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STUDY ON EARTHQUAKE RESISTANT BUILDINGS ON GROUND SURFACE BY USING E-TABS

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ABSTRACT

In the present study to find the effect of flat and sloping ground on building performance ground slopes of 0^0 and 10^0 are considered in modeling of buildings of height G+15 RCC structures having material properties M40 grade for concrete and Fe500 for reinforcing steel and structures dimensions are length = 6x10= 60m, width = 6x5 = 30m and heights of G+15 is 48m from the plinth level, the support conditions are chosen to be fixed base and foundation depth is considered as 2m below the ground level structures are modeled using ETABS in seismic zones II, III, IV, V as per IS 1893-2002 methods used for seismic load generation are Linear static analysis, Response spectrum analysis and Time history analysis. The results are shown in terms of graphs and tables.

1. INTRODUCTION

Generally the structures are constructed on level ground. In some areas the ground itself is a slope. In that condition it is very difficult to excavation, leveling and it is very expensive .Due to the scarcity of level ground engineers started construction on sloppy ground itself. Some of the hilly areas are more prone to the earthquake. In that areas generally construction works carried out by locally available materials such as bamboo, timber, brick, RCC and also they gave more important to the light weight materials for the construction of houses. As the population density increases at hilly region requirement of structure also increases. The popularity and demand of multistory building on hilly slope is also increases.

The unsymmetrical buildings require great attention in the analysis and design under the action of seismic excitation. Past earthquakes in which, buildings located near the edge of a stretch of hills or on sloping ground suffered serious damages. The shorter column attracts more forces and undergoes damage, when subjected to earthquakes. The other problems associated with hill buildings are, additional lateral earth pressure at various levels, slope instability, different soil profile yielding unequal settlement of foundation.

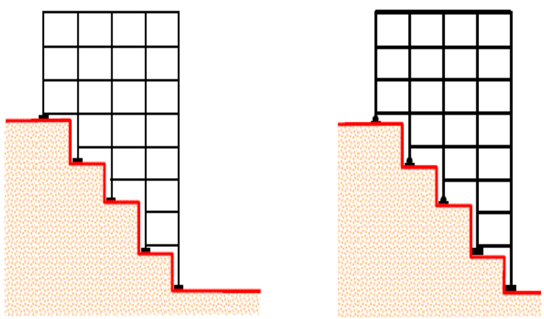

Fig 1.1: buildings on sloping grounds

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1.1 origin of earthquake:

Sudden movement on faults is responsible for earthquakes. An earthquake is simply the vibrations caused by the blocks of rock on either side of a fault rubbing against each other as they move in opposite directions. Bigger the movement of faultsbigger the earthquake.

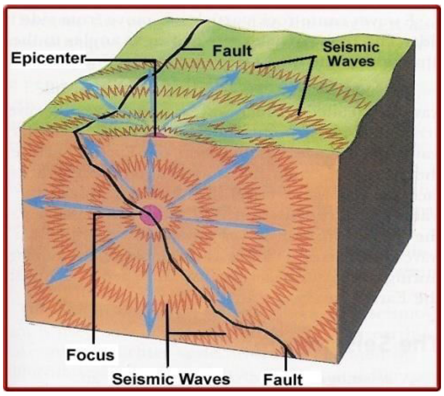


Fig 1.2: origin of earthquake from earth

1.2 Seismic zones India:

Based on magnitude of the earthquake India is classified into four zones (II, III, IV, and V) where zone V is high severity zone

Table 2 Zone Factor, *Z*

(*Clause* 6.4.2)

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

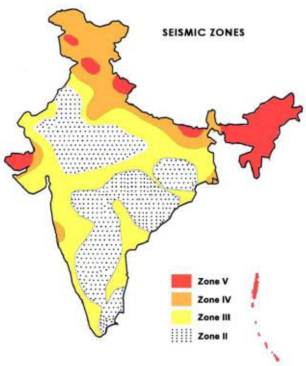


Fig 1.3: seismic map of India

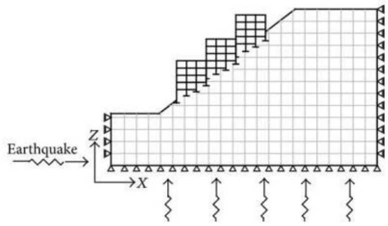
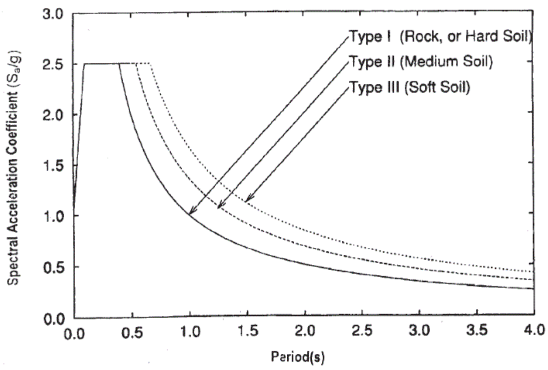


Fig 1.4: effect of seismic waves on structures



For rocky, or hard soil sites

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

For medium soil sites

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

For soft soil sites

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

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Table 7 Response Reduction Factor [1], *R*, for Building Systems

(*Clause* 6.4.2)

Sl No.	Lateral Load Resisting System	*R*
(1)	(2)	(3)
	Building Frame Systems	
i)	Ordinary RC moment-resisting frame (OMRF)[2]	3.0
ii)	Special RC moment-resisting frame (SMRF)[3]	5.0
iii)	Steel frame with	
	a) Concentric braces	4.0
	b) Eccentric braces	5.0
iv)	Steel moment resisting frame designed as per SP 6 (6)	5.0
	Building with Shear Walls[4]	
v)	Load bearing masonry wall buildings[5]	
	a) Unreinforced	1.5
	b) Reinforced with horizontal RC bands	2.5
	c) Reinforced with horizontal RC bands and vertical bars at corners of rooms and jambs of openings	3.0
vi)	Ordinary reinforced concrete shear walls[6]	3.0
vii)	Ductile shear walls[7]	4.0
	Buildings with Dual Systems[8]	
viii)	Ordinary shear wall with OMRF	3.0
ix)	Ordinary shear wall with SMRF	4.0
x)	Ductile shear wall with OMRF	4.5
xi)	Ductile shear wall with SMRF	5.0

1.3 Disadvantages on structures built on sloping hill surfaces

1. Shorter columns are subjected to higher seismic forces
2. Lateral Soil pressure should be considered in designs
3. Excavation of ground is difficult and costly
4. Lateral supporting systems like sheet piles should be adopted in excavation
5. Laying of roadways to hill stop is costly
6. Accessibility of structures is difficult
7. Costly drainage systems should be adopted
8. More prone to natural disasters like landslides etc
9. Subjected to high wind velocities
10. Dynamic analysis should be carried out using soil structure interaction

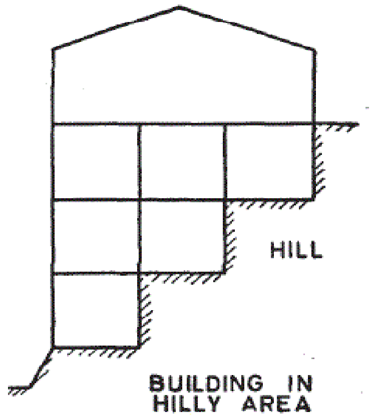

Fig 1.5: buildings constructed on hilly slopes as per IS: 1893-1984

ANNEX E

(*Foreword*)

ZONE FACTORS FOR SOME IMPORTANT TOWNS

Town	*Zone*	*Zone Factor, Z*	*Town*	*Zone*	*Zone Factor, Z*
Agra	III	0.16	Chitradurga	II	0.10
Ahmedabad	III	0.16	Coimbatore	III	0.16
Ajmer	II	0.10	Cuddalore	III	0.16
Allahabad	II	0.10	Cuttack	III	0.16
Almora	IV	0.24	Darbhanga	V	0.36
Ambala	IV	0.24	Darjeeling	IV	0.24
Amritsar	IV	0.24	Dharwad	III	0.16
Asansol	III	0.16	Dehra Dun	IV	0.24
Aurangabad	II	0.10	Dharampuri	III	0.16
Bahraich	IV	0.24	Delhi	IV	0.24
Bangalore	II	0.10	Durgapur	III	0.16
Barauni	IV	0.24	Gangtok	IV	0.24
Bareilly	III	0.16	Guwahati	V	0.36
Belgaum	III	0.16	Goa	III	0.16
Bhatinda	III	0.16	Gulbarga	II	0.10
Bhilai	II	0.10	Gaya	III	0.16
Bhopal	II	0.10	Gorakhpur	IV	0.24
Bhubaneswar	III	0.16	Hyderabad	II	0.10
Bhuj	V	0.36	Imphal	V	0.36
Bijapur	III	0.16	Jabalpur	III	0.16
Bikaner	III	0.16	Jaipur	II	0.10
Bokaro	III	0.16	Jamshedpur	II	0.10

