SEISMIC ANALYSIS OF PLAN IRREGULAR BUILDINGS

A DISSERTATION

SUBMITTED IN THE PARTIAL FULFILLMENT OF REQUIREMENTS
FOR THE AWARD OF THE DEGREE
OF
MASTER OF TECHNOLOGY
IN

STRUCTURAL ENGINEERING

Submitted by:

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CANDIDATE'S DECLARATION

I do hereby certify that the work presented is the report entitled "**SEISMIC ANALYSIS OF PLAN IRREGULAR STRUCTURE**" within the partial fulfilment of the requirement for the award of the degree of "Master of Technology" in Structural Engineering submitted within the branch of Civil Engineering, Delhi Technological university, is an real file of my very own paintings executed beneath the supervision of Assistant Prof.Hrishikesh Dubey, branch of Civil Engineering. I've not submitted the matter embodied inside the report for the award of any other diploma or degree to any other group.

(VIPUL CHANDRA)

(2K16/STE/20)

CERTIFICATE

This is certified that the work contained in this minor project entitled "**SEISMIC ANALYSIS OF PLAN IRREGULAR STRUCTURE**" by VIPUL CHANDRA (2K16/STE/20) is the requirement for the fulfilment of the degree of STRUCTURAL ENGINEERINGE at Delhi Technological University. This work was completed under my direct supervision and guidance. The student has completed his work with utmost sincerity and diligence.

Place: Delhi

Date : 30 / 07 /2018

Signature

(ASSIST. PRO.HRISHIKESH DUBEY)

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ABSTRACT

Abstract-This analysis aims to the seismic response of various vertical irregularity structures. The project is done by Response spectrum analysis (RSA) of vertically irregular RC building. This study includes the modelling of regular and H-shape plan irregular building having area of 20X15m and height of 3.2 m from each except ground floor for G+7 storey .The performance of this framed building during study earthquake motions depends on the distribution of stiffness, strength, and mass in both the horizontal and vertical planes of the building. The main aim of this work is comparative study of the stiffness of the structure by considering the three models in Regular Structure and three models in Plan irregular structure with different Vertical irregular structure. All models are analysedwith dynamic earthquake loading for the Zones V .Result found from the response spectrum analysis that in irregular shaped building displacements are more than that of regular shaped building. All building frames are modelled & analysed in software Staad.Pro V8i. Various seismic responses like base shear, frequency, node displacement, etc. are obtained. The overall performance of regular building is found better than irregular building .The seismic performance of multistory regular building is determined by Response Spectrum analysis in STAAD Pro. Software.

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LIST OF ABBREVIATIONS

IS	Indian Standard
RCC	Reinforced cement concrete
A_h	Design horizontal seismic coefficient
Z	Zone factor
R	Response reduction factor
S_a/g	Response acceleration coefficient
T	Fundamental natural time period
h	Height of building
d	Base dimension of building at plinth level
Q_i	Design lateral force at floor i
W_i	Seismic weight of floor i
h_i	Height of floor i measured from base
n	Number of stories in the building
M	Mass matrix
K	Stiffness matrix
X	Acceleration vector
F	Force vector
X	Displacement vector
ϕ	Mode shape
P_k	Modal participation factor of mode k
g	Acceleration due to gravity
ω	Natural circular frequency of vibration
ω^2	Eigen-value
λ_k	Absolute value of response quantity in mode k
M_k	Modal mass of mode k
λ^*	Peak response quantity due to closely spaced modes
λ	Peak response quantity due to all modes considered

CONTENTS

CHAPTER 1

INTRODUCTION

1.1 GENERAL

Experience in the past earthquake has shown that the buildings with simple and uniform configurations are subjected to less damage. A building with discontinuity is subjected to concentration of forces and deformations at the point of discontinuity which may leads to the failure of members at the junction and collapse of building. The analysis procedure quantifying the earthquake forces and its demand depending on the importance and cost, the method of analyzing the structure varies from linear to nonlinear. The behavior of a building during an earthquake depends on several factors, stiffness, and adequate lateral strength, and ductility, simple and regular configurations. The buildings with regular geometry and uniformly distributed mass and stiffness in plan as well as in elevation suffer much less damage compared to ir-regular configurations. But nowadays need and demand of the latest generation and growing population has made the architects or engineers inevitable towards planning of irregular configurations.

1.2. OBJECTIVES OF THE STUDY

1. To determine seismic capacity of reinforced concrete framed buildings with regular plan (rectangular) and irregular plan (according to IS 1893-2002) such as L U T & H shape by using Response spectrum analysis.

2. To compare the behaviour of a regular building and plan irregular buildings in terms of Response Spectrum Analysis.

3. To study the displacement of irregular buildings at each floor level and compare with the regular structure.

1.3 DEFINITIONS

1.3.1 PLAN IRREGULARITIES ; IRREGULARITY TYPE AND DESCRIPTION

(i) Torsion Irregularity

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

(ii)Re-entrant Corners

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

(iii)Diaphragm Discontinuity

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

(iv)Out-of-Plane Offsets

Discontinuities in a lateral force resistance path, such as out-of-plane offsets of vertical elements Non-parallel Systems The vertical elements resisting the lateral force are not parallel to or symmetric about the major orthogonal axes or the lateral force resisting elements.

1.3.2 VERTICAL IRREGULARITY ; IRREGULARITY TYPE AND DESCRIPTION

(i) 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

b) Stiffness Irregularity — Extreme Soft Storey

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

(ii)Mass Irregularity

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

(iii) Vertical Geometric

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

(iv)In-Plane Discontinuity in Vertical Elements Resisting Lateral Force

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

(v)Discontinuity in Capacity — Weak Storey

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

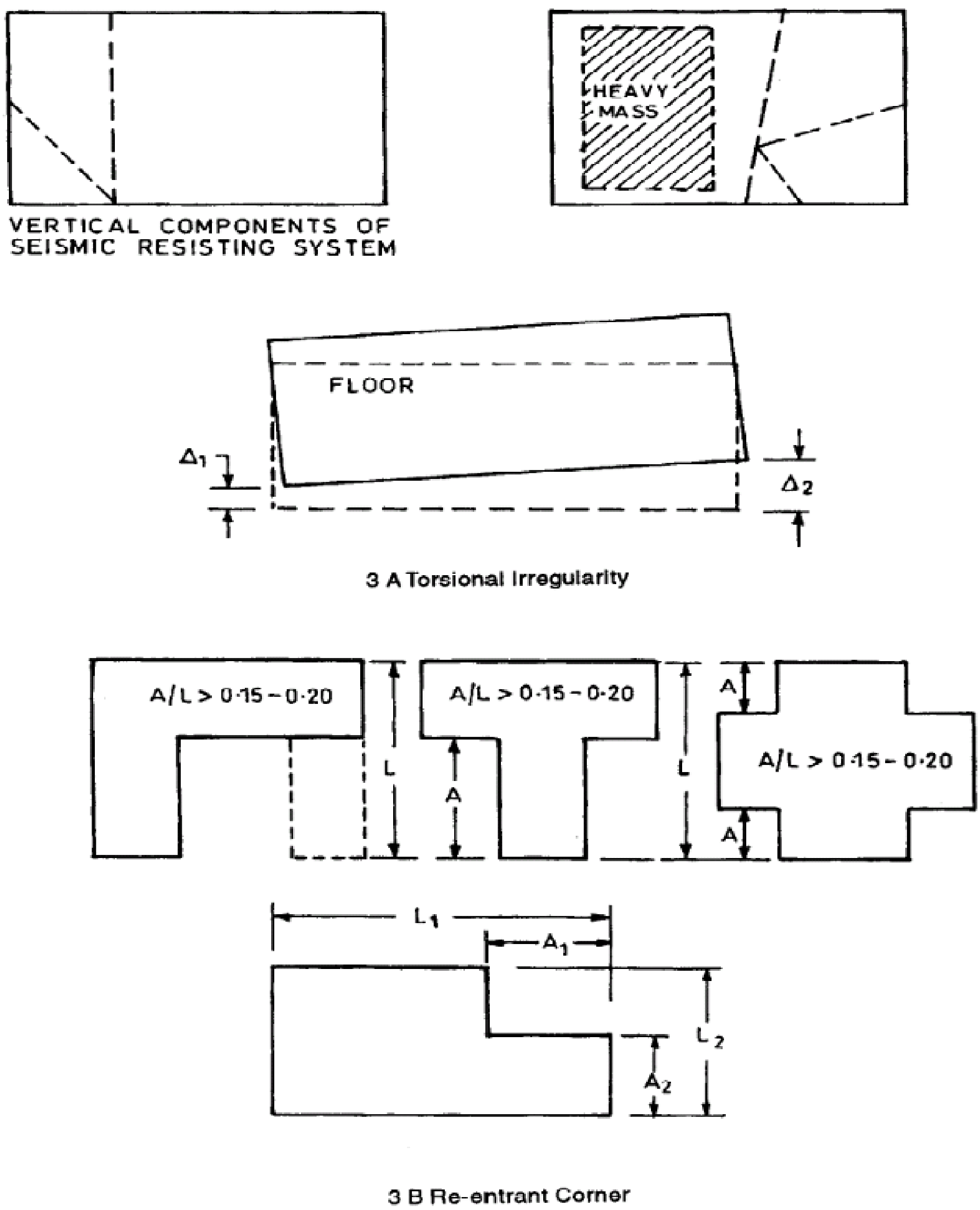
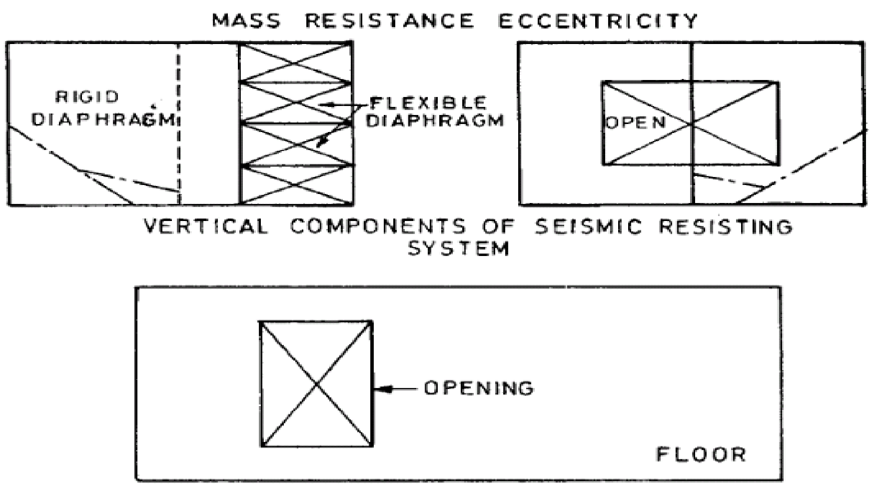
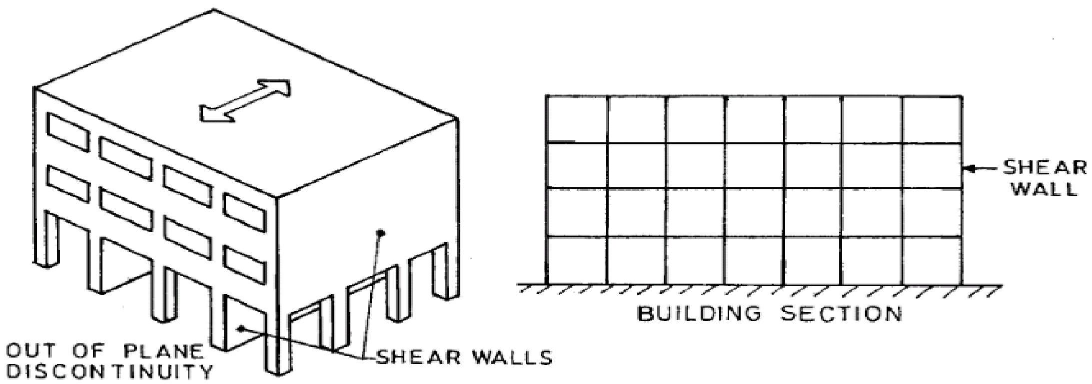


Fig 1.1

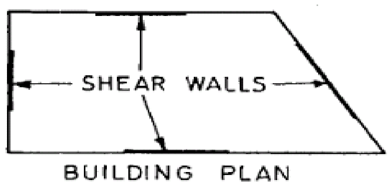
Plan Irregularity



3 C Diaphragm Discontinuity



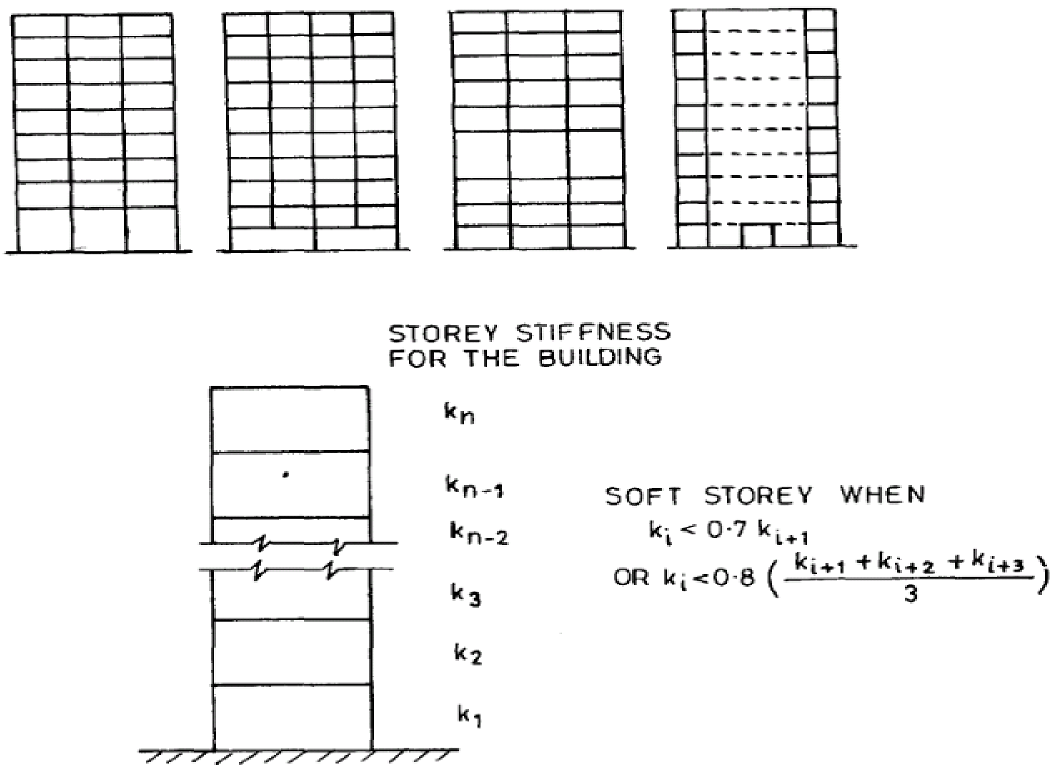
3 D Out-of-Plane Offsets



3 E Non-Parallel System

Fig 1.2

Plan Irregularity



4 A Stiffness Irregularity

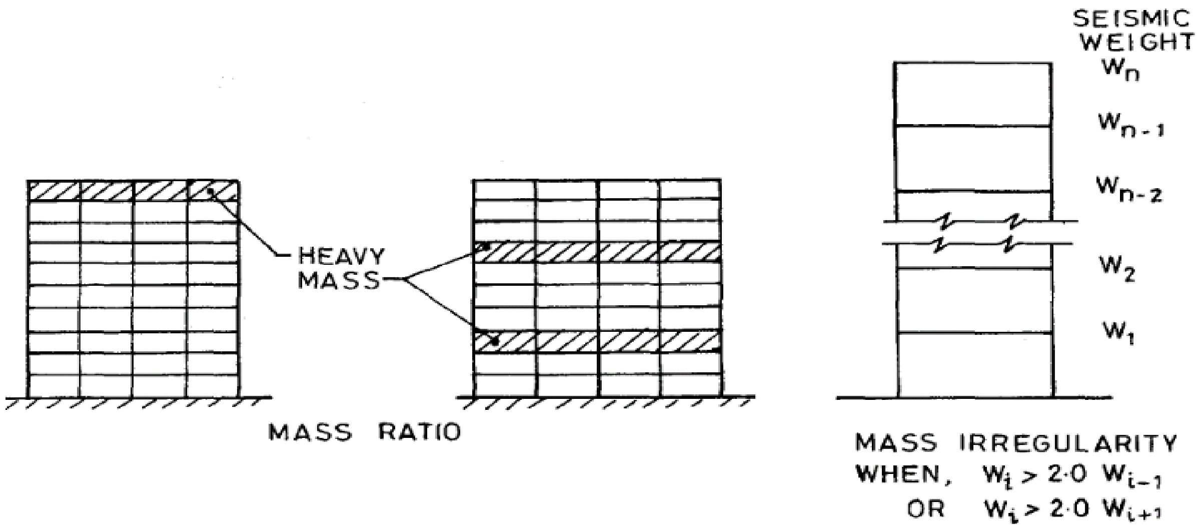
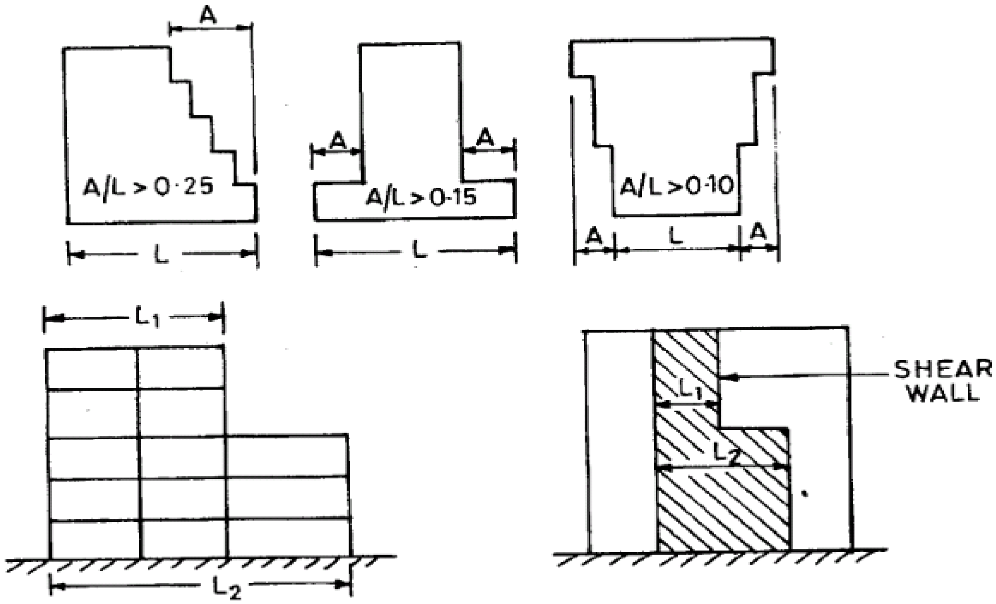
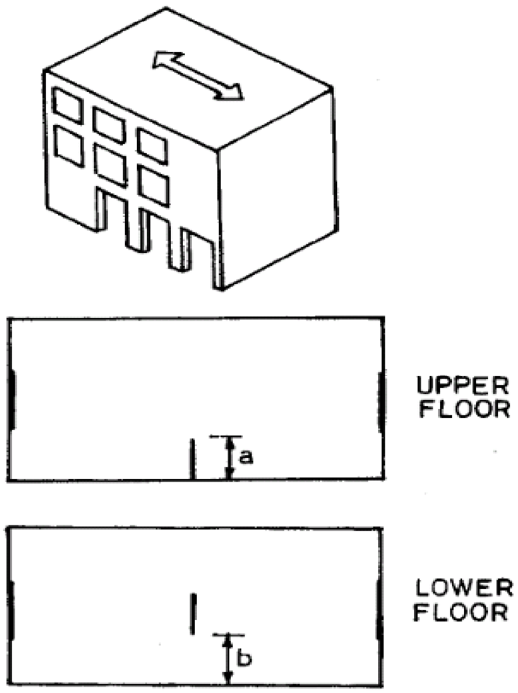


Fig 1.3

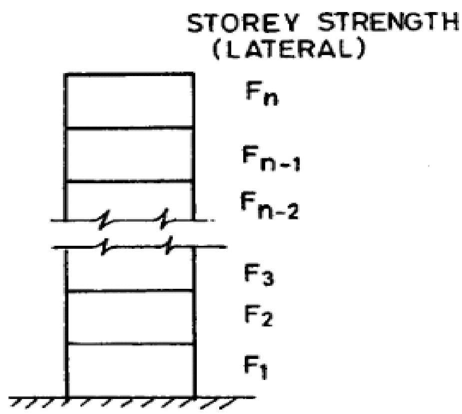
Vertical Irregularity



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



In-Plane Discontinuity in Vertical Elements Resisting
Lateral Force when $b > a$



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

Fig 1.4

Vertical Irregularity

CHAPTER 2

REVIEW OF LITERATURE

2.1 GENERAL

Disasters per se have been dealt by management experts, government and semi-government agencies in the past and the role of engineers has been mostly relegated to retrofitting and strengthening post disaster. Most international codes have now started addressing the situation as disasters are occurring at a higher frequency across the globe. Traditionally declared disaster prone zones are ever expanding into new domains. Thus awareness among engineers, architects and equally among non-engineers has increased and resulted into various alternatives for mitigation and prevention aspects. Available literature examines individual aspects of each disaster. International guidelines describe the methodology that can be adopted for structural analysis and design for earthquakes, but there is no standardized protocol for other disasters. Thus it is difficult to truly handle the complex dynamics of real-time forces of earthquake, wind, fire or flood. Proprietary software on the other hand leave very little scope of flexibility to incorporate specific aspects of forces that could have disastrous effects. Once again the catch in available software is the modeling effort and the assurance of a robust model depicting the real life situation. Thus both literature and software do not enable the engineer to have, on hand, a mechanism of finding a solution to his customized needs nor to study the effects in a post processor instead of tabulated or two-dimensional graphical outputs. Besides, there has been no attempt at mirroring the outputs in a virtual environment which would show the actual behaviour of the building in a real-life manner.

Studies have thus been highly focused on addressing the structural aspects of various disasters.

Habibullah and Pyle in 2002 [6], presented simple steps for performing pushover analysis using SAP2000 software. The SAP2000 static pushover analysis capabilities, which are fully integrated into the program, allow quick and easy implementation of the pushover procedures prescribed in the ATC-40 and FEMA-273 documents for both two and three-dimensional buildings.

Moghadam and Tso in 2004 [7], extended pushover analysis to cover plan eccentric buildings and took the three-dimensional torsional effect into account. Because of torsional deformation, floor displacements of the building will consist of both translational and rotational components. Torsional effect can be particularly damaging to elements located at or near the flexible edge of the building where the translational and rotational components of the floor displacement are additive. In view of the damage observed in many eccentric buildings in past earthquakes.

