Design and Behavioral Analysis of Multi storied RCC Moment Resisting Frame Using Linear Spectrum Analysis in Seismic Zone-IV of Indian Subcontinent

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ABSTRACT

In this paper seismic response of (G+15)R.C. framed building is analyses for seismic load case by using STAAD-Pro software as per IS1893:2002 part-1.This paper consider different seismic parameter like seismic zone(IV), response reduction factor(R), importance factor(I)& other parameters like rock/soil type, structure type, damping ratio etc. This paper provides complete guidelines for STAAD-Pro software analysis & STAAD –Pro gives the results after run analysis in the STAAD output viewer which shows joint displacements, support reactions, member forces, base shear and lateral load.

If we consider the concrete era of construction activities, the land is scarce, especially in metro cities. Even though if there is the availability of land it may be in the sloping ground, hillocks, or on land-filled areas, in such areas, there will be difficulty in the construction and design aspects. To maintain the slope of the strata, different degrees of such buildings step back towards the slanting slope and may likewise also have set back simultaneously. Hence in the present paper, an attempt has been made to study, the G+15 storey building assumed to be on flat ground and also on sloping ground with a 20-degree inclination. The model is considered to be a soft storey with infill walls and two different shear wall arrangements. The building has been modeled and analyzed in STADD PRO software with the response spectrum method of analysis. The study reveals that a model with a shear wall improves the performance of the structure in terms of displacement, drift, and time period apart from the fact that the structure is being constructed in normal ground or sloping ground.

STAADPRO is one of the finest tools for the design of structures. In this project, we analyzed the G+15 building through response spectrum analysis to develop the economic design. IS: 1893 (Part I) for seismic design is utilized to perform the dynamic analysis. The results show that multistoried buildings are generally stiff for earthquake excitation as the modal participation factor is more than 75 percent.

Keywords: STAADPRO, Response Spectrum Analysis, Storey drift, storey displacement and base shear.

INTRODUCTION

An earthquake is a sudden movement of the earth's crust, which originates naturally at or below the surface of the crust. The study of earthquakes is called seismology. The instrument used for measuring the intensity of an earthquake is called a seismograph. The earthquake occurs at shallow depths (2-8km) are mostly small. The occurrence of an earthquake with a magnitude greater than 6 is rare. About 90% of all earthquakes result from tectonic events, primarily movements on the faults. The remaining is related to volcanism, the collapse of subterranean cavities, or manmade effects. Tectonic earthquakes are triggered when the accumulated strain exceeds the shearing strength of rocks. Elastic rebound theory gives the physics behind earthquake genesis. The seismic zoning map of India getting changed from then to now depending on the data obtained during an Earthquake. In the past Indian map is divided into five zones (I, II, III, IV, V).In which zone I is completely safe from Earthquakes, Zone II is the low-risk zone, zone III is moderate risk zone in which low-frequency Earthquakes may occur, zone IV is the high-risk zone in which low to high-frequency Earthquakes may occur, zone V is the very high-risk zone where Earthquake may occur of any frequency at any time. Later on, after experiencing a lot of Earthquakes it is concluded that there is no such region that is completely safe. So, the seismic Zoning map of India got modified and zone I is removed. The present seismic zoning map used in India is divided into four zones (II, III, IV, V).

A. Seismic analysis of Building: There are different methods of analysis that provide different degrees of accuracy.

B.Equivalent static method: It can only be used for regular structures with limited height.1Seismic analysis of most of the structures is still carried out based on lateral force assumed to be equivalent to the actual loading.

C.Response spectrum analysis: This method is applicable for those structures where modes other than the fundamental one affect significantly the response of the Structure. This method is more scientific than the Equivalent static method and is recommended by the Indian code for the design of building greater than 40m and up to 90m situated in all zones of India.. A building can be designed in accordance with standard protocols to resist earthquakes with certain amount of damage, but without causing collapse/failure and affecting the livelihood, causing threat to life and property. The response spectrum represents an interaction between ground acceleration and the structural system, by envelope of several different ground motion records. For the purpose of the seismic analysis the design spectrum given in fig.2 of IS 1893 (Part 1): 2002 is used. Response spectrum analysis of the building model is performed using STAADPRO. The lateral loads generated by STAADPRO correspond to the seismic zone IV and 5% damped response spectrum given in IS 1893 (Part1): 2002.

