ISSN XXXX XXXX © 2018 IJESC

IJESC

Research Article Volume 8 Issue No.6

Generation of Site Specific Response Spectrum Curve

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Abstract:
Response spectrum is one that which is applicable for linear system, it can also be generated for non-linear system, but are not applicable to system with the same non-linearity. For the purpose of safety in building system it is important to have information on expected earthquake events, this earthquake information varies from place to place as the magnitude of earthquake will be maximum at its generation point and certain nearby region around generation point, as the waves tries to travel longer distance its effect of magnitude get reduces. The modelling and analysis is done using ETABS 9.7.0. In our thesis the response spectrum analysis is done for as per IS code and site specific response spectrum situated near and far region. Response spectrum curve is generated for near (Shimoga) and far (Mangalore) region using attenuation equation. Results are evaluated by studying displacement. Storey drift, column moment and storey forces.

Keywords: response spectrum, magnitude, ETABS 9.7.0, displacement, Storey drift,

1. INTRODUCTION

The adverse increase in population and rapid growth of industries causes migration of people from rural regions to city side. This social process led to the less area for housing for developing population rate. As the land required for adoption increased its cost also get hiked. At certain phase of time, growth of building in vertical fashion i.e. construction of multi-storeyed buildings came into existence. For multi-storeyed buildings, the established load carrying structures become wasteful as they need huge sections to carry large moments and loads. In case of framed structure, system frame consists of a network of beams and columns were built as single unit and inflexible with each other at their joints. Due to inflexibility at the joints, moments gets reduced and also the structure likely to distribute the loads more regularly and remove the additional effects caused due to localized loads. Also for non-load bearing framed structures, the moments and forces value become minimum which reduces the sections size of the members. As the wall element does not carry any load they are considered of thinner dimensions. Hence usage of lighter materials downgrades the value of self weight their by helps in load considerations. In addition to above aspects framed system is having good resistance to earthquake and wind loads. Response spectrum is one that which is applicable for linear system, it can also be generated for non-linear system, but are not applicable to system with the same non-linearity. For the purpose of safety in building system it is important to have information on expected earthquake events, this earthquake information varies from place to place as the magnitude of earthquake will be maximum at its generation point and certain nearby region around generation point, as the waves tries to travel longer distance its effect of magnitude get reduces. The point of focus (earthquake generation point and nearby region) must be considered with large safety criteria as compared to far distance during the construction of structure. Throughout the country we use single response spectrum curve for all earthquake analysis, if we consider this value for all aspects of construction throughout the country it lead to the increase in the provision for section of main structural elements (Beam, column, foundation etc.), area of steel and displacement value. Hence it is necessary to generate suitable response spectrum curve for a particular locality (site condition) based on fault features and other geological aspects. Since we are using single type of response spectrum for the various zone it is inappropriate in accessing safety at particular region in order to overcome this generation of response spectrum at particular region with the help of empirical formula and software system found to be helpful, through this result it is possible to ensure necessary safety and strength of the building system also can make the structure economical. So to reduce cost of construction and to get accurate analysis for particular region, development of site specific response is carried.

2. LITERATURE REVIEW

1. Prabhu muthuganeisan and S.T.G. Raghukanth
In this paper the site specific probabilistic seismic hazard of Himachal Pradesh, India. Earthquake active region is located in the North-West (NW) part of Himalaya. In this study, ground motion relation (the relation is presented in the companion article) are used to develop the site-specific seismic hazard for the study region. The latitude and longitude of the state Himachal Pradesh is 30°20'N to 33°15'N and 75°45'E to 79°00'E respectively at a 0.1° grid interval(to evaluate the seismic hazard). The contour maps are developed for two return periods of 475(~500) and 2475(~2500) years which almost 10 and 2% possibility of exceed in 50 years for two different classes are class C and class D. To estimate the earthquake force in this study area PSHA method is used. The calculations of the possible exceed in intensity level in a time period of the further T years can be expressed as

