SEISMIC RESPONSE OF MULTI-STOREY SHEAR WALL FRAMED STRUCTURE WITH SOFT STORY

A DISERTATION

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS

FOR THE AWARD OF THE DEGREE OF

MASTER OF TECHNOLOGY

IN

STRUCTURAL ENGINEERING

SUBMITTED BY:

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CANDIDATE'S DECLARATION

I, Kirti chandra joshi (2K20/STE/27), student of M.Tech (Structural Engineering), hereby declare that the project Dissertation titled "**SEISMIC RESPONSE OF MULTI-STOREY SHEAR WALL FRAMED STRUCTURE WITH SOFT STORY**" 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 the 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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CERTIFICATE

I hereby certify that the project Dissertation titled "**SEISMIC RESPONSE OF MULTI-STOREY SHEAR WALL FRAMED STRUCTURE WITH SOFT STORY**" which is submitted by submitted by Kirti Chandra Joshi (2K20/STE/27) to the Department of Civil Engineering, Delhi Technological University, Delhi in partial fulfillment 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.

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ABSTRACT

A high-rise building whose first floor is composed of open spaces is called a soft floor building. Such floors have a substantial impact on a building's seismic performance.. This is owing to the floors abrupt lateral stiffness and strength fluctuations. A large earthquake can cause enormous damage or collapse of a building. Previous studies have shown that structural damage from earthquakes is the cause of large displacements. If the structure, is intended for horizontal loads, the structure will show greater deflection. Braces and shear walls are the most common lateral load-bearing systems for reducing displacement. Shear walls and braces are used for improving lateral stiffness, ductility, minimal lateral displacement, and safety. Story drift and lateral displacement are essential considerations in seismic design of structures. Shear wall was added inside the proposed structure to counter the lateral load induced by earthquake and to improve structure's stiffness. Therefore, by making use of shear walls in the building, it is possible to prevent large displacements and thus damage due to displacements. In addition, Bracing is also mainly used for structures exposed to wind and seismic loads. It resists the forces of the bracing element in both compression and tension. As a result, the brace system withstands horizontal loads very efficiently. The brace frame makes the system more efficient and stiffens the structure laterally. By adding material to the bare frame, it forms an efficient structure for higher heights.

In this thesis work, the seismic response of soft-floor RCC building is studied using seismic analysis method. The parameters considered in this study include soft floor heights, shear wall position, bracing types and arrangements along the height of the building. Furthermore, the effectiveness of using simple strengthening procedures to increase structural safety will be investigated without causing large changes to the building's architectural and functional needs will be studied. The motive of this study is to investigate the impacts of shear walls as well as different types of braces provided at different locations in soft-story buildings and compare the behaviour of soft floor building with building having shear walls and bracings with stiffness irregularity. In this study, the regular shape plan of a G + 10-story reinforced concrete building in Zone V was selected. The model is analyzed in three phases, the first phase of which is a soft-storey building in ground floor. In second phase, building is analyzed with shear walls and soft story in ground floor, and in third phase, same building is analyzed with braces and soft story in ground floor. In the second phase, shear walls are also added to the model in two different cases, center and corner, to investigate the optimal location of the shear walls in the building. The third phase also provides different types of X and V type brace arrangements in the central and corner spans across the height of the building. The models are analyzed and results are tabulated with ETABS 18.0.2 software using IS 1893 (Part1): 2016 code in form of maximum storey drift, displacement, story stiffness ,base shear value, modal shapes by performing Linear dynamic i.e response spectrum Method and Non-linear static i.e pushover analysis method. The findings demonstrate the efficiency of shear walls in enhancing stiffness and decreasing displacement. Providing shear walls in buildings has proven to be effective and economical. In addition, the provision of bracing systems for strengthening the buildings with soft floors would improve the performance of these structures. The results were summarized based on the response of the building.

ACKNOWLEDGEMENT

The accomplishment of a Major project necessitates the assistance and contribution of a large number of people and the organization as a whole. The pleasure and well-being of successfully completing a dissertation would be incomplete without mentioning the people who made it possible, whose consistent guidance and encouragement crowned our effort with success.

I would like to express my heartfelt gratitude to Mr. Hrishikesh Dubey, Assistant professor, Department of Civil Engineering for his valuable guidance, comments and suggestions throughout the course of the project. His valuable and prompt comments during this research work and thesis preparation is highly appreciated. I would like to express my gratitude to all the panel faculties during all the progress reviews for their guidance, constant oversight, and motivation to complete my work. They consistently provided new ideas, provided the necessary information and urged me to get the job done.

I would like to acknowledge Indian council for Cultural Relations, Ministry of External Affairs, Govt. of India for providing me scholarship to pursue Master of Technology (Structural Engineering) at Delhi Technological University ,Delhi under Silver Jubilee Scholarship scheme, and providing other necessary facilities for carrying out the research work.

I also appreciate all the constant support I received from all my classmates, friends and family throughout the project course.

Place: Delhi — Kirti ChandraJoshi
Date: 31/05/2022 — 2K20/STE/27

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ABBREVIATIONS

RCC	Reinforced cement concrete
IO	Immediate occupancy
LS	Life safety
CP	Collapse prevention
U	Poisson's ratio
α	Co-efficient of thermal expansion
G	Shear modulus
E	Modulus of Elasticity
fck	Compressive strength
fy	Yield stress
Z	Seismic zone
IS	Indian standard
DBE	Design based Earthquake
G+	Including Ground
D.L	Dead load
L.L	Live load
E.L	Earthquake load
I	Importance factor
Sa/g	Response acceleration coefficient
T	Fundamental time period
SMRF	Special moment resisting frame
SS	Soft storey
C_eSW	Centre shear wall
C_oSW	Corner shear wall
X-MB	Cross bracing at mid bay
X-CB	Cross bracing at corner bay
V-MB	V-type bracing at mid bay
V-CB	V-type bracing at corner bay
RSA	Response spectrum analysis

CHAPTER 1

INTRODUCTION

1.1 General

Earthquakes are horrific natural disasters caused by the sudden release of energy underground and are considered one of the worst natural disasters, shaking parts of the surface and all man-made objects, life, soil and the non-living thing that exists on it. Vibrations are generated from the energy released, all due to substances inside and outside the surface, resulting in loss of life and damage to structures. The intensities and magnitudes of the earthquake varies hence it is critical to investigate the seismic behaviour of an RCC structures with various parameters in terms of response such as shear at base, displacement etc. Dynamic analysis is required for the structure to be safe and to study its nature at impact. Also, it must be done to find the utmost response to base excitation. Structures receive lateral loads from earthquakes besides gravity loads that cause fluctuations. Compared to high-rise buildings, low-rise buildings are much less likely to fluctuate. The growth of industry, economic factors, inhabitants, their lifestyles in city areas will result in tall, laterally loaded vulnerable buildings. If the structure, primarily the structure of the building, is intended for horizontal loads, the structure will show greater deflection. Bracings and structural walls are the most common lateral load-bearing systems for reducing displacement. The building is designed according to DBE, however actual force acting on it is much greater than the force of the DBE. The main goal in design of seismic structures is to provide ductility to withstand seismic forces.

Structural engineers sought to counter the lateral forces and achieve enough stiffness using moment-resistant frame, diaphragms, braces, and shear walls. Shear walls are built to withstand earthquake loads and provide the stiffness and strength that structures require when they are subjected to them .Shear walls are considered to be the most effective compared to all lateral load resistance systems, especially for high-rise buildings and elevator housings.

1.2 Code provisions

The specifications of the soft storey are as follows.

- **IS1893 (Part 1): 2002** and ASCE 7-16 defines stiffness irregularities as follows:

a) A soft floor is a floor that has less than 70% of the lateral stiffness of above floor above or less than 80% of the average lateral stiffness of three floors above.

b) An extreme soft floor has less than 60% of the lateral stiffness of the floor above, or less than 70% of the average lateral stiffness of three floors above.

- **IS1893 (Part 1): 2016** defines the lateral stiffness of a soft floor is less than lateral stiffness of the upper floor. The seismic lateral stiffness is the total stiffness of all seismic forces that resist the element and that resists the lateral seismic vibration effect in the considered direction.

- **IS13920: 2016** defines the shear wall as a vertical planar element intended to withstand lateral forces (axial, shear, and bending moments) primarily in its own plane.

1.3 Regular and Irregular Classification

Structures can be classified based on the irregularities of various structures. This classification should be based on structural configurations. In general, structural irregularities are defined as follows according to IS 1893: 2016:

Plan Irregularities- Plan irregularities can be divided into five categories:

1) Torsional irregularities: Torsional irregularities are supposed to be exist when peak horizontal displacement of floor in direction of lateral force at one end of floor is 1.5 of the peak displacement at other end of same floor in same direction.

2) Re-entrant corner irregularities occur incase planar projections of the structure beyond the re-entrant corners go above fifteen percentage of planar dimensions in specified direction.

3) Diaphragm Discontinuity Irregularity: Diaphragm discontinuity exists when the diaphragm exhibits a sudden discontinuity or change in stiffness. This includes a diaphragm with an opening area of greater than fifty percentage of total closed area of diaphragm, or a vary in diaphragm stiffness greater than fifty percent from one of subsequently floor.

4) Out-of-plane offset Irregularity occurs if there is a discontinuity in lateral forces resisting path like at least one out-of plane offset of vertical element.

5) Non-parallel system Irregularity occurs if vertical lateral force resistance element is unparallel to orthogonal axes of lateral force resisting system.

Vertical irregularities fall into seven types:

1) Stiffness irregularity is defined when stiffness of the storey is lower than lateral stiffness of the above storey.

2) Weight (mass) Irregularity: Mass irregularities are defined incase effective mass of one floor surpasses 150 percent of effective mass of nearby floors. In general, roof is lighter than the floor below, so it should't be taken into account.

3) Vertical geometric irregularities occur when horizontal dimensions of a lateral force resisting system on one floor exceed 125% of adjacent floors.

4) In-plane discontinuities in vertical resistance elements occur if the in-plane offset exceeds planned length of 20% for these elements.

5) Strength Irregularity: Weak storey irregularities are defined when lateral strength of story is lower than lateral strength of the above storey.

6) Floating column can cause intensive damage to the structure.

7) Irregular mode of oscillations in two principal plan directions: If first three modes account for less than 65 percentage of the mass participation factor in each principal direction and the natural period of building in two each principal directions is only 10 percent closer to the larger value, the building has lateral storey irregularities in the principal plan direction.

1.4 Soft Storey

Most high rise buildings require an open floor called Soft Storey for parking lots, retail stores, conference rooms, and more. The existence of soft story, as illustrated in the diagram 1.1, is the fundamental issue that civil engineers encounter.

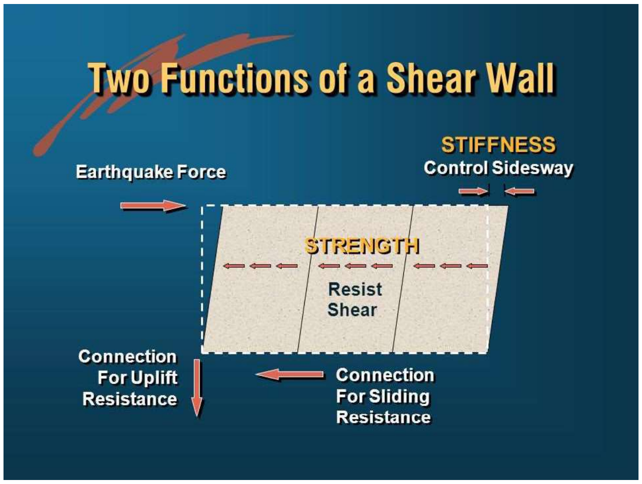
Fig 1.1 Buildings failure due to soft storey

It creates structural irregularities in aspects of strength and stiffness. As a result in design process for predicting the seismic performance of high-rise structures, it is essential to find out requirements for soft storey and their impact on the building. Implement a parametric analysis on bare frame and shear wall systems as a result of modifying the bracing arrangement in buildings with soft story is part of this research.

1.5 Shear wall

Shear wall is an structural system made up of shear panels that is used to mitigate the impact of lateral loads on a structure. Its primary purpose is to strengthen the rigidity of the lateral load resistance and to give the structure with the necessary stiffness and strength. Shearing walls, which are created as vertically oriented wide beams in an RCC structure, is used to mitigate the effects of lateral loads present on buildings .These are added to the structure's slabs, beams, and columns, giving the rigidity required for residential construction. Because buildings, particularly high-rise structures, are more susceptible to lateral loads and forces, shear walls are particularly critical. The beams and columns size in high-rise structures is relatively very high, and the reinforcement of the beam-column joints is very heavy, resulting in clogging of the joints. Using shearing walls as the way in order to provide appropriate stiffness to tackle these practical difficulties.

The major goal of the project is to investigate the effective behaviour of the presence of shearing walls and bracings in various locations in soft-floor buildings and to compare buildings with bracing and shear walls in different locations to buildings without bracings and shear walls and observe changes in various parameter like storey drift, displacement, stiffness ,storey shear, base shear, and time period. Shear walls are erected in the corners and centre of the soft-story structure in this study to observe the effect on the behaviour of the building.



Two Functions of a Shear Wall

STIFFNESS
Control Sidesway

Earthquake Force

STRENGTH
Resist Shear

Connection For Uplift Resistance

Connection For Sliding Resistance

Fig 1.2 Function of shear wall

1.6 Shear wall geometry and location

Shear walls cross sections includes rectangular and irregularly shaped cross sections like L, T, C, and U. Rectangular cross section has one dimension substantially greater than other, is often utilized as an irregular cross section. In order to withstand seismic forces, shape and position of shear wall has considerable effect on behaviour of building. Shearing walls are added in the preferred position in structure in order to build an effective lateral resistance system with minimal lateral displacement due to seismic loads. For the structure to be efficient, the shear walls are placed symmetrically to minimize the effect of torsion.

1.7 Purpose of constructing Shear walls

Shear walls are just not designed to withstand gravity or vertical load, but also to withstand lateral seismic / wind loads. The walls are statically connected to the roof/floor and other vertically running side walls, giving the building three-dimensional stability.The shearing wall structure system has a higher level of stability.This is due to the fact that, unlike the RCC skeleton structure, the load-bearing area in comparison to the entire floor plan area of the structure is relatively large. The wall must withstand the uplift induced by the pull of wind and must withstand the shear forces. The wall must withstand the lateral force of wind trying to move forward the wall away from the building. Such wall is built quickly because the method chosen to build the shear wall is to concrete the panels with formwork. Shear-bearing walls provide a high level of precision that the walls themselves do not require plaster, so no extra plaster or finishing is required.

1.8 Bracings

Bracing the frame structure against wind loads is an extremely efficient and cost-effective method. The brace arch is made up of regular columns and beams whose main function is to sustain gravity loads and diagonal braces connected so to facilitate the entire set of parts form a vertical cantilever truss which resist horizontal forces. The braces are effective because the diagonals act under axial tension.

1.9 Bracings types

Brace systems are defined depending on the usage and the usage depends on the connection of column as well as beam. Braces are connected at two different joints i.e. column beam joint and away from column beam joint. Braces are classified into various types:

1.9.1 Material Base

a) RC brace: Cross section of this type is of a beam or column. These braces are strong in compression because the concrete is very strong in compression and the structure is hard and not used. These braces are expensive because they can be used once due to the excitation of an earthquake.

b) Steel brace: These are made of steel and use steel profile types such as angle section,U section, tube section for steel braces. Steel braces usually withstand high tensile forces and break when buckled. The advantage of steel braces is that they can be reused many times after damage and are generally not expensive.

1.9.2 Based on connections to frames:

a) Concentric: These are connected by beam or column connections. Here are some examples of configuration-based concentric braces: K type, V type, X type brace.

b) Eccentric: These are connected to another point in the specified section. Sections that connect to the member support the transfer of energy from plastic drift seismic activity. These braces increase lateral stiffness and increase energy dissipation. With eccentric braces, the lateral stiffness of the frame depends on the bending deformation.

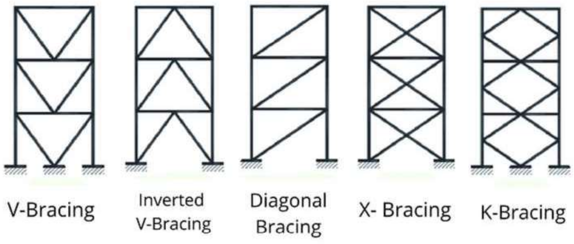


Fig 1.3 Bracings types

In this study, X-bracing and V-bracing are provided in the corner and middle bays throughout the building with soft storey to observe its effect on behaviour of building.

