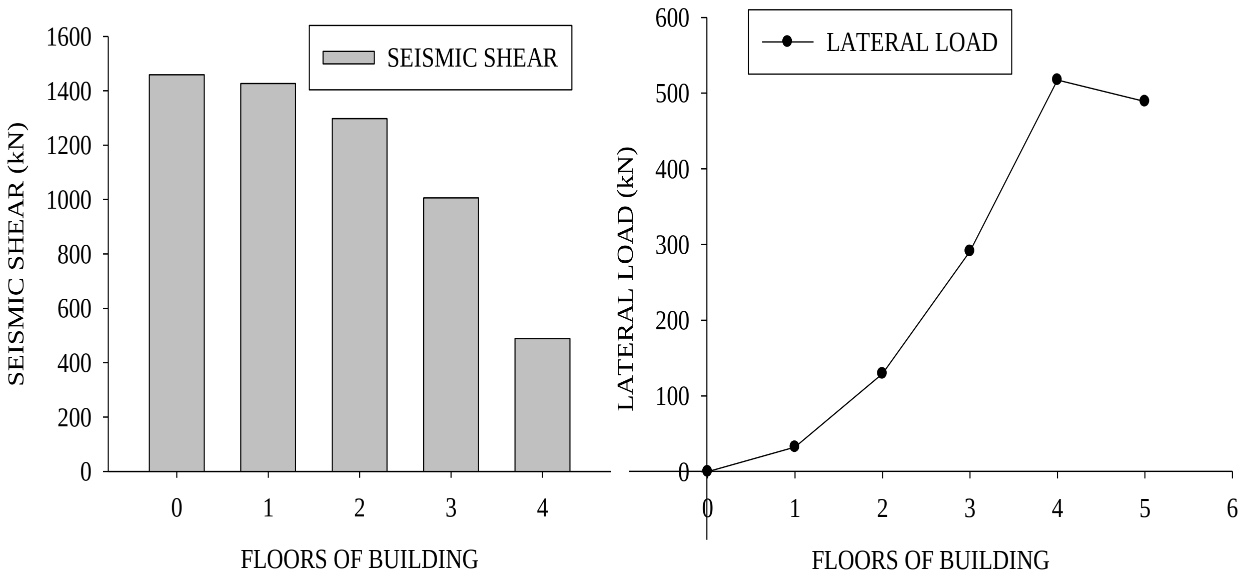
Seismic shear and lateral load as per IS: 1893-2016 for zone 5

Floors	Floors weight (kN)	h	h^2	Wh^2	Lateral load coefficient	Base shear (kN)	Q (kN)	Seismic shear (kN)
Roof	2662.13	16	256	681504	0.33518	3307.43	1108.6	1108.58
4 Floor	4400.25	12.8	163.84	720936.96	0.35457	3307.43	1172.7	2281.30
3 Floor	4400.25	9.6	92.16	405527.04	0.19945	3307.43	659.66	2940.95
2 Floor	4400.25	6.4	40.96	180234.24	0.08864	3307.43	293.18	3234.13
1 Floor	4400.25	3.2	10.24	45058.56	0.02216	3307.43	73.30	3307.43
$\sum Wh^2$				2033260.8				

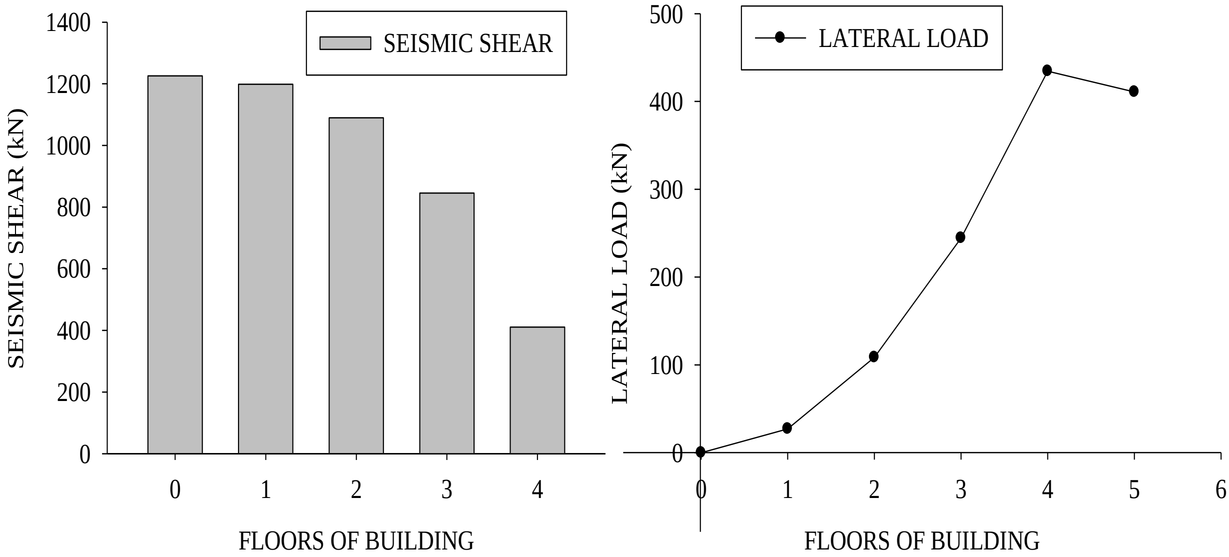
Following are the graphical representations for shear and lateral load variations in accordance with various version of IS: 1893 for zone 5.



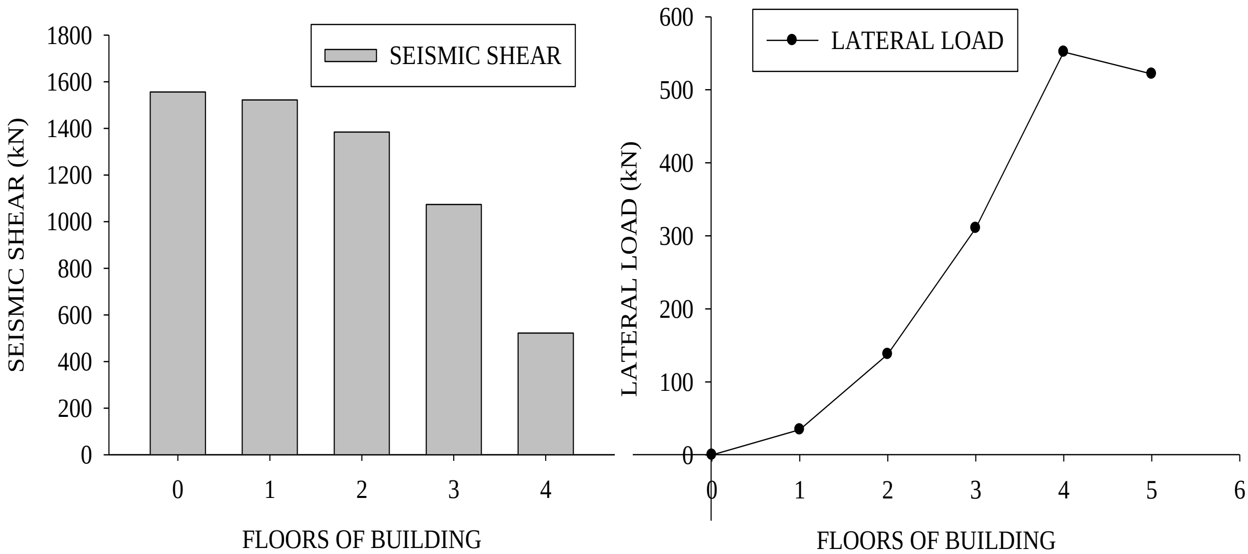
GRAPH 5.17: Variation of seismic shear and lateral load with floors of building for zone 5 as per IS: 1893-1962



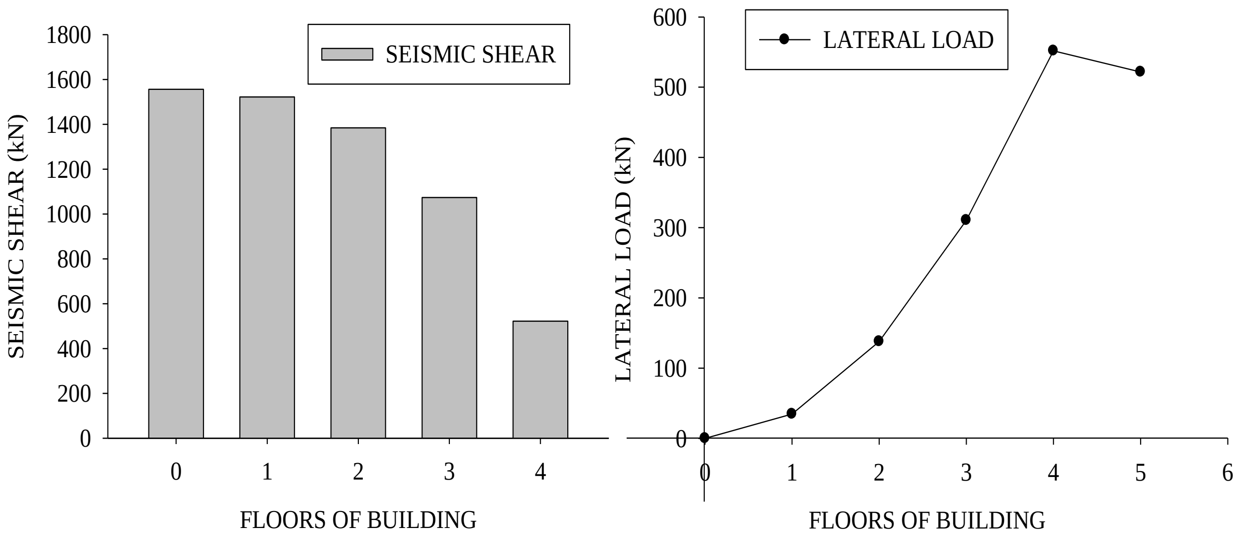
GRAPH 5.18: Variation of seismic shear and lateral load with floors of building for zone 5 as per IS: 1893-1966



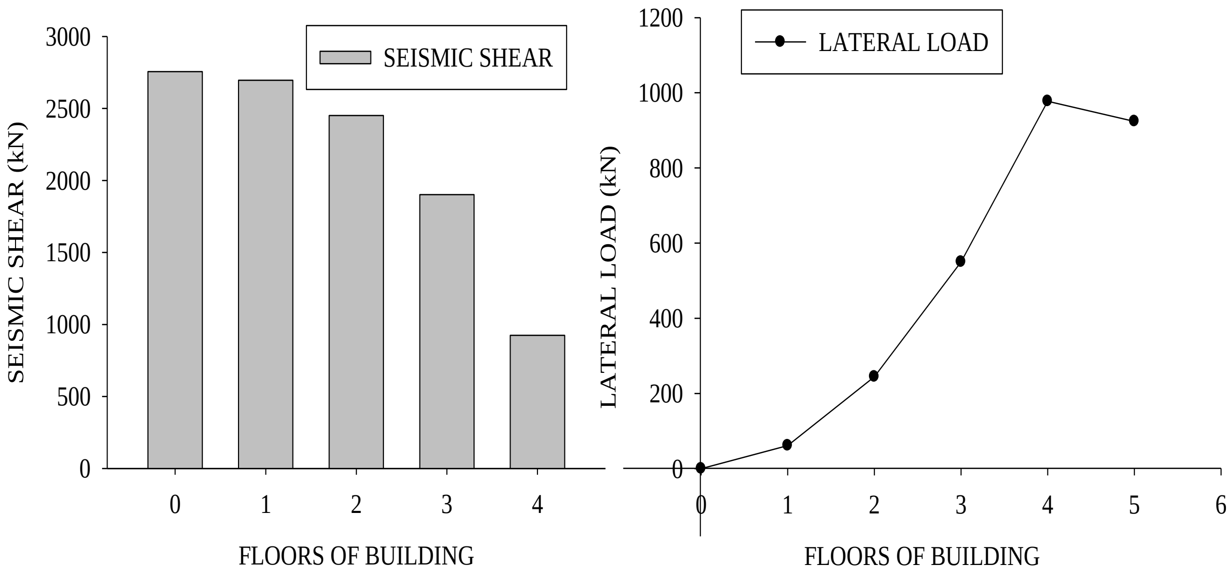
GRAPH 5.19: Variation of seismic shear and lateral load with floors of building for zone 5 as per IS: 1893-1970



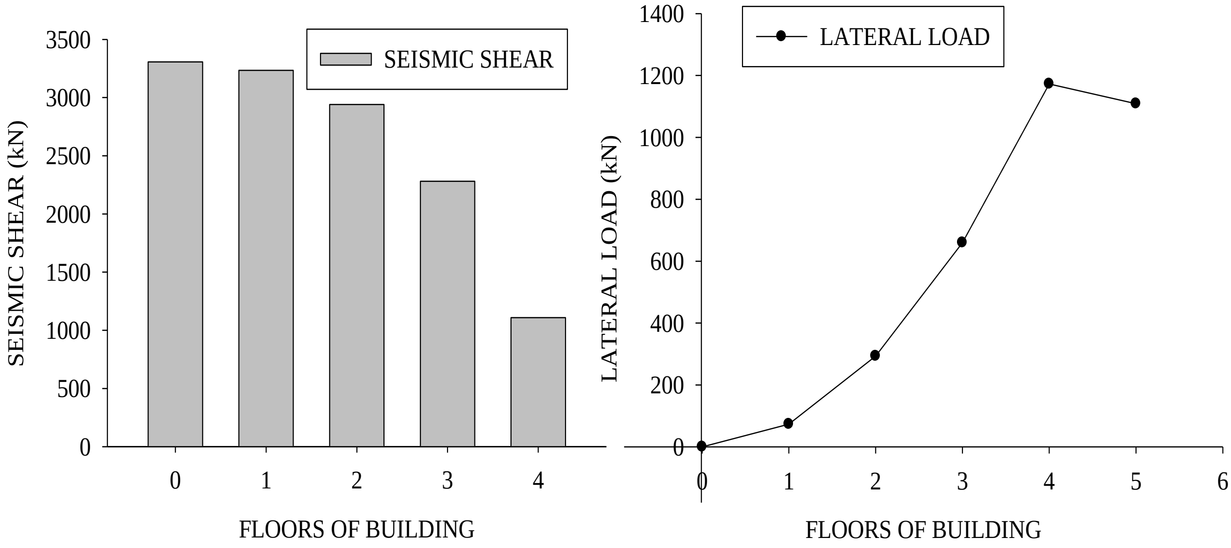
GRAPH 5.20: Variation of seismic shear and lateral load with floors of building for zone 5 as per IS: 1893-1975



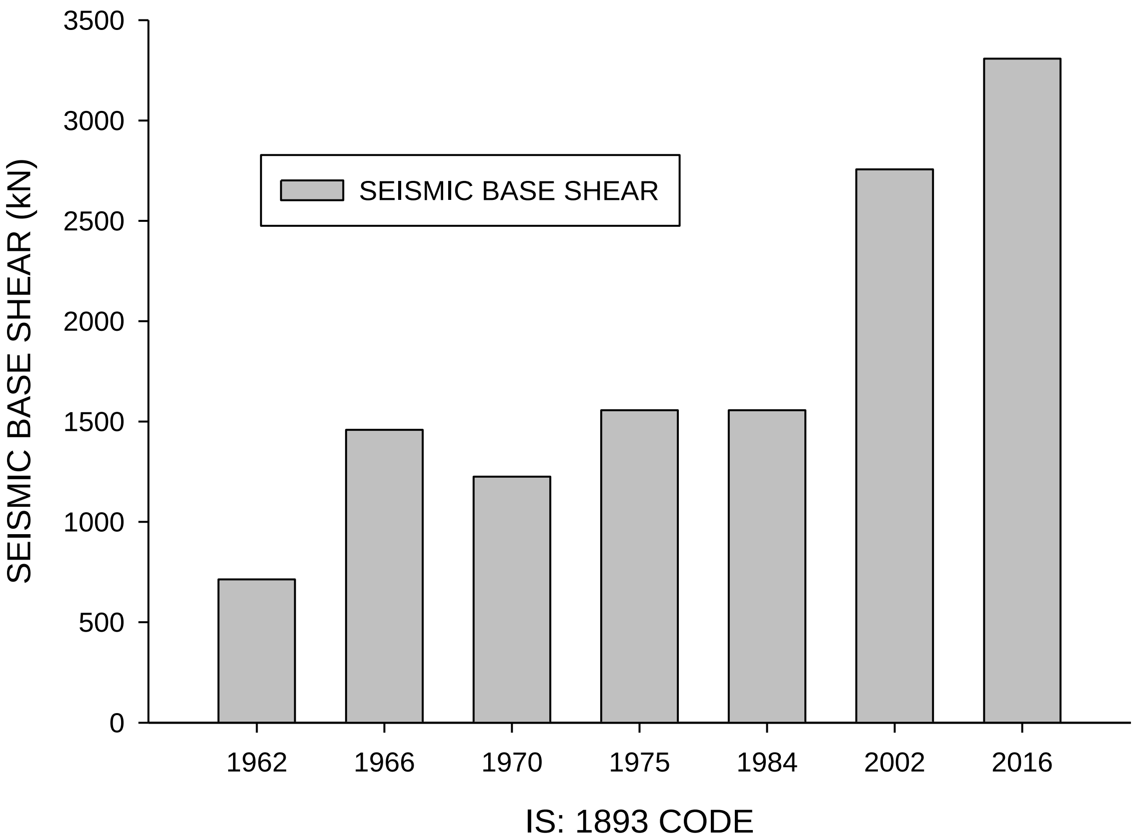
GRAPH 5.21: Variation of seismic shear and lateral load with floors of building for zone 5 as per IS: 1893-1984



GRAPH 5.22: Variation of seismic shear and lateral load with floors of building for zone 5 as per IS: 1893-2002



GRAPH 5.23: Variation of seismic shear and lateral load with floors of building for zone 5 as per IS: 1893-2016



GRAPH 5.24: Comparison of seismic base shear computed through various iterations of IS: 1893 code for zone 5

CHAPTER 6
ANALYSIS OF MODELS

In this chapter, building frame is modelled in STAAD Pro software. Then, lateral load is applied on the building, calculated above in excel sheet, as per previous seismic codes for different zones i.e. 3, 4 and 5. Building frame is analyzed and various data are collected to study the effect of revisions of codes on the building.