$P(Y > y^* \text{ in T years}) = 1\text{-}e^{-\mu_{y^*} T}$

Where,

μ_{y^*} = mean annual rate of exceed of ground motion measure y*

$\mu_{y^*} = N_i(m_0) \times P[Y>y^*|m,r]\ p_{R|M}(r|m)\ p_M(m)drdm$

where, m_0 and m_u are the threshold magnitude found at the fault which are of minimum and maximum values respectively, r_{min} and r_{max} are the measured location (site) distance from fault region which are of minimum and maximum values respectively, $p_M(m)$ is the value gained through Gutenberg-Richter relation which indicates probabilistic function of distributed magnitude, $p_{R|M}$ (r|m) is the probability density function which is conditional in nature of focal distance (hypocenter) obtained numerically for evaluated reference point, P[Y>y*|m,r] can be evaluated using ground motion relationship (magnitude and distance) denoting the exceeding intensity level of selected ground motion, K is the number of faults in the location. The current article gives the hazard maps of seismic hazard behavior of particular region by considering active seismic intensity and characteristics of site region. Here Connell-Mc-Guire approach is used to perform probabilistic seismic hazard analysis. It was found that site region is having around 301 faults in and around, estimated through several sources obtained from decades. Contour maps for different earthquake parameters such as peak ground acceleration (PGA), spectral acceleration for both short and long period are to estimated for the site region. The city of Bilaspur and Chamba were having high hazard nature. The map developed is helpful in developing seismic vulnerability of the structures present in the state of Himachal Pradesh, through this it is possible to get seismic hazard of the site (location) in terms of other ground motion characters like spectral velocity, spectral displacement etc.

2. S. T. G. Raghukanth and Surendra Nadh Somala

In this thesis "Modeling of Strong- motion data in North-eastern India". In this study they have used seismological model to study the strong-motion accelerograms in north-eastern part of India. Required data from various seven earthquake was collected which ranges from M_w 5.2 – 7.2. This values are used to obtain source and path parameters. The Q value of subduction zone of Indo-Burma tectonic domain obtained is $431f^{0.7}$, Quality factor at Bengal region estimated as $224f^{0.93}$. Vertical and horizontal component for Kappa factor is obtained as 0.013 and 0.033 for soft rock. K_o is estimated as 0.025 and 0.041 for vertical and horizontal component for firm ground sites respectively. Horizontal to vertical ration used to found site amplification for various cases such as soft rock and firm ground condition. The slope of Fourier amplitude spectra is obtained which characterizes the near surface attenuation is used to find kappa factor independently in both the condition soft rock and firm ground is selected area. Due to lack of site specific information about shear wave velocity and density profile at shilling array, when is a strong motion station. Site amplification function are found for 39 strong motion station separately using the ratio of horizontal to vertical Fourier spectra by assuming the vertical amplitude spectrum by local condition get very less affect when compared to horizontal Fourier spectra. Average site amplification factor is derived to have an advantage in preliminary engineering studies. During strong earthquake this is used to simulating site spectra ground motion. It is also used to calculate quality factor from horizontal component. The stimulated motion obtained from the model which helps in ground motion prediction equation. Hence the obtained amplification function from horizontal to vertical ration is used to have rough estimation in local site effect the shear wave velocity used in the analysis is of high accuracy and it can be used confidently to have required result. The obtained parameter can be used in delineating seismic hazard in varies cities of north-eastern part of India.

3. Prabhu muthuganeisan and S.T.G. Raghukanth

In this paper investigated in site specific ground motion relation developed for the state of Himachal Pradesh for four region. Using ground motion prediction equation the spectral acceleration is determined.

$$\ln(S_a/g) = c_1 + c_2M + c_3M^2 + c_4r + c_5\ln(r + c_6e^{c7M}) + c_8 \log(r)\, f_0 + \ln(\varepsilon)$$

where,

S_a = Spectral acceleration

M = Moment magnitude

r = hypo-central distance

c_1, c_2.........c_8 = coefficient

in this paper the methodology adopted was incorporated the site effects characterized through active multi-channel analysis of surface wave (MASW) test are carried out in 22 cities.