CHAPTER 2

LITERATURE REVIEW

2.1 Review of the Literature

1) Mariem M. Abd-Alghanya et al. (2021) modelled and analyzed a 20 story soft story building with Etabs software by linear Static and RSA . The parameter included in study take account of the elevation of Soft floor, the dimensional irregularities of the structure plan, position of the soft floor through structure height. Structural wall is placed in centre of building to investigate the change in relative stiffness, provided cross brace in 6 cases , and investigated the effect to strengthen the soft floor building using the brace system. The results focus on the effects of various parameters on lateral displacement, relative stiffness, and storey drift. Shear walls have been proven quite helpful in increasing stiffness irregularities while reducing the displacement and drift. In addition, cross braces have proven to an excellent and cost-effective means of strengthening buildings having soft floors while decreasing the stiffness irregularities.

2) Shaik Akhil Ahamad, K.V. Pratap (2020) focuses on investigating the use of shear walls at various locations of 21 multi-story structure in various zones of earthquake in Etabs . They investigating nature of seismically exposed structures by applying response spectrum analysis. Storey drift, shear, higher permissible displacement and twisting irregularities are investigated in Multi-storey buildings are investigated for. Structural investigation as well as modelling will be performed using Etabs for all earthquake zones mandated as per IS 1893 code. The goal of the study is to investigate behaviour of the multi storey structure including and excluding shear walls, as well as the results of all seismic zone investigation . The four-ended shear wall building was found to give better results for displacement, drift and shear at base.

3) Hema Mukundan, S.Manivel (2015) performed RSA of ten multi-storey building in Zone IV including and excluding reinforced concrete structural wall with Etabs and produces results for greatest displacements, shear, modal shape and drifts. Models with regular configurations excluding shear wall is differentiated with models including shear walls. In addition, they investigated the effects of irregularity incorporating

opening, as well as changing depth of the to the concrete structural wall. It was highlighted that presence of shear walls into the structure reduced the column moments, and the incorporation of shear walls reduced maximum displacement of the structure with fifty- percent.

4) Mohammad Qadeem Afghan et al. (2020) performed both seismic coefficient method as well as dynamic RSA to evaluate the behaviour of G + 10-multistorey buildings with different shear wall locations. They investigated four various model of RCC structure (one without concrete structural walls and other three with various placements of structural wall building model). Of four models studied; core shear wall model performed better than all other models

5) Jaswant N. Arlekar et al. (1997) uses two different analysis methods: seismic coefficient and dynamic method to explore various probable cases of soft story by incorporating 9 various model in his study. It is summarized that performance of RC building consist of the first floor open was found to be poor during a strong earthquake shake.

6) P.b Lamb et al. (2012) used a stiffness irregularity building in zone IV to model and examine it. This research, on the other hand, concentrates on the properties of stiffness, drift and shear and moment in terms of structure response during earthquake motion. Incorporating braces as well as structural walls also minimises bending moments as well as stiffness irregularities, while increasing column size reduces drift.

7) Mohammad Noor Jan Ahmadi et al. (2017) selected L-shape plan for a G+7 storey RCC frame structure including stiffness irregularity in first storey for a two-step study. The model is analyzed in the first phase excluding structural wall while the second phase including structural wall. Structure investigation is performed by STAADPro software incorporating seismic coefficient methods. To confirm soft floor of the selected model, they manually calculated the stiffness on the ground and first floors. It was found that that displacement, storey drift, moments as well as forces in beam-column are reduced in building with shear walls and soft-storey in Ground floor in regard to structure excluding concrete structural wall and stiffness irregularity in Ground floor.

8) Chethan A S et al. (2015) carried out nonlinear static analysis method to investigate difference in behaviour for G+3 RCC frame considering earthquake load in zone II. The investigation is carried out with SAP2000 . Eccentric, diagonal as well as inverted v bracings were inserted into the frame and analysis were performed for with and without braces and pushover curves was generated. The braces on the frame improve overall performance against lateral loads.

9) Vidhya K (2021) studied the non-linear static behaviour of structural wall having door and window with/ without openings. A G + 9 structure is modelled and a pushover investigation of building is performed with ETABS software considering soil type II according to IS 1893: 2002. In the first case, the building model has shear walls in the corners without openings. Similarly, in the 2nd and 3rd cases, structural wall is provided on corners with mid and zigzag openings. It was summarized structure having corner walls without openings has greater shear resistance as compared to model having corner walls with central and zigzag openings and hence first case shows better seismic performance than second and third cases.

10) Yaseer Alashkar et al. (2015) conducted relative seismic retrofit investigation for a ten storey RCC frame structure in Zone III using steel braces and a shear wall system. Comparisons were made based on the performance for braces having concrete walls in various position within the structure. Analysis is performed in SAP2000 software. Six models were constructed with core and boundary shear walls, X and V braces were created in corner as well as core of structure, and results of displacement, story drift, moments and shear in Beam-column were compared. Shear wall located at core performs better than at boundary of building, while the cross brace is more effective than the V brace.

11) S.Arunkumar , Dr. G. Nandini Devi (2015) performed a pushover analysis of ten storey RC structure having soft storey on ground floor, with Etabs software, taking into account Seismic Zone III and Soil Type II according to the IS Code. The survey is carried out including shear walls and cross braces in reinforcing soft floors. Results are generated for maximum base shear, displacement, storey drift, shear, overturn moment. Drift is minimal for shear wall and building having structural wall at soft story perform better than others.

12) M.D. Kevadkar, P.B. Kodag (2013) modelled and analyzed the G +12 storey R.C.C. buildings in three parts: a model without braces and shear walls, a model with structural wall as well as a model having cross braces. The analysis is performed using ETABS for IS 1893:2002 for Seismic Zone III. Building performance is compared in provisions of Drifts, Displacement , Shear, Performance point. Storey drift of Structural wall as well as steel brace model were within limits specified in IS-1893 :2002.

13) Jyoti Patil and Dr. D.K. Kulkarni (2015) performed equivalent static and pushover investigation taken into account the Indian standard code in Etabs for seismic zone V. Shearing wall of 2 types, Refined and Simplified, were modelled in various two structures. Shearing walls were added on various locations at core and in both axes direction in building. Conclusions from Refined and simplified models were used for comparing with frames without structural wall for shear value at base, displacements, fundamental natural period and performance point for different load combinations. Pushover analysis was performed on all models and performance points for each model were generated and compared. The addition of shearing walls improves overall stiffness of entire structure and other models have less stiffness and strength than refined one.

14) P. Eswaramoorthi, Sylviya B (2018) performed an investigation of the reinforced concrete structure by repositioning the shearing wall within the building. The response spectra has been used as seismic method with Etabs software according to the IS code. Building seismic performance was compared based on storey drift, base shear and storey displacements. Four different RC building models were studied, one excluding shearing walls while other three models having various locations for shear walls at periphery, intermediate wall and at core. Placing of shearing wall at the centre of structure generates torsion on the first oscillation mode, and it is more efficient to have the shearing wall at periphery the building.

15) Anil Baral , Dr. SK. Yajdan (2015)) performed seismic coefficient and linear dynamic examination using the Indian standard code with Etabs for seismic zone V. Five different Models of G+ 9 storey RCC buildings under seismic considerations were studied, one excluding shearing wall while other four models having various locations for shearing wall at middle, corner and at middle of structure. Corner shearing wall is also incorporated in two different cases. Investigation was carried out for different

characteristics like displacement, drift, time period , Beam-column force. Static analysis produces higher displacement values as compared to response spectrum for all the five models analyzed in this study and shear wall located at corner performed better and gives least displacement among all in both static analysis and response spectrum method.

16) Karnati Vijetha , Dr. B. Panduranga Rao (2019) performed a static analysis of a 16 story RCC structure with Etabs , taking into account seismic zone III and soil type II according to the IS code. The study is performed incorporating Shearing wall as well as steel braces at outermost portion of the structure. The floor elevation of structure was kept the same with the exception of bottom storey elevation. By inserting shear walls and bracings, displacement due to an earthquake is reduced and the structure is stabilized against seismic loads. Shear walls provide the structure with proper lateral stability.

2.2 Literature Gap

- The Indian Standard IS 1893: 2002 provides for the study of open first-storey structures not taking stiffness of infill into account, however with a multiplying factor of 2.5 to account for stiffness irregularity. Open ground storey columns and beams must be design 2.5 times of storey shears and moments calculated under bare frame . However, engineers have experienced a multiplying factor of 2.5 is unrealistic for lowrise structure.

- In IS codes, there are insufficient design procedures/steps for strengthening techniques. Theoretical aspects and case studies are covered in more depth in the code and research paper, but the designing portion is largely absent.

- Shear wall is commonly examined by placing it in various positions and taking various shapes of shear wall to determine its appropriate location in most of the study. In the literature, moreover study on providing shear wall by increasing and reducing its percent in each principle direction is found to be missing.

- The Indian standard code has yet to include the pushover analysis in detail.

2.3 Objective

- To evaluate the seismic performance of building with soft story & to investigate nature of structure subjected to earthquake using dynamic and pushover analysis.
- To examine the structure in terms of base shear reaction, displacement, drift pattern, stiffness, time period and mode shapes.
- To reduce the impact, locate the best location for the soft story across the building height.
- To investigate the effectiveness of the presence of shear walls in building with soft floor.
- To investigate the effect of adopting simple strengthening measures in building to increase structural safety .

2.4 Scope of project

- Only multi-storey frames are taken into account.
- Irregularities in the plan are ignored.
- Shear walls and bracings are considering a framework to study dynamic and pushover analysis .
- The response spectrum is adopted as a dynamic method for predicting actual performance of RC shear wall frames under lateral loads. Pushover analysis is also carried out on specific structures.
- The building is strengthen by applying different brace system.

2.5 Need for research

- Since structures are never completely regular, designers regularly assess the extent of irregularities that can occur during an earthquake and the impact of those irregularities on the structure is needed. Research is needed to obtain an economical and efficient lateral stiffness system for seismically vulnerable areas.

- To design and optimise high-rise structures with various structural systems that are subject to seismic loads.

- Research the efficiency of shear wall systems and seismic retrofitting approaches, as well as the seismic behaviour of structures with soft story irregularities.

CHAPTER 3

MATERIAL AND SPECIFICATIONS

3.1 Introducing modelled structures

- A model structure of G + 10 story RC frame structure with soft history and 30x30m floor plan is adopted. The models are designed in three phases, in First phase the building is modelled having soft storey in ground floor . In second Phase, building is modelled with shear wall and having soft-storey in Ground floor and in third Phase same building is modelled with bracings and having soft-storey in Ground floor.

- Various analyzes, i. e. Linear dynamic response spectra, nonlinear static pushover analysis are performed in ETABS software version 18.0.2 based on the IS 1893: 2016 guidelines.

- Shear wall have been provided on different locations- Corner and at core of the building with soft storey.

- Bracings arrangements- X and V type bracings has been provided on corner and mid bays throughout the building height.

- Results were compared tabular and graphically for different storey displacements, drift, stiffness, base shear and time period.

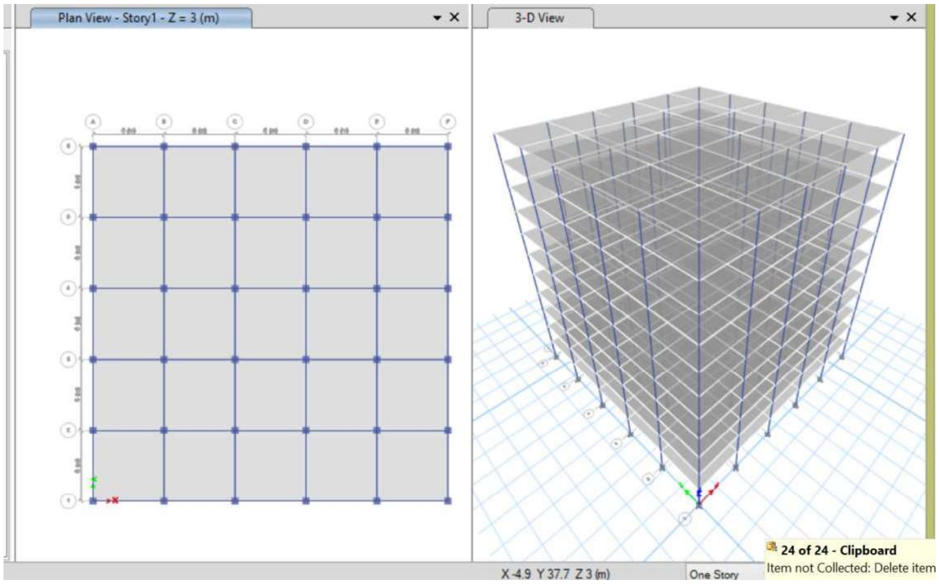


Fig 3.1 Model plan and elevation

3.2 Code, standards and specifications

The specifications and software used are:

- The Loading i.e. Dead, Live and Earthquake were received using IS codes.
- Seismic analysis response spectra and pushover analyzes were performed by using IS 1893: 2016.
- The structure and its specifications are designed according to IS 456: 2000.
- ETABS software version 18.0.2 was used to investigate and plan the basic components.

3.3 Properties of material

3.3.1 Steel

The properties of the steel in this thesis depend on the data recorded in Table 3.1.

Table 3.1 Properties of steel

Material	Isotropic
Specific weight density	76.97 kN/m^3
Specific mass density	7850 kg/m^3
U	0.3
α	0.0000117 1/^{0}c
G	80769.23 MPa
E	210000 mpa

3.3.2 Concrete

The properties of the concrete in this thesis depend on the data shown in Table 3.2.

Table 3.2 Properties of concrete

Material	Isotropic
Specific weight Density	25 KN/m^3
Specific Mass Density	2548 kg/m^3
U	0.2
α	0.0000055 1/^{0}c
G	10416.67 mPa
E	25000MPa
fck	25

3.4 Non-linear properties

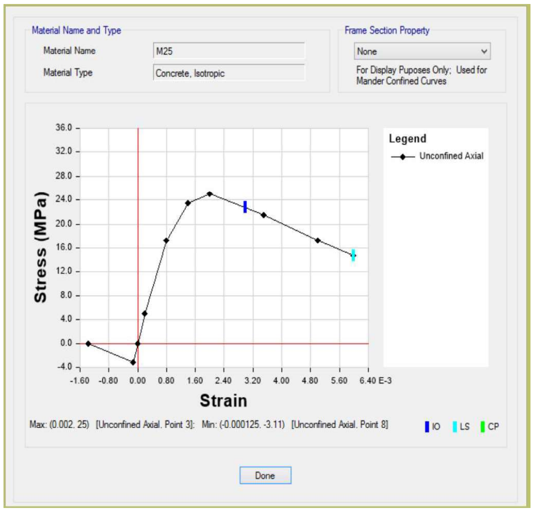
The non-linear properties of steel and concrete are used as per compression-strain as well as tension-strain which are recorded in table 3.3 & 3. 4 respectively. Stress v$_s$ strain graph of Steel and concrete is as shown in figure 3.2 & 3.3 respectively.

Table 3.3 Concrete Nonlinear properties

	Strain in tension	Strain in compression
I O	0. 01	- 0. 003
L S	0. 02	- 0. 006
C P	0. 05	- 0. 015

Table 3.4 Non-linear properties of steel

	Strain in tension	Strain in compression
I O	0. 01	- 0. 005
L S	0. 02	- 0. 01
C P	0. 05	- 0. 02



Material Name: M25

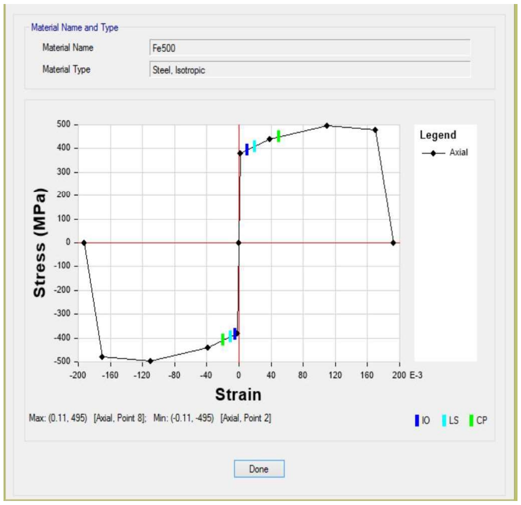
Material Type: Concrete, Isotropic

None

For Display Puposes Only; Used for Mander Confined Curves

Max: (0.002, 25) [Unconfined Axial, Point 3]; Min: (-0.000125, -3.11) [Unconfined Axial, Point 8]

Fig 3.2 Stress v_s strain plot of concrete



Material Name: Fe500

Material Type: Steel, Isotropic

Max: (0.11, 495) [Axial, Point 8]; Min: (-0.11, -495) [Axial, Point 2]

Fig 3.3 Stress v_s strain plot of concrete

3.5 Model structural load parameters

3.5.1 Floor D.L Assessment

a) D.L

Unit tables from the IS code are utilised in software to analyse loads and allow the programme to calculate density. Etabs will calculate the structure's dead load automatically.

b) L.L

The imposed load value is taken as specified in IS 875-Part 2. Its value on roof are not taken into account as mentioned in IS 1893-2016 for calculation of design seismic force in thesis work. In addition, 25% of imposed load is considered in floors in calculation of seismic weight as per IS 1893-2016.

c)Design Load Criteria

Various load combinations were:

1.5 (D.L+L.L)

1.2 (D.L+ L.L ± ELX)

1.2 (D.L+ L.L ± ELY)

1.5 (D.L ± ELX)

1.5 (D.L ± ELY)

0.9 D.L ± 1.5EL X

0.9 D.L ± 1.5ELY

D.L:-Dead Loads,

L.L:-Live Loads

E.L:- Earthquake Load in X And Y .