6.1 IS: 1893-1962

CASE 1: G+4 building is modelled and subjected to lateral load computed from IS: 1893-1962. This model has been analysed in STAAD PRO. to determine the various parameters of the building, located in zone 3, 4 and 5.

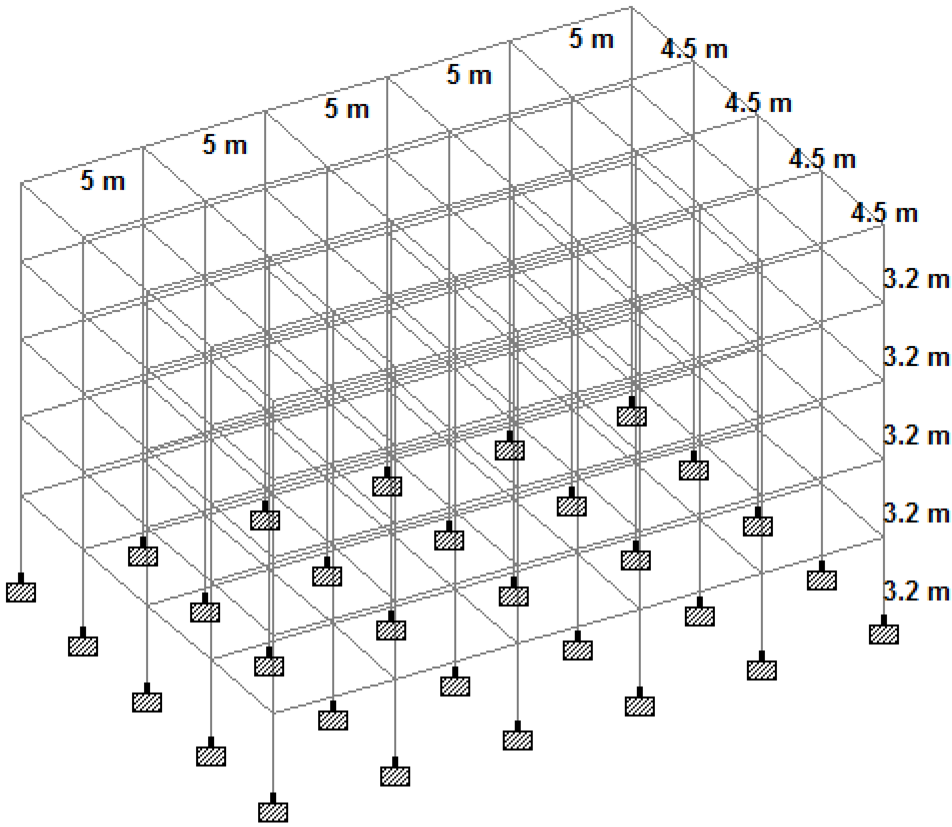


FIG. 6.1: Frame model of building in STAAD PRO.

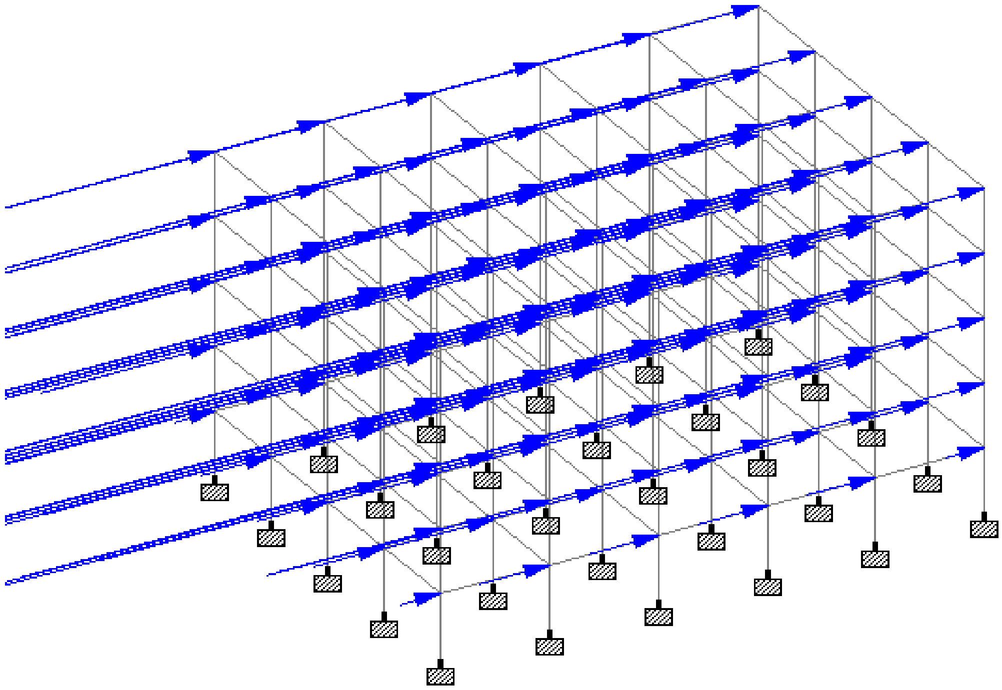


FIG. 6.2: Lateral load acting on the building due to earthquake in x-direction.

6.1.1 Average displacement & Storey drift

TABLE 6.1: Average displacement & storey drift for case 1 in zone 3

Height (m)	Average Displacement		Storey Drift	
	x	z	x	z
0	0	0	0	0
3.2	2.213	3.987	2.213	3.987
6.4	5.657	9.079	3.444	5.093
9.6	8.824	13.507	3.165	4.428
12.8	11.237	16.831	2.413	3.324
16	12.674	18.67	1.437	1.839

TABLE 6.2: Average displacement & storey drift for case 1 in zone 4

Height (m)	Average Displacement		Storey Drift	
	x	z	x	z
0	0.00	0.00	0.00	0.00
3.2	2.66	4.78	2.66	4.78
6.4	6.79	10.90	4.13	6.11
9.6	10.59	16.21	3.80	5.31
12.8	13.48	20.20	2.90	3.99
16	15.20	22.40	1.72	2.21

TABLE 6.3: Average displacement & storey drift for case 1 in zone 5

Height (m)	Average Displacement		Storey Drift	
	x	z	x	z
0	0.00	0.00	0.00	0.00
3.2	3.54	6.38	3.54	6.38
6.4	9.05	14.53	5.51	8.15
9.6	14.11	21.61	5.06	7.09
12.8	17.97	26.93	3.86	5.32
16	20.27	29.87	2.30	2.94

6.1.2 Axial force in column A, B & C

TABLE 6.4: Axial force in columns A, B & C for case 1 in zone 3

Storey number	Axial force (kN)		
	Column A	Column B	Column C
0	551.63	967.86	1747.56
1	437.66	764.11	1372.68
2	320.8	557.34	996.33
3	202.83	349.41	619.61
4	83.59	140.38	242.46

TABLE 6.5: Axial force in columns A, B & C for case 1 in zone 4

Storey number	Axial force (kN)		
	Column A	Column B	Column C
0	551.63	967.86	1747.56
1	437.66	764.11	1372.68
2	320.80	557.34	996.33
3	202.83	349.41	619.61
4	83.59	140.38	242.46

TABLE 6.6: Axial force in columns A, B & C for case 1 in zone 5

Storey number	Axial force (kN)		
	Column A	Column B	Column C
0	551.63	967.86	1747.56
1	437.66	764.11	1372.68
2	320.8	557.34	996.33
3	202.83	349.41	619.61
4	83.59	140.38	242.46

6.1.3 Moment about x and z direction in column A, B & C

TABLE 6.7: M_x & M_z in column A, B & C for case 1 in zone 3

Storey number	Mx (kN.m)			Mz (kN.m)		
	Column A	Column B	Column C	Column A	Column B	Column C
0	36.62	37.05	44.29	44.75	54.01	54.51
1	35.54	45.45	37.23	38.82	38.06	39.57
2	33.33	43.89	32.61	39.23	34.36	33.43
3	29.02	41.21	25.44	36.71	28.2	27.38
4	26	39.03	14.97	37.26	18.11	16.5

TABLE 6.8: M_x & M_z in column A, B & C for case 1 in zone 4

Storey number	Mx (kN.m)			Mz (kN.m)		
	Column A	Column B	Column C	Column A	Column B	Column C
0	44.47	54.40	53.15	54.49	64.80	65.31
1	40.22	49.20	44.67	42.68	45.66	47.18
2	37.50	47.23	39.13	43.39	41.24	40.13
3	32.40	43.91	30.52	39.76	33.85	33.03
4	27.83	39.99	17.97	39.26	21.75	20.14

TABLE 6.9: M_x & M_z in column A, B & C for case 1 in zone 5

Storey number	Mx (kN.m)			Mz (kN.m)		
	Column A	Column B	Column C	Column A	Column B	Column C
0	60.16	70.09	70.87	73.97	86.39	86.90
1	49.58	58.13	59.97	51.73	60.86	62.38
2	45.85	54.61	52.17	50.90	55.00	54.07
3	39.15	49.31	40.70	46.66	45.15	43.33
4	31.48	42.91	23.96	43.25	29.03	27.43

6.1.4 Maximum moment in beam P, Q & R

TABLE 5.10: Maximum moment in beam P, Q & R for case 1 in zone 3

Storey number	Max moment (kN.m)		
	Beam P	Beam Q	Beam R
5	36.57	37.28	47.68
4	61.2	58.52	75.95
3	67.59	65.34	82.5
2	71.53	69.69	87.37
1	69.23	68.05	87.93

TABLE 6.11: Maximum moment in beam P, Q & R for case 1 in zone 4

Storey number	Max moment (kN.m)		
	Beam P	Beam Q	Beam R
5	38.56	39.10	47.68
4	64.28	61.46	78.38
3	72.22	69.65	86.90
2	77.24	74.87	92.79
1	74.29	68.05	87.93

TABLE 6.12: Maximum moment in beam P, Q & R for case 1 in zone 5

Storey number	Max moment (kN.m)		
	Beam P	Beam Q	Beam R
5	42.55	42.73	48.34
4	70.43	67.35	84.26
3	82.22	78.50	95.68
2	91.25	87.21	103.61
1	86.56	83.95	104.22

6.2 IS: 1893-1966

MODEL 2: G+4 building is modelled and subjected to lateral load computed from IS: 1893-1966. This model has been analysed in STAAD PRO. to determine the various parameters of the building, located in zone 3, 4 and 5.

6.2.1 Average displacement & Storey drift

TABLE 6.13: Average displacement & storey drift for case 2 in zone 3

Height (m)	Average Displacement		Storey Drift	
	x	z	x	z
0	0	0	0	0
3.2	4.677	8.3	4.677	8.3
6.4	12.364	19.65	7.687	11.345
9.6	19.809	30.145	7.445	10.5
12.8	25.621	38.236	5.811	8.091
16	29.008	42.547	3.387	4.311

TABLE 6.14: Average displacement & storey drift for case 2 in zone 4

Height (m)	Average Displacement (mm)		Storey Drift (mm)	
	x	z	x	z
0	0.00	0.00	0.00	0.00
3.2	5.61	9.96	5.61	9.96
6.4	14.84	23.58	9.22	13.62
9.6	23.77	36.18	8.93	12.60
12.8	30.74	45.88	6.97	9.71
16	34.81	51.06	4.06	5.17

TABLE 6.15: Average displacement & storey drift for case 2 in zone 5

Height (m)	Average Displacement		Storey Drift	
	x	z	x	z
0	0.00	0.00	0.00	0.00
3.2	7.48	13.28	7.48	13.28
6.4	19.78	31.43	12.30	18.15
9.6	31.69	48.23	11.91	16.80
12.8	40.98	61.18	9.30	12.95
16	46.40	68.08	5.42	6.90

6.2.2 Axial force in column A, B & C

TABLE 6.16: Axial force in columns A, B & C for case 2 in zone 3

Storey number	Axial force (kN)		
	Column A	Column B	Column C
0	551.63	967.86	1747.56
1	437.66	764.11	1372.68
2	320.80	557.34	996.33
3	202.83	349.41	619.61
4	83.59	140.38	242.46

TABLE 6.17: Axial force in columns A, B & C for case 2 in zone 4

Storey number	Axial force (kN)		
	Column A	Column B	Column C
0	578.58	967.86	1747.56
1	449.59	764.11	1372.68
2	320.8	557.34	996.33
3	202.83	349.41	619.61
4	83.59	140.38	242.46

TABLE 6.18: Axial force in columns A, B & C for case 2 in zone 5

Storey number	Axial force (kN)		
	Column A	Column B	Column C
0	632.39	967.86	1747.56
1	487.99	764.11	1372.68
2	340.98	557.34	996.33
3	203.30	349.41	619.61
4	84.21	140.38	242.46

6.2.3 Moment about x and z direction in column A, B & C

TABLE 6.19: M_x & M_z in column A, B & C for case 2 in zone 3

Storey number	Mx (kN.m)			Mz (kN.m)		
	Column A	Column B	Column C	Column A	Column B	Column C
0	78.03	76.22	91.43	97.31	112.60	113.11
1	63.23	71.78	83.08	61.47	86.96	88.48
2	61.87	70.63	77.39	66.85	80.61	79.69
3	53.98	62.76	62.48	62.88	69.05	68.23
4	38.01	48.99	34.85	50.66	42.61	41.01

TABLE 6.20: M_x & M_z in column A, B & C for case 2 in zone 4

Storey number	Mx (kN.m)			Mz (kN.m)		
	Column A	Column B	Column C	Column A	Column B	Column C
0	94.15	92.35	109.72	117.56	135.12	135.62
1	73.44	81.99	99.69	70.16	104.34	105.86
2	71.76	80.52	92.86	76.55	96.75	95.82
3	62.35	71.13	74.98	72.12	82.87	82.05
4	42.24	53.21	41.82	55.33	51.15	49.55

TABLE 6.21: M_x & M_z in column A, B & C for case 2 in zone 5

Storey number	Mx (kN.m)			Mz (kN.m)		
	Column A	Column B	Column C	Column A	Column B	Column C
0	126.40	124.60	146.30	158.07	180.14	180.65
1	93.87	102.42	132.92	87.53	139.11	140.63
2	91.53	100.29	123.82	95.93	129.01	128.08
3	79.08	87.86	99.97	90.59	110.51	109.69
4	50.70	61.67	55.76	64.68	68.24	71.19

6.2.4 Maximum moment in beam P, Q & R

TABLE 6.22: Maximum moment in beam P, Q & R for case 2 in zone 3

Storey number	Max moment (kN.m)		
	Beam P	Beam Q	Beam R
5	49.69	49.50	53.78
4	83.58	79.52	96.05
3	105.23	99.81	113.45
2	115.65	109.72	124.56
1	105.52	101.19	120.63

TABLE 6.23: Maximum moment in beam P, Q & R for case 2 in zone 4

Storey number	Max moment (kN.m)		
	Beam P	Beam Q	Beam R
5	54.64	53.76	57.26
4	92.8	88.33	103.11
3	119.1	112.69	126.33
2	131.74	124.57	140.12
1	120.06	114.35	135.54

TABLE 6.24: Maximum moment in beam P, Q & R for case 2 in zone 5

Storey number	Max moment (kN.m)		
	Beam P	Beam Q	Beam R
5	63.99	62.28	64.23
4	111.25	105.96	117.85
3	146.83	138.44	152.78
2	163.91	154.28	171.24
1	149.14	140.66	165.34

6.3 IS: 1893-1970

CASE 3: G+4 building is modelled and subjected to lateral load computed from IS: 1893-1970. This model has been analysed in STAAD PRO. to determine the various parameters of the building, located in zone 3, 4 and 5.