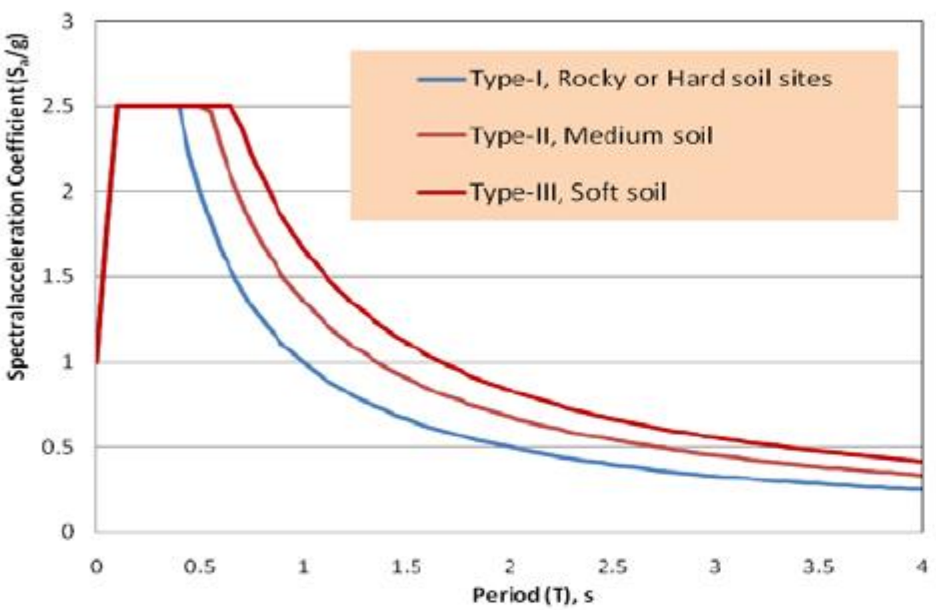

Figure.1 Design Response Spectrum for different soil (5% damping)

A. Objectives of Study

1.To determine dynamic response of a multi-storey building for earthquake load. To estimate the structural response to short, nondeterministic, transient dynamic events.

2.To observe story displacement, story shear, story drift using response spectrum analysis for a regular multi-storey building.

3.To study response spectrum analysis of regular multi-storey building using STAADPRO

B. Response Spectrum Analysis

A response spectrum is a function of frequency or period, showing the peak response of a simple harmonic oscillator that is subjected to a transient event. The response spectrum is a function of the natural frequency of the oscillator and of its damping. Thus, it is not a direct representation of the frequency content of the excitation (as in a Fourier transform), but rather of the effect that the signal has on a postulated system with a single degree of freedom (SDOF).

Response spectrum analysis is a method to estimate the structural response to short, nondeterministic, transient dynamic events. Examples of such events are earthquakes and shocks. Since the exact time history of the load is not known, it is difficult to perform a time-dependent analysis. Due to the short length of the event, it cannot be considered as an ergodic ("stationary") process, so a random response approach is not applicable either.

The response spectrum method is based on a special type of mode superposition. The idea is to provide an input that gives a limit to how much an eigenmode having a certain natural frequency and damping can be excited by an event of this type.

In most cases, the engineer performing a response spectrum analysis is presented with a given design response spectrum.