Town	*Zone*	*Zone Factor, Z*	*Town*	*Zone*	*Zone Factor, Z*
Kanchipuram	III	0.16	Pondicherry	II	0.10
Kanpur	III	0.16	Pune	III	0.16
Karwar	III	0.16	Raipur	II	0.10
Kohima	V	0.36	Rajkot	III	0.16
Kolkata	III	0.16	Ranchi	II	0.10
Kota	II	0.10	Roorkee	IV	0.24
Kurnool	II	0.10	Rourkela	II	0.10
Lucknow	III	0.16	Sadiya	V	0.36
Ludhiana	IV	0.24	Salem	III	0.16
Madurai	II	0.10	Simla	IV	0.24
Mandi	V	0.36	Sironj	II	0.10
Mangalore	III	0.16	Solapur	III	0.16
Monghyr	IV	0.24	Srinagar	V	0.36
Moradabad	IV	0.24	Surat	III	0.16
Mumbai	III	0.16	Tarapur	III	0.16
Mysore	II	0.10	Tezpur	V	0.36
Nagpur	II	0.10	Thane	III	0.16
Nagarjunasagar	II	0.10	Thanjavur	II	0.10
Nainital	IV	0.24	Thiruvananthapuram	III	0.16
Nasik	III	0.16	Tiruchirappali	II	0.10
Nellore	III	0.16	Tiruvennamalai	III	0.16
Osmanabad	III	0.16	Udaipur	II	0.10
Panjim	III	0.16	Vadodara	III	0.16
Patiala	III	0.16	Varanasi	III	0.16
Patna	IV	0.24	Vellore	III	0.16
Pilibhit	IV	0.24	Vijayawada	III	0.16
			Vishakhapatnam	II	0.10

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1.4 Linear static analysis

Displacements, strains, stresses, and reaction forces under the effect of applied loads are calculated.. A series of **assumptions** are made with respect to a linear static analysis:

Small Deflections Determine whether the deflections obtained or predicted are small relative to the size of the structure.

Small Rotations In linear codes all rotations are assumed to be small. Any angle measured in radians should be small enough that the tangent is approximately equal to the angle.

Material Properties Linear solvers assume that all material behaves in a linear elastic manner. Some materials have a non-linear elastic behavior, and although they do not necessarily yield.

1.5 Time history method:

The usage of this method shall be on an appropriate ground motion and shall be performed using accepted principles of dynamics. In this method, the mathematical model of the building is subjected to accelerations from earthquake records that represent the expected earthquake at the base of the structure.

1.6 Response spectrum method:

The word spectrum in engineering conveys the idea that the response of buildings having a broad range of periods is summarized in a single graph. This method shall be performed using the design spectrum specified in code or by a site-specific design spectrum for a structure prepared at a project site. The values of damping for building may be taken as 2 and 5 percent of the critical, for the purposes of dynamic analysis of steel and reinforce concrete buildings, respectively

1.7 Response Spectrum Analysis as per IS: 1893-2002

This method is also known as modal method or mode superposition method. It is based on the idea that the response of a building is the superposition of the responses of individual modes of vibration, each mode responding with its own particular deformed shape, its own frequency, and with its own modal damping.

According to IS 1893(Part-l):2002, high rise and irregular buildings must be analysed by response spectrum method using design spectra Sufficient modes to capture such that at least 90% of the participating mass of the building (in each of two orthogonal principle horizontal directions) have to be considered for the analysis. However, in this method, the design base shear (V_B) shall be compared with a base shear (V_b) calculated using a fundamental period T. If V_B is less than V_b, all response quantities are (for example member forces, displacements, storey forces, storey shears and base reactions) multiplied by V_B/ V_b.

1.8 Modal combination as per IS: 1893-2002

Modal Response quantities for each mode of response may be combined by the complete quadratic combination (CQC) technique or by taking the square root of the sum of the squares (SRSS) of each mode of the modal values or absolute sum (ABS) method.

(i) CQC method: The peak response quantities shall be combined as per the complete quadratic combination (CQC) method.

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$$\lambda = \sqrt{\sum_{i=1}^{r}\sum_{j=1}^{r} \lambda_i \rho_{ij} \lambda_j}$$

where

r = Number of modes being considered,

ρ_{ij} = Cross-modal coefficient,

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

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

(ii)SRSS method: If the building does not have closely spaced modes, then the peak response quantity due to all modes considered shall be obtained as

$$\lambda = \sqrt{\sum_{k=1}^{r} (\lambda_k)^2}$$

where

λ_k = Absolute value of quantity in mode k, and

r = Number of modes being considered.

(iii) ABS method: If the building has a few closely spaced modes, then the peak response quantity due to all modes considered shall be obtained as

$$\lambda^* = \sum_{c}^{r} \lambda_{c'}$$

Where, the summation is for the closely-spaced modes only. This peak response quantity due to the closely spaced modes (λ^*) is then combined with those of the remaining well-separated modes by the method described above.

1.9 El Centro earthquake for time history analysis

The 1940 El Centro earthquake occurred at 21:35 Pacific Standard Time on May 18 (05:35 UTC on May 19) in the Imperial Valley in southeastern Southern California near the international border of the United States and Mexico. It had a moment magnitude of 6.9 and a maximum perceived intensity of X (*Extreme*) on the Mercalli intensity scale. The earthquake was the result of a rupture along the Imperial Fault, with its epicenter 5 miles (8.0 km) north of Calexico, California, The event caused significant damage in the towns of Brawley, Imperial, El Centro, Calexico and Mexicali and was responsible for the deaths of nine people

1.10 Mass source for the calculation of seismic weights:

1. 100% of Dead loads from structural members and brick work are considered
2. 50% of live loads/imposed loads are considered

1.11 About ETABS

The modeling and the analysis of the building frames were carried out using commercial software ETABS. The important features of this software are as follows:

- ETABSis widely used software package from Computers and Structures, Inc for building structures.
- ETABShas fully graphical user interface. It is used to generate the model, which can then be analyzed.
- The ETABS engine: It is a general purpose calculation engine for structural analysis & integrated steel, concrete, timber & aluminum.

2. RELATED WORK

B.G. Birajdar1, S.S. Nalawade2. Made a study on seismic analysis of buildings resting on slopingground by considering 24 RC buildings with three differentconfigurations like, Step back

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building, Step back Set back building and Set back building arepresented. 3 –D analysis including torsional effect has been carried out by using responsespectrum method. The dynamic response properties *i.e.* fundamental time period, top storeydisplacement and, the base shear action induced in columns have been studied with referenceto the suitability of a building configuration on sloping ground. In the present study, three groups of building (*i.e. configurations*) are considered, out of which twoare resting on sloping ground and third one is on plain ground. The first two are step back buildingsand step back-setback buildings; and third is the set back building. The slope of ground is 27 degreewith horizontal, which is neither too steep or nor too flat. The height and length of building in aparticular pattern are in multiple of blocks (in vertical and horizontal direction), the size of block isbeing maintained at 7 m x 5 m x 3.5 m. The depth of footing below ground level is taken as 1.75 mwhere, the hard stratum is available. The performance of STEP back building during seismic excitation could prove morevulnerable than other configurations of buildings. Hence, Step back Set back buildings are found to be less vulnerablethan Step back building against seismic ground motion.In Step back buildings and Step back-Set back buildings, it is observed that extreme leftcolumn at ground level, which are short, are the worst affected. Special attention should begiven to these columns in design and detailing.