3. METHODOLOGY

3.1 BRIEF EXPLAINATION

RC building consist on basement and G+7 storey building model is considered for study. Site specific Response spectrum curve is derived for near (Shimoga) and far (Mangalore) region using the attenuation equation developed by S. T. G. Raghukanth. Modeling is developed in ETABS 9.7.0 Analysis is done for gravity load and lateral load such as dead load, super dead load, live load, earthquake load ad per IS 1983 Response spectrum analysis is carried as per IS code provision and also analysis is done for near and far region. Result of analysis is extracted from the ETABS and compared all the results parameters of near and far region with IC code results.

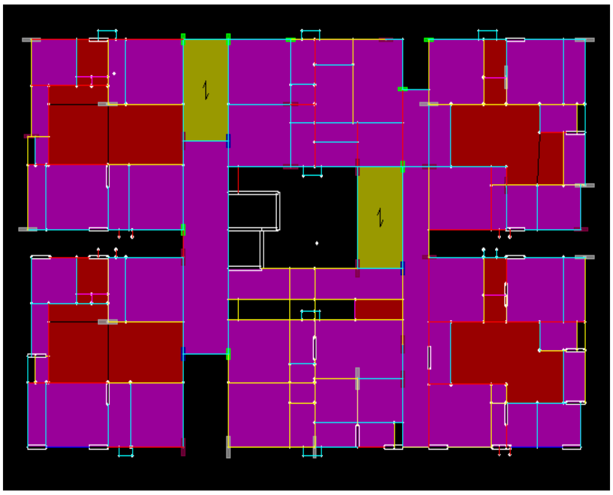


Figure.3.1. Typical Floor Plan

3.2 LOAD CONSIDERATION

Dead Load Calculation

Dead load = 1 (modeling includes its own weight)

Super dead load (SDL)

Floor Finish = 0.05 x 20
= 1 KN/m^2

Ceiling = 0.015 x 22
= 0.33 KN/m^2

SDL = 1.33 KN/m^2 ≈ 1.5 KN/m^2

Live load (As per IS: 875-2000, Part-2)

Room = 2 KN/m^2

Corridor = 3 KN/m^2

Toilet = 2 KN/m^2

Balcony = 3 KN/m^2

Staircase = 3 KN/m^2

Wall load

Main wall = (3-0.45) x 0.2 x 22
= 11.22 KN/m^2

Partition wall = (3-0.45) x 0.1 x 22
= 5.61KN/m^2

3.3 MODELLING:

3.3.1 GENERAL:

Modeling is done according to structural layout drawing and architectural draft provided and drawing which is in AutoCAD is imported into the ETABS by converting them into the DXF format. After importing is done following procedure need to be followed. As a initial step of modeling properties of materials are assigned in the menu bar option called material property where value of modulus of elasticity, poisson's ratio, characteristic compressive strength of concrete and steel, density of concrete etc. are defined. Type of structural elements and their section sizes are defined in property called frame section. Here grade, depth and width of beams and columns are made, also slab thickness and type of slab are described. Then previously designated properties are assigned to the imported plot and beam release is performed in order to avoid transfer of torsional moment from secondary to main beam, which would likely to cause crack in large number once it gets transferred, then meshing and property modifier is done for slab element. Also support conditions are assigned as fixed end conditions and diaphragm is applied in order to make the impact of whole structural weight into the single concentrated point. Enter the grid line spacing in X and Y direction, Number of lines in X and Y direction and number of stories, storey height. Defining material properties of concrete such as unit weight of the concrete, modulus of elasticity, strength of the concrete etc.. Defining the thickness, width depth of the section. The static loads adopted in this example includes dead load, live load, earthquake load and wind loads acting on the building.

3.4 ANALYSIS:

In the analysis of response spectrum peak ground acceleration value of earthquake in all direction is obtained as a curve of digitized response spectrum of response of psudo-spectral acceleration versus time period. Response spectrum acceleration is made using ETABS by considering aspects of mode superposition, ritz vectors here Ritz vectors are used because as they provide more precious results for the similar numbers of modes taken. Response spectrum curve is taken in all three direction as a input value, the single positive response quantities considered for the analysis, each evaluated result value represents magnitude of maximum response quantity, when the graph of spectral acceleration which is false in nature against time period is plotted and used in analysis. The acceleration value obtained is considered to be idealized and it will be not having any units instead those units are accompanied with scale factor which multiplies the function and is defined in response spectrum cases for near and far region.

