# CHAPTER 1

# INTRODUCTION

## 1.1 Regular and Irregular structures

Structures are designated as structurally regular or irregular. A regular structure has no significant discontinuities in plan, vertical configuration, or lateral force resisting systems. An irregular structure, on the other hand, has significant discontinuities such as horizontal irregularities and vertical irregularities. The various types of structural irregularities are as shown:

- Vertical stiffness irregularity (soft storey)
- Weight (mass) irregularity
- Vertical geometric irregularity
- In-plane discontinuity
- Out-of-plane offsets
- Discontinuity in capacity (weak storey)
- Torsional sensitivity
- Non-orthogonal systems

## 1.2 Soft storey building and its behaviour

A soft story is defined as a story in a building that has substantially less stiffness or inadequate ductility (energy absorption capacity) to resist the earthquake induced building stresses. If a building has a floor which is 70% less stiff than the floor above it, it is considered a soft story building. This soft story creates a major weak point in an earthquake, and since soft stories are classically associated with retail spaces and parking garages, they are often on the lower stories of a building, which means that when they collapse, they can take the whole building down with them, causing serious structural damage which may render the structure totally unusable.

Many building structures having parking or commercial areas in their first stories, suffered major structural damages and collapsed in the recent earthquakes. Large open areas with less infill and exterior walls and higher floor levels at the ground level result in soft stories and hence damage. In such buildings, the stiffness of the lateral load resisting systems at those stories is quite less than the stories above or below. In Fig. below, the lateral displacement diagram of a building with a soft storey under lateral loading is shown.

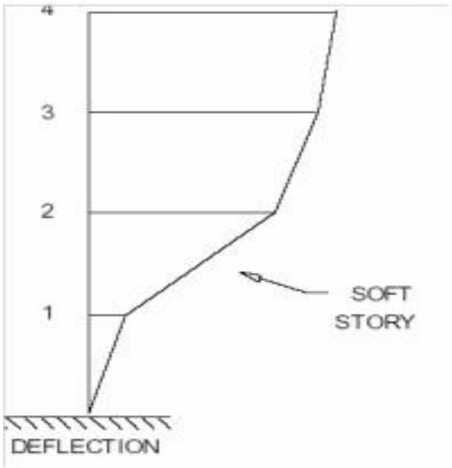



**Fig. 1**Soft story behaviour of a building structure under lateral loading [35]

During an earthquake, if abnormal inter-story drifts between adjacent stories occur, the lateral forces cannot be well distributed along the height of the structure. This situation causes the lateral forces to concentrate on the storey (or stories) having large displacement(s). In addition, if the local ductility demands are not met in the design of such a building structure for that storey and the inter-storey drifts are not limited, a local failure mechanism or, even worse, a storey failure mechanism, which may lead to the collapse of the system, may be formed due to the high level of load deformation (P-Δ) effects.

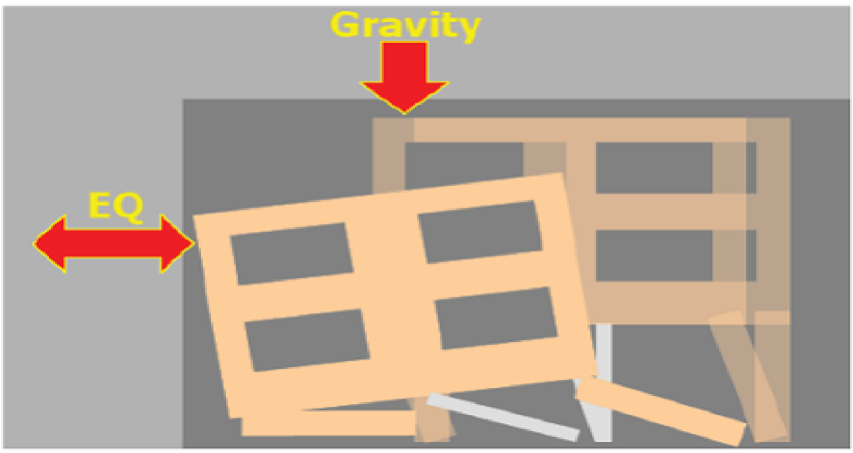



**Fig.2** Collapse mechanism of such a building structure with a soft storey under both earthquake and gravity loads [35]

Lateral displacement of a storey is a function of stiffness, mass and lateral force distributed on that storey. It is also known that the lateral force distribution along the height of a building is directly related to mass and stiffness of each story. If the P-Δ effect is considered to be the main reason for the dynamic collapse of building structures during earthquakes, accurately determined lateral displacements calculated in the elastic design process may provide very important information about the structural behaviour of the system. Therefore dynamic analysis procedure is required in many of the actual codes for accurate distribution of the earthquake forces along the building height, determining modal effects and local ductility demands efficiently. Although some of the current codes define soft storey irregularity by stiffness comparison of adjacent floors, displacement based criteria for such irregularity determination is more efficient, since it covers all the mass, stiffness and force distribution concepts.

## 1.3 Preventing soft storey irregularities

In constructions where it is necessary to build a soft storey, lateral rigidity of this particular storey should be brought to the rigidity level of the other storeys. To be able to do this, the number of columns and shear walls should be increased. because of this increase, longitudinal and lateral reinforcement should also be increased. These raise the cost of the construction. Soft storey is an irregularity which affects the behaviour of a construction during a quake and also increases the construction costs. For this reason, soft storeys should be avoided as much as possible. In case it is necessary, by the controls to be performed as a result of calculation made, irregularities can be eliminated as follows:

- Building additional walls (Fig.3.a)
- Increasing the rigidity of the columns and the shear walls on the soft storey (Fig.3.b)
- Regulating the dimensions of the columns and shear walls by longitudinal and lateral reinforcement so that the soft floor would show a ductile behaviour (Fig.3.c)
- Preventing cracking by placing the wall at a certain distance from columns and walls that are on the soft storey (Fig.3.d)

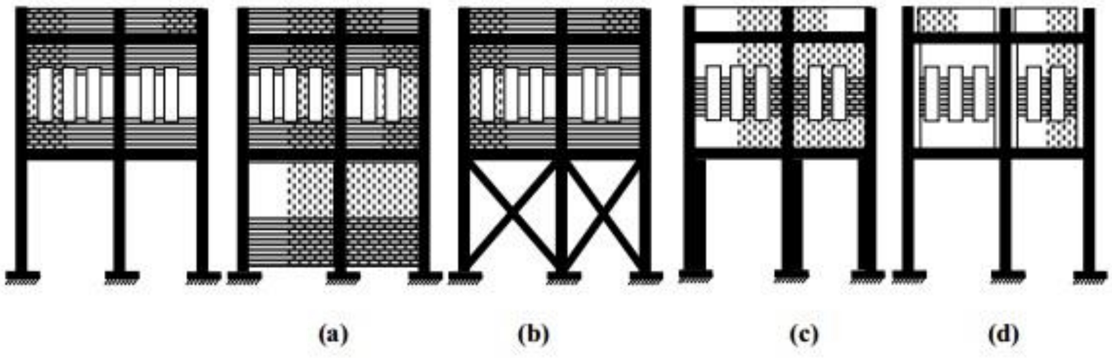



**Fig. 3** Methods of preventing soft storey irregularities

[34]

Now that we cannot leave the already present buildings, we should turn them into resisting ones according to the new Code of Earthquake. Since the codes and regulations are changed as a result of technological advances and examination of the quake results, those constructions which are considered resistant according to the previous regulations can be weakness according to the new regulations. To be able to do this, present irregularities should be eliminated. Upon investigation in the quake region, it was observed that constructions built in accordance with the previous Code of Earthquake (1975) underwent greater damage, and those built in accordance with the new Code (1998) underwent less damage, and some did not even undergo any damage. to bring the present buildings into resistant state of being, proper one of the following method is applied:

- Increasing the lateral rigidity of this storey by putting up additional walls between single structural elements on the soft storey.
- Increasing the lateral rigidity of this storey by placing steel diagonals between the columns and shear walls3. Putting flexible material between columns and walls on the storey atop the soft storey thus preventing it to work together with the soft storey.
- Increasing the rigidity of the soft storey by reinforcing the columns of the soft storey.

## 1.4 Motivation of study

The determination of seismic demand of a building plays an imperative role in the design of irregular building. If these mentioned demands are not estimated accurately during the design or evaluation phase of the building structure, a local or a progressive collapse becomes unavoidable in a severe earthquake. The evaluation of irregular structures, such as building structures with soft stories, becomes more important as they have been seriously damaged or collapsed in the earthquakes due to their special collapse mechanisms.. In these condition the role of structural engineer become more critical if the building located in seismically active zone. In order to provide the solution which meets the structural performance of building as specified by governing code and simultaneously providing satisfactory output to clients, structural engineer should have sound understanding of response of different types, parts and configuration of building during seismic event. So structure engineer needs a design procedure that can calculate seismic demands of irregular building.

## 1.5 Specific point of study

Irregularity arises in building when there is non uniform distribution of mass, stiffness, and/or strength along height of building exist. When one or more of these properties is non-uniformly distributed, either individually or in combination with other properties in any direction, the structure is referred to as being irregular. In the present investigation seismic behaviour of building due to stiffness irregularity has been studied. The five storey building model is programmed on STAAD PRO following the guidelines of Indian codes. The stiffness of each storey is varied and corresponding behaviour of building is examined by determining the numerous parameters.

## 1.6 Organization Of Dissertation

For presentation purposes, the dissertation is structured in six chapters. Summaries of the contents of these chapters are given hereafter.

Chapter 1 introduces the background, specific point of study, motivation of study.

Chapter 2 present detailed objective of study.

Chapter3 present literature review, past earthquake event.

Chapter4 discusses programme of study that include building details, input parameters and output parameters and different codal provision.

Chapter 5 present results and discussion.

Chapter6 conclude the dissertation by drawing conclusion from different chapter and suggesting future research requirement.

Appendix present staad editor file of original building which is designed in STAAD PRO V8i.

# CHAPTER 2

# OBJECTIVES

## Following are the objectives of study:

1. To develop model of a real building actually constructed or to be constructed. This building may or may not be properly regular as per guideline of IS 1893 Part 1-2202.
2. To study the guideline of IS 1893 Part 1-2002 and IS 875 with respect to general principles and design criteria.
3. To study stiffness irregularities or soft storey criteria as per IS 1893 and that of relevant characteristics in the ground storey of the real building model.
4. To consider appropriate changes in physical parameters in real building model and to study the effects of these changes on soft storey characteristics of building model and on seismic performance of building.
5. To study the effect of application of changes (as described in objective no.5 above) in other study of the building model and to study of the real building model and to study changes in seismic performance of building.
6. To compare changes in seismic performances effected because of changes in stiffness in ground floor storey (as per objective no.4) and in other stories (as per objective no.5 above).
7. To draw graphs for changes in building performance indices Vs changes in storey stiffness and to attempt at developing characteristic equation for relationships amongst various parameters.

# CHAPTER 3

# LITERATURE REVIEW

In the evaluation of the inelastic behaviour of the building structures, there are twocommon methods, which are based on the nonlinear static pushover analysis. Capacity Spectrum Method, which is also referred in ATC-40 [2], is one of the mostpopular methods utilized for the evaluation of buildings. It was developed by Freeman et.al. [1]. In the method, the structural capacity curve is calculated andcompared with the demand spectrum. A performance point that lies on both thecapacity spectrum and the demand spectrum is obtained for performance evaluation of the structure. The second method, which is called Displacement CoefficientMethod that is described in FEMA-356 [2], is based on the displacementmodification factors used for modifying the elastic spectral displacement of anequivalent SDOF system.The approximations made for these methods bring some weaknesses such as notconsidering the higher mode effects and invariant lateral load patterns. In theliterature, many researchers investigated and tried to improve these weaknesses. Forexample, Fajfar and Fischinger [3] offered using invariant story forces proportional to the deflected shape of the structure. On the same subject, Eberhard and Sozen [4]offered load patterns based on mode shapes derived from secant stiffness at each loadstep. In a similar study, Park and Eom [5] proposed a new design method using secant stiffness. It is stated that the new method directly calculates the inelastic strength and deformation demands more effectively. In their study, they emphasizedthat the soft-story can only be prevented by energy dissipation among the structure and only spreading the plastic hinges along the building height can maximize it.

Moghaddam [6] studied a method to determine the higher mode effects in tallbuildings. A series of pushover analysis is performed on the buildings in which theelastic mode shapes are used as load patterns.

Sasaki, Freeman and Paret [7] proposed a multimodal procedure to predict highmode effects. The proposed procedure is said to be successful in predicting in high mode effects but it cannot provide exact seismic response of such structures. Different from the above-mentioned procedures, Chopra and Goel [8] formed aprocedure forpushover analysis and named it as Modal Pushover Analysis (MPA).Comparing the results obtained by thisprocedure with various load patterns indicatedthat the MPA is more accurate than all pushover analysis methods in estimating floordisplacements, story drifts, plastic hinge rotations and plastic hinge locations as theother pushover methods underestimate the story drift demands and lead to large errors in plastic hinge rotations. In addition, it was stated that MPA results werefound to be similar to the time history analysis results. In another study by

Chintanapakdee and Chopra [9], the accuracy of MPA procedure is evaluated and itwas stated that the MPA results were in good correlation with nonlinear dynamicanalyses. In that study, the MPA procedure is also used to estimate seismic demandof inelastic systems with seismic demand being defined by an elastic design spectrum. The same authors investigated the accuracy of modal pushover analysisprocedure for irregular frames. It is stated in that study that, the MPA is found tobe more reliable than FEMA-356 [10] force distributions for all irregular frames. It isalso expressed that if sufficient modes are taken into account, MPA gives very closeresults to the time history analysis results while compared with the other loaddistributions. Furthermore, it is added that the irregularities influence the variation ofstory drifts, with the effects of strength irregularity larger than stiffness irregularity,and the combination of both has the largest among them.

Attard and Fafitis [10] studied a modified method of MPA in which a variant loadpattern is obtained from a mode shape of a yielding point. It is stated in that studythat, after iteration on the parameters obtained from time history analysis, the proposed method gives almost the same results.

In another study by Chopra and Goel [11], the role of higher mode effects inpushover analysis is investigated. It is found out that the higher mode pushovercurves lead to plastic hinge mechanisms that are not detected by the effective first mode load pattern or other force distributions given by FEMA-356. On the otherhand, it is stated that these mechanisms do not develop during ground motion in aregular building without a soft and/or weak story. It is also shown in that study thatreversals in a higher mode pushover curve occurs after formation of a mechanism if the resultant force above the bottom of the mechanism is in the direction that moves the roof in a direction opposite to that prior to formation of the mechanism. Reversalscan occur only in higher mode pushover analyses but not in the pushover analyses for the first mode or other FEMA-273 [12] force distributions. In case of soft and/orweak story it is stated that the story drift demands in the modified and neighbouringstories is increased and the drift demands in other stories is decreased. On the otherhand, a stiff and/or strong story decreases the drift demand in the modified andneighbouring stories and increases the drift demands in other stories. Additionally, itis expressed that while the roof displacement is usually insensitive to verticalirregularity, it is significantly different for frames that are stiffness-and-strengthirregular in their lower half. Irregularity in the base story or lower stories hassignificant influence on the height-wise distribution of floor displacements.

Gupta and Kunnath [13] investigated the FEMA-356 procedures and offered a newprocedure called Adaptive Pushover Procedure (APM) to account for the highermode effects and to overcome the shortcomings of the FEMA-356 procedure. It is noted that the FEMA 356 procedure fails in accurate determination of ductilitydemands, and APM is more accurate in determining seismic demands.

Kalkan and Kunnath [14] focused on the prediction of seismic demands of structuresand the results of time history analysis results are compared with various nonlinearpushover static loadings. It is stated that, the FEMA-356 method and Upper-BoundPushover Procedure give poor predictions of demands when higher mode effects aresignificant and MPA procedure leads to more accurate predictions. However, the MPA method is found to be misleading in determining the demands in upper stories as it ignores the inelastic contribution of higher modes. They noted that the bestmethod for predicting the seismic demands of a building structure is the AdaptiveModal Combination Procedure, which integrates the capacity spectrum, modalcombination and adaptive loading patterns. In another study by the same authors [36], the local component demands of FEMA-356 are investigated. The pushovermethods are mentioned as an improvement over existing elastic force-basedprocedures and provide critical information on potential collapse mechanisms and the vulnerability for soft stories. It is also stated that, for the structures respondingprimarily in the first mode, nonlinear static methods may be a reliable option toestimate inelastic demands but may also be misleading in the determination of theseismic demands of upper stories in mid-rise structures.In addition to the studies on the nonlinear static pushover procedures mentionedabove, the studies on various load patterns have also been carried out.

Mwafy andElnashai [15] investigated the applicability and accuracy of inelastic static pushoveranalysis in predicting the seismic response of reinforced concrete buildings. It isstated that, if the load pattern is chosen carefully, the model may represent theinelastic response of the low and mid-rise buildings. For high-rise buildings, due to the problem of predicting the higher mode effects, it is recommended to use more load patterns. In addition, the uniform load pattern is found to be very conservativein prediction of seismic demands in that study.

Krawinkler and Seneviratna [17] summarized basic concepts on which the pushoveranalysis can be based. In addition, they assessed the accuracy of pushover predictions and identified the conditions under which the pushover will provideadequate information. They also identified the cases in which the pushoverpredictions will be inadequate or even misleading. It is noted that carefullyperformed pushover analysis may provide insight into structural aspects that controlperformance during severe earthquakes. It is also stated that the structures for whichthe primary mode of vibration is the fundamental mode, demands will be obtainedbetter with pushover analysis. Weaknesses such as story mechanisms, excessivedeformation demands, strength irregularities and overloads on columns andconnections that may remain hidden in an elastic analysis will be made obvious withthis analysis. However, for structures in which higher mode effects are significant and in which the applied load pattern affects the story shear versus story drift relations, the deformation estimates obtained from a pushover analysis may be veryinaccurate. A possible solution to overcome this problem is to several load patternsincluding ones that can account for the higher mode effects. Another critical aspect for the pushover analysis is that although the first local mechanism that will form in an earthquake will be detected through this analysis, other weaknesses that occur when the structure's dynamic characteristics change after formation of the first localmechanism may not be reflected.

Moghaddam and Hajirasouliha [18] investigated the potentialities of the pushoveranalysis to estimate the seismic deformation demands of concentrically braces steelframes. It is stated that the results of a pushover analysis is quite sensitive to theapplied load pattern and generally inaccurate demands are obtained in such analysis.

Inelet. al. [19] evaluated various load patterns used in pushover analysis. The work also covered buildings with a soft-story. It was found out that simplified inelasticprocedures provide very good estimates of peak displacement response for bothregular and weak-story buildings. It is added that the results of inter-story drift andstory shear were generally improved when multiple modes are taken into account. The results also indicated that simplifications in the first mode lateral load patternmight easily be applied with a negligible loss of accuracy.

Korkmaz and Sarı [20] evaluated the performance of the frame structures for variousload patterns by performing pushover and nonlinear dynamic time history analysis.According to this paper, for high-rise frame structures, first yielding and shear failureof the columns is experienced at the larger story displacements and uniformdistribution always give the higher base shear-weight ratio comparing to other loaddistributions for the corresponding story displacement. Also it's found that results ofnonlinear static pushover analysis do not match with nonlinear dynamic time historyanalysis results especially for long period high-rise reinforced concrete framestructures. It was added that the pushover analyses results for uniform load distribution estimate maximum seismic demands during the given earthquakes morereasonable than the other load distributions.

Kömür and Elmas [21], evaluated the reinforced concrete frame systems which aredesigned according to current Turkish Codes by nonlinear pushover analysesutilizing various multimodal processes and inverted triangle loadings. It is found outthat the pushover curves of multimodal loading process and inverted triangle loadingare practically same so as the collapse limits. Due to this, multimodal procedure is not found to be very effective in the evaluation of such building structures.

Oguz [22] evaluated the pushover analysis method for various load patterns andprocedures. It is found out that, the variation in the results of all the modal loadpatterns and the triangle load patterns is negligible for low and mid-rise structures. It is also added that the triangular load patterns predict displacements and inter-storydrift ratios between the results of MPA and Elastic First Mode load patterns in low and mid-rise structures. In the analyses, none of the load patterns can capture the exact demands and hinge locations obtained by time history analysis but the accuracy of the results may be reasonable depending on the load patterns for low and mid-risestructures. The accuracy is found to be decreasing in high-rise buildings. Moreover, in their study, no improvement was observed for the usage of FEMA-273 and MPAprocedures, which consider higher mode effects. She suggested using elastic first mode load pattern in the pushover analyses and to avoid using uniform load patternin view of the results on real demands and accuracy obtained in her study.

Bayülkeet. al. [23] studied on the earthquake damaged and undamaged reinforcedconcrete buildings by non-linear pushover analysis method, in order to determinelateral force displacement relations and to compare the limit lateral forces with thelateral load level as calculated from elastic acceleration spectrums for the analyticallycalculated R factors. It is concluded that the buildings with symmetric shear walls inplan do not loose their lateral stiffness' in a dangerous way like the ones without shear walls after the limit lateral force level and it is added that the formation of thecollapse mechanism is found to be very quick and progressive for the buildingswithout shear walls.

Polat et.al. [24], presented a case study on the of conventional retrofitting with linearanalysis. Evaluating the seismic demands and cost requirements obtained by linearanalysis is found to be irrational and the usage of more realistic analysis methods arestrongly recommended in such cases. By a similar study, Hasgür et al. [27] studied the level of expected damages due to destructive earthquakes and determined therelations and propriety of seismic damage indices with the results of non-linear analysis for RC building structures having elements of various bending, shear and yield capacities and corresponding curvatures before and after strengthening. Justlike Polat et. al. [24], it is stated that retrofitting by using the results of the nonlinearanalysis methods are more accurate and better in cost concerns.

Türkeret. al. [25] evaluated a set of models considering the effects of the in-fills. It isfound out that including effects of the in-fills to the nonlinear pushover analysis thebuilding structures show better performances. It is recommended that the newTurkish Code should give more detailed information on such analysis methods..

Inel et.al. [26] studied the evaluation of the buildings reflecting existing construction practise. The paper also covered some models with a soft story. It is concluded in that study that, (a) the increase in the confinement level increases the sustained level of damage, (b) the affect of infills are significant in low rise buildings with weaker members, (c) the main reason for a collapse is found to be weak columns and strong beams, (c) the structural irregularities like short column, soft story and heavy overhangs are quite dangerous but the soft story irregularity with a heavy overhang is the most dangerous one, (d) the irregularity effect are found to be more significant in mid rise structures that the low rise ones, (e) the soft story irregularity formed by the absence of infills at the ground story is found to be more dangerous than the stiffness based ones.

Inel and Özmen [27] studied the effects of default and user defined nonlinear component properties. Pointing out that the confinement amount has direct affect on the displacement capacity of a structure, it is stated that the default hinge models must be avoided, as the response of a structure may not be accurately determined.

Athanassiadou [28] studied multi-story analytical models, which are irregular invertical, and compared the ductility levels and pushover analysis results. High ductility and normal ductility demands are concluded to be not effective in cost and their seismic performance is found to be equally satisfactory. Although the beams of normal ductile structures said to have some weakness in shear capacity the over strength of the both ductility levels found to be similar. It is also added that inelastic pushover procedures are found to be in accurate in demand predictions as they ignore higher mode effects.

Among the studies on soft story behaviour and irregularities in the building structures, Ruiz and Diederich [29] studied a set of analytical models with a weak story and investigated the local ductility demands. It's found that the performances of the frames depend on the resistance factors and closeness of the dominant response period and dominant period of earthquake. In addition to these, the ductility demands while P-_ effects considered are found to be bigger.

Esteva [30] studied the nonlinear response of buildings with excessive stiffness and strength above the first story. It is stated that the response of a building is quite sensitive to the stiffness variation along the height of the structure and the p-_ effects are significant on the response. The use of a safety factor to meet the local ductility demands in a soft story, which is dependent to the natural period of a structure, is offered.

Chang and Kim [31] investigated a 20-story building with a soft story by nonlinear time-history and nonlinear pushover analysis. It is stated that low strength reduction factor with perfectly yielding mechanisms are required for effective protection and it is also advised that an amplification factor must be applied to soft stories for which the displacements might be reduced by this way.

Chopra et al. [32] investigated the yielding point of a soft first story for the adequate protection of upper stories from significant yielding. It is concluded that, to limit the force transmitted to the adjacent story above, an elastic-perfectly plastic mechanisms needed as any residual stiffness increase the shear force transmitted. Even if the first story limits the forces transmitted to upper stories, the resulting shear wave propagates and any weakness of strength in an upper story may lead to collapse. In this paper it is also stated that the first soft story mechanisms must be designed according to very large displacements.

Mezzi [33] studied the retrofitting choices of buildings with a soft story and stated that although passive control systems are very effective solutions for retrofitting, base isolation is the most economic one.

# CHAPTER 4

# PROGRAMME OF STUDY

## 4.1 Introduction

Many building structures having parking or commercial areas in their first stories, suffered major structural damages and collapsed in the recent earthquakes. Large open areas with less infill and exterior walls and higher floor levels at the ground level result in soft stories and hence damage.