Chopra in 2008 [8] stated in a PEER report that the standard response spectrum analysis (RSA) for elastic buildings is reformulated as a Modal Pushover Analysis (MPA). The peak response of the elastic structure due to its nth vibration mode can be exactly determined by pushover analysis of the structure subjected to lateral forces distributed over the height of the building. The structure is pushed to the roof displacement determined from the peak deformation of the nth-mode elastic SDF system. Combining these peak modal responses by modal combination rule leads to the MPA procedure. Thus the trend of comparing computed hinge plastic rotations against rotation limits established in FEMA-273 to judge structural performance should be replaced and Performance evaluation should be based on story drifts known to be closely related to damage and can be estimated to a higher degree of accuracy by pushover analyses.

FEMA-368 (2009)[11] define criteria for the design and construction of new buildings, additions and alterations to existing buildings to enable them to resist the effects of earthquake ground motions. These provisions provide minimum seismic design criteria of safety for structures by minimizing the earthquake related risk to life and improve the capability of existing structures to function during and after design earthquakes. Whereas, FEMA-369 (2001) [12] provides general requirements, background information, and explanations for applying the analysis and design criteria in the Provisions of FEMA-368.

Hasan R. in 2012 [13] presented a simple computer-based push-over analysis technique for performance-based design of building frameworks subject to earthquake loading. The technique was based on the conventional displacement method of elastic analysis. Through the use of a plasticity-factor that measured the degree of plastification, the standard elastic and geometric stiffness matrices for frame elements (beams, columns, etc.) were progressively modified to account for nonlinear elastic-plastic behavior under constant gravity loads and incrementally increasing lateral loads. The method accounted for first-order elastic and second order geometric stiffness properties, and the influence that combined stresses have on plastic behavior.

After designing and detailing the reinforced concrete frame structures, **Korkmaz** in **2014 [14]** carried out a nonlinear pushover analysis and nonlinear dynamic time history analysis for evaluating the structural seismic response for the acceptance of load distribution for inelastic behavior. It was assumed for pushover analysis that seismic demands at the target displacement are approximately maximum seismic demands during the earthquake. First yielding and shear failure of the columns was experienced at the larger story displacements and rectangular distribution always give the higher base shear weight ratio compared to other load distributions for the corresponding story displacement. The pushover analyses results for rectangular load distribution estimated maximum seismic demands during the given earthquakes were more reasonable than the other load distributions.

A trial application of the SAC-FEMA method was presented by **Lupoi** in **2008[15].** Existing RC buildings not designed for earthquake loads may fail due to several possible weak mechanisms, whose relevance was unpredictable before an accurate analysis was carried out. Concepts and procedures of the SACFEMA method were proven to apply to such complicated cases as well. In particular, the stability of the final outcome of the analysis, the total annual risk, record-to record variability, randomness of the material properties and inadequate knowledge on the capacity side, was fully confirmed. This fundamental feature, together with the relative simplicity of the approach, made it all the more desirable for it to be gradually adopted as a design method for new, well conceived and detailed, earthquake resistant constructions.

Menjivar and **Pinho** in **2014 [16]** extended the pushover method to assess the performance of 3D irregular RC structures. The issues of diaphragm effects, loading profiles and incremental dynamic analysis were studied. The modeling based on Displacement Based and Force Based Pushover was compared. Conventional verses Adaptive Pushover results have been compared and werefound to be close.

Jan in 2016 [17] stated that when evaluating the seismic demands of tall buildings, engineers were more likely to adopt simplified non-linear static analytical procedures, or pushover analyses, instead of the more complicated non-linear response history analysis. Since the conventional procedure has some drawbacks in predicting the inelastic seismic demands of high-rise buildings, in this paper, a new simplified pushover analysis procedure, considering higher mode effects, was proposed. The basic features of the proposed procedure were the response spectrum-based higher mode displacement contribution ratios, a new formula for determining the lateral load pattern and the upper-bound (absolute sum) modal combination rule for determining the target roof displacement.

2.2. SCOPE OF THE STUDY

The Present work is focused on the study of seismic demand of different irregular RC buildings. The configuration involves plan irregularities such as re-entrant corners. The performance is studied in terms of, base shear, lateral displacements, performance point and hinge status in Non linear analysis using ATC40. Also in this paper an attempt is made to identify the performance levels. The entire modeling, analysis and design is carried out by using STADD Pro nonlinear version software.

- Regular and Irregular Shaped Building are considered for study.
- Response Spectrum Analysis
- Only Plan Irregularity is considered in this study
- Zone V is taken for study because of higher possibility of high magnitude Earth Quake in this zone.

CHAPTER 3
METHODOLOGY

3.1 LOAD CONSIDERATION

3.1.1 GENERAL

The present study is concerned with analyzing seismic behavior of Regular and Irregular buildings. In such buildings percentage of irregularity and shape of buildings with same plan area of same heights in same storey are usually observed. In the present study two methods namely Equivalent static method and Response spectrum method are used to study the seismic response of irregular buildings using STAAD.Pro software.

3.2 LOADS

The knowledge of various types of loads and their worst combinations to which a structure may be subjected during its life span is essential for safe design of structure. Forces acting on structures are called loads. Primary loads acting on the building have been considered as dead load, live load and earthquake load. The dead load and live load has been applied in gravity direction and earthquake load has been applied in lateral direction.

3.2.1 Dead load

Dead loads are permanent loads and acts vertically downward. Dead loads are basically due to self weight of structure as well as due the weight of floor slab, beams, columns, walls and floor finish. Dead load of buildings can be calculated by calculating the self weight of each structural element and adding them. The formula used for calculating self weight of each structural element in kN/m is unit weight of material (kN/m3) × depth of element × width of element.

3.2.2 Live load

Live loads are those which may change in position and magnitude. The use of the term live load‟ has been modified to „imposed load‟ to cover not only the physical contribution due to persons but also due to nature of occupancy, the furniture and other equipments which are a part of the character of the occupancy. The imposed load assumed to be produced by the intended use or occupancy of a building, including the weight of movable partitions, distributed, concentrated loads, load due to impact and vibration, and dust load but excluding wind, seismic, snow and other loads due to temperature changes, creep, shrinkage, differential settlement, etc. Imposed loads for residential buildings are taken as per IS 875 Part 2 as described below.

Table 3.1 (UDL for Building Parts)

RESIDENTIAL BUILDING	**UNIFORMLY DISTRIBUTED LOAD (KN/m^2)**
All Room And Kitchen	**2**
Toilet And Bathroom	**2**
Corridors, passages, staircases and store rooms	**3**
Balconies	**3**
Dining rooms, cafeterias and restaurants	**4**

3.2.3 Seismic Loads

North and northeast parts of India have large scales of hilly terrain, which fall sunder seismic zone IV and V. Buildings in such regions are highly prone to earthquake. Earthquake generates due to collision of tectonic plates and hence epicenter of earthquakes is generally located at fault lines. During past earthquakes, reinforced concrete (RC) frame buildings that have columns of different heights within one storey, suffered more damage in the shorter columns as compared to long columns in the same storey and hence demands careful design of buildings on hill slopes. Indian Standard: 1893: (1962, 1966, 1970, 1975, 1984, 2002) code of practice on the “Criteria for Earthquake Resistant Design of Structures” by the Bureau of Indian Standards (BIS) provides guidelines for design of earthquake resistant structures. Determination of design lateral force is an important aspect of seismic analysis.

3.3 CODE OF PRACTICE

List of Indian Standards on Earthquake Engineering:-

The following Indian Standards are necessary adjuncts to this standard:

IS No.	Title
456:2000	Code of practice for plain and reinforced concrete (fourth revision)
800:1984	Code of practice for general construction in steel (second revision)
875	Code of practice for design loads (other earthquake) for buildings and structures: .
(Part l): 1987	Dead loads — Unit weights of building material and stored materials (second revision)
(Part 2):1987	Imposed loads (second revision)
(Part 5):1987	Special loads and load combinations (second revision)
1498:1970 .	Classification and identification of soils for general engineering purposes (first revision)
1888:1982	Method of load test on soils (second revision)
1893 (Part4)	Criteria for earthquake resistant design of structures: Part 4 Industrial structures including stack like structures .
2131:1981	Method of standard penetration test for soils (first revision)
4326:1993	Earthquake resistant design and construction of buildings — Code of practice (second revision)
6403:1981	Code of practice for determination of bearing capacity of shallow foundations (first revision)
13827:1993	Improving earthquake resistance of earthen buildings —

Guidelines

SP6 (6) :1972 Handbook for structural engineers: Application of plastic theory in design of steel structures

ATC 40 Seismic evaluation and Retrofit of concrete buildings

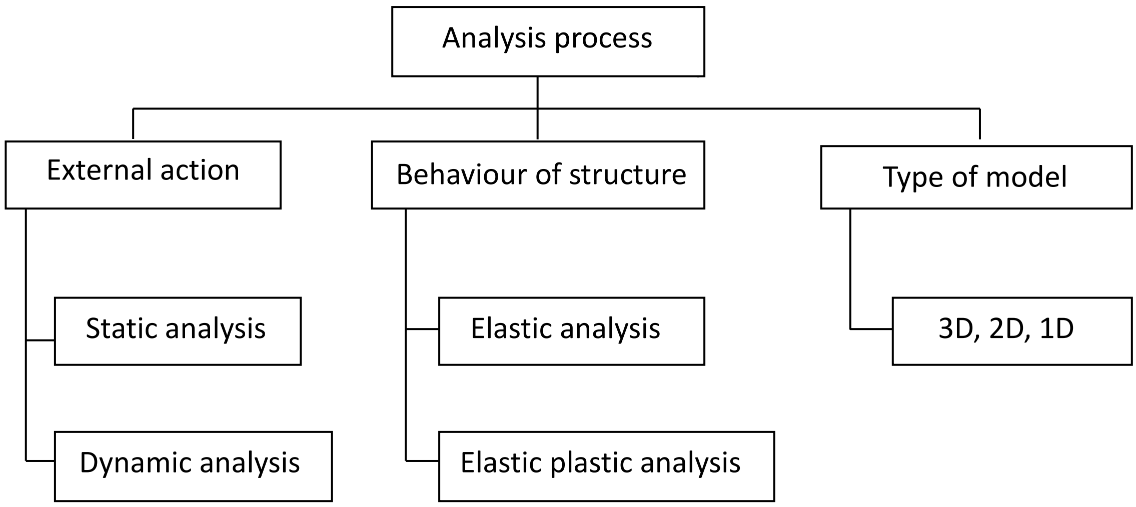
3.4 LOAD COMBINATIONS

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

1) 1.5(Dead load + Impose load)
2) 1.2(Dead load + Imposed load ± Earthquake load)
3) 1.5(Dead load ± Earthquake load)
4) 0.9Dead load ± 1.5 Earthquake load

3.5 METHODS OF SEISMIC ANALYSIS

There are different methods of analysis which provide different degrees of accuracy. The analysis process can be categorized on the basis of three factors: the type of externally applied loads, the behaviour of structure or structural materials, and the type of structural model selected. Based on the type of external action and behaviour of structure, the analysis can be further classified as linear static analysis, linear dynamic analysis, nonlinear static analysis, or non-linear dynamic analysis.



Linear static analysis or equivalent static analysis can only be used for regular structure with limited height. Linear dynamic analysis can be performed in two ways either by mode superposition method or response spectrum method and elastic time history method. This analysis will produce the effect of the higher modes of vibration and the actual distribution of forces in the elastic range in a better way. They represent an improvement over linear static analysis. The significant difference between linear static and dynamic analysis is the level of force and their distribution along the height of the structure.

Non-linear static analysis is an improvement over the linear static or dynamic analysis in the sense that it allows the inelastic behaviour of the structure. The method still assumes a set of static incremental lateral load over the height of the structure. The method is relatively simple to be implemented, and provides information on the strength, deformation and ductility of the structure and the distribution of demands. This permit to identify critical members likely to reach limit states during the earthquake, for which attention should be given during the design and detailing process. But this method contains many limited assumptions, which neglect the variation of loading patterns, the influence of higher modes, and the effect of resonance. This method, under the name of Push over Analysis has acquired a great deal of popularity nowadays and in spite of these deficiencies this method provides reasonable estimation of the global deformation capacity, especially for structures which primarily respond according to the first mode. A non-linear dynamic analysis or inelastic time history analysis is the only method to describe the actual behaviour of the structure during an earthquake. The method is based on the direct numerical integration of the motion differential equations by considering the elasto-plastic deformation of the structur element. This method captures the effect of amplification due to resonance, the variation of displacements at diverse levels of a frame, an increase of motion duration and a tendency of regularization of movements results as far as the level increases from bottom to top. The present study is concern with analysis of buildings on hill slopes using Equivalent static method and Response spectrum method described in detail below.

3.5.1 EQUIVALENT STATIC ANALYSIS

The equivalent static method is the simplest method of analysis. Here, force depend upon the fundamental period of structures defined by IS Code 1893:2002 with some changes. First, design base shear of complete building is calculated, and then distributed along the height of the building, based on formulae provided in code. Also, it is suitable to apply only on buildings with regular distribution of mass and stiffness.

Following are the major steps in determining the seismic forces:-

5.1.1Determination of Base shear

The total design lateral force or design base shear along any principal direction is determined by the expression:-

V = AW……....(3.1)

Where,

A = design horizontal seismic coefficient for a structure

W = seismic weight of building

The design horizontal seismic coefficient for a structure A is given by:-

A = (ZISa)/ 2Rg…………….(3.2)

Z is the zone factor in Table 2 of IS 1893:2002 (part 1)

I is the importance factor

R is the response reduction factor; Sa/g is the average response acceleration coefficient for rock and soil sites as given in figure 2 of IS 1893:2002 (part 1). The values are given for 5% damping of the structure.

Table 3.2 Zone factor, Z

Seismic zone	**II**	**III**	**IV**	**V**
Seismic intensity	Low	Moderate	Severe	Very severe
Zone factor	0.10	0.16	0.24	0.36

Table 3.3 Importance factor, I

Structure	Importance factor
Important service and community buildings, such as hospitals; schools; monumental structures; emergency buildings like telephone exchange, television stations, radio stations, railway stations, fire station buildings; large community halls like cinemas, assembly halls and subway stations, power stations	1.5
All other buildings	1.0

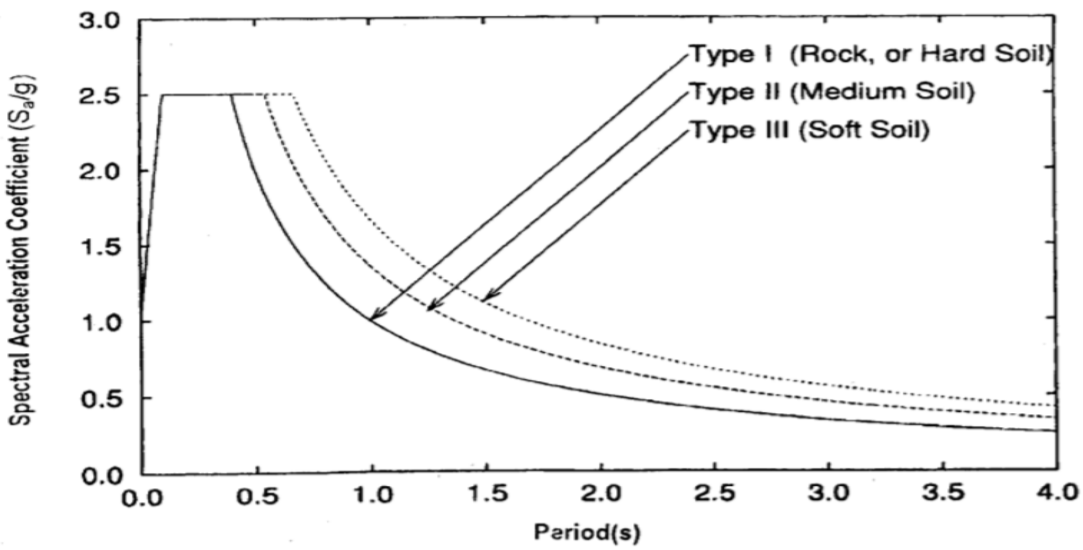


Fig. 3.1 Spectral Acceleration Coefficient Vs. Period

For rocky, or hard soil sites

$$\frac{S_a}{g} = \begin{cases} 1+15T; 0.00 \le T \le 0.10 \\ 2.50; 0.10 \le T \le 0.40 \\ 1.00/T; 0.40 \le T \le 4.00 \end{cases}$$

For medium soil sites

$$\frac{S_a}{g} = \begin{cases} 1+15T; & 0.00 \le T \le 0.10 \\ 2.50; & 0.10 \le T \le 0.55 \\ 1.36/T; & 0.55 \le T \le 4.00 \end{cases}$$

For soft soil sites

$$\frac{S_a}{g} = \begin{cases} 1+15T; & 0.00 \le T \le 0.10 \\ 2.50; & 0.10 \le T \le 0.67 \\ 1.67/T; & 0.67 \le T \le 4.00 \end{cases}$$

T is the fundamental natural period for buildings calculated as per clause 7.6 of IS 1893:2002 (part1).

$T_a = 0.075h^{0.75}$ for moment resisting frame without brick infill walls

$T_a = 0.085h^{0.75}$ for resisting steel frame building without brick infill walls

$T_a = 0.09h/\sqrt{d}$ for all other buildings including moment resisting RC frames

h is the height of the building in m and d is the base dimension of building at plinth level in m.

3.5.1(a) Lateral Distribution of Base Shear

The total design base shear has to be distributed along the height of the building. The base shear at any story level depends on the mass and deformed shape of the building. Earthquake forces tend to deflect the building in different shapes, the natural mode shape which in turn depends upon the degree of freedom of the building. A lumped mass model is idealized at each floor, which in turn converts a multi storied building with infinite degree of freedom to a single degree of freedom in lateral displacement, resulting in degrees of freedom being equal to the number of floors.

The magnitude of lateral force at floor (node) depends upon:-

- Mass of that floor
- Distribution of stiffness over the height of the structure
- Nodal displacement in given mode

Distribution of base shear along the height is done according to this equation:-

$$Q_i = V_B \times \frac{W_i\, h_i^2}{\sum_{j=1}^{n} W_j\, h_j^2} \qquad \text{……………….(3.3)}$$

Where,

Q_i = Design lateral force at floor i,

W_i = Seismic weight of floor i

h_i = Height of floor *i* measured from base and

N = Number of storeys in the building at which the masses are located.

5.1.3 Load calculations

Loads and Load combinations are given as per Indian standards. (IS 875:1984, IS 1893:2002 and IS 800:2007*)*

3.5.1(b) Seismic Loading

Seismic load is given as per IS 1893- 2002. Following assumptions are used for the calculation.

Zone factor – 0.36

Soil type – 2 (medium stiff Soil)

Importance Factor – 1

Response reduction – 5

Time period in X-direction – 0.48 seconds

Time period in Z-direction – 0.48 seconds

3.5.1(c) Dead loads

For floors; unit weight of reinforces cement concrete= 25 kN/m^3

Assume depth of slab= 150mm

3.5.1(d) Imposed loads

For residential buildings i.e. hostels

Hostels, hotels, boarding houses, lodging houses, dormitories, residential clubs:

Living rooms, bed rooms and dormitories = 2.0 kN/m^3 (IS: 875, Part 2- 1987)

5.1.1(e) Load combinations

1) 1.5 (DL+ IL)
2) 1.2 (DL+ IL $\pm$ EL)
3) 0.9 DL$\pm$ 1.5 EL
4) 1.2 (DL+ IL $\pm$ WL)
5) 0.9 DL$\pm$ 1.5 WL

3.5.2 RESPONSE SPECTRUM METHOD

IS 1893(part 1): 2002 has recommended the method of dynamic analysis of buildings in case of (i) Regular buildings-those higher than 40 m in height in zones IV and V, and those higher than 90 m in height in zones II and III.(ii) Irregular buildings- all framed buildings higher than 12 m in height in zones IV and V and those higher than 40m in height in zones II and III. The purpose of dynamic analysis is to obtain the design seismic forces, with its distribution to different levels along the height of the building and to the various lateral load resisting elements similar to equivalent lateral force method. In dynamic analysis it is assumed thatall the masses are lumped at the storey level and only sway displacement is permitted at each storey. The procedure of dynamic analysis of irregular type of buildings should be based on 3D modeling of building that will adequately represent its stiffness and mass distribution along the height of the building so that its response to earthquake could be predicted with sufficient accuracy. The dynamic analysis procedure involves the following steps:

Step 1 Determination of Eigen-values and Eigen vectors

The dynamic equilibrium equation of mass at each floor can be expressed in matrix

form as, M$\ddot{X}$ + KX = F………………..(3.4)

Where, M and K are called mass and stiffness matrices respectively, which are symmetrical. $\ddot{X}$, X and F are called acceleration, displacement and force vectors respectively, and all are functions of time (t).

If the structure is allowed to freely vibrate with no external force (vector F is equal to zero) and no damping in simple harmonic motion, then the system represents undamped free vibration. In that case, displacement x can be defined at time t is,

x t = x sin(ωt + φ)………………………(3.5)

Where, x = Amplitude of vibration,

ω = Natural circular frequency of vibration

φ = Phase difference, which depends on the displacement and velocity at time t=0

Differentiating x t twice with respect to time enables the relationship between acceleration and displacement

x t = $-\omega^2$X sin ωt + φ = $-\omega^2$ x(t)……………….(3.6)

On substituting value of x t in equation (1) it becomes

KX =ω^2MX………………………………………….(3.7)

Where ω^2 is known as Eigen-value or natural frequencies of the system.

From the relation T = 2π/ω, natural time period can be calculared.

X in equation (iv) is known as Eigen- vector or mode shape, represented as

{ φ }={ φ1 φ2 φ3 ………φn }………………………(3.8)

Step 2 Determination of modal participation factors

The modal participation factor (Pk) of any mode k is calculated as,

$$P_k = \frac{\sum_{i=1}^{n} W_i Q_i}{\sum_{i=1}^{n} W_i (Q_i)^2} \ldots\ldots(3.9)$$

W_i = Seismic weight of floor i, and

φ_{ik} = Mode shape coefficient at floor i in mode k

Step 3 Determination of modal mass

The modal mass (M_k) of mode k is given by,

$M_k = \frac{\left[\sum_{i=1}^{n} W_i Q_i\right]^2}{g\left[\sum_{i=1}^{n} W_i (Q_i)^2\right]}$…………………………(3.10)
Where, g = Acceleration due to gravity

Step 4 Design lateral force at each floor in each mode

The design lateral force (Qik) at floor i in mode k is given by,

$Q_{ik} = A_k \varphi_{ik} P_k W_i$……………………………(3.11)

Where Ak is design horizontal acceleration spectrum value of mode k and for various modes it is calculated as,

$A_h = \frac{Z}{2} \frac{I}{R} \frac{S_a}{g}$……………………………..(3.12)

Step 5 Storey shear forces in each mode

The peak shear force (Vik) acting in storey i in mode k is given by,

$V_{ik} = \sum_{j=i+1}^{n} Q_{ik}$…………………………(3.13)

Step 6 Storey shear force due to all modes considered

The peak storey shear force (Vi) in storey i due to all modes considered is obtained by combining those due to each mode in accordance with the following modal combinations.