3.5.2 Earthquake Load

IS1893 is used to calculate seismic load. Earthquakes act in two directions, the x direction and the y direction. When resolving seismic loads on structures, several methods can be combined. There are two easy ways to do the following: One is solved manually and the other is used in computer calculations.

The static equivalence method is a technique for estimating a structure's load bearing capacity. Here,we will use IS code 1893: 2016 and firstly find the basic shear and then distribute the load evenly throughout the structure.

Base and lateral shear is plotted by code given by the mass distribution, which means the seismic weight of the structure. Zones for each area location are provided in code by describing terms: I, Z, and R.

The base shear is estimated using the Indian standard guideline. As you can see from the IS code.

$V_b = A_h \times w$

A_h = horizontal seismic coefficient

w = Seismic weight of the structure under consideration.

The horizontal seismic coefficient design of given structure and various parameters is given as

$A = (Z^* I * S_a) / (2^*R^*G)$

Z is zone coefficients.

I is Importance factor and R is Response reduction factor.

S_a/g is acceleration coefficient

T - Fundamental time period

$T_a = 0.075 \times h \times 0.75$ - RCC frame design

$T_a = (0.09 \times h) / \sqrt{d}$ - moment resisting frame

h = building height (m).

3.5.3 Lateral distribution of base shear force

Base shear force is formulated alongside structure's elevation. Base shear on a particular floor depends on floor height, concentrated mass, and building shape.

The value of lateral force at nod of the soil is determined as follows.

1) Stiffness distribution throughout the height of the specified structure
2) Nodal displacement
3) Floor mass

3.6 Etabs software

Etabs is a designing program package that deal under consideration multistorey constructing research as well as plan arrangements. Display units as well as formats, code primarily base totally trouble remedy, research techniques and arrangements strategies, all arrange with the network like math one in all a type to the present class of structure. ETABS could be used to evaluate fundamental or stepped forward frameworks in static or dynamic scenarios. For a tasteful evaluation of seismic execution, modular and direct time history investigation might be combined with P delta and extensive displacement impact. Etabs is a ready and profitable tool for plans ranging from 2D edges to expanding existing excessively tall constructions.

3.6.1 Features and benefits of Etabs

- ETABS information, yield, and numerical layout strategies are designed solely to take advantage of the new physical and mathematical properties of building structures. Therefore, this examination and style device supports information preparation, understanding of results, and overall execution.

- Structural engineers adopt indirect unique examination as a recurring event and program for specific reasons to leverage the better PC power currently available to create a larger explanatory framework. The need for is more apparent than ever.

CHAPTER 4

METHODOLOGY

4.1 Methodology

To workout the forces evoked seismically inside the structures, there comes a extensive variety of examinations which provide numerous tiers of exactness relying upon numerous factors. The study process includes numerous steps:

1) Formulate Statement of the problem and identify motive of the research,

2) Literature survey,

3) Selection of parameters and software program used for study,

4) Create Numerical models and carry out the usage of Dynamic analysis and pushover analysis-

- Structure with moment resisting frames
- Create soft storey in Ground floor
- Adding shearing wall at corner and core of the structure throughout the building height
- Apply retrofitting by adding bracing at mid and corner bays throughout the building height.

5) Discussion of the results obtained,

6) Conclusion,

7) Documentation.

4.2 Method of seismic analysis

- Linear static Analysis (LSA)
- Linear dynamic Analysis (LDA)
- Non-linear static Analysis (NSA)

- Non-linear dynamic Analysis (NDA)

For regular buildings with restricted height, linear static analysis is applied. The response spectrum or superposition method is taken to analyze LDA. These techniques can affect the building's higher vibration modes as well as the force distribution. within the elastic limit. This is preferable to LSA.

The magnitude of the force as well as its distribution over structure's height are major dissimilarities among LSA and LDA. NSA is step forward from LSA and LDA, allowing for inelastic behaviour of specified structures. The lateral load is assumed to increase monotonically along the structure's height in this method. This approach is easy to use and yields information regarding structural deformation, ductility as well as strength.Only way to understand the actual response of structures for the period of ground motion is to use NDA- time history. The elastic as well as plastic deformation of structural components is considered in this methodology, which is depends on direct integration of kinetic differential equations. This system capture effects of resonance-induced amplification, which is different deflections at different degrees of structure.

4.2.1 Static Method

The LSA is simple method for replacing the dynamic load effects of a normal earthquake with static forces horizontally distributed over the structure. The total seismic force applied can be calculated along two planes parallel to building's primary axis. This ensures that the structure responds in the ultimate horizontal mode. In order to avoid underground movement, the building must have a low slope and be symmetrical. The structure must be prepared to resist the consequence of seismic forces in both directions, however it cannot withstand both directions at the same time.

4.2.2 Linear dynamic analysis

Because the structure's reaction to seismic action is estimated in time domain and only linear property is supposed, this method preserves all phase information. This method explains that the sum of the inertial force vector, the summation of viscous damping force vector, and summation of internal force vector is equal to the summation of the external force vector.

4.2.2.1 Response Spectrum Analysis

RSA consider different modes of response in which a building reacts. To each of mode, the reaction corresponding to modal frequency and modal mass is taken from design spectrum and then combine to approximate overall response. various types of combination methods are:

a) Addition of absolute peak value.

b) SRSS,

c) CQC, method of expressing an enhancement in SRSS.

4.2.3 Non Linear Static Analysis

This is also known as pushover analysis and is a non linea r method of determining a structure's ultimate load and deflection capacity. This is an analysis that includes a non-linear relationship between force and displacement and the stiffness matrix does not remain constant. The dynamic force exerted on a structure is transmitted to other components when individual section yields or breaks. Pushover analysis replicates this phenomena by loading the structure until a weak link is discovered, analysing the model, and incorporating the weak link's modifications into the structure.The structure will be squeezed once more until a second weak link is discovered. This cycle is repeated until the complete structure's yield design under seismic load is identified. This is use so as to determine seismic limit of existing structures and seismic plans for retrofitting. It is considered to be an advance over using linear analysis because it is based on a more accurate estimate of the yielding within the structure rather than the expected uniform ductility. Similarly, generation of pushover curves under lateral load Provides non-linear behaviour of the structure.

4.2.3.1 Definition as per FEMA 273 And ATC 40

It is nonlinear static method that calculates seismic-structural deformation using nonlinear method. This is an incremental static study used to estimate a structure's or structural element's force-displacement relationship or capacity curve. The study entails applying incremental horizontal loads to the structure in a predetermined way, such as push the structure and recording overall lateral displacement related with the shear force provided at each increment until the structural or collapse state is reached.

4.1.3.2 Purpose of Pushover Analysis

Using inelastic method for designing and assessment help engineers in understanding structure behaviour when it is exposed to a large earthquake that is expected to exceed the elastic capacitance of the structure. Pushover analysis isneeded to determine the capacitance above the elastic limit. Engineers can better understand how a structure responds when subjected to a large earthquake that is projected to exceed the structure's elastic capacity by using the inelastic technique for design and evaluation. This eliminates few uncertainties that come along code and elastic procedures. A structure's overall load-bearing capacity is determined by the strength and deformability of its separate components.

4.2.3.3 Advantages

This method leads to the evaluation of response variables that static analysis cannot.

i. Estimating the deformation requirements of elements that must be elastically deformed to dissipate energy.

ii. The result of a decrease in the strength of individual elements with respect to stability of overall structure.

iii. Recognition of important areas where high inelastic deformation is predicted.

iv. Identify the plan or elevation strength irregularities that produce changes in the inelastic region's dynamic properties.

v. Estimating drift between floors considering the discontinuity of stiffness and strength. Damage to non-structural parts can be controlled in this way.

4.2.3.4 Target displacement

In DBE, it is an guesstimate of overall displacementof structure. The roof displacement at the structure centre of gravity is the target displacement. Models that directly include inelastic material responses under the non-linear static method are transformed into target displacements to determine internal deformation. It is intended to signify the maximum displacement that can occur during a DBE.

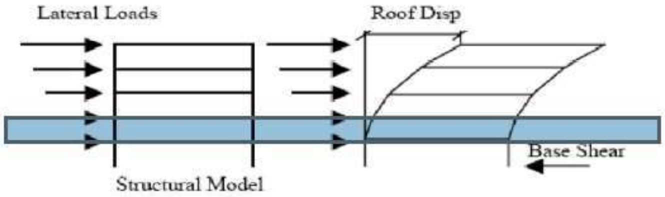


Fig 4.1 Lateral load and roof displacement

As per phase 3.3.3.3.2 of FEMA-356 ,the target displacement is estimated by:

$\delta_t = C_0 C_1 C_2 C_3 S_a \ (T_e^2/4\Pi^2)g$

Where,

- C_0 is SDOF-MDOF modification element
- c_1, c_2, c_3 denotes Modification Factor
- S_a denotes Acceleration of response spectrum
- T_e indicates Reaction spectrum's period.

4.2.4 Non-Linear Dynamic analysis

It includes detailed methodology for simulating structures' response subject to extreme level of seismic excitation. This method emphasizes the ability to localize the inelastic dynamic response of structure.The accuracy of the survey and the straightness of the model can overcome the unpredictability associated with nonlinear dynamic analysis. The model methodology is used in a system of limited programs for seismic response analysis of structures. Program consistency and accuracy are checked by mathematically reproducible pseudo-dynamic tests on full- scale structures.

CHAPTER 5

MODELLING AND CALCULATION

5.1 Details of RCC Buildings Selected for study

In this study, the regular shape plan of a G + 10-story reinforced concrete building in Zone V was selected. The model is analyzed in three phases, the first phase of which is a soft-storey building in ground floor. In second phase, building is analyzed with shear walls and soft story in ground floor, and in third phase, same building is analyzed with braces and soft story in ground floor. In the second phase, shear walls are also added to the model in two different cases, center and corner, to investigate the optimal location of the shear walls in the building. The third phase also provides different types of X and V type brace arrangements in the central and corner spans across the height of the building.The construction plan is shown in Figure 5.1. The analysis data of the building is as follows:

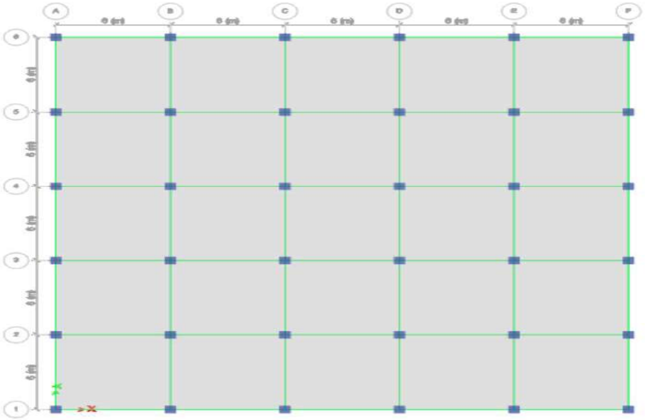


Fig 5.1 Plan of G+10 storey RCC building

General

a) Concrete material grade is M25.

Analysis Property Data

b) f_y = 415 N /mm^2

c) Compressive strength = 25 N/mm^2

d) Poisson ratio = 0.2

e) Analysis is performed with Etabs 18.0.2

Detail of building

a) Type : SMRF regular plan

b) Plan dimension: 30m x 30m

c) No. of stories: G +10

d) Floor height: Typical storey 3.0m, Bottom storey: 5m

e) Slab depth: 150mm

f) Beam size: 300mm × 600mm

g) Column size: 600mm × 600mm

h) Bay no (X-axis) : 5

i) Bay no (Y-axis): 5

j) width of bay both directions: 6m

k) Live load : 2 KN/m^2

l) Floor and partition: 1.5 KN $/m^2$

m) Wall load: 14 KN /m

n) Material: M25 concrete, Fe 500 steel

o) Masonry thickness: 230mm

p) Shear wall thickness: 200mm

q) concrete density: 25 KN/m^3

r) Masonry unit weight : 19 KN/m^3

s) Soil type : II

t) Equivalent lateral loads: According to Indian standard 1893 part1

u) Seismic zone: V

w) Damping of structure: 5%

x) Support conditions: Fixed

y) Response reduction factor : 5(SMRF)

z) Importance factor: 1.2

5.2 Calculation of Stiffness

The stiffness of first storey is calculated to know if the ground storey is a soft floor or not. Since height of columns on bottom storey is 5m and height of first floor is 3m, stiffness in the bottom storey and the 1**st storey** was calculated.

Ground floor stiffness: The stiffness of the the floor columns is calculated as follows. $K = 12\ EI / L^3$

Here, E = Concrete elastic module

I = Column inertia

L = Column height.

For concrete M25E, E = 5000 x √fck = 5000 x √25 = 25000 N/mm^2 = 25000×10^3 KN/m^2

Column moment of inertia, I = bd3 / 12 = (0.6 × 0.63) / 12 = 0.0108 m^4

The total number of columns on the first floor is 36, all columns are of same size, and the height of column is 5 m . The concrete grade for these columns is M25.

Stiffness of Ground floor= 36 x 12 x (25000× 103× 0.0108)/53 = 933120 KN/m.

Stiffness of First floor : Total number of columns of is 36, all the columns are of same size and its height is 3m. The cross section dimensions of First floor columns are same

as Ground floor column, and

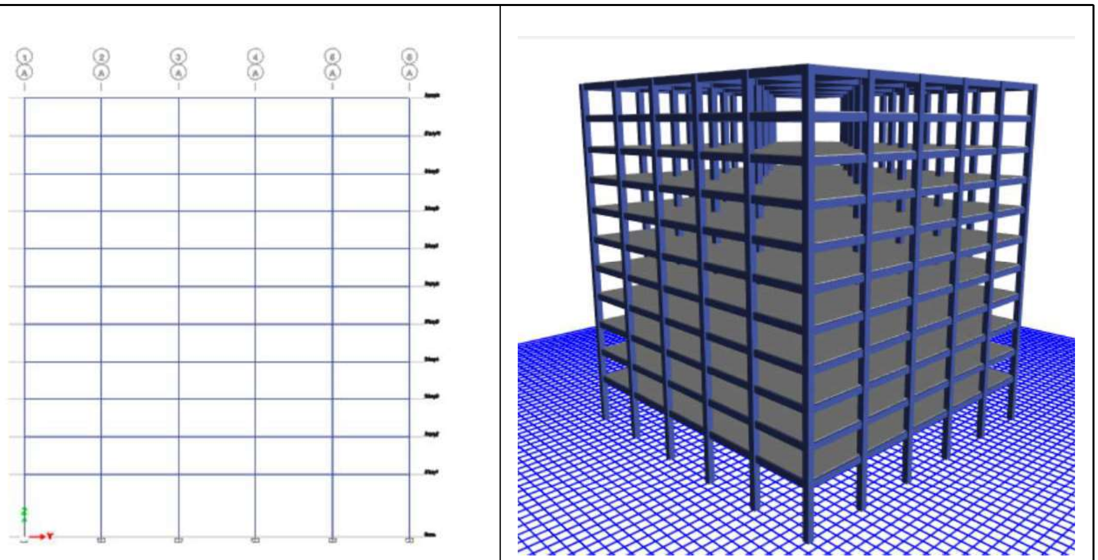
grade of concrete used is also M25.

Stiffness of First floor= 36 x 12 x (25000× 103× 0.0108)/33 = 4320000 KN/m.

The stiffness of Ground floor is 21.6 % of of 1^{st} storey, so bottom storey has lesser value of stiffness. According to IS 1893 (Part 1): 2016: "Soft floors have less lateral stiffness than upper floors." Therefore, the selected model has stiffness irregularity in bottom storey. For analysis, selected G + 10 reinforced concrete skeleton building was modelled by the Etabs 18.0.2 software and analyzed according to the data specified using the IS 1893: 2016 code, and the load combinations Prepared according to IS 1893: 2016. As mentioned earlier, the analysis is performed in three phases. The results obtained from each model are compared.