Calculation of response spectrum values for NEAR and FAR region

Using below attenuation equation spectral acceleration is calculated for different time period

$\ln(S_a/g) = c_1 + c_2M + c_3M^2 + c_4r + c_5 \ln(r + c_6\, e^{c7M}) + c_8 \log(r)\, f_0 + \ln(\varepsilon)$

where,

$c_1, c_2, \ldots\ldots\ldots c_8$ are co-efficient values are in table no. 4.1

M = 5

r = hypo-central distance

$= \sqrt{((\text{epicentral distance})^2 + (\text{focal depth})^2)}$

i. **For near region (Shimoga)**
   Epi-central distance = 1km (Assume)
   Focal depth 35km

$r = \sqrt{((1)^2 + (35)^2)}$

= 38.0143km

$f_0 = \max(\ln(r/100), 0)$

= max (-1.0494, 0)

- For 0 second
  $\ln(S_a/g) = (-5.2182) + (1.6543 \times 5) + (-0.0309 \times 5^2) + (-0.0029 \times 38.0143) + (-1.4428 \times \ln(38.0143 + 0.0188 \times e^{0.9968 \times 5})) + 0.1237 \log(38.0143) \times -1.0494 + 0.3843$
  $\ln(S_a/g) = -2.9997$

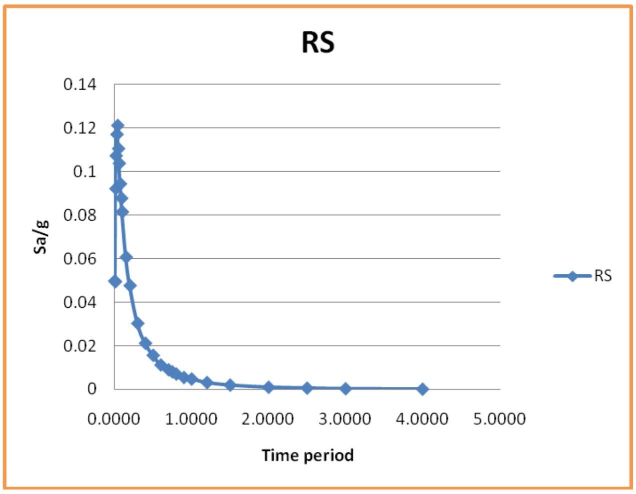
$S_a/g = e^{-2.997}$

$S_a/g = 0.0498$

- For 0.01 second
  $\ln(S_a/g) = (-5.2204) + (1.6523 \times 5) + (-0.0307 \times 5^2) + (-0.0029 \times 38.0143) + (-1.4422 \times \ln(38.0143 + 0.0187 \times e^{0.9971 \times 5})) + 0.1237 \log(38.0143) \times -1.0494 + 0.3837$
  $\ln(S_a/g) = -3.0049$
  $S_a/g = e^{-3.0049}$
  $S_a/g = 0.0495$

Table 3.1: Response spectrum values for near region

PERIOD	Sa/g
0.0000	0.049801
0.0100	0.049543
0.0150	0.092159
0.0200	0.107241
0.0300	0.117035
0.0400	0.121119
0.0500	0.110498
0.0600	0.103738
0.0750	0.094362
0.0900	0.087764
0.1000	0.08151
0.1500	0.060777
0.2000	0.047756
0.3000	0.030412
0.4000	0.021318
0.5000	0.015786
0.6000	0.011382
0.7000	0.009149
0.7500	0.008188
0.8000	0.007221
0.9000	0.005621
1.0000	0.00494
1.2000	0.003293
1.5000	0.002136
2.0000	0.001167
2.5000	0.000739
3.0000	0.000468
4.0000	0.000251



Graph .3.1: Response spectrum curve for near region

ii. For Far region (Mangalore)

Epi-central distance = 137.02km

Focal depth 35km

$r = \sqrt{((137.02)^2 + (35)^2)}$

= 141.42 km

f_0 = max (ln(r/100), 0)

= max (0.0605, 0)