(i) Maximum absolute response (ABS)

The Maximum Absolute Response for any system response quantity is obtained by assuming that the maximum response in each mode occurs at the same instant of time. Thus the maximum value of the response quantity is the sum of the maximum absolute value of the response associated with each mode. Therefore using ABS, peak response quantity due to closely spaced modes (λ∗) shall be obtained as,

$\lambda^* = \sum_{k=1}^{r} |\lambda_k|$……………………………(3.14)

Where λk is absolute value of response quantity in mode k and r is the numbers of modes

being considered.

Using above method, the storey shears are as follows,

Vn = [|Vn1|+|Vn2|+|Vn3|+…………….+|Vnn |]…….(3.15)

(ii) Square root of sum of squares (SRSS)

The peak response quantity (λ) due to all modes considered shall be obtained as,

λ=$\sqrt{\sum_{k=1}^{r}(\lambda_k)^2}$………..(3.16)

Where λ k

is the absolute value of response quantity in mode k and r is the numbers of

modes being considered.

Using above method, the storey shears are as follows,

Vn = [(Vn1) 2 +(Vn2) 2 +(Vn3) 2 +…………….+(Vnn) 2]$^{1/2}$……..(3.17)

(iii) Complete Quadratic Combination (CQC)

For three-dimensional structural systems exhibiting closely spaced modes, the

peak response quantities shall be combines as per Complete Quadratic Combination (CQC)

method.

The peak response quantity (λ) due to all modes considered shall be obtained as,

λ=$\sum_{i=1}^{r}\sum_{j=1}^{r}\lambda_i\rho_{ij}\lambda_j$……………….(3.18)

Where, r = Number of modes being considered,

λi = Response quantity in mode i (including sign),

λj = Response quantity in mode j (including sign),

ρij = Cross modal coefficient and is given by,

ρ=$\frac{8\zeta^2(1+\beta_{ij})\beta^{1.5}}{(1-\beta_{ij}{}^2)+4\zeta^2\beta_{ij}(1+\beta_{ij})^2}$…………(3.19)

Where, ζ = Modal damping ratio (in fraction),

βij = Frequency ratio , $\frac{\omega_i}{\omega_j}$

ωi = Circular frequency in ith mode, and

ωj = Circular frequency in jth mode

Step 7 Lateral force at each storey due to all modes

The design lateral forces Froof and Fi, at ith floor, are calculated as,

Froof = Vroof , and Fi= Vi − Vi+1

CHAPTER 4

PROCEDURE OF ANALYSIS IN STAAD.PRO 2007

For analyzing the behavior of irregular buildings under the effect of an earthquake, the following procedure is adopted.

4.1 Modeling of buildings using STAAD.Pro 2007

Step 1: Choose type of structure, name the file then file location and unit

a) Select the type of structure. The type of structure used in this research is 3D building frame.

b) A title can be put for the file.

c) Make sure that the length unit is in meter and the force unit in kilo Newton.

d) Click Next.

e) Make sure the Add Beam is checked.

f) Click Finish.

Step 2: Modeling the geometry of building

(a) Click on the Geometry tab.

(b) Set the coordinate system in X-Y plane.

(c) Click on Beam tab.

(d) Insert the required coordinates in the Nodes table.

(e) From the top menu bar of Geometry, choose add beam command to add member between required nodes.

(f) Continue the process until obtaining a required building elevation.

(g) Go to the Geometry command and choose Translational Repeat command to get a 3-D building shape.

Step 3: **Assigning section properties and material**

(a) Choose the General tab and choose the property option.

(b) Choose the Define command in dialog box of Property and select material as concrete and type of section as square and insert cross-section dimension as 0.4×0.4m.

(c) In the table of property, highlight the section selected and choose Assign to View option and click As

Step 4: **Assigning supports**

(a) In the General tab choose the support option.

(b) In the dialog box of support click on Create option.

(c) Choose the Fixed support and Add.

(d) Highlight the required support in the Support dialog box and choose Assign to Selected Nodes, click Assign.

(e) Click on nodes where required to add support.

Step 5: **Assigning loadings**

(a) Still in the General tab choose Load & Definition option.

(b) Click on seismic definition and enter the values of zone factor, response reduction
factor, importance factor, type of soil, type of structure and damping ratio.

(c) Still in seismic definition, enter the values of dead load and live load at different floor levels.

(d) Create new primary load case; give the title of load (Seismic Load, Deal Load and Live Load respectively).

(e) Enter the values of seismic Load, deal Load and live Load and different floor levels.

(f) For load combinations select Define Combinations in Load Case Details command. Enter the values of factors for different loads as per IS specifications.

4.2 Analysis of models using STAAD.Pro 2007

Step 1: Analyzing building models

(a) Click the Analysis/Print tab.

(b) Select Perform Analysis option. Choose No Print.

(c) Click Add.

(d) Select Post Print option and click on Define Commands.

(e) A dialog box will appear from which select Joint Displacement option, Member Forces option, Support Reaction option, Mode Shapes, Storey Drift and Analysis Result option and add all of them.

(f) In the top menu bar of Analyze, choose Run Analysis.

(g) Click Run Analysis for STAAD Analysis.

(h) Click Save. Then click done.

Step 2: View results of analysis

(a) To view the output results, choose view output file option.

(b) Click on Results option and view results by selecting Eigen solution, Mass Participation Factors, Analysis Results and Storey Drift option in STAAD OutputViewer.

CHAPTER 5
PROBLEM STATEMENT AND ANALYSIS

5.1 PROBLEM STATEMENT :-

Consider G+7 storey concrete buildings of different shape (regular , T , L&U) in plan as shown in figure. The buildings are located in seismic zone V . The soil are medium stiff and entire building is supported by fix support.

Description Of Structure

1. Height of Building = 26.6 m
2. Plan Area = 300 m^2
3. Size Of Beam = 500*400 mm
4. Size Of Column = 400*400 mm
5. Thickness Of Slab = 150 mm
6. Grade Of Concrete = M20

Seismic Loading

1. Self Load With Factor 1
2. Floor Weight or Lump Weight

Dead Load

1. External Wall Load = 0.23*.20 = 4.6 KN/m^2
2. Load of Plaster on external side = 0.016*21 = 0.336 KN/m^2
3. Load of Plaster on Internal side= 0.012*21=0.0252 KN/m^2
4. Internal Wall Load=0.115*20=2.3 KN/m^2
5. Load of Plaster on external side =0.016*21=0.336 KN/m^2
6. Load of Plaster on Internal side=0.012*21=0.0252 KN/m^2
7. Load of Floor Finish=0.05*24=1.24 KN/m^2
8. Load of slab = 0.150*25 = 3.75 KN/m^2

Total Dead Load = 5.188+2.888+1.2+3.75 = 13.026 KN/m^2

Live Load

1. Residential buildings = 2 KN/m^2
2. Commercial buildings = 3 KN/m^2

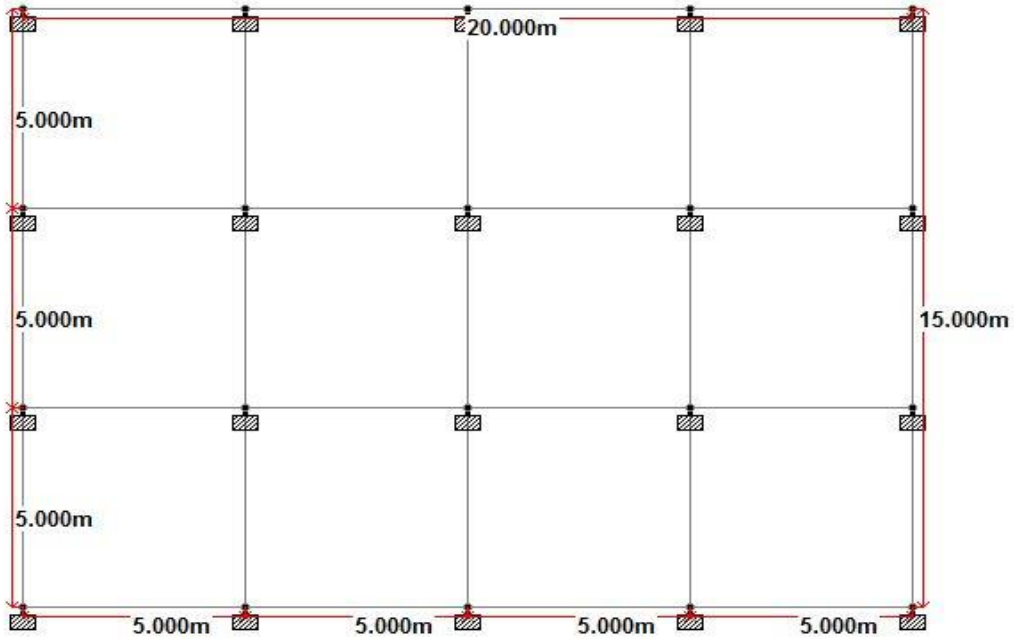
Lump Weight =DL+(0.25 or 0.50) LL

- Lump Weight on Floors = 13.026+0.50*3=14.026 KN/m^2
- Lump Weight on Roof = 13.026+0.25*1=13.562 KN/m^2

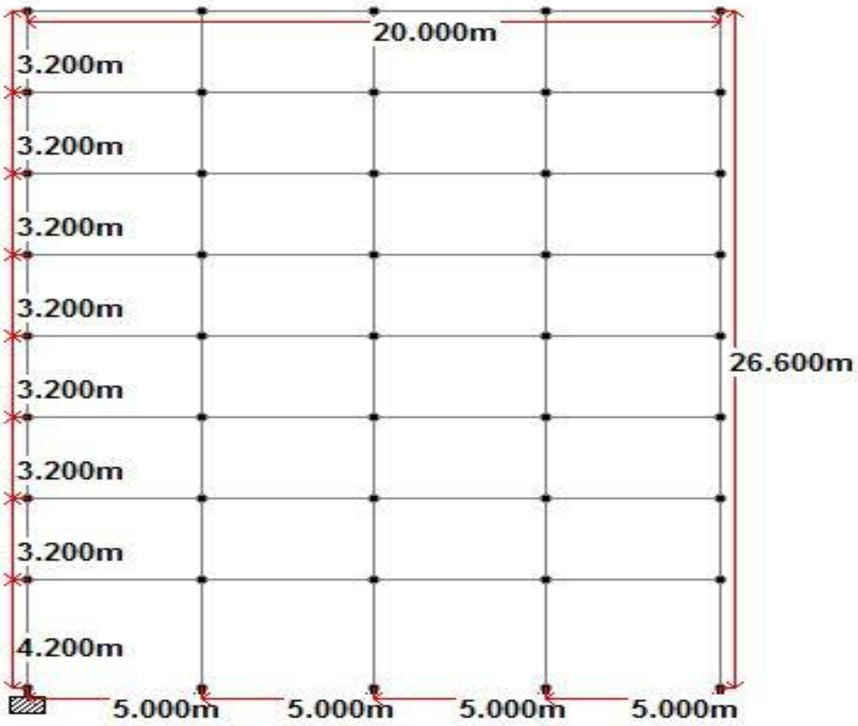
In the present study, the following building configurations are considered for analysis.

5.2 ANALYSIS OF STRUCTURES

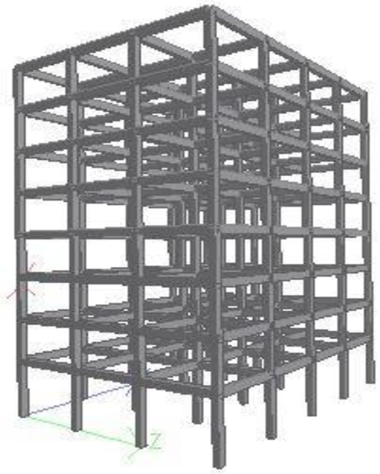
(a) G+7 Regular shape building



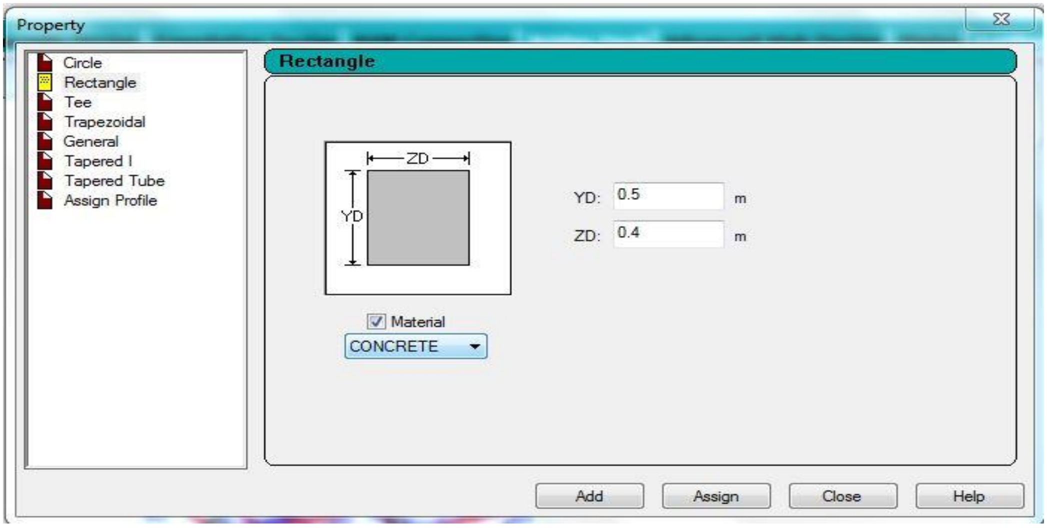
(Fig 5.1) Plan of Regular Shape Structure



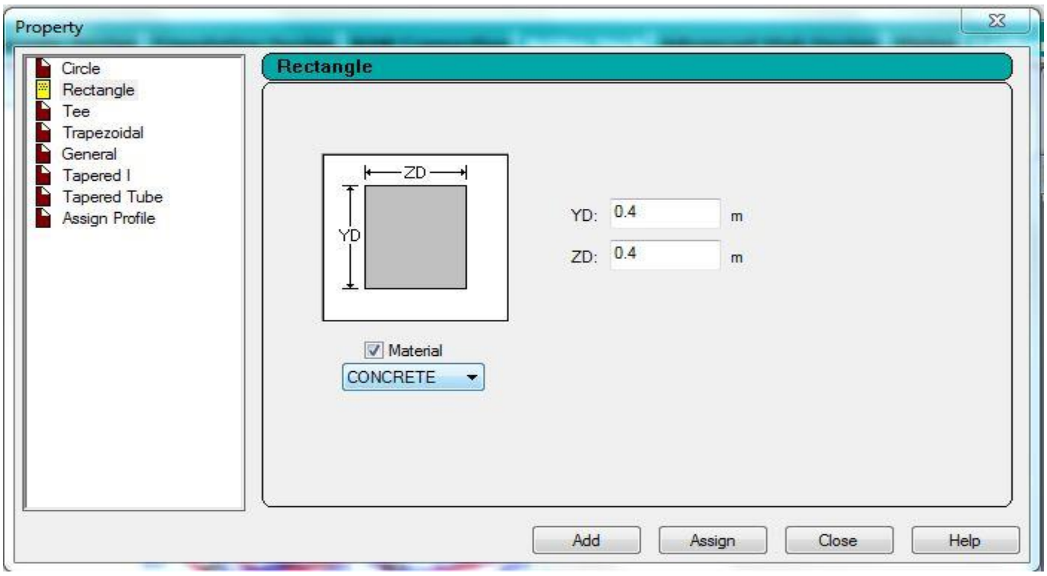
(FIg.5.2) Elevation of Regular Shape Structure



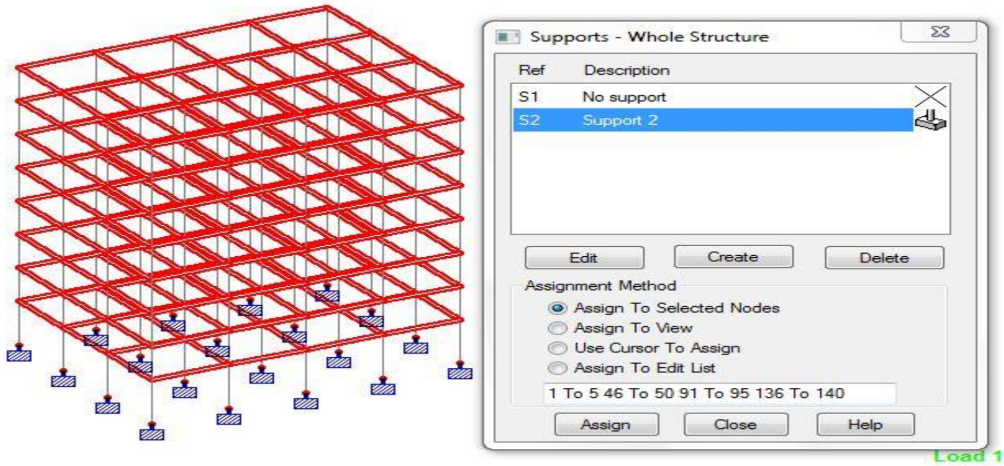
(Fig 5.3) 3D View Of Regular Shape Structure



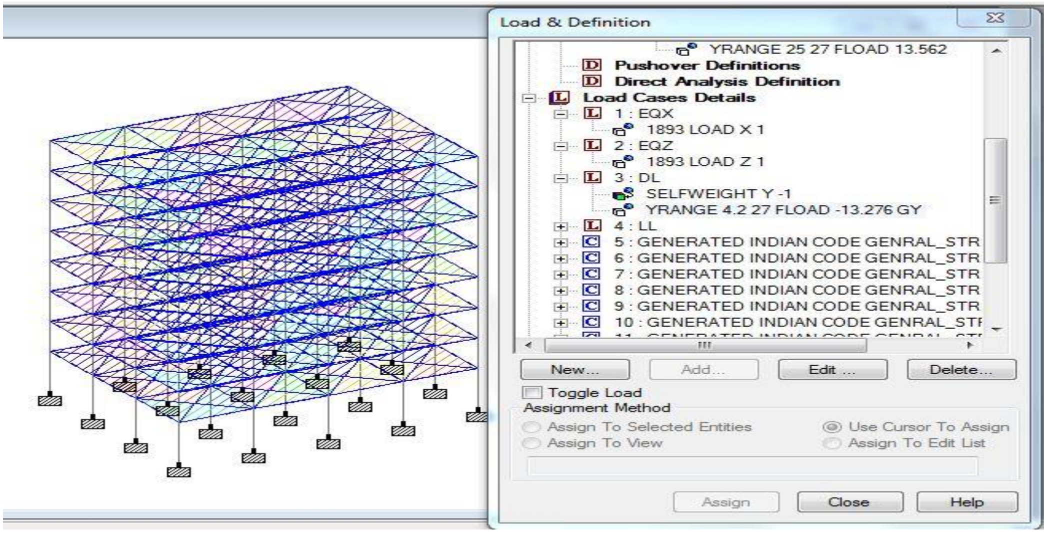
(Fig 5.4) Beam Section of Regular Structure



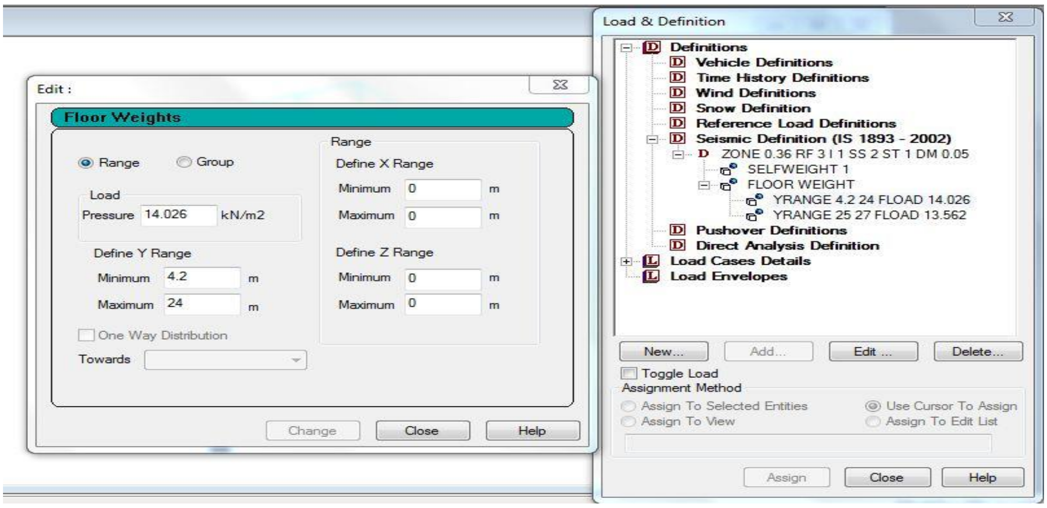
(Fig 5.5) Column Section Of Regular Structure