The models are analyzed in three cases, in first case the building is analyzed with soft storey in the ground floor (see fig 5.2). In second case, Shear walls are added in two different cases. In First case of shear wall, four shear walls are considered, two in left corner and two in the opposite right corner and in this case the shear walls are arrange in such that two walls are located along X-direction and other two are located along Y-direction, therefore the stiffness of shear in both directions is same (see fig 5.3). In second case of shear wall , it is located at core of the structure (see fig 5.4). In third case, two types of Bracings arrangements X and V type are provided in mid and corner bays throughout the building height (see fig 5.5-5.8).

5.3 Case 1: Soft story in Ground floor

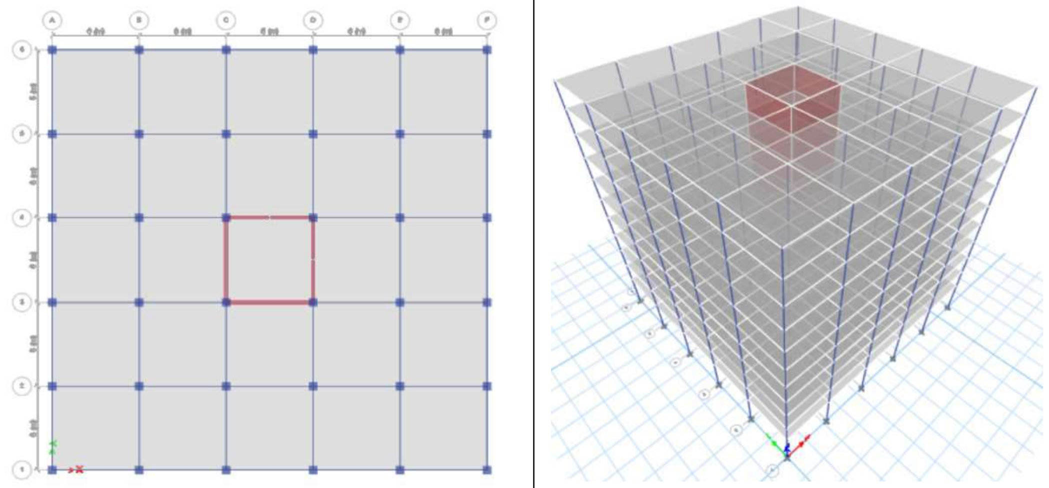


Elevation view

Rendered view

Fig 5.2 Building having soft storey in Ground floor

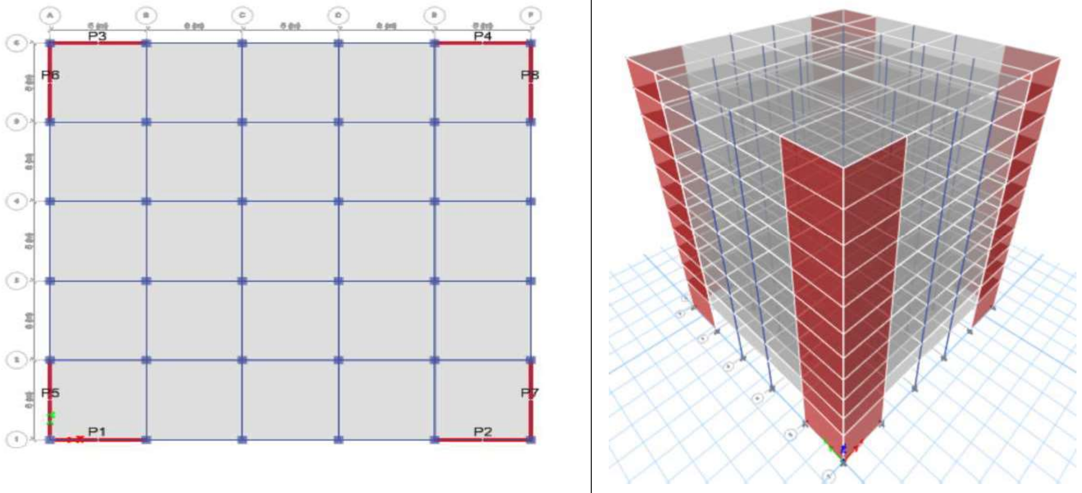
5.4 Case 2:Core Shear wall in building with soft story


Plan view

3-D view

Fig 5.3 Core Shear wall in building with soft story

5.5 Case 3:Corner Shear wall in building with soft story

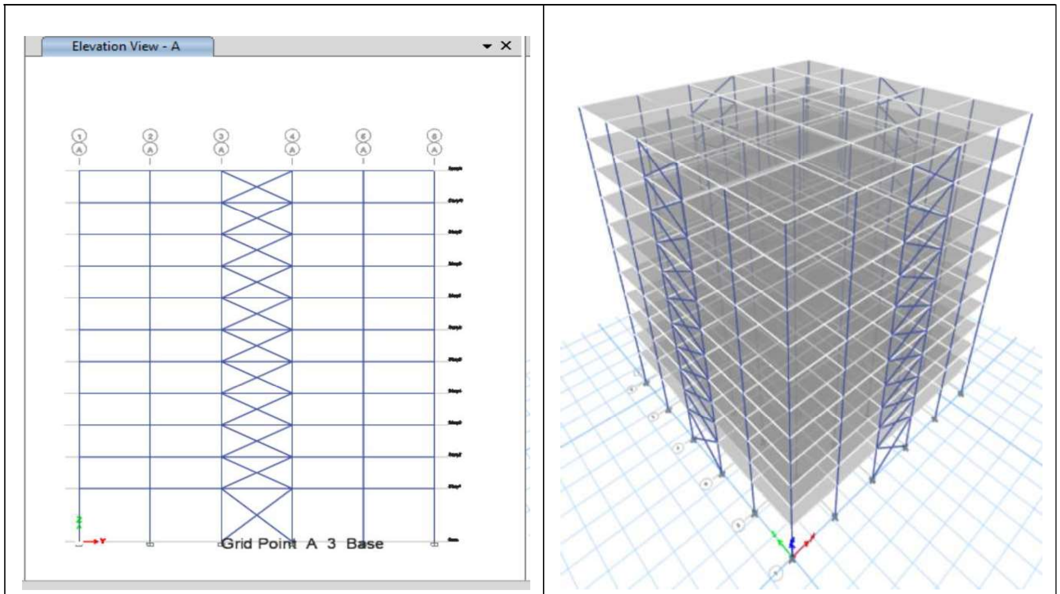


Plan view

3-D view

Fig 5.4 Corner Shear wall in building with soft story

5.6 Case 4:Cross bracing at mid bay

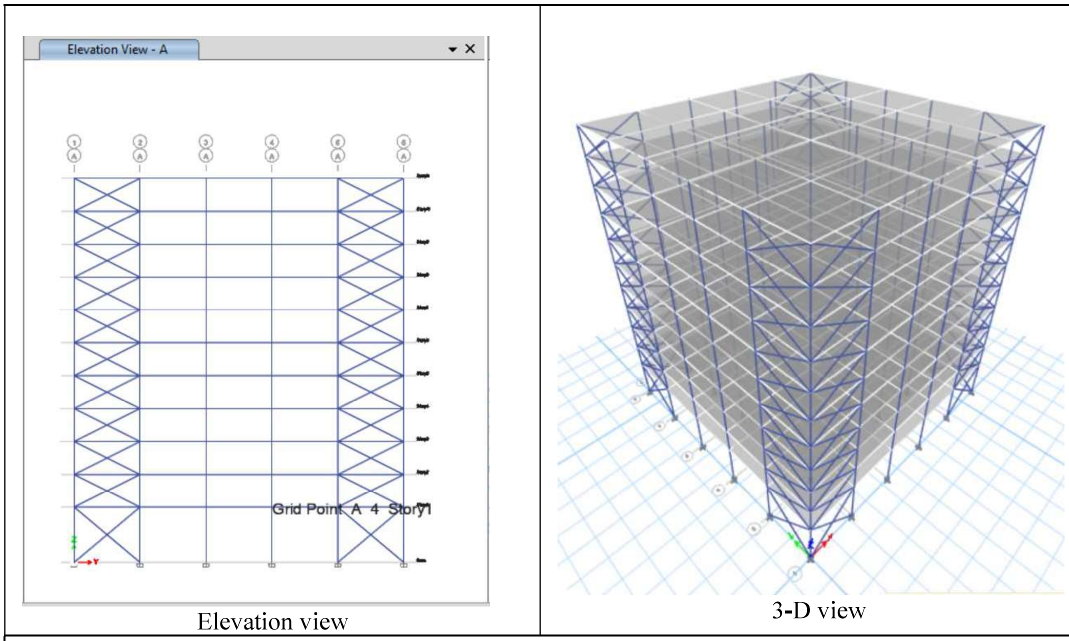


Elevation view

3-D view

Fig 5.5 Cross Bracing at mid bay

5.7 Case 5:Cross bracing at corner bay

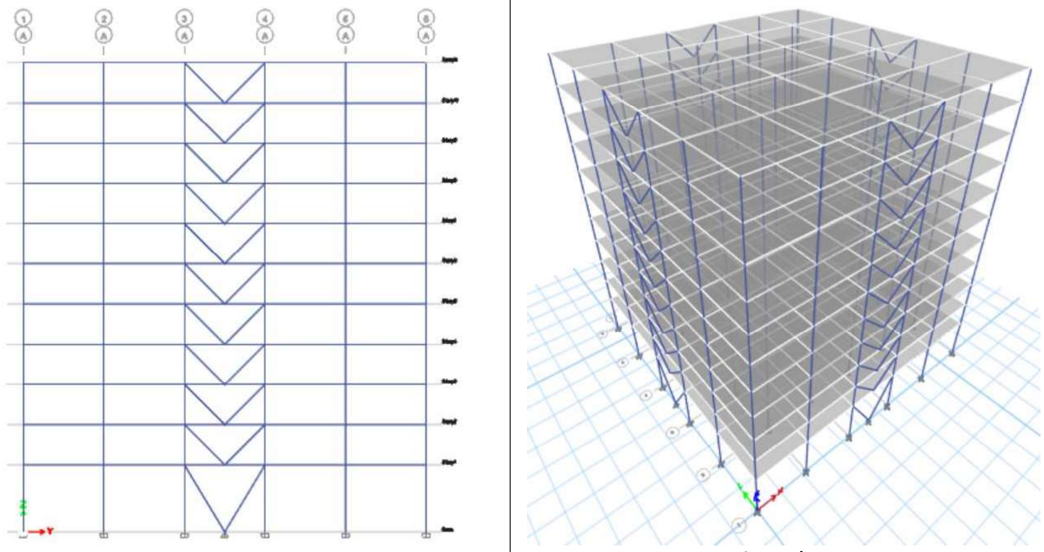


Elevation view

3-D view

Fig 5.6 Cross bracing at corner bays

5.8 Case 6:V-type bracing at mid bay

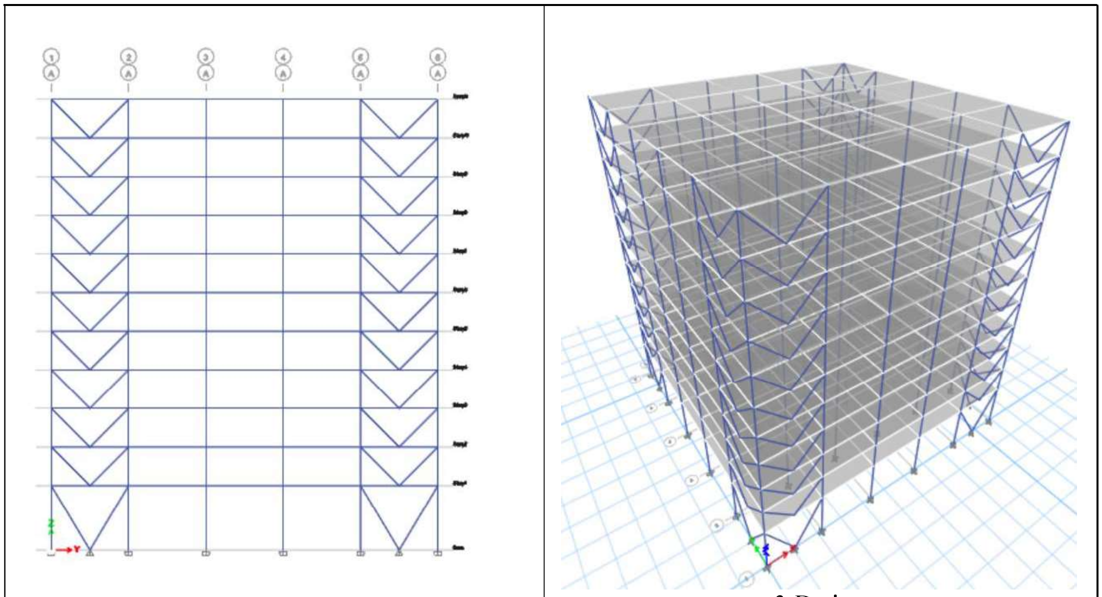


Elevation view

3-D view

Fig 5.7 V- type Bracing at mid bay

5.9 Case 7:V-type bracing at corner bay



Elevation view

3-D view

Fig 5.8 V-type Bracing at corner bays

CHAPTER 6

RESULTS

6.1 Response spectrum analysis

The process of RCC frame modelling and their analysis were completed, various results obtain from response spectrum analysis are:

Table 6.1 Storey displacement

	Soft story	Centre bracing		corner bracing		Centre shear wall	Corner shear wall
		X-type	V-type	X-type	V-type		
Story 11	46.707	39.335	40.307	35.646	36.837	33.173	28.599
Story 10	45.569	37.498	38.539	33.5	34.762	30.64	25.892
Story 9	43.599	35.044	36.161	30.901	32.251	27.67	23.06
Story 8	40.798	32.058	33.284	27.917	29.367	24.484	20.122
Story 7	37.299	28.645	29.976	24.636	26.176	21.139	17.117
Story 6	33.244	24.91	26.335	21.145	22.763	17.707	14.106
Story 5	28.763	20.96	22.466	17.541	19.219	14.276	11.157
Story 4	23.973	16.906	18.471	13.922	15.636	10.941	8.35
Story 3	18.963	12.858	14.452	10.391	12.108	7.807	5.773
Story 2	13.788	8.928	10.499	7.052	8.727	4.985	3.522
Story 1	8.38	5.182	6.564	3.989	5.469	2.597	1.705

Table 6.2 Storey shear

	Soft story	Centre bracing		corner bracing		Centre shear wall	Corner shear wall
		X-type	V-type	X-type	V-type		
Story 11	604.95	777.264	740.209	894.09	838.411	1110.52	1306.75
Story 10	1399.9	1797.95	1712.12	2068.53	1939.22	2575.89	3042
Story 9	2056.21	2638.81	2513.03	3035.27	2845.62	3781.07	4468.61
Story 8	2587.47	3317.44	3159.71	3814.65	3576.67	4751.56	5616.85
Story 7	3007.26	3851.45	3668.9	4427	4151.43	5512.84	6516.97
Story 6	3329.15	4258.43	4057.37	4892.65	4588.95	6090.38	7199.2
Story 5	3566.78	4555.97	4341.89	5231.93	4908.28	6509.62	7693.77
Story 4	3733.74	4761.66	4539.24	5465.16	5128.53	6796.02	8030.89
Story 3	3843.68	4893.1	4666.24	5612.66	5268.78	6975.01	8240.79
Story 2	3910.18	4967.86	4739.76	5694.73	5348.24	7072.03	8353.64
Story 1	3947.56	5004.45	4777.69	5732.73	5387.27	7114.08	8401.88

Table 6.3 Story stiffness

	Soft story	Centre bracing		corner bracing		Centre shear-wall	Corner shear-wall
		X-type	V-type	X-type	V-type		
Story 11	545714.9	443490.1	439055	435157.3	422730.2	429810.7	503236.5
Story 10	734572.6	756810.8	750373.2	814847	792634.3	885438.9	1096386
Story 9	764771.4	913892	899117.9	1042736	1007254	1229273	1552232
Story 8	773128.3	1005840	984658.2	1192153	1146158	1487234	1908532
Story 7	777012.9	1067268	1040636	1301162	1245504	1696583	2208871
Story 6	779672	1116127	1083738	1392971	1326773	1888350	2491874
Story 5	781844.6	1163364	1123759	1483784	1404348	2092307	2797999
Story 4	783150.1	1217679	1167755	1588361	1490346	2345275	3181461
Story 3	780868.7	1288113	1220050	1725286	1598000	2706843	3735548
Story 2	760181.5	1371271	1241626	1908638	1680500	3314211	4693694
Story 1	495186.9	997083.8	763493.9	1475695	1026528	3235906	5035780