Likhitharadhya Y R1, Praveen J V2, Sanjith J3, Ranjith A4 performed Seismic Analysis of Multi-Storey BuildingResting On Flat Ground and Sloping Ground In this study, G+ 10 storeys RCC building andthe ground slope varying from 100 to 300 have been considered for the analysis. The seismic analysis was done by the response spectrum analyses have been carried out as per IS:1893(part 1): 2002. The results were obtained in the form of top storey displacement, Storey Acceleration, Base shear andMode period. It is observed that short column is affected more during the earthquake. Base shear is maximum at 200 slope compared to other models.Period also increases.From the analysis, Storey displacement is decrease with increase in slope angle.From the analysis, Storey Acceleration is decrease with increase in slope angle.Acceleration is maximum in storey-11 when compared to storey-1 in all other models along x and y-direction.

Dr. R. B. Khadiranaikar1 and Arif Masali2 review on Seismic performance of buildings resting on sloping ground and the conclusions drawn are1. Step back buildings produce higher base shear, higher value of time period, higher value of top storey displacement compared to step back set back building. During seismic excitation Step back building could prove more vulnerable than other configuration of buildings. 2. It is observed that, short columns attracts more forces and are worst affected during seismic excitation. From design point of view, special attention should be given to the size (strength), orientation (stiffness)

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and ductility demand of short column. 3. The hill slope buildings are subjected to significant torsional effects, due to uneven distribution of shear force in the various frames of building suggest development of torsional moment, which is found to be higher in step back building.4. Many researchers suggested as step back set back buildings may be favoured on sloping ground. 5. From the study it is concluded that the presence of infill wall and shear wall influences the behaviour of structure by reducing storey displacement and storey drifts considerably, but may increase the base shear, hence special attention should be given in design to reduce base shear.

3. MODELLING AND METHODOLOGY

3.1: modeling of structures

In the present study three G+15 structure models with foundation depth of 2m and bay widths in length and width directions of 6m each, support conditions are assumed to be fixed at the bottom or at the supports/footings. The structures having length = 6x10 = 60m, width = 6x5 = 30m and height = 20m. Ground slopes considered of angles 0^0, 10^0.The structures modeled in ETABS structural analysis and design software by considering various loads and load combinations by their relative occurrence are considered the material properties considered are M30 grade concrete and Fe415 reinforcing steel bars. Methods of analysis considered are linear static analysis, Response spectrum analysis and Time history analysis

Structure-1: G+15 structure on 0^0 ground slope

Structure-2: G+15 structure on 10^0 ground slope

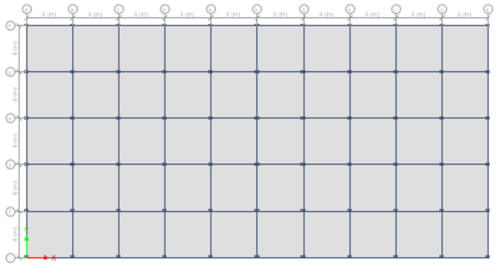

Fig 3.1: floor plan of structure-1 and structure-2

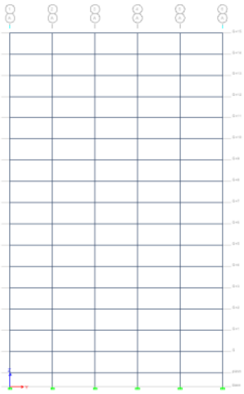

Fig 3.2: elevation of structure-1resting on 0^0 ground slope

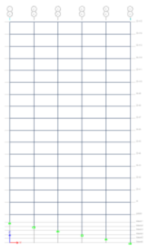

Fig 3.3: elevation of structure-2 resting on 10^0 ground slope

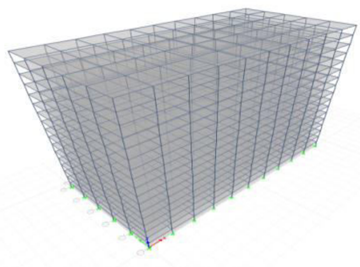

Fig 3.4: three dimensional views of structure-1 and structure-2

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Table 3.1: Design data used in modeling and analysis of structures

Materials	M30, Fe415
Loadings	Dead, live, earthquake
Heights of building	G+15
Length	6x10 = 60m
Width	6x5 = 30m
Foundation depth	2.0m
Floor to floor height	3.0m
zones	II,III,IV,V
Software	ETABS
Size of column	400x600
Beam size	300x500
Soil type	Hard
Ground slopes	0^0; 10^0
Geometry of Building	Symmetric
Methods used in analysis	Linear static analysis
	Response spectrum analysis
	Time history analysis

3.2 Is codes used in analysis and Design

[1] IS 1893:1984,"Criteria for earthquake resistant design of structures", Bureau of Indian Standards, New Delhi, India.

[2] IS 456: 2000,"Plain reinforced concrete-code of practice", Bureau of Indian Standards, New Delhi, India.

[3] IS 875-3: 1987,"Code of practice for design wind loads(other than earthquake) for buildings and structures", Bureau of Indian Standards, New Delhi, India.

3.3 Loads and load combination considered for analysis

In the limit state design of reinforced and prestressedconcrete structures, the following load combinationsshall be accounted for:

1) 1.5(DL+LL)
2) 1.2(DL+LL+EL)
3) 1.5(DL+EL)
4) 0.9DL+1.5EL

Loads and load combinations considered in analysis of structures using ETABS

1. DL
2. LL
3. ELX
4. ELY
5. 1.5(DL+LL)
6. 1.2(DL+LL+ELX)
7. 1.2(DL+LL+ELY)
8. 1.5(DL+ELX)
9. 1.5(DL+ELY)
10. 0.9DL+1.5ELX
11. 0.9DL+1.5ELY

DL = DEAD LOAD
LL = LIVE LOAD
ELX = EARTHQUAKE LOAD ALONG X DIRECTION
ELY = EARTHQUAKE LOAD ALONG Y DIRECTION

3.4 G+15 Wind calculations As per IS: 875 (PART 3) – 1987

WIND PRESSURE CALCULATIONS G+15

As per IS: 875 (PART 3) – 1987

DESIGN DATA:

Type of structure ; G+15 ; RCC BUILDINGS with Terrain category = 1

Length = 60m, Width = 30m, Height= 48m; Class-B(20m-50m)

Type of city = VISAKHAPATNAM

Basic WIND SPEED (V_b) 47 m/sec

Risk coefficient for important buildings/towers 1

K_2 = terrain, structure height and size factor

K_3 = topography factor (upwind slope < 3°) 1

Design WIND SPEED = $V_Z = V_B K_1 K_2 K_3$

Design WIND PRESSURE = $P_z = 0.6 V_Z^2$

S.NO	HEIGHT (m)	V_B (m/sec)	K_1	K_2	K_3	V_z (m/sec)	P_z (k.N/m^2)
1	2	47	1	1.03	1	48.41	1.41
2	5	47	1	1.03	1	48.41	1.41
3	8	47	1	1.03	1	48.41	1.41
4	11	47	1	1.038	1	48.786	1.43
5	14	47	1	1.062	1	49.914	1.49
6	17	47	1	1.085	1	50.995	1.56
7	20	47	1	1.1	1	51.7	1.60
8	23	47	1	1.109	1	52.123	1.63
9	26	47	1	1.118	1	52.546	1.66
10	29	47	1	1.127	1	52.969	1.68
11	32	47	1	1.135	1	53.345	1.71
12	35	47	1	1.142	1	53.674	1.73
13	38	47	1	1.15	1	54.05	1.75
14	41	47	1	1.157	1	54.379	1.77
15	44	47	1	1.16	1	54.52	1.78
16	47	47	1	1.17	1	54.99	1.81
16	50	47	1	1.18	1	55.46	1.85

Table: 3.2 seismic design parameters used in analysis and modeling

Parameters	values
Type of building	Residential
Live load	3kN/m^2
Member load	11.5kN/m
Slab thickness	150mm
Response reduction(R)	5
Importance factor	1
Soil type	II
Time history function	el Centro