6.3.1 Average displacement & Storey drift

TABLE 6.25: Average displacement & storey drift for case 3 in zone 3

Height (m)	Average Displacement (mm)		Storey Drift (mm)	
	x	z	x	z
0	0	0	0	0
3.2	3.144	5.578	3.144	5.578
6.4	8.311	13.202	5.167	7.624
9.6	13.316	20.258	5.005	7.056
12.8	17.222	25.695	3.907	5.437
16	19.5	28.592	2.278	2.897

TABLE 6.26: Average displacement & storey drift for case 3 in zone 4

Height (m)	Average Displacement (mm)		Storey Drift (mm)	
	x	z	x	z
0	0	0	0	0
3.2	3.929	6.972	3.929	6.972
6.4	10.387	16.502	6.456	9.53
9.6	16.642	25.322	6.255	8.82
12.8	21.518	32.119	4.822	6.796
16	24.37	35.74	2.846	3.622

TABLE 6.27: Average displacement & storey drift for case 3 in zone 5

Height (m)	Average Displacement		Storey Drift	
	x	z	x	z
0	0.00	0.00	0.00	0.00
3.2	6.29	11.16	6.29	11.16
6.4	16.62	26.40	10.33	15.25
9.6	26.62	40.52	10.01	14.11
12.8	34.43	51.39	7.81	10.87
16	38.98	57.18	4.55	5.79

6.3.2 Axial force in column A, B & C

TABLE 6.28: Axial force in columns A, B & C for case in zone 3

Storey number	Axial force (kN)		
	Column A	Column B	Column C
0	551.63	967.86	1747.56
1	437.66	764.11	1372.68
2	320.8	557.34	996.33
3	202.83	349.41	619.61
4	83.59	140.38	242.46

TABLE 6.29: Axial force in columns A, B & C for case 3 in zone 4

Storey number	Axial force (kN)		
	Column A	Column B	Column C
0	551.63	967.86	1747.56
1	437.66	764.11	1372.68
2	320.8	557.34	996.33
3	202.83	349.41	619.61
4	83.59	140.38	242.46

TABLE 6.30: Axial force in columns A, B & C for case 3 in zone 5

Storey number	Axial force (kN)		
	Column A	Column B	Column C
0	595.78	967.86	1747.56
1	461.52	764.11	1372.68
2	325.19	557.34	996.33
3	202.83	349.41	619.61
4	83.59	140.38	242.46

6.3.3 Moment about x and z direction in column A, B & C

TABLE 6.31: M_x & M_z in column A, B & C for case 3 in zone 3

Storey number	Mx (kN.m)			Mz (kN.m)		
	Column A	Column B	Column C	Column A	Column B	Column C
0	51.58	49.78	61.44	64.09	75.68	76.18
1	47.23	55.03	55.83	47.23	58.45	59.97
2	50.96	54.42	52.00	50.96	54.16	53.23
3	40.26	50.20	41.99	47.74	46.39	45.56
4	31.08	42.59	23.42	42.99	29.60	27.00

TABLE 6.32: M_x & M_z in column A, B & C for case 3 in zone 4

Storey number	Mx (kN.m)			Mz (kN.m)		
	Column A	Column B	Column C	Column A	Column B	Column C
0	65.13	63.32	76.81	81.11	94.59	95.1
1	55.06	63.61	69.78	54.53	73.05	74.57
2	53.97	62.73	65.01	59.1	67.71	66.78
3	47.29	56.07	52.48	55.5	57.99	57.17
4	34.63	45.6	29.27	46.92	35.78	34.17

TABLE 6.33: M_x & M_z in column A, B & C for case 3 in zone 5

Storey number	Mx (kN.m)			Mz (kN.m)		
	Column A	Column B	Column C	Column A	Column B	Column C
0	105.76	103.96	122.89	132.14	151.33	151.83
1	80.79	89.34	111.65	89.25	116.86	118.37
2	78.87	87.63	104.01	83.52	108.36	107.43
3	68.37	77.15	83.97	78.77	92.82	92.00
4	45.29	56.26	46.84	58.70	57.31	55.70

6.3.4 Maximum moment in beam P, Q & R

TABLE 6.34: Maximum moment in beam P, Q & R for case 3 in zone 3

Storey number	Max moment (kN.m)		
	Beam P	Beam Q	Beam R
5	42.30	42.51	48.06
4	70.62	67.50	84.48
3	82.49	78.70	96.10
2	89.27	85.36	102.14
1	81.67	79.62	100.06

TABLE 6.35: Maximum moment in beam P, Q & R for case 3 in zone 4

Storey number	Max moment (kN.m)		
	Beam P	Beam Q	Beam R
5	46.22	46.09	50.99
4	76.82	73.42	90.41
3	94.14	89.51	104.99
2	102.78	97.83	112.59
1	93.88	90.67	109.88

TABLE 6.36: Maximum moment in beam P, Q & R for case 3 in zone 5

Storey number	Max moment (kN.m)		
	Beam P	Beam Q	Beam R
5	58.01	56.83	59.77
4	99.45	94.68	108.19
3	129.08	121.96	135.85
2	143.32	135.27	151.32
1	130.53	123.82	146.27

6.4 IS: 1893-1975

MODEL 4: G+4 building is modelled and subjected to lateral load computed from IS: 1893-1975. This model has been analysed in STAAD PRO. to determine the various parameters of the building, located in zone 3, 4 and 5.

6.4.1 Average displacement & Storey drift

TABLE 6.37: Average displacement & storey drift for case 4 in zone 3

Height (m)	Average Displacement		Storey Drift	
	x	z	x	z
0	0.00	0.00	0.00	0.00
3.2	3.99	7.08	3.99	7.08
6.4	10.55	16.76	6.56	9.68
9.6	16.91	25.72	6.35	8.96
12.8	21.87	32.63	4.96	6.90
16	24.76	36.31	2.89	3.68

TABLE 6.38: Average displacement & storey drift for case 4 in zone 4

Height (m)	Average Displacement (mm)		Storey Drift (mm)	
	x	z	x	z
0	0	0	0	0
3.2	4.989	8.854	4.989	8.854
6.4	13.188	20.955	8.199	12.102
9.6	21.129	32.155	7.941	11.2
12.8	27.328	40.785	6.198	8.63
16	30.94	45.384	3.613	4.599

TABLE 6.39: Average displacement & storey drift for case 4 in zone 5

Height (m)	Average Displacement		Storey Drift	
	x	z	x	z
0	0.00	0.00	0.00	0.00
3.2	7.98	14.17	7.98	14.17
6.4	21.10	33.53	13.12	19.36
9.6	33.80	51.45	12.70	17.92
12.8	43.72	65.26	9.91	13.81
16	49.49	72.62	5.78	7.36

6.4.2 Axial force in column A, B & C

TABLE 6.40: Axial force in columns A, B & C for case 4 in zone 3

Storey number	Axial force (kN)		
	Column A	Column B	Column C
0	551.63	967.86	1747.56
1	437.66	764.11	1372.68
2	320.80	557.34	996.33
3	202.83	349.41	619.61
4	83.59	140.38	242.46

TABLE 6.41: Axial force in columns A, B & C for case 4 in zone 4

Storey number	Axial force (kN)		
	Column A	Column B	Column C
0	563.32	967.86	1747.56
1	438.53	764.11	1372.68
2	320.8	557.34	996.33
3	202.83	349.41	619.61
4	83.59	140.38	242.46

TABLE 6.42: Axial force in columns A, B & C for case 4 in zone 5

Storey number	Axial force (kN)		
	Column A	Column B	Column C
0	647.64	969.53	1747.56
1	499.04	764.11	1372.68
2	347.78	557.34	996.33
3	206.52	349.41	619.61
4	85.16	140.38	242.46

6.4.3 Moment about x and z direction in column A, B & C

TABLE 6.43: M_x & M_z in column A, B & C for case 4 in zone 3

Storey number	Mx (kN.m)			Mz (kN.m)		
	Column A	Column B	Column C	Column A	Column B	Column C
0	66.20	64.40	78.02	82.45	96.09	96.60
1	55.74	64.29	70.89	55.10	74.21	75.73
2	54.63	63.38	66.04	59.75	68.78	67.86
3	47.85	56.62	53.32	56.11	58.92	58.09
4	34.91	45.89	29.74	47.23	36.35	34.74

TABLE 6.44: M_x & M_z in column A, B & C for case 4 in zone 4

Storey number	Mx (kN.m)			Mz (kN.m)		
	Column A	Column B	Column C	Column A	Column B	Column C
0	83.4	81.6	97.53	104.06	120.11	120.61
1	66.63	75.18	88.61	64.37	92.75	94.27
2	65.17	73.93	82.55	70.08	85.99	85.06
3	56.77	65.55	66.64	65.96	73.66	72.84
4	39.42	50.4	37.17	52.22	45.46	43.85

TABLE 6.45: M_x & M_z in column A, B & C for case 4 in zone 5

Storey number	Mx (kN.m)			Mz (kN.m)		
	Column A	Column B	Column C	Column A	Column B	Column C
0	135.00	133.20	156.05	168.87	192.15	192.66
1	99.32	107.87	141.78	108.12	148.38	149.90
2	96.80	105.56	132.07	101.10	137.16	136.69
3	83.54	92.32	106.63	83.54	117.88	117.06
4	52.95	63.92	59.47	67.18	72.80	71.19

6.4.4 Maximum moment in beam P, Q & R

TABLE 6.46: Maximum moment in beam P, Q & R for case 4 in zone 3

Storey number	Max moment (kN.m)		
	Beam P	Beam Q	Beam R
5	46.53	46.38	51.22
4	77.32	73.89	90.88
3	95.06	90.37	105.69
2	103.85	98.82	113.42
1	94.85	91.55	110.66

TABLE 6.47: Maximum moment in beam P, Q & R for case 4 in zone 4

Storey number	Max moment (kN.m)		
	Beam P	Beam Q	Beam R
5	51.52	50.92	54.94
4	86.65	82.45	98.41
3	109.85	104.1	117.51
2	121.01	114.67	129.75
1	110.36	105.58	125.6

TABLE 6.48: Maximum moment in beam P, Q & R for case 4 in zone 5

Storey number	Max moment (kN.m)		
	Beam P	Beam Q	Beam R
5	66.48	64.56	66.09
4	116.17	110.66	122.55
3	154.22	145.30	159.84
2	172.49	162.21	179.53
1	156.90	147.67	173.29

6.5 IS: 1893-1984

MODEL 4: G+4 building is modelled and subjected to lateral load computed from IS: 1893-1984. This model has been analysed in STAAD PRO. to determine the various parameters of the building, located in zone 3, 4 and 5.

6.5.1 Average displacement & Storey drift

TABLE 6.49: Average displacement & storey drift for case 4 in zone 3

Height (m)	Average Displacement		Storey Drift	
	x	z	x	z
0	0.00	0.00	0.00	0.00
3.2	3.99	7.08	3.99	7.08
6.4	10.55	16.76	6.56	9.68
9.6	16.91	25.72	6.35	8.96
12.8	21.87	32.63	4.96	6.90
16	24.76	36.31	2.89	3.68

TABLE 6.50: Average displacement & storey drift for case 4 in zone 4

Height (m)	Average Displacement (mm)		Storey Drift (mm)	
	x	z	x	z
0	0	0	0	0
3.2	4.989	8.854	4.989	8.854
6.4	13.188	20.955	8.199	12.102
9.6	21.129	32.155	7.941	11.2
12.8	27.328	40.785	6.198	8.63
16	30.94	45.384	3.613	4.599

TABLE 6.51: Average displacement & storey drift for case 4 in zone 5

Height (m)	Average Displacement		Storey Drift	
	x	z	x	z
0	0.00	0.00	0.00	0.00
3.2	7.98	14.17	7.98	14.17
6.4	21.10	33.53	13.12	19.36
9.6	33.80	51.45	12.70	17.92
12.8	43.72	65.26	9.91	13.81
16	49.49	72.62	5.78	7.36

6.5.2 Axial force in column A, B & C

TABLE 6.52: Axial force in columns A, B & C for case 4 in zone 3

Storey number	Axial force (kN)		
	Column A	Column B	Column C
0	551.63	967.86	1747.56
1	437.66	764.11	1372.68
2	320.80	557.34	996.33
3	202.83	349.41	619.61
4	83.59	140.38	242.46

TABLE 6.53: Axial force in columns A, B & C for case 4 in zone 4

Storey number	Axial force (kN)		
	Column A	Column B	Column C
0	563.32	967.86	1747.56
1	438.53	764.11	1372.68
2	320.8	557.34	996.33
3	202.83	349.41	619.61
4	83.59	140.38	242.46

TABLE 6.54: Axial force in columns A, B & C for case 4 in zone 5

Storey number	Axial force (kN)		
	Column A	Column B	Column C
0	647.64	969.53	1747.56
1	499.04	764.11	1372.68
2	347.78	557.34	996.33
3	206.52	349.41	619.61
4	85.16	140.38	242.46

6.5.3 Moment about x and z direction in column A, B & C

TABLE 6.55: M_x & M_z in column A, B & C for case 4 in zone 3

Storey number	Mx (kN.m)			Mz (kN.m)		
	Column A	Column B	Column C	Column A	Column B	Column C
0	66.20	64.40	78.02	82.45	96.09	96.60
1	55.74	64.29	70.89	55.10	74.21	75.73
2	54.63	63.38	66.04	59.75	68.78	67.86
3	47.85	56.62	53.32	56.11	58.92	58.09
4	34.91	45.89	29.74	47.23	36.35	34.74

TABLE 6.56: M_x & M_z in column A, B & C for case 4 in zone 4

Storey number	Mx (kN.m)			Mz (kN.m)		
	Column A	Column B	Column C	Column A	Column B	Column C
0	83.4	81.6	97.53	104.06	120.11	120.61
1	66.63	75.18	88.61	64.37	92.75	94.27
2	65.17	73.93	82.55	70.08	85.99	85.06
3	56.77	65.55	66.64	65.96	73.66	72.84
4	39.42	50.4	37.17	52.22	45.46	43.85

TABLE 6.57: M_x & M_z in column A, B & C for case 4 in zone 5

Storey number	Mx (kN.m)			Mz (kN.m)		
	Column A	Column B	Column C	Column A	Column B	Column C
0	135.00	133.20	156.05	168.87	192.15	192.66
1	99.32	107.87	141.78	108.12	148.38	149.90
2	96.80	105.56	132.07	101.10	137.16	136.69
3	83.54	92.32	106.63	83.54	117.88	117.06
4	52.95	63.92	59.47	67.18	72.80	71.19

6.5.4 Maximum moment in beam P, Q & R

TABLE 6.58: Maximum moment in beam P, Q & R for case 4 in zone 3

Storey number	Max moment (kN.m)		
	Beam P	Beam Q	Beam R
5	46.53	46.38	51.22
4	77.32	73.89	90.88
3	95.06	90.37	105.69
2	103.85	98.82	113.42
1	94.85	91.55	110.66

TABLE 6.59: Maximum moment in beam P, Q & R for case 4 in zone 4

Storey number	Max moment (kN.m)		
	Beam P	Beam Q	Beam R
5	51.52	50.92	54.94
4	86.65	82.45	98.41
3	109.85	104.1	117.51
2	121.01	114.67	129.75
1	110.36	105.58	125.6

TABLE 6.60: Maximum moment in beam P, Q & R for case 4 in zone 5

Storey number	Max moment (kN.m)		
	Beam P	Beam Q	Beam R
5	66.48	64.56	66.09
4	116.17	110.66	122.55
3	154.22	145.30	159.84
2	172.49	162.21	179.53
1	156.90	147.67	173.29

6.6 IS: 1893-2002

MODEL 6: G+4 building is modelled and subjected to lateral load computed from IS: 1893-2002. This model has been analysed in STAAD PRO. to determine the various parameters of the building, located in zone 3, 4 and 5.