C. Seismic zoning in India

Seismic zoning is a process, which calibrates information about any decision making criterion for regional planning and/or for earthquake design in earthquake prone locations. In theory, seismic zoning map is the primary source of zoning in India, which displaysmetrics related to the plausible frequency and intensity of shaking caused by an impending earthquake.The procedure of seismic zoning is multidisciplinary and requires the best of inputs from geologists, geotechnical, seismologists, earthquake and structural engineers.The rapid urbanization due to population explosion, brooding of mega cities in potential seismic zones is the primary reason of the seismic hazards in the Indian Subcontinent. The recent release of IS 1893 (Part-1):2016 has a big impact on Seismic analysis procedure in India. This standard has clearly streamlined the analysis procedure to be used for general structures and buildings. It has introduced some special checks to be performed. This standard specifies a clear guideline on dynamic analysis. Equivalent static analysis procedure is driven by computing approximate fundamental time-period using empirical equations catering different types of lateral load resisting systems present in the building. Minimum base shear criteria have been introduced to consider minimum required strength of structure. Consideration of vertical motion in seismic analysis has been made compulsory under certain conditions. Seismic analysis using cracked sections for RCC structures has been a major requirement. STAAD.Pro CONNECT Edition has been a market leader for structural analysis and design. It has the facility to perform high-end analysis. Seismic analysis feature of this software is widely used. Seismic analysis process in this software is according to the state of art. The program is capable of producing detailed calculations. Dynamic analysis procedure in this software is quite user friendly. IS 1893 (Part-1):2016 has been incorporated in STAAD.Pro CONNECT Edition. A book with a step by step process on using IS 1893 (Part-1):2016 in STAAD.Pro CONNECT Edition will help users to deal with their requirement effectively. This book encompasses the understanding required by the structural engineers to use Indian Standard for earthquake analysis. It deals with examples to understand different parameters used in STAAD.Pro CONNECT Edition for Static and Dynamic analysis as per the requirement of Indian Standard. It also contains a manual verification to the examples used in different chapters. "STAAD.Pro CONNECT Edition - Seismic Analysis using IS 1893 (Part-1)-2016" serves as a useful guide for structural engineers

IS 1893:2002 provisions for zones:

According to IS 1893 code, seismic zoning map of a country is a guide to seismic status of a region and its susceptibility to earthquake. India has been divided into four zones with respect to severity of earthquakes Zone factor (Z) given in table

4.1, is for the maximum considered earthquake (MCE) and service life of a structure in a zone. For design horizontal seismic coefficient

$$Ah=(Z/2)(Sa/g)(I/R)$$

Factor 2 in the denominator of Z is used so as to reduce the Maximum Considered Earthquake zone factor to the factor for design basis earthquake (DBE). For any structure with t<0.1 s, the value of Ah will not be taken less than Z/2 whatever be the value of I/R.

LITERATURE REVIEW

Prakriti Chandrakar, Dr. P. S. Bokare,"A Review - Comparison between Response Spectrum Method and Time History Method for Dynamic Analysis of Multistoried Building".

Objectives

To determine dynamic response of multi-story building for earthquake load.

To study story displacement, story shear, story drift using response spectrum analysis for a regular multistory building.

To study response spectrum analysis of regular multistory building using computer programs (STAADPRO,ETABS)

Dhananjay Shrivastava, Dr. Sudhir Singh Bhaduria "Analysis of Multi-Storey RCC Frames of Regular and Irregular Plan Configuration using Response Spectrum Method";

This research paper focuses on the structural behaviour of multi-storey building for different plan configuration such as regular building along with L- shape and I- shape in accordance with the seismic provisions suggested in IS: 1893-2002 to analyze the performance of existing buildings if exposed to seismic loads. The main target of this research work isanalysis of Multi-Storey RCC Frames of Regular and Irregular Plan Configuration using Response Spectrum Method.

Mario De Stefano,Barbara Pintucchi, "A review of research on seismic behaviour of irregular building structures since 2002"

Bulletin of Earthquake Engineering 6(2):285-308

DOI:10.1007/s10518-007-9052-3

Analysing and designing a structure progress in research regarding seismic response of plan and vertically irregular building structures. Three areas of research are surveyed. The first is the study of the effects of plan-irregularity by means of single-storey and multi-storey building models. The second area encompasses passive control as a strategy to mitigate torsional effects, by means of base isolation and other types of devices. Lastly, the third area concerns vertically irregular structures and setback buildings.