4. RESULTS AND DISCUSSION

4.1 Results of G+15 buildings resting on Zero Degrees ground slope: Linear Static analysis

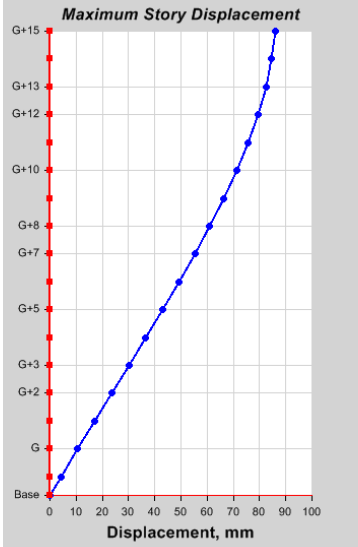

Fig: 4.1 maximum lateral displacements of structure-1

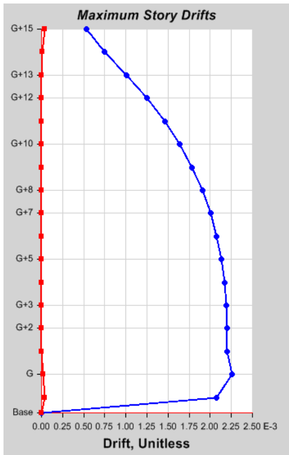

Fig: 4.2 maximum storey drift of structure-1

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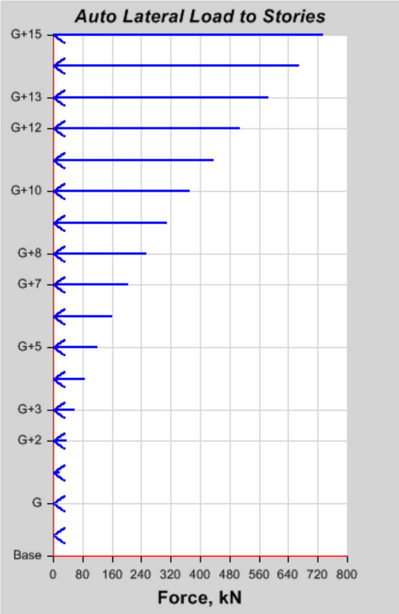

Fig: 4.3 lateral seismic load distribution on structure-1

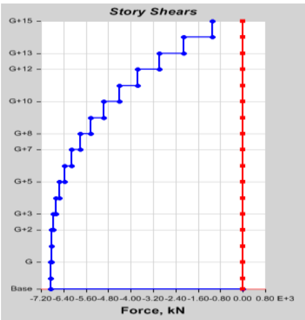

Fig: 4.4 storey shears acting on structure-1

4.2 Results of G+15 buildings resting on zero ground slope: response spectrum analysis

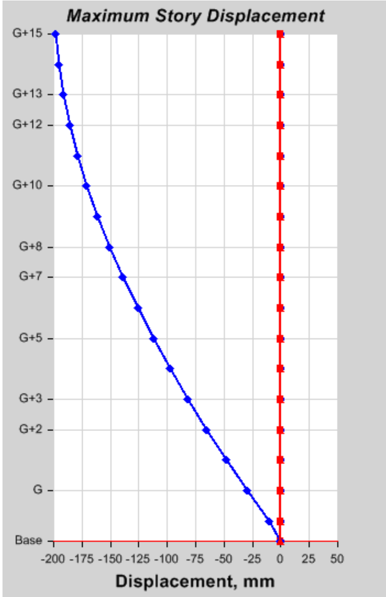

Fig: 4.5 maximum storey displacements acting on structure-1

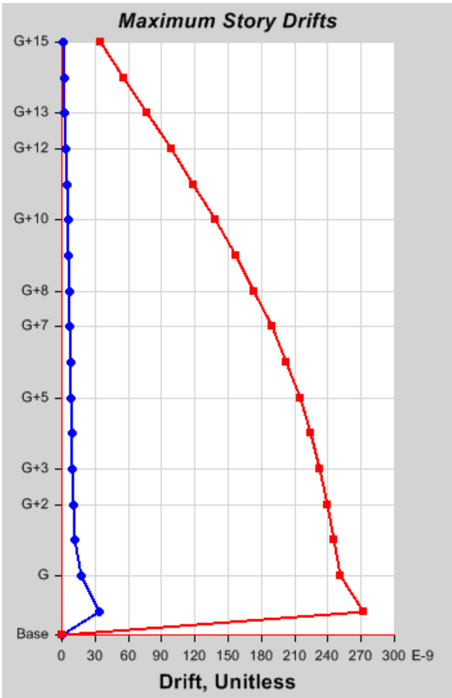

Fig: 4.6 maximum storey drift acting on structure-1

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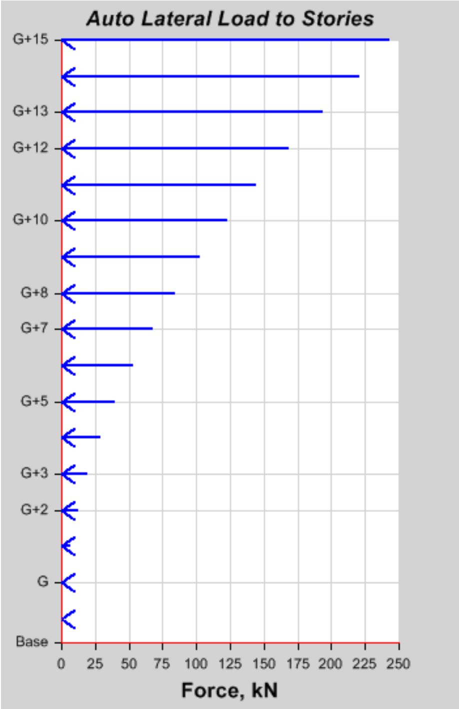

Fig: 4.7 lateral load acting on structure-1

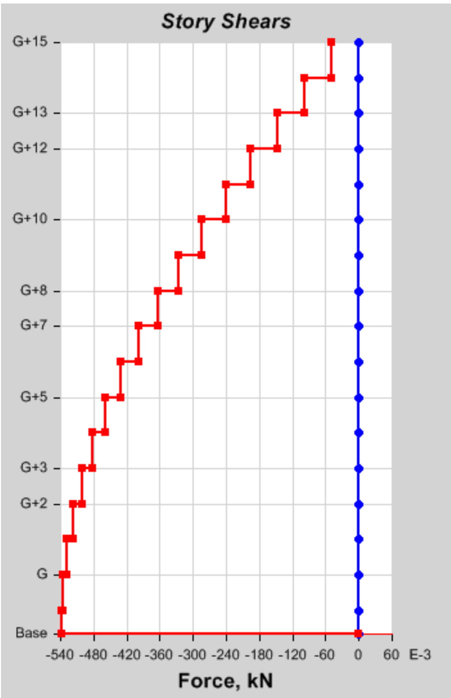

Fig: 4.8 storey shear on structure-1

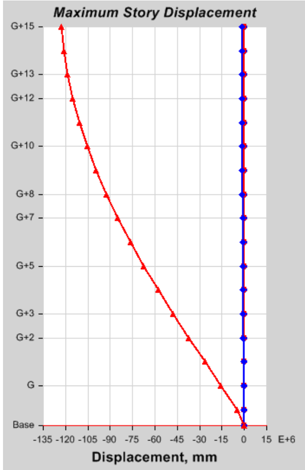

Fig: 4.9 maximum storey displacements on structure-1

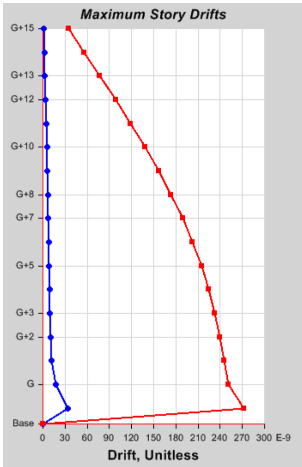

Fig: 4.10 maximum storey drift on structure-1

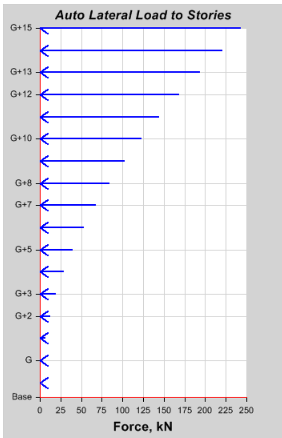

Fig: 4.11 lateral load acting on structure-1

4.3 Results of G+15 buildings resting on zero ground slope: time history analysis

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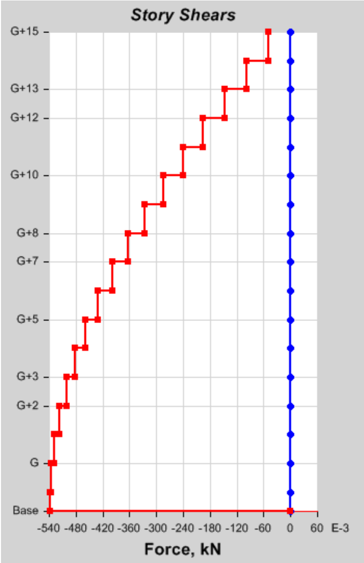