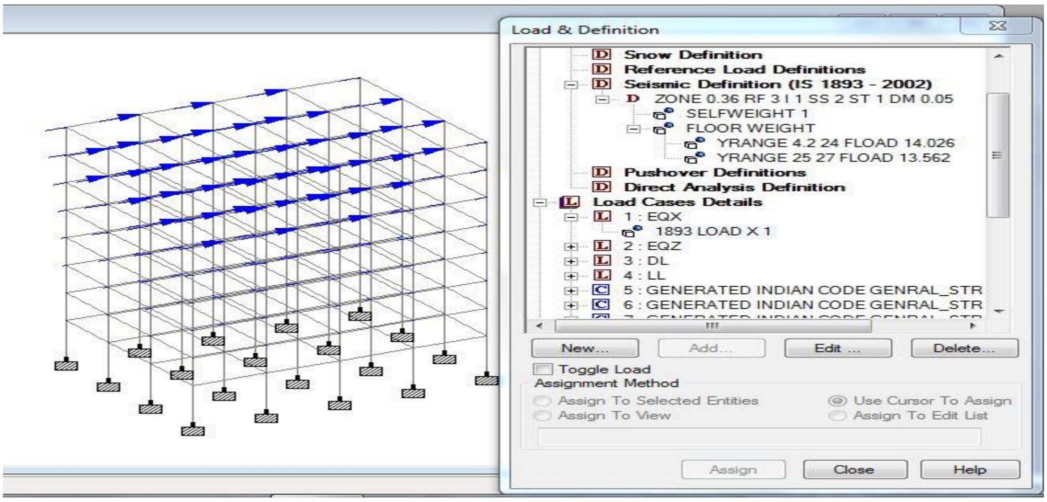
(Fig 5.6) Support Of Regular Section



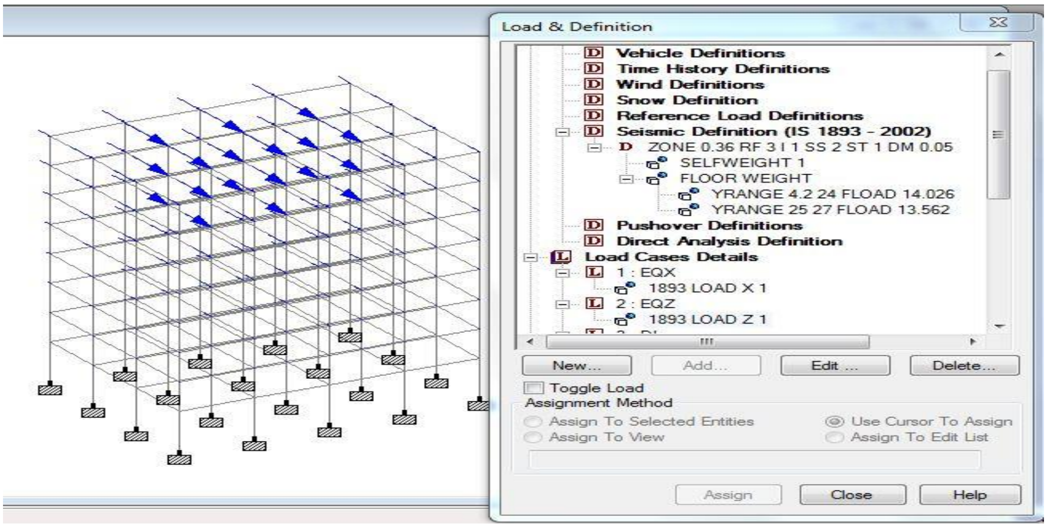
(Fig 5.7) Loads On Regular Structure



(Fig 5.8) Lump Weight On Regular Structure



(Fig 5.9) Seismic Load EQX

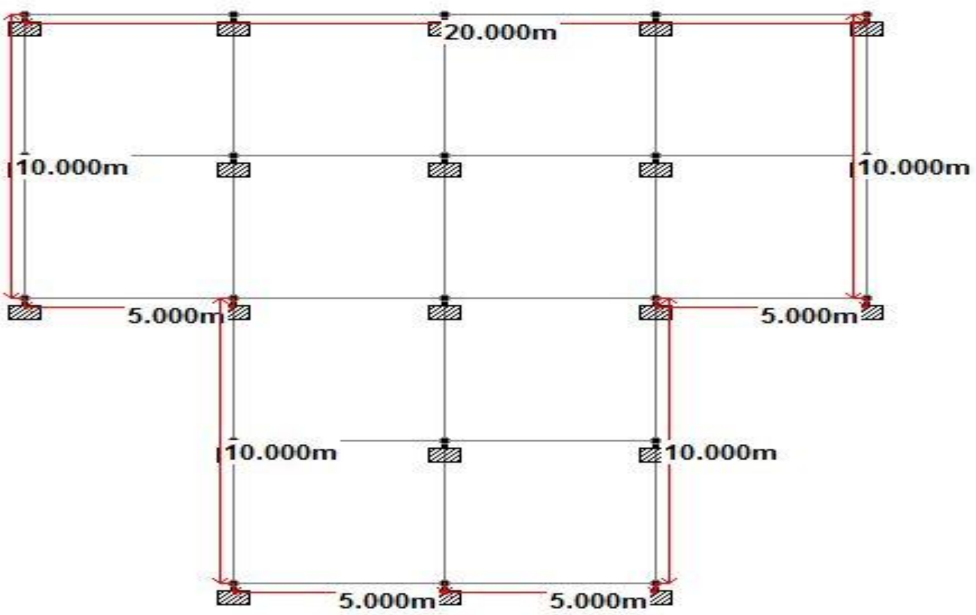


(Fig 5.10) Seismic Load EQZ

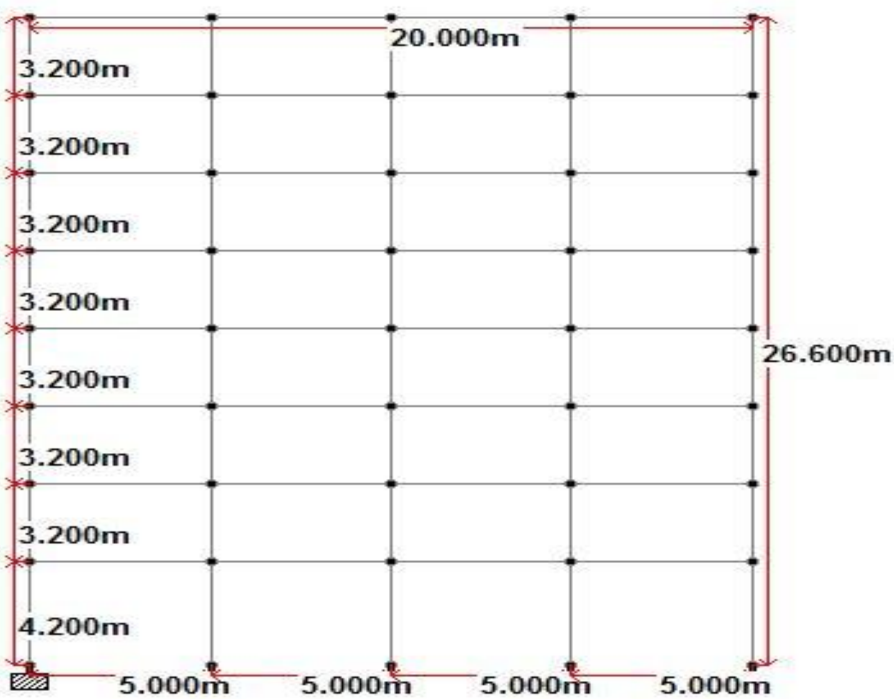
5.3 ANALYSIS OF IRREGULAR SHAPE STRUCTURES

a) G+7 T Shape

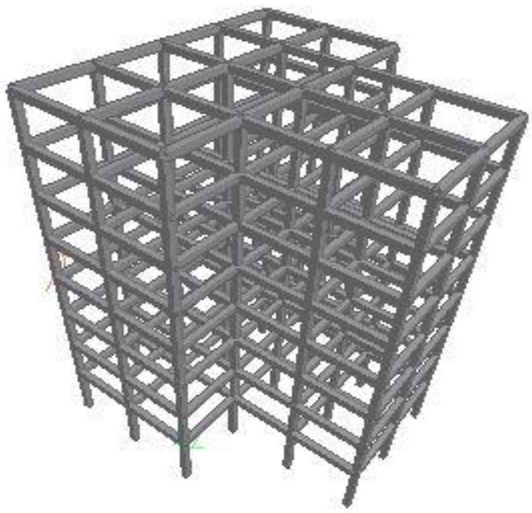
All design parameter is same as in regular shaped building.



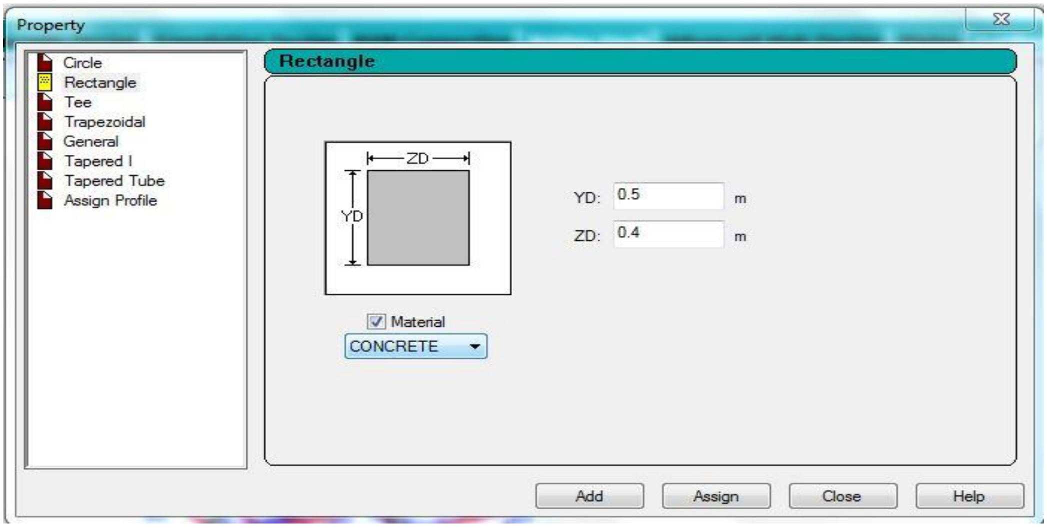
(Fig 5.11) Plan of T shape Structure



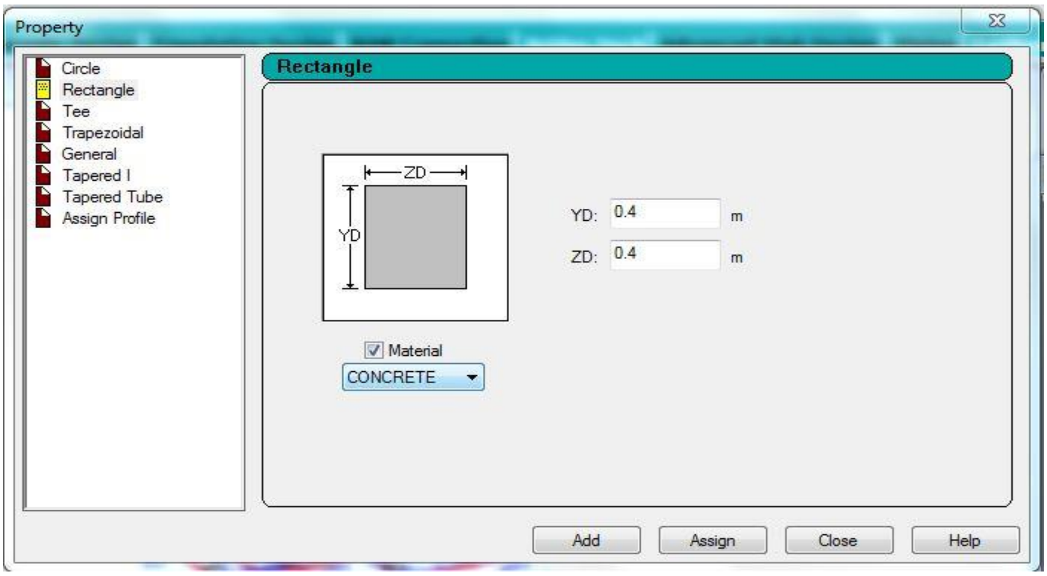
(Fig 5.12) Elevation of T Shape Structure



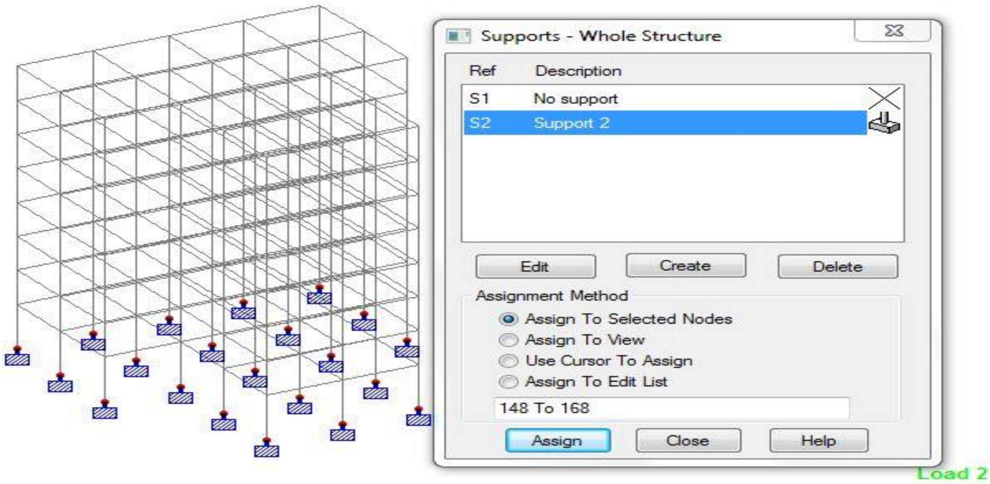
(Fig 5.13) 3D View Of T Shape Structure



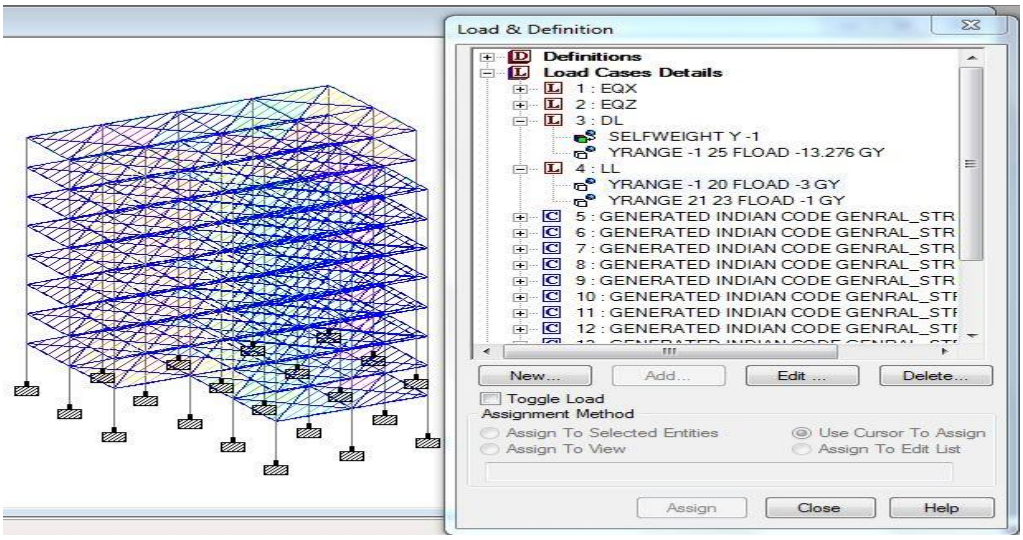
(Fig 5.14) Beam Of T Shape Structure



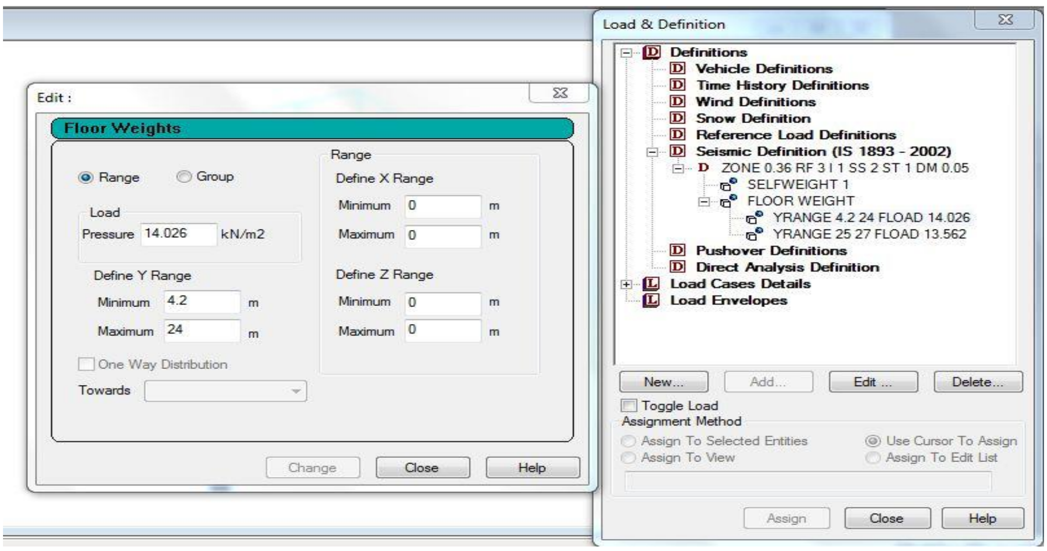
(Fig 5.15) Column Of T Shaped Structure



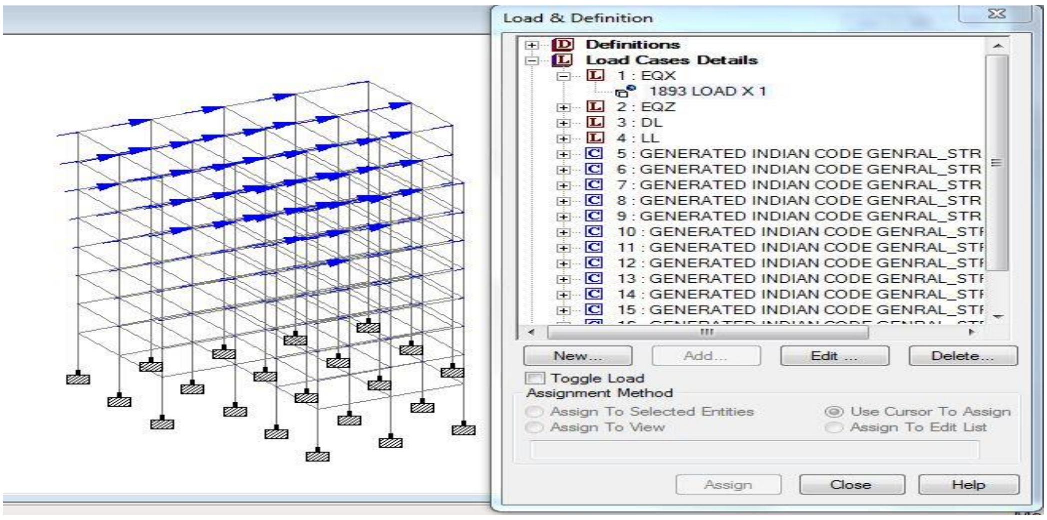
(Fig 5.16) Support Of T Shaped Structure



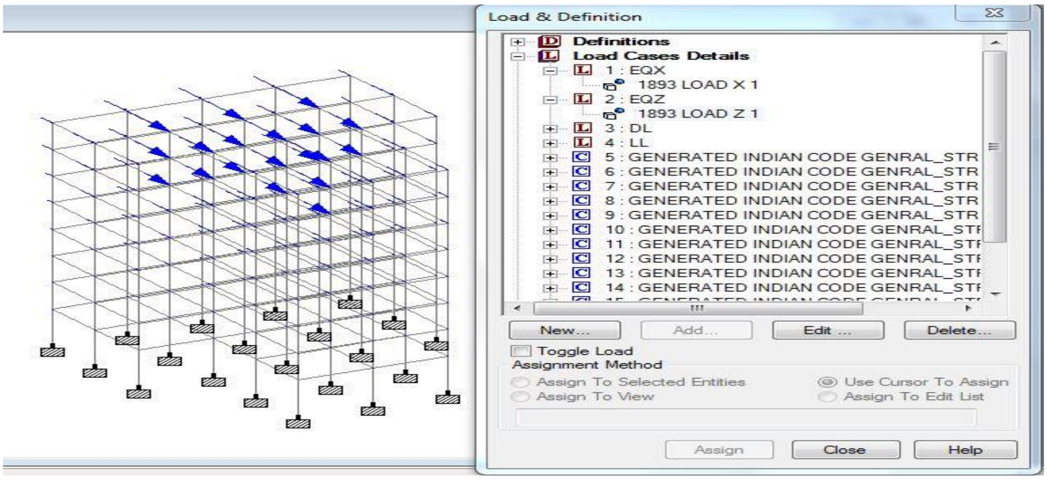
(Fig 5.17) Loads On T Shaped Structure



(Fig 5.18) Lump Weight On T Shaped Structure

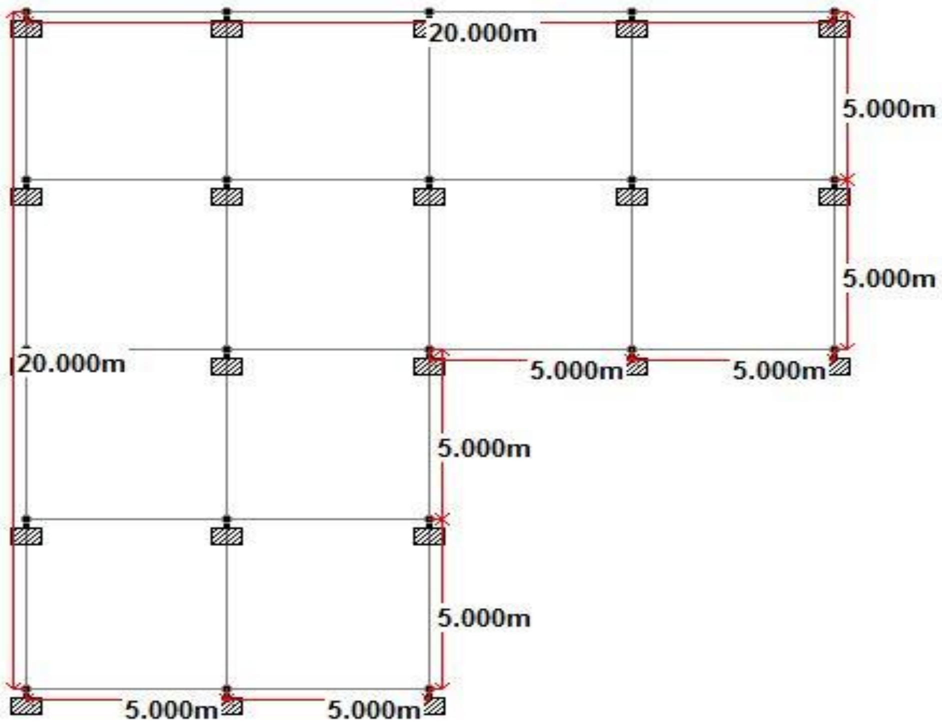


(Fig 5.19)Seismic Load EQX

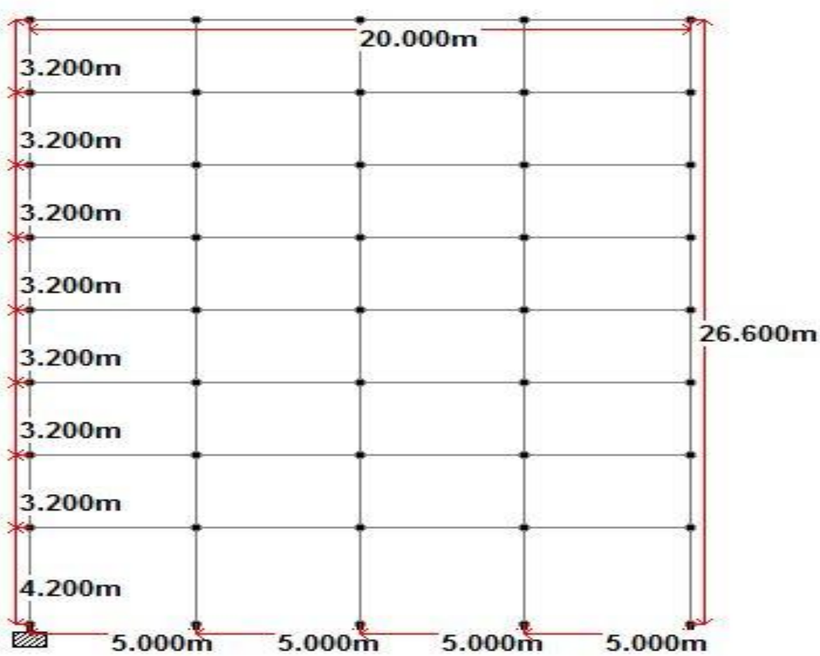


(Fig 5.20) Seismic Load EQZ

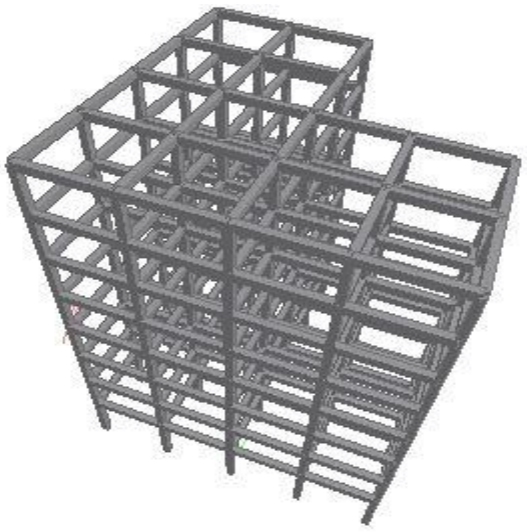
b) G+7 L Shape



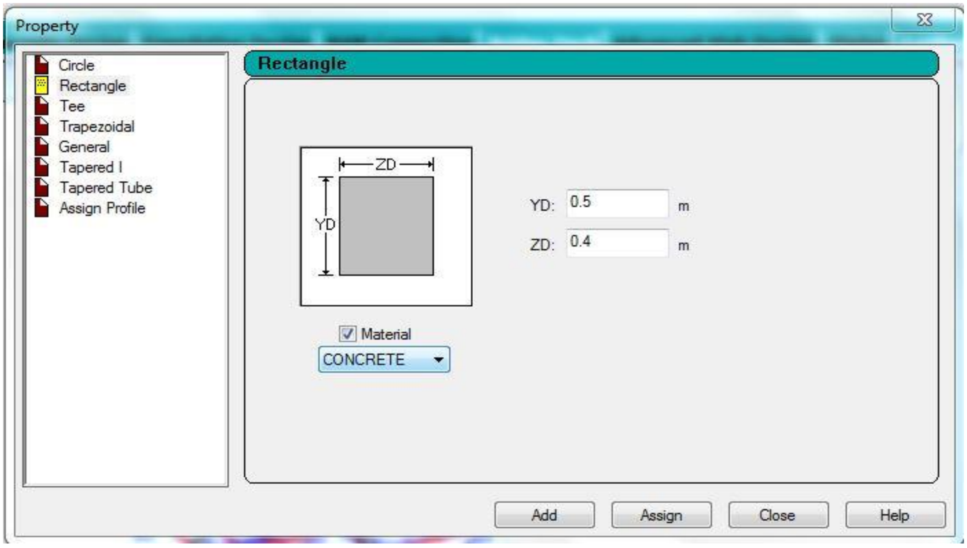
(Fig 5.21) Plan of L shape (Irregular) Structure