Table 6.4 Story drift

	Soft story	Centre bracing		corner bracing		Centre shear wall	Corner shear wall
		X-type	V-type	X-type	V-type		
Story 1	0.001676	0.001036	0.001279	0.000798	0.001065	0.000519	0.000341
Story 2	0.001803	0.001249	0.001322	0.001021	0.001093	0.000796	0.000606
Story 3	0.001725	0.00131	0.001323	0.001113	0.00113	0.00094	0.000751
Story 4	0.00167	0.001349	0.001344	0.001177	0.00118	0.001045	0.000859
Story 5	0.001597	0.001351	0.001337	0.001206	0.001198	0.001112	0.000936
Story 6	0.001493	0.001317	0.001295	0.001201	0.001186	0.001144	0.000983
Story 7	0.001352	0.001245	0.00122	0.001163	0.001143	0.001144	0.001004
Story 8	0.001166	0.001138	0.001111	0.001094	0.001071	0.001115	0.001001
Story 9	0.000934	0.000995	0.000969	0.000995	0.00097	0.001062	0.000979
Story 10	0.000657	0.000818	0.000793	0.000867	0.000841	0.00099	0.000944
Story 11	0.000379	0.000612	0.000589	0.000715	0.000692	0.000893	0.000903

Table 6.5 Modal load participation ratio

Model type		Modal load participation
Soft story		100.00%
Centre bracing	X-type	100.00%
	V-type	100.00%

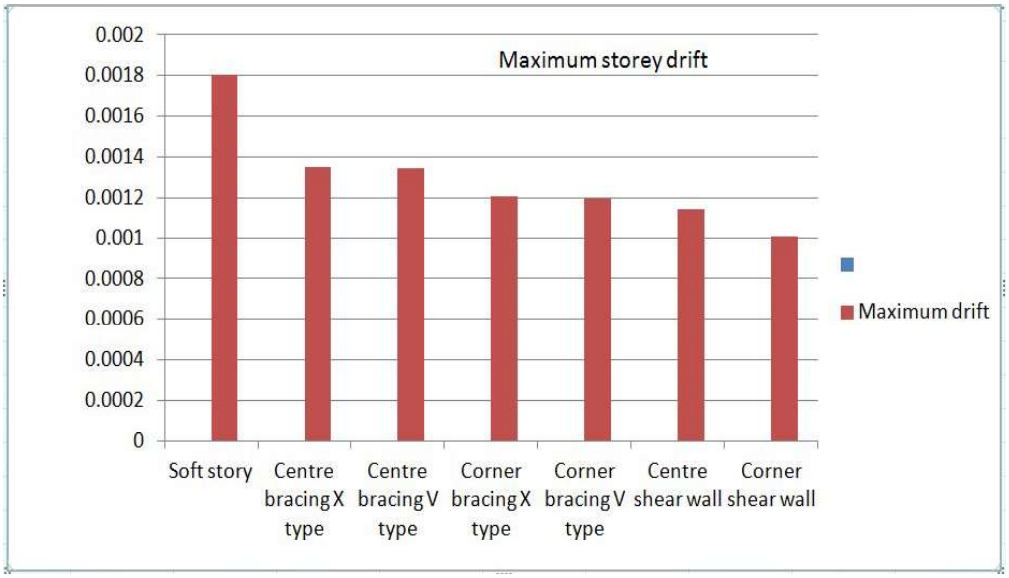
Corner bracing	X-type	100.00%
	V-type	100.00%
Centre shear wall		99.99%
Corner shear wall		100.00%

Maximum number of modes are selected to 30 for which modal mass participation ratios for each case comes out to be 100%.

Fig 6.1 Storey displacement graph

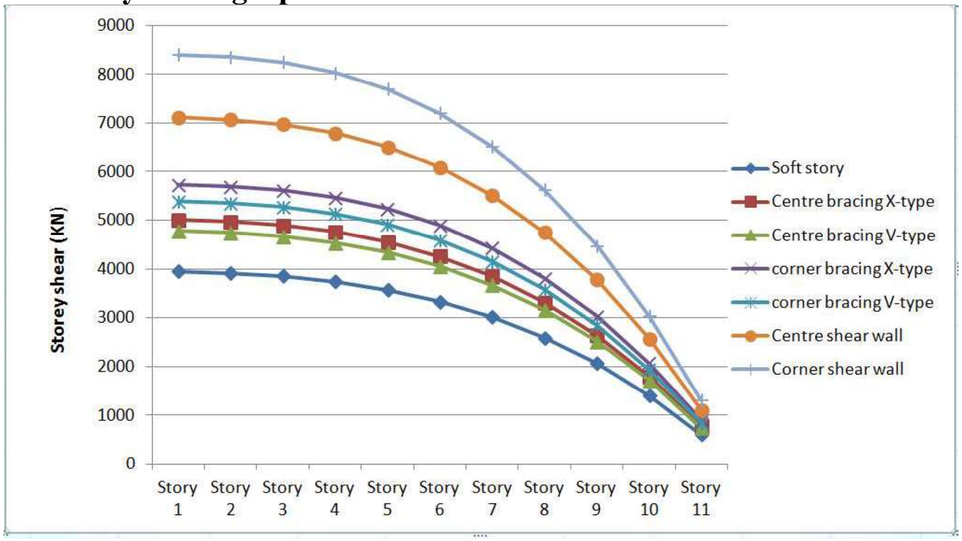
The maximum value is recorded in top storey in all cases for which its value was 46.707 mm under earthquake load which is maximum in structure with soft story model and in structure model having corner shear wall , it was having a minimum value of 28.599 mm among all model types. X-type brace provides lesser displacement value when compared to V-type bracing. Shearing wall when placed at all four corner gives lesser displacement value as compared to when placed at core .The displacement of all models are within the allowable limit (less than 0.004H) i.e 140mm in selected building model prescribed by IS 1893-2016. (Less than 0.004H).

Fig 6.2 Maximum storey drift chart



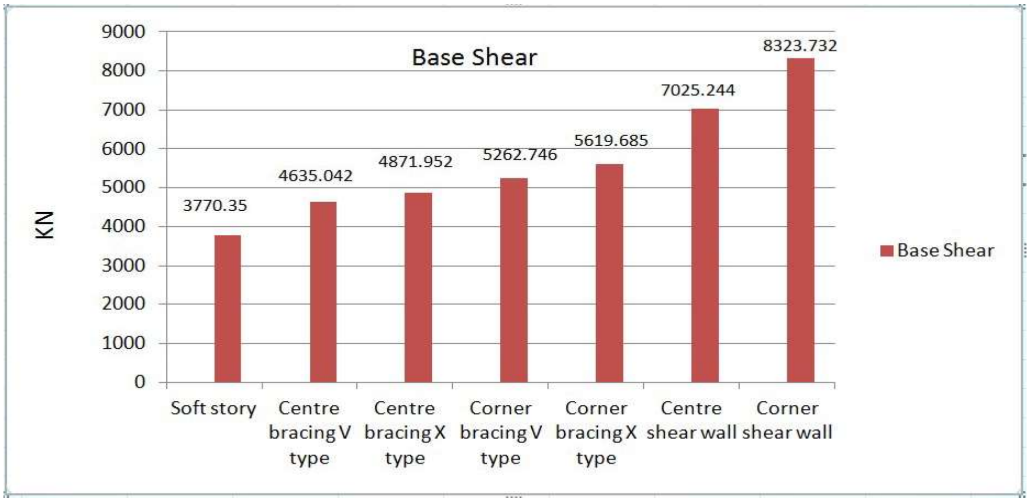
The maximum drift is 0.001803 under earthquake load which is maximum in structure with soft story model and in structure model having corner shear wall , it was having a minimum value among all model types 0.001004 mm. Drift value is minimum when bracings are placed in corner bays rather than mid-bays and was lesser in V-type bracing as compared to X-type bracing. Shearing wall when placed at all four corner gives lesser value of drift as compared to to when placed at core.The storey drift of all the model is within the allowable limit i.e less than 0.004 as prescribed by IS 1893-2016.

Fig 6.3 Storey shear graph



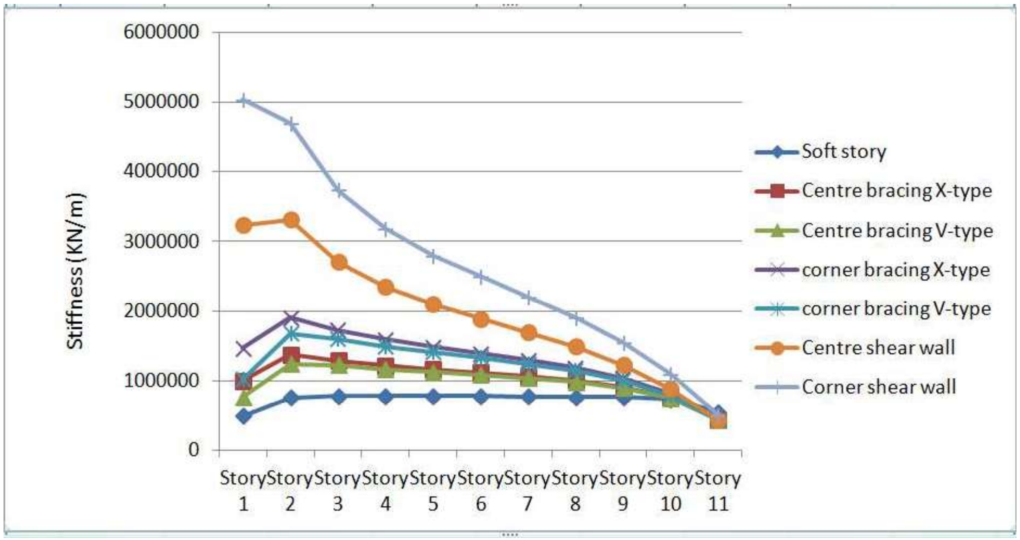
Storey shear is more i.e 7114.07 KN in case of model having corner shear wall as compared to other six models while it it less in case of model with soft story i.e 3497.56 KN. Storey shear is maximum when bracings are placed in corner bays rather than mid-bays and was greater in X type bracing as compared to V type bracing. Shearing wall when placed at all four corner gives higher shear value as compared to shear wall placed at core.

Fig 6.4 Base shear chart



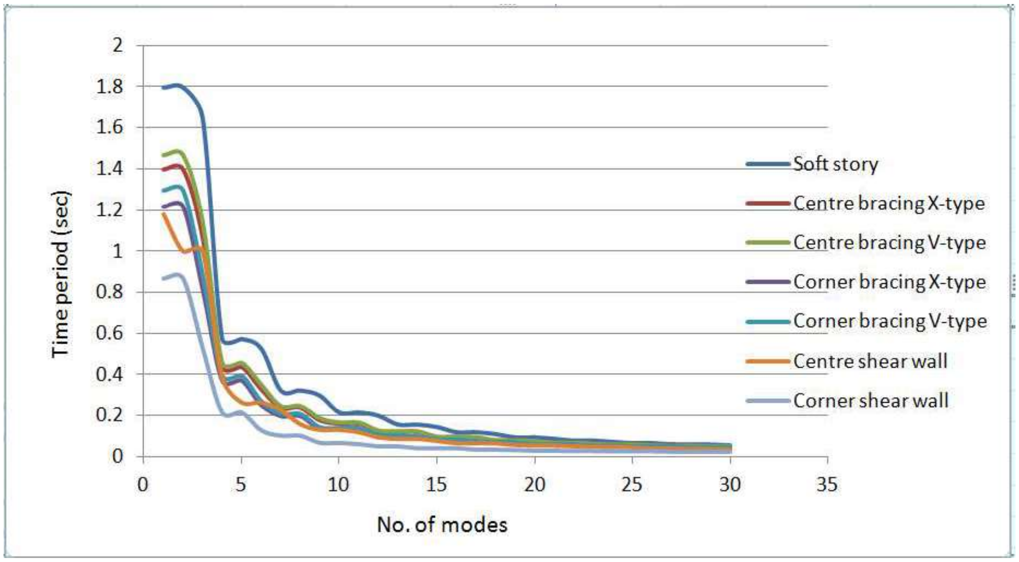
The value of base shear is shown in increasing order in figure 6.4. RCC frame modelled having shearing wall located at four ends gives maximum value of Base shear among all the model types.

Fig 6.5 Storey stiffness graph



Storey stiffness is more i.e 5035779.586 KN/m in case of model having corner shear wall as compared to other six models while it it less in case of model with soft story i.e 783150.066KN/m. Storey stiffness increases when bracings are placed in corner bays rather than mid-bays and was greater in X-type bracing as compared to V-type bracing. Shearing wall when placed at all four corners gives higher value of stiffness as compared to shear wall placed at core. Soft story irregularity was reduced totally when shear wall is placed on all four corners giving maximum value of stiffness in ground floor.

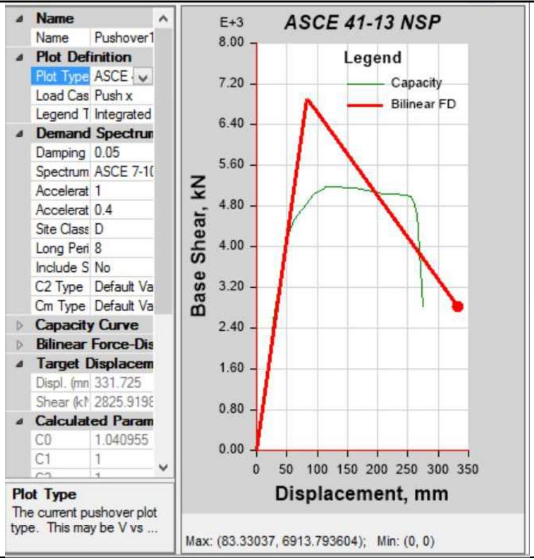
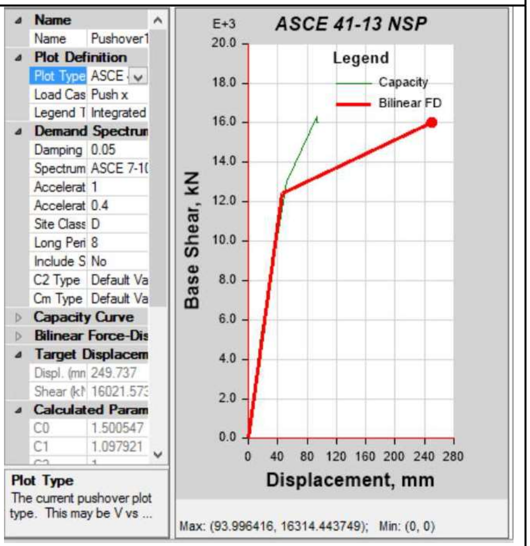
Fig 6.6 Time period vs Number of modes

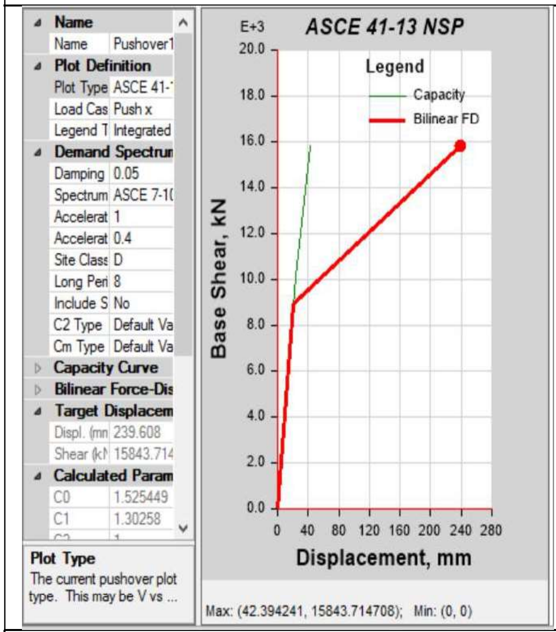
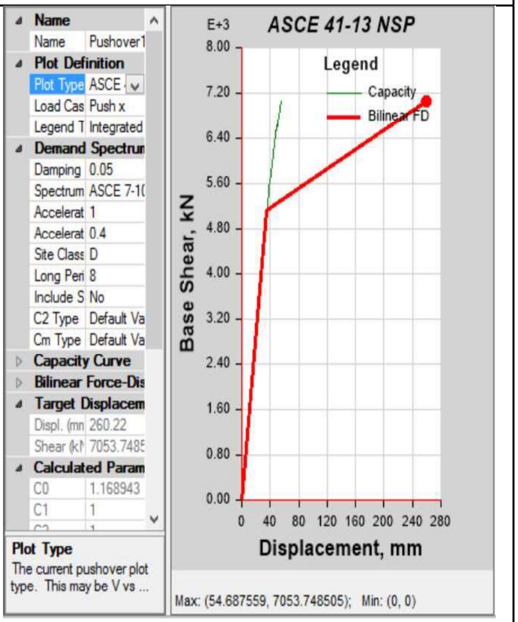


The time period value is decreasing with increase in mode number on each of building model. Model having corner shear wall is having the minimum vibration period of 0.87 sec under seismic loads while model with soft story is having maximum vibration period of 1.798 sec. Time period is minimum when bracings are placed in corner bays rather than mid-bays and was lesser in X-type bracing as compared to V-type bracing. Shearing wall when placed at all four corners gives lesser value of time period as compared to shear wall placed at core.