Fig: 4.12 storey shears acting on structure-1

4.2 Results of G+15 buildings resting on Ten Degrees ground slope: Linear Static analysis

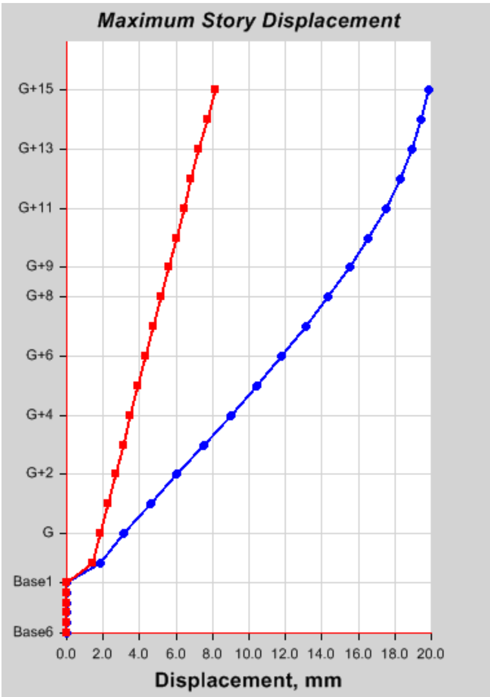

Fig: 4.13 maximum lateral displacements of structure-2

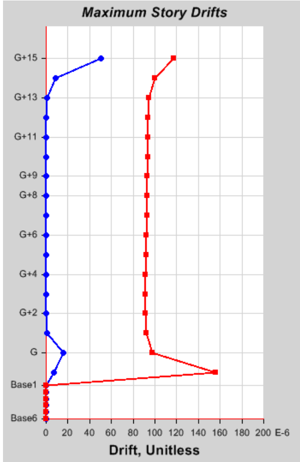

Fig: 4.14 maximum storey drift of structure-2

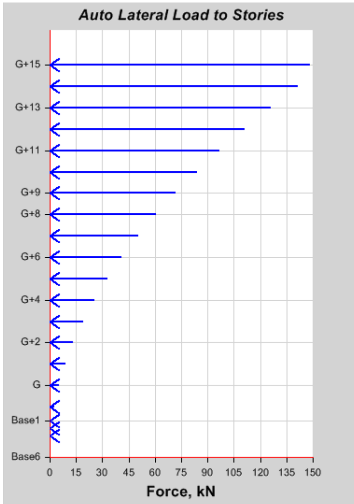

Fig: 4.15 lateral seismic load distribution on structure-2

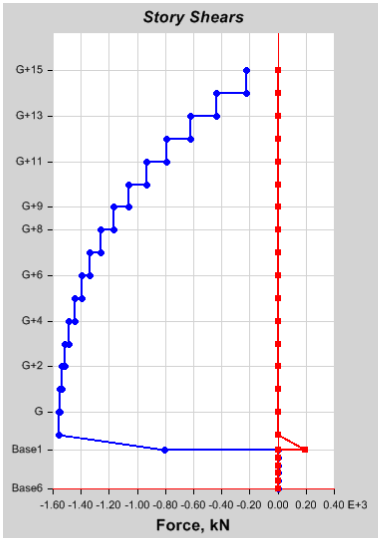

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Fig: 4.16 storey shears acting on structure-2

4.3 Results of G+15 buildings resting on 10 °ground slope: response spectrum analysis

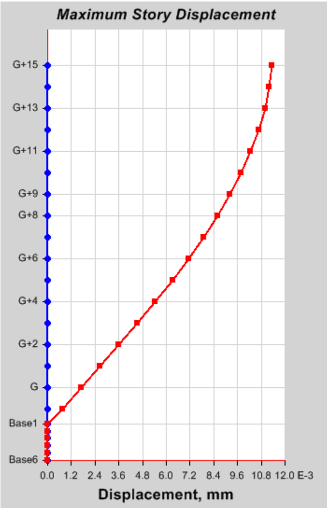

Fig: 4.17 maximum storey displacement of structure-2

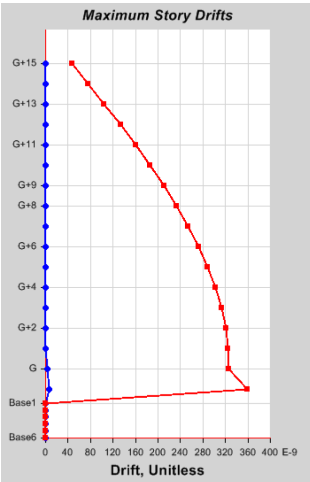

Fig: 4.18 maximum storey drift of structure-2

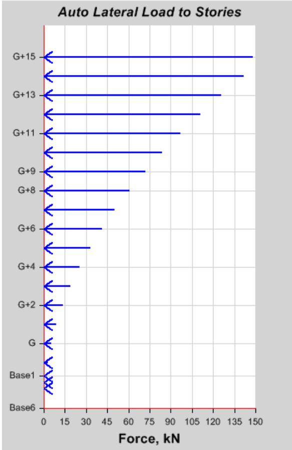

Fig: 4.19 lateral seismic load distribution on structure-2

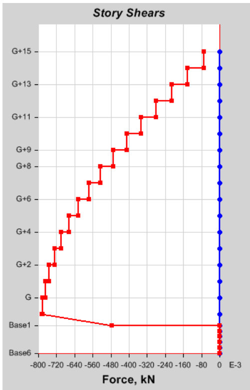

Fig: 4.20 storey shears acting on structure-2

4.4 Results of G+15 buildings resting on 10^0 ground slope: time history analysis

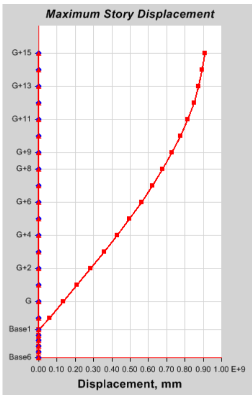

Fig: 4.21 maximum storey displacement of structure-2

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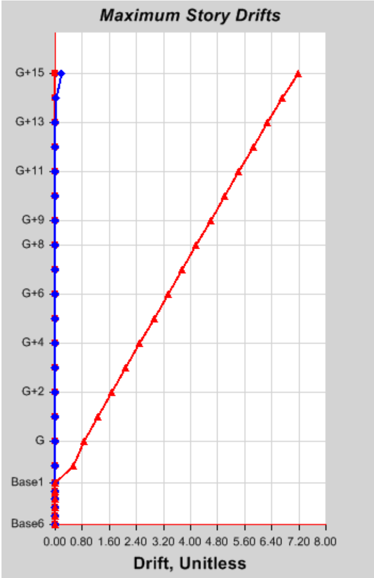