- For 0 second

  $\ln(S_a/g) = (-5.2182) + (1.6543 \times 5) + (-0.0309 \times 5^2) + (-0.0029 \times 141.42) + (-1.4428 \times \ln(141.42 + 0.0188 \times e^{0.9968 \times 5})) + 0.1237 \log(141.42) \times 0.0605 + 0.3843$

  $\ln(S_a/g) = -4.90103$

  $S_a/g = e^{-4.90103}$

$S_a/g = 0.00744$

- For 0.01 second

  $\ln(S_a/g) = (-5.2204) + (1.6523 \times 5) + (-0.0307 \times 5^2) + (-0.0029 \times 141.42) + (-1.4422 \times \ln(141.42 + 0.0187 \times e^{0.9971 \times 5})) + 0.1237 \log(141.42) \times 0.0605 + 0.3837$

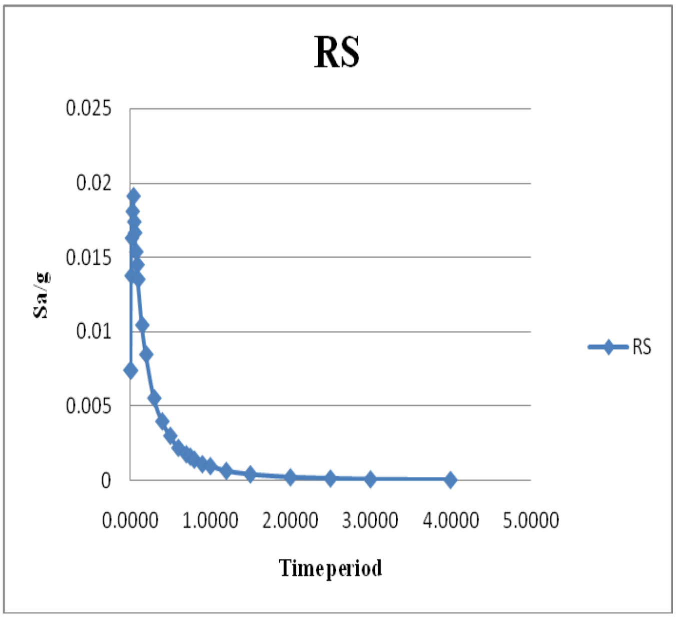
  $\ln(S_a/g) = -4.90574$

$S_a/g = e^{-4.90574}$

$S_a/g = 0.0074$

Table 3.2: Response spectrum values for far region

Period	**Sa/g**
0.0000	0.007439
0.0100	0.007404
0.0150	0.013778
0.0200	0.016305
0.0300	0.018101
0.0400	0.019123
0.0500	0.017394
0.0600	0.016663
0.0750	0.015384
0.0900	0.014514
0.1000	0.013533
0.1500	0.01046
0.2000	0.008485
0.3000	0.005552
0.4000	0.003992
0.5000	0.003016
0.6000	0.002209
0.7000	0.00178
0.7500	0.001619
0.8000	0.001419
0.9000	0.001113
1.0000	0.000983
1.2000	0.000661
1.5000	0.000428
2.0000	0.000233
2.5000	0.000149
3.0000	9.43E-05
4.0000	4.98E-05



Graph 3.2: Response spectrum curve for far region

During the earthquake ground motion, the depiction of the peak response of idealized single degree freedom systems having certain period and damping. The peak value of response is plotted against the un-damped natural period and for different damping values, and is given as maximum value of spectral outcome i.e. displacement, velocity and acceleration. For different loading cases according to IS 875(Part2), the earthquake force is determined for complete dead load plus partial quantity of super imposed load. As the storey height gets increased the effect of live load over the height gets decreased, hence in order to achieve this criteria live load reduction factors are applied. After analysis is done, we have to check the any errors is there in the model, the errors in the model we have debug the errors and once again we run the model. Then we get the analysis results like beam, column forces and bending moment, displacement, storey drift etc..