If a building has a floor which is 70% less stiff than the floor above it, it is considered a soft story building. This soft story creates a major weak point in an earthquake; they are often on the lower stories of a building, which means that when they collapse, they can take the whole building down with them, causing serious structural damage which may render the structure totally unusable**.**

In present study different input, output parameters and suitable analysis process are discussed A five storey building is selected as shown in figure below:

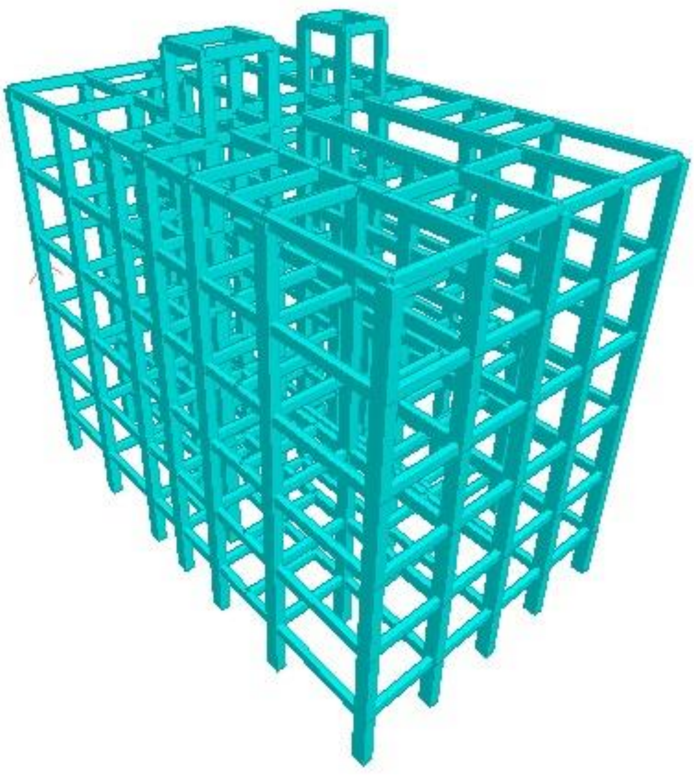


**Fig. 4** 3-D View Of Building (Column-Beam View)

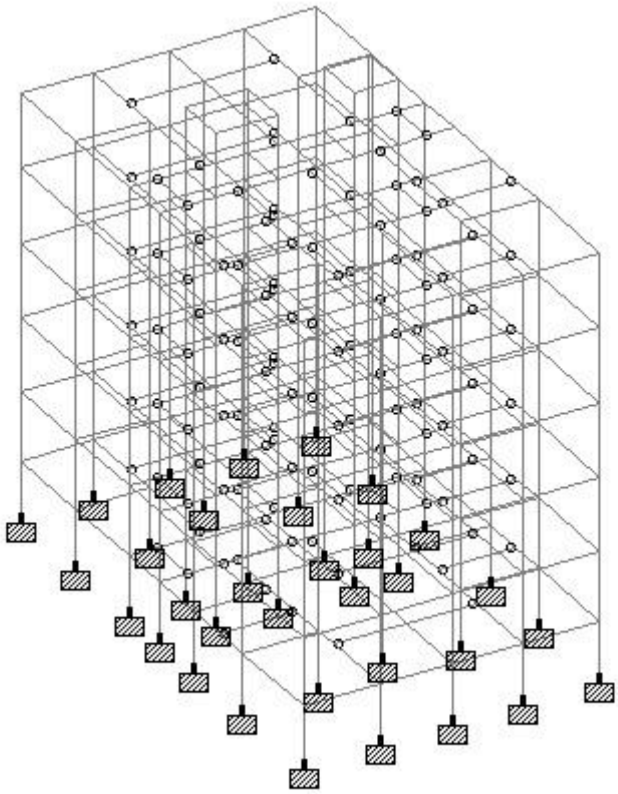


**FIG. 5** 3-D View Of Building

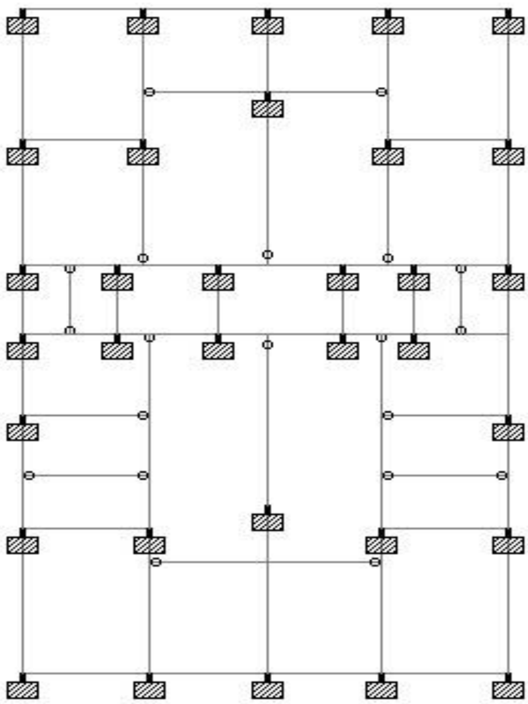


**FIG. 6** Plan View Of Building

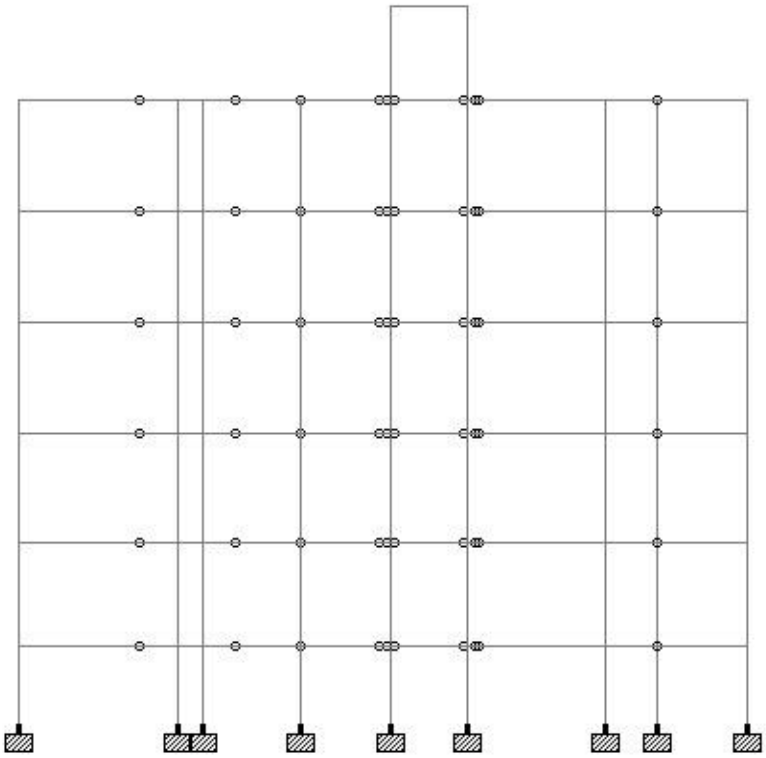


**FIG. 7** Elevation View Of Building

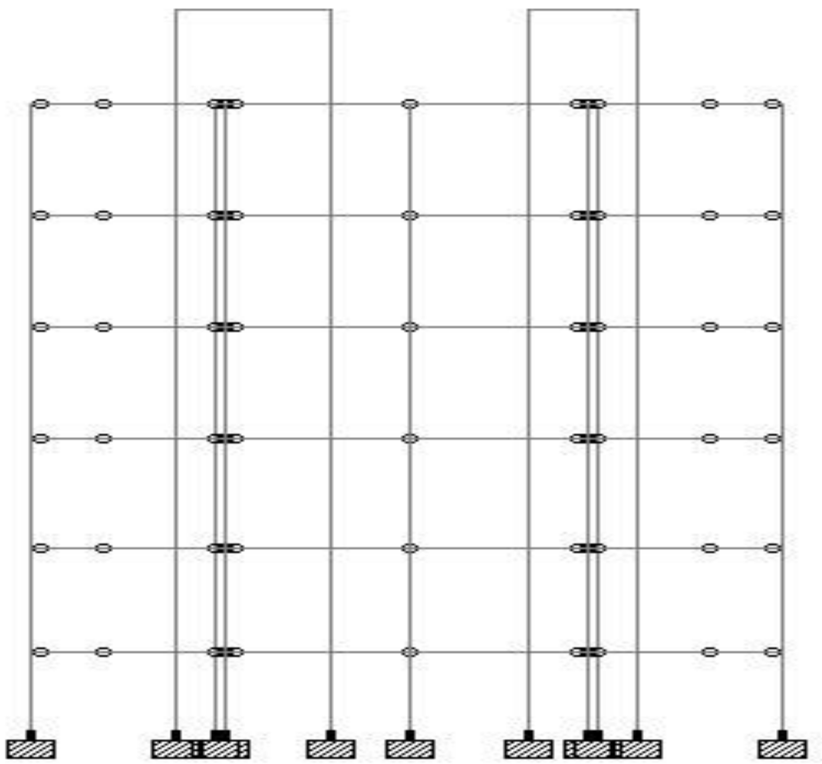


**FIG. 8** Side View Of Building

**Details of building**

**Table 1 Structural Data**

| STRUCTURAL DATA | |
|---|---|
| HEIGHT | 15.45m |
| WIDTH | 15.65m |
| LENGTH | 33.0m |
| NO. OF STOREY | 4 |
| STOREY HEIGHT | 3.3m |
| TOTAL NO. OF COLUMN | 159 |
| TOTAL NO. OF BEAM | 346 |
| CONCRETE GRADE | M25 |
| STEEL GRADE | Fe415 |
| DENSITY OF CONCRETE | 2400 kg/m^3 |
| POISION RATIO | 0.17 |
| YOUNG'S MODULUS OF ELASTICITY | 25000N/MM^2 |
| BEAM DIMENSION | 0.45*0.30m |
| COLUMN DIMENSION | 0.45*0.60m |

**Table 2 Earthquake Data**

| EARTHQUAKE DATA | |
|---|---|
| ZONE VALUE | 0.24 |
| IMPORTANCE FACTOR | 1.5 |
| RESPONSE REDUCTION FACTOR | 5 |
| TYPE OF SOIL | 2 |
| DAMPING | 5% |
| CUT OFF MODE | 21 |

**Table 3 Dead Load**

| DEAD LOAD | |
|---|---|
| ROOF | 4657.86kN |
| 4TH FLOOR | 4887.00kN |
| 3RD FLOOR | 4887.00kN |
| 2ND FLOOR | 4887.00kN |
| 1ST FLOOR | 4887.00kN |

**Table 4 Live Load**

| LIVE LOAD | |
|---|---|
| ROOF | 1559kN |
| 4TH FLOOR | 1823kN |
| 3RD FLOOR | 1823kN |
| 2ND FLOOR | 1964kN |
| 1ST FLOOR | 1823kN |

## 4.2 Input Parameters

Input parameters are weight on each floor, seismic weight on each floor, dimension of building, beam and column, site condition of building , purpose of building, type of materials used.

All of them are described as follows:-

**Modal Mass**: Modal mass of a structure subjected to horizontal or vertical, as the case maybe, ground motion is a part of the total seismic mass of the structure that is effective in mode ***k*** of vibration. The modal mass for a given mode has a unique value irrespective of scaling of the mode shape.

**Normal Mode**: A system is said to be vibrating in a normal mode when all its masses attain maximum values of displacements and rotations simultaneously, and pass through equilibrium positions simultaneously.

**Damping**: The effect of internal friction, imperfect elasticity of material, slipping, sliding, etc in reducing the amplitude of vibration and is expressed as a percentage of critical damping.

**Design Acceleration Spectrum**: Design acceleration spectrum refers to an average smoothened plot of maximum acceleration as a function of frequency or time period of vibration for a specified damping ratio for earthquake excitations at the base of a single degree of freedom system.

**Importance Factor**: It is a factor used to obtain the design seismic force depending on the functional use of the structure, characterized by hazardous consequences of its failure, its post-earthquake functional need, historic value, or economic importance.

**Zone Factor (Z)**: It is a factor to obtain the design spectrum depending on the perceived maximum seismic risk characterized by Maximum Considered Earthquake (MCE) in the zone in which the structure is located.

**Response Reduction Factor**: It is the factor by which the actual base shear force, that would be generated if the structure were to remain elastic during its response to the Design Basis Earthquake (DBE) shaking, shall be reduced to obtain the design lateral force

**Seismic Weight**: It is the total dead load plus appropriate amounts of specified imposed load.

**Structural Response Factor ( $\frac{S_a}{g}$ )**: It is a factor denoting the acceleration response spectrum of the structure subjected to earthquake ground vibrations, and depends on natural period of vibration and damping of the structure.

**Partial safety factors for limit state design of reinforced concrete structures**

In the limit state design of reinforced concrete structures, the following load combinations shall be accounted for:

1) 1.5 (DL+LL)

2) 1.2 ( DL+ZL+EL)

3) 1.5 ( DL+EL)

4) 0.9DL+1.5EL

## 4.3 Earthquake Lateral Force Analysis

The design lateral force shall first be computed for the building as a whole. Then design lateral force calculated shall be distributed to the various floor levels. The overall design seismic force thus obtained at each floor level shall then be distributed to individual lateral load resisting elements depending on the floor diaphragm action. There are two commonly used procedures for specifying seismic design lateral forces:

### 4.3.1Equivalent static force analysis

The equivalent lateral force analysis for an earthquake converts a dynamic analysis into partly dynamic and partly static analyses for finding the maximum displacement (or stresses) induced in the structure due to earthquake excitation. The equivalent lateral force for an earthquake is defined as a set of lateral static forces which will produce the same peak response of the structure as that obtained by the dynamic analysis of the structure under the same earthquake. This equivalence is restricted only to a single mode of vibration of the structure. Inherently, equivalent static lateral force analysis is based on the following assumptions:

1. Structure is rigid.
2. Perfect fixity between structure and foundation.
3. Same acceleration is induced in each point of structure during ground motion.

4. Dominant effect of earthquake is equivalent to horizontal force of varying magnitude over the height.
5. Base shear on the structure is determined approximately.

However, during an earthquake structure does not remain rigid, it deflects, and thus base shear is disturbed along the height.

**The limitation of equivalent static lateral force analysis:**

Empirical relationships are used to specify dynamic inertial forces as static forces which do not explicitly account for the dynamic characteristics of the particular structure being designed or analyzed. These formulas were developed to approximately represent the dynamic behaviour of regular structures. For such structures, the equivalent static force procedure is most often adequate. Structures that are classified as *irregular* violate the assumptions on which the empirical formulas, used in the equivalent static force procedure, are developed.

**Step by step procedure for Equivalent static force analysis:**

Step-1: Depending on the location of the building site, identify the seismic zone and assign Zone factor (Z).

Step-2: Compute the seismic weight of the building (W) as per code.

*Step-3:* Compute the natural period of the building ($T_a$)as per code.

Step-4: Obtain the data pertaining to type of soil conditions of foundation of the building as per code.

Step-5: Using ($T_a$)and soil type, compute the average spectral acceleration as per code.

Step-6: Assign the value of importance factor ($I$) depending on occupancy and/or functionality of structure as per code.

Step-7: Assign the values of response reduction factor ($R$) depending on type of structure as per code.

Step-8: Knowing $Z$, $\frac{S_a}{g}$ ,$R$ and $I$ compute design horizontal acceleration coefficient $A_h$ as per code.

Step-9: Using $A_h$ and W compute design seismic base shear ($V_B$), from $V_b = A_h W$ as per code

### 4.3.2 Dynamic Analysis

Dynamic analysis is classified into two types:

a) Response spectrum method
b) Time history method

Dynamic analysis shall be performed to obtain the design seismic force and its distribution along the height of the building and to the various lateral load resisting elements, for the following buildings:

1. Regular buildings — Those greater than 40 m in height in Zones IV and V and those greater than 90 m in height in Zones II and III.
2. Irregular buildings — All framed buildings higher than 12 m in Zones IV and V, and those greater than 40 m in height in Zones II and III.

a) Time History Method: Time history method of analysis, when used, shall be based on an appropriate ground motion and shall be performed using accepted principles of dynamics.
b) Response Spectrum Method: Response spectrum method of analysis shall be performed using the design spectrum

**Modes to be considered:**

The number of modes to be used in the analysis should be such that the sum total of modal masses of all modes considered is at least 90%.

**Step by step procedure for Response spectrum method**

Step-1: Depending on the location of the building site, identify the seismic zone and assign Zone factor (Z).

Step-2: Compute the seismic weight of the building (W) as per code.

Step-3: Establish mass [M] and stiffness [K] matrices of the building using system of masses lumped at the floor levels with each mass having one degree of freedom, that of lateral displacement in the direction under consideration. Accordingly, to develop stiffness matrix effective stiffness of each floor is computed using the lateral stiffness coefficients of columns and infill walls. Usually floor slab is assumed to be infinitely stiff.

Step-4: Using [M] and [K] of previous step and employing the principles of dynamics compute the modal frequencies, {w} and corresponding mode shapes, [j].

Step-5: Compute modal mass Mk of mode k as per code.

Step-6: Compute modal participation factors $P_k$ of mode k as per code.

Step-7: Compute design lateral force ($Q_{ik}$) at each floor in each mode as per code.

Step-8: Compute storey shear forces in each mode ($V_{ik}$) acting in storey i in mode k as per code.

Step-9: Compute storey shear forces due to all modes considered, Vi in storey i, by combining shear forces due to each mode as per code.

## 4.3.3Output Parameters

Parameter in which changes is noted after modifying the structure are frequency, time period, spectral acceleration, base shear, SRSS shear, CQC shear, shear 10PT shear, ABS shear, storey shear, storey drift, mass participation factor.

**Storey drift Limitation**: The storey drift in any due to minimum specified design lateral load with partial factor of safety 1.0 shall not be increased by 0.004 times the storey height.

**Modal Participation Factor**: Modal participation factor of mode k of vibration is the amount by which mode k contributes to the overall vibration of the structure under horizontal and vertical earthquake ground motions. Since the amplitudes of 95 percent mode shapes can be scaled arbitrarily, the value of this factor depends on the scaling used for mode shapes.

**Natural Period**: Natural period of a structure is its time period of undamped free vibration.

**Storey Drift:** It is the displacement of one level relative to the otherlevel above or below.

**Storey Shear:** It is the sum of design lateral forces at all levels above the storey under consideration**.**

**SRSS METHOD:** Itis approximate for combining modal response. In this method, the squares of a specific response are summed. The square root of this sum is taken to be combines effect. It is important to note that the quantities combined are those for each individual mode.

$$r_o = \left(\sum_{n=1}^{nN} {r_{no}}^2\right)^{0.5}$$

.

This method gives excellence response estimates for structure with well separated natural frequencies.

**CQC METHOD**: It is modal combination method based on the use of cross modal coefficient. The cross modal coefficient reflects the duration and frequency content of seismic event as well as the modal frequencies and damping ratio of the structure.

$$r_o = \left(\sum_{i=1}^{N}\sum_{n=1}^{N} \rho_{in} r_{io} r_{no}\right)^{0.5}$$

This method gives acceptable response estimates for types of structure having well separated natural frequencies as well as to those having closely spaced natural frequencies like in multi-storey building with unsymmetrical plan.

**ABS METHOD:** It is modal combination method based on assumption that all modal peaks occurs at the same time and algebraic sign is ignored to get an upper bound to the peak value of the total response. This upper bound value (ABS VALUE) is too conservative.

$$r_o \leq \sum_{n=0}^{N} r_{no}$$

## 4.4 Codal Provision

Most building codes propose a simplified method called the equivalent lateral force (ELF) procedure or the multi-mode response spectrum method to compute design forces. These methods assume that the dynamic forces developed in a structure during an earthquake are proportional to the maximum ground acceleration and the modal characteristics of the structure. These forces are approximated as a set of equivalent lateral forces which are distributed over the height of the structure. However, the ELF method is based on a number of assumptions which are true for regular structures “structures with uniform distribution of stiffness, strength, and mass over the height”. So the current building codes define criteria in order to categorize building structures as either regular or irregular as explained below.

**IS CODE 1893 (PART 1) : 2002 (TABLE 5 CLAUSE 7.1)**

a) **Stiffness Irregularity —Soft Storey**

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

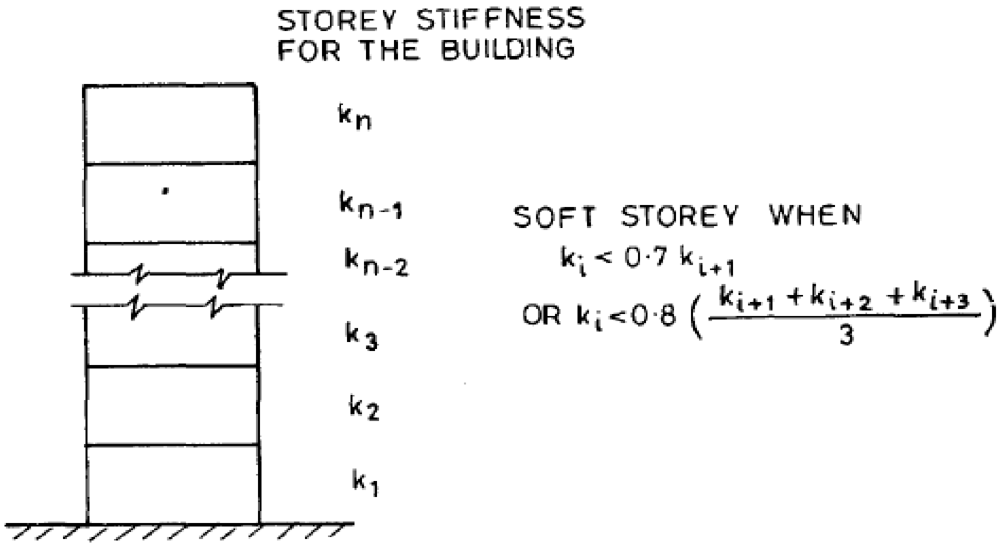



**FIG.9** Stiffness Irregularity

**According to UBC,**

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

**NZS 1170.5 defines irregularity (in Clause 4.5) as:**

Vertical stiffness irregularity (soft storey) – The lateral storey stiffness is less than 70% of adjacent storey stiffness or less than 80% of average stiffness of storey above or below.
NEHRP code (BSSC, 2003) has similar specification to that of IS 1893 (PART 1): 2002

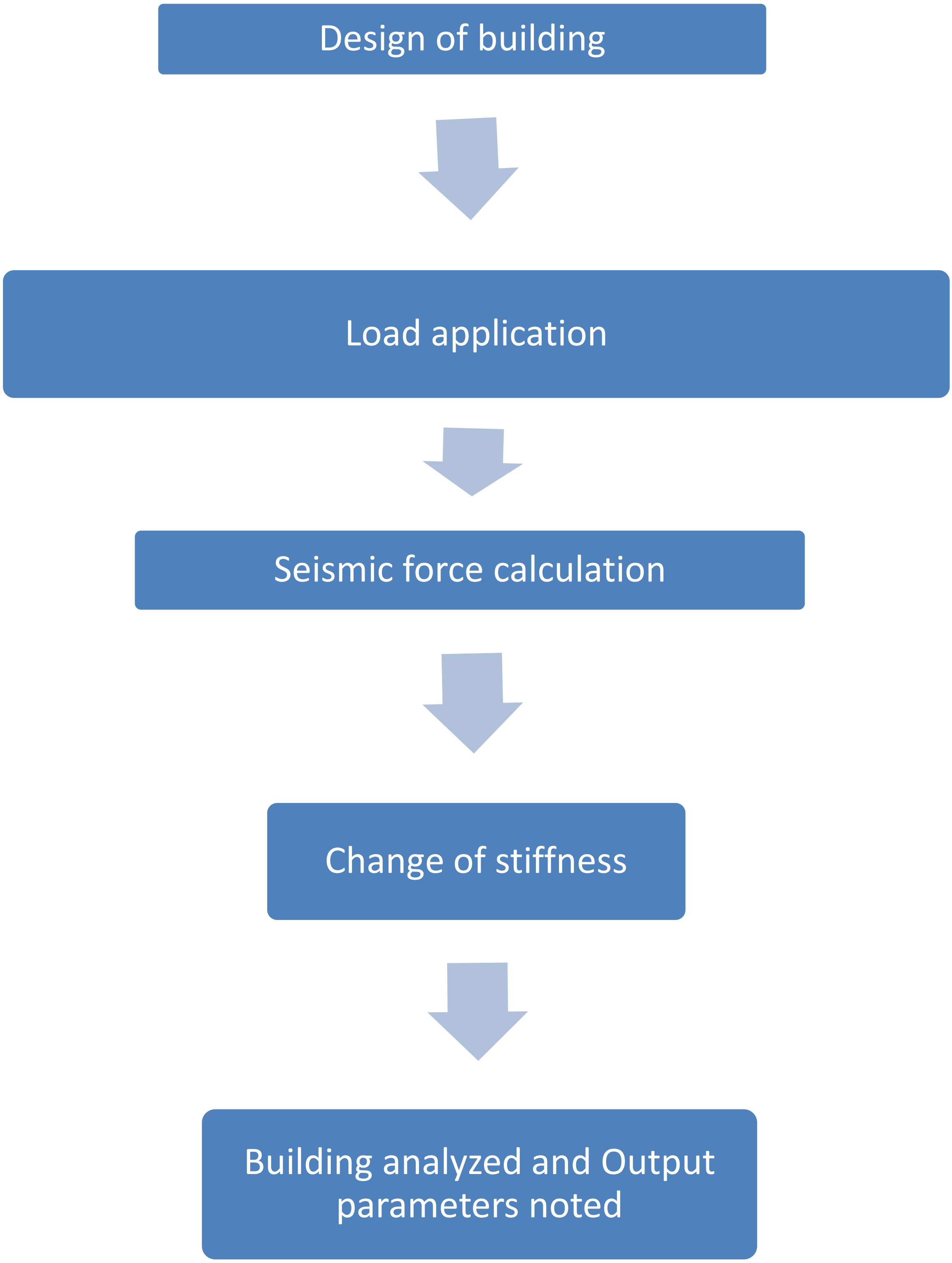
**International Building Code (IBC):**

Soft Story: is defined to exist when there is a story in which the lateral stiffness is less than 70% of that in the story above or less than 80% of the average stiffness of the three stories above.