6.6.1 Average displacement & Storey drift

TABLE 6.61: Average displacement & storey drift for case 6 in zone 3

Height (m)	Average Displacement		Storey Drift	
	x	z	x	z
0	0.00	0.00	0.00	0.00
3.2	6.28	11.15	6.28	11.15
6.4	16.61	26.39	1.03	15.24
9.6	26.61	40.50	10.00	14.11
12.8	34.41	51.37	7.81	10.87
16	38.96	57.16	4.55	5.79

TABLE 6.62: Average displacement & storey drift for case 6 in zone 4

Height (m)	Average Displacement (mm)		Storey Drift (mm)	
	x	z	x	z
0	0	0	0	0
3.2	9.424	16.726	9.424	16.726
6.4	24.909	39.588	15.485	28.62
9.6	39.907	60.747	14.918	21.159
12.8	51.612	77.051	11.705	16.304
16	58.433	85.739	6.821	8.688

TABLE 6.63: Average displacement & storey drift for case 6 in zone 5

Height (m)	Average Displacement (mm)		Storey Drift (mm)	
	x	z	x	z
0	0.00	0.00	0.00	0.00
3.2	14.13	25.09	14.13	25.09
6.4	37.36	59.38	23.23	34.29
9.6	59.86	91.12	22.50	31.74
12.8	77.41	115.58	17.56	24.46
16	87.64	128.61	10.23	13.03

6.6.2 Axial force in column A, B & C

TABLE 6.64: Axial force in columns A, B & C for case 6 in zone 3

Storey number	Axial force (kN)		
	Column A	Column B	Column C
0	595.70	967.86	1747.56
1	461.47	764.11	1372.68
2	325.16	557.34	996.33
3	202.83	349.41	619.61
4	83.59	140.38	242.46

TABLE 6.65: Axial force in columns A, B & C for case 6 in zone 4

Storey number	Axial force (kN)		
	Column A	Column B	Column C
0	691.75	1004.82	1747.56
1	531	778.3	1372.68
2	367.45	557.34	996.33
3	215.83	349.41	619.61
4	87.91	140.38	242.46

TABLE 6.66: Axial force in columns A, B & C for case 6 in zone 5

Storey number	Axial force (kN)		
	Column A	Column B	Column C
0	835.82	1120.08	1747.56
1	635.38	861.81	1372.68
2	431.69	600.05	996.33
3	246.25	349.41	619.61
4	96.88	140.38	242.46

6.6.3 Moment about x and z direction in column A, B & C

TABLE 6.67: M_x & M_z in column A, B & C for case 6 in zone 3

Storey number	Mx (kN.m)			Mz (kN.m)		
	Column A	Column B	Column C	Column A	Column B	Column C
0	105.72	103.91	122.83	132.08	151.26	151.77
1	80.76	89.32	111.60	76.39	116.81	118.32
2	78.85	87.60	103.96	83.50	108.31	107.39
3	68.35	77.12	83.93	78.74	92.78	91.96
4	45.27	56.25	46.81	58.69	57.28	55.67

TABLE 6.68: M_x & M_z in column A, B & C for case 6 in zone 4

Storey number	Mx (kN.m)			Mz (kN.m)		
	Column A	Column B	Column C	Column A	Column B	Column C
0	159.87	158.07	184.25	200.1	226.87	227.38
1	115.07	123.62	167.41	105.56	175.19	176.7
2	112.04	120.8	155.94	116.05	162.49	161.57
3	96.45	105.22	125.9	109.75	139.2	138.38
4	59.47	70.44	70.22	74.39	85.97	84.37

TABLE 6.69: M_x & M_z in column A, B & C for case 6 in zone 5

Storey number	Mx (kN.m)			Mz (kN.m)		
	Column A	Column B	Column C	Column A	Column B	Column C
0	241.11	239.30	276.37	302.13	340.29	340.80
1	166.52	175.07	251.11	176.56	262.76	264.28
2	161.84	170.60	233.91	164.88	243.76	242.84
3	138.60	147.37	188.85	156.27	208.82	208.00
4	80.77	91.74	105.33	97.94	129.01	127.40

6.6.4 Maximum moment in beam P, Q & R

TABLE 6.70: Maximum moment in beam P, Q & R for case 6 in zone 3

Storey number	Max moment (kN.m)		
	Beam P	Beam Q	Beam R
5	57.99	56.82	59.76
4	99.42	94.65	108.17
3	129.04	121.92	135.81
2	143.27	135.22	151.28
1	130.48	123.78	146.22

TABLE 6.71: Maximum moment in beam P, Q & R for case 6 in zone 4

Storey number	Max moment (kN.m)		
	Beam P	Beam Q	Beam R
5	73.69	71.13	71.47
4	130.4	124.25	136.16
3	175.6	165.16	180.24
2	197.3	185.11	203.53
1	179.32	167.96	196.27

TABLE 6.72: Maximum moment in beam P, Q & R for case 6 in zone 5

Storey number	Max moment (kN.m)		
	Beam P	Beam Q	Beam R
5	97.25	92.59	89.02
4	176.88	168.65	180.61
3	245.45	230.01	246.87
2	278.34	259.95	281.91
1	252.57	234.22	271.34

6.7 IS: 1893-2016

MODEL 6: G+4 building is modelled and subjected to lateral load computed from IS: 1893-2016. This model has been analysed in STAAD PRO. to determine the various parameters of the building, located in zone 3, 4 and 5.

6.7.1 Average displacement & Storey drift

TABLE 6.73: Average displacement & storey drift for case 7 in zone 3

Height (m)	Average Displacement		Storey Drift	
	x	z	x	z
0	0.00	0.00	0.00	0.00
3.2	7.54	13.38	7.54	13.38
6.4	19.93	31.67	12.39	18.29
9.6	31.93	48.60	12.00	16.93
12.8	41.29	61.64	9.37	13.04
16	46.75	68.59	5.55	6.95

TABLE 6.74: Average displacement & storey drift for case 7 in zone 4

Height (m)	Average Displacement (mm)		Storey Drift (mm)	
	x	z	x	z
0	0	0	0	0
3.2	11.308	20.071	11.308	20.071
6.4	29.889	47.506	18.581	27.435
9.6	47.886	72.896	17.997	25.39
12.8	61.931	92.46	14.045	19.564
16	70.115	102.885	8.184	10.425

TABLE 6.75: Average displacement & storey drift for case 7 in zone 5

Height (m)	Average Displacement		Storey Drift	
	x	z	x	z
0	0.00	0.00	0.00	0.00
3.2	16.96	30.11	16.96	30.11
6.4	44.83	71.26	27.87	41.15
9.6	71.82	109.34	26.99	38.09
12.8	92.89	138.69	21.07	29.35
16	105.16	154.33	12.27	15.64

6.7.2 Axial force in column A, B & C

TABLE 6.76: Axial force in columns A, B & C for case 7 in zone 3

Storey number	Axial force (kN)		
	Column A	Column B	Column C
0	634.12	967.86	1747.56
1	489.24	764.11	1372.68
2	341.75	557.34	996.33
3	203.67	349.41	619.61
4	84.32	140.38	242.46

TABLE 6.77: Axial force in columns A, B & C for case 7 in zone 4

Storey number	Axial force (kN)		
	Column A	Column B	Column C
0	749.38	1050.92	1747.56
1	572.75	811.7	1372.68
2	393.14	569.21	996.33
3	228	349.41	619.61
4	91.5	140.38	242.46

TABLE 6.78: Axial force in columns A, B & C for case 7 in zone 5

Storey number	Axial force (kN)		
	Column A	Column B	Column C
0	922.27	1192.48	1747.56
1	698.01	911.91	1372.68
2	470.23	630.88	996.33
3	264.49	367.12	619.61
4	102.26	145.07	242.46

6.7.3 Moment about x and z direction in column A, B & C

TABLE 6.79: M_x & M_z in column A, B & C for case 7 in zone 3

Storey number	Mx (kN.m)			Mz (kN.m)		
	Column A	Column B	Column C	Column A	Column B	Column C
0	127.38	125.57	147.40	159.29	181.51	182.01
1	94.49	103.04	133.92	88.06	140.16	141.68
2	92.12	100.88	124.75	96.52	129.98	129.06
3	79.59	88.36	100.72	91.14	111.35	110.53
4	50.95	61.93	56.18	64.97	68.76	67.15

TABLE 6.80: M_x & M_z in column A, B & C for case 7 in zone 4

Storey number	Mx (kN.m)			Mz (kN.m)		
	Column A	Column B	Column C	Column A	Column B	Column C
0	192.36	190.56	221.1	240.91	272.24	272.75
1	135.65	144.2	200.89	123.06	210.22	211.73
2	131.96	140.72	187.13	135.58	195	194.07
3	113.31	122.08	151.08	128.36	167.05	166.23
4	83.81	103.18	84.27	83.81	103.18	101.58

TABLE 6.81: M_x & M_z in column A, B & C for case 7 in zone 5

Storey number	Mx (kN.m)			Mz (kN.m)		
	Column A	Column B	Column C	Column A	Column B	Column C
0	289.85	288.05	331.65	363.35	408.35	408.85
1	197.40	205.95	301.33	177.05	315.30	316.82
2	191.71	200.47	280.70	194.18	292.53	291.60
3	163.88	172.66	226.63	184.18	250.60	249.78
4	93.55	154.83	126.40	112.07	154.83	153.22

6.7.4 Maximum moment in beam P, Q & R

TABLE 6.82: Maximum moment in beam P, Q & R for case 7 in zone 3

Storey number	Max moment (kN.m)		
	Beam P	Beam Q	Beam R
5	64.27	62.54	64.45
4	111.81	106.49	118.38
3	147.66	139.21	153.58
2	164.88	155.18	172.18
1	150.02	141.45	166.24

TABLE 6.83: Maximum moment in beam P, Q & R for case 7 in zone 4

Storey number	Max moment (kN.m)		
	Beam P	Beam Q	Beam R
5	83.11	79.71	78.49
4	148.99	142.01	153.94
3	203.54	191.1	206.89
2	229.71	215.05	234.88
1	208.62	194.46	226.3

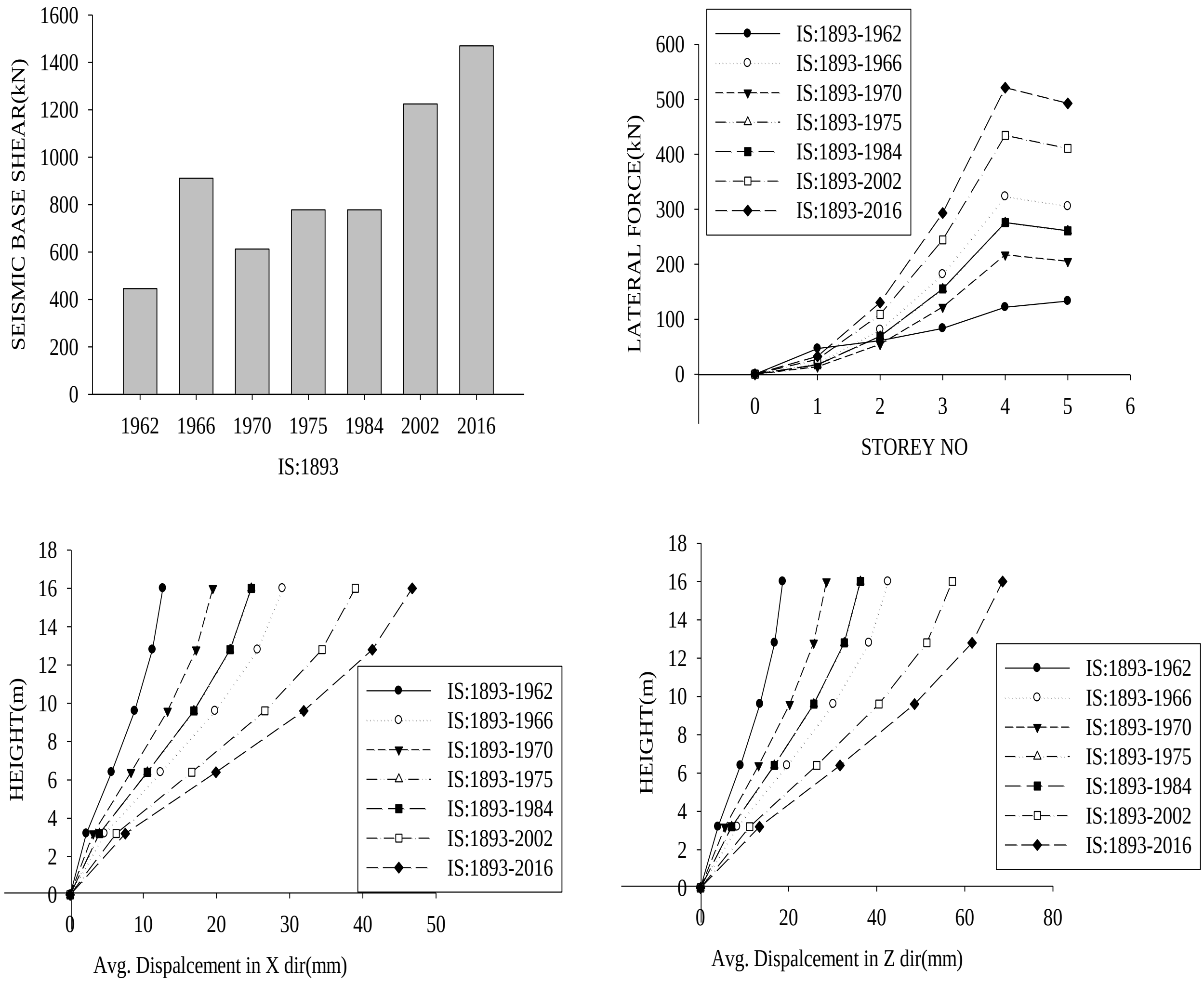
TABLE 6.84: Maximum moment in beam P, Q & R for case 7 in zone 5

Storey number	Max moment (kN.m)		
	Beam P	Beam Q	Beam R
5	111.38	105.47	99.56
4	204.76	195.29	207.28
3	287.36	268.93	286.86
2	326.97	304.85	328.94
1	296.53	273.98	316.39

CHAPTER 7
RESULT & DISCUSSION

In this chapter, the results obtained after analyzing the frame model in STAAD Pro are discussed below, for building located in different zones i.e. 3, 4 and 5. In this section, average displacement along x and z direction, base shear, axial forces in column, maximum moment in beams, etc. are discussed in details. Variation of these parameters are analyzed and compared, to understand the effect of revision of seismic code on the adequacy of the buildings to sustain the earthquake forces and to appreciate upgradation requirements in them. Now, the results obtained are studied under different zones considered in the study.

7.1 Zone 3



GRAPH 7.1: Comparison of seismic base shear, lateral load, average displacement along x and z direction through various iterations of IS: 1893 code for zone 3

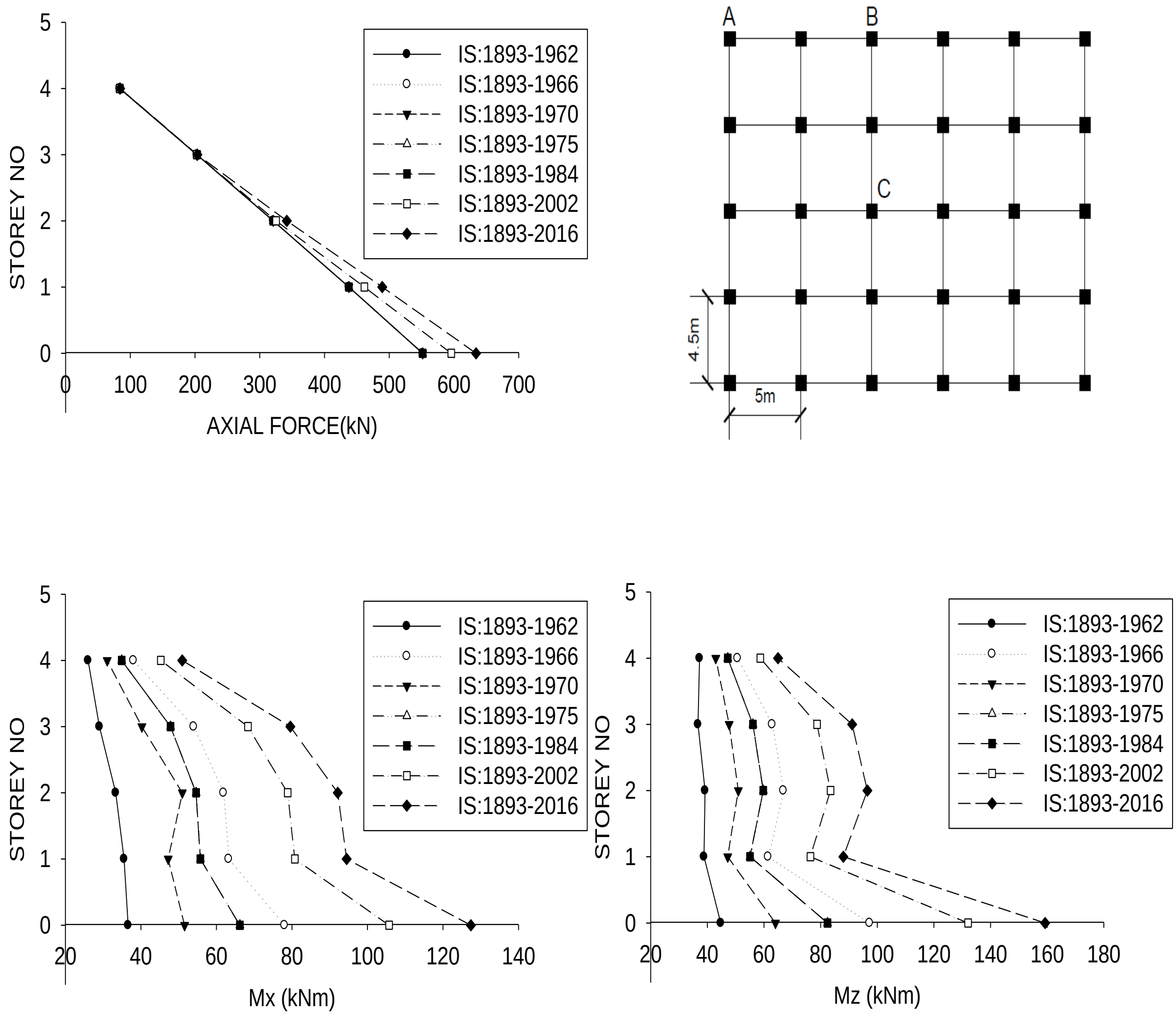
In plot of variation of seismic base shear with previous codes of IS: 1893, maximum seismic base shear is found to be from code revised in year 2016. Base shear is found to be equal in year 1975 and 1984. Minimum seismic base shear is found to be from 1962, which estimates the least value of seismic base shear. Value of seismic base shear computed from 1966 is more than the value of seismic base shear computed from 1962, 1970, 1975 and 1984. Value of seismic base shear increases with changes made in code except IS: 1893-1966.