S. R. Kangle, D. S. Yerudkar, "Response Spectrum Analysis for Regular Multistory Structure in Seismic Zone III": International Journal of Engineering Research & Technology (IJERT) ISSN: 2278-0181 IJERTV9IS090262 (This work is licensed under a Creative Commons Attribution 4.0 International License.) Vol. 9 Issue 09, September-2020

The Comparative Study on Analysis Results of Multistoried Commercial Building (G+15) by STAADPRO and ETABS".STAADPROis one of the leading software's for the design of structures. In this project we had analyzed the G+15 building through response spectrum analysis to develop the economic design.

Kavan M R , Chethan Kumar D C, "RESPONSE SPECTRUM ANALYSIS OF UNSYMMECTRICAL MULTYSTORY BUILDING."
"RESPONSE SPECTRUM ANALYSIS OF UNSYMMECTRICAL MULTYSTORY BUILDING", International Journal of Science & Engineering Development Research (www.ijsdr.org), ISSN:2455-2631,Vol.3, Issue 11, page no.92 - 99, December-2018, Available :http://www.ijsdr.org/papers/IJSDR1812016.pdf

The main objectives of present work are as follows;

1) Analysis of multistorey building using E-TABS by considering Earthquake Zone -II and Zone –IV.

2) Comparison of storey stiffness, story drift and mass participation for conventional and ductiledetailing building.

METHODOLOGY:

Reinforced concrete moment resisting frame building of different story heights are considered. The bottom story height is kept 3m and a typical height of 3m is kept for the entire story in the building. The aim of the study is to find the difference of base reactions, modal participation factors and periods and frequencies using ETABS and STAADPRO.

The ETABS & STAADPRO software is used for modelling as well as analysis of the structure. The symmetrical plan of reinforced concrete structure having 15 story is considered. First the Earthquake loads as per IS1893-2002, Part-1 are applied for structure located in zone III. And dynamic analyses i.e. Response spectrum method is carried out for 5% damping and scale factor considered as per IS code in both X and Y directions. Assuming that material property is linear static and Response spectrum analysis is performed.

Loadings and material properties M25 grade of concrete and Fe 500 grade of Steel are used for all slabs and beams of the building whereas M30 is used for columns with same grade of Steel. Elastic material properties of these materials are taken as per IS 456-2000. The short-term modulus of elasticity (Ec) of concrete is taken as $E_c = 5000\sqrt{f_{ck}}$ Mpa,fck =characteristic compressive strength of concrete cube For the Steel rebar with stress and modulus of elasticity is taken as per IS 456-2000. While applying the loads to the structure we consider only the external loads which are actually acting on the members neglecting its self-weight because ETABS 2018 & STAADPRO automatically take the members selfweight. The Seismic loads EQ-x and EQ-y are given in Load patterns directly using Code IS1893:2002. Also the Wind loads wind-x and wind-y are IS875:2015 by ETABS 2018 given using code IS875:2015 by ETABS 2018

Table1: Structural property of building

Type of Building	Residential
Length of the building	16 m
Width of the building	16 m
Height of the building	63 m
Height of each storey	3 m
Number of storey	G+15
Beam size	(450*450)mm
Column size	(500*500)mm
Surface thickness	260mm
Concrete grade	M25
Steel reinforcement	Fe415
Zone	IV
Soil type	Hard
Damping Ratio	5%
Concrete cover	30 mm
Storey drift	0.004
Dead load	24 KN/m^2
Live load	3.75 KN/m^2
Support Condition	Fixed

The different MODELS of buildings are given below:-
G+15Building with shear wall
CASE 1: When shear wall is at perimeter.
CASE 2: When shear wall is at corner.