4. RESULT AND DICUSSION

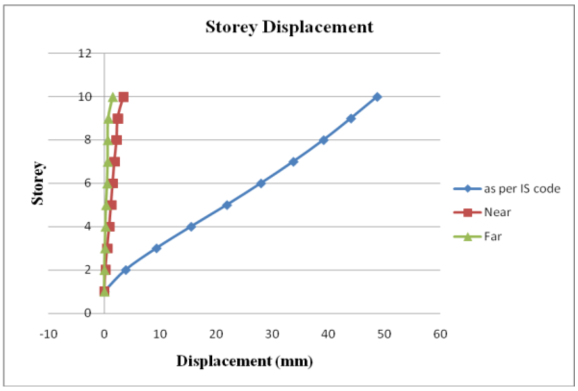
4.1 Storey Displacement

Displacement of the different storey is given below. The displacement for model as per IS code, for near region and far region in X and Y direction.

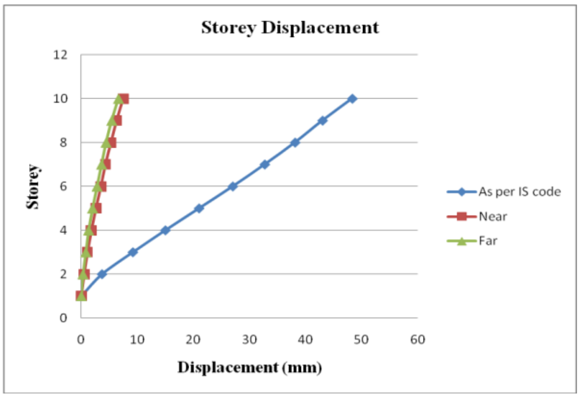
Table.4.1. Storey displacement for IS code, near and far region

Storey	Code		Near		Far	
	X	Y	X	Y	X	Y
10	48.8	48.3	3.4	7.5	1.5	6.6
9	44.1	43	2.4	6.3	0.7	5.4
8	39.2	38.1	2.2	5.3	0.6	4.4
7	33.8	32.7	1.8	4.3	0.6	3.6
6	28	27	1.5	3.5	0.5	2.8
5	21.9	21	1.2	2.6	0.3	2
4	15.5	15	0.9	1.8	0.2	1.3
3	9.3	9.2	0.5	1.1	0.1	0.8
2	3.8	3.7	0.2	0.5	0	0.3
1	0	0	0	0	0	0

From the data represented in table 5.1 shows story displacement in X and Y direction. When the models are subjected to lateral load analysis. From the table 5.1 it can be observed that the storey displacement for building as per IS code, the displacement in X direction 48.8mm at the top and it is decreases gradually to zero mm in basement floor and the displacement in Y direction is 48.3mm at the top and it is reduces to zero mm at basement floor. The building situated near to the fault, the displacement in X direction is 3.4mm at top and in it is reduces gradually to zero mm at bottom and similarly in Y direction the force 7.5mm and reduce to zero mm at bottom. The building site is far to the fault zone, storey displacement in X direction for building is 1.5mm at head room and gradually decreases to zero mm at basement floor and similarly in Y direction 6.6mm at head room and its is gradually decreases to zero mm at basement floor. The maximum storey displacement in as per IS code is 48.8 mm in X direction and 48.3mm in Y direction compare to building near and far to fault zone. The effect of earthquake in building is more in as per IS code compare to building near and far to fault zone.



Graph 4.1: Storey displacement in X direction



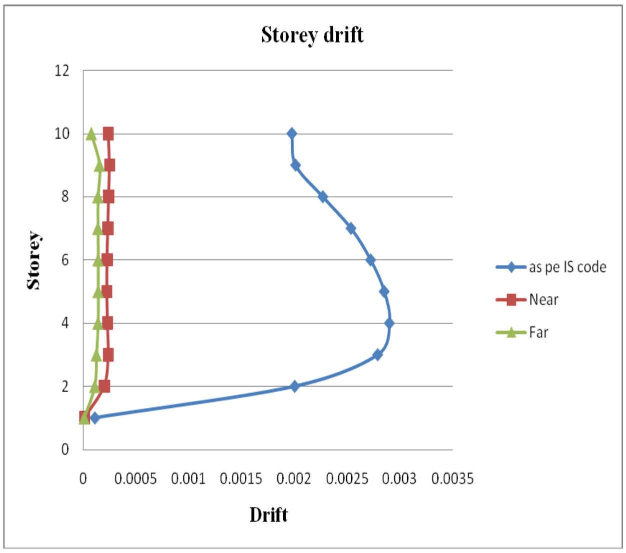
Graph 4.2: Storey displacement in Y direction