In the plot of lateral load with storey number, lateral load is found to be maximum at storey below roof except in case of IS: 1893-1962. Maximum lateral load value is found to be from IS: 1893-2016, which yields the maximum value of seismic base shear. And minimum value of lateral load is found to be in case of 1962. In each case, value of lateral load is found to be zero at the base of the building.

In the plot of average displacement in x-direction with height of the building, displacement of the building increases with increase in height of the building. Maximum displacement is found to be at the top of the building. And displacement at the bottom of the building is minimum and equal to zero. Maximum displacement of the building is found to be in case of IS: 1893-2016, which yields maximum value of lateral load.

In the plot of average displacement in z-direction with height of the building, displacement of the building increases with increase in height of the building. Maximum displacement is found to be at the top of the building. And displacement at the bottom of the building is minimum and equal to zero. Maximum displacement of the building is found to be in case of IS: 1893-2016, which yields maximum value of lateral load. Displacement in z-direction is found to be more than x-direction, as the length along x-direction of building is more than length along z-direction.

7.1.1 Column A

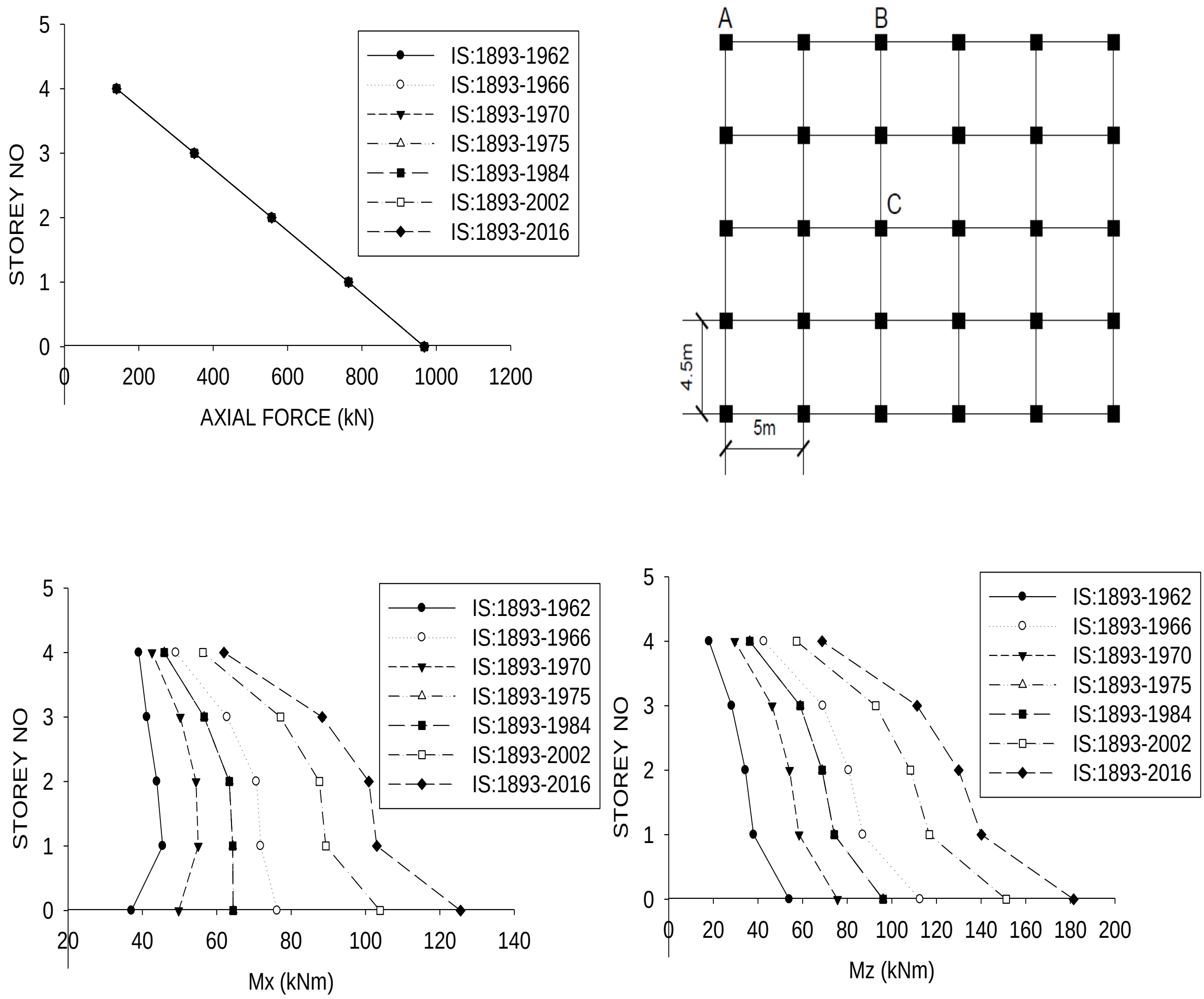


GRAPH 7.2: Comparison of axial force, moment about x and z axis in column A computed through various iterations of IS: 1893 code for zone 3

In the plot of axial force in column A with storey number, axial force is found to be minimum at the top storey of the building in each case. Maximum axial force is found to be at the ground storey of the building. Axial force in column decreases with increase in storey number of the building. Maximum axial force in column A is found to be in case of IS: 1893-2016, at the ground storey. It is found that axial force is of equal magnitude in each case at the third and fourth storey of the building.

In the plot of moment about x and z direction in column A with storey number of the building, moment is found to be minimum at the top storey of the building. And it's found to be maximum at the ground storey of the building. Maximum moment is found to be from IS: 1893-2016, which yields maximum value of lateral load. Moment about z-direction is found to be more than moment about x-direction.

7.1.2 Column B

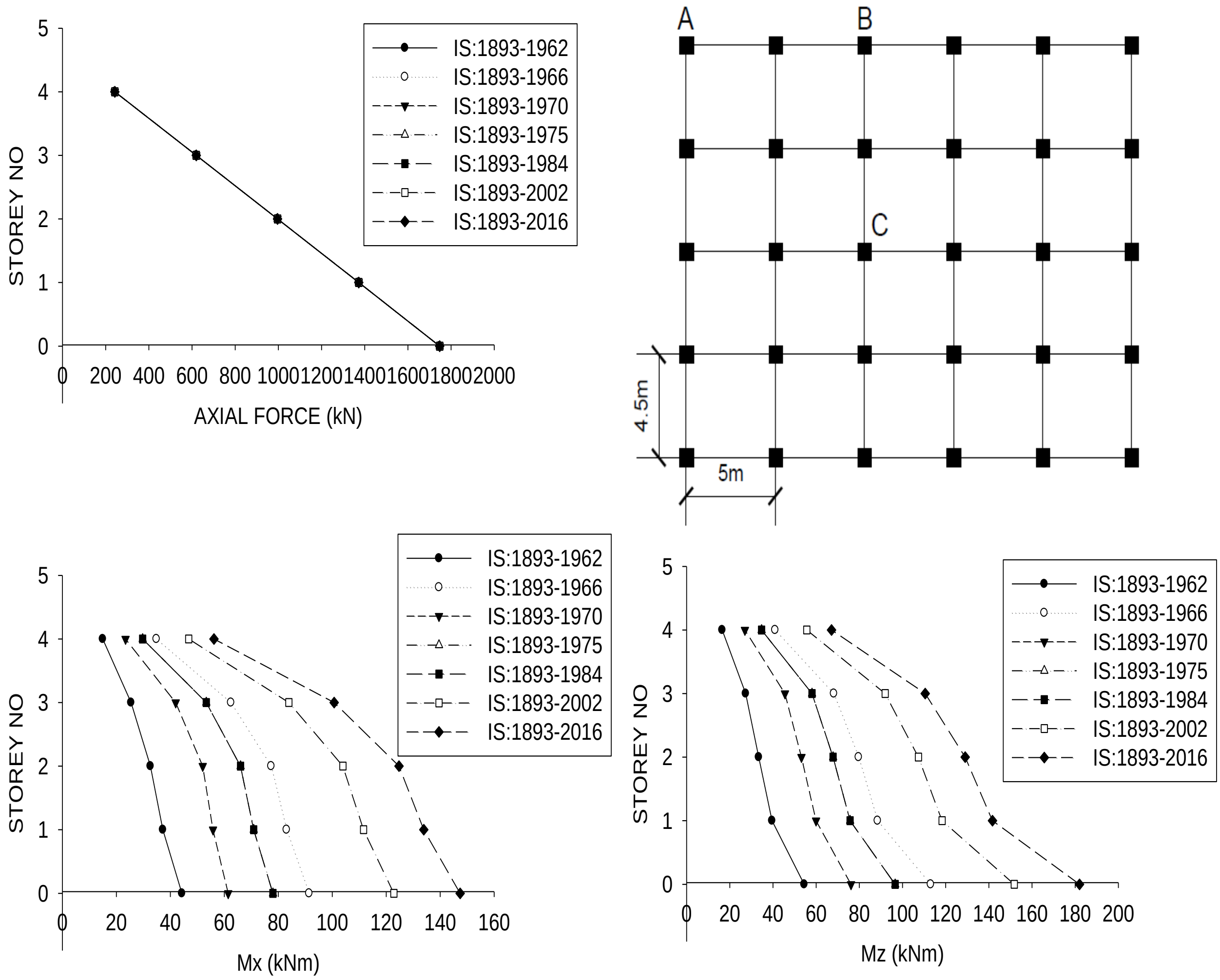


GRAPH 7.3: Comparison of axial force, moment about x and z axis in column B through various iterations of IS: 1893 code for zone 3

In the plot of axial force in column B with storey number, axial force is found to be minimum at the top storey of the building in each case. Maximum axial force in column B, is found to be at the ground storey of the building. Axial force in column decreases with increase in storey number of the building. Axial force variation in column B for zone 3, found to be equal in each case, which corresponds to the load combination 1.5(DL+LL). As this combination, does not include the effect of lateral load.

In the plot of moment about x and z direction in column B with storey number of the building, moment is found to be minimum at the storey of the building. And it's found to be maximum at the ground storey of the building. Maximum moment is found to be from IS: 1893-2016, which yields maximum value of lateral load. Moment about z-direction is found to be more than moment about x-direction.

7.1.3 Column C

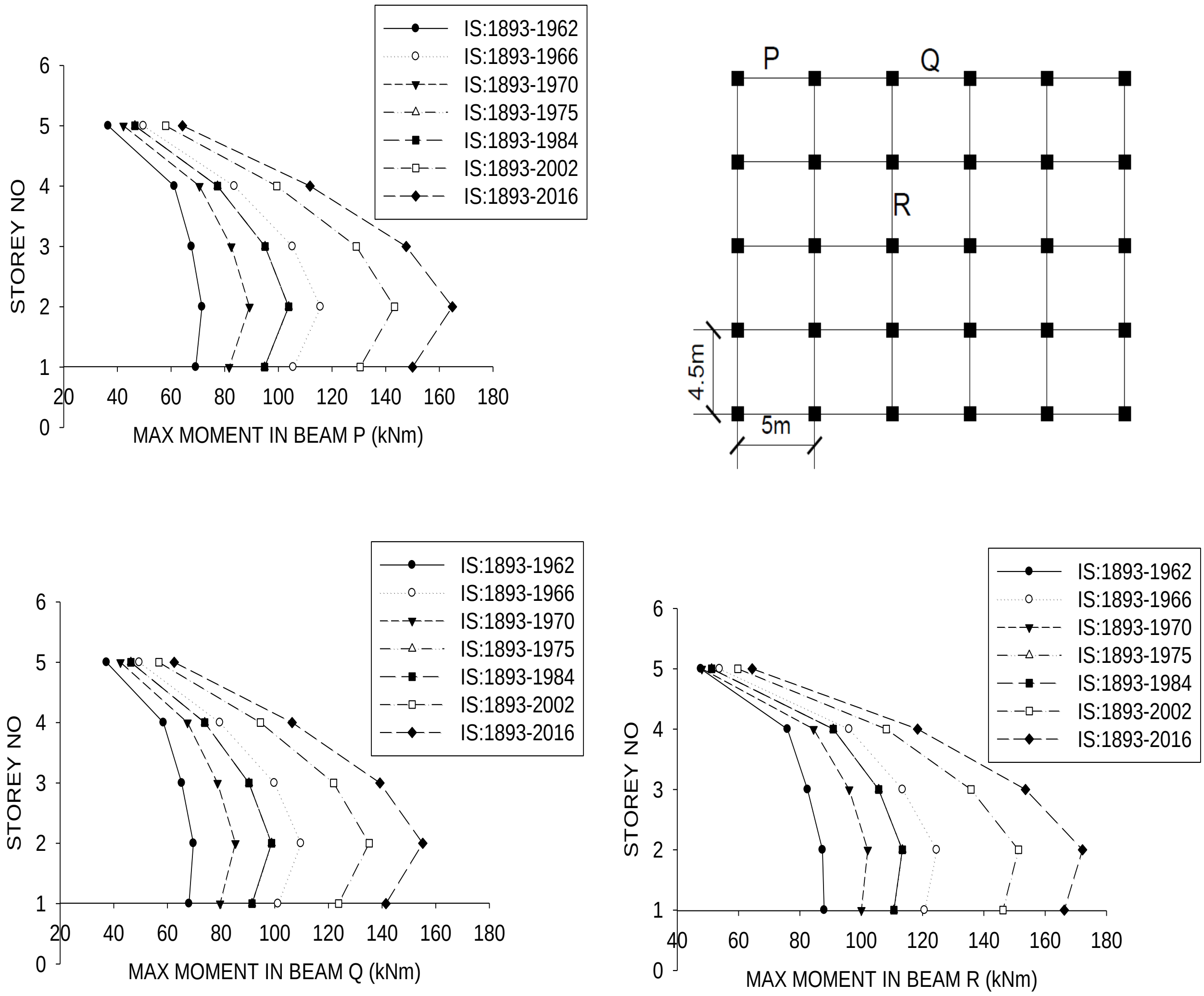


Graph 7.4: Comparison of axial force, moment about x and z axis in column C through various iterations of IS: 1893 code for zone 3

In the plot of axial force in column C with storey number, axial force is found to be minimum at the top storey of the building in each case. Maximum axial force in column B, is found to be at the ground storey of the building. Axial force in column decreases with increase in storey number of the building. Axial force variation in column C for zone 3, found to be equal in each case, which corresponds to the load combination 1.5(DL+LL). As this combination, does not include the effect of lateral load.

In the plot of moment about x and z direction in column C with storey number of the building, moment is found to be minimum at the top storey of the building. And it's found to be maximum at the ground storey of the building. Maximum moment is found to be from IS: 1893-2016, which yields maximum value of lateral load. Moment about z-direction is found to be more than moment about x-direction.