Fig: 4.22 maximum storey drift of structure-2

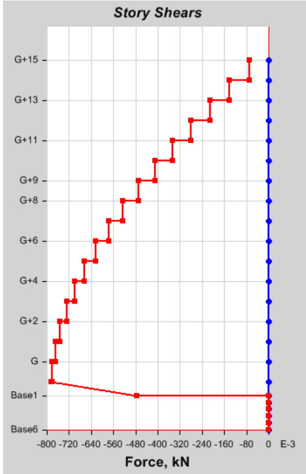

Fig: 4.24 maximum storey shear of structure-2

4.5 deformed shapes of buildings subjected to static and dynamic loading

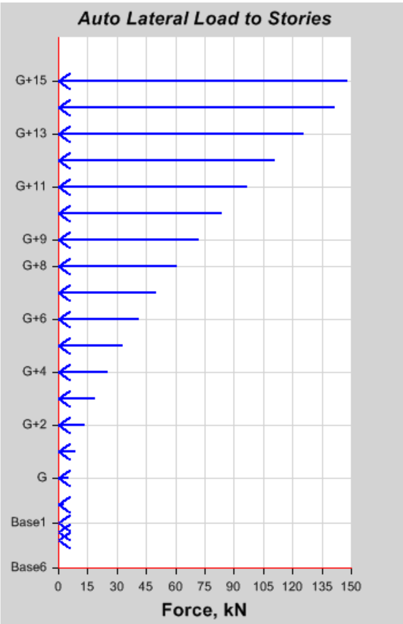

Fig: 4.23 maximum storey drift of structure-2

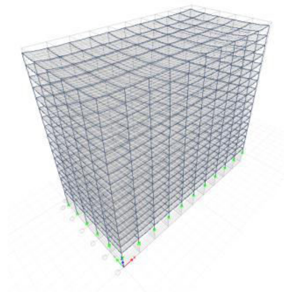

Fig: 4.25 displacement of structure in 3d view

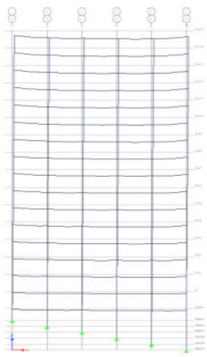

Fig: 4.26 vertical displacement of structure

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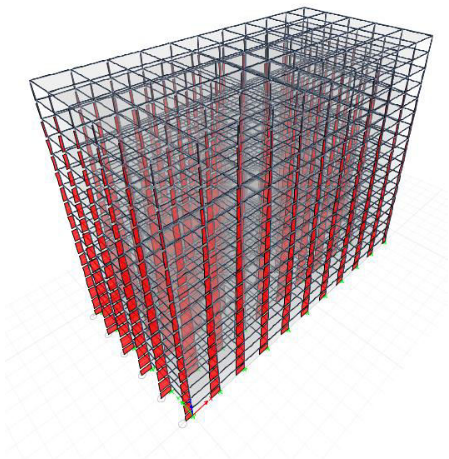

Fig: 4.27 axial load variation in columns

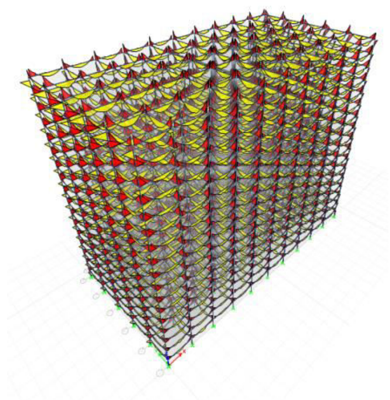

Fig: 4.28 bending moment variation in beams

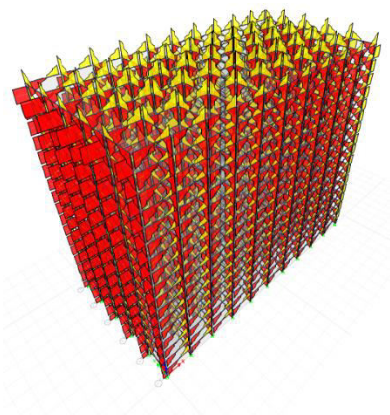

Fig: 4.29 shear force variation in beams

4.6 base reactions for structure-1

Table 4.1: base reactions from linear static analysis

Table 4.2: base reactions from response spectrum analysis

Load Case/Combo	FX	FY	FZ
	kN	kN	kN
Dead	0	0	296187.3573
Live	0	0	97200

Load Case/Combo	FX	FY	FZ
	kN	kN	kN
Dead	0	0	296187.3573
Live	0	0	97200
EL+X	-4570.5266	0	0
EL+Y	0	-4570.5266	0
1.5DL+1.5LL	0	0	590081.036
1.2DL+1.2LL+1.2ELX	-5484.632	0	472064.8288
1.2DL+1.2LL+1.2ELY	0	-5484.632	472064.8288
1.5DL+1.5ELX	-6855.79	0	444281.036
1.5DL+1.5ELY	0	-6855.79	444281.036
0.9DL+1.5ELX	-6855.79	0	266568.6216
0.9DL+1.5ELY	0	-6855.79	266568.6216

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EL+X Max	13395.4943	0.0022	0
EL+Y Max	13395.4943	0.0022	0
1.5DL+1.5LL	0	0	590081.036
1.2DL+1.2LL+1.2ELX Max	16074.5931	0.0026	472064.8288
1.2DL+1.2LL+1.2ELX Min	-16074.5931	-0.0026	472064.8288
1.2DL+1.2LL+1.2ELY Max	16074.5931	0.0026	472064.8288
1.2DL+1.2LL+1.2ELY Min	-16074.5931	-0.0026	472064.8288
1.5DL+1.5ELX Max	20093.2414	0.0033	444281.036
1.5DL+1.5ELX Min	-20093.2414	-0.0033	444281.036
1.5DL+1.5ELY Max	20093.2414	0.0033	444281.036
1.5DL+1.5ELY Min	-20093.2414	-0.0033	444281.036
0.9DL+1.5ELX Max	20093.2414	0.0033	266568.6216
0.9DL+1.5ELX Min	-20093.2414	-0.0033	266568.6216
0.9DL+1.5ELY Max	20093.2414	0.0033	266568.6216
0.9DL+1.5ELY Min	-20093.2414	-0.0033	266568.6216

Table 4.3: base reactions from Time history base reactions

Load Case/Combo	**FX**	**FY**	**FZ**
	kN	kN	kN
Dead	0	0	296187.3573
Live	0	0	97200
EL+X Max	386190.8233	5947497436	0.0001
EL+X Min	-184886	-11080000000	-0.00004544
EL+Y Max	386190.8233	5947497557	0.0001
EL+Y Min	-184886	-11080000000	-0.00004544
1.5DL+1.5LL	0	0	590081.036
1.2DL+1.2LL+1.2ELX Max	463428.988	7136996923	472064.8289
1.2DL+1.2LL+1.2ELX Min	-221864	-13300000000	472064.8287
1.2DL+1.2LL+1.2ELY Max	463428.988	7136997069	472064.8289
1.2DL+1.2LL+1.2ELY Min	-221864	-13300000000	472064.8287
1.5DL+1.5ELX Max	579286.235	8921246154	444281.0361
1.5DL+1.5ELX Min	-277329	-16620000000	444281.0359
1.5DL+1.5ELY Max	579286.235	8921246336	444281.0361
1.5DL+1.5ELY Min	-277329	-16620000000	444281.0359

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0.9DL+1.5EL X Max	579286.235	8921246154	266568.6217
0.9DL+1.5EL X Min	-277329	-16620000000	266568.6215
0.9DL+1.5EL Y Max	579286.235	8921246336	266568.6217
0.9DL+1.5EL Y Min	-277329	-16620000000	266568.6215

Table 4.4: Joint Displacements for structure-1 from linear static analysis

Story	Load Case/Combo	UY(mm)
G+15	1.5DL+1.5ELY	113.4
G+14	1.5DL+1.5ELY	111.5
G+13	1.5DL+1.5ELY	108.4
G+12	1.5DL+1.5ELY	104.2
G+11	1.5DL+1.5ELY	99.1
G+10	1.5DL+1.5ELY	93.2
G+9	1.5DL+1.5ELY	86.5
G+8	1.5DL+1.5ELY	79.3
G+7	1.5DL+1.5ELY	71.6
G+6	1.5DL+1.5ELY	63.6
G+5	1.5DL+1.5ELY	55.3
G+4	1.5DL+1.5ELY	46.8
G+3	1.5DL+1.5ELY	38.2
G+2	1.5DL+1.5ELY	29.5
G+1	1.5DL+1.5ELY	20.9
G	1.5DL+1.5ELY	12.2
plinth	1.5DL+1.5ELY	3.9
Base	1.5DL+1.5ELY	0

Table 4.5: Joint Displacements for structure-1 from response spectrum analysis

Story	Load Case/Combo	UY(mm)
G+15	1.5DL+1.5ELY Max	-0.01325
G+14	1.5DL+1.5ELY Max	0.00729
G+13	1.5DL+1.5ELY Max	0.001754
G+12	1.5DL+1.5ELY Max	0.00221
G+11	1.5DL+1.5ELY Max	0.002462
G+10	1.5DL+1.5ELY Max	0.002667
G+9	1.5DL+1.5ELY Max	0.002665
G+8	1.5DL+1.5ELY Max	0.002635
G+7	1.5DL+1.5ELY Max	0.002721
G+6	1.5DL+1.5ELY Max	0.002811
G+5	1.5DL+1.5ELY Max	0.002786
G+4	1.5DL+1.5ELY Max	0.002781
G+3	1.5DL+1.5ELY Max	0.003004
G+2	1.5DL+1.5ELY Max	0.00325
G+1	1.5DL+1.5ELY Max	0.002961
G	1.5DL+1.5ELY Max	0.00587
plinth	1.5DL+1.5ELY Max	0.02585
Base	1.5DL+1.5ELY Max	0