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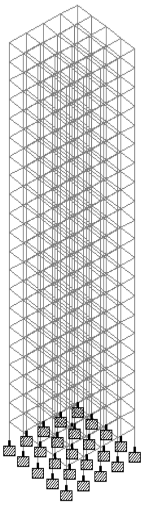
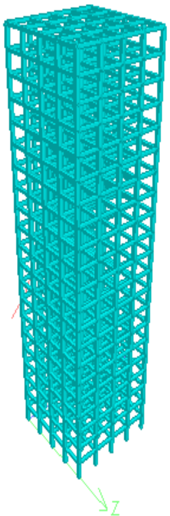




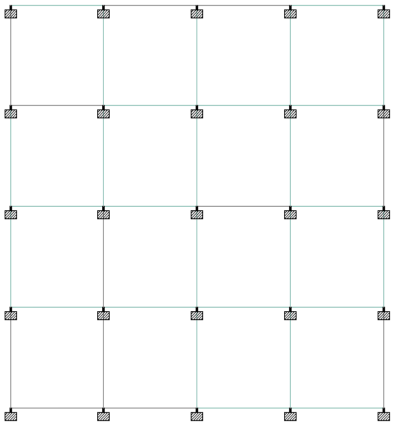
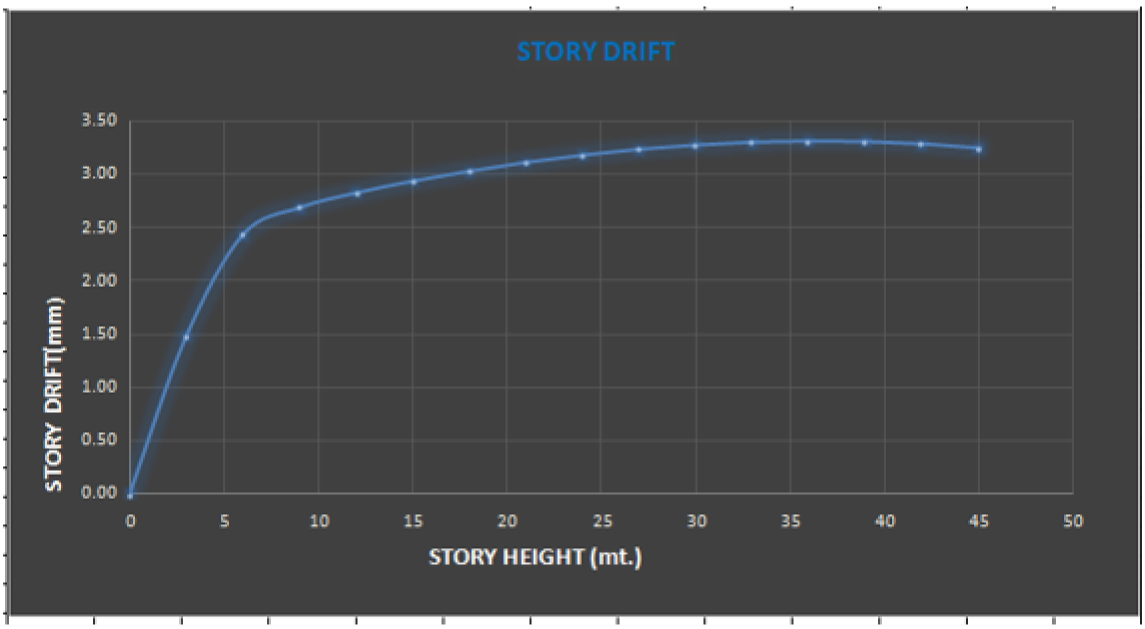


Fig a: G+15 Structure Fig b:3D rendered view Fig c: base plan view

RESULTS AND DISCUSSION

Result obtain from the analysis are recorded in tabular form for the different locations of the shear wall i.e at perimeter and at corner.And for the three different parameters the graphs are plotted:

1. Storey drift:



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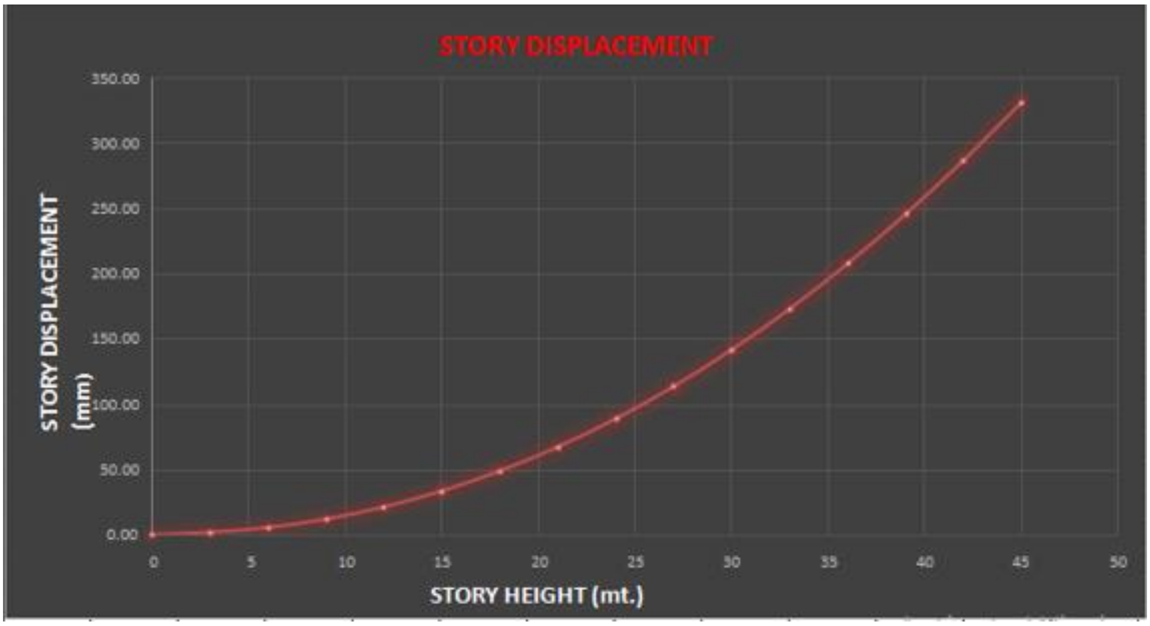
2. Storey displacement:



3. Base Shear:

MASS PARTICIPATION FACTORS IN PERCENT BASE SHEAR IN KN

MODE	X	Y	Z	SUMM-X	SUMM-Y	SUMM-Z	X	Y	Z
1	73.86	0.00	0.00	73.861	0.000	0.000	8667.98	0.00	0.00
2	0.00	0.00	0.00	73.861	0.000	0.000	0.00	0.00	0.00
3	12.02	0.00	0.00	85.877	0.000	0.000	4431.96	0.00	0.00
4	0.00	0.00	0.00	85.877	0.000	0.000	0.00	0.00	0.00
5	3.54	0.00	0.00	89.418	0.000	0.000	2155.05	0.00	0.00
6	0.00	0.00	0.00	89.418	0.000	0.000	0.00	0.00	0.00

	X	Y	Z
TOTAL SRSS SHEAR	9970.98	0.00	0.00
TOTAL 10PCT SHEAR	9970.98	0.00	0.00
TOTAL ABS SHEAR	15254.99	0.00	0.00
TOTAL CSM SHEAR	9970.98	0.00	0.00

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*****************************************************
* UNITS - KN    METE                       *
* TIME PERIOD FOR X 1893 LOADING =    2.46010 SEC     *
* SA/G PER 1893=    0.553, LOAD FACTOR= 1.000        *
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International Journal of Scientific Research in Engineering and Management (IJSREM)
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* FACTOR V PER 1893= 0.0160 X-188586.31 *
* VB Min based on Clause 7.2.2 = -3017.38 *
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4. CALCULATED FREQUENCIES FOR LOAD CASE