6.2 Results from pushover analysis

The process of RCC frame modelling and their analysis were completed, various results obtained from the pushover analysis are:

Case 1: Soft story in Ground floor	**Case 2:Core Shear wall in building with soft story**
 Name Name Pushover1 Plot Definition Plot Type ASCE Load Cas Push x Legend T Integrated Demand Spectrun Damping 0.05 Spectrum ASCE 7-1(Accelerat 1 Accelerat 0.4 Site Class D Long Peri 8 Include S No C2 Type Default Va Cm Type Default Va Capacity Curve Bilinear Force-Dis Target Displacem Displ. (mn 331.725 Shear (kN 2825.9198 Calculated Param C0 1.040955 C1 1 Plot Type The current pushover plot type. This may be V vs ... Max: (83.33037, 6913.793604); Min: (0, 0)	 Name Name Pushover1 Plot Definition Plot Type ASCE Load Cas Push x Legend T Integrated Demand Spectrun Damping 0.05 Spectrum ASCE 7-1(Accelerat 1 Accelerat 0.4 Site Class D Long Peri 8 Include S No C2 Type Default Va Cm Type Default Va Capacity Curve Bilinear Force-Dis Target Displacem Displ. (mn 249.737 Shear (kN 16021.573 Calculated Param C0 1.500547 C1 1.097921 Plot Type The current pushover plot type. This may be V vs ... Max: (93.996416, 16314.443749); Min: (0, 0)
Fig 6.7: Base shear-Displacement graph (SS model)	Fig 6.8: Base shear-Displacement graph (C_eSW model)

Case 3:Corner Shear wall in building with soft story	**Case 4:Cross bracing at mid bay**
 Name Name Pushover1 Plot Definition Plot Type ASCE 41- Load Cas Push x Legend T Integrated Demand Spectrun Damping 0.05 Spectrum ASCE 7-1(Accelerat 1 Accelerat 0.4 Site Class D Long Peri 8 Include S No C2 Type Default Va Cm Type Default Va Capacity Curve Bilinear Force-Dis Target Displacem Displ. (mn 239.608 Shear (kN 15843.714 Calculated Param C0 1.525449 C1 1.30258 Plot Type The current pushover plot type. This may be V vs ... Max: (42.394241, 15843.714708); Min: (0, 0) 	 Name Name Pushover1 Plot Definition Plot Type ASCE Load Cas Push x Legend T Integrated Demand Spectrun Damping 0.05 Spectrum ASCE 7-1(Accelerat 1 Accelerat 0.4 Site Class D Long Peri 8 Include S No C2 Type Default Va Cm Type Default Va Capacity Curve Bilinear Force-Dis Target Displacem Displ. (mn 260.22 Shear (kN 7053.7485 Calculated Param C0 1.168943 C1 1 Plot Type The current pushover plot type. This may be V vs ... Max: (54.687559, 7053.748505); Min: (0, 0)
Fig 6.9: Base shear-Displacement graph (C_oSW model)	Fig 6.10: Base shear-Displacement graph (X-MB model)

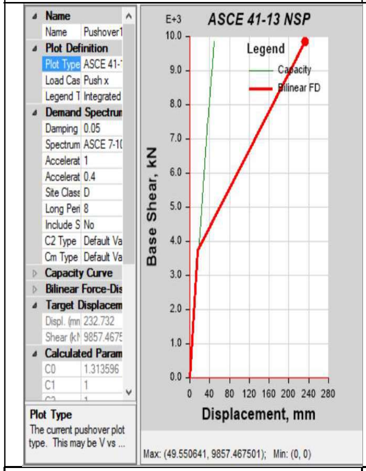
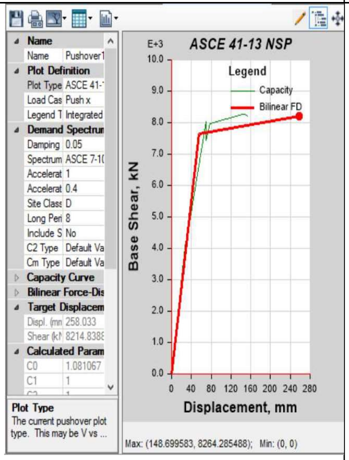
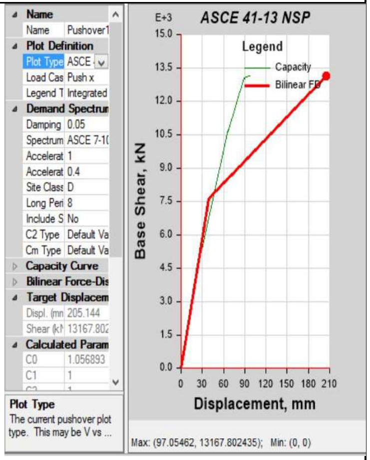
Case 5:Cross bracing at corner bay	**Case 6:V-type bracing at mid bay**	**Case 7:V-type bracing at corner bay**
 Name Name Pushover1 Plot Definition Plot Type ASCE 41- Load Cas Push x Legend T Integrated Demand Spectrun Damping 0.05 Spectrum ASCE 7-1(Accelerat 1 Accelerat 0.4 Site Class D Long Peri 8 Include S No C2 Type Default Va Cm Type Default Va Capacity Curve Bilinear Force-Dis Target Displacem Displ. (mn 232.732 Shear (kN 9857.4675 Calculated Param C0 1.313596 C1 1 Plot Type The current pushover plot type. This may be V vs ... Max: (49.550641, 9857.467501); Min: (0, 0) 	 Name Name Pushover1 Plot Definition Plot Type ASCE 41- Load Cas Push x Legend T Integrated Demand Spectrun Damping 0.05 Spectrum ASCE 7-1(Accelerat 1 Accelerat 0.4 Site Class D Long Peri 8 Include S No C2 Type Default Va Cm Type Default Va Capacity Curve Bilinear Force-Dis Target Displacem Displ. (mn 258.033 Shear (kN 8214.8388 Calculated Param C0 1.081067 C1 1 Plot Type The current pushover plot type. This may be V vs ... Max: (148.699583, 8264.285488); Min: (0, 0) 	 Name Name Pushover1 Plot Definition Plot Type ASCE Load Cas Push x Legend T Integrated Demand Spectrun Damping 0.05 Spectrum ASCE 7-1(Accelerat 1 Accelerat 0.4 Site Class D Long Peri 8 Include S No C2 Type Default Va Cm Type Default Va Capacity Curve Bilinear Force-Dis Target Displacem Displ. (mn 205.144 Shear (kN 13167.802 Calculated Param C0 1.056893 C1 1 Plot Type The current pushover plot type. This may be V vs ... Max: (97.05462, 13167.802435); Min: (0, 0)
Fig 6 .11: Base shear-Displacement graph (X-CB model)	Fig 6 .12: Base shear-Displacement graph (V-MB model)	Fig 6 .13: Base shear-Displacement graph (V-CB model)

Table 6.6 Storey displacement value

	Soft story	Centre bracing		corner bracing		Centre shear wall	Corner shear wall
		X-type	V-type	X-type	V-type		
Story 11	24.65	8.187	16.084	9.691	18.619	16.346	11.943
Story 10	24.292	7.862	15.516	9.204	17.702	15.054	10.917
Story 9	23.643	7.445	14.774	8.617	16.655	13.664	9.837
Story 8	22.65	6.945	13.87	7.944	15.453	12.199	8.715
Story 7	21.3	6.358	12.798	7.186	14.097	10.662	7.553
Story 6	19.589	5.686	11.567	6.348	12.599	9.066	6.363
Story 5	17.515	4.933	10.178	5.437	10.966	7.437	5.164
Story 4	15.08	4.11	8.645	4.469	9.218	5.81	3.983
Story 3	12.282	3.231	6.988	3.461	7.384	4.23	2.853
Story 2	9.12	2.314	5.226	2.438	5.494	2.756	1.818
Story 1	5.577	1.36	3.348	1.424	3.546	1.46	0.933

Table 6.7 Storey shear value

	Soft story	Centre bracing		corner bracing		Centre shear-wall	Corner shear-wall
		X-type	V-type	X-type	V-type		
Story 11	36.8298	66.5774	139.1312	119.9673	210.5667	279.7285	294.7646
Story 10	74.2287	191.551	377.9261	328.8638	561.5336	741.8507	783.9848
Story 9	111.7286	316.6455	616.9887	537.8635	912.7315	1203.9774	1273.1826
Story 8	149.3288	441.8515	856.3104	746.9546	1264.1468	1666.0788	1762.334
Story 7	187.0275	567.157	1095.8795	956.1206	1615.7632	2128.1137	2251.4074
Story 6	224.8221	692.5457	1335.6809	1165.3403	1967.5608	2590.031	2740.363
Story 5	262.7083	817.9965	1575.6964	1374.5866	2319.5173	3051.7684	3229.1533
Story 4	300.6791	943.4823	1815.9068	1583.8262	2671.6118	3513.2515	3717.7218
Story 3	338.7219	1068.9676	2056.2973	1793.0163	3023.8351	3974.3917	4206.0013
Story 2	376.8088	1194.4003	2296.8615	2002.1	3376.2084	4435.082	4693.9111
Story 1	414.9162	1324.5239	2545.8511	2218.3988	3740.6038	4914.8694	5206.9082

Table 6.8 Story stiffness value

	Soft story	Centre bracing		corner bracing		Centre shear wall	Corner shear wall
		X-type	V-type	X-type	V-type		
Story 11	426681.90	341656.535	380625.243	392154.867	381407.915	349199.837	466230.206
Story 10	584784.53	602767.337	661746.727	743910.491	719967.8	749128.52	1027310.71
Story 9	609331.10	744395.309	804065.043	963816.72	923681.503	1051955.85	1460566.03
Story 8	614449.50	832069.008	888316.644	1110074.095	1059355.37	1283499.82	1800802.56
Story 7	616004.72	892826.407	944575.661	1218454.523	1157979.5	1475909.392	2090043.903
Story	616840.17	942228.321	988398.089	1310814.725	1239598.352	1655186.11	2364165.825

6							
Story 5	617531.90	990575.48	1029238.913	1402931.495	1318186.545	1847801.469	2661852.475
Story 4	617999.81	1046490.404	1073832.244	1509680.675	1405427.695	2087754.53	3035401.919
Story 3	617466.59	1119456.68	1125550.668	1650382.273	1512613.598	2432040.702	3576663.887
Story 2	611706.69	1215860.71	1156838.08	1843134.695	1599836.39	3010968.743	4509728.74
Story 1	421876.32	932907.491	737120.62	1471745.074	1008795.483	3027594.199	4790126.626

Table 6.9 Story drift data

	Soft story	Centre bracing		corner bracing		Centre shear wall	Corner shear wall
		X-type	V-type	X-type	V-type		
Story 11	0.000557	0.000114	0.000194	0.000162	0.000314	0.000431	0.000342
Story 10	0.000945	0.000139	0.000248	0.000196	0.00035	0.000464	0.00036
Story 9	0.001337	0.000168	0.000302	0.000224	0.000402	0.000488	0.000374
Story 8	0.001672	0.000197	0.000358	0.000253	0.000454	0.000512	0.000387
Story 7	0.001941	0.000226	0.000414	0.00028	0.000504	0.000532	0.000397
Story 6	0.002149	0.000253	0.000467	0.000303	0.000549	0.000543	0.0004
Story 5	0.002302	0.000276	0.000515	0.000323	0.000587	0.000542	0.000394
Story 4	0.002411	0.000295	0.000557	0.000336	0.000617	0.000527	0.000377
Story 3	0.002486	0.000307	0.000593	0.000341	0.000635	0.000491	0.000345
Story 2	0.002556	0.000318	0.000645	0.000338	0.000677	0.000432	0.000295
Story 1	0.002247	0.000272	0.000652	0.000285	0.00069	0.000292	0.000187

Table 6.10 Target displacement

Model type		Target displacement(mm)
Soft story		331.725
Centre bracing	X-type	260.22
	V-type	258.033
Corner bracing	X-type	232.732
	V-type	205.144
Centre shear wall		249.737
Corner shear wall		239.608

Hinge step

Hinges steps in each step of pushover analysis for soft story model.

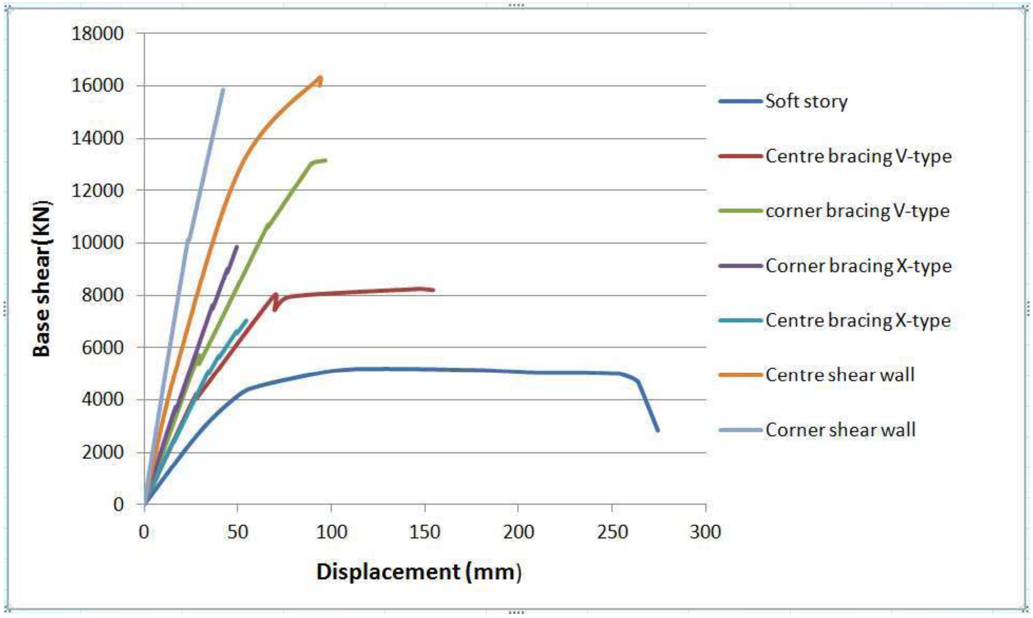
Table 6.11 Hinge step

Step	Monitored dis max	Base shear	A - I O	I O- L S	L S- C P	> C P	Total hinges
0	0	0	4224	0	0	0	4224
1	-28.916	2702.545	4224	0	0	0	4224
2	-50.067	4141.28	4224	0	0	0	4224
3	-61.893	4520.778	4224	0	0	0	4224
4	-95.019	5028.74	4220	0	0	4	4224
5	-112.278	5162.527	4213	0	0	11	4224
6	-113.588	5168.915	4211	0	0	13	4224
7	-126.901	5171.851	4189	0	0	35	4224
8	-130.552	5172.278	4188	0	0	36	4224
9	-132.29	5171.77	4188	0	0	36	4224
10	-136.791	5171.245	4188	0	0	36	4224
11	-139.043	5170.565	4188	0	0	36	4224
12	-144.383	5164.697	4188	0	0	36	4224
13	-146.096	5164.575	4188	0	0	36	4224
14	-152.058	5157.239	4188	0	0	36	4224
15	-153.379	5156.993	4188	0	0	36	4224
16	-154.889	5155.987	4188	0	0	36	4224
17	-160.372	5147.542	4188	0	0	36	4224
18	-161.656	5146.373	4188	0	0	36	4224
19	-169.746	5131.061	4188	0	0	36	4224
20	-171.623	5129.385	4188	0	0	36	4224
21	-182.421	5113.138	4152	36	0	36	4224
22	-210.523	5027.776	4152	36	0	36	4224
23	-217.801	5030.869	4152	36	0	36	4224
24	-231.314	5027.213	4152	20	16	36	4224
25	-234.078	5025.624	4152	20	16	36	4224
26	-237.391	5022.324	4152	20	16	36	4224
27	-242.986	5012.578	4152	16	20	36	4224
28	-243.76	5012.328	4152	16	20	36	4224
29	-249.947	5000.536	4152	14	18	40	4224
30	-251.494	4999.962	4152	12	17	43	4224
31	-253.041	4996.988	4152	9	16	47	4224
32	-254.588	4986.555	4152	7	14	51	4224
33	-260.775	4826.902	4150	2	16	56	4224
34	-263.482	4713.169	4150	2	12	60	4224
35	-264.255	4654.335	4150	2	7	65	4224
36	-274.699	2825.92	4149	3	0	72	4224