Table 4.6: Joint Displacements for structure-1 from time history analysis

Story	Load Case/Combo	UY(mm)
G+15	1.5DL+1.5ELY Max	234712280.1
G+14	1.5DL+1.5ELY Max	231667152.7
G+13	1.5DL+1.5ELY Max	226781502
G+12	1.5DL+1.5ELY Max	219999030.3
G+11	1.5DL+1.5ELY Max	211376724.8

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G+10	1.5DL+1.5ELY Max	201179587.6
G+9	1.5DL+1.5ELY Max	189340772.4
G+8	1.5DL+1.5ELY Max	175949211.5
G+7	1.5DL+1.5ELY Max	161120624
G+6	1.5DL+1.5ELY Max	144983536.3
G+5	1.5DL+1.5ELY Max	127678742.7
G+4	1.5DL+1.5ELY Max	109358726.2
G+3	1.5DL+1.5ELY Max	90187370.5
G+2	1.5DL+1.5ELY Max	70341749.1
G+1	1.5DL+1.5ELY Max	50020743.9
G	1.5DL+1.5ELY Max	29520946.2
plinth	1.5DL+1.5ELY Max	9524187.7
Base	1.5DL+1.5ELY Max	0

Table 4.7: Joint Displacements for structure-2 from linear static analysis

Story	Load Case/Combo	UY(mm)
G+15	1.5DL+1.5ELY	29.1
G+14	1.5DL+1.5ELY	28.3
G+13	1.5DL+1.5ELY	27.3
G+12	1.5DL+1.5ELY	26.1
G+11	1.5DL+1.5ELY	24.8
G+10	1.5DL+1.5ELY	23.3
G+9	1.5DL+1.5ELY	21.6
G+8	1.5DL+1.5ELY	19.9
G+7	1.5DL+1.5ELY	18
G+6	1.5DL+1.5ELY	16.1
G+5	1.5DL+1.5ELY	14.1
G+4	1.5DL+1.5ELY	12.1
G+3	1.5DL+1.5ELY	10
G+2	1.5DL+1.5ELY	7.9
G+1	1.5DL+1.5ELY	5.8
G	1.5DL+1.5ELY	3.7
plinth	1.5DL+1.5ELY	1.8
Base4	1.5DL+1.5ELY	0

Table 4.8: Joint Displacements for structure-2 from response spectrum analysis

Story	Load Case/Combo	UY(mm)
G+15	1.5DL+1.5ELY Max	1947.6
G+14	1.5DL+1.5ELY Max	1926
G+13	1.5DL+1.5ELY Max	1889.5
G+12	1.5DL+1.5ELY Max	1837.4
G+11	1.5DL+1.5ELY Max	1769.9
G+10	1.5DL+1.5ELY Max	1687.8
G+9	1.5DL+1.5ELY Max	1591.9
G+8	1.5DL+1.5ELY Max	1482.8
G+7	1.5DL+1.5ELY Max	1361.7
G+6	1.5DL+1.5ELY Max	1229.5

G+5	1.5DL+1.5ELY Max	1087.3
G+4	1.5DL+1.5ELY Max	936.3
G+3	1.5DL+1.5ELY Max	778
G+2	1.5DL+1.5ELY Max	613.7
G+1	1.5DL+1.5ELY Max	445.9
G	1.5DL+1.5ELY Max	279.5
plinth	1.5DL+1.5ELY Max	134
Base4	1.5DL+1.5ELY Max	0

Table 4.9: Joint Displacements for structure-2 from time history analysis

Story	Load Case/Combo	UY(mm)
G+15	1.5DL+1.5ELY Max	907512739.5
G+14	1.5DL+1.5ELY Max	895257181.2
G+13	1.5DL+1.5ELY Max	875820029.6
G+12	1.5DL+1.5ELY Max	849092361.6
G+11	1.5DL+1.5ELY Max	815447182.5
G+10	1.5DL+1.5ELY Max	775386396.5
G+9	1.5DL+1.5ELY Max	729450824
G+8	1.5DL+1.5ELY Max	678179514.9
G+7	1.5DL+1.5ELY Max	622082326
G+6	1.5DL+1.5ELY Max	561627446
G+5	1.5DL+1.5ELY Max	497245544.3
G+4	1.5DL+1.5ELY Max	429349327.9
G+3	1.5DL+1.5ELY Max	358364319.6
G+2	1.5DL+1.5ELY Max	284767679
G+1	1.5DL+1.5ELY Max	209161216.6
G	1.5DL+1.5ELY Max	132532614.6
plinth	1.5DL+1.5ELY Max	59801515.8
Base 4	1.5DL+1.5ELY Max	0

Table 4.10: column forces in structure-2 RS 1.5DL+1.5ELX Max

Story	**Column**	**P**	**V2**	**T**	**M2**	**M3**
		kN	kN	kN-m	kN-m	kN-m
G+15	C17	-329.4825	105.7653	1.8402	39.8867	-117.9677
G+14	C17	-662.4349	-56.499	3.241	68.5219	-104.553
G+13	C17	-984.5886	-50.5315	4.4651	96.2082	-89.0502
G+12	C17	-1298.2668	-41.6874	5.4842	118.9228	-73.026
G+11	C17	-1605.1018	-34.9441	6.3171	137.1453	-60.5514
G+10	C17	-1906.364	-28.5541	7.0122	152.1262	-49.7093

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		7				
G +9	C17	-2202.6799	-22.4629	7.6049	164.7081	-39.4801
G +8	C17	-2494.3141	-16.6422	8.1232	175.4266	-29.7429
G +7	C17	-2781.3359	-10.8735	8.5967	184.9065	-20.5924
G +6	C17	-3063.6307	-4.772	9.0514	193.8059	-11.5312
G +5	C17	-3340.8756	1.8317	9.5001	202.4787	-1.8212
G +4	C17	-3612.5918	8.8291	9.9468	211.0151	8.7193
G +3	C17	-3878.2439	16.2911	10.3893	219.5117	20.206
G +2	C17	-4137.37	23.8648	10.7923	228.2475	32.0852
G +1	C17	-4389.7705	36.244	10.9957	236.4518	59.2165
G	C17	-4637.6889	39.578	9.5643	276.234	88.4636
plinth	C69	-4914.2396	37.3586	5.5924	136.059	186.8264

Table 4.11: column forces in structure-2 LS 1.5DL+1.5ELX Max

Story	**Column**	**P**	**V2**	**V3**	**M2**	**M3**
		kN	kN	kN	kN-m	kN-m
G +15	C17	-335.6134	-114.6666	2.1781	3.0654	-138.7585
G +14	C17	-680.2192	-75.4376	2.579	3.8051	-120.6761
G +13	C17	-1021.6434	-77.0322	2.2693	3.4113	-118.2529
G +12	C17	-1360.9332	-74.1939	2.2564	3.3632	-113.9943
G +11	C17	-1697.9773	-71.9949	2.1516	3.2051	-110.1547
G +10	C17	-2032.7928	-69.6099	2.0335	3.0238	-106.1855
G +9	C17	-2365	-67.1	1.894	2.8119	-102.