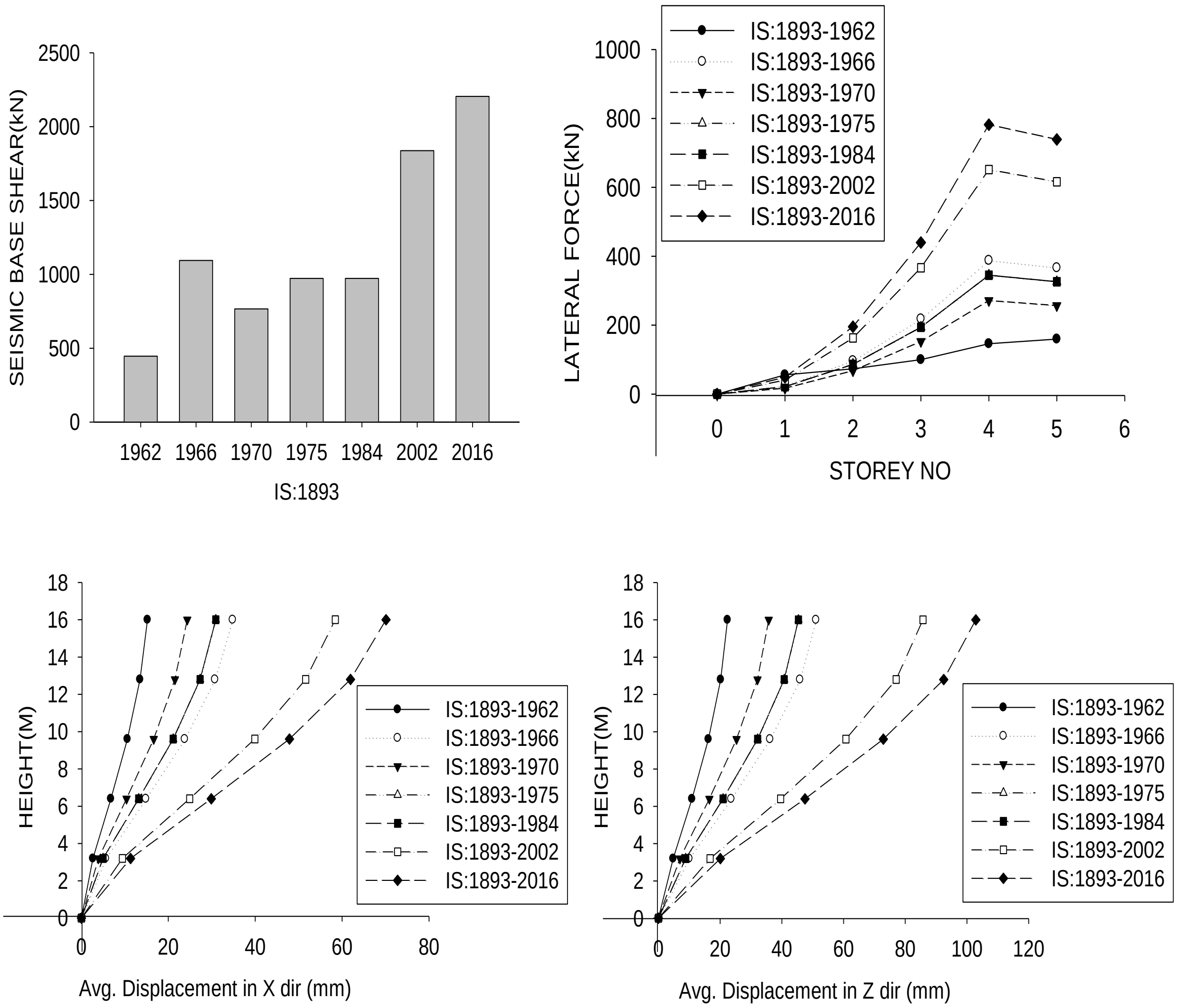
7.1.4 Beams



Graph 7.5: Comparison of maximum moment in beams P, Q and R through various iterations of IS: 1893 code for zone 3

In the plot of maximum moment in the beam P, Q and R with storey number, moment is found to be minimum at the top storey of the building. Moment in beam increases towards the base of the building. Maximum values occur at the second storey of the building. Value of bending moment in beam is found to be maximum in the beam located, internally in the plan of the building i.e. beam R. Moment in beam P, Q and R, for the case of IS: 1893-1975 & IS: 1893-1984, are plotted with same line, as there is no difference in the value of lateral load and other loading conditions. Maximum value of moment in beam P, Q and R; found to be in case of IS: 1893-2016, which compute the maximum value of lateral load. Similarly, minimum value of moment in beam P, Q and R; found to be from IS: 1893-1962, which estimate the least value of lateral load among the other cases.

7.2 Zone 4



Graph 7.6: Comparison of seismic base shear, lateral load, average displacement along x and z direction through various iterations of IS: 1893 code for zone 4

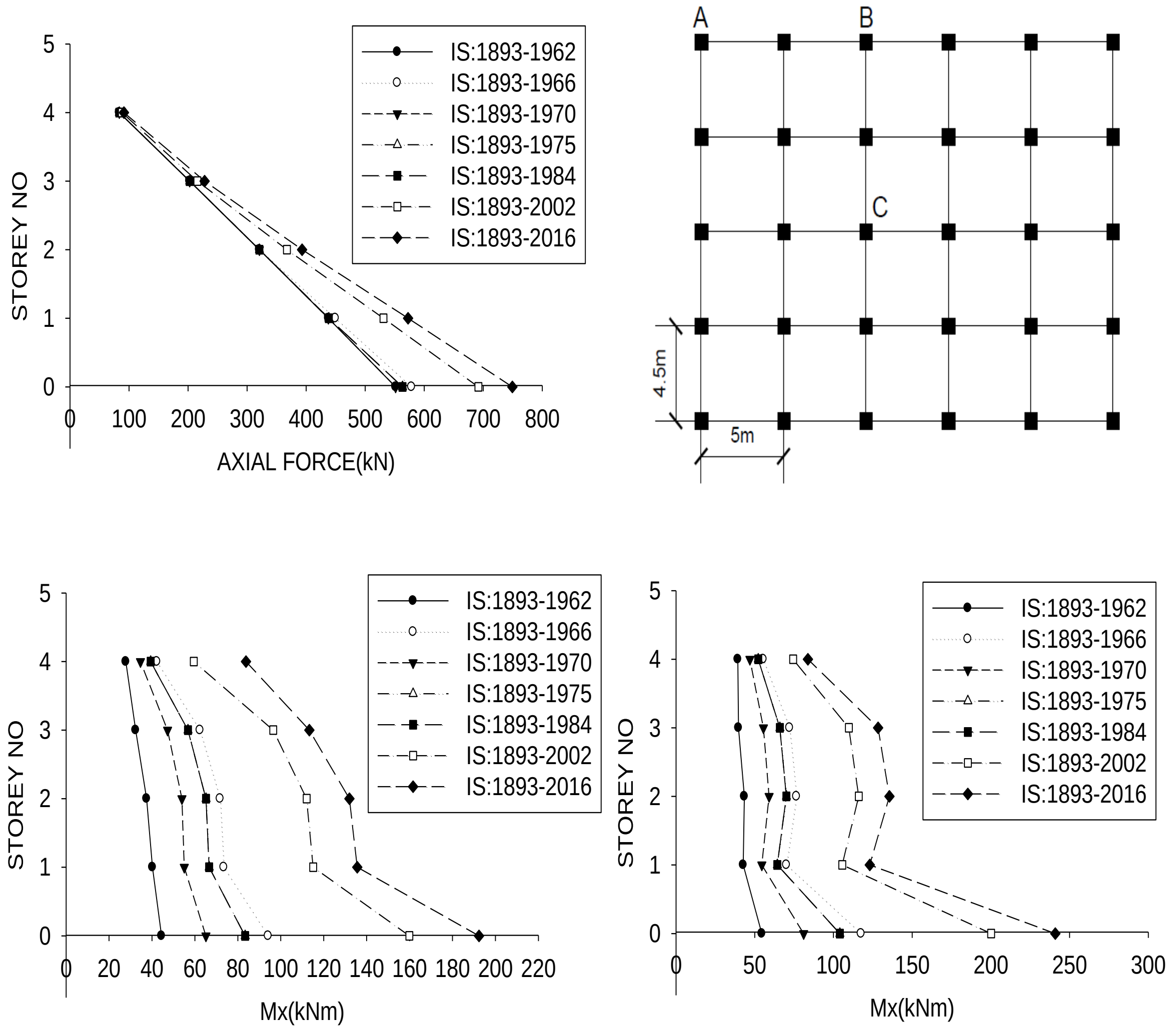
In plot of variation of seismic base shear with previous codes of IS: 1893, maximum seismic base shear is found to be from code revised in year 2016. Base shear is found to be equal in year 1975 and 1984. Minimum seismic base shear is found to be from 1962, which estimates the least value of seismic base shear. Value of seismic base shear computed from 1966 is more than the value of seismic base shear computed from 1962, 1970, 1975 and 1984. Value of seismic base shear increases with changes made in code except IS: 1893-1966.

In the plot of lateral load with storey number, lateral load is found to be maximum at storey below roof except in case of IS: 1893-1962. Maximum lateral load value is found to be from IS: 1893-2016, which yields the maximum value of seismic base shear. And minimum value of lateral load is found to be in case of 1962. In each case, value of lateral load is found to be zero at the base of the building.

In the plot of average displacement in x-direction with height of the building, displacement of the building increases with increase in height of the building. Maximum displacement is found to be at the top of the building. And displacement at the bottom of the building is minimum and equal to zero. Maximum displacement of the building is found to be in case of IS: 1893-2016, which yields maximum value of lateral load.

In the plot of average displacement in z-direction with height of the building, displacement of the building increases with increase in height of the building. Maximum displacement is found to be at the top of the building. And displacement at the bottom of the building is minimum and equal to zero. Maximum displacement of the building is found to be in case of IS: 1893-2016, which yields maximum value of lateral load. Displacement in z-direction is found to be more than x-direction, as the length along x-direction of building is more than length along z-direction.

7.2.1 Column A

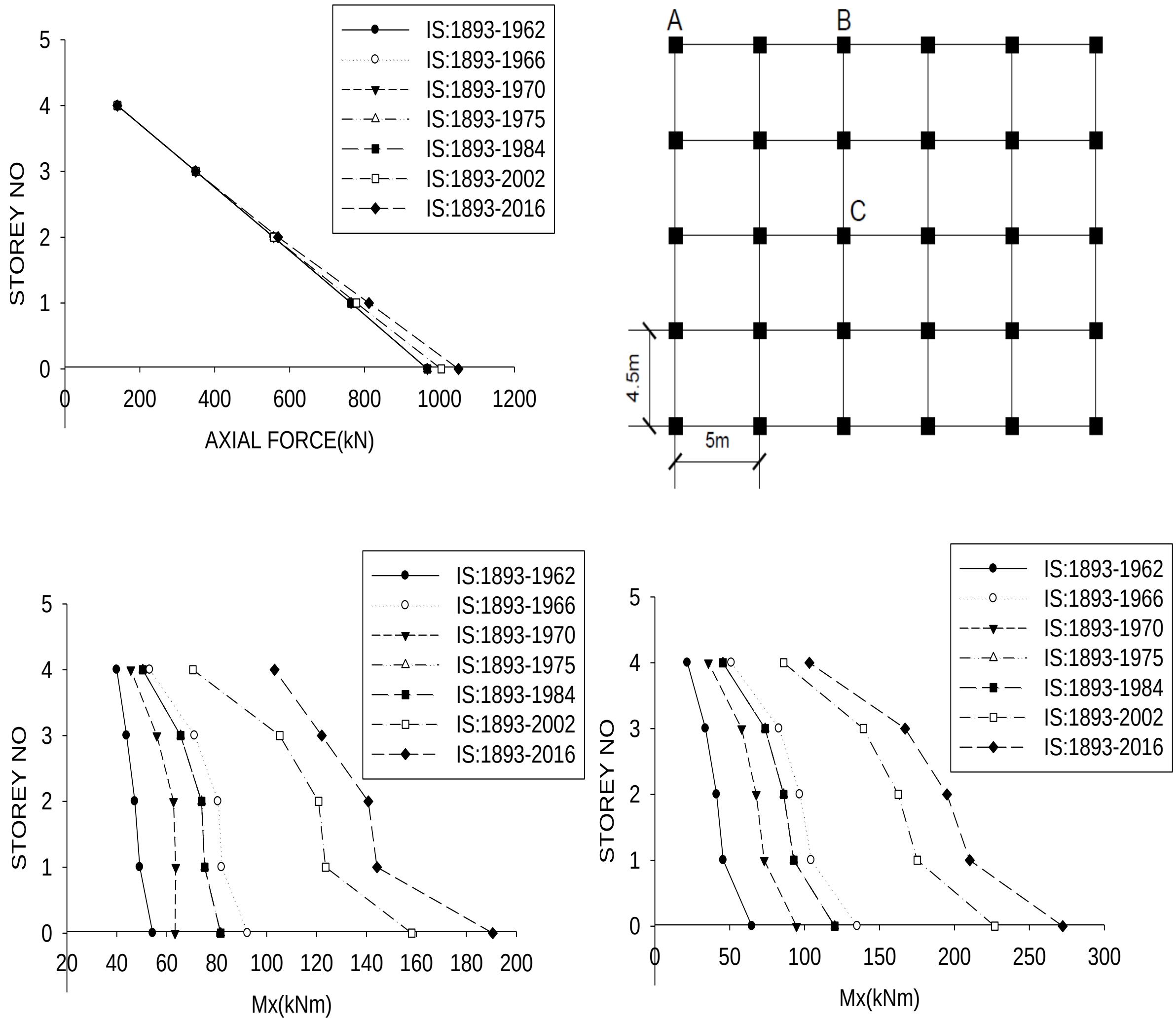


Graph 7.7: Comparison of axial force, moment about x and z axis in column A through various iterations of IS: 1893 code for zone 4

In the plot of axial force in column A with storey number, axial force is found to be minimum at the top storey of the building in each case. Maximum axial force is found to be at the ground storey of the building. Axial force in column decreases with increase in storey number of the building. Maximum axial force in column A is found to be in case of IS: 1893-2016, at the ground storey of the building. It is found that axial force is of equal magnitude in each case at the top storey of the building.

In the plot of moment about x and z direction in column A with storey number of the building, moment is found to be minimum at the top storey of the building. And it’s found to be maximum at the ground storey of the building. Maximum moment is found to be from IS: 1893-2016, which yields maximum value of lateral load. Moment about z-direction is found to be more than moment about x-direction.

7.2.2 Column B

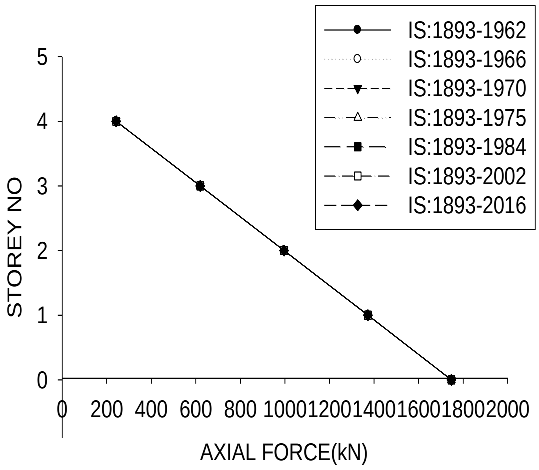


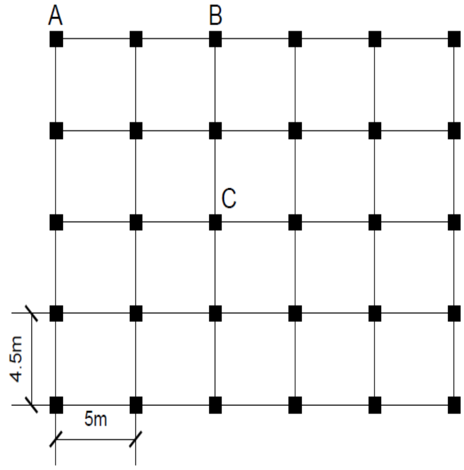
Graph 7.8: Comparison of axial force, moment about x and z axis in column B through various iterations of IS: 1893 code for zone 4

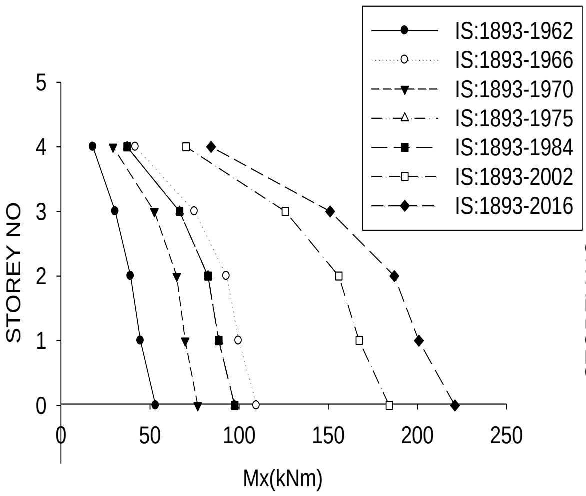
In the plot of axial force in column B with storey number, axial force is found to be minimum at the top storey of the building in each case. Maximum axial force in column B, is found to be at the ground storey of the building. Axial force in column decreases with increase in storey number of the building. Axial force variation in column B for zone 4, found to be equal in each case, for the upper three storey of the building which corresponds to the load combination 1.5(DL+LL). As this combination, does not include the effect of lateral load.

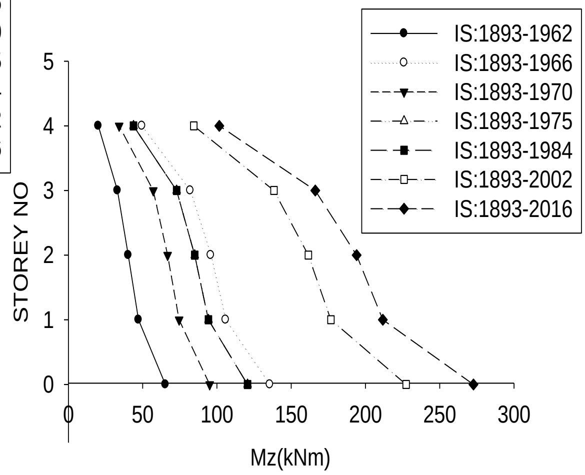
In the plot of moment about x and z direction in column B with storey number of the building, moment is found to be minimum at the storey of the building. And it's found to be maximum at the ground storey of the building. Maximum moment is found to be from IS: 1893-2016, which yields maximum value of lateral load. Moment about z-direction is found to be more than moment about x-direction.