4.2 Storey drift

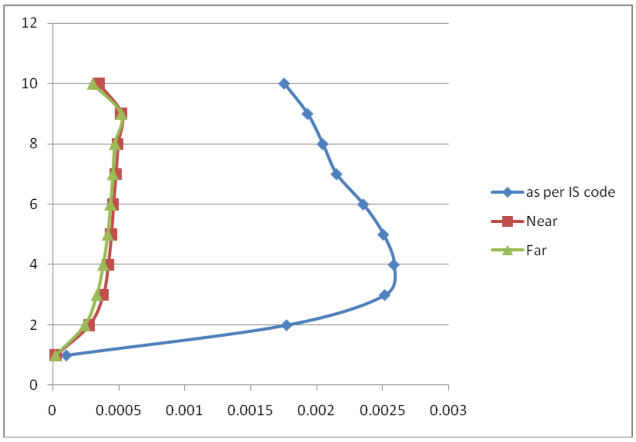
Table 4.2 : Storey Drift for IS code, near and far region

Storey	Code		Near		Far	
	X	Y	X	Y	X	Y
10	0.0197	0.0175	0.000236	0.000349	0.000075	0.000302
9	0.0201	0.0193	0.000247	0.00052	0.000152	0.000516
8	0.0227	0.0205	0.000239	0.000493	0.000137	0.000468
7	0.0253	0.0215	0.000232	0.000477	0.000137	0.000453
6	0.0272	0.0235	0.000224	0.000458	0.000139	0.000435
5	0.0285	0.025	0.000223	0.000442	0.000139	0.000414
4	0.029	0.0258	0.000228	0.000419	0.000138	0.00038
3	0.0279	0.0252	0.000235	0.000381	0.000123	0.000332
2	**0.002**	0.0177	0.000196	0.000276	0.000107	0.000241
1	**0.001**	0.0001	0.000011	0.000021	0.000009	0.000021

From the data represented in table 5.2 shows storey drift in X and Y direction. When the models are subjected to lateral load analysis. From the table 5.2 it can be observed that the storey drift for building as per IS code, the drift in X direction 0.00197 at the top and it is decreases gradually to 0.00011 in basement floor and the drift in Y direction is 0.00175 at the top and it is reduces to 0.0001 at basement floor. The building situated near to the fault, the drift in X direction is 0.000236 at top and in it is reduces gradually to 0.000011 at bottom and similarly in Y direction the force 0.000349 and reduce to 0.000021 at bottom floor. The building site is far to the fault zone, storey drift in X direction for building is 0.000075 at head room and gradually decreases to 0.000009 at basement floor and similarly in Y direction 0.000302 at head room and its is gradually decreases to 0.00002 at basement floor. The maximum storey drift in as per IS code is 0.00197 in X direction and 0.00175 in Y direction compare to building near and far to fault zone. The effect of earthquake in building is more in as per IS code compare to building near and far to fault zone.



Graph 4.3: Storey drift in X direction



Graph 5.4: Storey drift in Y dirction

4.3 Storey forces

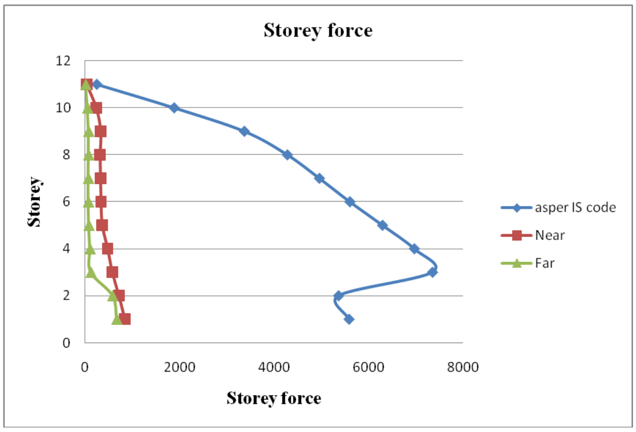
The storey force is a total shear force acting in the horizontal direction on the building. At the base of the building the storey force is maximum.