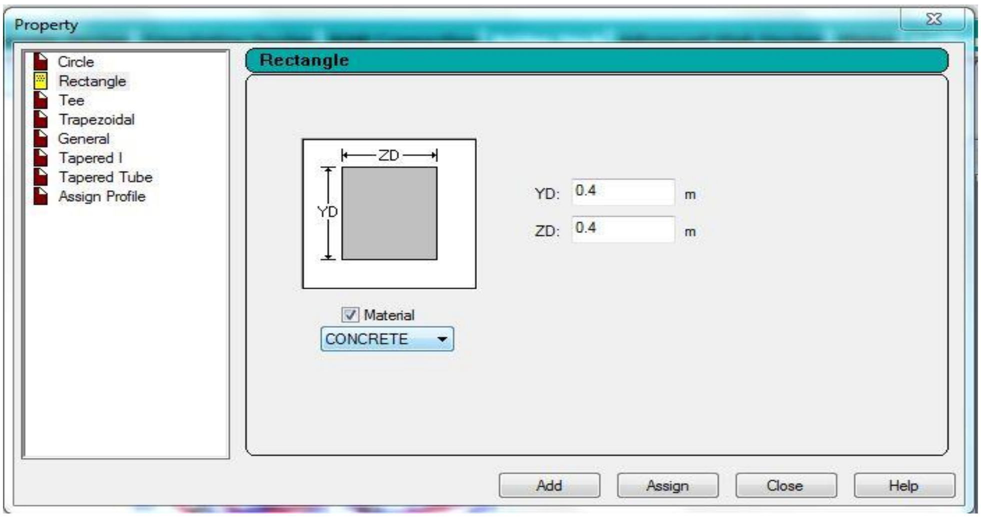
(Fig 5.22) Elevation of L Shape (Irregular) Structure



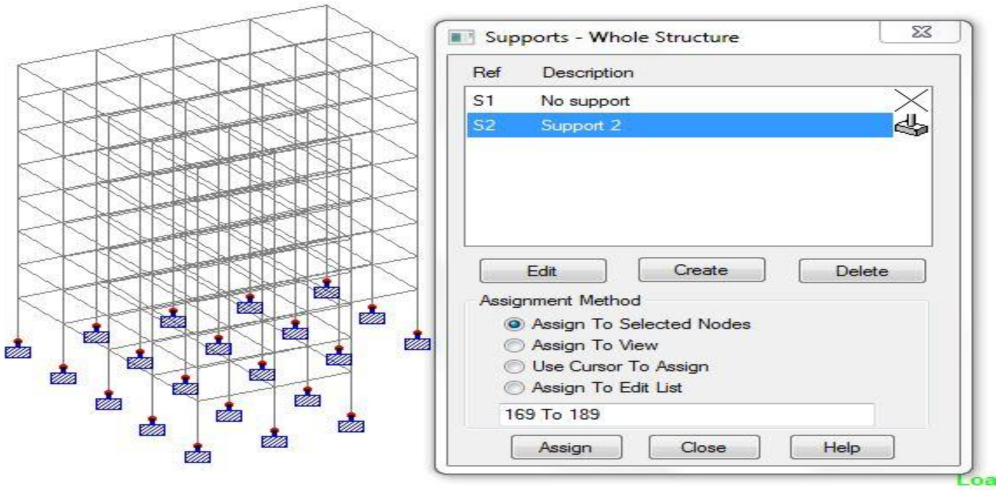
(Fig 5.23) 3D View Of L Shape Structure



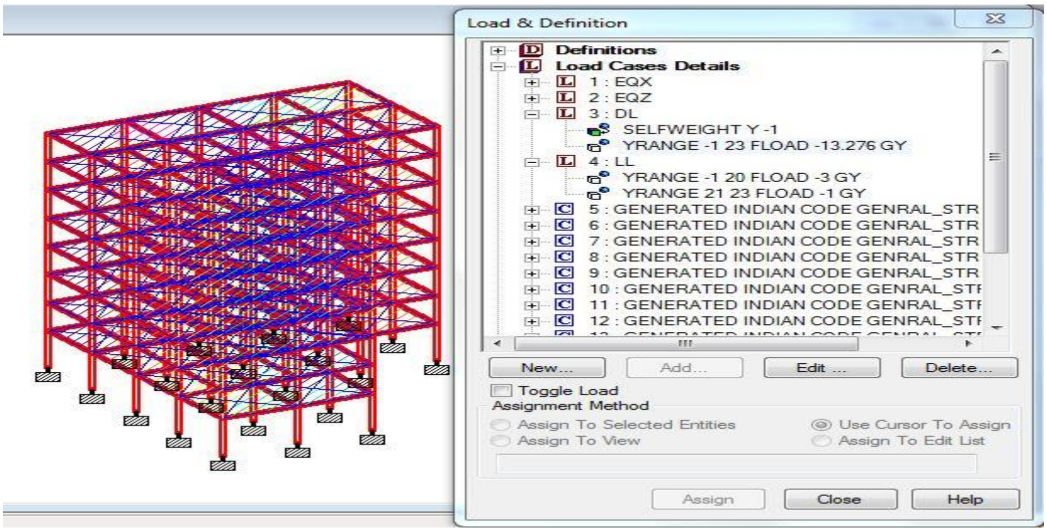
(Fig 5.24) Beam Of L Shaped Structure



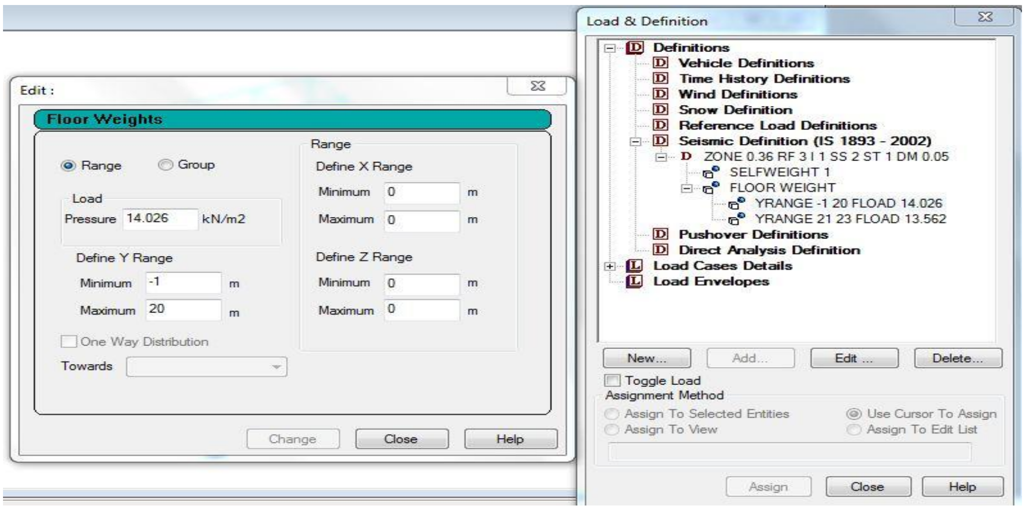
(Fig 5.25) Column Of L Shaped Structure



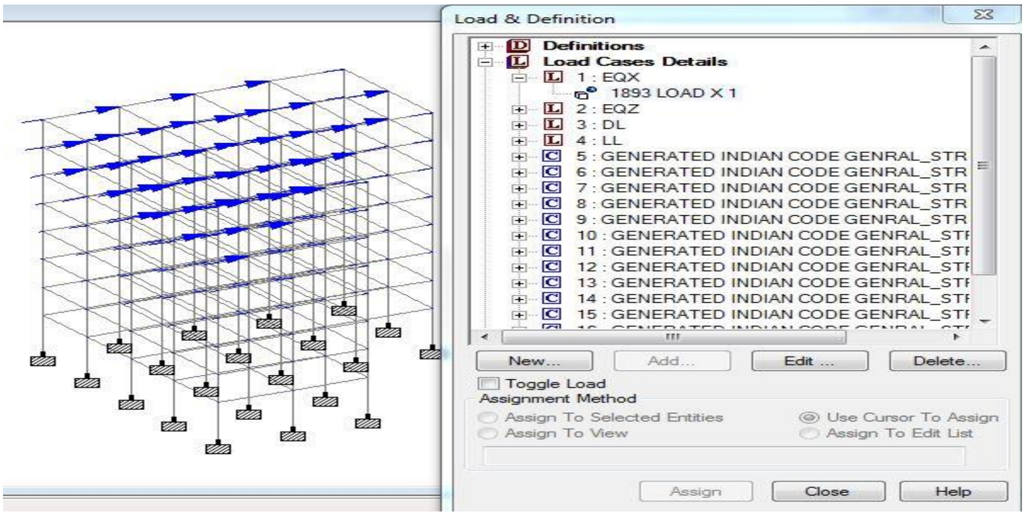
(Fig 5.26) Support Of L Shaped Structure



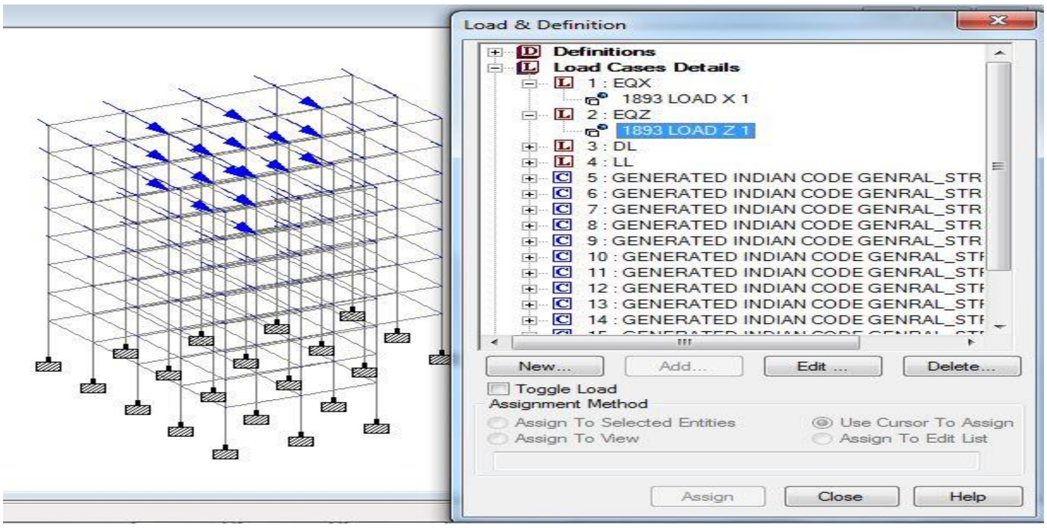
(Fig 5.27) Loads On L Shaped Structure



(Fig 5.28) Lump Weight On L Shaped Structure

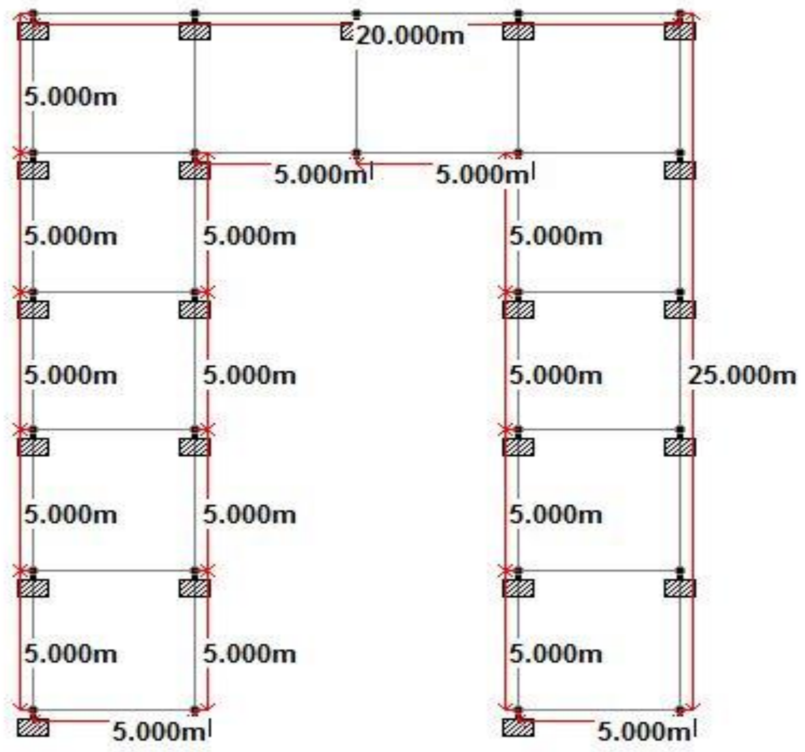


(Fig 5.29) Seismic Load EQX

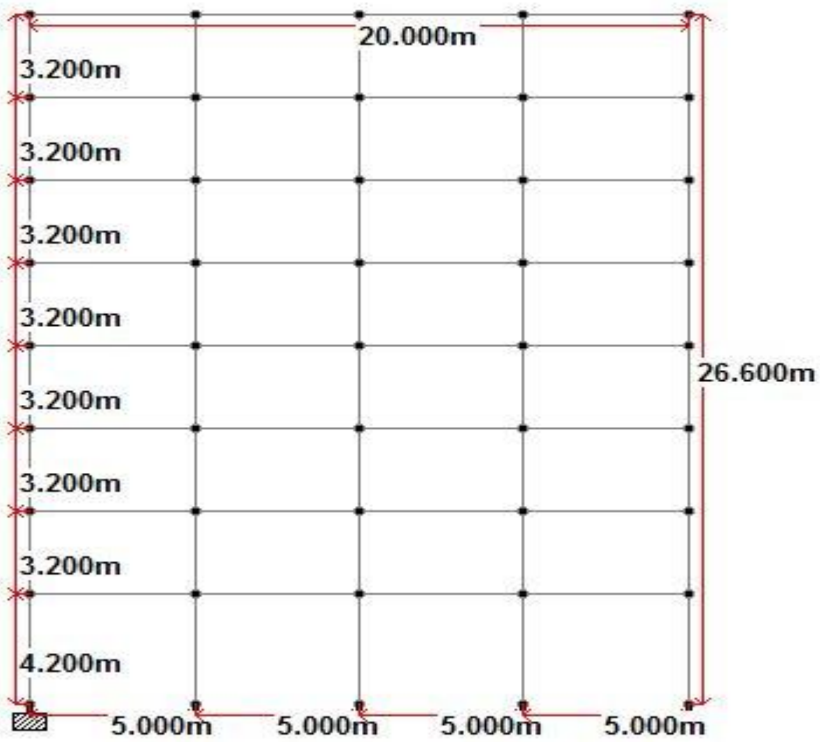


(Fig 5.30) Seismic Load EQZ

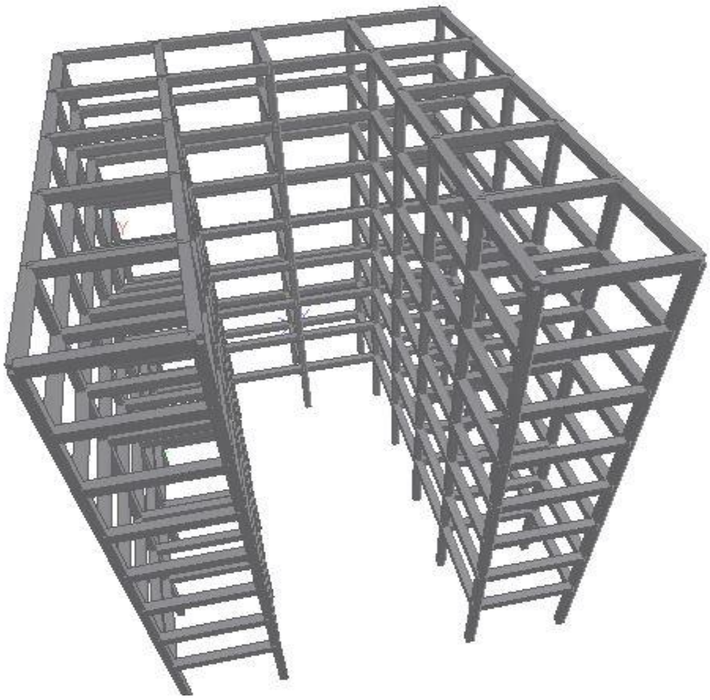
C) G+7 U Shape



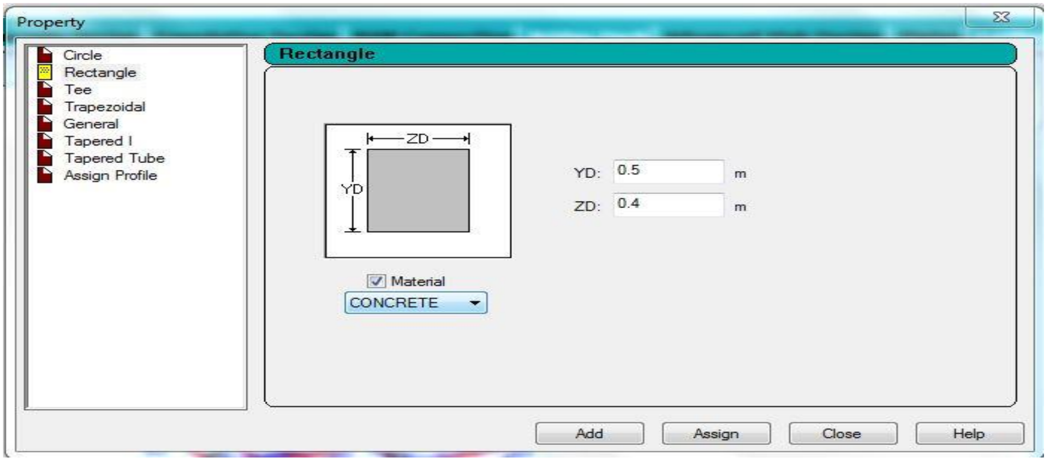
(Fig 5.31) Plan of U Shape (Irregular) Structure



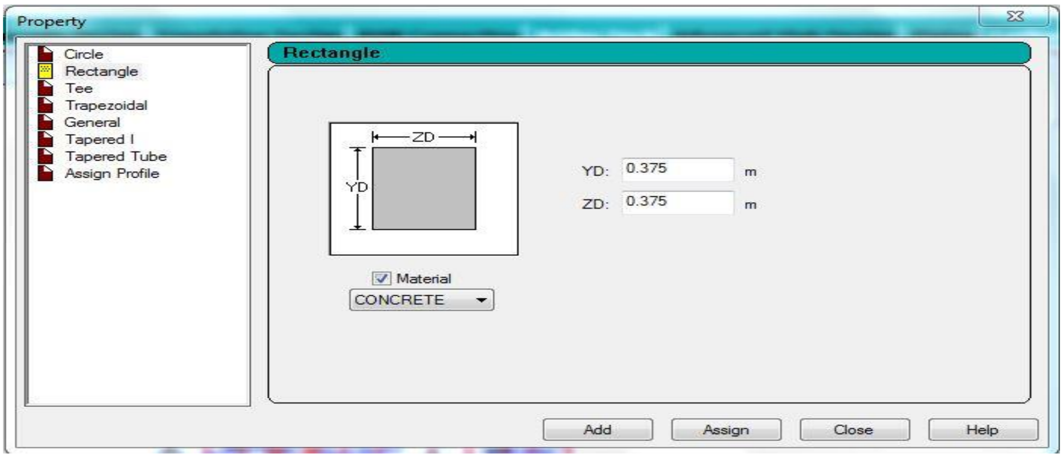
(Fig 5.32) Elevation of U Shape (Irregular) Structure