7.2.3 Column C







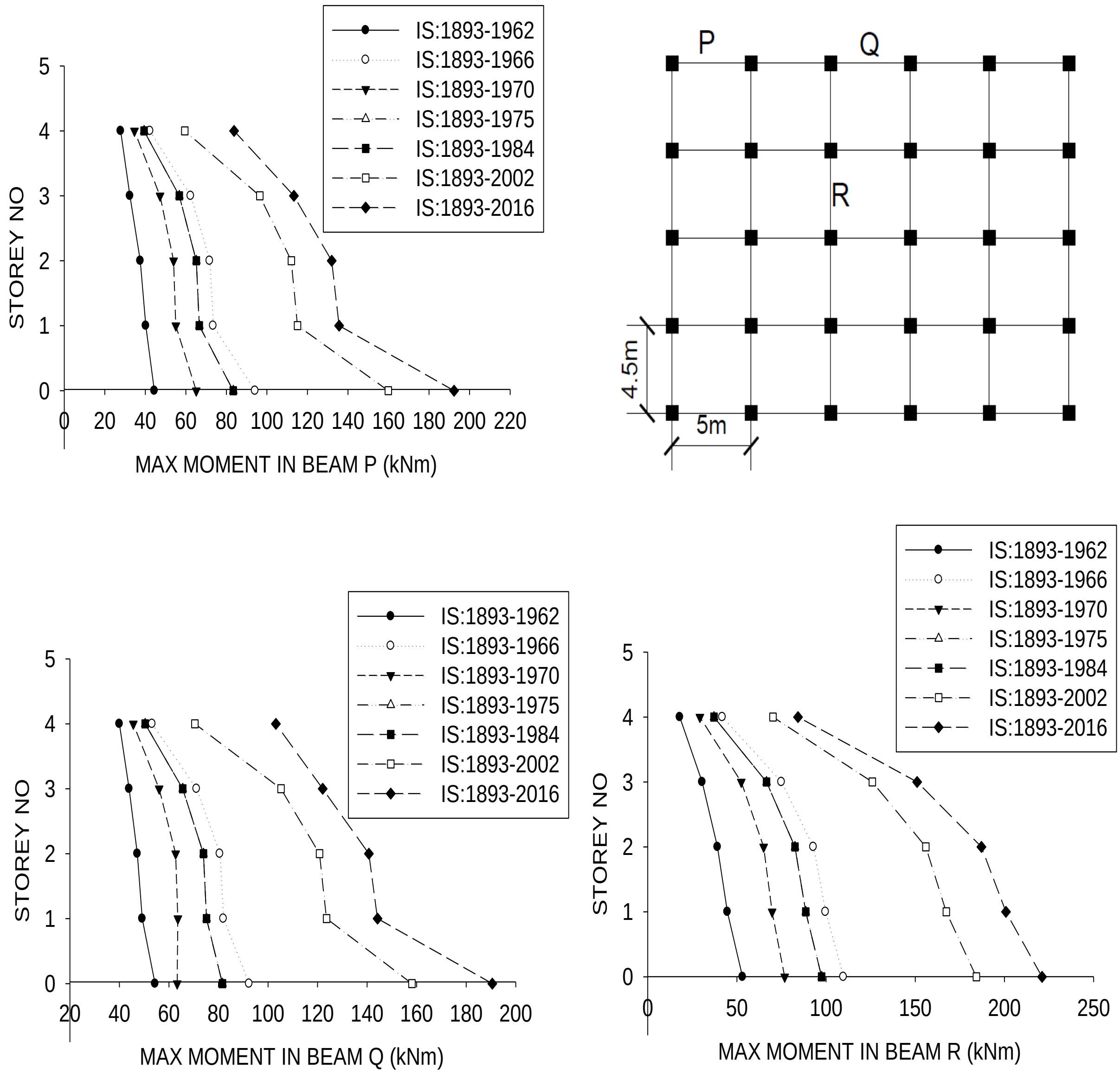


Graph 7.9: Comparison of axial force, moment about x and z axis in column C through various iterations of IS: 1893 code for zone 4

In the plot of axial force in column C with storey number, axial force is found to be minimum at the top storey of the building in each case. Maximum axial force in column B, is found to be at the ground storey of the building. Axial force in column decreases with increase in storey number of the building. Axial force variation in column C for zone 4, found to be equal in each case, which corresponds to the load combination 1.5(DL+LL). As this combination, does not include the effect of lateral load.

In the plot of moment about x and z direction in column C with storey number of the building, moment is found to be minimum at the top storey of the building. And it's found to be maximum at the ground storey of the building. Maximum moment is found to be from IS: 1893-2016, which yields maximum value of lateral load. Moment about z-direction is found to be more than moment about x-direction.

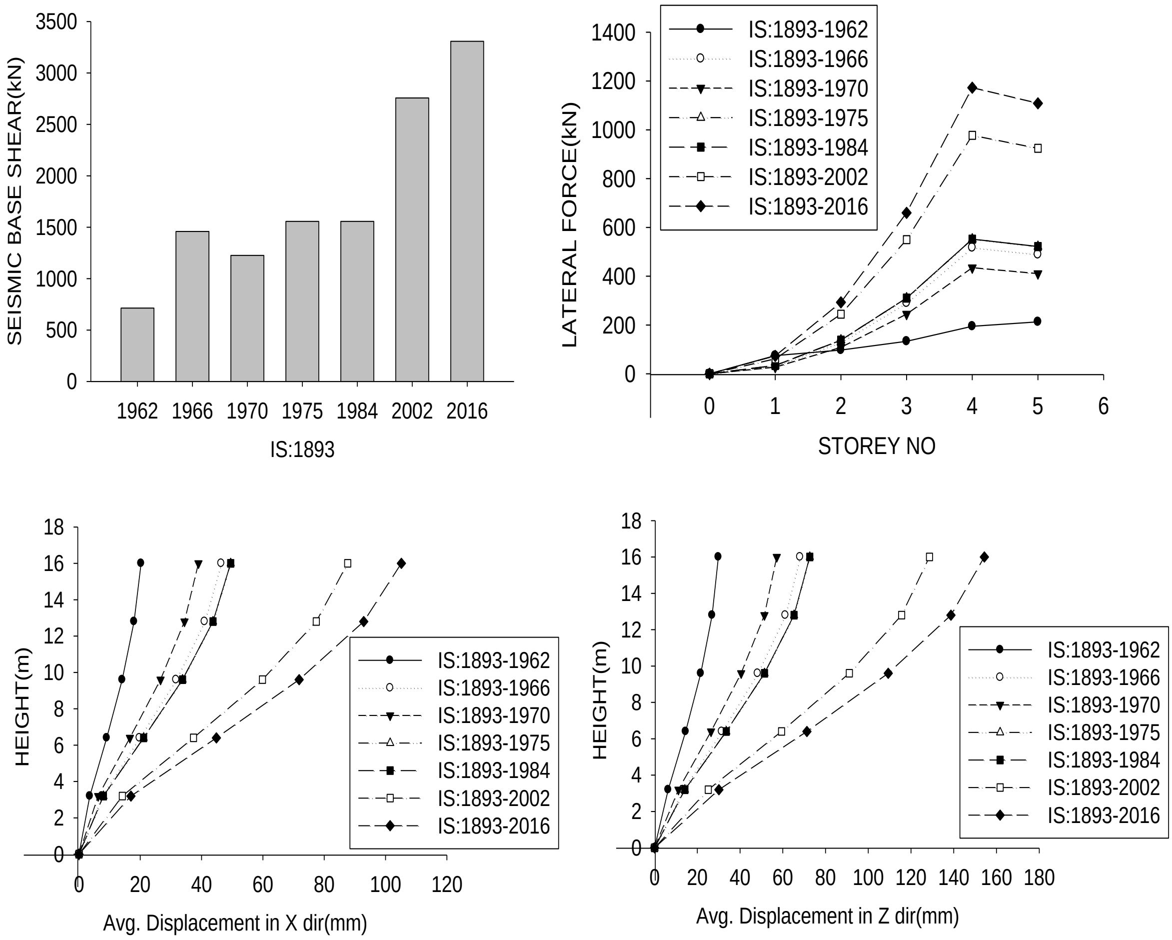
7.2.4 Beams



Graph 7.10: Comparison of maximum moment in beams P, Q and R through various iterations of IS: 1893 code for zone 4

In the plot of maximum moment in the beam P, Q and R with storey number, moment is found to be minimum at the top storey of the building. Moment in beam increases towards the base of the building. Maximum values occur at the second storey of the building. Value of bending moment in beam is found to be maximum in the beam located, internally in the plan of the building i.e. beam R. Moment in beam P, Q and R, for the case of IS: 1893-1975 & IS: 1893-1984, are plotted with same line, as there is no difference in the value of lateral load and other loading conditions. Maximum value of moment in beam P, Q and R; found to be in case of IS: 1893-2016, which compute the maximum value of lateral load. Similarly, minimum value of moment in beam P, Q and R; found to be from IS: 1893-1962, which estimate the least value of lateral load among the other cases.

7.3 Zone 5



Graph 7.11: Comparison of seismic base shear, lateral load, average displacement along x and z direction through various iterations of IS: 1893 code for zone 5

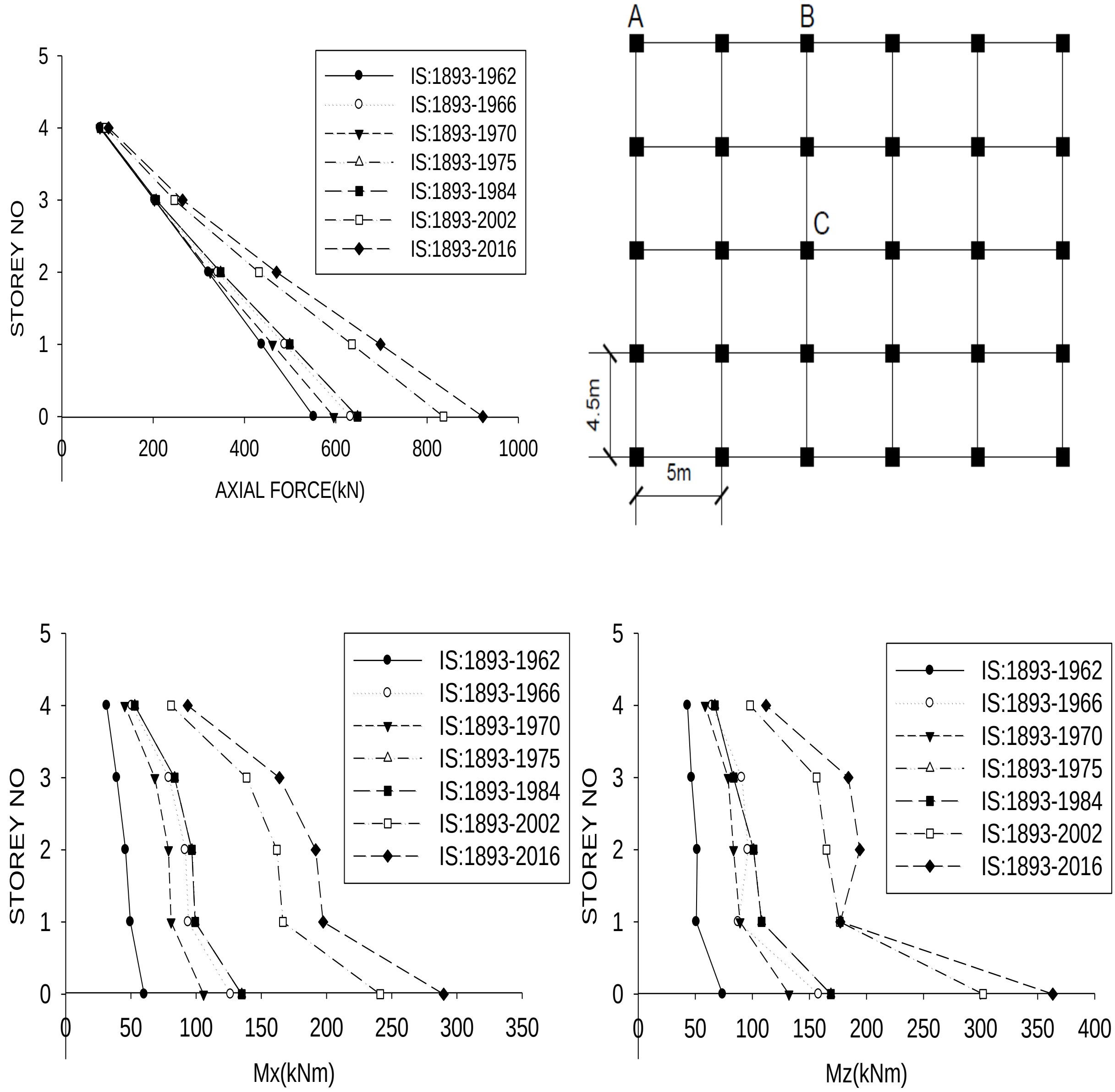
In plot of variation of seismic base shear with previous codes of IS: 1893, maximum seismic base shear is found to be from code revised in year 2016. Base shear is found to be equal in year 1975 and 1984. Minimum seismic base shear is found to be from 1962, which estimates the least value of seismic base shear. Value of seismic base shear computed from 1966 is more than the value of seismic base shear computed from 1962 and 1970. Value of seismic base shear increases with changes made in code IS: 1893. For zone 5, value estimated through IS: 1893-1975 and IS: 1893-1984 is found to be more than value computed through IS: 1893-1966.

In the plot of lateral load with storey number, lateral load is found to be maximum at storey below roof except in case of IS: 1893-1962. Maximum lateral load value is found to be from IS: 1893-2016, which estimates the maximum value of seismic base shear. And minimum value of lateral load is found to be in case of 1962.

In the plot of average displacement in x-direction with height of the building, displacement of the building increases with increase in height of the building. Maximum displacement is found to be at the top of the building. And displacement at the bottom of the building is minimum and equal to zero. Maximum displacement of the building is found to be in case of IS: 1893-2016, which yields maximum value of lateral load.

In the plot of average displacement in z-direction with height of the building, displacement of the building increases with increase in height of the building. Maximum displacement is found to be at the top of the building. And displacement at the bottom of the building is minimum and equal to zero. Maximum displacement of the building is found to be in case of IS: 1893-2016, which yields maximum value of lateral load. Displacement in z-direction is found to be more than x-direction, as the length along x-direction of building is more than length along z-direction.

7.3.1 Column A

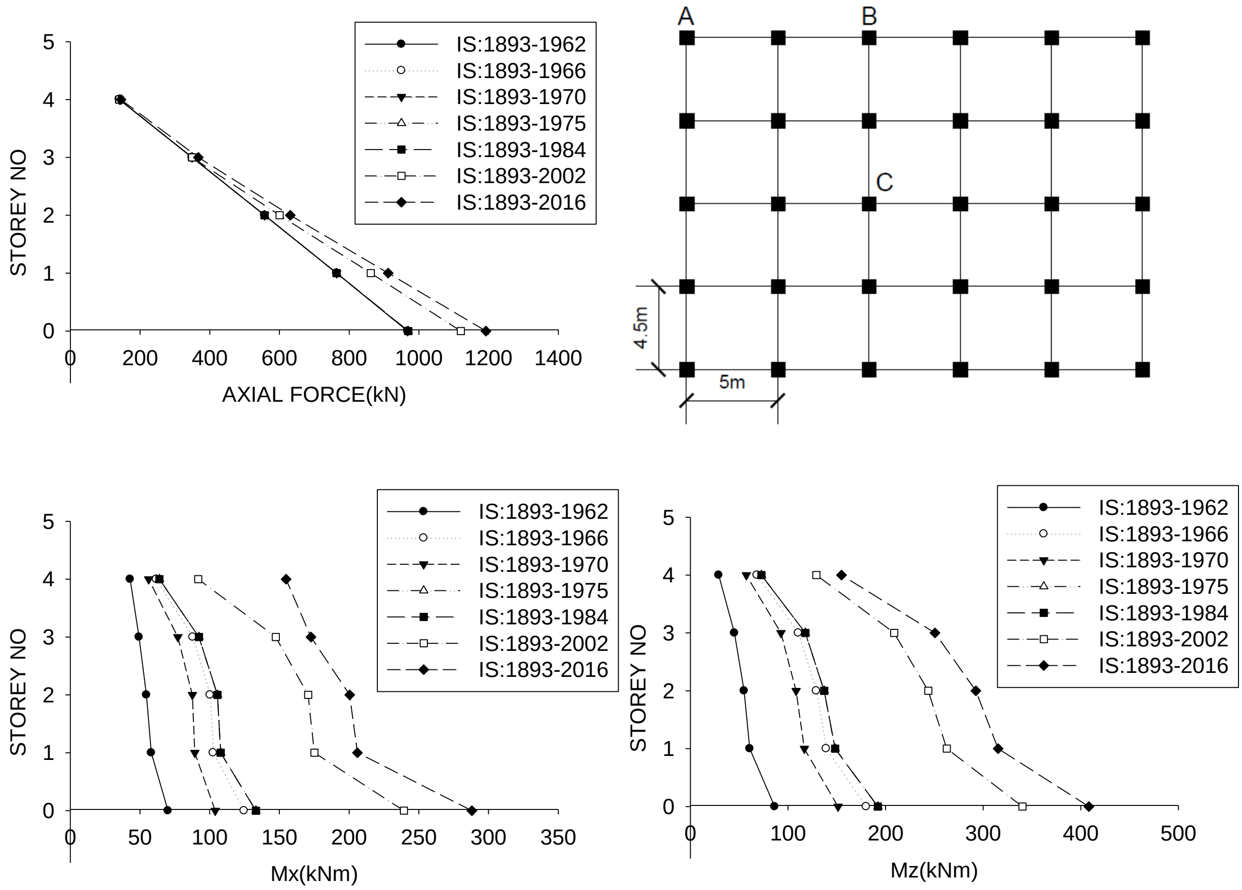


Graph 7.12: Comparison of axial force, moment about x and z axis in column A through various iterations of IS: 1893 code for zone 5

In the plot of axial force in column A with storey number, axial force is found to be minimum at the top storey of the building in each case. Maximum axial force is found to be at the ground storey of the building. Axial force in column decreases with increase in storey number of the building. Maximum axial force in column A is found to be in case of IS: 1893-2016, at the ground storey.