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		.3281	869	9		1541
G+8	C17	-2695.5199	-64.6771	1.7374	2.5725	-98.0178
G+7	C17	-3023.2806	-62.0618	1.5632	2.3085	-93.7449
G+6	C17	-3348.4982	-59.3173	1.3745	2.0236	-89.3005
G+5	C17	-3671.0348	-56.418	1.1737	1.7208	-84.6435
G+5	C17	-3659.7881	-56.418	1.1737	0.2537	-14.1211
G+4	C17	-3990.7266	-53.3464	0.9647	1.4073	-79.7514
G+3	C17	-4307.3814	-50.0208	0.7487	1.0804	-74.4298
G+2	C17	-4620.8065	-46.6971	0.5391	0.776	-69.2567
G+1	C17	-4930.7561	-41.5158	0.2088	0.0748	-59.3303
G	C17	-5237.563	-44.8503	-0.032	-1.6689	-68.8937

		7		8		
plinth	C69	-5560.0251	-6.741	6.8687	20.7632	8.9375

Table 4.12: column forces in structure-2 TH 1.5DL+1.5ELX Max

Story	**Column**	**P**	**V2**	**V3**	**M2**	**M3**
		kN	kN	kN	kN-m	kN-m
G+15	C17	3889270	397353.874	167916986	200061688	481285.727
G+14	C17	1196447	-78.011	251013924	332151916	56195.9831
G+13	C17	-1026.2977	78175.9587	351506203	482467271	97802.7144
G+12	C17	-1370.2584	52297.4292	443297871	623268920	80197.1996
G+11	C17	-1713.3884	46846.3225	528658824	754590590	71752.6793
G+10	C17	-2055.5342	43674.2885	606721199	875100032	66827.1952

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G+9	C17	-2396.4851	43054.8805	677592585	984709417	65274.7503
G+8	C17	-2736.0334	42370.7551	741691202	1083924513	63791.4902
G+7	C17	-3073.9613	40000.9511	799614779	1173614888	59909.1856
G+6	C17	-3410.0415	33227.2033	851902387	1254666129	48634.8973
G+5	C17	-3744.0348	27265.3543	898811784	1327620905	45169.3278
G+4	C17	-4075.6895	185.8018	940215256	1392528395	321.701
G+3	C17	-4404.737	41302.7584	975274585	1448273110	97213.5959
G+2	C17	-4730.9083	-60.0783	1004316622	1497237757	-89.3119
G+1	C17	-5053.8501	3964477	1014135735	1515695966	9854227
G	C17	-5373.4933	-59.2053	1118470446	1813953867	-94.9214
plinth	C69	-5705.9356	5192034	237796224	806849147	12350667

Table 4.13: column forces in structure-1 LS 1.5DL+1.5ELX

Story	Column	P	V2	V3	T	M2	M3
		kN	kN	kN	kN-m	kN-m	kN-m
G+15	C4	-332.1385	-112.2662	1.8417	-0.0013	2.5638	-144.3631
G+14	C4	-657.328	-61.9313	2.1923	0.0013	0.4983	-36.2471
G+13	C4	-995.3575	-57.5282	1.9272	0.0007	2.8936	-100.5726
G+12	C4	-1314.2176	-48.9846	1.9185	0.0006	2.857	-86.3136
G+11	C4	-1625.7223	-41.9597	1.834	0.0004	2.728	-73.6905
G+10	C4	-1930.5777	-35.4375	1.739	0.0004	2.5813	-62.073

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G+9	C4	-2229.3623	-29.5031	1.6282	0.0004	2.411	-51.4427
G+8	C4	-2522.5758	-24.0339	1.5031	0.0003	2.22	-41.6537
G+7	C4	-2810.6258	-18.9415	1.366	0.0003	2.0115	-32.571
G+6	C4	-3093.827	-14.1334	1.2194	0.0002	1.7893	-24.0579
G+5	C4	-3372.4009	-9.5134	1.0657	0.0002	1.5573	-15.9657
G+4	C4	-3646.4756	-5.0057	0.9084	0.0001	1.3208	-8.1931
G+3	C4	-3916.0879	-0.3756	0.7511	0.0002	1.0859	-0.2108
G+2	C4	-4181.219	3.7028	0.5886	0.0004	0.8433	6.3701
G+1	C4	-4441.7835	10.8146	0.431	-0.0064	0.564	20.2605
G	C4	-4697.4995	-3.1705	0.5812	-0.0093	0.9269	-20.9673
plinth	C4	-4937.373	314.744	-0.4702	0.0229	-0.6366	547.4877

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Table 4.14: column forces in structure-1TH 1.5DL+1.5ELX Max

Story	Column	P	V2	V3	T	M2	M3
		kN	kN	kN	kN-m	kN-m	kN-m
G+15	C4	1230367	118963.7165	42251118	135706.01	50206536	258106.4559
G+14	C4	1037500	103127.4131	63903482	211084.8586	84355201	68019.5914
G+13	C4	948498.4558	185930.2257	89893747	307091.5879	123159924	106220.3765
G+12	C4	846824.786	280575.2495	114040281	397855.933	159929776	242205.4434
G+11	C4	750483.4491	370684.2067	137335298	486165.1908	195376541	384141.048
G+	C4	106720	457909	1592	570607	2289	523196

10		1	.6577	26717	.2365	13253	.5686
G+9	C4	1567205	541490.9572	179562116	650522.0605	260184974	658324.7532
G+8	C4	2149530	621020.9799	198201559	725243.5639	288972038	788739.1618
G+7	C4	2811619	696107.0425	215024687	794130.9223	315087057	913730.2719
G+7	C4	2811630	696107.0425	215024687	794130.9223	46306198	44471.1193
G+6	C4	3544575	766410.4157	229920898	856576.8431	338360460	1032657
G+5	C4	4346723	831733.9592	243085410	912084.4108	358787869	1145210
G+4	C4	5217412	891148.4178	254418842	960532.8043	376845887	1249114
G+3	C4	6157458	947500.0905	263435285	1002867	391543308	1350717
G+2	C4	7169194	993789.1439	269730027	1038725	402255275	1434063
G+1	C4	8253763	1028958	275042579	1096470	414214001	1484399
G	C4	9444762	3889572	258498672	1209687	387198876	13091609
plinth	C4	11405297	19960624	609969421	5001247	800552441	26835489

Table 4.15: column forces in structure-1RS 1.5DL+1.5ELX Max

Story	**Column**	**P**	**V2**	**V3**	**T**	**M2**	**M3**
		kN	kN	kN	kN-m	kN-m	kN-m
G+15	C4	-318.6764	-92.4958	1.8665	0.0046	2.6042	-100.2198
G+14	C4	-631.9448	-26.2414	2.3405	0.0061	3.4429	-75.1787
G+1	C4	-925.545	-12.544	2.0246	0.0055	3.0454	-40.667

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3		3	8				3
G+12	C4	-1205.1954	0.8584	2.019	0.0045	3.0065	-12.7886
G+11	C4	-1475.2778	10.743	1.9286	0.0034	2.8689	5.2911
G+10	C4	-1738.1579	21.1585	1.8275	0.0036	2.7125	20.2812
G+9	C4	-1994.0278	32.2313	1.7102	0.0042	2.5323	36.5053
G+8	C4	-2242.0779	43.1291	1.5774	0.0042	2.3299	53.7345
G+7	C4	-2481.4203	53.7354	1.4318	0.0037	2.1086	70.4546
G+6	C4	-2711.3615	64.5106	1.2771	0.0037	1.874	87.0379
G+5	C4	-2931.373	75.3518	1.117	0.0044	1.6323	104.4265
G+4	C4	-3141.1425	85.7173	0.9528	0.0045	1.3862	121.7222
G+3	C4	-3340.57	96.3523	0.7851	0.0036	1.1346	138.4899

		75					
G+2	C4	-3529.6186	106.5329	0.6457	0.0027	0.9296	151.526
G+1	C4	-3707.9547	126.2687	0.5218	0.0159	0.8588	186.9722
G	C4	-3874.8279	85.3662	1.0764	0.0184	1.8287	71.3532
plinth	C4	-4017.1776	1000.2207	2.8295	0.063	2.9102	1632.0034

5. CONCLUSIONS

The following are the results drawn from the analysis of G+15 buildings resting on non-sloping and sloping ground levels by using linear static, response spectrum and time history analysis slopes considered are 0^0(structure-1)and 10^0(structure-2) seismic loads are applied parallel to x and y directions.

1. It is observed that with the increase in the seismic zones from zone-2 to zone-5 the parameters such as bending moments, shear forces and deflections are in increasing order.
2. Shorter columns are observed to be stiffer than longer columns and are subjected to higher storey forces.
3. Storey drift, lateral load on story's and storey shear and found to be same in structure- 1 & structure-2
4. Lateral load is found to be 730kN in structure-1for linear static analysis and

240kN for response spectrum and time history analysis.

5. Lateral load in structure-1 is reduced by 67.13%for response spectrum and time history analysis.
6. Lateral load is found to be 150kN in structure-2 for linear static analysis, response spectrum and time history analysis.
7. Storey shears are found to be 7200kN in structure-1 and 1600kN in structure-2
8. Maximum Support reactions at the base are 4570.52kN, 13395.49kN and 184886kN for linear static, response spectrum and time history analysis.
9. Maximum Joint displacements in structure-1 is 113.4mm and in structure-2 is 29.1mm
10. Column forces such as axial forces, shear forces and bending moments are found to be less in response spectrum analysis for structure-1 and 2 when compared with linear static and time history analysis

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