**Various output parameter used in this study are expressed in following unit:**

| | |
|---|---|
| 1. Frequency | cycle/sec |
| 2. Time period | shear |
| 3. Shear | Mt |
| 4. Drift | cm |
| 5. Height | m |
| 6. Force reaction | Newton (N) |
| 7. Moment reaction | Kilonewton-metre (kNm) |

## 4. Details of Steps Performed



# CHAPTER 5

# RESULT AND DISCUSSIONS

## 5.1 Variation Of Frequency Vs Stiffness%

**Table 5 Variation Of Frequency Vs Stiffness%**

| FREQUENCY VS STIFFNESS% | | | | | |
|---|---|---|---|---|---|
| Stiffness | 1ST STOREY | 2ND STOREY | 3RD STOREY | 4TH STOREY | 5TH STOREY |
| 100% | 0.909 | 0.909 | 0.909 | 0.909 | 0.909 |
| 90% | 0.907 | 0.907 | 0.908 | 0.908 | 0.909 |
| 80% | 0.904 | 0.904 | 0.906 | 0.907 | 0.909 |
| 70% | 0.901 | 0.901 | 0.903 | 0.906 | 0.908 |
| 60% | 0.896 | 0.896 | 0.9 | 0.904 | 0.908 |
| 50% | 0.89 | 0.89 | 0.896 | 0.902 | 0.907 |

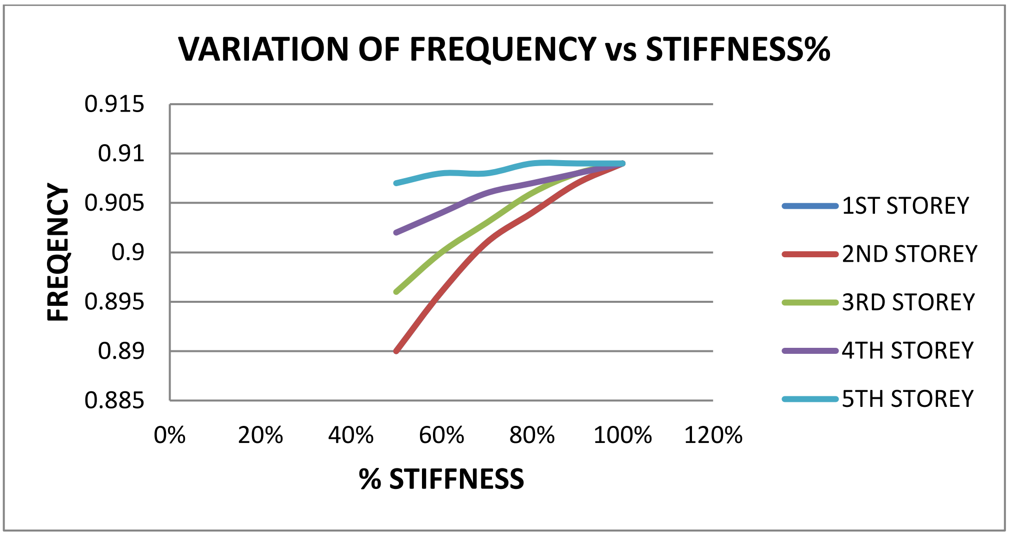



**Fig. 10** Variation of frequency Vs stiffness%

**Table 6 Equation of curve of Frequency Vs Stiffness% for each floor (here 'y' represent frequency and 'x' represent % stiffness.**

| FLOOR | EQUATION |
|---|---|
| 1 | $y = -0.05x^2 + 0.1124x + 0.8464$ |
| 2 | $y = -0.05x^2 + 0.1124x + 0.8464$ |
| 3 | $y = -0.0339x^2 + 0.0772x + 0.8659$ |
| 4 | $y = -0.0161x^2 + 0.0378x + 0.8871$ |
| 5 | $y = -0.0089x^2 + 0.0174x + 0.9006$ |

Frequency decreases with decrease in stiffness irrespective of location of decreasing of stiffness. The maximum variation in frequency is seen when stiffness is changed in first storey and second storey and it is 2.1% less than base case. The minimum variation in frequency is seen in fifth storey or topmost storeys.

## 5.2 Variation Of Time-Period Vs Stiffness%

**Table 7 Variation Of Time-Period Vs Stiffness%**

| TIME-PERIOD VS STIFFNESS% | | | | | |
|---|---|---|---|---|---|
| STIFFNESS | 1ST STOREY | 2ND STOREY | 3RD STOREY | 4TH STOREY | 5TH STOREY |
| 100% | 1.09981 | 1.09981 | 1.09981 | 1.09981 | 1.09981 |
| 90% | 1.102565 | 1.10268 | 1.10185 | 1.1009 | 1.10014 |
| 80% | 1.1061 | 1.10619 | 1.10434 | 1.10222 | 1.10053 |
| 70% | 1.11027 | 1.11048 | 1.10737 | 1.1038 | 1.10099 |
| 60% | 1.11598 | 1.11635 | 1.11146 | 1.10594 | 1.10161 |
| 50% | 1.12318 | 1.12379 | 1.11669 | 1.10862 | 1.10237 |

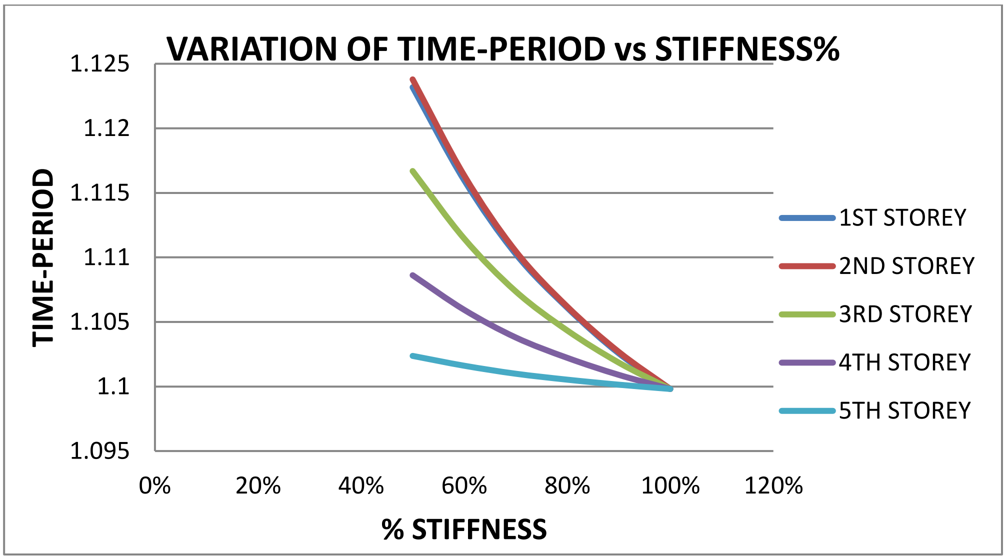



**Fig. 11** Variation of time period Vs stiffness%

**Table 8 Equation of curve of Time Period Vs Stiffness% for each floor**

| FLOOR | EQUATION |
|---|---|
| 1 | $y = 0.0552x^2 - 0.1289x + 1.1737$ |
| 2 | $y = 0.0577x^2 - 0.1337x + 1.176$ |
| 3 | $y = 0.0399x^2 - 0.0931x + 1.153$ |
| 4 | $y = 0.0201x^2 - 0.0474x + 1.127$ |
| 5 | $y = 0.0055x^2 - 0.0133x + 1.1076$ |

Time-period increases with decreases in stiffness. The maximum variation in time-period is seen in second storey and it is 2.08% more than base case. The minimum variation is seen in fifth storey or topmost storey.

## 5.3 Variation Of Spectral Acceleration Vs Stiffness%

**Table 9 Variation Of Spectral Acceleration Vs Stiffness%**

| SPECTRAL ACCELERATION VS STIFFNESS% | | | | | |
|---|---|---|---|---|---|
| STIFFNESS | 1ST STOREY | 2ND STOREY | 3RD STOREY | 4TH STOREY | 5TH STOREY |
| 100% | 1.23658 | 1.23658 | 1.23658 | 1.23658 | 1.23658 |
| 90% | 1.23339 | 1.23336 | 1.23428 | 1.23535 | 1.23621 |
| 80% | 1.22955 | 1.22944 | 1.2315 | 1.23388 | 1.23577 |
| 70% | 1.22493 | 1.2247 | 1.22813 | 1.23211 | 1.23525 |
| 60% | 1.21866 | 1.21826 | 1.22362 | 1.22973 | 1.23456 |
| 50% | 1.21085 | 1.21019 | 1.21788 | 1.22675 | 1.2337 |

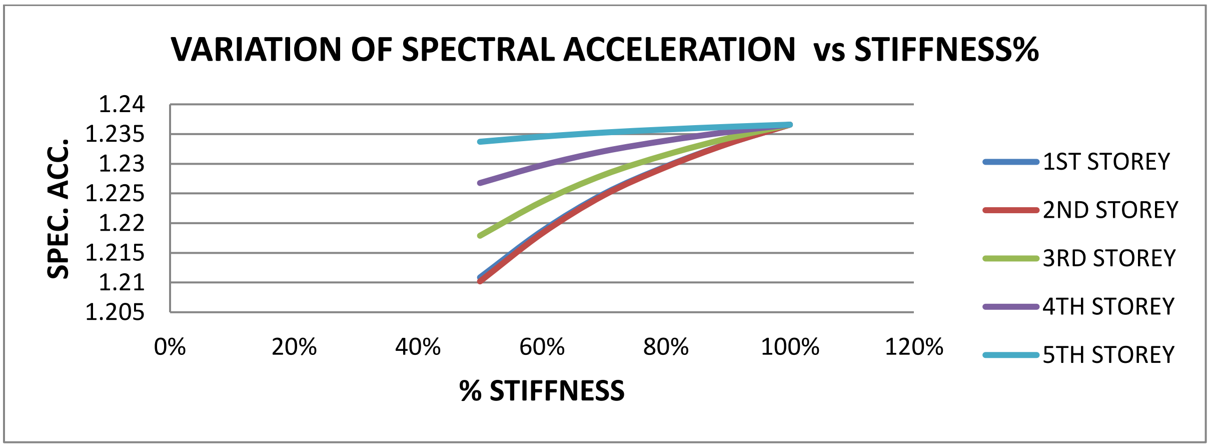



**Fig. 12** Variation of spectral acceleration Vs stiffness%

**Table 10 Equation of curve of Spectral Acceleration Vs Stiffness% for each floor**

| FLOOR | EQUATION |
|---|---|
| 1 | $y = -0.0613x^2 + 0.144x + 1.1537$ |
| 2 | $y = -0.0613x^2 + 0.144x + 1.1537$ |
| 3 | $y = -0.0431x^2 + 0.1014x + 1.1781$ |
| 4 | $y = -0.0221x^2 + 0.0526x + 1.2061$ |
| 5 | $y = -0.0062x^2 + 0.0149x + 1.2278$ |

Spectral acceleration decreases with decrease in stiffness. The maximum variation in spectral acceleration is seen in second storey which is quite similar to that of first storey. Maximum variation is 2.07% with respect to base case that is seen in second storey. The minimum variation is seen in fifth storey or top-most storey.

## 5.4 Variation Of Base Shear Vs Stiffness%

**Table 11 Variation Of Base Shear Vs Stiffness%**

| BASE SHEAR VS STIFFNESS% | | | | | |
|---|---|---|---|---|---|
| STIFFNESS | 1ST STOREY | 2ND STOREY | 3RD STOREY | 4TH STOREY | 5TH STOREY |
| 100% | 58.3 | 58.3 | 58.3 | 58.3 | 58.3 |
| 90% | 58.23 | 58.16 | 58.16 | 58.21 | 58.27 |
| 80% | 58.11 | 57.94 | 57.95 | 58.08 | 58.24 |
| 70% | 57.91 | 57.63 | 57.68 | 57.92 | 58.2 |
| 60% | 57.6 | 57.16 | 57.27 | 57.67 | 58.13 |
| 50% | 57.13 | 56.5 | 56.7 | 57.34 | 58.05 |

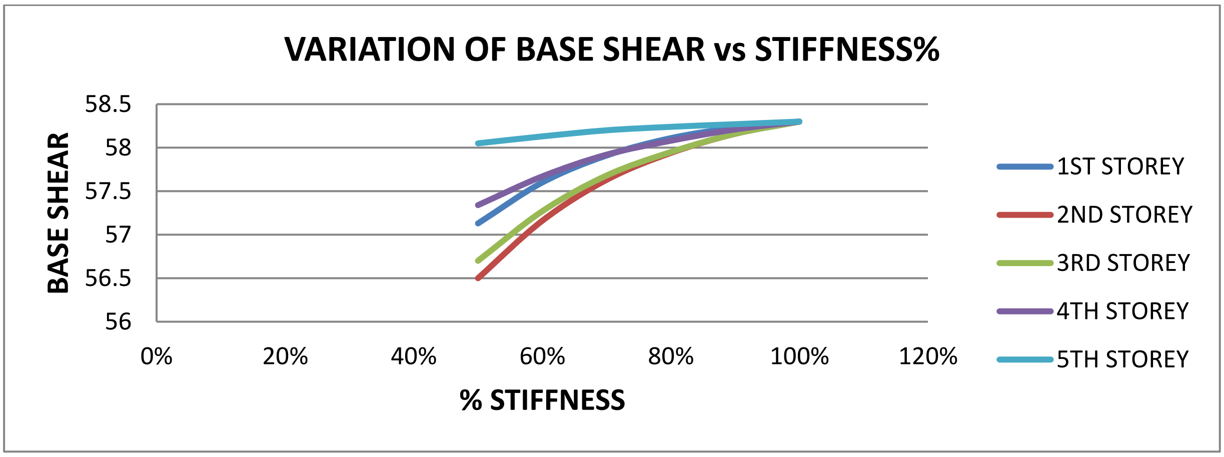



**Fig. 13** Variation of base shear Vs stiffness%

**Table 12 Equation of curve of Base Shear Vs Stiffness% for each floor**

| FLOOR | EQUATION |
|---|---|
| 1 | $y = -4.9286x^2 + 9.6614x + 53.55$ |
| 2 | $y = -6.4286x^2 + 13.16x + 51.549$ |
| 3 | $y = -5.2679x^2 + 11.028x + 52.523$ |
| 4 | $y = -3x^2 + 6.38x + 54.91$ |
| 5 | $y = -0.7321x^2 + 1.5868x + 57.441$ |

Base shear decrease with decrease in stiffness. The maximum variation is seen when stiffness changes in the second storey which is quite closer to the variation that is in first storey. The maximum variation is 3.07% with respect to base case that is seen in second storey. The minimum variation is seen in fifth storey or topmost storey.

## 5.5 Variation Of Square root of sum of square of shear Vs Stiffness%

**Table 13 Variation Of Square root of sum of square of shear Vs Stiffness%**

| SRSS VS STIFFNESS% | | | | | |
|---|---|---|---|---|---|
| STIFFNESS | 1ST STOREY | 2ND STOREY | 3RD STOREY | 4TH STOREY | 5TH STOREY |
| 100% | 60.7 | 60.7 | 60.7 | 60.7 | 60.7 |
| 90% | 60.59 | 60.53 | 60.54 | 60.59 | 60.65 |
| 80% | 60.48 | 60.3 | 60.37 | 60.55 | 60.63 |
| 70% | 60.33 | 60.02 | 60.17 | 60.46 | 60.64 |
| 60% | 60.05 | 59.6 | 59.83 | 60.27 | 60.62 |
| 50% | 59.59 | 58.97 | 59.33 | 60 | 60.56 |

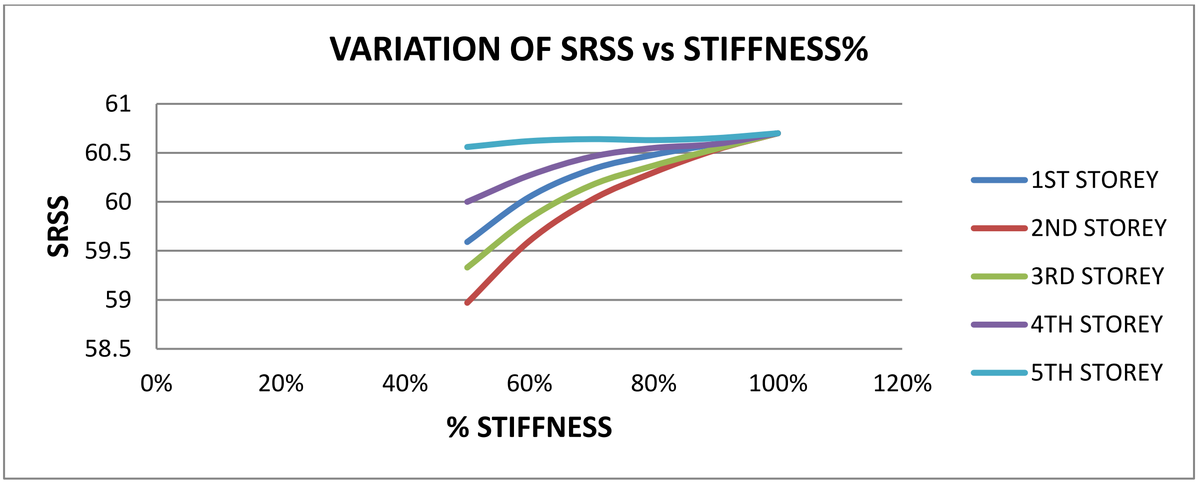



**Fig. 14**Variation of SRSS Vs stiffness%

**Table 14 Equation of curve of SRSS Vs Stiffness% for each floor**

| FLOOR | EQUATION |
|---|---|
| 1 | $y = -4.3393x^2 + 8.6004x + 56.407$ |
| 2 | $y = -5.4643x^2 + 11.545x + 54.594$ |
| 3 | $y = -4.25x^2 + 8.9979x + 55.923$ |
| 4 | $y = -2.5x^2 + 5.05x + 58.12$ |
| 5 | $y = -0.0893x^2 + 0.3568x + 60.419$ |

## 5.6 Variation Of 10 PCT Vs Stiffness%

**Table 15 Variation Of10 PCTVs Stiffness%**

| 10 PCT VS STIFFNESS% | | | | | |
|---|---|---|---|---|---|
| STIFFNESS | 1ST STOREY | 2ND STOREY | 3RD STOREY | 4TH STOREY | 5TH STOREY |
| 100% | 62.6 | 62.6 | 62.6 | 62.6 | 62.6 |
| 90% | 62.52 | 62.47 | 62.48 | 62.52 | 62.58 |
| 80% | 62.41 | 62.3 | 62.32 | 62.42 | 62.55 |
| 70% | 62.28 | 62.09 | 62.12 | 62.3 | 62.51 |
| 60% | 62.12 | 61.81 | 61.86 | 62.12 | 62.46 |
| 50% | 61.95 | 61.5 | 61.54 | 61.89 | 62.39 |

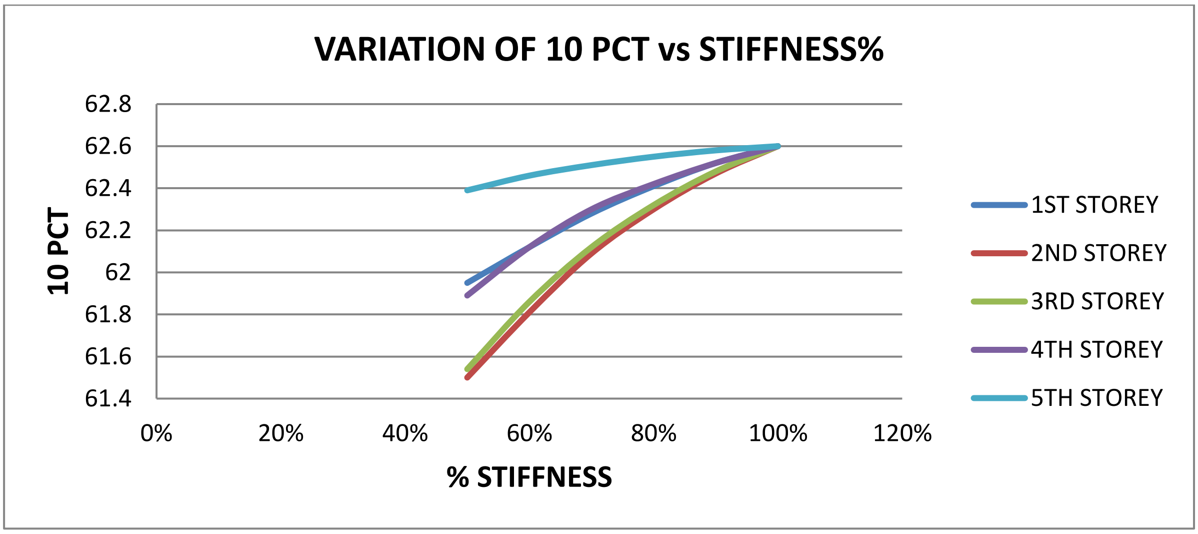



**Fig. 15** Variation of 10PCT Vs stiffness%

**Table 16 Equation of curve of 10 PCT Vs Stiffness% for each floor**

| FLOOR | EQUATION |
|---|---|
| 1 | $y = -1.1607x^2 + 3.0496x + 60.713$ |
| 2 | $y = -2.3929x^2 + 5.7864x + 59.204$ |
| 3 | $y = -2.5x^2 + 5.8529x + 59.243$ |
| 4 | $y = -1.9107x^2 + 4.2575x + 60.246$ |
| 5 | $y = -0.5893x^2 + 1.2982x + 61.89$ |

## 5.7 Variation Of Absolute Sum Shear Vs Stiffness%

**Table 17 Variation Of ABS Vs Stiffness%**

| ABS VS STIFFNESS% | | | | | |
|---|---|---|---|---|---|
| STIFFNESS | 1ST STOREY | 2ND STOREY | 3RD STOREY | 4TH STOREY | 5TH STOREY |
| 100% | 97.83 | 97.83 | 97.83 | 97.83 | 97.83 |
| 90% | 97.59 | 97.64 | 97.75 | 97.8 | 97.81 |
| 80% | 97.3 | 97.41 | 97.66 | 97.77 | 97.78 |
| 70% | 96.95 | 97.15 | 97.55 | 97.73 | 97.75 |
| 60% | 96.48 | 96.8 | 97.42 | 97.69 | 97.71 |
| 50% | 95.89 | 96.38 | 97.26 | 97.66 | 97.66 |

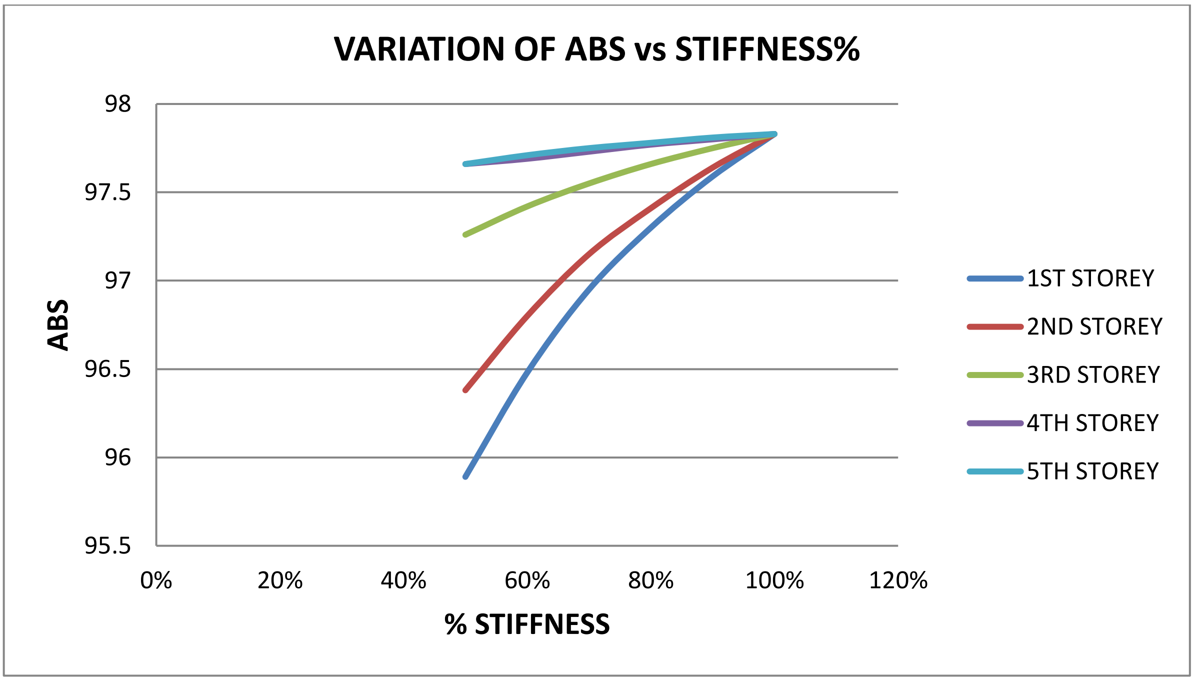



**Fig. 16** Variation of ABS Vs stiffness%

**Table 18 Equation of curve of ABS Vs Stiffness% for each floor**

| FLOOR | EQUATION |
|---|---|
| 1 | $y = -4.4107x^2 + 10.439x + 91.787$ |
| 2 | $y = -2.9107x^2 + 7.2318x + 93.5$ |
| 3 | $y = -1x^2 + 2.6286x + 96.199$ |
| 4 | $y = -0.3393x^2 + 0.8461x + 97.323$ |
| 5 | $y = -0.3393x^2 + 0.8461x + 97.323$ |

## 5.8 Variation Of Complete Quadratic Combination shear Vs Stiffness%

**Table 19 Variation Of CQCVs Stiffness%**

| CQC VS STIFFNESS% | | | | | |
|---|---|---|---|---|---|
| STIFFNESS | 1ST STOREY | 2ND STOREY | 3RD STOREY | 4TH STOREY | 5TH STOREY |
| 100% | 65.2 | 65.2 | 65.2 | 65.2 | 65.2 |
| 90% | 65.05 | 64.99 | 65.02 | 65.09 | 65.16 |
| 80% | 64.86 | 64.74 | 64.81 | 64.95 | 65.12 |
| 70% | 64.63 | 64.42 | 64.54 | 64.79 | 65.06 |
| 60% | 64.31 | 63.97 | 64.18 | 64.57 | 64.99 |
| 50% | 63.88 | 63.39 | 63.71 | 64.28 | 64.9 |

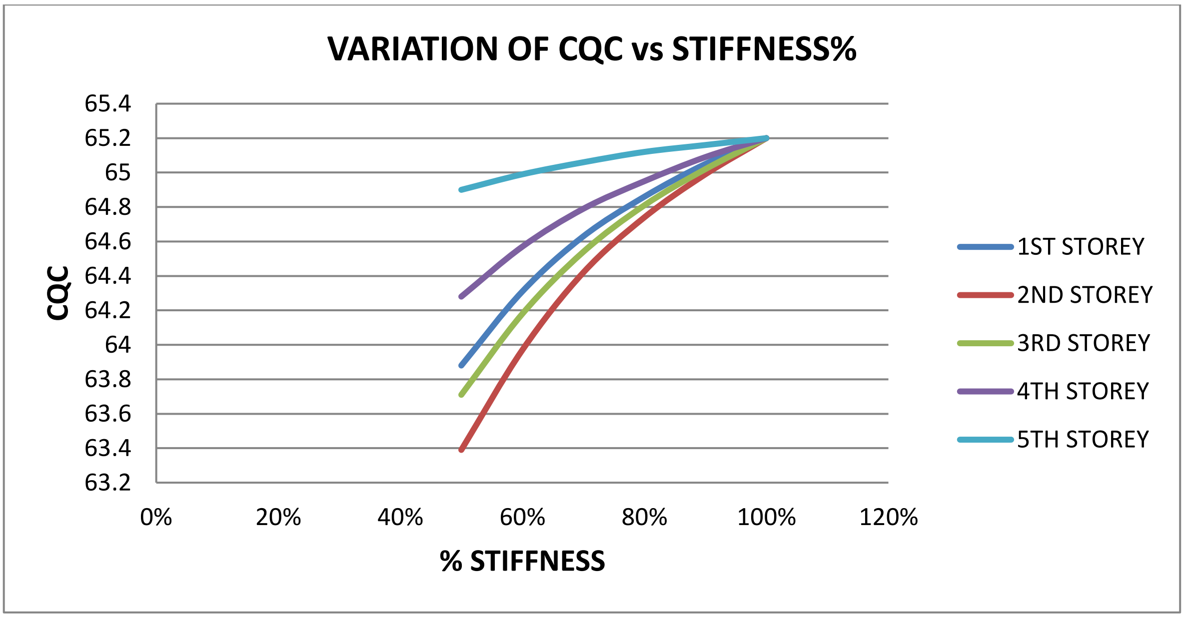



**Fig. 17** Variation of CQC Vs stiffness%

**Table 20 Equation of curve of CQC Shear Vs Stiffness% for each floor:**

| FLOOR | EQUATION |
|---|---|
| 1 | $y = -3.4286x^2 + 7.7286x + 60.887$ |
| 2 | $y = -4.7321x^2 + 10.65x + 59.264$ |
| 3 | $y = -3.6607x^2 + 8.4168x + 60.43$ |
| 4 | $y = -2.1786x^2 + 5.0736x + 62.297$ |
| 5 | $y = -0.6607x^2 + 1.5825x + 64.276$ |

SRSS Shear , CQC Shear, Shear 10pct Shear shows the same trend as Base Shear. In ABS Shear case the variation is seen maximum in first storey.