Table shows the hinge state details at each step of the analysis. The total number of hinges created in column is 4224, as can be seen.The target displacement calculated was 331.725mm for this model .At displacement value of 274.69mm which is before reaching the performance point , 98% of hinges are within the IO limits and around 2%

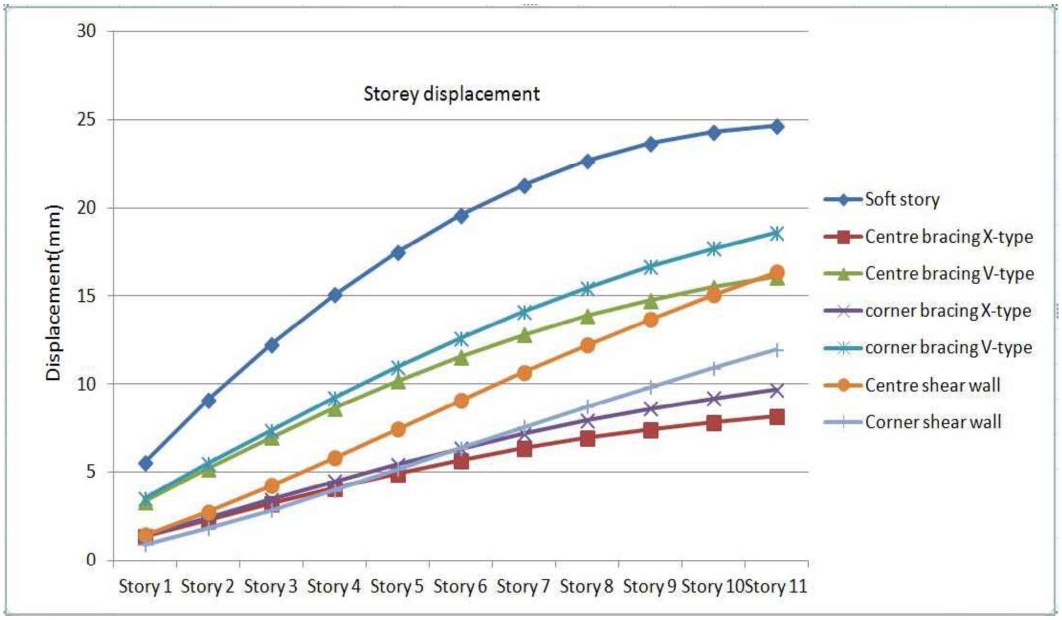
have crossed the CP level. Hence, it gives idea that strengthening of column in soft story is required.

Fig 6.14 Base shear vs displacement



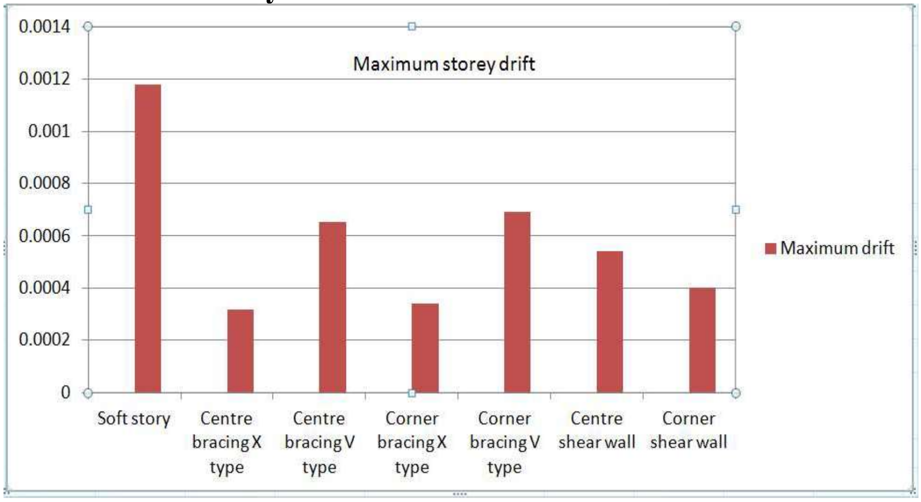
The results for an ASCE 41-13 displacement modification pushover study is presented as a graph between Base shear versus Displacement for a pushover load case. The maximum displacement plotted was 274.699 mm for soft story building model and it was reduced after providing shear wall and bracings. The maximum displacement plotted was 42.394mm for shear wall when located at corner while, maximum displacement plotted was 94.176mm when located at core. Similarly, the maximum displacement plotted was 54.688 mm and 49.551 mm for cross bracing placed at mid and corner bays and it was 154.18 mm and 97.055 mm for V-type bracing placed at mid and corner bays.

Fig 6.15 Storey displacement plot



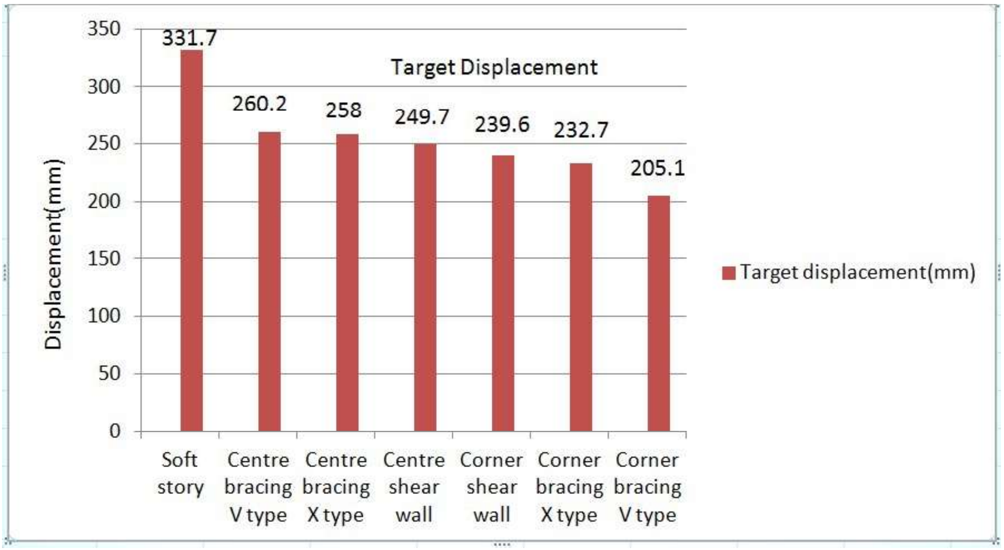
The maximum value is recorded in top storey in all cases for which its value was 24.65 mm under pushover load in X-direction which is maximum in structure with soft story model and in structure model having cross bracings at centre , it was having a minimum value of 8.187 mm among all model types. X type brace provides lesser displacement value when compared to V type bracing. Shearing wall when placed at all four corner gives lesser displacement value as compared to when placed at core .The displacement of all models are within the allowable limit (less than 0.004H) i.e 140mm in selected building model prescribed by IS 1893-2016. (Less than 0.004H).

Fig 6.16 Maximum storey drift chart



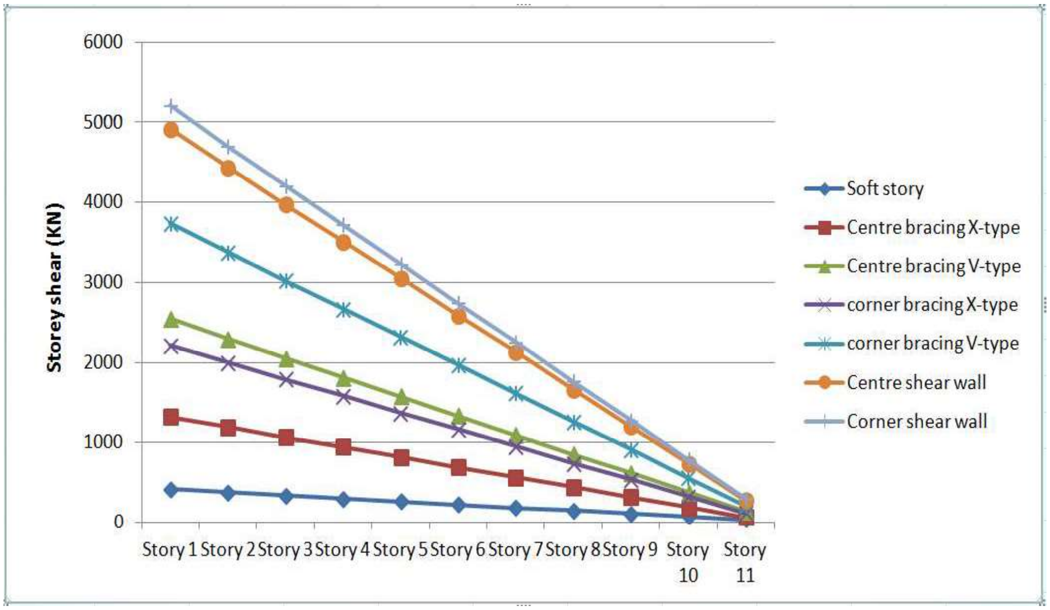
The maximum drift is 0.001181 under pushover load which is maximum in structure with soft story model and in structure model having cross bracings at centre, it was having a minimum value of 0.000318 mm among all model types. Drift value is minimum when bracings are placed in corner bays rather than mid-bays and was lesser in X-type bracing as compared to V-type bracing. Shearing wall when placed at all four corner gives lesser value of drift as compared to to when placed at core.The storey drift of all the model is within the allowable limit i.e less than 0.004 as prescribed by IS 1893-2016.

Fig 6.17 Target displacement chart



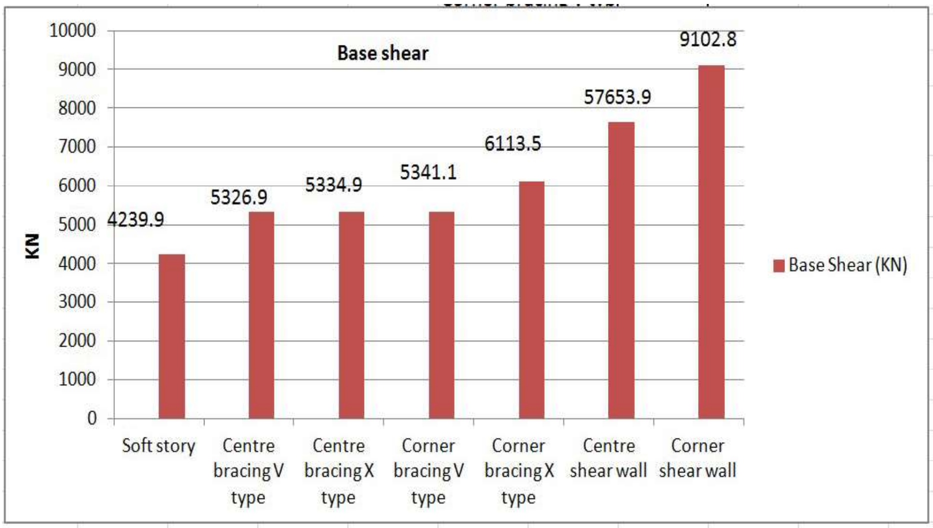
The value of target displacement are in shown in decreasing order in figure 1. RC frame modelled with V-type bracing placed at all corners calculates minimum value of 205.1mm target displacement.

Fig 6.18 Storey shear plot



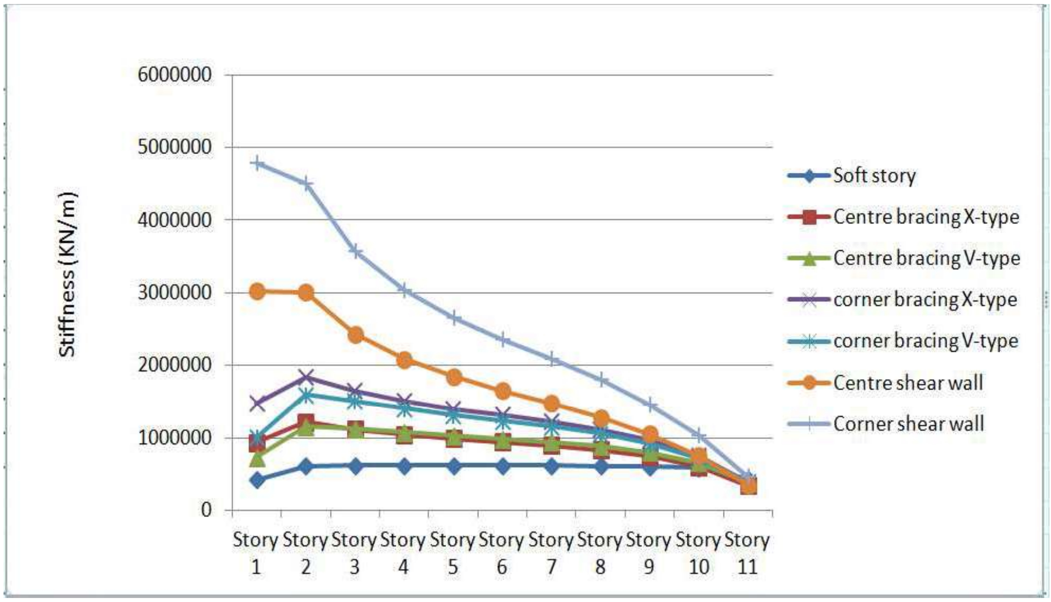
Storey shear is more i.e 5206.9082 KN in case of model having corner shear wall as compared to other six models while it it less in case of model with soft story i.e 414.9 KN. Storey shear is maximum when bracings are placed in corner bays rather than mid-bays and was greater in V-type bracing as compared to X-type bracing. Shearing wall when placed at all four corners gives higher value of shear a compared when placed at core.

Fig 6.19 Base shear chart



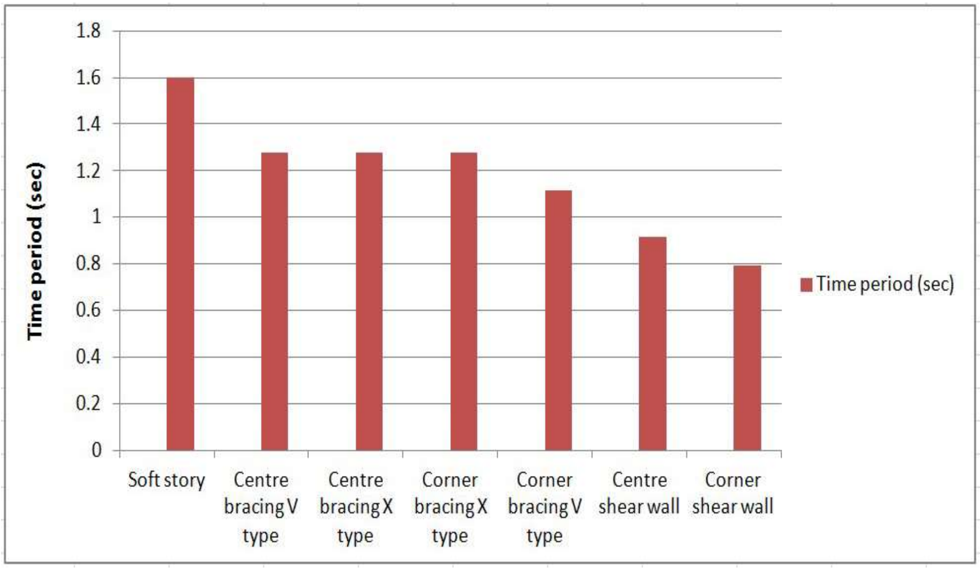
The value of base shear is shown in increasing order in figure 6.4. RCC frame modelled having shearing wall located at four ends gives maximum value of Base shear among all the model types.

Fig 6.20 Storey stiffness plot



Storey stiffness is more i.e 4790126.626 KN/m in case of model having corner shear wall as compared to other six models while it it less in case of model with soft story i.e 617999.8 KN/m. Storey stiffness increases when bracings are placed in corner bays rather than mid-bays and was greater in X-type bracing as compared to V-type bracing. Shearing wall when placed at all four corners gives higher stiffness as compared to wall placed at core. Soft story irregularity was reduced totally when shear wall is introduced in both corner and at core giving to a maximum value of stiffness in ground floor.