MODE	ACCELERATION-G	DAMPING
1	0.48216	0.05000
2	0.83819	0.05000
3	1.51536	0.05000
4	2.40054	0.05000
5	2.50000	0.05000
6	2.50000	0.05000

5. RESPONSE LOAD CASE

MODAL WEIGHT (MODAL MASS TIMES g) IN KN GENERALIZED

MODE	X	Y	Z	WEIGHT
1	1.997486E+05	0.000000E+00	0.000000E+00	1.068013E+05
2	1.071067E-11	0.000000E+00	0.000000E+00	5.322264E+04
3	3.249658E+04	0.000000E+00	0.000000E+00	1.141232E+05
4	1.313379E-08	0.000000E+00	0.000000E+00	5.444908E+04
5	9.577985E+03	0.000000E+00	0.000000E+00	1.199269E+05
6	4.672827E-08	0.000000E+00	0.000000E+00	5.701564E+04

6. RESPONSE SPECTRUM 1893

MODE	SPECTRAL ACCELERATION	DESIGN SEISMIC COEFFICIENT		
		X	Y	Z
1	0.48216	0.0434	0.0000	0.0000
2	0.83819	0.0754	0.0000	0.0000
3	1.51536	0.1364	0.0000	0.0000
4	2.40054	0.2160	0.0000	0.0000
5	2.50000	0.2250	0.0000	0.0000
6	2.50000	0.2250	0.0000	0.0000

7. PEAK STORY SHEAR

STORY	LEVEL IN METE	PEAK STORY SHEAR IN KN		
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		X	Y	z
17	80.00	5421.03	0.00	0.00
16	75.00	5763.51	0.00	0.00
15	70.00	6069.98	0.00	0.00
14	65.00	6386.62	0.00	0.00
13	60.00	6722.30	0.00	0.00
12	55.00	7057.63	0.00	0.00
11	50.00	7368.72	0.00	0.00
10	45.00	7648.97	0.00	0.00
9	40.00	7917.04	0.00	0.00
8	35.00	8207.09	0.00	0.00
7	30.00	8546.22	0.00	0.00
6	25.00	8932.22	0.00	0.00
5	20.00	9326.36	0.00	0.00
4	15.00	9665.90	0.00	0.00
3	10.00	9888.91	0.00	0.00
2	5.00	9962.78	0.00	0.00
1	1.52	9970.98	0.00	0.00
BASE	0.00	9970.98	0.00	0.00

MODE	ACCELERATION-G	DAMPING
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1	0.48216	0.05000
2	0.83819	0.05000
3	1.51536	0.05000
4	2.40054	0.05000
5	2.50000	0.05000
6	2.50000	0.05000

CONCLUSIONS:

In thus project the main aim was to compare the effects of shear wall when applied to a structure at two different locations and the parameter for the compraision was Storey drift, Storey displacement and base shear.

Taking Case I: as When shear wall is applied at corner and Case II: as When shear wall is applied at perimrter, the following conclusions can be drawn:

1 Among all the load combinations, the load combination of 1.5DL+1.5LL is critical combination for both the models.
2 From the graph we can say that the storey drift is minimum when the shear wall is applied at the perimter as compared to when shear wall is applied at the corner.But the difference between the drifts is not much large.
3 The maximum drift on the structure for case I is 0.0584 cm while the maximum drift Case II is 0.0394 cm.
4 The percentile difference between these two drifts is about 32.52%.
5 From the above graph we can also say that the displacement of the structure is maximum when the shear wall is applied at the corners only as compared to shear wall applied at perimter of the structure.
6 The maximum displacementfor case II is 5.69 cm and The maximum displacement for case I is 0.8015 cm.
7 The base shear for case I is 163.952KN and for case II is 120.576KN.

Provison of shear wall at perimeter reults in the reduction of drift,displacement and base shear which means the storey drift, storey displacement and base shear will be minimum of the shear wall is applied at the whole perimeter rather that at corners only.

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