## 5.9 Variation Of Roof Drift Vs Stiffness%

**Table 21 Variation Of Roof Drift Vs Stiffness%**

| ROOF DRIFT VS STIFFNESS% | | | | | |
|---|---|---|---|---|---|
| STIFFNESS | 1ST STOREY | 2ND STOREY | 3RD STOREY | 4TH STOREY | 5TH STOREY |
| 100% | 0.016 | 0.016 | 0.016 | 0.016 | 0.016 |
| 90% | 0.016 | 0.016 | 0.016 | 0.016 | 0.016 |
| 80% | 0.016 | 0.016 | 0.016 | 0.016 | 0.016 |
| 70% | 0.016 | 0.016 | 0.016 | 0.016 | 0.016 |
| 60% | 0.016 | 0.016 | 0.016 | 0.016 | 0.016 |
| 50% | 0.016 | 0.0159 | 0.0159 | 0.0161 | 0.0159 |

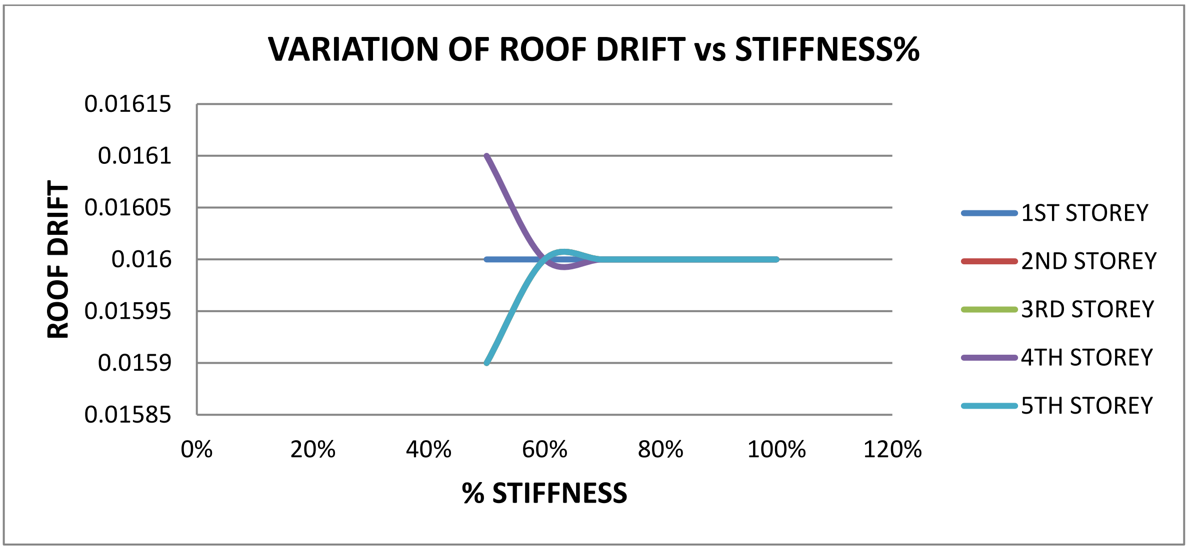



**Fig. 18** Variation of roof drift Vs stiffness%

**Table 22 Equation of curve of Roof drift Vs Stiffness for each floor:**

| FLOOR | EQUATION |
|---|---|
| 1 | y = 0.016 |

For present building variation in roof drift is observed negligible with given building specification.

## 5.10 Variation of max. Fx Vs Stiffness%

**Table 23 Variation of max. Fx Vs stiffness%**

| STIFFNESS | 100 | 90 | 80 | 70 | 60 | 50 |
|---|---|---|---|---|---|---|
| 1ST STOREY | 61797.69 | 60395.27 | 58830.17 | 57085.01 | 55049.06 | 52784.83 |
| 2ND STOREY | 61797.69 | 62246.81 | 62749.51 | 63311.31 | 63915.38 | 64536.55 |
| 3RD STOREY | 61797.69 | 61984.25 | 62188.41 | 62406.91 | 62590.55 | 62748.21 |
| 4TH STOREY | 61797.69 | 61941.72 | 62100.35 | 62271.59 | 62432.72 | 62566.12 |
| 5TH STOREY | 61797.69 | 61874.31 | 61963.36 | 62065.29 | 62176.78 | 62285.24 |

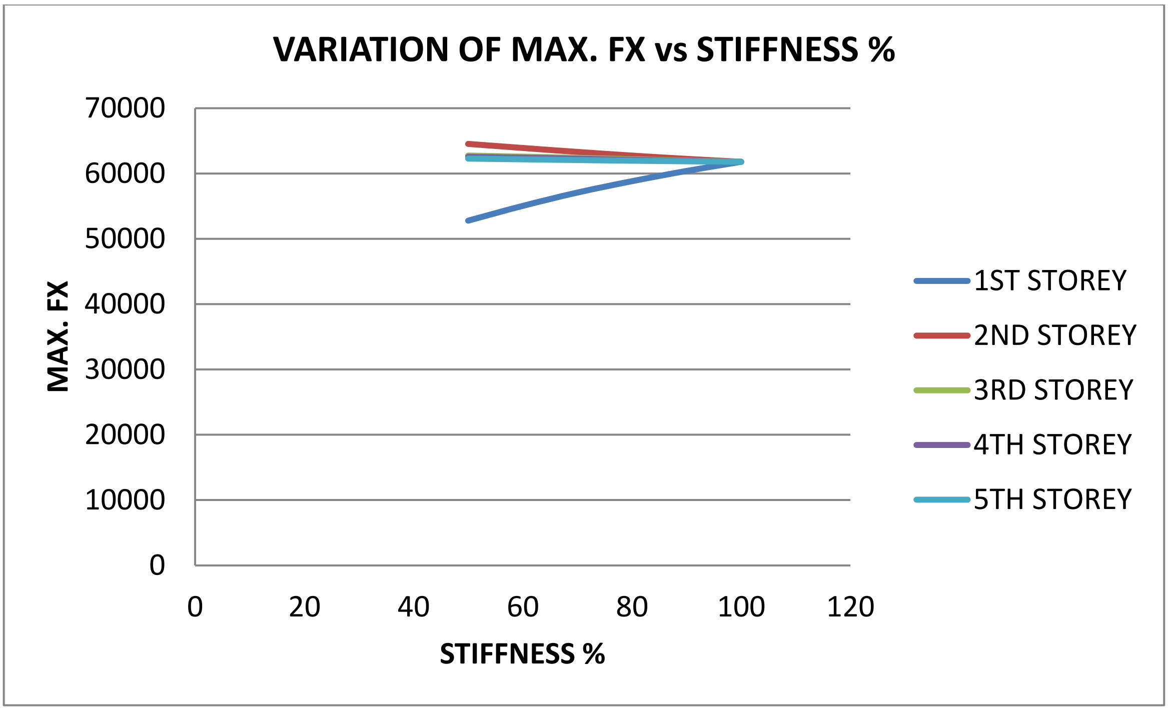



**Fig. 19** Variation of max. Fx Vs. Stiffness%

**Table 24 Equation of curve of MAX. Fx Vs Stiffness% for each floor:**

| FLOORS | EQUATION |
|---|---|
| 1 | $y = -1.1058x^2 + 345.44x + 38292$ |
| 2 | $y = 0.226x^2 - 88.937x + 68426$ |
| 3 | $y = 0.0445x^2 - 16.517x + 63003$ |
| 4 | $y = 0.226x^2 - 88.937x + 68426$ |
| 5 | $y = 0.0445x^2 - 16.517x + 63003$ |

## 5.11 Variation Of max. Fy Vs Stiffness%

**Table 25 Variation of max. Fy Vs stiffness%**

| STIFFNESS | 100 | 90 | 80 | 70 | 60 | 50 |
|---|---|---|---|---|---|---|
| 1ST STOREY | 4.72E+06 | 4.81E+06 | 4.92E+06 | 5.05E+06 | 5.19E+06 | 5.32E+06 |
| 2ND STOREY | 4.72E+06 | 4.81E+06 | 4.92E+06 | 5.04E+06 | 5.17E+06 | 5.30E+06 |
| 3RD STOREY | 4.72E+06 | 4.79E+06 | 4.88E+06 | 4.98E+06 | 5.09E+06 | 5.21E+06 |
| 4TH STOREY | 4.72E+06 | 4.77E+06 | 4.83E+06 | 4.91E+06 | 4.99E+06 | 5.07E+06 |
| 5TH STOREY | 4.72E+06 | 4.75E+06 | 4.78E+06 | 4.81E+06 | 4.86E+06 | 4.90E+06 |

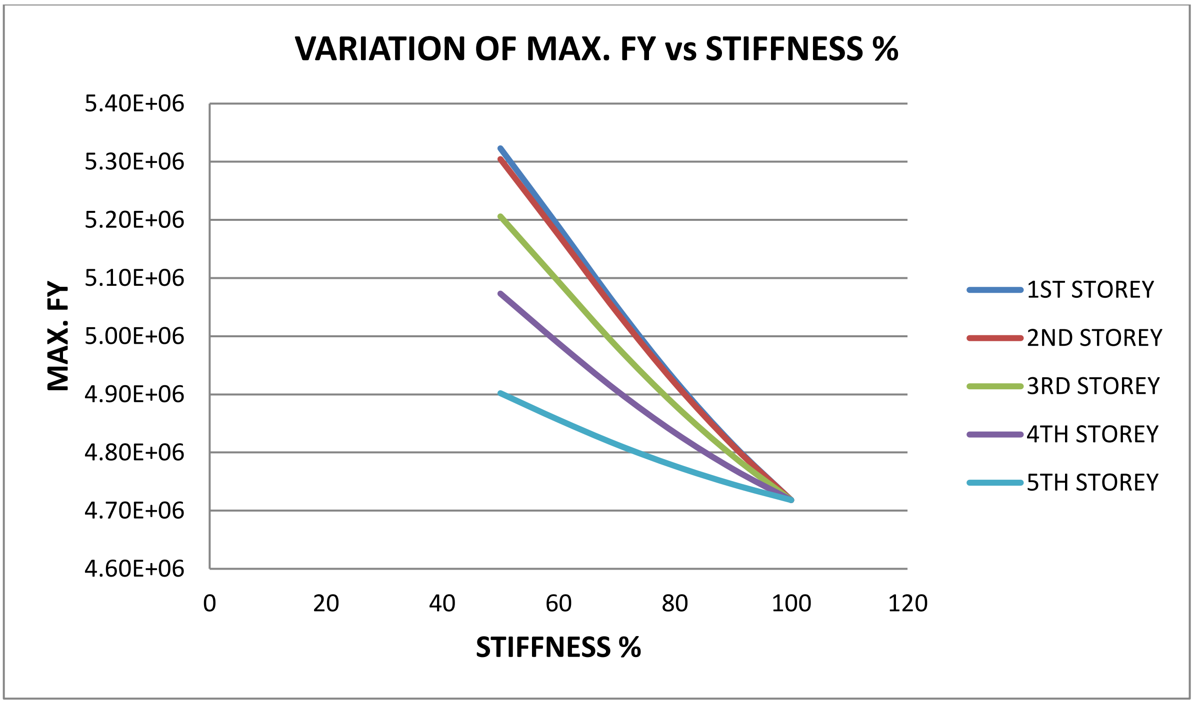



**Fig. 20** Variation of max. Fy Vs stiffness%

**Table 26  Equation of curve of MAX. Fy Vs Stiffness% for each floor**

| FLOOR | EQUATION |
|---|---|
| 1 | $y = 53.588x^2 - 20254x + 6E+06$ |
| 2 | $y = 50.877x^2 - 19463x + 6E+06$ |
| 3 | $y = 49.629x^2 - 17270x + 6E+06$ |
| 4 | $y = 42.211x^2 - 13464x + 6E+06$ |
| 5 | $y = 24.525x^2 - 7363x + 5E+06$ |

## 5.12 Variation Of max. Fz Vs Stiffness%

**Table 27 Variation of max. Fz Vs stiffness%**

| STIFFNESS | 100 | 90 | 80 | 70 | 60 | 50 |
|---|---|---|---|---|---|---|
| 1ST STOREY | 1.86E+06 | 1.92E+06 | 2.00E+06 | 2.09E+06 | 2.20E+06 | 2.33E+06 |
| 2ND STOREY | 1.86E+06 | 1.91E+06 | 1.98E+06 | 2.05E+06 | 2.14E+06 | 2.23E+06 |
| 3RD STOREY | 1.86E+06 | 1.91E+06 | 1.96E+06 | 2.03E+06 | 2.10E+06 | 2.18E+06 |
| 4TH STOREY | 1.86E+06 | 1.89E+06 | 1.94E+06 | 1.99E+06 | 2.04E+06 | 2.10E+06 |
| 5TH STOREY | 1.86E+06 | 1.88E+06 | 1.90E+06 | 1.92E+06 | 1.95E+06 | 1.98E+06 |

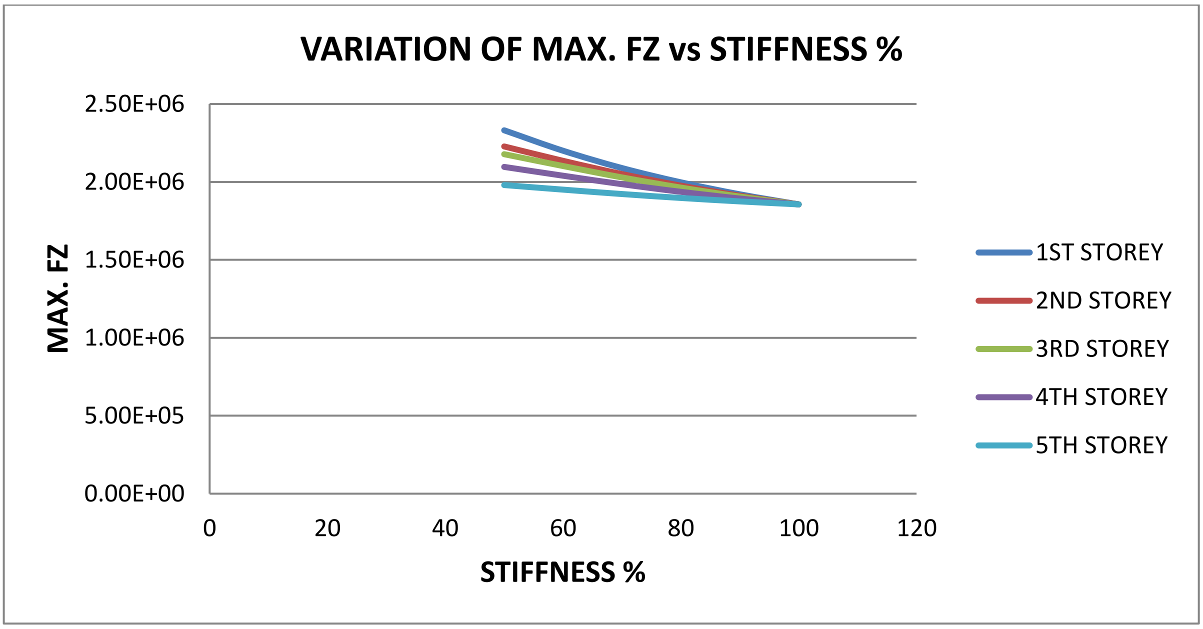



**Fig. 21** Variation of max.Fz Vs stiffness%

**Table 28 Equation of curve of MAX. Fz Vs Stiffness% for each floor**

| FLOOR | EQUATION |
|---|---|
| 1 | $y = 83.961x^2 - 22042x + 3E+06$ |
| 2 | $y = 47.395x^2 - 14549x + 3E+06$ |
| 3 | $y = 34.086x^2 - 11579x + 3E+06$ |
| 4 | $y = 25.088x^2 - 8592.2x + 2E+06$ |
| 5 | $y = 13.636x^2 - 4536.5x + 2E+06$ |

## 5.13 Variation Of max. Mx Vs Stiffness%

**Table 29 Variation of max.Mx Vs stiffness%**

| STIFFNESS | 100 | 90 | 80 | 70 | 60 | 50 |
|---|---|---|---|---|---|---|
| 1ST STOREY | 10554.86 | 10923.19 | 11360.26 | 11881.14 | 12513.14 | 13260.36 |
| 2ND STOREY | 10554.86 | 10871.99 | 11239.46 | 11661.98 | 12146.66 | 12672.33 |
| 3RD STOREY | 10554.86 | 10840.74 | 11168.9 | 11541.24 | 11957.89 | 12390.89 |
| 4TH STOREY | 10554.86 | 10768.74 | 11014.33 | 11293.37 | 11603.81 | 11926.08 |
| 5TH STOREY | 10554.86 | 10664.37 | 10790.33 | 10933.71 | 11094.32 | 11263.08 |

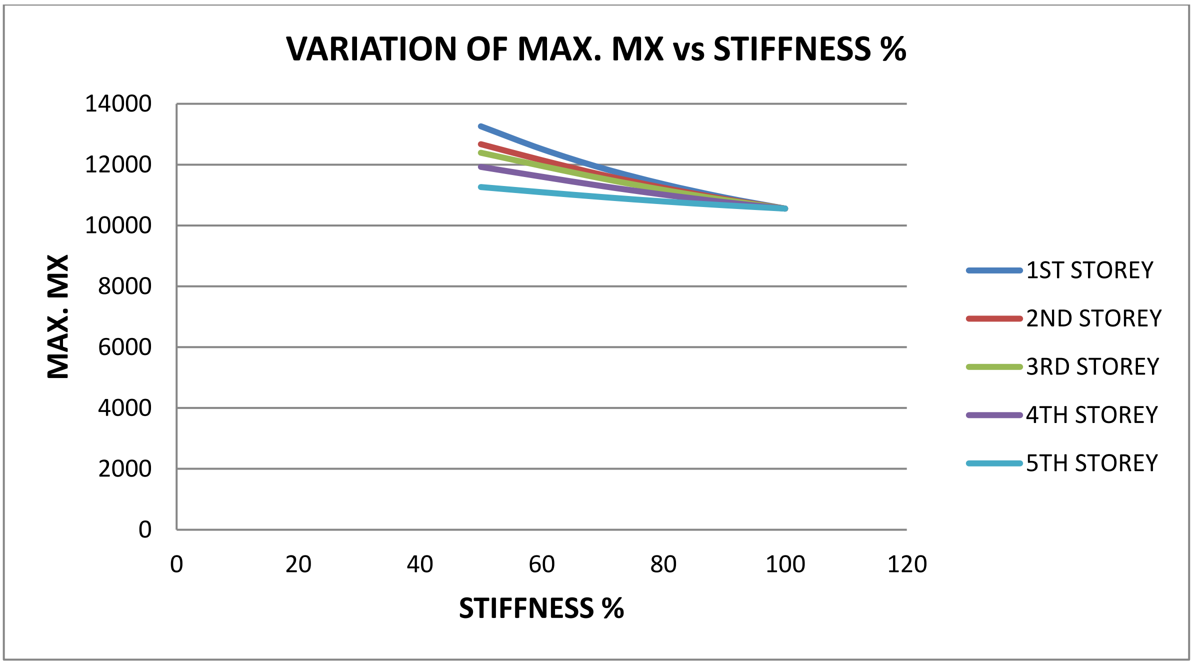



**Fig. 22** Variation of max.Mx Vs stiffness%

**Table 30 Equation of curve of MAX. Mx Vs Stiffness% for each floor**

| FLOOR | EQUATION |
|---|---|
| 1 | $y = 0.4775x^2 - 125.4x + 18328$ |
| 2 | $y = 0.2699x^2 - 82.871x + 16143$ |
| 3 | $y = 0.1946x^2 - 66.053x + 15212$ |
| 4 | $y = 0.1431x^2 - 49.008x + 14022$ |

## 5.14 Variation of max. My Vs Stiffness%

**Table 31 Variation of max. My Vs stiffness**

| STIFFNESS | 100 | 90 | 80 | 70 | 60 | 50 |
|---|---|---|---|---|---|---|
| 1ST STOREY | 72.801 | 74.127 | 75.636 | 77.384 | 79.362 | 81.638 |
| 2ND STOREY | 72.801 | 73.963 | 75.269 | 76.717 | 78.26 | 79.786 |
| 3RD STOREY | 72.801 | 73.912 | 75.177 | 76.596 | 78.12 | 79.671 |
| 4TH STOREY | 72.801 | 73.637 | 74.591 | 75.66 | 76.813 | 77.971 |
| 5TH STOREY | 72.801 | 73.24 | 73.74 | 74.297 | 74.905 | 75.51 |

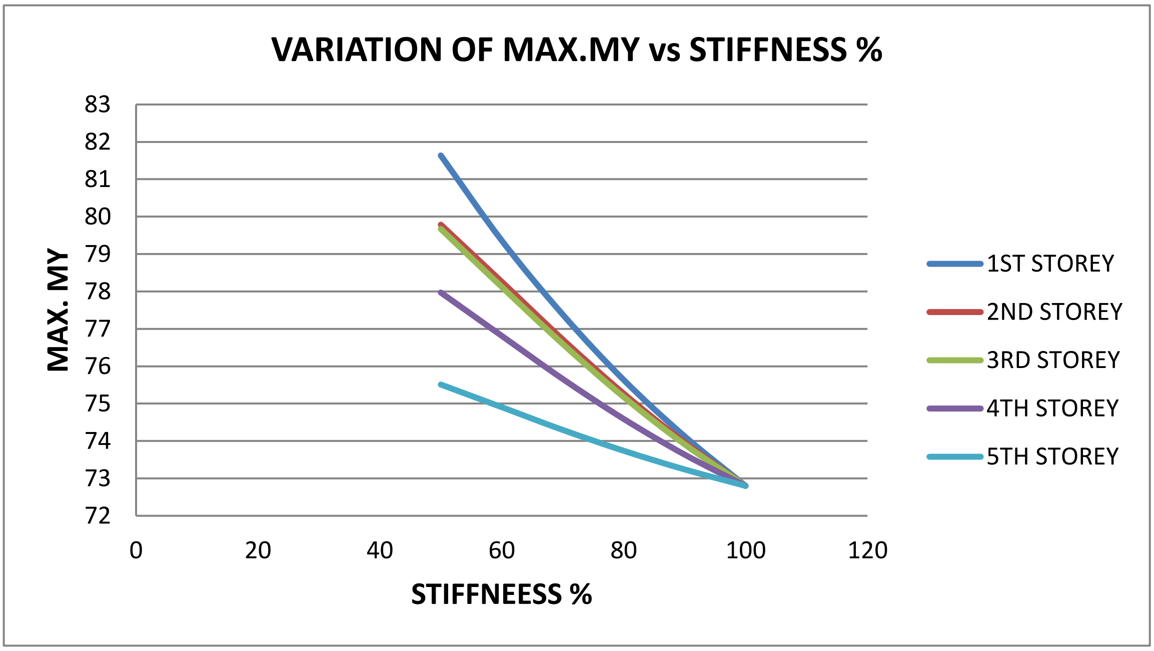



**Fig. 23** Variation of max. My Vs stiffness%

**Table 32 Equation of curve of MAX. My Vs Stiffness% for each floor**

| FLOOR | EQUATION |
|---|---|
| 1 | $y = 0.0012x^2 - 0.3536x + 96.343$ |
| 2 | $y = 0.0005x^2 - 0.2149x + 89.325$ |
| 3 | $y = 0.0006x^2 - 0.2249x + 89.498$ |
| 4 | $y = 0.0004x^2 - 0.1686x + 85.347$ |
| 5 | $y = 0.0002x^2 - 0.0884x + 79.376$ |

## 5.15 Variation Of max. Mz Vs Stiffness%

**Table 33 Variation of max.Mz Vs stiffness**

| STIFFNESS | 100 | 90 | 80 | 70 | 60 | 50 |
|---|---|---|---|---|---|---|
| 1ST STOREY | 848.693 | 845.19 | 841.484 | 837.689 | 833.414 | 829.221 |
| 2ND STOREY | 848.693 | 850.069 | 851.532 | 853.098 | 854.381 | 855.308 |
| 3RD STOREY | 848.693 | 848.979 | 849.151 | 849.155 | 848.287 | 846.909 |
| 4TH STOREY | 848.693 | 848.847 | 848.936 | 848.923 | 848.48 | 847.526 |
| 5TH STOREY | 848.693 | 848.891 | 849.135 | 849.428 | 849.713 | 849.888 |

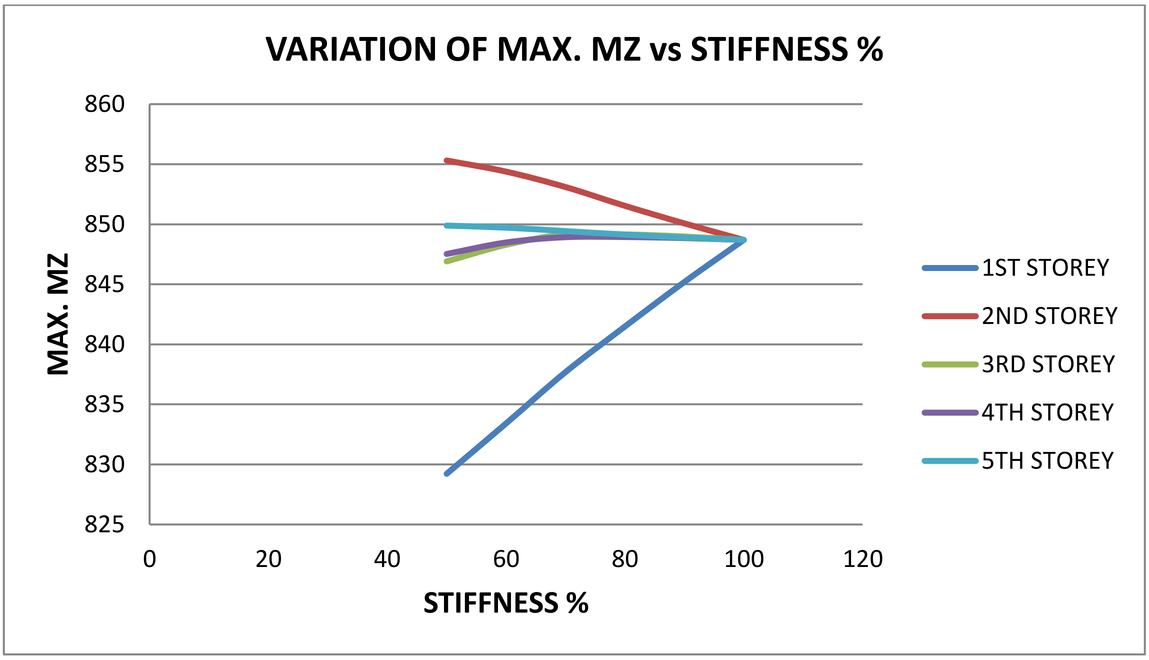



**Fig. 24** Variation of max.Mz Vs stiffness%

**Table 34 Equation of curve of MAX. Mz Vs Stiffness% for each floor:**

| FLOOR | EQUATION |
|---|---|
| 1 | $y = -0.001x^2 + 0.5433x + 804.58$ |
| 2 | $y = -0.0005x^2 - 0.0565x + 859.55$ |
| 3 | $y = -0.0022x^2 + 0.3657x + 834.29$ |
| 4 | $y = -0.0014x^2 + 0.2252x + 839.78$ |
| 5 | $y = 9E-06x^2 - 0.0263x + 851.21$ |

Max FX, FY, FZ, MX, MY and MZ increases with decrease in stiffness. The maximum FX decrease with increases in stiffness in first storey while increases in other storey. FY, FZ, MX, MY shows maximum variation in first storey and shows least variation in fifth storey or top-most variation. MZ shows different variation with respect to other parameter in first storey.