Fig 6.21 Time period chart



Model having corner shear wall is having the minimum vibration period of 0.795 sec while model with soft story is having maximum vibration period of 1.599 sec. Time period is minimum when bracings are placed in corner bays rather than mid-bays and was lesser in X-type bracing as compared to V-type bracing. Shearing wall when placed at all four corners gives lesser value of time period as compared to shear wall placed at core.

6.3 Comparative results of response spectrum and pushover analysis

Table 6.12 Base shear comparison

Model type		Base shear (KN)	
		Response spectrum	Pushover analysis
Soft story		3770.35	4239.9485
Centre bracing	X-type	4871.952	5334.98
	V-type	4635.042	5326.9284
Corner bracing	X-type	5619.685	6113.5851
	V-type	5262.746	5341.164
Centre shear wall		7025.244	7653.9342
Corner shear wall		8323.732	9102.8918

Table 6.13 Maximum storey displacement comparison

Model type	Displacement (mm)	
	Response spectrum	Pushover analysis
Soft story	46.707	24.65

Centre bracing	X-type	39.335	8.187
	V-type	40.307	16.084
Corner bracing	X-type	35.646	9.691
	V-type	36.837	18.619
Centre shear wall		33.173	16.346
Corner shear wall		28.599	11.943

Table 6.14 Maximum storey drift comparison

Model type		Drift	
		Response spectrum	Pushover analysis
Soft story		0.001803	0.001181
Centre bracing	X-type	0.001351	0.000318
	V-type	0.001344	0.000652
Corner bracing	X-type	0.001206	0.000341
	V-type	0.001198	0.00069
Centre shear wall		0.001144	0.000543
Corner shear wall		0.001004	0.0004

Table 6.15 Maximum Storey stiffness comparison

Model type		Stiffness (K N /m)	
		Response spectrum	Pushover analysis
Soft story		783150.066	617999.819
Centre bracing	X-type	1371270.52	1215860.719
	V-type	1241625.623	1156838.08
Corner bracing	X-type	1908637.753	1843134.695
	V-type	1680500.183	1599836.39
Centre shear wall		3314210.711	3027594.199
Corner shear wall		5035779.586	4790126.626

Table 6.16 Maximum Storey shear comparison

Model type		Storey shear (KN)	
		Response spectrum	Pushover analysis
Soft story		3947.56	414.9162
Centre bracing	X-type	5004.45	1324.5239
	V-type	4777.69	2545.8511
Corner bracing	X-type	5732.73	2218.3988
	V-type	5387.27	3740.6038
Centre shear wall		8401.879	4914.8694
Corner shear wall		7114.0788	5206.9082

Table 6.17 Time period comparison

Model type		Time period (sec)	
		Response spectrum	Pushover analysis
Soft story		1.798	1.599
Centre bracing	X-type	1.397	1.276
	V-type	1.467	1.276
Corner bracing	X-type	1.216	1.118
	V-type	1.295	1.276
Centre shear wall		0.998	0.916
Corner shear wall		0.87	0.795

CHAPTER 7

DISCUSSION AND CONCLUSION

7.1 Discussion

The major characteristic influenced by the occurrence of a soft floor is structure's stiffness. The soft story condition is caused by considerable changes in stiffness between adjacent stories, which are established by modifying the base story height.

The ETABS 18.0.2 software using IS 1893 (Part1): 2016 code is used in order to analyze the seismic response of soft-floor RC buildings is studied in term of maximum storey displacement, drift, story stiffness ,base shear value as well as modal shapes by performing Linear dynamic i.e response spectrum and Pushover analysis method. The parameter included in the study include soft floor heights, shear wall position, bracing types and arrangements along the structure's height. The provision of a shearing wall and bracings reduces roof displacement and drift while increasing base shear value and stiffness. When shear walls and bracings are placed along the building's corners, they are more effective.

Soft story irregularity was completely reduced when shear wall is introduced giving to a maximum value of stiffness in ground .Pushover analysis, from observations, produces a superior soft story check than response spectrum method. The findings of the study could aid design engineer in incorporating soft floor deficiency into their work.

7.2 Conclusion

Response spectrum analysis	**Pushover analysis**
• The displacement of all models are within the maximum limits specified in IS 1893 :2016. The maximum storey displacement is 46.707mm under earthquake load which is maximum in structure with soft story model and among all the model types it is reduced by 38.7%	• The displacement of all models are within the maximum limits specified in IS 1893 :2016. The maximum storey displacement is 24.65 mm under pushover load in X-direction which is maximum in structure with soft story model and among all the model types it is reduced to a value

leading to a value of 28.599 mm in structure model having corner shear wall.	of of 8.187 mm in structure model having cross bracings at centre.
• The storey drifts of all models meet the limits specified in IS 1893 :2016. The maximum drift is 0.001803 under earthquake load which is maximum in structure with soft story model and in structure model having corner shear wall , it is reduced by 44.3% giving a minimum value of 0.001004 mm among all model types.	• The storey drifts of all models meet the limits specified in IS 1893 : 2016. The maximum drift is 0.001181 under pushover load which is maximum in structure with soft story model and in structure model having cross bracing at centre , it is reduced by to a minimum value of 0.000318 mm among all model types.
• The time period decreased as the number of modes increased for all building model types. Model having corner shear wall is having the minimum vibration period of 0.87 sec under seismic loads while model with soft story is having maximum vibration period of 1.798 sec.	• Model having corner shear wall is having the minimum vibration period of 0.795 sec while model with soft story is having maximum vibration period of 1.599 sec. Time period is minimum when bracings are placed in corner bays rather than mid-bays and was lesser in X-type bracing as compared to Vtype bracing.
•RC frame modelled having shear wall placed at four ends gives maximum Base shear value of 8323.732 KN.Base shear increases by 86 % and 120% when shearing wall are located at core and at four corners. Base shear increases by 29 % and 49% when cross bracings are placed at mid and corner bays. . Base shear increases by 22.9 % and 39.5% when V-type bracings are placed at mid and corner bays.	• RC frame modelled having shear wall placed at four ends gives maximum Base shear value of 9102.8 KN.Base shear increases by 80 % and 114% when shearing wall are located at core and at four corners. Base shear increases by 25.8 % and 44% when cross bracings are placed at mid and corner bays. . Base shear increases by 25 % and 26% when V-type bracings are placed at mid and corner

	bays.
• Storey shear is maximum when bracings are placed in corner bays rather than mid-bays and was greater in X-type bracing as compared to V-type bracing. Storey shear is more i.e 7114.07 KN in case of model having corner wall than other six models while it it less in case of model with soft story i.e 3497.56 KN. Shearing wall when placed at all four corners gives higher value of shear as compared when placed at core.	• Storey shear is maximum when bracings are placed in corner bays rather than mid-bays and was greater in V-type bracing as compared to X-type bracing. Storey shear is more i.e 5206.9082 KN in case of model having corner shearing wall as compared to other six models while it it less in case of model with soft story i.e 414.9 KN. Shearing wall when placed at all four corners gives higher value of shear as compared when placed at core.
•Storey stiffness is having higher value of 5035779.586 KN/m in case of model having corner wall than other six models while it it less in case of model with soft story i.e 783150.066KN/m. Soft story irregularity was reduced totally when shear wall is placed on all four corners giving maximum value of stiffness in ground floor.	•Storey stiffness is having higher value of 4790126.626 KN/m in case of model having corner wall than other six models while it it less in case of model with soft story i.e 617999.8 KN/m. Soft story irregularity was reduced totally when shear wall is introduced in both corner and at core giving to a maximum value of stiffness in ground floor.
• The maximum mode shape value selected in response spectrum method is 30 for which total modal mass of the mode is more than 90 percent of entire seismic mass of building specified in IS 1893: 2016. The modal mass participation ratio for each of the seven cases is 100%.	• RC frame modelled with V-type bracing placed at all corners calculates minimum value of target displacement among all model types. • The idealised force-displacement plot was created by converting the pushover curve obtained when the structure was loaded to collapse. • For a soft storey case, majority of the

hinges are formed within the IO limits while few have crossed the CP level. Hence, strengthening of column in soft story is required.

- The corner shear wall structure model shows high base shear indicating greater stiffness. Storey stiffness is strongly influenced by the presence of shear wall in the building.

Shearing wall when placed at all four corners gives higher stiffness value as compared to shear wall placed at core. Storey stiffness increases when bracings are placed in corner bays rather than mid-bays and was greater in Xtype bracing as compared to Vtype bracing.

- Shear walls have proven to be particularly successful in improving soft storey irregularity while reducing drift and displacement. Proper placing of such walls will improve performance of the structure during earth movement because of an earthquake. The performance of the shear walls placed at the four corners has been improved compared to the shear walls placed in the core.

- Steel braces are one of most effective methods to strengthen structure with soft-storey. The X-brace system exhibits minimum displacement and time period and exhibits higher stiffness and shear values compared to V-brace.

- The Natural time period of the model above is significantly reduced after placing the braces and Shear walls to soft storey model.

7.3 Comparative conclusion between response spectrum and pushover analysis

1) Base shear values were observed more in pushover analysis than in response spectrum analysis. Maximum base shear was observed in model having shearing wall when locaded at all four corners among all models from both RSA and pushover analysis.

2) The displacements for all models is within the maximum limits specified in IS 1893 :2016 . Pushover analysis has a lower maximum displacement value above compared to response spectrum analysis. The least displacement values were observed from both response spectra and pushover analysis in models with shear walls in all four corners among all models. Bracings placed at mid bays shows lesser displacement from pushover analysis while bracings placed at corner bays shows lesser values in response spectrum.

3) Pushover analysis has a lower storey drift value than response spectrum analysis. The lowest drift values were observed from both response spectra and pushover analysis in models with shearing walls when located at all four corners among all models. Type X braces compared to type V braces show less drift from the pushover analysis and slightly higher values in the response spectrum analysis.

•4) Soft story irregularity was completely reduced when shear wall is introduced in both corner and at core giving to a maximum value of stiffness in ground floor from pushover analysis while irregularity effect was reduced fully only when shear wall was placed in all four corners in response spectrum analysis. Storey stiffness increases when bracings are placed in corner bays rather than mid-bays and was greater in X-type bracing as compared to V-type bracing. Also, shearing walls when located at all four corners gives higher value of stiffness as compared when placed at core in both analysis methods.

5) Storey shear is maximum when bracings are placed in corner bays rather than mid-bays in both response spectrum and pushover analysis. X-type bracing shows higher value of storey shear from response spectrum analysis and shows lesser value in pushover analysis as compared to V-type bracing .In both response spectrum and pushover analysis, Storey shear is more in case of model having corner shear wall as compared to other six models while it it less in case of model with soft story and Shearing wall when placed at all four corners gives higher value of shear as compared to shear wall placed at core.

6) In both response spectrum and pushover analysis, model having corner shear wall is having the minimum vibration period while model with soft story is having maximum vibration period. With either analysis method, if the brace was placed on the corner bays instead of the mid bay, the time duration was minimal and the X brace having lesser period than the V brace.

7.4 Future scope

- Time history analysis can be utilised to provide a more accurate assessment of structure's capacity and to grasp a more realistic demand scenario.
- Shear walls can be erected and analysed in a variety of locations.
- Different forms of bracing like diagonal and Inverted V shapes,and various multi-storey buildings can be used.
- More literature study to examine research work from various literatures and to find more gaps .
- Investigate building behaviour by making opening in the shearing wall as well as modifying thickness of the shearing wall, investigate behaviour by raising or lowering the percentage of the shear wall in both direction, and conduct analysis during extreme seismic occurrences.

REFERENCES

1. IS 1893 (part1): 2016 , “Criteria for Earthquake resistance design of structures; Part 1 General provisions and buildings”, Bureau of Indian standards, New Delhi-110002.

2. Abd-Alghany Mariem M., El-Kashif Khaled F. and Abdalla Hany A.,“Seismic response of multi-storey reinforced concrete buildings with soft floor”,HBRC journal 2021, Vol. 17, NO. 1, 407–428,Taylor and francis group.

3. Ahamad Shaik Akhil, Pratap K.V., “Dynamic analysis of G + 20 multi storied building by using shear walls in various locations for different seismic zones by using Etabs”, Materials Today: Proceedings(2020).

4. IS 15988 (2013): Seismic Evaluation, Repair and Strengthening of existing reinforced concrete Buildings – Guidelines, Bureau of Indian Standards.

5. Afghan Mohammad Qadeem, Zazai Naqibullah, Sediqi Hamidullah, “ Seismic response of multi-storeyed RC framed buildings with different location of shear walls”, IJARW, ISSN (O) - 2582-1008 July 2020, Vol. 2 Issue1.

6. Mukundan Hema, Manivel S., “ Effect of Vertical Stiffness Irregularity on Multi-Storey Shear Wall-framed Structures using Response Spectrum Analysis”, IJIRSET, ISSN(Online): 2319 - 8753 ,Vol. 4, Issue 3, March 2015.

7. Ozkul Tulay Aksu, Kurtbeyoglu Ahme, Borekci Muzaffer, Zengin Basak & Kocak Ali , “Effect of shear wall on seismic performance of RC frame buildings”,Engineering failure analysis(2019).

8. Ahmadi Mohammad Noor Jan and Prof. Dr. Sanghvi C. S., “ Comparative study of response of irregular structures and effect of shear walls on irregular buildings”, International journal of advanced research, IJAR, ISSN: 2320-5407,February 2017.

9. Vijetha Karnati, Dr Rao. B. Panduranga, “Comparative Study of Shear Walls and Bracings for A Multistoried Structure Under Seismic Loading”, International Journal of Engineering Research & Technology (IJERT), ISSN: 2278-0181, Vol. 8 Issue 07, July-2019.

10. ATC-40 , " seismic evaluation and retrofit of concrete buildings", Volume 1,Report No. SSC 96-01,November 1996.

11. Arlekar Jaswant N., Jain Sudhir K. and Murty C.V.R. , "Seismic Response of RC Frame Buildings with Soft First Storeys", CBRI Golden Jubilee Conference on Natural Hazards in Urban Habitat,New Delhi,1997.

12. Lamb P.B., Dr Londhe R.S. , "Seismic Behavior of Soft First Storey", IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE),ISSN: 2278-1684 Volume 4, Issue 5 (Nov. - Dec. 2012).

13. Khanal N, Singh SK, Wagley S. , "Seismic consideration of soft story in RC frame buildings using various national codes", International Journal of Civil Engineering and Technology (IJCIET), Volume 10, Issue 09, September 2019.

14. Chethan A S Chethan, Ismail Mohamed, sushma C k, "Evaluation of capacity of Rcc framed structure with different brace configurations using pushover analysis", International Research Journal of Engineering and Technology (IRJET), Volume 2, Issue 02, May 2015.

15. K Vidhya, C G Sivakumar , "Pushover Analysis of RC Frame with Shear Wall and Openings", International Journal of Mechanical Engineering, ISSN: 0974-5823, Vol. 6 No. 3 October-December, 2021.

16. Alashkar Yaseer, Nazar Sohaib , Ahmed Mohammad , "A Comparative Study of Seismic Strengthening of RC Buildings by Steel Bracings and Concrete Shear walls", International Journal of Civil and Structural Engineering Research, ISSN 2348-7607, Vol. 2, Issue 2,March 2015.

17. IS 875 (part2): 1987 , "Code of practice for deign loads (other than earthquake) for building and structures, Part 2 Imposed loads 2nd revision", Bureau of Indian standards, New Delhi-110002.

18. Arunkuman S. ,Dr. Devi G. Nandini, "Seismic demand study of soft storey building and it's Strengthening for seismic resistance", International Journal of Emerging Trends & Technology in Computer Science (IJETTCS), Volume 5, Issue 2, March - April 2016.

19. Kevadkar M.D. ,Kodag P.B. , "Lateral Load Analysis of R.C.C. Building", International Journal of Modern Engineering Research (IJMER), ISSN: 2249-6645 ,Vol.3, Issue.3, May-June 2013.

20. Patil Jyoti, Dr. Kulkarni D.K. , "Performance based evaluation of framed reinforced concrete shear walls by pushover analysis", International Research Journal of Engineering and Technology (IRJET), Volume 2, Issue 5, August 2016.

21. B Sylviya, Eswaramoorthi P., "Analysis of RCC Building with Shear Walls at Various Locations and In Different Seismic Zones", International Journal of Innovative Technology and Exploring Engineering (IJITEE), ISSN: 2278-3075, Volume-8, Issue-2S, December 2018.

22. Baral Anil , Dr. Yajdani SK , "Seismic Analysis of RC Framed Building for Different Position of Shear wall", International Journal of Innovative Research in Science, Engineering and Technology, Volume 4, Issue 5, May 2015.