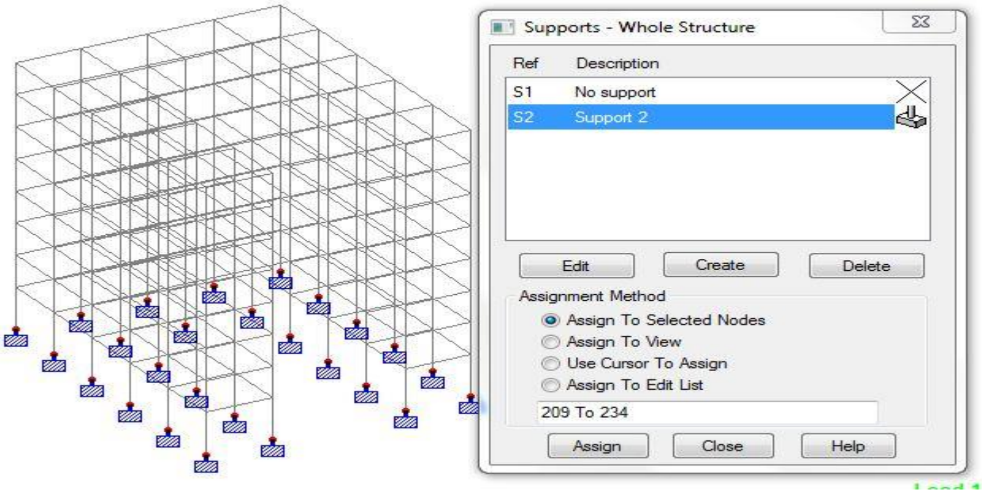
(Fig 5.33) 3D View Of U Shape Structure



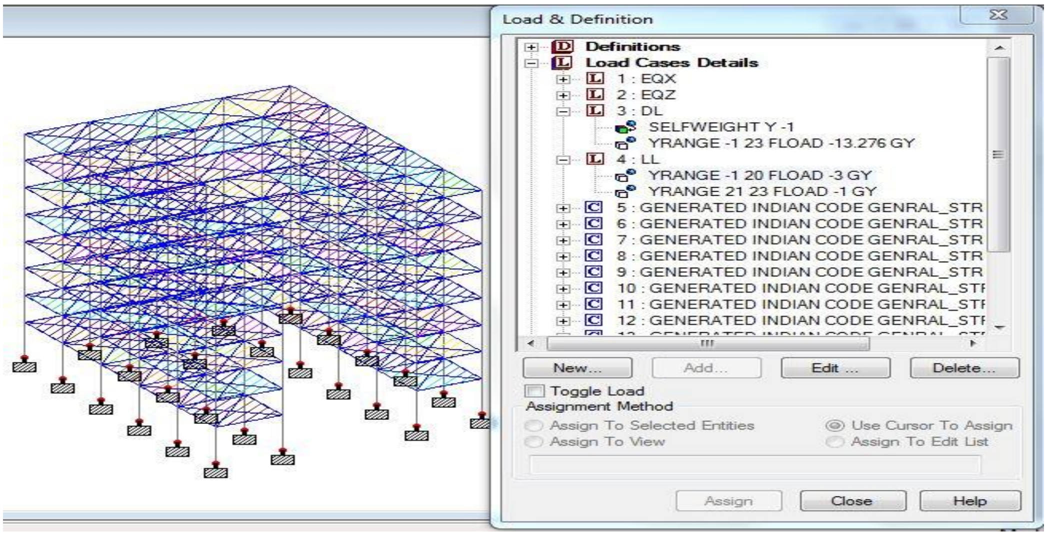
(Fig 5.34) Beam Of U Shape Structure



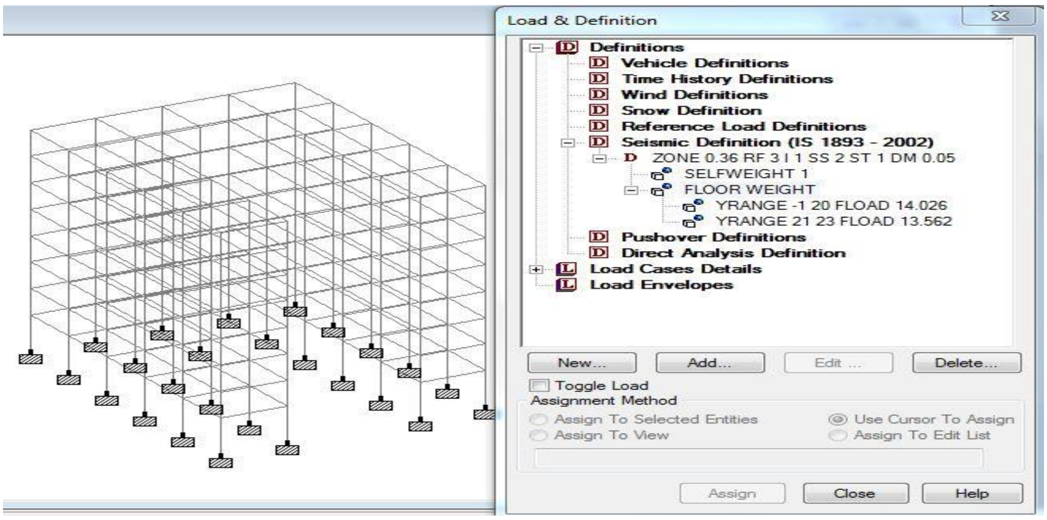
(Fig 5.35) Column Of U Shape Structure



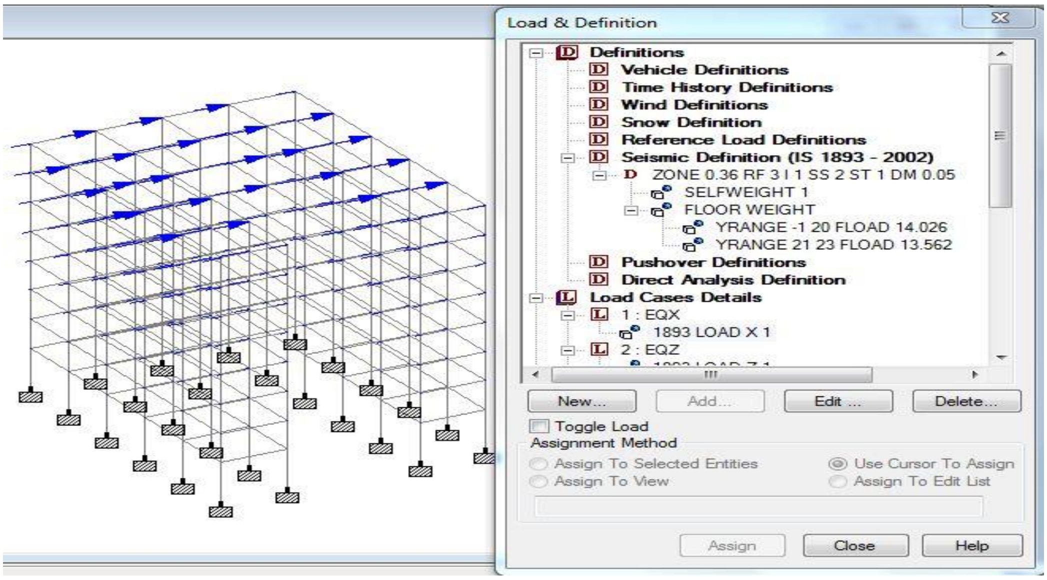
(Fig 5.36) Support On U Shape Structure



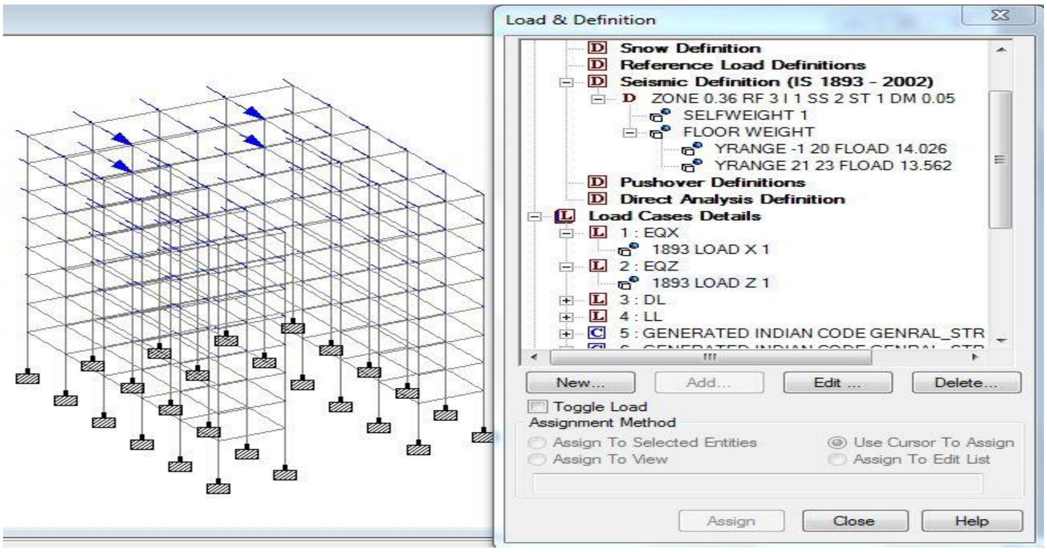
(Fig 5.37) Load On U Shape Structure



(Fig 5.38) Lump Weight Of U Shape Structure



(Fig 5.39) Seismic Load EQX



(Fig 5.40) Seismic Load EQZ

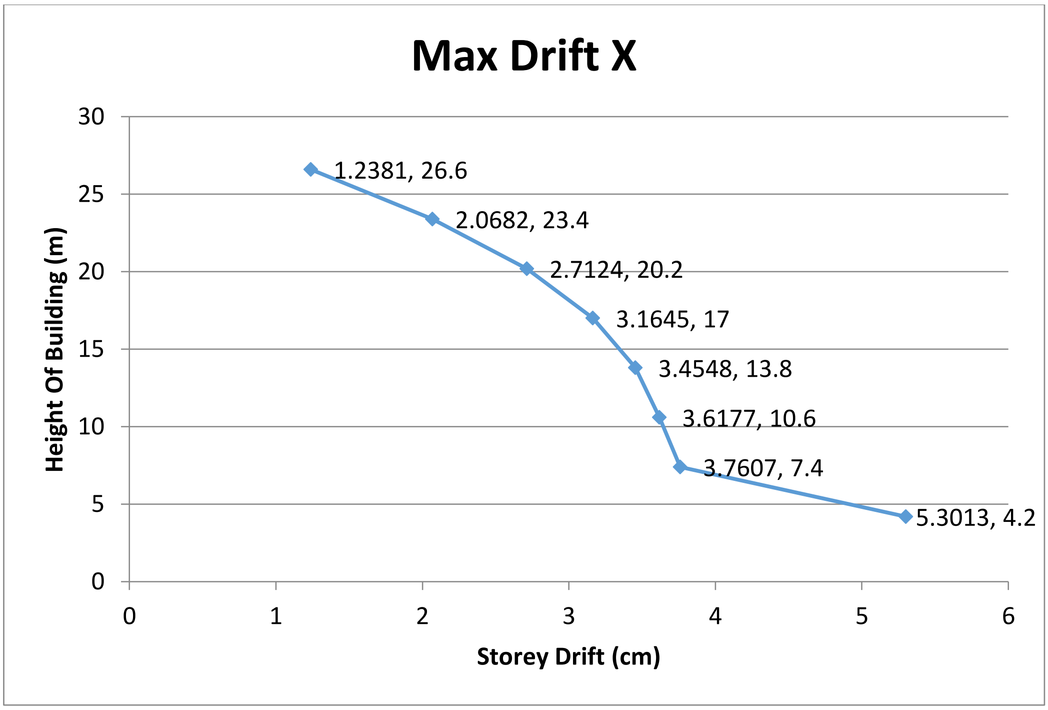
CHAPTER 6

RESULT AND DISCUSSION

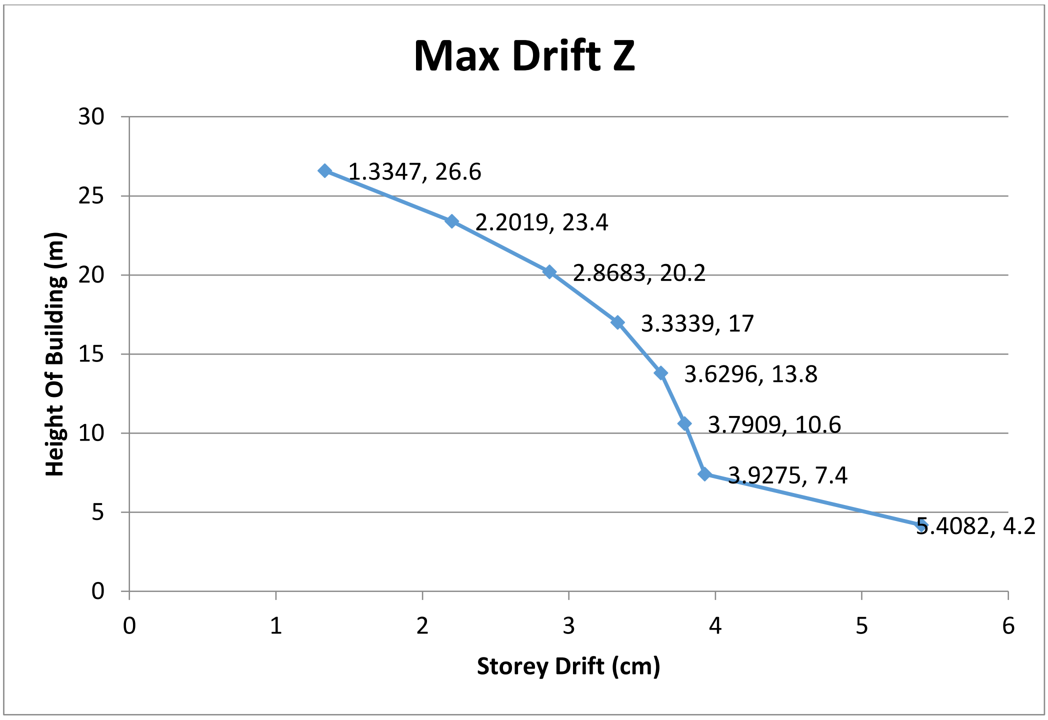
6.1 Drift and average displacement at each floor level for G+7 Regular shape Building.

Table 6.1 G+7 Regular Shape

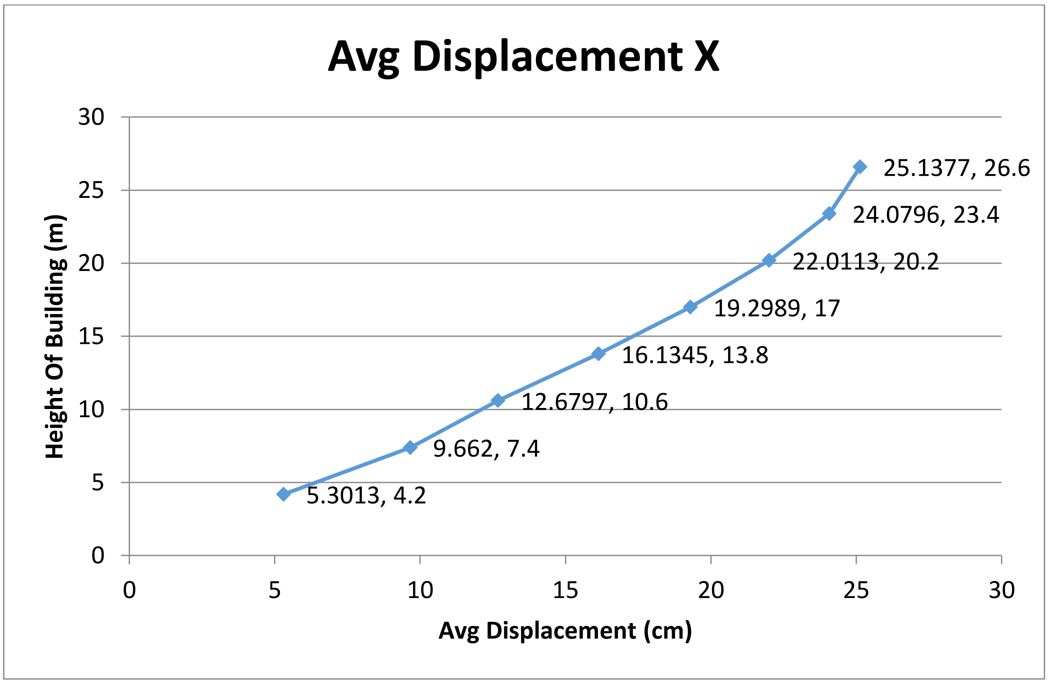
Height (m)	Max Drift X(cm)	Max Drift Z(cm)	Avg. Dis. X(cm)	Avg. Dis. Z(cm)
4.2	5.3013	5.4082	5.3013	5.4082
7.4	3.7607	3.9275	9.662	9.3358
10.6	3.6177	3.7909	12.6797	13.1266
13.8	3.4548	3.6296	16.1345	16.7563
17	3.1645	3.3339	19.2989	20.0902
20.2	2.7124	2.8683	22.0113	22.9586
23.4	2.0682	2.2019	24.0796	25.1604
26.6	1.2381	1.3347	25.1377	26.5051



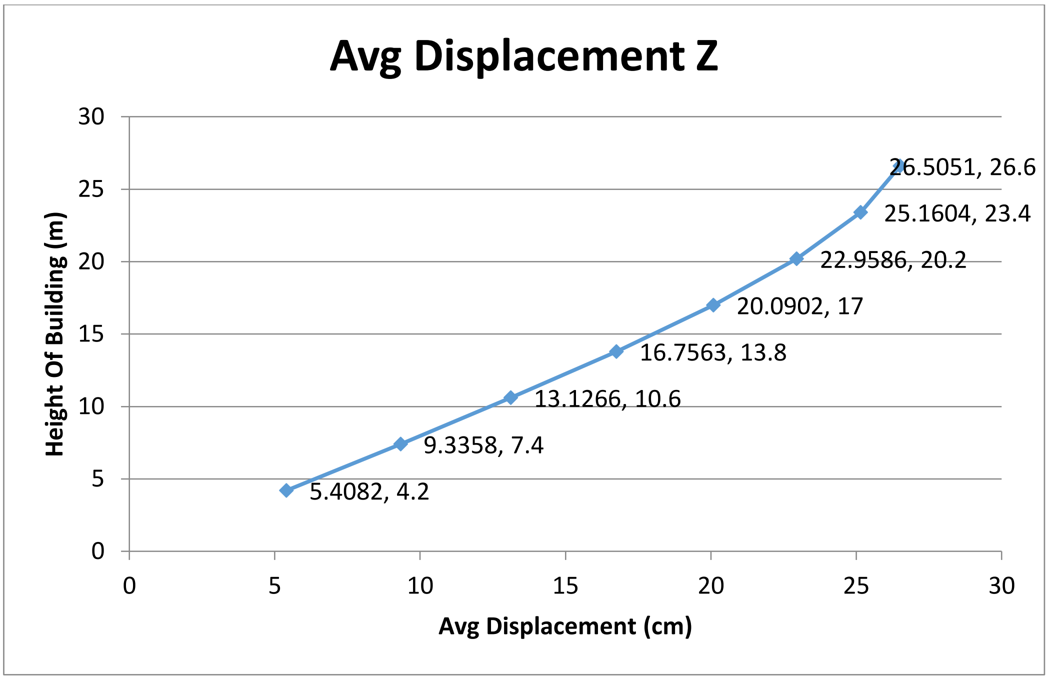
(Fig 6.1) Max Drift In X



(Fig 6.2) Max Drift In Z



(Fig 6.3) Average Displacement In X

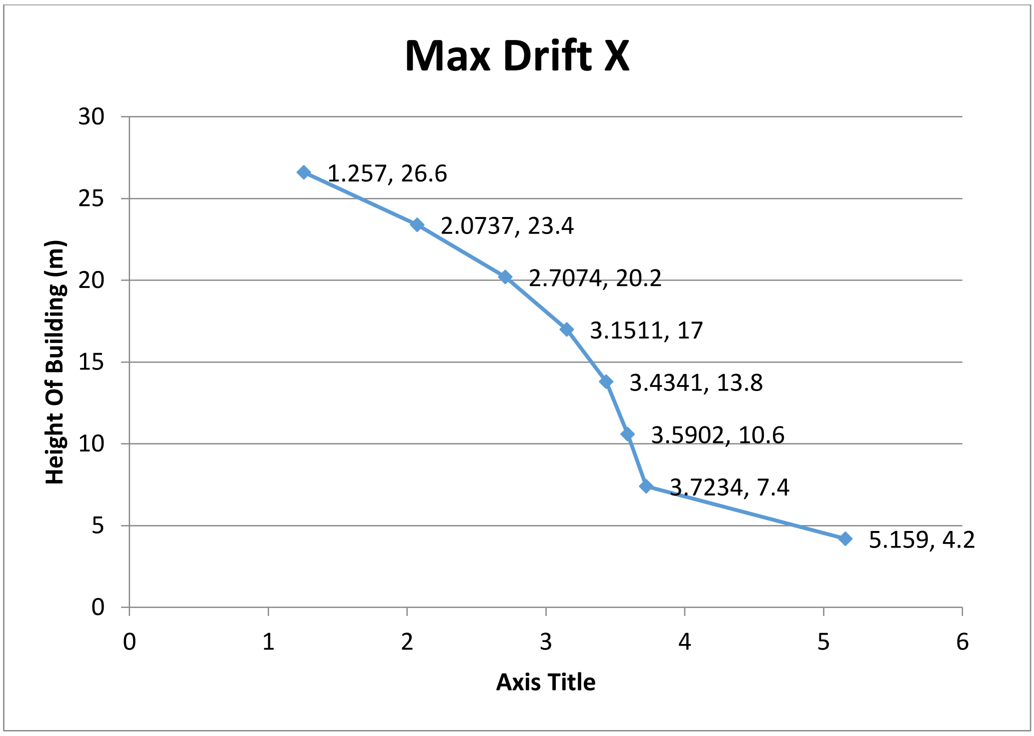


(Fig 6.4) Average Displacement In Z

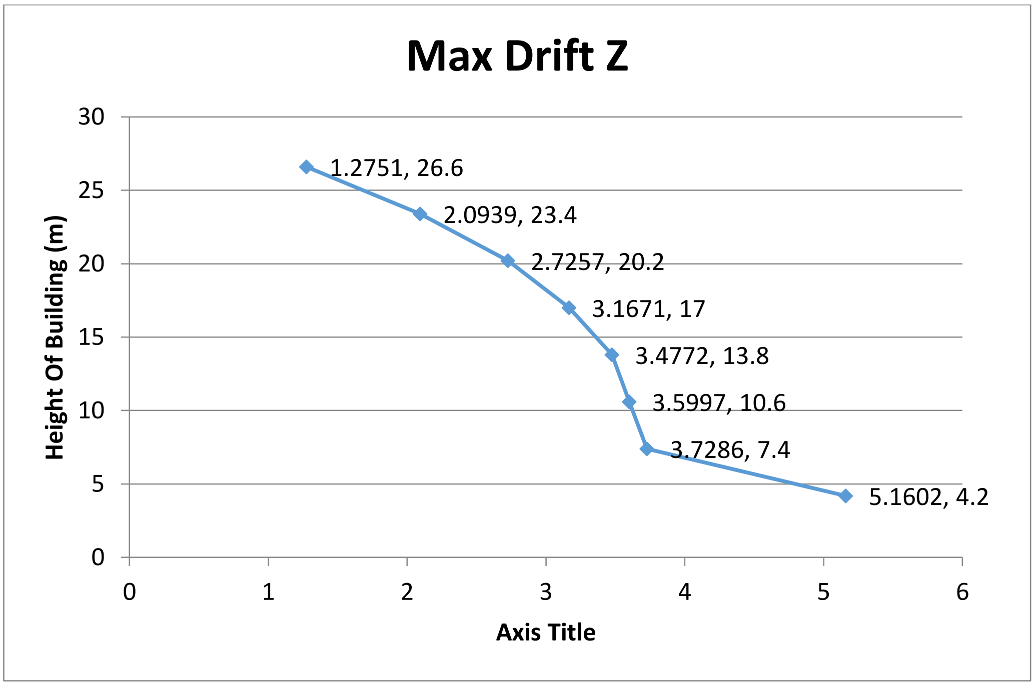
6.2 Drift and average displacement at each floor level for G+7 Irregular shape Buildings.