In the plot of moment about x and z direction in column A with storey number of the building, moment is found to be minimum at the storey of the building. And it’s found to be maximum at the ground storey of the building. Maximum moment is found to be from IS: 1893-2016, which yields maximum value of lateral load. Moment about z-direction is found to be more than moment about x-direction.

7.3.2 Column B

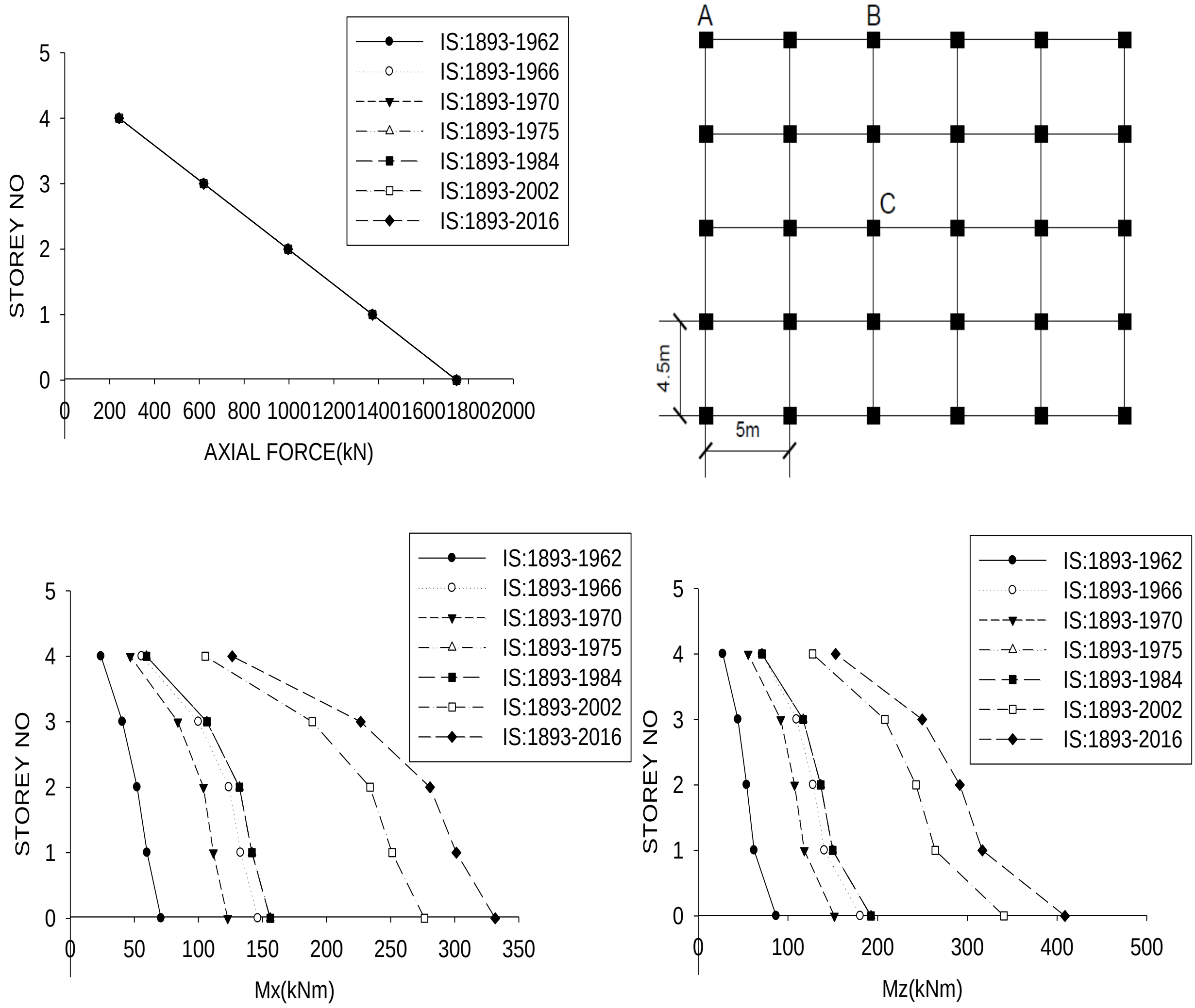


Graph 7.13: Comparison of axial force, moment about x and z axis in column B through various iterations of IS: 1893 code for zone 5

In the plot of axial force in column B with storey number, axial force is found to be minimum at the top storey of the building in each case. Maximum axial force in column B, is found to be at the ground storey of the building. Axial force in column decreases with increase in storey number of the building. Axial force variation in column B for zone 5, found to be equal in each case, for the upper two stories of the building which corresponds to the load combination 1.5(DL+LL). As this combination, does not include the effect of lateral load.

In the plot of moment about x and z direction in column B with storey number of the building, moment is found to be minimum at the storey of the building. And it’s found to be maximum at the ground storey of the building. Maximum moment is found to be from IS: 1893-2016, which yields maximum value of lateral load. Moment about z-direction is found to be more than moment about x-direction.

7.3.3 Column C

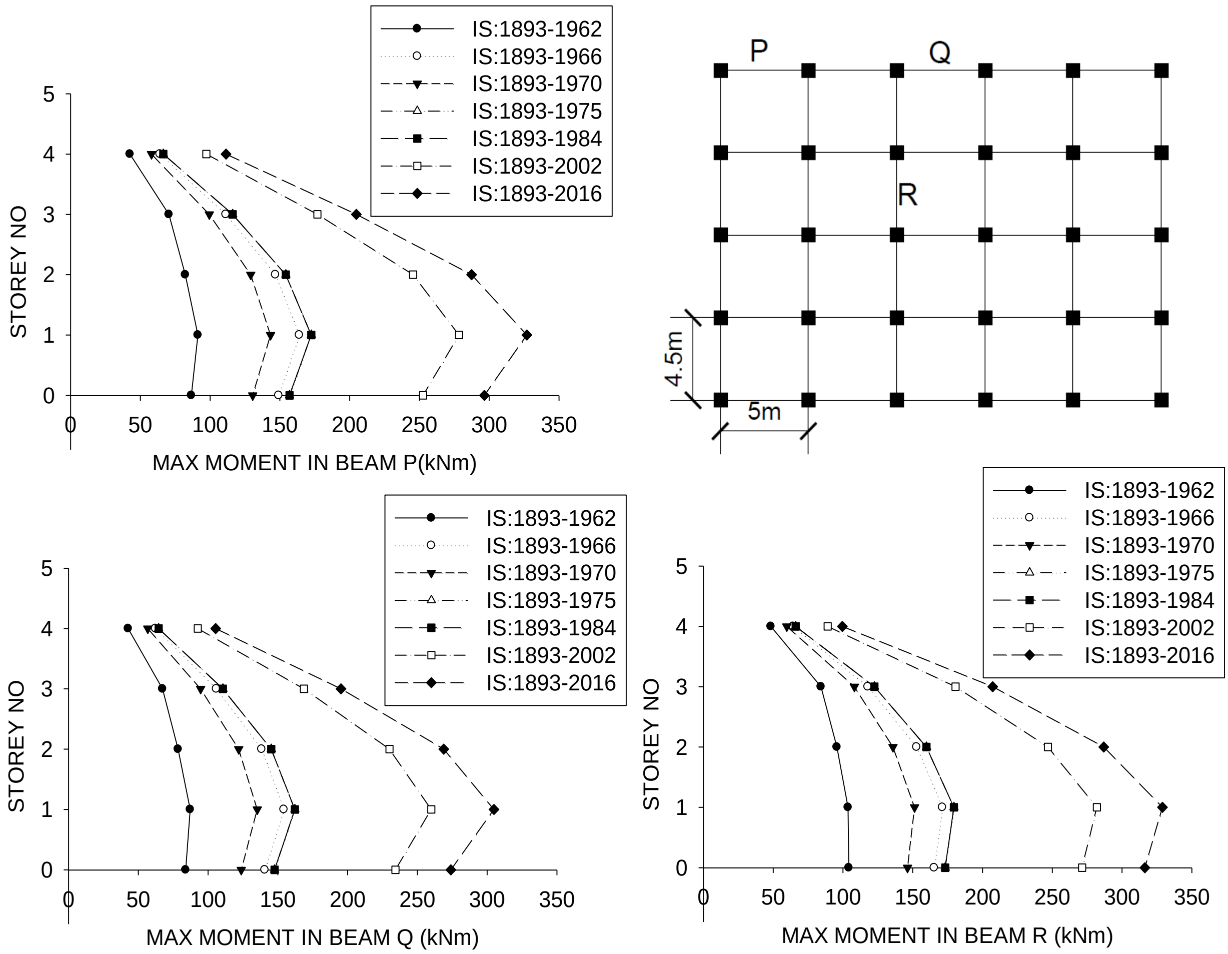


Graph 7.14: Comparison of axial force, moment about x and z axis in column C through various iterations of IS: 1893 code for zone 5

In the plot of axial force in column C with storey number, axial force is found to be minimum at the top storey of the building in each case. Maximum axial force in column B, is found to be at the ground storey of the building. Axial force in column decreases with increase in storey number of the building. Axial force variation in column C for zone 5, found to be equal in each case, which corresponds to the load combination 1.5(DL+LL). As this combination, does not include the effect of lateral load.

In the plot of moment about x and z direction in column C with storey number of the building, moment is found to be minimum at the top storey of the building. And it's found to be maximum at the ground storey of the building. Maximum moment is found to be from IS: 1893-2016, which yields maximum value of lateral load. Moment about z-direction is found to be more than moment about x-direction.

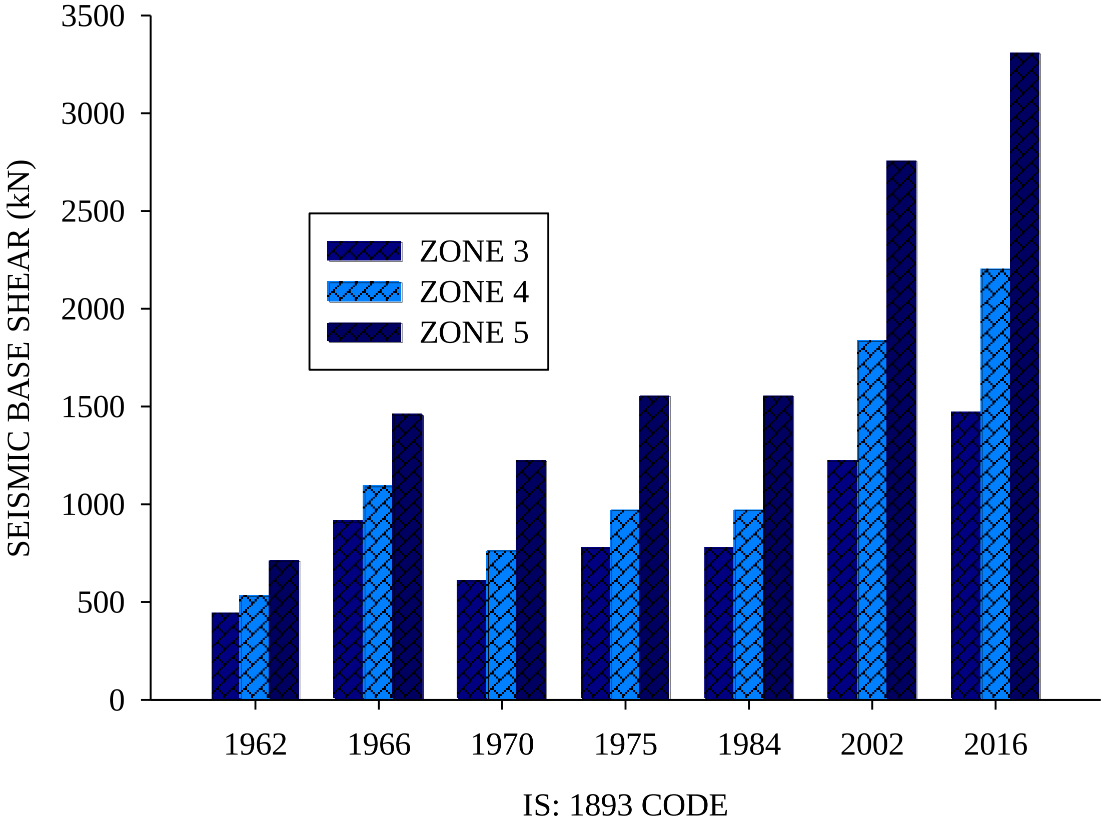
7.3.4 Beams



Graph 7.15: Comparison of maximum moment in beams P, Q and R through various iterations of IS: 1893 code for zone 5

In the plot of maximum moment in the beam P, Q and R with storey number, moment is found to be minimum at the top storey of the building. Moment in beam increases towards the base of the building. Maximum values occur at the second storey of the building. Value of bending moment in beam is found to be maximum in the beam located, internally in the plan of the building i.e. beam R. Moment in beam P, Q and R, for the case of IS: 1893-1975 & IS: 1893-1984, are plotted with same line, as there is no difference in the value of lateral load and other loading conditions. Maximum value of moment in beam P, Q and R; found to be in case of IS: 1893-2016, which compute the maximum value of lateral load. Similarly, minimum value of moment in beam P, Q and R; found to be from IS: 1893-1962, which estimate the least value of lateral load among the other cases.

7.4 Variation of seismic base shear



Graph 7.16: Variation of seismic base shear computed through various iterations of IS: 1893 for zone 3, 4 and 5

Variation of seismic base shear plotted in above graph for different zones, computed through various iterations of IS: 1893 code. It can be inferred from the above graph that seismic base shear increases with increasing seismic zone. So, there is an effect of change in seismic zone on the building. For zone 3, zone 4 and zone 5; seismic base shear increases with changes made in the code IS: 1893 i.e. for earthquake resistant design of building. In case of zone 3 and 4, seismic base shear computed from IS: 1893-1966, yields more value than the other revised code i.e. IS: 1893-1962, 1970, 1975 and 1984. It shows a change in the pattern of increasing seismic base shear with various iterations of IS: 1893. For zone 3, 4 and 5; maximum value of base shear is obtained through latest revision of IS: 1893 i.e. 2016 and minimum value of base shear is obtained through earlier version of IS: 1893 i.e. 1962. In comparison to previous version of seismic code for earthquake resistant design of building, IS: 1893-2016 shows maximum change in the value of seismic base shear computed for different zones.

CHAPTER 8
CONCLUSION

8.1 General

1. On the basis of above study, it seems to be found that seismic base shear values are increasing with various iterations of IS: 1893 code except first revision of code shows a change in this pattern.
2. Seismic base shear seems to increase with increasing seismic zone of the building.
3. Average displacement increases with increase in lateral load.
4. The study seems to indicate that upgradation requirements of of building may be assessed by applying specification of various codes in a systematic manner.
5. Wide variations in output values as per different codes, this indicates urgent and sizeable upgradation requirement of building.
6. There are seismic zonal variations in output indicating difference in upgradation requirements in various seismic zones.
7. Change in seismic base shear and storey drift, upgradation requirements in term of additional reinforcement in columns may be defined in terms of characteristics equations which may be found to be helpful in case of calculation of upgradation requirements for bulk housing.
8. The approach seems to be user friendly for calculation of upgradation requirements for public and engineers alike, considering the wide spread availability of computers nowadays.
9. Those buildings which are designed up to latest revised version of IS CODE: 1893 has to be retrofitted for making them earthquake resistant building.

8.2 Scope of future study

1. This thesis can be used for the detailed study of various changes occurred since 1962 in IS: 1893.
2. Any structural engineer can study this paper as a reference for seismic analysis of any multi-storeyed building using seismic coefficient method i.e. static method.
3. More number of beams and columns can be taken for more analysis.
4. Different type of plan and elevation of building can be taken for the study of effect caused due to change in seismic code.
5. Seismic parameters can be changed for the further study on different models.
6. Dynamic analysis using response spectrum method and modal analysis method can be used for different building model to compute the lateral load.

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