## 5.16 Variation Of Storey shear Vs Stiffness%

**Table 35 Variation of Storey shear Vs stiffness% in X direction in first storey**

FIRST STOREY

| HEIGHT | STIFFNESS % | | | | | |
|---|---|---|---|---|---|---|
| | 100 | 90 | 80 | 70 | 60 | 50 |
| 16.9 | 18.22 | 18.14 | 18.05 | 17.94 | 17.78 | 17.58 |
| 13.9 | 35.17 | 35.04 | 34.89 | 34.71 | 34.45 | 34.11 |
| 10.9 | 47.17 | 47.58 | 47.4 | 47.17 | 46.86 | 46.45 |
| 7.9 | 57.17 | 57.17 | 56.98 | 56.73 | 56.39 | 55.94 |
| 4.9 | 63.55 | 63.41 | 63.24 | 63.02 | 62.72 | 62.32 |
| 2.1 | 65.2 | 65.05 | 64.86 | 64.63 | 64.31 | 63.88 |

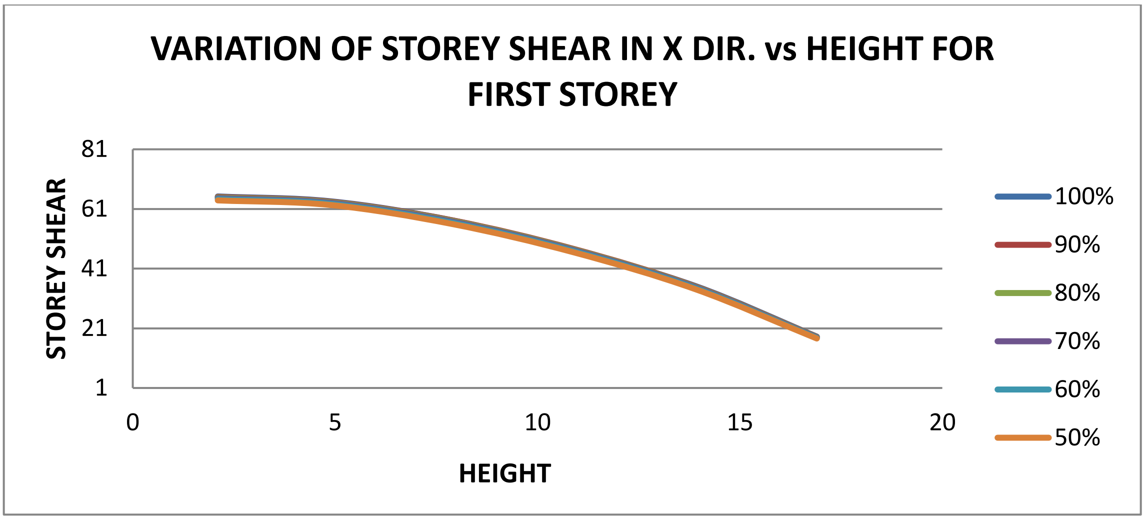



**Fig. 25** Variation of storey shear in X dir. Vs height for first storey

**Table 36 Equation of curve of Storey Shear in X direction Vs Stiffness% for each floor:**

| STIFFNESS | EQUATION |
|---|---|
| 100% | $y = -0.1952x^2 + 0.5658x + 63.771$ |

**Table 37 Variation of Storey shearVs stiffness% in Z direction in first storey**

| HEIGHT | STIFFNESS % | | | | | |
|---|---|---|---|---|---|---|
| | 100 | 90 | 80 | 70 | 60 | 50 |
| 16.9 | 22.28 | 22.31 | 22.35 | 22.38 | 22.41 | 22.45 |
| 13.9 | 40.61 | 40.66 | 40.72 | 40.78 | 40.83 | 40.88 |
| 10.9 | 53.72 | 53.79 | 53.86 | 53.94 | 54.01 | 54.08 |
| 7.9 | 64.37 | 64.45 | 64.52 | 64.61 | 64.68 | 64.77 |
| 4.9 | 71.54 | 71.6 | 71.66 | 71.73 | 71.8 | 71.87 |
| 2.1 | 73.48 | 73.55 | 73.63 | 73.71 | 73.79 | 73.87 |

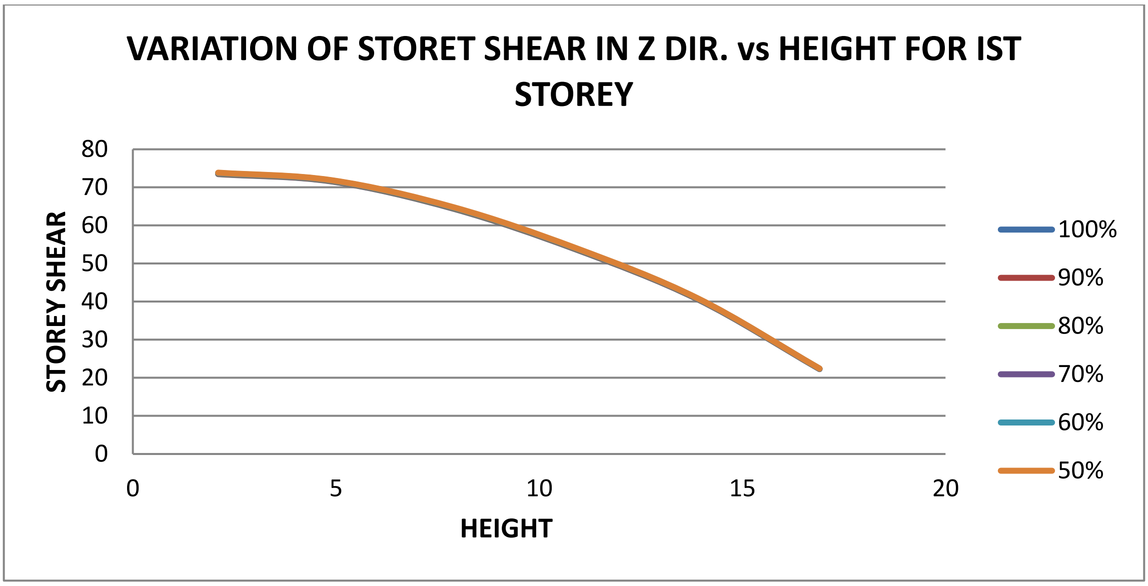



**Fig. 26** Variation of storey shear in Z dir. Vs height for first storey

**Table 38 Equation of curve of Storey Shear in Z direction Vs Stiffness% for each floor:**

| **STIFFNESS** | **EQUATION** |
|---|---|
| **100%** | $y = -0.0011x^4 + 0.0435x^3 - 0.7725x^2 + 3.2639x + 70.027$ |

**Table 39 Variation of Storey shearVs stiffness% in X direction in second store**

SECOND STOREY

| HEIGHT | STIFFNESS % | | | | | |
|---|---|---|---|---|---|---|
| | 100 | 90 | 80 | 70 | 60 | 50 |
| 16.9 | 18.22 | 18.14 | 18.05 | 17.94 | 17.79 | 17.61 |
| 13.9 | 35.17 | 35.04 | 34.88 | 34.68 | 34.41 | 34.06 |
| 10.9 | 47.17 | 47.58 | 47.38 | 47.14 | 46.8 | 46.36 |
| 7.9 | 57.17 | 57.17 | 56.97 | 56.72 | 56.36 | 55.9 |
| 4.9 | 63.55 | 63.34 | 63.09 | 62.77 | 62.33 | 61.75 |
| 2.1 | 65.2 | 64.99 | 64.74 | 64.42 | 63.97 | 63.39 |

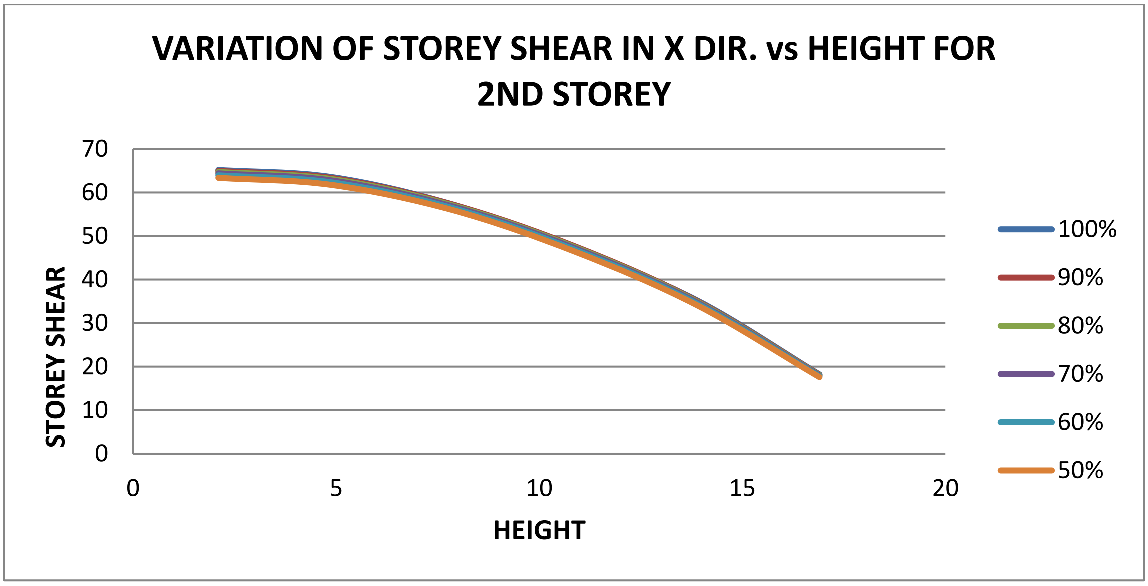



**Fig. 27** Variation of storey shear in X dir. Vs height for second storey

**Table 40 Variation of Storey shear Vs stiffness% in Z direction in second storey**

| HEIGHT | STIFFNESS % | | | | | |
|---|---|---|---|---|---|---|
| | 100 | 90 | 80 | 70 | 60 | 50 |
| 16.9 | 22.28 | 22.31 | 22.34 | 22.37 | 22.4 | 22.42 |
| 13.9 | 40.61 | 40.65 | 40.69 | 40.72 | 40.74 | 40.75 |
| 10.9 | 53.72 | 53.77 | 53.82 | 53.86 | 53.88 | 53.9 |
| 7.9 | 64.37 | 64.42 | 64.46 | 64.5 | 64.52 | 64.53 |
| 4.9 | 71.54 | 71.6 | 71.66 | 71.71 | 71.74 | 71.75 |
| 2.1 | 73.48 | 73.55 | 73.61 | 73.66 | 73.69 | 73.72 |

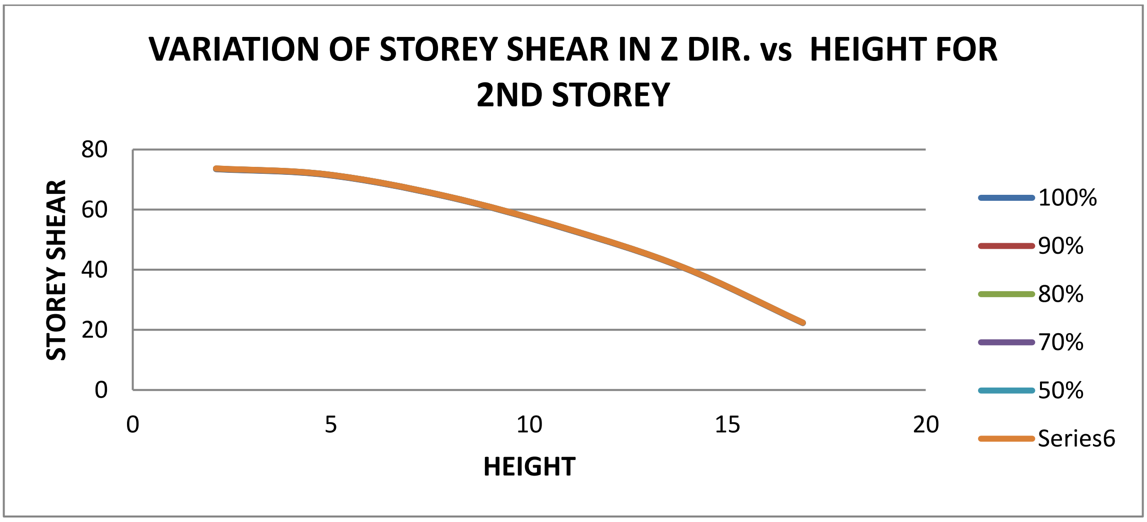



**Fig. 28** Variation of storey shear in Z dir. Vs height for second storey

**Table 41 Variation of Storey shear Vs stiffness% in X direction in third storey**

THIRD STOREY

| HEIGHT | STIFFNESS % | | | | | |
|---|---|---|---|---|---|---|
| | 100 | 90 | 80 | 70 | 60 | 50 |
| 16.9 | 18.22 | 18.17 | 18.11 | 18.04 | 17.94 | 17.82 |
| 13.9 | 35.17 | 35.09 | 34.99 | 34.87 | 34.71 | 34.5 |
| 10.9 | 47.17 | 47.64 | 47.52 | 47.47 | 47.17 | 46.9 |
| 7.9 | 57.17 | 57.18 | 56.99 | 56.76 | 56.43 | 56.01 |
| 4.9 | 63.55 | 63.37 | 63.16 | 62.89 | 62.53 | 62.05 |
| 2.1 | 65.2 | 65.02 | 64.81 | 64.54 | 64.18 | 63.71 |

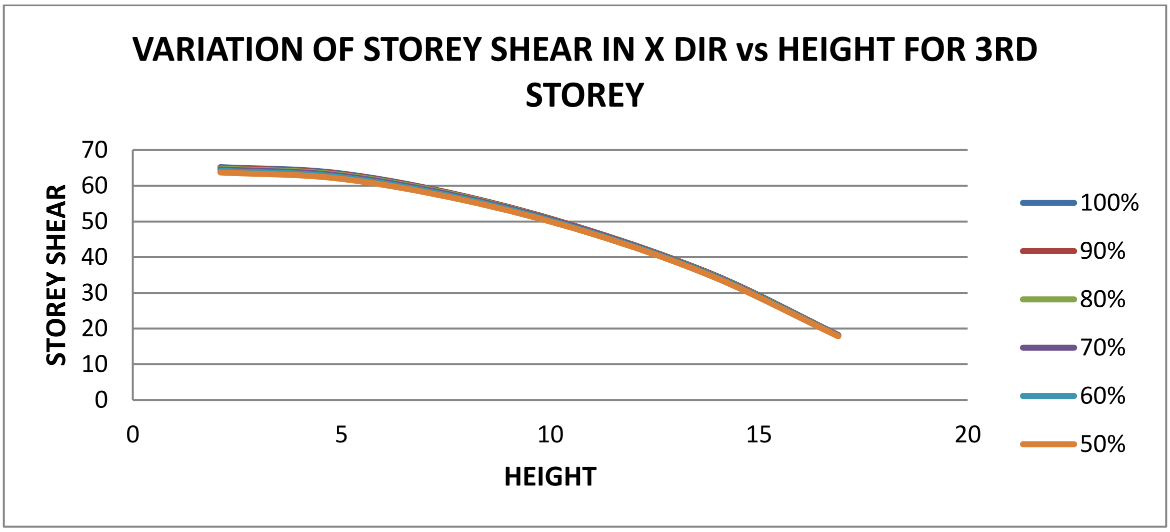



**Fig. 29** Variation of storey shear in X dir. Vs height for third storey

**Table 42 Variation of Storey shear Vs stiffness% in Z direction in third storey**

| HEIGHT | STIFFNESS % | | | | | |
|---|---|---|---|---|---|---|
| | 100 | 90 | 80 | 70 | 60 | 50 |
| 16.9 | 22.28 | 22.31 | 22.33 | 22.26 | 22.39 | 22.42 |
| 13.9 | 40.61 | 40.63 | 40.67 | 40.69 | 40.73 | 40.76 |
| 10.9 | 53.72 | 53.7 | 53.78 | 53.77 | 53.84 | 53.85 |
| 7.9 | 64.37 | 64.3 | 64.48 | 64.41 | 64.56 | 64.59 |
| 4.9 | 71.54 | 71.6 | 71.69 | 71.74 | 71.82 | 71.87 |
| 2.1 | 73.48 | 72.83 | 73.63 | 72.98 | 73.76 | 73.81 |

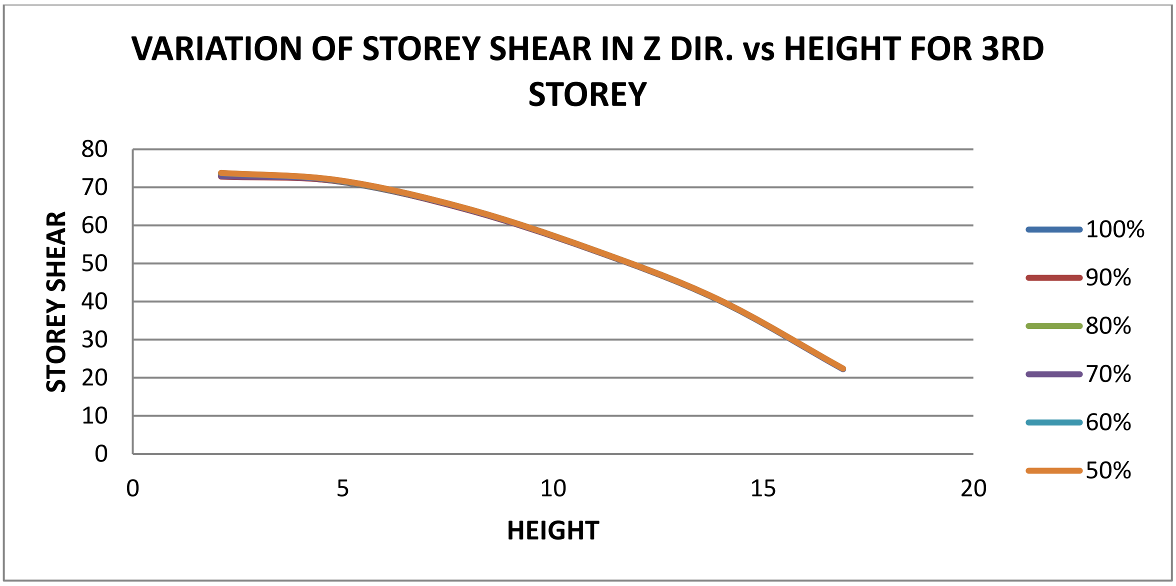



**Fig. 30** Variation of storey shear in Z dir. Vs height for third storey

**Table 43 Variation of Storey shear Vs stiffness% in X direction in fourth storey**

FOURTH STOREY

| HEIGHT | STIFFNESS % | | | | | |
|---|---|---|---|---|---|---|
| | 100 | 90 | 80 | 70 | 60 | 50 |
| 16.9 | 18.22 | 18.2 | 18.18 | 18.15 | 18.11 | 18.06 |
| 13.9 | 35.17 | 35.16 | 35.14 | 35.12 | 35.09 | 35.05 |
| 10.9 | 47.17 | 47.66 | 47.58 | 47.47 | 47.32 | 47.13 |
| 7.9 | 57.17 | 57.23 | 57.12 | 56.97 | 56.77 | 56.51 |
| 4.9 | 63.55 | 63.44 | 63.6 | 63.14 | 62.91 | 62.62 |
| 2.1 | 65.2 | 65.09 | 64.95 | 64.79 | 64.57 | 64.28 |

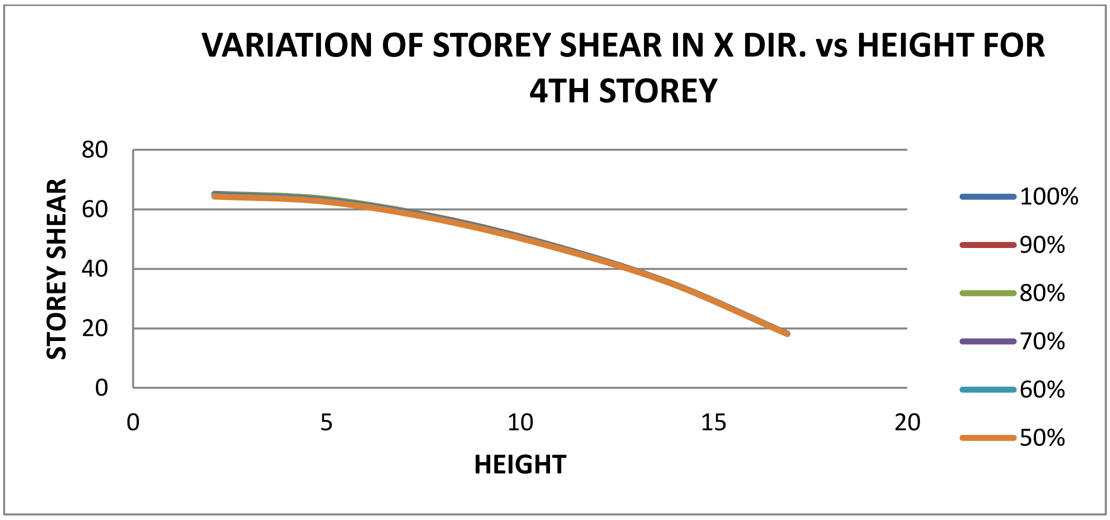



**Fig. 31** Variation of storey shear in X dir. Vs height for fourth storey

**Table 44 Variation of Storey shear Vs stiffness% in Z direction in fourth storey**

| HEIGHT | STIFFNESS % | | | | | |
|---|---|---|---|---|---|---|
| | 100 | 90 | 80 | 70 | 60 | 50 |
| 16.9 | 22.28 | 22.29 | 22.3 | 22.31 | 22.32 | 22.32 |
| 13.9 | 40.61 | 40.61 | 40.61 | 40.62 | 40.62 | 40.63 |
| 10.9 | 53.72 | 53.76 | 53.8 | 53.84 | 53.88 | 53.91 |
| 7.9 | 64.37 | 64.42 | 64.48 | 64.53 | 64.59 | 64.64 |
| 4.9 | 71.54 | 71.61 | 71.67 | 71.74 | 71.81 | 71.87 |
| 2.1 | 73.48 | 73.55 | 73.61 | 73.68 | 73.75 | 73.81 |

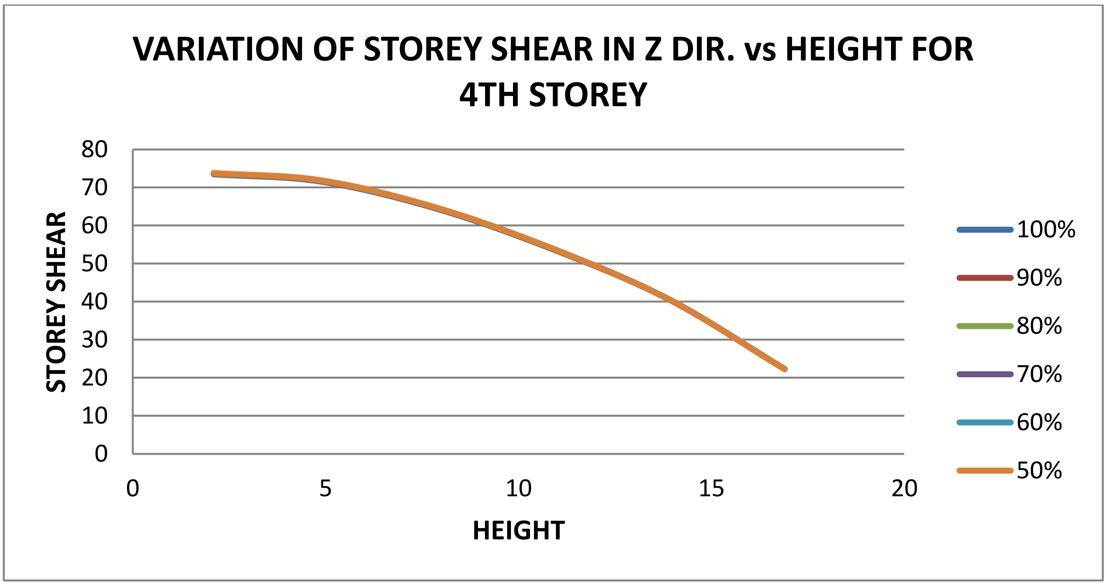



**Fig. 32** Variation of storey shear in Z dir. Vs height for fourth storey

**Table 45 Variation of Storey shear Vs stiffness% in X direction in fifth storey**

FIFTH STOREY

| HEIGHT | STIFFNESS % | | | | | |
|---|---|---|---|---|---|---|
| | 100 | 90 | 80 | 70 | 60 | 50 |
| 16.9 | 18.22 | 18.24 | 18.27 | 18.3 | 18.35 | 18.41 |
| 13.9 | 35.17 | 35.16 | 35.15 | 35.13 | 35.11 | 35.08 |
| 10.9 | 47.17 | 47.7 | 47.67 | 47.63 | 47.58 | 47.52 |
| 7.9 | 57.17 | 57.3 | 57.26 | 57.22 | 57.16 | 57.09 |
| 4.9 | 63.55 | 63.51 | 63.46 | 63.41 | 63.33 | 63.24 |
| 2.1 | 65.2 | 65.16 | 65.12 | 65.06 | 64.99 | 64.9 |