Table 6.2 G+7 T Shape

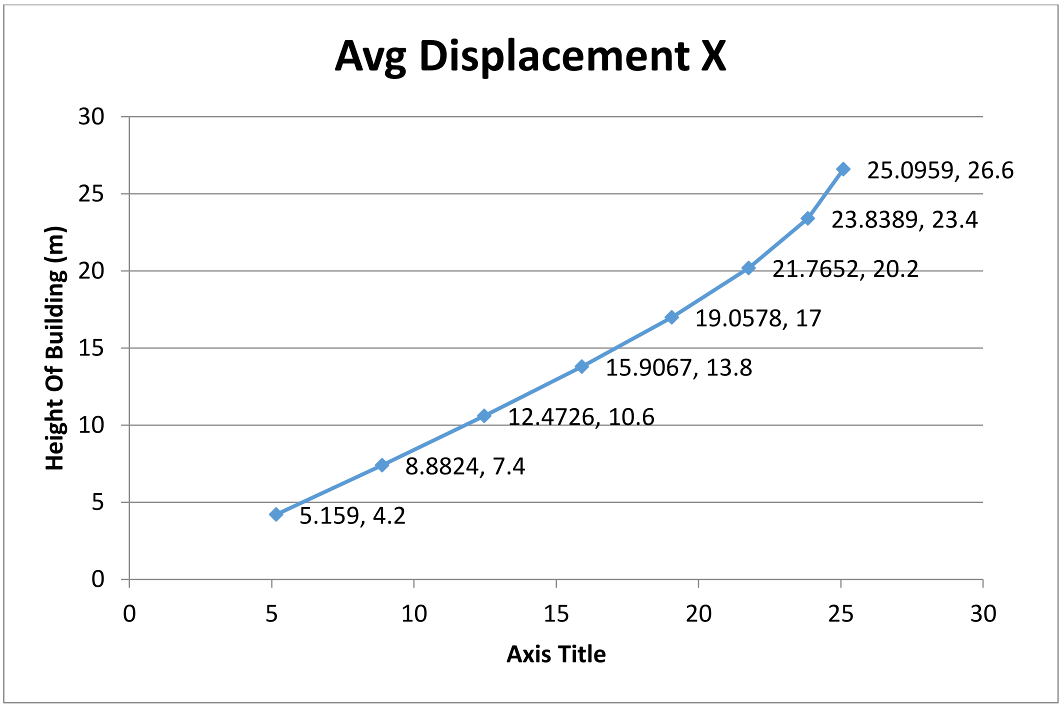
Height (m)	Max Drift X(cm)	Max Drift Z(cm)	Avg. Dis. X(cm)	Avg. Dis. Z(cm)
4.2	5.159	5.1602	5.159	5.1602
7.4	3.7234	3.7286	8.8824	8.8895
10.6	3.5902	3.5997	12.4726	12.4891
13.8	3.4341	3.4772	15.9067	15.9363
17	3.1511	3.1671	19.0578	19.1034
20.2	2.7074	2.7257	21.7652	21.8292
23.4	2.0737	2.0939	23.8389	23.9231
26.6	1.257	1.2751	25.0959	25.1982



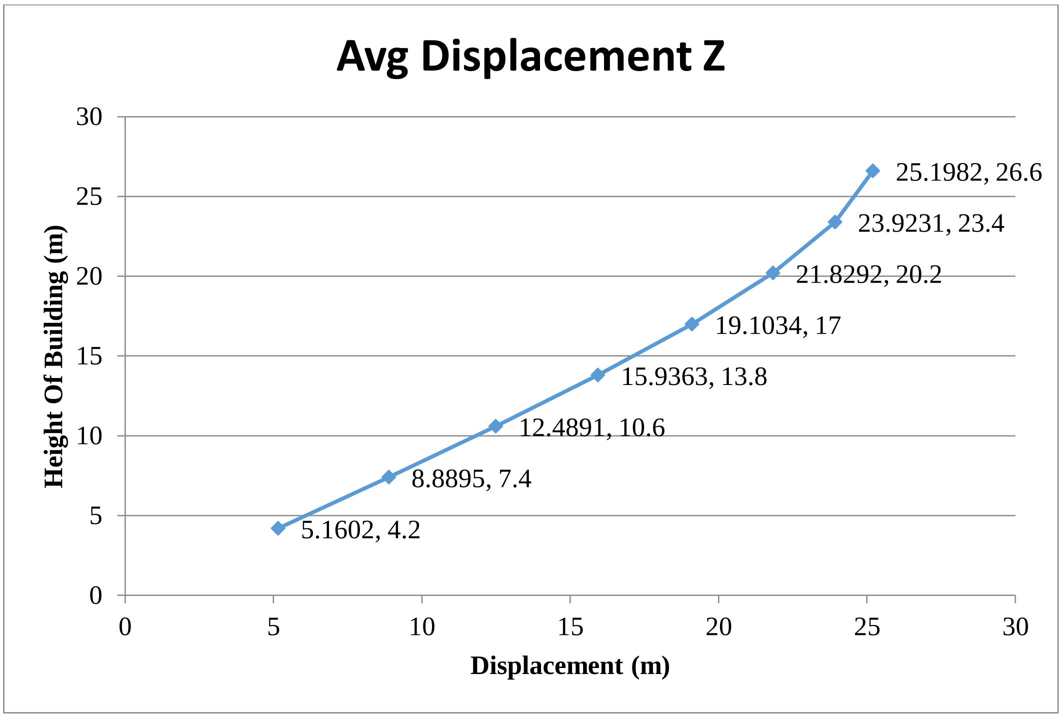
(Fig 6.5) Max Drift In X



(Fig 6.6) Max Drift In Z



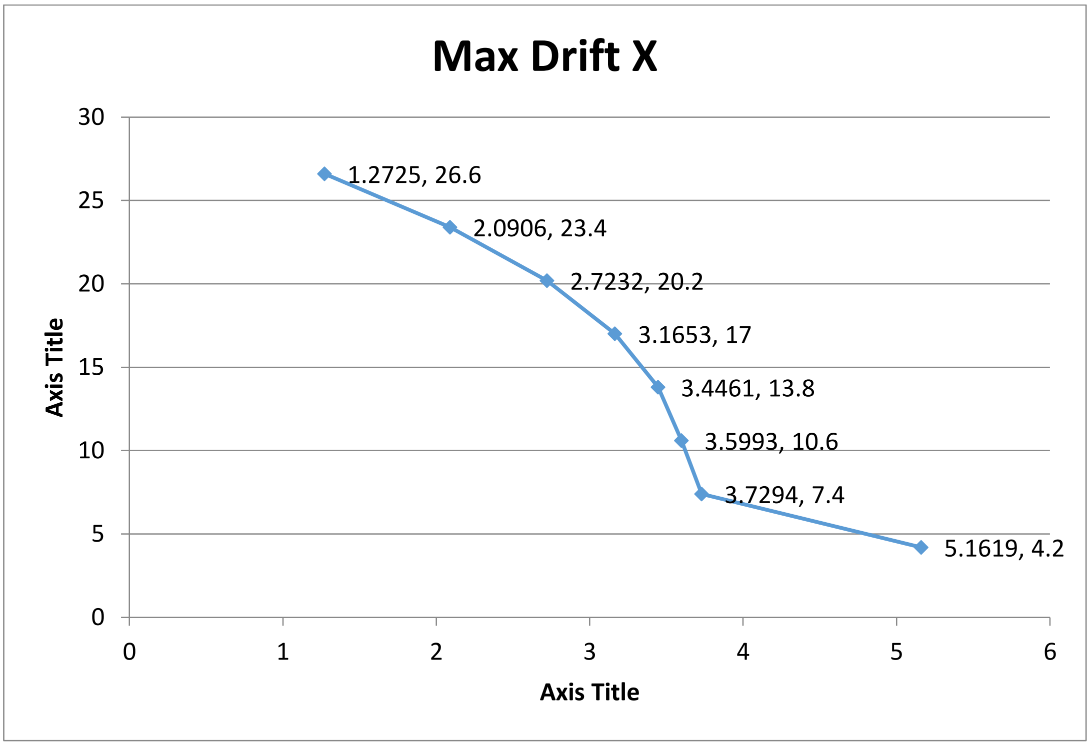
(Fig 6.7) Avg. Displacement In X



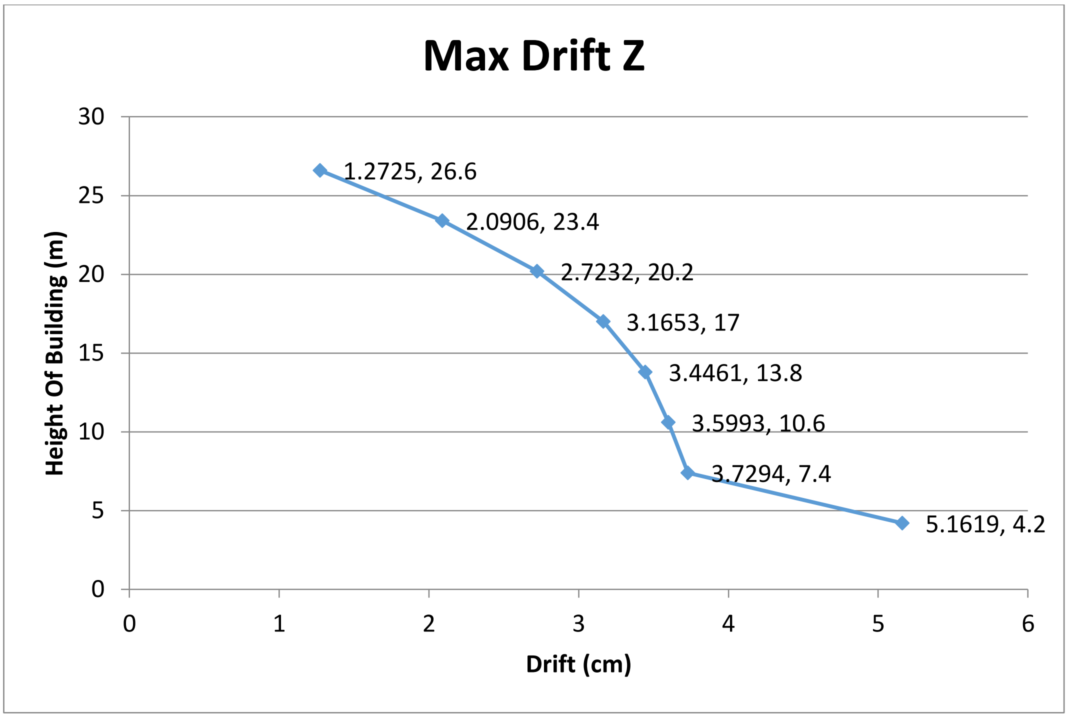
(Fig 6.8) Avg. Displacement In Z

Table 6.3 G+7 L Shape Building

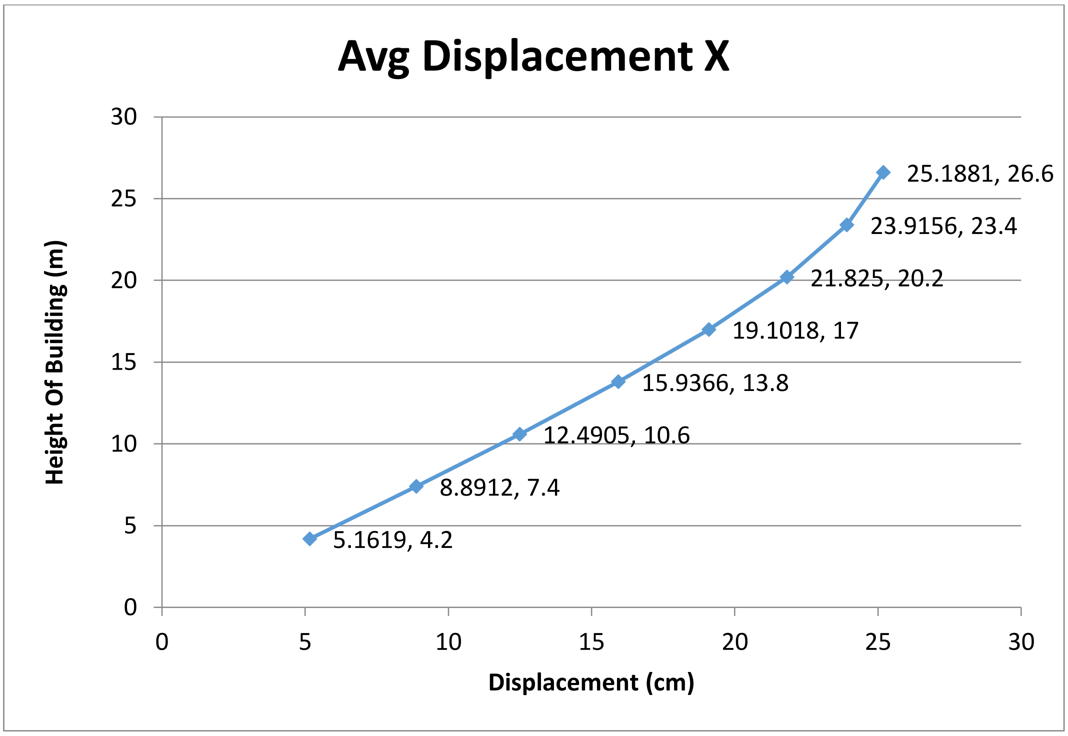
Height L	Max Drift X	Max Drift Z	Avg Dis X	Avg Dis Z
4.2	5.1619	5.1619	5.1619	5.1619
7.4	3.7294	3.7294	8.8912	8.8912
10.6	3.5993	3.5993	12.4905	12.4905
13.8	3.4461	3.4461	15.9366	15.9366
17	3.1653	3.1653	19.1018	19.1018
20.2	2.7232	2.7232	21.825	21.825
23.4	2.0906	2.0906	23.9156	23.9156
26.6	1.2725	1.2725	25.1881	25.1881



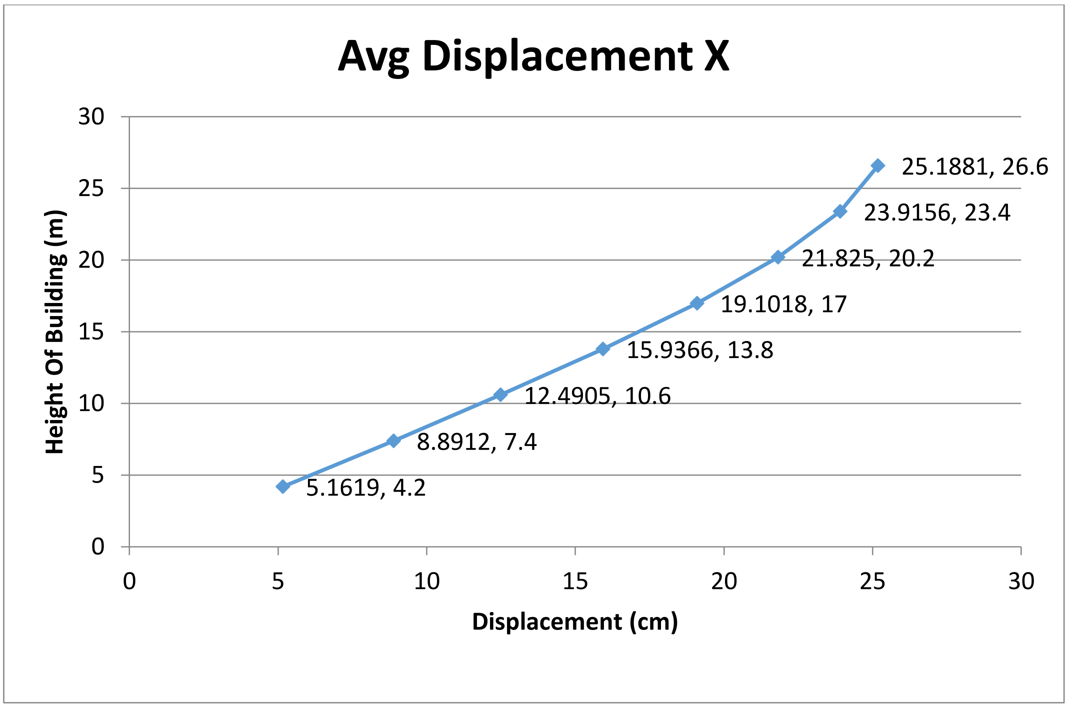
(Fig 6.9) Max Drift In X



(Fig 6.10) Max Drift In Z



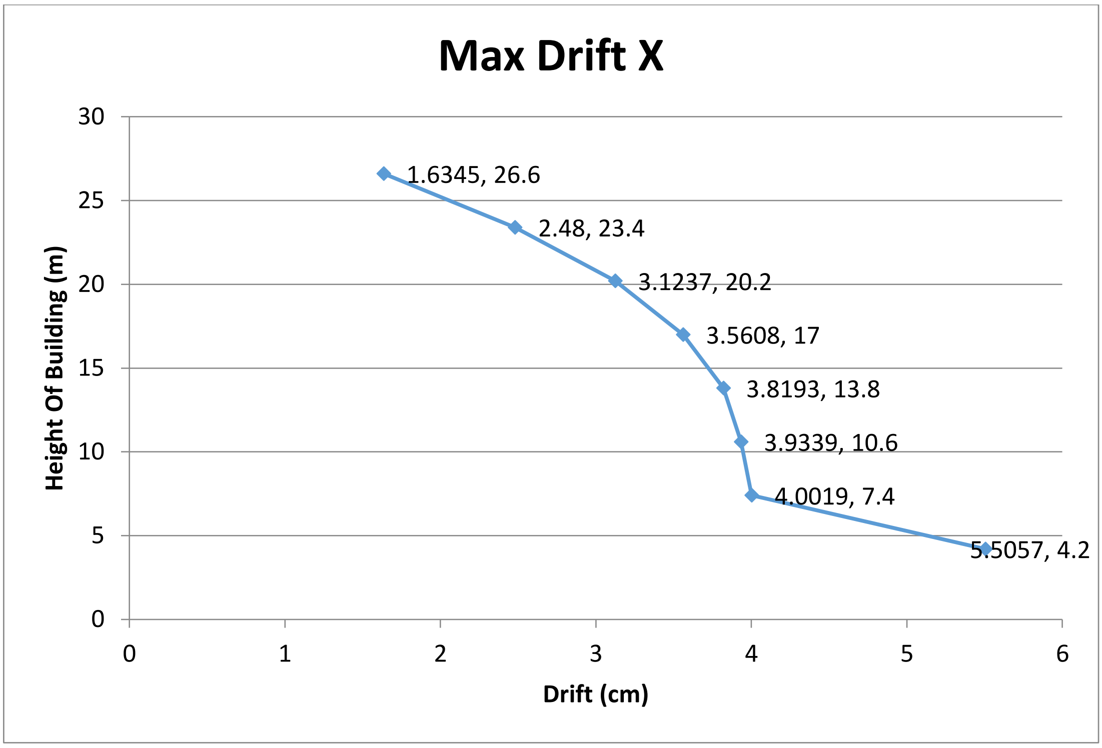
(Fig 6.11) Avg. Displacement In X



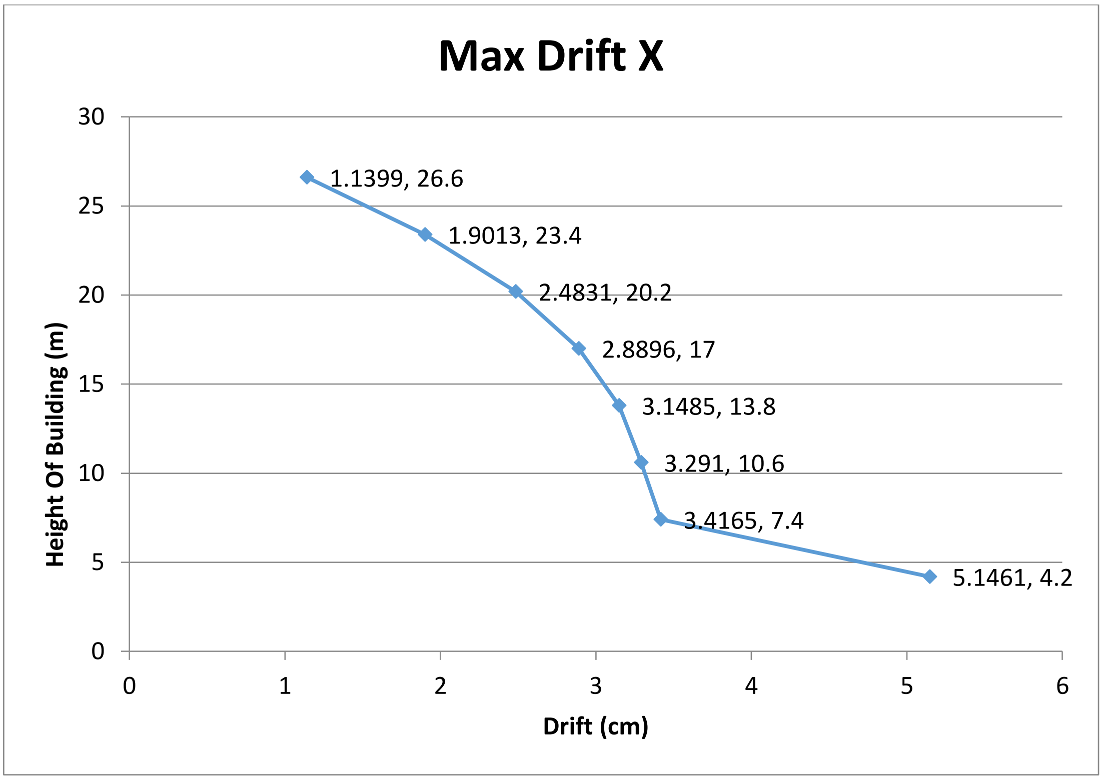
(Fig 6.12) Avg. Displacement in Z

Table 6.4 G+7 U Shape Building

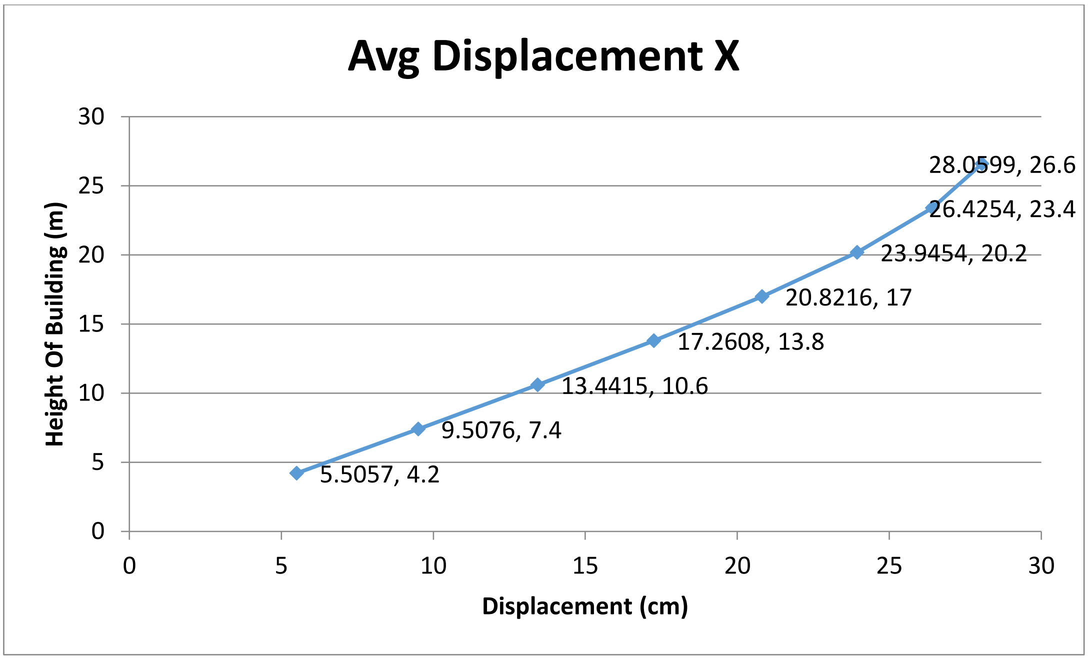
Height U	Max Drift X	Max Drift Z	Avg. Dis. X	Avg. Dis. Z
4.2	5.5057	5.1461	5.5057	5.1461
7.4	4.0019	3.4165	9.5076	8.5626
10.6	3.9339	3.291	13.4415	11.8536
13.8	3.8193	3.1485	17.2608	15.0021
17	3.5608	2.8896	20.8216	17.8917
20.2	3.1237	2.4831	23.9454	20.3749
23.4	2.48	1.9013	26.4254	22.2761
26.6	1.6345	1.1399	28.0599	23.416