Table 5.4 Storey forces for IS code, near and far region

Storey	Code		Near		Far	
	X (kN)	Y (kN)	X (kN)	Y (kN)	X (kN)	Y (kN)
11	368.28	252.12	64.58	36.54	12	7.11
10	2473.38	1888.78	317.04	236.49	63.53	47.2
9	4295.25	3374.63	423.47	330.58	89.36	69.08
8	5382.21	4284.93	416.02	318.42	88.15	68
7	6188.68	4963.06	423.56	325.41	82.13	63.83
6	6991.19	5608.34	423.18	337.3	80.04	63.47
5	7889.85	6299.68	468.91	361.77	96.19	73.87
4	8734.88	6972.76	624.1	475.93	129.52	99.46
3	9192.99	7357.51	740.77	572.99	151.63	118.05
2	9498.21	5368.51	698.82	711.25	299.1	577.15
1	9616.82	5591.02	781.48	836.72	316.27	665.3

From the data represented in table 5.4 shows storey forces in X and Y direction. When the models are subjected to lateral load analysis. From the table 5.4 it can be observed that the storey forces for building as per IS code, the force in X direction 368.28kN at the top and it is increases gradually to 9616.82kN in plinth and the storey force in Y direction is 252.12kN at the top and it is become greater to 5591.02kN at plinth. The building situated near to the fault, the storey force in X direction is 64.58kN at top and it is increases gradually to 781.48kN at bottom and similarly in Y direction the force is 36.54kN at top of the building and increases to 836.72kN at bottom floor of the building. The building site is far to the fault zone, storey forces in X direction for building is 12kN at head room and gradually increases to 316.27kN at bottom of the building and similarly in Y direction 7.11kN at head room and its is gradually increases to 665.3kN at plinth level. The maximum storey forces in as per IS code is 9616.82kN in X direction and 5591.02kN in Y direction compare to building near and far to fault zone. The effect of earthquake in building is more in as per IS code compare to building near and far to fault zone.

Graph 4.5: Storey force in X direction



Graph 4.6: Storey force in Y direction

5. CONCLUSION

1. This clause elucidate the functions of response spectrum which is responsible for behavior of building according to IS 1893
2. A building system is considered and response spectrum analysis is made to which site specific response curve is evaluated
3. This evaluation of curve is carried using empirical equation, through which spectral acceleration, displacement, velocity in other words spectral functions are ascertained for varying time period for near and far region..
4. In the study, the behavior of the RC Structural building in as per IS code effect is more compare to Near and Far region to fault and more effect in the building near to fault compare to building far to fault.
5. In this study the four parameter is considered such as storey displacement, storey drift, column axial forces storey forces are shown in table also in graph, the effect of building is more in IS code compare to Near and Far region to fault zone.
6. Storey displacement of near locality in y direction seemed to be greater as compared to far direction. Similarly it is true for x direction
7. But codal provision results sets nearly equivalent margin between x and y direction, hence it can be clearly declared that satisfactory result as been got as compared to codal method.
8. In case of storey drift it was found that codal provision is having more value compared to near and far place, which means near place experiences large earthquake and thus,

storey drift and storey displacement will be high, but accordingly codal results were of abruptly higher kind.

9. In case of storey force, the maximum storey force in IS code compare to building near and building situated far to fault zone, and the storey force in near is more compare to building far to fault zone

6. ACKNOWLODGENMENT

I am extremely thankful to internal guide **Mrs. Deepthishree S A, Assistant Professor, Dept. of Civil Engineering, Sahyadri College of Engineering and Management, Mangalore**, for her valuable guidance, encouragement and suggestions offered throughout my project work. She played an important role in completion of my project and for making me work to the best of my abilities. I express my gratitude **to Mr. Avinash Gornale, Assistant Prefessor, Dept. of civil engineering, Maharaa Istitute of technology,Mysore.** for his guidance in every stage of the project and for the successful completion of the work assigned.

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