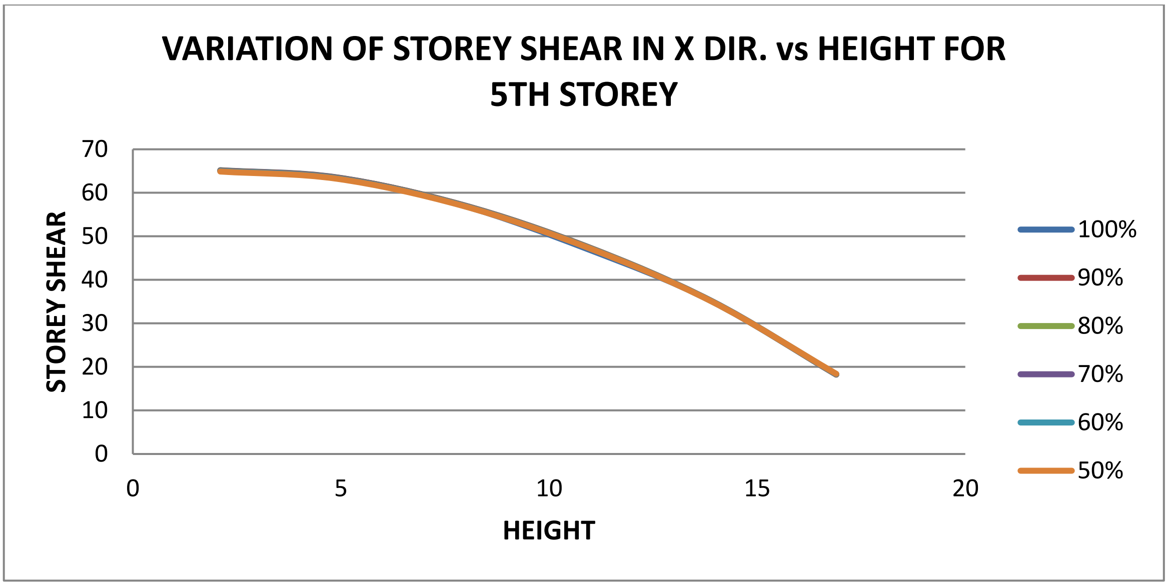



**Fig. 33** Variation of storey shear in X dir. height for fifth storey

**Table 46 Variation of Storey shear Vs stiffness% in Z direction in fifth storey**

| HEIGHT | STIFFNESS % | | | | | |
|---|---|---|---|---|---|---|
| | 100 | 90 | 80 | 70 | 60 | 50 |
| 16.9 | 22.28 | 22.26 | 22.24 | 22.23 | 22.21 | 22.2 |
| 13.9 | 40.61 | 40.62 | 40.62 | 40.63 | 40.63 | 40.63 |
| 10.9 | 53.72 | 53.74 | 53.77 | 53.79 | 53.81 | 53.84 |
| 7.9 | 64.37 | 64.4 | 64.43 | 64.46 | 64.49 | 64.52 |
| 4.9 | 71.54 | 71.57 | 71.61 | 71.64 | 71.68 | 71.71 |
| 2.1 | 73.48 | 73.51 | 73.55 | 73.58 | 73.62 | 73.65 |

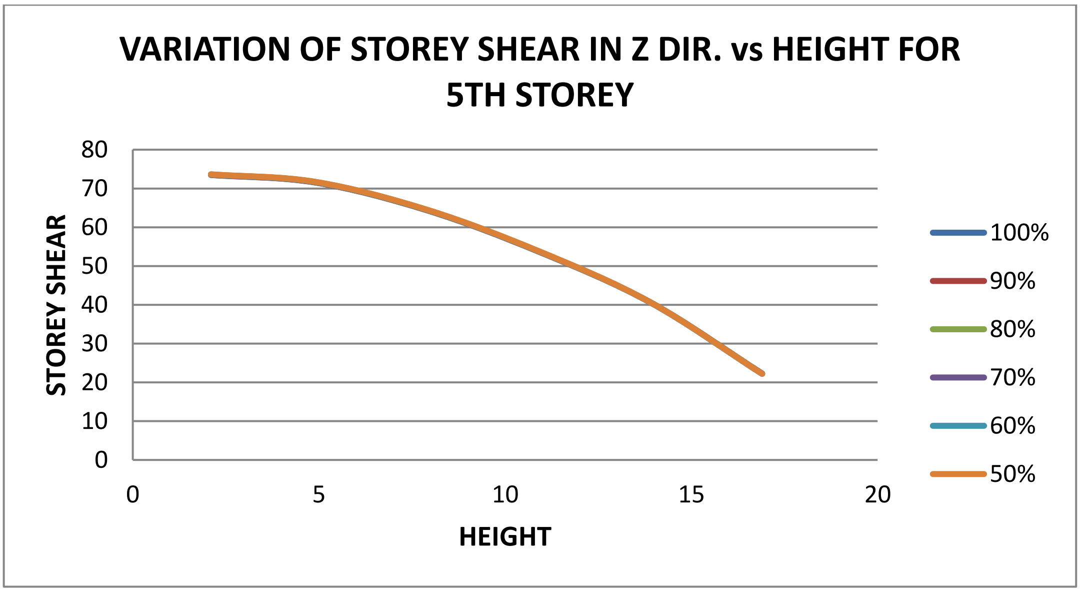



**Fig. 34** Variation of storey shear in Z dir. Vs height for fifth storey

Storey shear shows expected trend of decreasing with height. There is very little effect of change of stiffness on storey shear. Storey shear in both X and Z direction similar trend with respect to stiffness changes.

## 5.17 Variation Of Storey DriftVsHeight w.r.to change in stiffness%

**Table 47 Variation Of Storey Drift Vs Height w.r.to change in stiffness%**

1ST STOREY

| | STOREY DRIFT VS HEIGHT W.R.T. CHANGE IN STIFFNESS | | | | | | |
|---|---|---|---|---|---|---|---|
| STIFFNESS | 100% | 90% | 80% | 70% | 60% | 50% | HEIGHT |
| STOREY DRIFT | 0.016 | 0.016 | 0.016 | 0.016 | 0.016 | 0.0159 | 19.5 |
| | 0.0075 | 0.0075 | 0.0075 | 0.0075 | 0.0075 | 0.0075 | 16.9 |
| | 0.0084 | 0.0084 | 0.0084 | 0.0084 | 0.0084 | 0.0084 | 13.9 |
| | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 10.9 |
| | 0.0071 | 0.0071 | 0.0071 | 0.0071 | 0.0072 | 0.0072 | 7.9 |
| | 0.0054 | 0.0055 | 0.0056 | 0.0057 | 0.0059 | 0.0062 | 4.9 |
| | 0.0017 | 0.0017 | 0.0017 | 0.0017 | 0.0017 | 0.0017 | 2.1 |

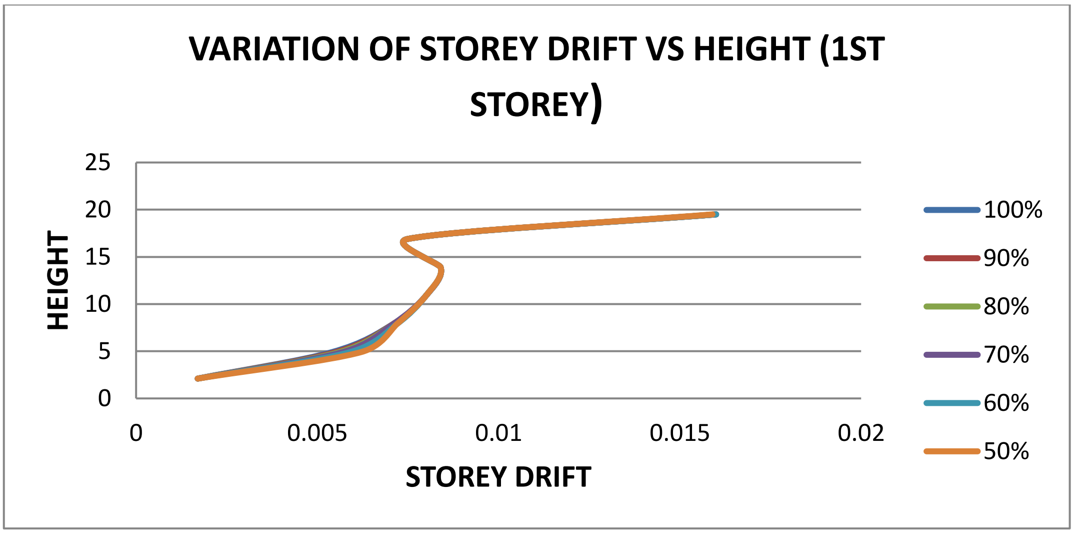



**Fig. 35**Variation of storey driftVsheight (1st storey)

**Table 48 Variation Of Storey Drift Vs Height w.r.to change in stiffness%:**

2ND STOREY

| STIFFNESS% | 100% | 90% | 80% | 70% | 60% | 50% | HEIGHT |
|---|---|---|---|---|---|---|---|
| STOREY DRIFT | 0.016 | 0.016 | 0.016 | 0.016 | 0.016 | 0.0159 | 19.5 |
| | 0.0075 | 0.0075 | 0.0075 | 0.0075 | 0.0075 | 0.0075 | 16.9 |
| | 0.0084 | 0.0084 | 0.0084 | 0.0084 | 0.0084 | 0.0084 | 13.9 |
| | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 10.9 |
| | 0.0071 | 0.0072 | 0.0074 | 0.0076 | 0.0078 | 0.0081 | 7.9 |
| | 0.0054 | 0.0054 | 0.0054 | 0.0054 | 0.0054 | 0.0054 | 4.9 |
| | 0.0017 | 0.0017 | 0.0017 | 0.0017 | 0.0017 | 0.0017 | 2.1 |

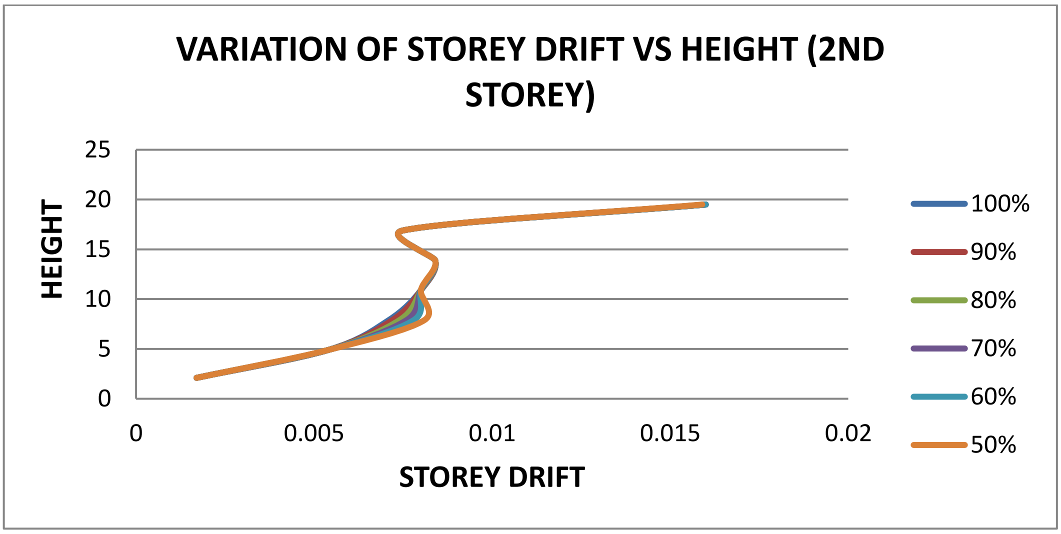



**Fig. 36** Variation of storey shear Vs height (2nd storey)

**Table 49 Variation Of Storey Drift Vs Height w.r.to change in stiffness%**

3RD STOREY

| STOREY DRIFT VS HEIGHT W.R.T. CHANGE IN STIFFNESS | | | | | | | |
|---|---|---|---|---|---|---|---|
| STIFFNESS | 100% | 90% | 80% | 70% | 60% | 50% | HEIGHT |
| STOREY DRIFT | 0.016 | 0.016 | 0.016 | 0.016 | 0.016 | 0.0159 | 19.5 |
| | 0.0075 | 0.0075 | 0.0075 | 0.0075 | 0.0075 | 0.0075 | 16.9 |
| | 0.0084 | 0.0084 | 0.0084 | 0.0084 | 0.0084 | 0.0084 | 13.9 |
| | 0.008 | 0.0081 | 0.0083 | 0.0084 | 0.0087 | 0.009 | 10.9 |
| | 0.0071 | 0.0071 | 0.0071 | 0.0071 | 0.0071 | 0.0072 | 7.9 |
| | 0.0054 | 0.0054 | 0.0054 | 0.0054 | 0.0054 | 0.0054 | 4.9 |
| | 0.0017 | 0.0017 | 0.0017 | 0.0017 | 0.0017 | 0.0017 | 2.1 |

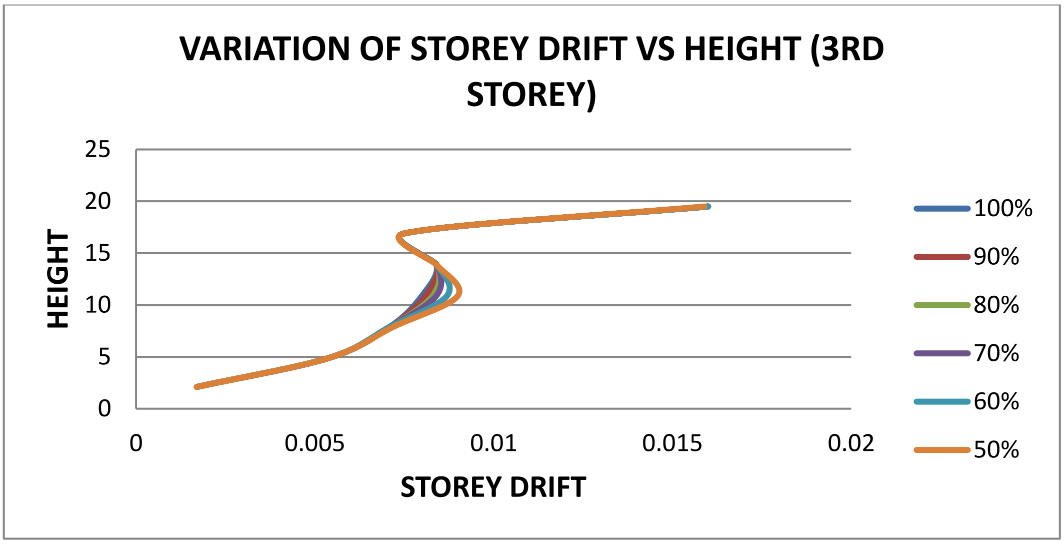



**Fig. 37** Variation of storey driftVs height (3rdstorey)

**Table 50 Variation Of Storey Drift Vs Height w.r.to change in stiffness%**

4TH STOREY

| STOREY DRIFT VS HEIGHT W.R.T. CHANGE IN STIFFNESS | | | | | | | |
|---|---|---|---|---|---|---|---|
| STIFFNESS | 100% | 90% | 80% | 70% | 60% | 50% | HEIGHT |
| STOREY DRIFT | 0.016 | 0.016 | 0.016 | 0.016 | 0.016 | 0.0161 | 19.5 |
| | 0.0075 | 0.0075 | 0.0075 | 0.0075 | 0.0075 | 0.0075 | 16.9 |
| | 0.0084 | 0.0085 | 0.0087 | 0.0089 | 0.0091 | 0.0094 | 13.9 |
| | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.0081 | 10.9 |
| | 0.0071 | 0.0071 | 0.0071 | 0.0071 | 0.0071 | 0.0071 | 7.9 |
| | 0.0054 | 0.0054 | 0.0054 | 0.0054 | 0.0054 | 0.0054 | 4.9 |
| | 0.0017 | 0.0017 | 0.0017 | 0.0017 | 0.0017 | 0.0017 | 2.1 |

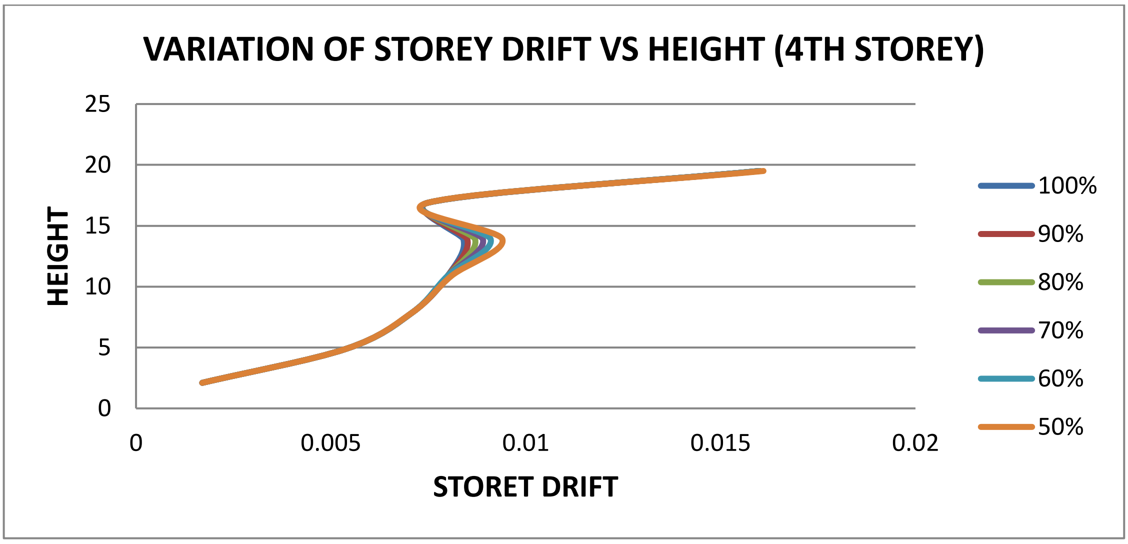



**Fig. 38** Variation of storey driftVs height (4thstorey)

**Table 51 Variation Of Storey Drift Vs Height w.r.to change in stiffness%**

5TH STOREY

| STOREY DRIFT VS HEIGHT W.R.T. CHANGE IN STIFFNESS% | | | | | | | |
|---|---|---|---|---|---|---|---|
| STIFFNESS | 100% | 90% | 80% | 70% | 60% | 50% | HEIGHT |
| STOREY DRIFT | 0.016 | 0.016 | 0.016 | 0.016 | 0.016 | 0.0159 | 19.5 |
| | 0.0075 | 0.0075 | 0.0076 | 0.0077 | 0.0078 | 0.008 | 16.9 |
| | 0.0084 | 0.0084 | 0.0084 | 0.0084 | 0.0083 | 0.0083 | 13.9 |
| | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 10.9 |
| | 0.0071 | 0.0071 | 0.0071 | 0.0071 | 0.0071 | 0.0071 | 7.9 |
| | 0.0054 | 0.0054 | 0.0054 | 0.0054 | 0.0054 | 0.0054 | 4.9 |
| | 0.0017 | 0.0017 | 0.0017 | 0.0017 | 0.0017 | 0.0017 | 2.1 |

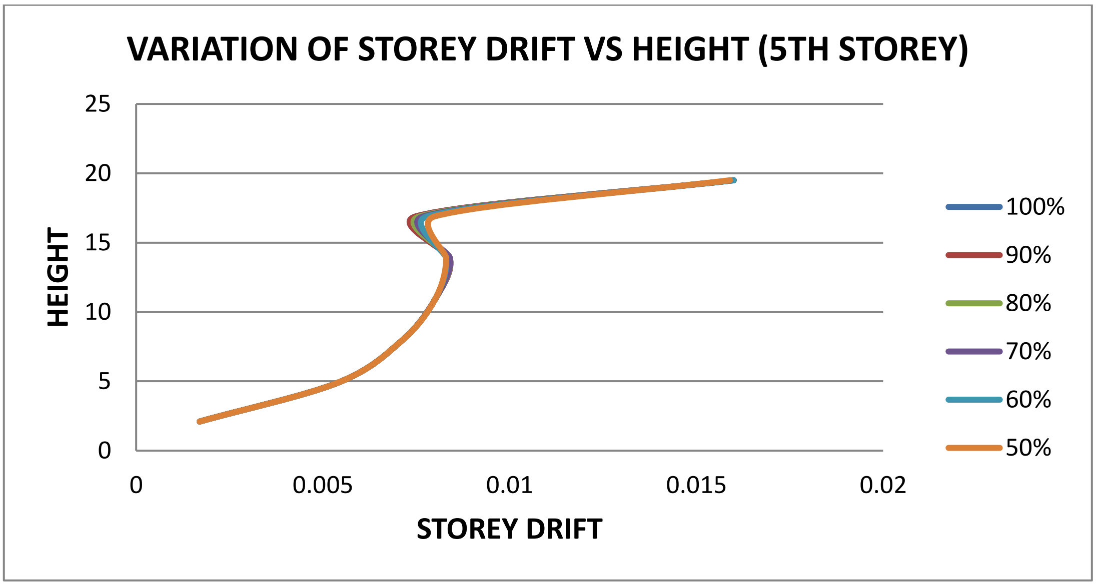



**Fig. 39** Variation of storey driftVs height (5th storey)

Storey drift suddenly increases from fourth storey to fifth storey or top most storey in every case. The variation in changes in drift of storey is large when stiffness is changed in that particular storey. Effect of change of stiffness in storey other than the storey in which stiffness is changed is negligible.

## 5.18 Variation of mass participation in x direction vs. different modes

**Table 52 Variation of mass participation in x direction vs. different modes**

| 1) 1STOREY | Mode | Participation X % |
|---|---|---|
| | 1 | 68.768 |
| | 2 | 1.998 |
| | 3 | 9.49 |
| | 4 | 0.013 |
| | 5 | 0.015 |
| | 6 | 5.451 |
| | 7 | 0.183 |
| | 8 | 3.285 |
| | 9 | 0.203 |
| | 10 | 0.002 |
| | 11 | 0.194 |
| | 12 | 0.003 |
| | 13 | 0.083 |
| | 14 | 0 |
| | 15 | 0.077 |
| | 16 | 1.776 |
| | 17 | 0.025 |
| | 18 | 0 |
| | 19 | 0.004 |
| | 20 | 0.003 |
| | 21 | 0 |

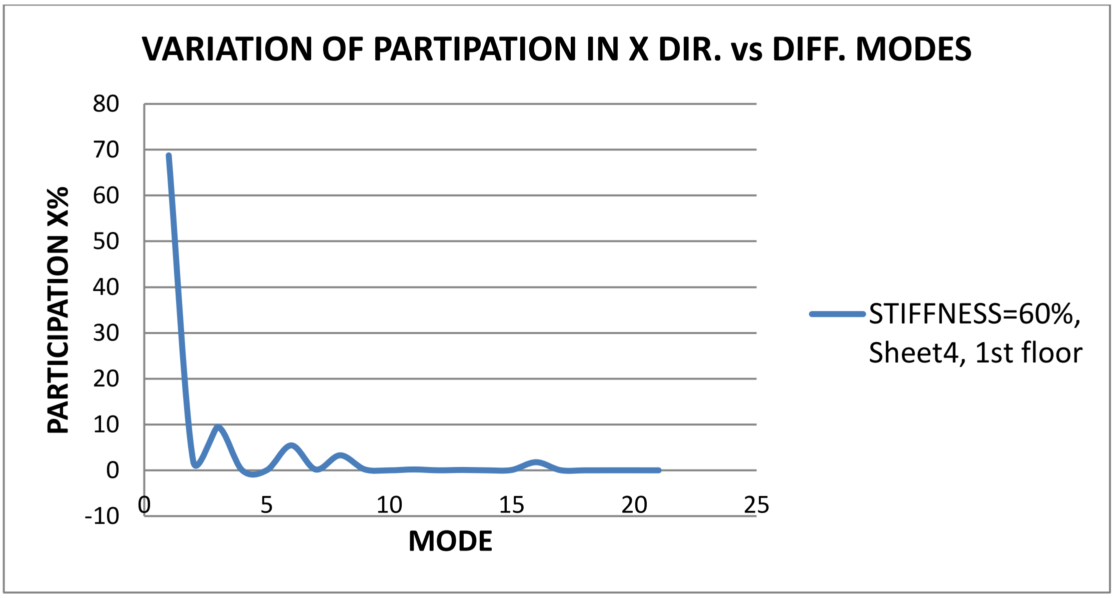



**Fig. 40** Variation of participation in X dir. Vs. diff. modes

**Table 53 Variation of mass participation in y direction vs. different modes**

| | Mode | Participation Y % |
|---|---|---|
| 1) 1STOREY | 1 | 0 |
| | 2 | 0.001 |
| | 3 | 0 |
| | 4 | 0 |
| | 5 | 0.001 |
| | 6 | 0 |
| | 7 | 0 |
| | 8 | 0 |
| | 9 | 0.003 |
| | 10 | 0 |
| | 11 | 0.002 |
| | 12 | 0 |
| | 13 | 0 |
| | 14 | 0 |
| | 15 | 0 |
| | 16 | 0 |
| | 17 | 0 |
| | 18 | 0.023 |
| | 19 | 0 |
| | 20 | 0 |
| | 21 | 0 |