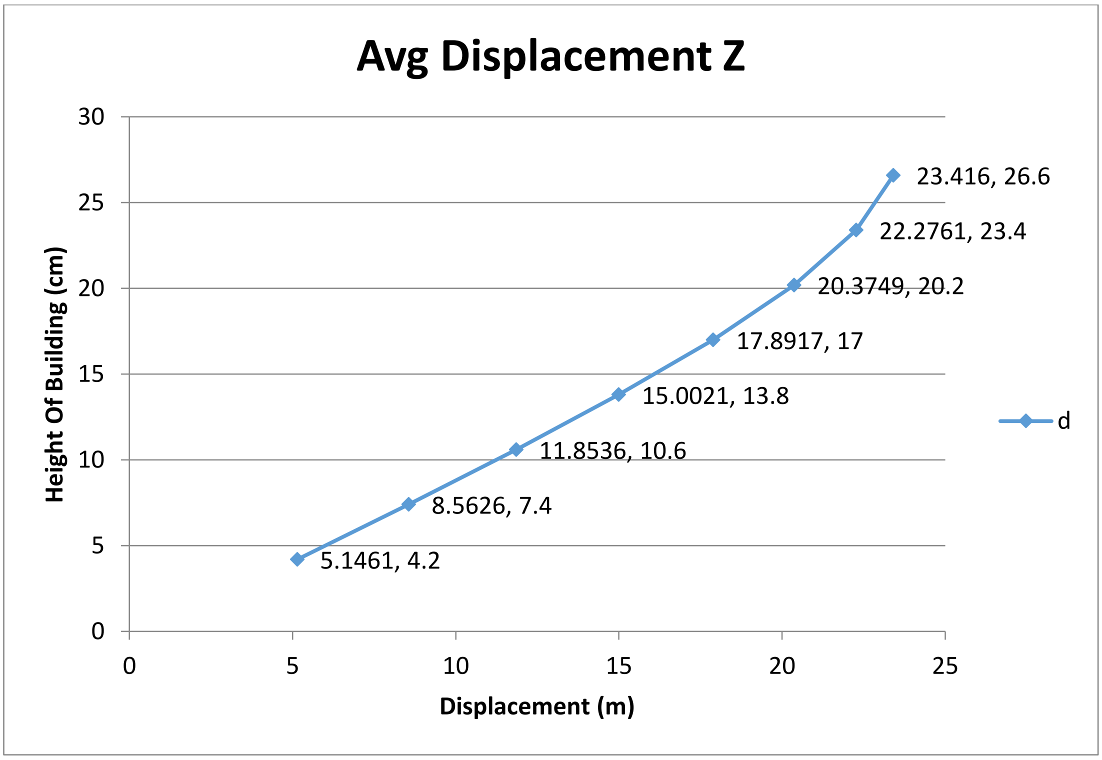
(Fig 6.13) Max Drift In X



(Fig 6.14) Max Drift in Z



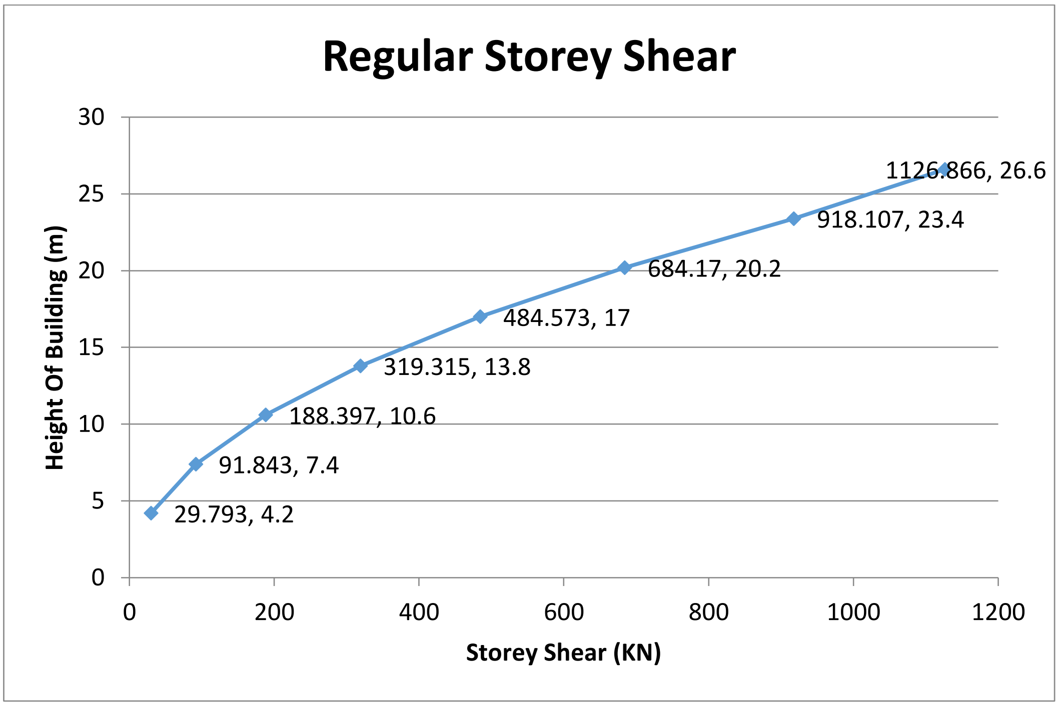
(Fig 6.15) Avg. Displacement In X



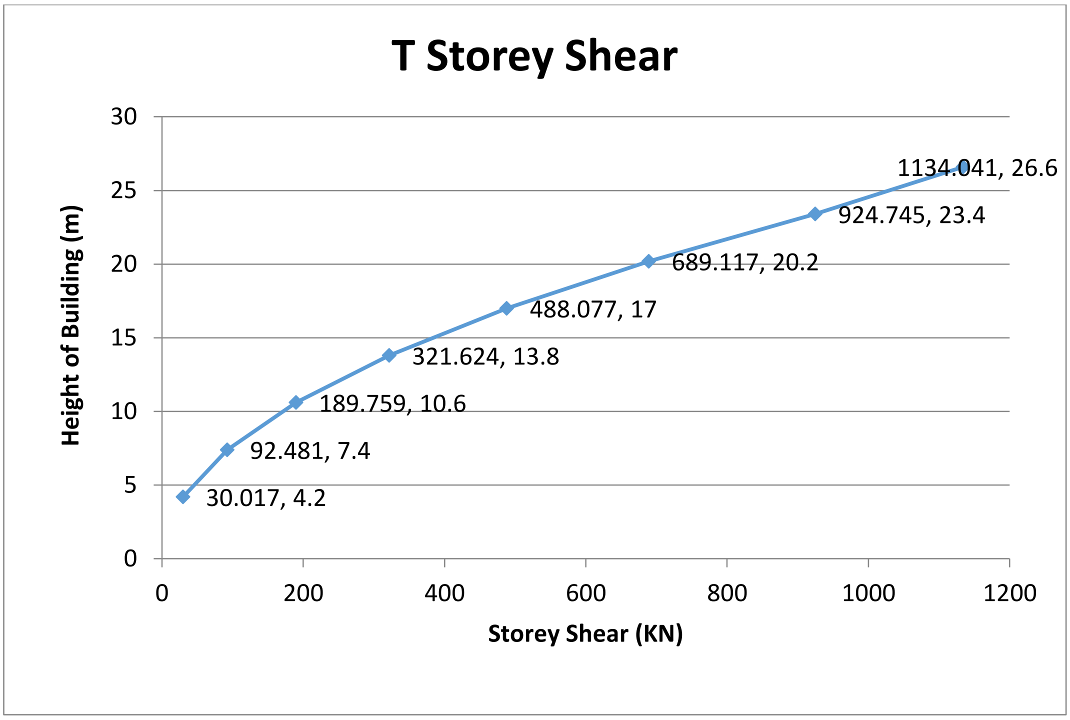
(Fig 6.16) Avg. Displacement In Z

Table 6.5 Storey Shear Of Different Structures

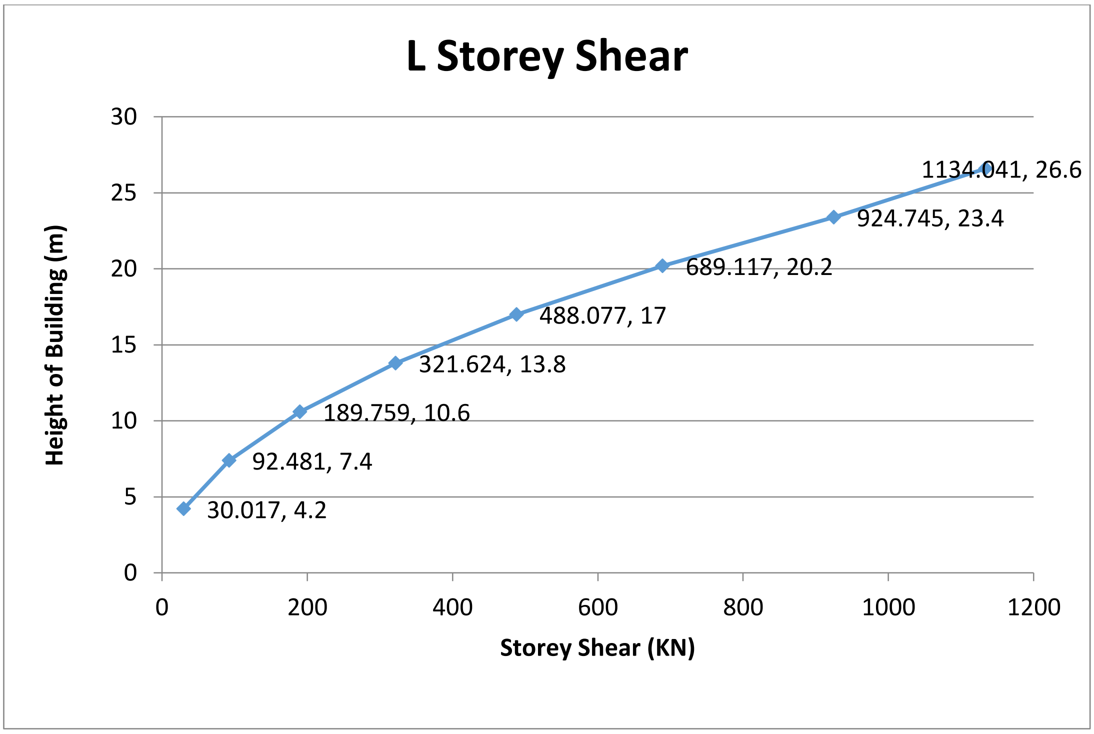
Regular Shape	T Shape	L Shape	U Shape
29.793	30.017	30.017	30.851
91.843	92.481	92.481	95.007
188.397	189.759	189.759	194.942
319.315	321.624	321.624	330.409
484.573	488.077	488.077	501.408
684.17	689.117	689.117	707.94
918.107	924.745	924.745	950.004
1126.866	1134.041	1134.041	1164.094



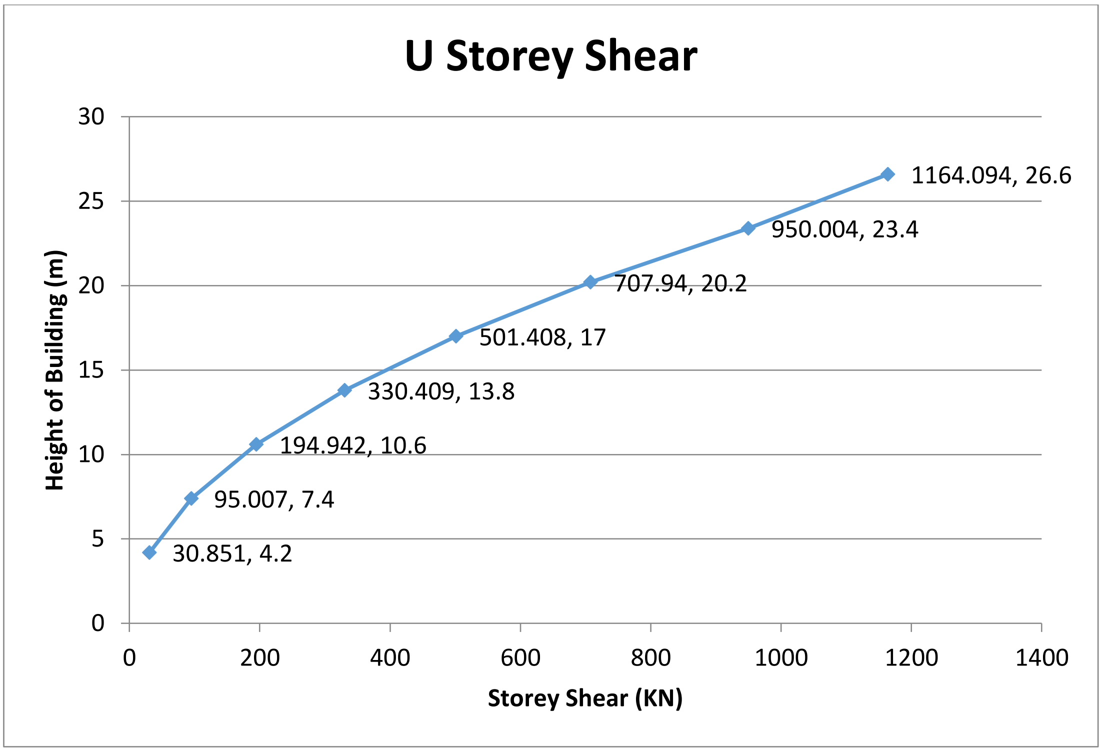
(Fig 6.17) R Storey Shear at Different Level



(Fig 6.18) T Storey Shear at Different Level

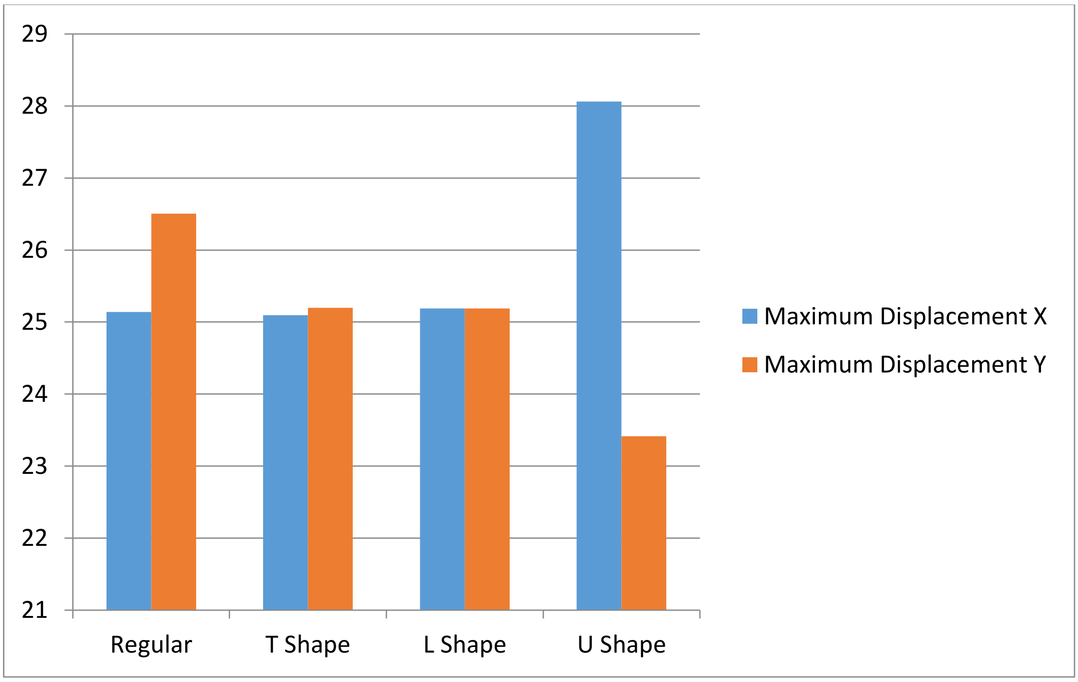


(Fig 6.19) L Storey Shear at Different Level



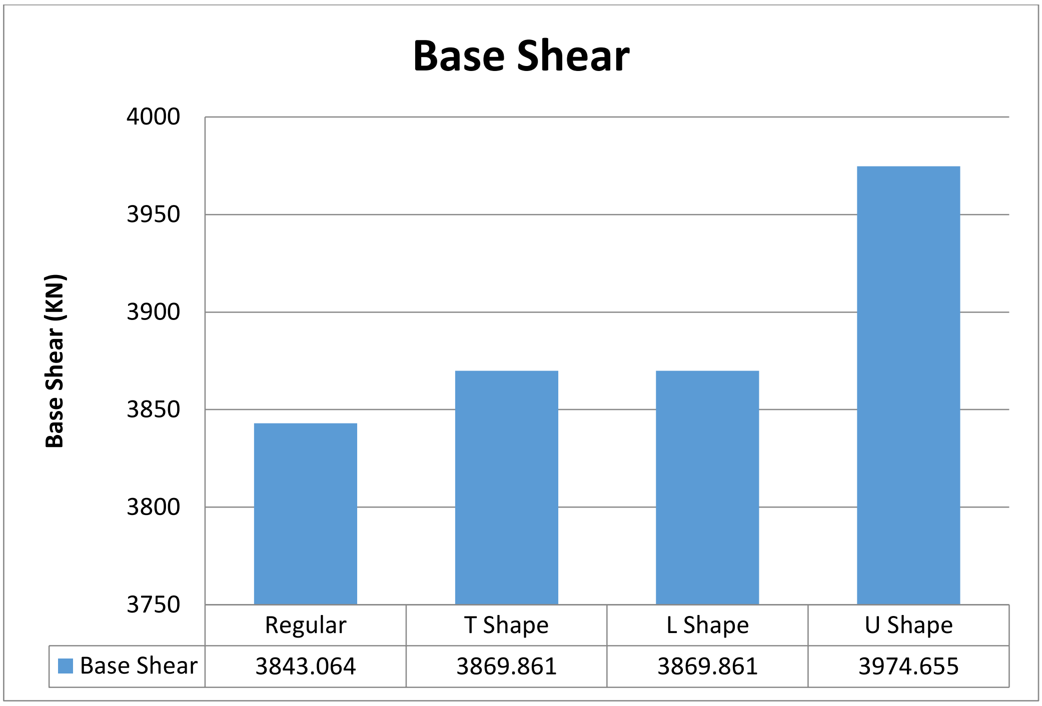
(Fig 6.20) U Storey Shear at Different Level

6.3 COMPARISON OF MAX DISPLACEMENT



(Fig 6.3) Comparison Of Max Displacement

6.4 COMPARISON OF BASE SHEAR OF STRUCTURES



(Fig 6.4) Comparison Of Base Shear

CHAPTER 7

CONCLUSION

7.1 GENERAL

In the present paper an analytical investigation of both regular and irregular shaped building is carried out using response spectrum method. It is performed on the building model G+7 storey of different shapes to study and identify the seismic behavior of the building. From the previous study it is observed that as the shape of building changes lateral load carrying capacity also changes but corresponding displacement increases. As the irregularities of building goes on increasing compared to regular building base shear decreases but displacement remains constant.

Now in this analysis it is found if height of building and plan area of building remains same but shape of building changes it is found that the maximum displacement of the building depends upon the orientation of building and percentage of irregularity.

The base shear of all the structure is also different in X and Z directions. But base shear of T and L shape buildings is same. This is because the orientation of building and percentage of irregularity. It is also easily seen that from all the structure the base shear goes increasing as the percentage of irregularity increases.

On the basis of present study following conclusion can be drawn:-

- Out of all the structure maximum base shear of that building which have maximum percentage of irregularity.
- Maximum displacement is in X direction for U shaped building.
- Maximum displacement is in Z direction for regular shaped building.
- Base shear in irregular shaped building is more than in regular shaped buildings.

7.2 SCOPE OF FUTURE STUDY

In the present study only plan irregular type of structure is considered. For future in order to develop generalized effect on different output parameter with mass irregularity , different types of building has to be considered i.e. buildings with mass and plan irregularity and different zone may be considered.

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