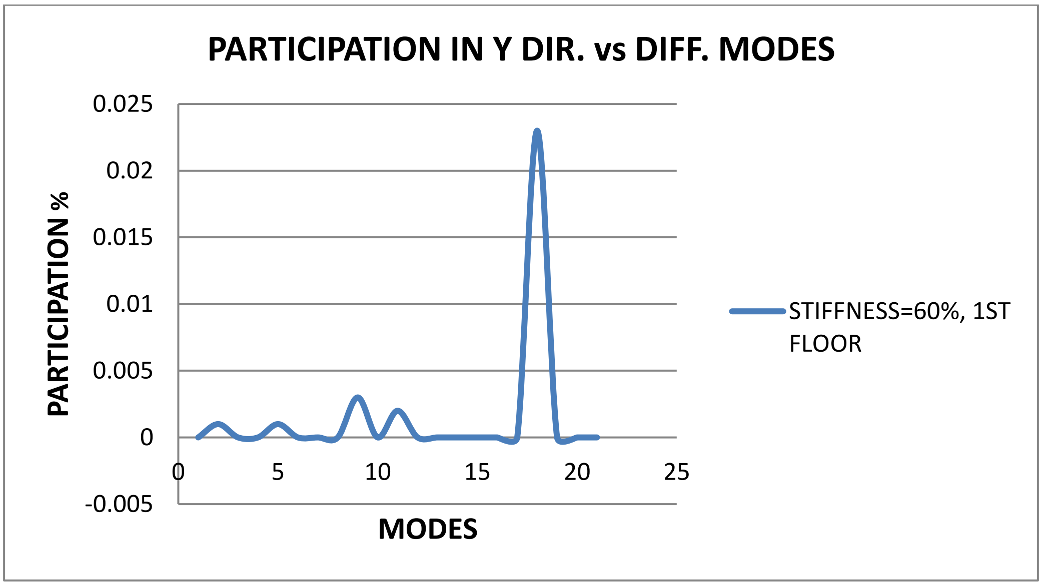



**Fig. 41** Variation of participation in Y dir. Vs diff. modes

**Table 54 Variation of mass participation in z direction vs. different modes**:

| | Mode | Participation Z % |
|---|---|---|
| 1) 1STOREY | | |
| | 1 | 0.244 |
| | 2 | 72.02 |
| | 3 | 6.669 |
| | 4 | 0.015 |
| | 5 | 0 |
| | 6 | 0.004 |
| | 7 | 0.011 |
| | 8 | 0.837 |
| | 9 | 9.434 |
| | 10 | 0.022 |
| | 11 | 0.007 |
| | 12 | 0.068 |
| | 13 | 0.003 |
| | 14 | 0 |
| | 15 | 0.001 |
| | 16 | 0 |
| | 17 | 0.002 |
| | 18 | 0 |
| | 19 | 0.11 |
| | 20 | 0.083 |
| | 21 | 0.004 |

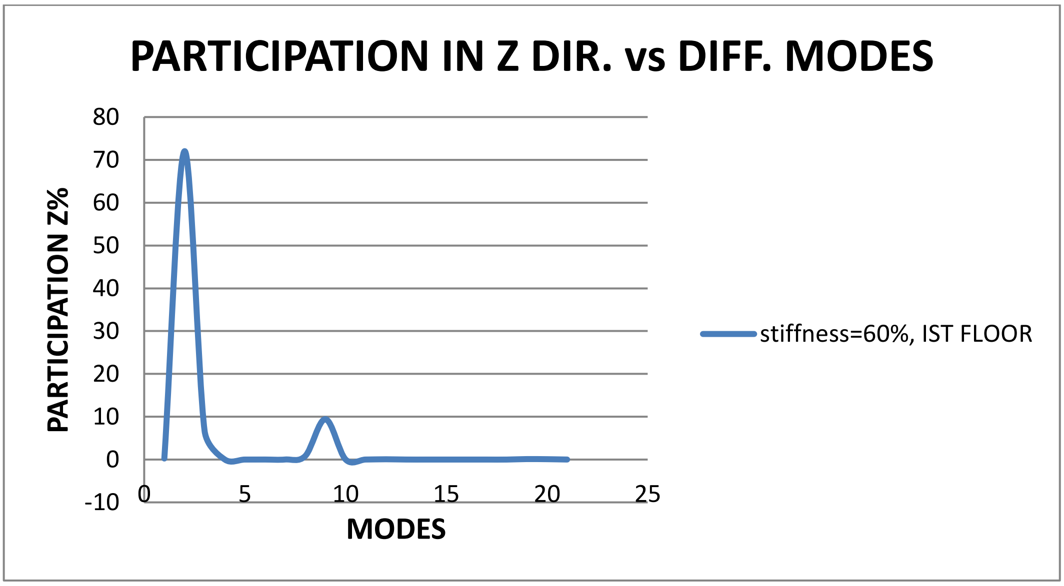



**Fig. 42**Participation in z dir. Vs. diff. modes

**Table 55 Equation of variation of Mass participation factor Vs Mode:**

| | EQUATION |
|---|---|
| X DIR. | $y = 0.0002x^6 - 0.0126x^5 + 0.3547x^4 - 4.9621x^3 + 35.644x^2 - 122.13x + 154.06$ |
| Z DIR. | y = -0.0002x6 + 0.0162x5 - 0.4265x4 + 5.3881x3 - 32.805x2 + 81.658x - 38.214 |
| Y DIR. | $y = -2E\text{-}08x^6 + 8E\text{-}07x^5 - 1E\text{-}05x^4 + 1E\text{-}04x^3 - 0.0002x^2 - 0.0004x + 0.0009$ |

When mass participation factor varies with modes it is observed that Mode 1 is dominant in X direction while Mode 2 is dominant in Z direction. Variation of Mass Participation factor in X direction from Mode 1 to Mode 2 varies from 68.768 to 1.998. Variation of Mass Participation factor in Z direction from Mode 1 to Mode 2 varies from 0.244 to 72.02.

## 5.19 Variation of mass participation vs. stiffness%

**Table56 Variation of mass participation in X dir. vs. stiffness%**

| **MODE 1** | STOREY | | | | |
|---|---|---|---|---|---|
| STIFFNESS % | 1 | 2 | 3 | 4 | 5 |
| 100 | 68.6 | 68.6 | 68.6 | 68.6 | 68.6 |
| 90 | 68.695 | 68.608 | 68.558 | 68.56 | 68.588 |
| 80 | 68.762 | 68.57 | 68.473 | 68.495 | 68.571 |
| 70 | 68.79 | 68.469 | 68.332 | 68.397 | 68.549 |
| 60 | 68.768 | 68.268 | 68.099 | 68.24 | 68.514 |
| 50 | 68.654 | 67.929 | 67.736 | 68.008 | 68.466 |

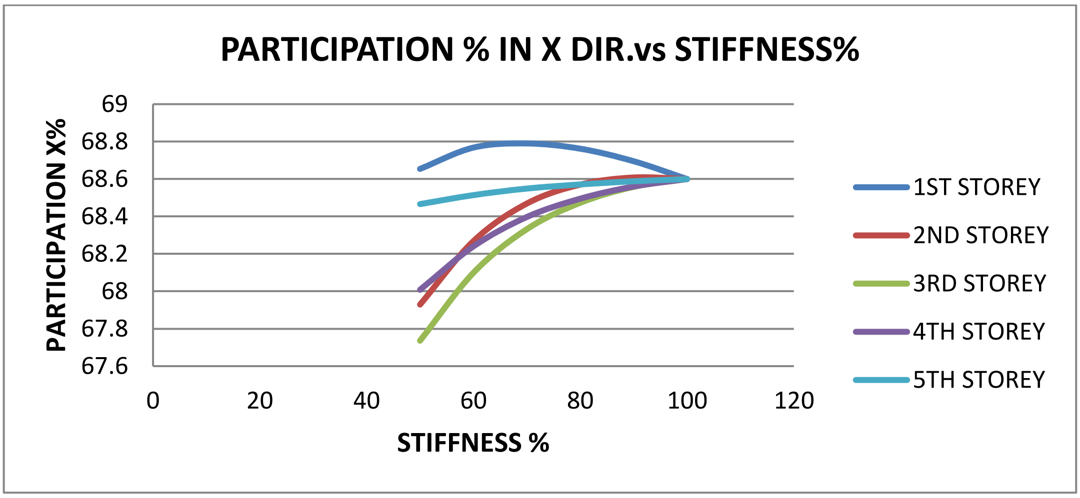



**Fig. 43**Participation % in x dir.Vs stiffness%

**Table57 Equation of variation of Mass participation factor in X direction Vs Stiffness%**

| FLOOR | EQUATION |
|---|---|
| 1 | $y = 3E\text{-}06x^3 - 0.001x^2 + 0.0896x + 66.233$ |
| 2 | $y = 5E\text{-}06x^3 - 0.0016x^2 + 0.1633x + 63.145$ |
| 3 | $y = 5E\text{-}06x^3 - 0.0015x^2 + 0.1578x + 63.026$ |
| 4 | $y = 3E\text{-}06x^3 - 0.0009x^2 + 0.0968x + 65.091$ |
| 5 | $y = 6E\text{-}07x^3 - 0.0002x^2 + 0.0191x + 67.885$ |

Mass participation factor in X direction decreases with decrease in stiffness. When the stiffness decrease from 100% to 50% in the 5th storey the value of Mass participation factor decrease from 68.6 to 68.466 which is the maximum variation compare to other storey.

**Table58 Variation of mass participation in Y dir. vs. stiffness%**

| **MODE 18** | | STOREY | | | |
|---|---|---|---|---|---|
| STIFFNESS % | 1 | 2 | 3 | 4 | 5 |
| 100 | 0.022 | 0.022 | 0.022 | 0.022 | 0.022 |
| 90 | 0.022 | 0.022 | 0.021 | 0.021 | 0.022 |
| 80 | 0.023 | 0.022 | 0.02 | 0.02 | 0.022 |
| 70 | 0.023 | 0.022 | 0.019 | 0.019 | 0.022 |
| 60 | 0.023 | 0.021 | 0.017 | 0.018 | 0.022 |
| 50 | 0.024 | 0.021 | 0.015 | 0.016 | 0.022 |

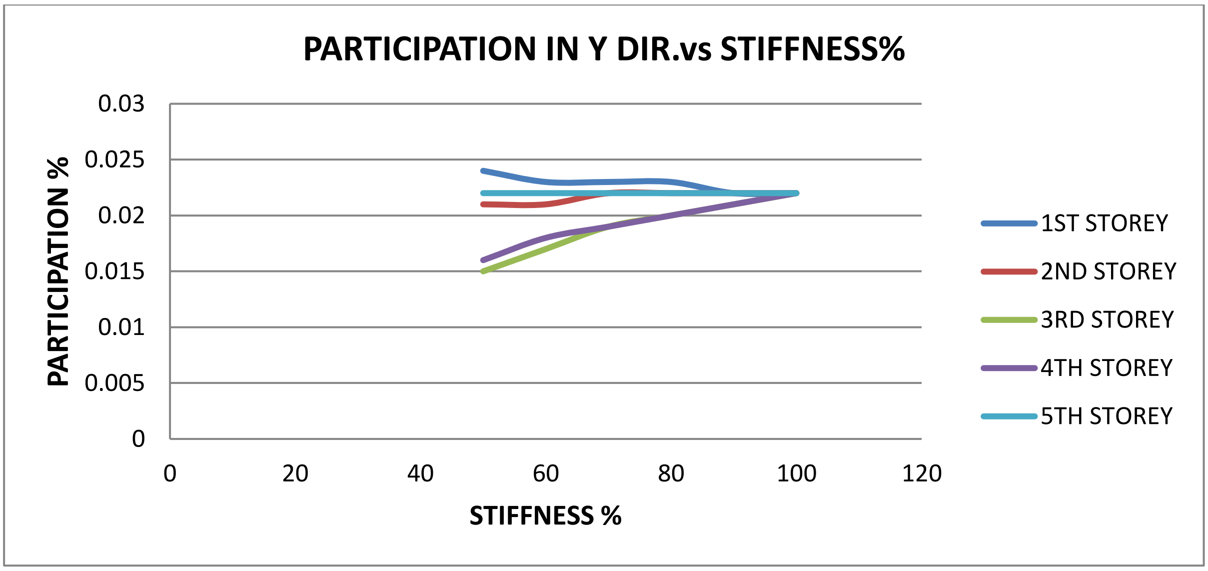



**Fig. 44**Participation in y dir.Vs stiffness%

**Table59 Equation of variation of Mass participation factor in Y direction Vs Stiffness%**

| FLOOR | EQUATION |
|---|---|
| 1 | $y = 6E\text{-}09x^4 - 2E\text{-}06x^3 + 0.0002x^2 - 0.0104x + 0.2115$ |
| 2 | $y = 4E\text{-}09x^4 - 1E\text{-}06x^3 + 0.0001x^2 - 0.0068x + 0.1394$ |
| 3 | $y = 3E\text{-}08x^3 - 8E\text{-}06x^2 + 0.0008x - 0.0105$ |
| 4 | $y = 5E\text{-}08x^3 - 1E\text{-}05x^2 + 0.001x - 0.0118$ |
| 5 | $y = -5E\text{-}20x^2 + 5E\text{-}18x + 0.022$ |

When the stiffness changes from 100% to 50% in 3rd storey, the value of Mass participation factor in Y direction changes from 0.022 to 0.015. When the stiffness changes from 100% to 50% in 1st storey, the value of Mass participation factor in Y direction changes from 0.022 to 0.024.

**Table60 Variation of mass participation in Z dir. vs. stiffness%**

| MODE 2 | STOREY | | | | |
|---|---|---|---|---|---|
| STIFFNESS % | 1 | 2 | 3 | 4 | 5 |
| 100 | 74.613 | 74.613 | 74.613 | 74.613 | 74.613 |
| 90 | 74.254 | 74.261 | 74.381 | 74.504 | 74.581 |
| 80 | 73.769 | 73.722 | 74.063 | 74.358 | 74.541 |
| 70 | 73.086 | 73.067 | 73.617 | 74.161 | 74.49 |
| 60 | 72.02 | 71.94 | 72.936 | 73.872 | 74.419 |
| 50 | 70.273 | 70.08 | 71.884 | 73.461 | 74.325 |

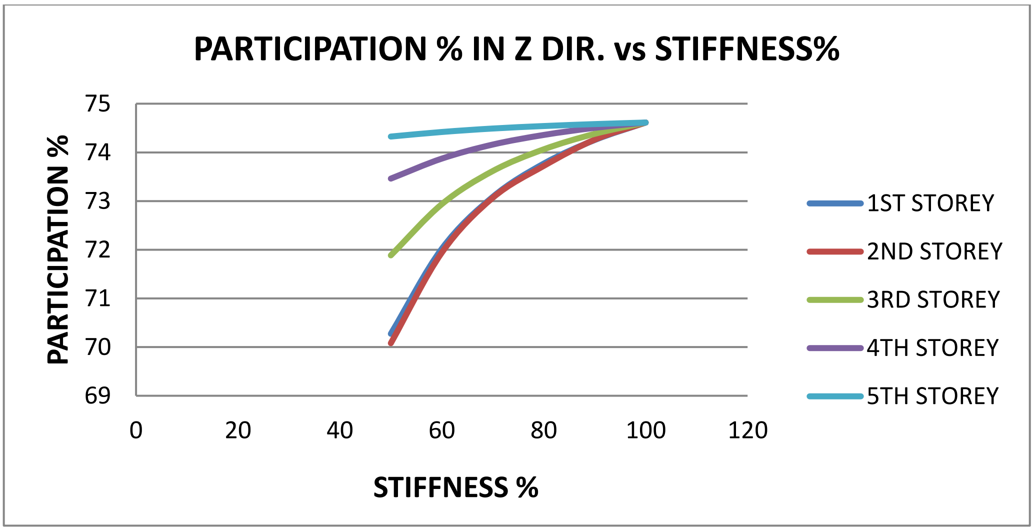



**Fig. 45**Participation % in z dir. Vs stiffness%

**Table 61 Equation of variation of Mass participation factor in Z direction Vs Stiffness%**

| FLOOR | EQUATION |
|---|---|
| 1 | $y = 3E\text{-}05x^3 - 0.0086x^2 + 0.836x + 46.107$ |
| 2 | $y = 4E\text{-}05x^3 - 0.0097x^2 + 0.9272x + 43.533$ |
| 3 | $y = -0.001x^2 + 0.2014x + 64.346$ |
| 4 | $y = -0.0004x^2 + 0.0782x + 70.496$ |
| 5 | $y = -8E\text{-}05x^2 + 0.0173x + 73.658$ |

Mass participation factor in Z direction decreases with decrease in stiffness. It shows increasing pattern when we move from lower to upper floors. When the stiffness decrease from 100% to 50% in the 5th storey the value of Mass participation factor decrease from 74.613 to 70.273 which is the maximum variation compare to other storey.

## 5.20 Mode Shapes

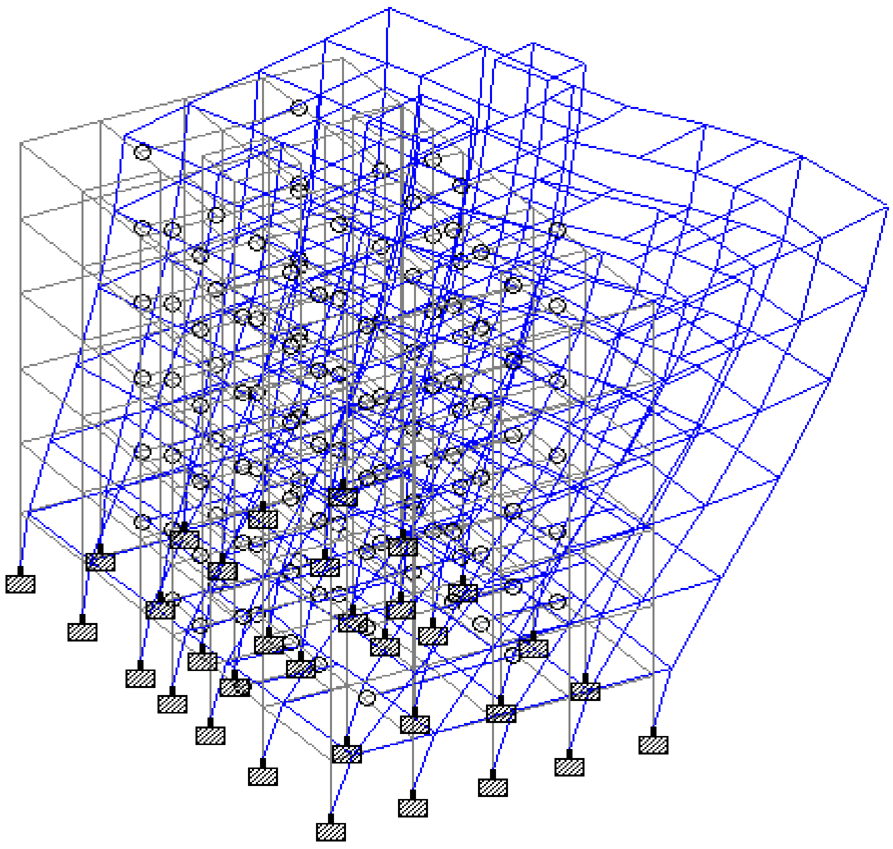


**Fig. 46**Mode Shape 1(3D view)

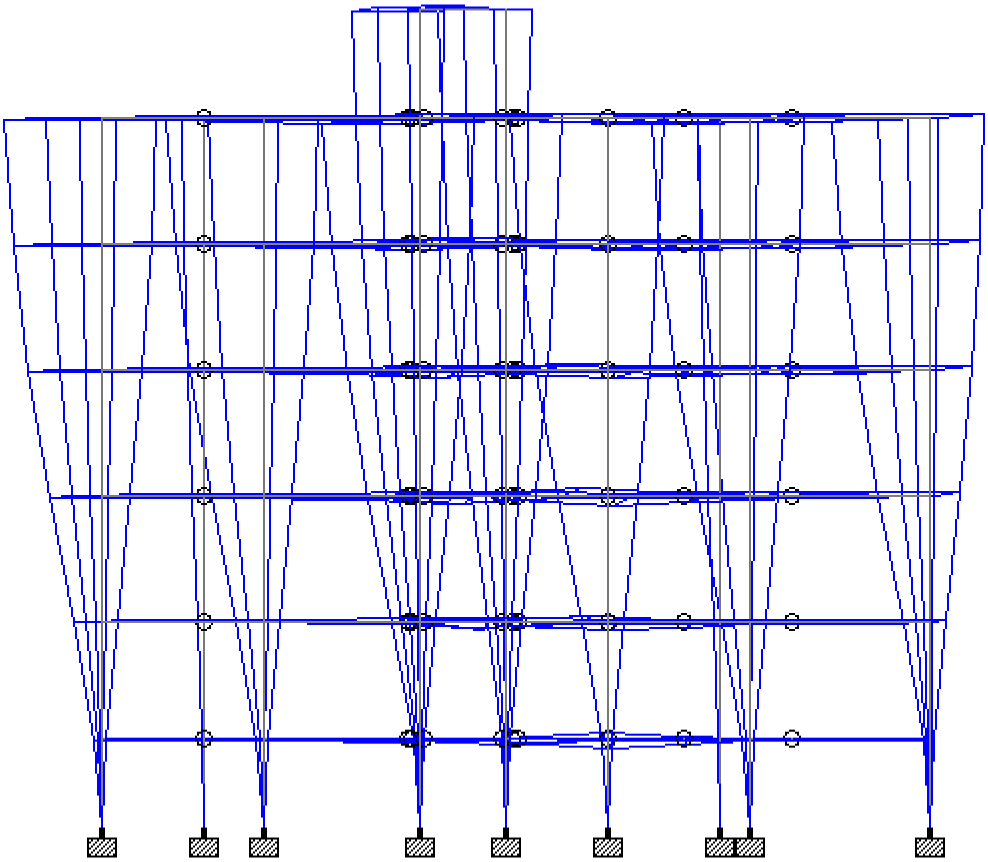


**Fig. 47**Mode Shape 1(Side view)

# CONCLUSION

## Based on this study, following conclusions may be drawn:

1. Frequency decreases with decrease in stiffness. The variation in frequency is maximum when stiffness is changed inlower storey. Changes in value of frequency are less when changes in stiffness are made in upper storey than that in lower storey. Time period shows opposite trend to that of frequency. Spectral acceleration shows same trend as that of frequency. The maximum variation in Spectral acceleration is seen when stiffness is changed in lower storey.
2. Base shear decrease with decrease in stiffness. The maximum variation is seen when stiffness changes in the lower storey. The SRSS, 10PCT, ABS, CQC shows same trend to that of Base shear.
3. Max FX, FY, FZ, MX, MY and MZ increases with decrease in stiffness except in case of first storey in which FX and MZ shows opposite trend.
4. The maximum variation in drift of storey is when stiffness is changed in that particular storey. Effect of change of stiffness in storey other than the storey in which stiffness is changed is very small. Storey drift suddenly increases in upper storey.
5. Storey shear shows expected trend of decreasing with height. In present building with given specification there is very little effect of change of stiffness on storey shear.
6. Mode 1 is dominant in X direction while Mode 2 is dominant in Z direction for mass participation factor. Mass participation factor decreases with decrease in stiffness in all direction.

# SCOPE OF FURTHER STUDY

In the present thesis, analysis of a multi-storey building under the effect of discontinuity in stiffness which is soft storey, is studied.

The present work can be extended for exhaustive study of various type of irregular and a generalised conclusion for design or such irregular buildings can be made which can help in understanding the behaviour of such irregular building.

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# APPENDIX

**Following is staad editor file of original building which is designed in STAAD PRO V8i**

**STAAD SPACE FILE FACTORY RESIDENCE AT (HARYANA)**

**START JOB INFORMATION**

**ENGINEER DATE 25-12-2012**

**JOB NAME 290 yard**

**END JOB INFORMATION**

**INPUT WIDTH 79**

**UNIT METER MTON**

**JOINT COORDINATES**

1 0 -2.1 0; 2 0 0 0; 3 0 2.8 0; 4 0 5.8 0; 5 0 8.8 0; 6 0 11.8 0; 7 0 14.8 0;

8 2.93 -2.1 0; 9 2.93 0 0; 10 2.93 2.8 0; 11 2.93 5.8 0; 12 2.93 8.8 0;

13 2.93 11.8 0; 14 2.93 14.8 0; 15 5.99 -2.1 0; 16 5.99 0 0; 17 5.99 2.8 0;

18 5.99 5.8 0; 19 5.99 8.8 0; 20 5.99 11.8 0; 21 5.99 14.8 0; 22 8.94 -2.1 0;

23 8.94 0 0; 24 8.94 2.8 0; 25 8.94 5.8 0; 26 8.94 8.8 0; 27 8.94 11.8 0;

28 8.94 14.8 0; 29 11.87 -2.1 0; 30 11.87 0 0; 31 11.87 2.8 0; 32 11.87 5.8 0;

33 11.87 8.8 0; 34 11.87 11.8 0; 35 11.87 14.8 0; 36 5.99 -2.1 2.44;

37 5.99 0 2.44; 38 5.99 2.8 2.44; 39 5.99 5.8 2.44; 40 5.99 8.8 2.44;

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**MEMBER INCIDENCES**

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696 370 373; 697 364 368; 698 372 373; 699 366 370; 700 374 375; 705 126 370;
706 119 373; 707 91 372; 708 105 366; 709 112 374; 710 147 375; 711 140 368;
712 84 364;

**DEFINE MATERIAL START**

**ISOTROPIC CONCRETE**

**E 2.21467e+006**

**POISSON 0.17**

**DENSITY 2.40262**

**ALPHA 1e-005**

**DAMP 0.05**

**END DEFINE MATERIAL**

**MEMBER PROPERTY INDIAN**

***COL**

706 707 711 712 PRIS YD 0.375 ZD 0.23

*BEAM

193 TO 197 199 TO 222 224 TO 244 251 253 TO 262 264 TO 266 270 TO 280 282 -
283 TO 336 338 339 341 TO 348 350 352 354 356 359 361 363 365 367 TO 417 419 -
420 422 TO 429 431 433 435 437 442 444 446 448 TO 498 500 501 503 TO 510 -
512 514 516 518 523 525 527 529 TO 579 581 582 584 TO 591 593 595 597 599 -
604 606 608 610 TO 660 662 663 665 TO 672 674 676 678 680 685 687 689 691 -
692 TO 700 PRIS YD 0.35 ZD 0.23

**MEMBER PROPERTY INDIAN**

705 708 TO 710 PRIS YD 0.45 ZD 0.23
337 340 349 351 353 355 357 358 360 362 364 366 418 421 430 432 434 436 438 -
439 TO 441 443 445 447 499 502 511 513 515 517 519 TO 522 524 526 528 580 -
583 592 594 596 598 600 TO 603 605 607 609 661 664 673 675 677 679 -
681 TO 684 686 688 690 PRIS YD 0.45 ZD 0.23

**UNIT MMS NEWTON**

**MEMBER PROPERTY**

1 1 TO 192 245 TO 250 PRIS YD 500 ZD 350

**UNIT METER MTON**

**MEMBER RELEASE**

211 254 259 262 272 284 287 305 340 345 348 354 365 368 386 421 426 429 435 -
446 449 467 502 507 510 516 527 530 548 583 588 591 597 608 611 629 664 669 -
672 678 689 692 START MZ
209 225 227 238 240 242 259 262 266 275 279 284 287 303 318 320 331 333 335 -
345 348 351 357 361 365 368 384 399 401 412 414 416 426 429 432 438 442 446 -
449 465 480 482 493 495 497 507 510 513 519 523 527 530 546 561 563 574 576 -
578 588 591 594 600 604 608 611 627 642 644 655 657 659 669 672 675 681 685 -
689 692 END MZ

**CONSTANTS**

BETA 90 MEMB 1 TO 42 55 TO 66 73 TO 90 97 TO 114 127 TO 192 245 TO 250 705 -
706 TO 708

**MATERIAL CONCRETE ALL**

**SUPPORTS**

1 8 15 22 29 36 43 50 57 64 71 78 85 92 99 106 113 120 127 134 141 148 155 -
162 169 176 183 190 197 204 211 218 229 FIXED

**CUT OFF MODE SHAPE 21**

**DEFINE 1893 LOAD**

**ZONE 0.24 RF 5 I 1.5 SS 2 ST 1 DM 0.05**

**SELFWEIGHT**

**CHECK SOFT STOREY**

**LOAD 1 EQX**

**JOINT LOAD**

1 FX 0.235

2 FX 4.96

3 FX 5.61

4 FX 5.636

5 FX 5.63

6 FX 5.666

7 FX 5.101

8 FX 0.235

9 FX 5.883

10 FX 9.146

11 FX 9.17

12 FX 9.171

13 FX 9.153

14 FX 7.963

15 FX 0.235

16 FX 5.43

17 FX 8.194

18 FX 8.296

19 FX 8.274

20 FX 8.342

21 FX 6.149

22 FX 0.235

23 FX 5.787

24 FX 8.967

25 FX 8.992

26 FX 8.993

27 FX 8.975

28 FX 7.793

29 FX 0.235

30 FX 4.972

31 FX 5.631

32 FX 5.657

33 FX 5.651

34 FX 5.687

35 FX 5.126

36 FX 0.235

37 FX 7.022

38 FX 18.501

39 FX 18.453

40 FX 18.468

41 FX 18.433

42 FX 13.281

43 FX 0.235

44 FX 6.981

45 FX 8.255

46 FX 8.287

47 FX 8.293

48 FX 8.261

49 FX 7.191

50 FX 0.235

51 FX 4.277

52 FX 10.873

53 FX 10.828

54 FX 10.832

55 FX 10.831

56 FX 8.548

57 FX 0.235

58 FX 4.278

59 FX 10.791

60 FX 10.747

61 FX 10.751

62 FX 10.75

63 FX 8.455

64 FX 0.235

65 FX 6.964

66 FX 8.238

67 FX 8.27

68 FX 8.276

69 FX 8.242

70 FX 7.175

71 FX 0.196

72 FX 4.884

73 FX 4.863

74 FX 4.887

75 FX 4.885

76 FX 4.887

77 FX 4.014

78 FX 0.196

79 FX 1.717

80 FX 2.932

81 FX 2.951

82 FX 2.952

83 FX 2.94

84 FX 2.988

85 FX 0.196

86 FX 2.686

87 FX 3.864

88 FX 3.876

89 FX 3.878

90 FX 3.874

91 FX 3.193

92 FX 0.235

93 FX 4.89

94 FX 4.88

95 FX 4.908

96 FX 4.907

97 FX 4.902

98 FX 3.99

99 FX 0.235

100 FX 3.342

101 FX 5.315

102 FX 5.332

103 FX 5.332

104 FX 5.335

105 FX 4.731

106 FX 0.235

107 FX 1.885

108 FX 4.516

109 FX 4.536

110 FX 4.536

111 FX 4.538

112 FX 5.64

113 FX 0.196

114 FX 2.82

115 FX 4.041

116 FX 4.055

117 FX 4.056

118 FX 4.055

119 FX 3.361

120 FX 0.235

121 FX 3.239

122 FX 5.121

123 FX 5.138

124 FX 5.137

125 FX 5.141

126 FX 4.537

127 FX 0.196

128 FX 3.757

129 FX 3.46

130 FX 3.49

131 FX 3.486

132 FX 3.499

133 FX 2.504

134 FX 0.196

135 FX 1.835

136 FX 3.308

137 FX 3.326

138 FX 3.327

139 FX 3.32

140 FX 3.395

141 FX 0.235

142 FX 1.818

143 FX 4.272

144 FX 4.294

145 FX 4.294

146 FX 4.295

147 FX 5.365

148 FX 0.235

149 FX 5.026

150 FX 6.586

151 FX 6.632

152 FX 6.632

153 FX 6.61

154 FX 4.884

155 FX 0.235

156 FX 5.064

157 FX 6.632

158 FX 6.676

159 FX 6.676

160 FX 6.656

161 FX 4.926

162 FX 0.235

163 FX 6.036

164 FX 7.478

165 FX 7.514

166 FX 7.527

167 FX 7.446

168 FX 6.33

169 FX 0.235

170 FX 6.037

171 FX 7.481

172 FX 7.516

173 FX 7.53

174 FX 7.448

175 FX 6.334

176 FX 0.307

177 FX 2.337

178 FX 4.195

179 FX 4.239

180 FX 4.231

181 FX 4.258

182 FX 2.258

183 FX 0.307

184 FX 2.338

185 FX 4.401

186 FX 4.231

187 FX 4.22

188 FX 4.248

189 FX 2.245

190 FX 0.235

191 FX 5.433

192 FX 6.289

193 FX 6.315

194 FX 6.308

195 FX 6.345

196 FX 5.793

197 FX 0.235

198 FX 6.195

199 FX 9.691

200 FX 9.726

201 FX 9.725

202 FX 9.713

203 FX 8.797

204 FX 0.235

205 FX 5.728

206 FX 8.969

207 FX 9.006

208 FX 8.996

209 FX 9.034

210 FX 7.763

211 FX 0.235

212 FX 6.104

213 FX 9.66

214 FX 9.565

215 FX 9.56

216 FX 9.548

217 FX 8.62

218 FX 0.235

219 FX 5.443

220 FX 6.305

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222 FX 6.324

223 FX 6.36

224 FX 5.814

225 FX 2.05

226 FX 2.091

227 FX 2.258

228 FX 2.295

229 FX 0.307

230 FX 3.721

231 FX 12.173

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234 FX 12.058

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263 FX 7.689

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375 FX 3.311

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3 FY 5.61

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17 FY 8.194

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19 FY 8.274

20 FY 8.342

21 FY 6.149

22 FY 0.235

23 FY 5.787

24 FY 8.967

25 FY 8.992

26 FY 8.993

27 FY 8.975

28 FY 7.793

29 FY 0.235

30 FY 4.972

31 FY 5.631

32 FY 5.657

33 FY 5.651

34 FY 5.687

35 FY 5.126

36 FY 0.235

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57 FY 0.235

58 FY 4.278

59 FY 10.791

60 FY 10.747

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64 FY 0.235

65 FY 6.964

66 FY 8.238

67 FY 8.27

68 FY 8.276

69 FY 8.242

70 FY 7.175

71 FY 0.196

72 FY 4.884

73 FY 4.863

74 FY 4.887

75 FY 4.885

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77 FY 4.014

78 FY 0.196

79 FY 1.717

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99 FY 0.235

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105 FY 4.731

106 FY 0.235

107 FY 1.885

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111 FY 4.538

112 FY 5.64

113 FY 0.196

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1 FZ 0.235

2 FZ 4.96

3 FZ 5.61

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6 FZ 5.666

7 FZ 5.101

8 FZ 0.235

9 FZ 5.883

10 FZ 9.146

11 FZ 9.17

12 FZ 9.171

13 FZ 9.153

14 FZ 7.963

15 FZ 0.235

16 FZ 5.43

17 FZ 8.194

18 FZ 8.296

19 FZ 8.274

20 FZ 8.342

21 FZ 6.149

22 FZ 0.235

23 FZ 5.787

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28 FZ 7.793

29 FZ 0.235

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61 FZ 10.751
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63 FZ 8.455
64 FZ 0.235
65 FZ 6.964
66 FZ 8.238
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68 FZ 8.276
69 FZ 8.242

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71 FZ 0.196

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78 FZ 0.196

79 FZ 1.717

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85 FZ 0.196

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92 FZ 0.235

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95 FZ 4.908

96 FZ 4.907

97 FZ 4.902

98 FZ 3.99

99 FZ 0.235

100 FZ 3.342

101 FZ 5.315

102 FZ 5.332

103 FZ 5.332

104 FZ 5.335

105 FZ 4.731

106 FZ 0.235

107 FZ 1.885

108 FZ 4.516

109 FZ 4.536

110 FZ 4.536

111 FZ 4.538

112 FZ 5.64

113 FZ 0.196

114 FZ 2.82

115 FZ 4.041

116 FZ 4.055

117 FZ 4.056

118 FZ 4.055

119 FZ 3.361

120 FZ 0.235

121 FZ 3.239

122 FZ 5.121

123 FZ 5.138

124 FZ 5.137

125 FZ 5.141

126 FZ 4.537

127 FZ 0.196

128 FZ 3.757

129 FZ 3.46

130 FZ 3.49

131 FZ 3.486

132 FZ 3.499

133 FZ 2.504

134 FZ 0.196

135 FZ 1.835

136 FZ 3.308

137 FZ 3.326

138 FZ 3.327

139 FZ 3.32

140 FZ 3.395

141 FZ 0.235

142 FZ 1.818

143 FZ 4.272

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148 FZ 0.235

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155 FZ 0.235

156 FZ 5.064

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158 FZ 6.676

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160 FZ 6.656

161 FZ 4.926

162 FZ 0.235

163 FZ 6.036

164 FZ 7.478

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167 FZ 7.446

168 FZ 6.33

169 FZ 0.235

170 FZ 6.037

171 FZ 7.481

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174 FZ 7.448

175 FZ 6.334

176 FZ 0.307

177 FZ 2.337

178 FZ 4.195

179 FZ 4.239

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182 FZ 2.258

183 FZ 0.307

184 FZ 2.338

185 FZ 4.401

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190 FZ 0.235

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197 FZ 0.235

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204 FZ 0.235

205 FZ 5.728

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207 FZ 9.006
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210 FZ 7.763
211 FZ 0.235
212 FZ 6.104
213 FZ 9.66
214 FZ 9.565
215 FZ 9.56
216 FZ 9.548
217 FZ 8.62
218 FZ 0.235
219 FZ 5.443
220 FZ 6.305
221 FZ 6.331
222 FZ 6.324
223 FZ 6.36
224 FZ 5.814
225 FZ 2.05
226 FZ 2.091
227 FZ 2.258
228 FZ 2.295
229 FZ 0.307
230 FZ 3.721
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232 FZ 12.098
233 FZ 12.122
234 FZ 12.058
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236 FZ 2.734
237 FZ 2.737
238 FZ 3.326
239 FZ 1.779

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260 FZ 4.183

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263 FZ 7.689

264 FZ 8.091

265 FZ 9.846

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267 FZ 4.773

268 FZ 4.642

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302 FZ 3.681

303 FZ 3.727

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305 FZ 7.009

306 FZ 2.591

307 FZ 7.674

308 FZ 8.071

309 FZ 9.934

310 FZ 4.306

311 FZ 4.832

312 FZ 4.702

313 FZ 2.91

314 FZ 4.301

315 FZ 3.817

316 FZ 6.235

317 FZ 7.9

318 FZ 7.605

319 FZ 6.172

320 FZ 3.699

321 FZ 5.608

322 FZ 6.897

323 FZ 3.821

324 FZ 3.681

325 FZ 3.723

326 FZ 4.195

327 FZ 6.997

328 FZ 2.59

329 FZ 7.674

330 FZ 8.029

331 FZ 9.995

332 FZ 4.386

333 FZ 4.828

334 FZ 4.697

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336 FZ 4.381

337 FZ 3.817

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342 FZ 2.305

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345 FZ 2.992

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347 FZ 2.326

348 FZ 4.009

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350 FZ 1.948

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361 FZ 6.226

362 FZ 5.517

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364 FZ 3.11

366 FZ 2.574

368 FZ 3.115

370 FZ 2.573

372 FZ 2.518

373 FZ 2.521

374 FZ 3.314

375 FZ 3.311

**SPECTRUM CQC 1893 TOR X 0.036 ACC SCALE 1 DAMP 0.05 MIS**

**SOIL TYPE 2**

**LOAD 2 EQZ**

**SPECTRUM CQC 1893 TOR Z 0.036 ACC SCALE 1 DAMP 0.05**

**SOIL TYPE 2**

**LOAD 3 DEAD LOAD**

**MEMBER LOAD**

193 TO 196 203 208 212 TO 221 228 TO 232 234 243 255 274 282 286 288 TO 291 -

297 302 306 TO 309 327 336 356 369 TO 372 378 383 387 TO 390 408 417 437 -

450 TO 453 459 464 468 TO 471 489 498 518 531 TO 534 540 545 549 TO 552 570 -

579 599 612 TO 615 630 TO 633 UNI GY -1.2

197 199 TO 202 204 TO 207 209 TO 211 222 224 TO 227 233 237 TO 242 244 251 -

253 254 256 TO 262 264 TO 266 270 TO 273 275 TO 280 283 TO 285 287 -

292 TO 296 298 TO 301 303 TO 305 310 TO 326 330 TO 335 337 TO 355 -

357 TO 368 373 TO 377 379 TO 382 384 TO 386 391 TO 407 411 TO 416 -

418 TO 436 438 TO 449 454 TO 458 460 TO 463 465 TO 467 472 TO 488 -

492 TO 497 499 TO 517 519 TO 530 535 TO 539 541 TO 544 546 TO 548 -

553 TO 569 573 TO 578 580 TO 598 600 TO 611 UNI GY -0.6

235 328 409 490 571 619 621 624 626 650 TO 653 658 660 674 680 UNI GY -1

634 TO 639 645 TO 649 665 687 691 693 TO 700 UNI GY -0.5

SELFWEIGHT Y -0.9

**LOAD 4 FLOOR LOAD**

**FLOOR LOAD**

YRANGE 2.8 11.8 FLOAD -0.5 XRANGE 0 2.93 ZRANGE 0 7.59 GY

YRANGE 2.8 11.8 FLOAD -0.75 XRANGE 2.93 8.94 ZRANGE 0 2.44 GY

YRANGE 2.8 11.8 FLOAD -0.5 XRANGE 8.94 11.87 ZRANGE 0 7.59 GY

YRANGE 2.8 11.8 FLOAD -0.55 XRANGE 2.93 8.94 ZRANGE 2.44 7.59 GY

YRANGE 2.8 11.8 FLOAD -0.75 XRANGE 0 2.279 ZRANGE 7.59 9.65 GY

YRANGE 2.8 11.8 FLOAD -0.75 XRANGE 2.279 4.764 ZRANGE 7.59 9.65 GY

YRANGE 2.8 11.8 FLOAD -0.5 XRANGE 4.764 7.841 ZRANGE 7.59 9.65 GY

YRANGE 2.8 11.8 FLOAD -0.75 XRANGE 9.591 11.87 ZRANGE 7.59 9.65 GY

YRANGE 2.8 11.8 FLOAD -0.5 XRANGE 0 3.07 ZRANGE 9.65 12.09 GY

YRANGE 2.8 11.8 FLOAD -0.75 XRANGE 0 3.07 ZRANGE 12.09 15.44 GY

YRANGE 2.8 11.8 FLOAD -0.5 XRANGE 0 3.07 ZRANGE 15.44 19.75 GY

YRANGE 2.8 11.8 FLOAD -0.55 XRANGE 3.07 8.8 ZRANGE 9.65 16.47 GY

YRANGE 2.8 11.8 FLOAD -0.5 XRANGE 3.07 8.8 ZRANGE 16.47 19.75 GY

YRANGE 2.8 11.8 FLOAD -0.5 XRANGE 8.8 11.87 ZRANGE 9.65 12.09 GY

YRANGE 2.8 11.8 FLOAD -0.75 XRANGE 8.8 11.87 ZRANGE 12.09 15.44 GY

YRANGE 2.8 11.8 FLOAD -0.5 XRANGE 8.8 11.87  ZRANGE 15.44 19.75  GY

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YRANGE 14.8 14.8 FLOAD -0.6 XRANGE 0 2.93  ZRANGE 0 7.59  GY

YRANGE 14.8 14.8 FLOAD -0.6 XRANGE 2.93 8.94  ZRANGE 0 2.44  GY

YRANGE 14.8 14.8 FLOAD -0.6 XRANGE 8.94 11.87  ZRANGE 0 7.59  GY

YRANGE 14.8 14.8 FLOAD -0.65 XRANGE 2.93 8.94  ZRANGE 2.44 7.59  GY

YRANGE 14.8 14.8 FLOAD -0.6 XRANGE 0 2.279  ZRANGE 7.59 9.65  GY

YRANGE 14.8 14.8 FLOAD -0.75 XRANGE 2.279 4.764  ZRANGE 7.59 9.65  GY

YRANGE 14.8 14.8 FLOAD -0.6 XRANGE 4.764 7.841  ZRANGE 7.59 9.65  GY

YRANGE 14.8 14.8 FLOAD -0.6 XRANGE 9.591 11.87  ZRANGE 7.59 9.65  GY

YRANGE 14.8 14.8 FLOAD -0.6 XRANGE 0 3.07  ZRANGE 9.65 12.09  GY

YRANGE 14.8 14.8 FLOAD -0.6 XRANGE 0 3.07  ZRANGE 12.09 15.44  GY

YRANGE 14.8 14.8 FLOAD -0.6 XRANGE 0 3.07  ZRANGE 15.44 19.75  GY

YRANGE 14.8 14.8 FLOAD -0.65 XRANGE 3.07 8.8  ZRANGE 9.65 16.47  GY

YRANGE 14.8 14.8 FLOAD -0.6 XRANGE 3.07 8.8  ZRANGE 16.47 19.75  GY

YRANGE 14.8 14.8 FLOAD -0.6 XRANGE 8.8 11.87  ZRANGE 9.65 12.09  GY

YRANGE 14.8 14.8 FLOAD -0.6 XRANGE 8.8 11.87  ZRANGE 12.09 15.44  GY

YRANGE 14.8 14.8 FLOAD -0.6 XRANGE 8.8 11.87  ZRANGE 15.44 19.75  GY

YRANGE 17.4 17.4 FLOAD -1 GY

**LOAD 5 LIVE LOAD**

**FLOOR LOAD**

YRANGE 2.8 11.8 FLOAD -0.2 XRANGE 0 2.93  ZRANGE 0 7.59  GY

YRANGE 2.8 11.8 FLOAD -0.2 XRANGE 2.93 8.94  ZRANGE 0 2.44  GY

YRANGE 2.8 11.8 FLOAD -0.2 XRANGE 8.94 11.87  ZRANGE 0 7.59  GY

YRANGE 2.8 11.8 FLOAD -0.2 XRANGE 2.93 8.94  ZRANGE 2.44 7.59  GY

YRANGE 2.8 11.8 FLOAD -0.2 XRANGE 0 2.279  ZRANGE 7.59 9.65  GY

YRANGE 2.8 11.8 FLOAD -0.3 XRANGE 2.279 4.764  ZRANGE 7.59 9.65  GY

YRANGE 2.8 11.8 FLOAD -0.2 XRANGE 4.764 7.841  ZRANGE 7.59 9.65  GY

YRANGE 2.8 11.8 FLOAD -0.2 XRANGE 9.591 11.87  ZRANGE 7.59 9.65  GY

YRANGE 2.8 11.8 FLOAD -0.2 XRANGE 0 3.07  ZRANGE 9.65 12.09  GY

YRANGE 2.8 11.8 FLOAD -0.2 XRANGE 0 3.07  ZRANGE 12.09 15.44  GY

YRANGE 2.8 11.8 FLOAD -0.2 XRANGE 0 3.07  ZRANGE 15.44 19.75  GY

YRANGE 2.8 11.8 FLOAD -0.2 XRANGE 3.07 8.8  ZRANGE 9.65 16.47  GY

YRANGE 2.8 11.8 FLOAD -0.2 XRANGE 3.07 8.8  ZRANGE 16.47 19.75  GY

YRANGE 2.8 11.8 FLOAD -0.2 XRANGE 8.8 11.87 ZRANGE 9.65 12.09 GY

YRANGE 2.8 11.8 FLOAD -0.2 XRANGE 8.8 11.87 ZRANGE 12.09 15.44 GY

YRANGE 2.8 11.8 FLOAD -0.2 XRANGE 8.8 11.87 ZRANGE 15.44 19.75 GY

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YRANGE 14.8 14.8 FLOAD -0.15 XRANGE 0 2.93 ZRANGE 0 7.59 GY

YRANGE 14.8 14.8 FLOAD -0.15 XRANGE 2.93 8.94 ZRANGE 0 2.44 GY

YRANGE 14.8 14.8 FLOAD -0.15 XRANGE 8.94 11.87 ZRANGE 0 7.59 GY

YRANGE 14.8 14.8 FLOAD -0.15 XRANGE 2.93 8.94 ZRANGE 2.44 7.59 GY

YRANGE 14.8 14.8 FLOAD -0.15 XRANGE 0 2.279 ZRANGE 7.59 9.65 GY

YRANGE 14.8 14.8 FLOAD -0.15 XRANGE 2.279 4.764 ZRANGE 7.59 9.65 GY

YRANGE 14.8 14.8 FLOAD -0.15 XRANGE 4.764 7.841 ZRANGE 7.59 9.65 GY

YRANGE 14.8 14.8 FLOAD -0.15 XRANGE 9.591 11.87 ZRANGE 7.59 9.65 GY

YRANGE 14.8 14.8 FLOAD -0.15 XRANGE 0 3.07 ZRANGE 9.65 12.09 GY

YRANGE 14.8 14.8 FLOAD -0.15 XRANGE 0 3.07 ZRANGE 12.09 15.44 GY

YRANGE 14.8 14.8 FLOAD -0.15 XRANGE 0 3.07 ZRANGE 15.44 19.75 GY

YRANGE 14.8 14.8 FLOAD -0.15 XRANGE 3.07 8.8 ZRANGE 9.65 16.47 GY

YRANGE 14.8 14.8 FLOAD -0.15 XRANGE 3.07 8.8 ZRANGE 16.47 19.75 GY

YRANGE 14.8 14.8 FLOAD -0.15 XRANGE 8.8 11.87 ZRANGE 9.65 12.09 GY

YRANGE 14.8 14.8 FLOAD -0.15 XRANGE 8.8 11.87 ZRANGE 12.09 15.44 GY

YRANGE 14.8 14.8 FLOAD -0.15 XRANGE 8.8 11.87 ZRANGE 15.44 19.75 GY

YRANGE 17.4 17.4 FLOAD -0.15 GY

***LOAD COMB 100 (FOR JOINT WEIGHT**)

*3 1.0 4 0.250

**LOAD COMB 6 (DL +EQ.LL)**

3 1.0 4 1.0 5 0.5

**LOAD COMB 7 1.5(DL + LL)100%**

3 1.5 4 1.5 5 1.5

**LOAD COMB 12 1.2(EQX + DL + 0.5LL)**

1 1.2 3 1.2 4 1.2 5 0.6

**LOAD COMB 13 1.2(-EQX + DL + 0.5LL)**

1 -1.2 3 1.2 4 1.2 5 0.6

**LOAD COMB 14 1.2(EQZ + DL + 0.5LL)**

2 1.2 3 1.2 4 1.2 5 0.6

**LOAD COMB 15 1.2(-EQZ + DL + 0.5LL)**

2 -1.2 3 1.2 4 1.2 5 0.6

**LOAD COMB 16 1.5(EQX + DL)**

1 1.5 3 1.5 4 1.5

**LOAD COMB 17 1.5(-EQX + DL)**

1 -1.5 3 1.5 4 1.5

**LOAD COMB 18 1.5(EQZ + DL)**

2 1.5 3 1.5 4 1.5

**LOAD COMB 19 1.5(-EQZ + DL)**

2 -1.5 3 1.5 4 1.5

**LOAD COMB 20 (1.5*EQX +0.9* DL)**

1 1.5 3 0.9 4 0.9

**LOAD COMB 21 (1.5*-EQX + 0.9*DL)**

1 -1.5 3 0.9 4 0.9

**LOAD COMB 22 (1.5*EQZ + 0.9*DL)**

2 1.5 3 0.9 4 0.9

**LOAD COMB 23 (1.5*-EQZ + 0.9*DL)**

2 -1.5 3 0.9 4 0.9

**LOAD COMB 24 (DL + LL)**

3 1.0 4 1.0 5 0.7

**LOAD COMB 25 (DL + LL)**

3 1.0 4 1.0 5 1.0

**LOAD COMB 32 (EQX + DL + 0.5LL)**

1 1.0 3 1.0 4 1.0 5 0.5

**LOAD COMB 33 (-EQX + DL + 0.5LL)**

1 -1.0 3 1.0 4 1.0 5 0.5

**LOAD COMB 34 (EQZ + DL + 0.5LL)**

2 1.0 3 1.0 4 1.0 5 0.5

**LOAD COMB 35 (-EQZ + DL + 0.5LL)**

2 -1.0 3 1.0 4 1.0 5 0.5

**LOAD COMB 36 (EQX + DL)**

1 1.0 3 1.0 4 1.0

**LOAD COMB 37 (-EQX + DL)**

1 -1.0 3 1.0 4 1.0

**LOAD COMB 38 (EQZ + DL)**

2 1.0 3 1.0 4 1.0

**LOAD COMB 39 (-EQZ + DL)**

2 -1.0 3 1.0 4 1.0

**LOAD COMB 40 (EQX +0.9* DL)**

1 1.0 3 0.9 4 0.9

**LOAD COMB 41 (-EQX + 0.9*DL)**

1 -1.0 3 0.9 4 0.9

**LOAD COMB 42 (EQZ + 0.9*DL)**

2 1.0 3 0.9 4 0.9

**LOAD COMB 43 (-EQZ + 0.9*DL)**

2 -1.0 3 0.9 4 0.9

PERFORM ANALYSIS

LOAD LIST 4

PRINT SUPPORT REACTION ALL

LOAD LIST 32 TO 43

PRINT SUPPORT REACTION ALL

LOAD LIST 32 TO 43

*PRINT JOINT DISPLACEMENTS LIST 184 TO 190 192 193 196 TO 224 226

LOAD LIST 7 12 TO 23

PERFORM ANALYSIS PRINT STATICS CHECK

LOAD LIST 3

PRINT SUPPORT REACTION

**START CONCRETE DESIGN**

**CODE INDIAN**

**UNIT MMS NEWTON**

FYMAIN 500 ALL

FYSEC 415 ALL

FC 25 ALL

MINMAIN 12 ALL

MAXMAIN 25 ALL

TRACK 2 MEMB 1 TO 192 245 TO 250 705 TO 712

**DESIGN COLUMN** 1 TO 192 245 TO 250 705 TO 712

**DESIGN BEAM** 193 TO 197 199 TO 222 224 TO 244 251 253 TO 262 264 TO 266 270 -

271 TO 280 282 TO 700

CONCRETE TAKE

END CONCRETE DESIGN

**PRINT STORY DRIFT**

**FINISH**

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