Seismic Analysis of RCC Slab with Overlying Water Tank at Different Position

Prof. A.R. Gupta[1], Miss Mayuri V. Ingle[2]
[1,2]Department of Civil Engg,COET,Akola, SGB Amravati University

Abstract — In this study seismic analysis of G+5 building structure with water tank is done by using STAAD Pro designing software. The building considered is situated in earthquake zone III; Ordinary moment resisting frame resting on medium soil and importance factor 1. Initially, validation of the software is done by considering a problem of a simply supported beam. Then according to specified criteria structure is analyzed for different positions of water tank. Results are compared for three different positions of water tank and it is found that headroom position is safe among three locations.
Keywords: Seismic Analysis, Water tank, Ductile detailing, Member Forces, Joint Displacement, Support Reaction, Storey Drift, Staad Pro V8i.

I. INTRODUCTION

A. Aim

To do the Seismic Analysis of RCC slab with overlying water tank at different positions.

B. Objective

1) Understand the Earthquake Threat.
2) To study the behavior of RCC slab during earthquake.
3) To study the analysis and designing concept of overlying water tank.
4) To study the effect of water tank on the slab of a building at various positions.
5) To study the failure pattern of RCC slab with overlying water tank during earthquake.

C. Scope

To conduct the seismic analysis of RCC slab with RC water tank resting at different locations for G+5 storey building located in zone III resting on medium soil.

D. Need

A water tank is an elevated reservoir constructed for storing water, the water tanks are utilized for some applications such as for putting away drinking water, irrigation agribusiness, fire concealment, agricultural cultivating, both for plants and animals, and it is also utilized for putting away chemicals or storing chemicals. These tanks are constructed using various types of support structures like reinforced concrete braced frame, steel frame etc. Their safety performance during strong earthquakes is of critical concern. They should not fail during and after the earthquake, so that they can be used in meeting essential needs like drinking water and putting out fires. These structures has large mass concentrated at the top of slender supporting structure hence these structure are especially vulnerable to horizontal forces due to earthquakes. All over the word, the elevated water tanks were collapsed or heavily damaged during the earthquakes because of unsuitable design of supporting system or wrong selection of supporting system and underestimated demand or overestimated strength. So, it is very important to select proper supporting system and the best suitable position of water tank so that it is less prone to earthquake.

II. LITERATURE REVIEW

B. Gireesh Babu et. al. (1), in this research paper author investigated for g+7 building structures by using STAAD PRO designing software. Author observed the response reduction of cases Ordinary moment resisting frame. For this earthquake zone 2, response factor 3 for Ordinary moment resisting frame and importance factor 1was adopted. Initially, author started with the designing of simple 2-dimensional frames and manually checked the accuracy of the software with our results. **Atul Jadhav et. al. (2),** presented the study of seismic performance of the elevated water tanks for high intensity seismic zones of India for various sections of elevated water tanks for different circular shape Author presented the effect of height of water tank in earthquake zones and section of tank on earthquake forces with the help of STAAD Pro software. Further a comparative analysis of various section of elevated water tank in the high intensity earthquakes zone was done and it was found out which section are most suitable in those region according to behavior of structure. Various types of forces on elevated tank and various effects like that sloshing effect were considered in this research by using STAAD Pro software. **Furquan Elahi Shaikh et. al (3**),in this research paper Author assessed the impact of earthquake forces on two types of tank systems based on their support that is Framed Staging and Shaft Staging. Response Spectrum Analysis was carried out and behavior of these staging systems is studied as per draft code Part II of IS 1893:2006 and IITk‟s GSDMA guidelines. Further from FEM software STAAD Pro. Parameters such as Base Shear, Nodal Displacement, Overturning Moment, and Vibration Analysis were obtained.**Zubair I. Syed et. al. (4),** aimed at exploring the structural behavior and performance of earthquake resistant reinforced concrete (RCC) frame structures under blast loading. For this study, typical reinforced concrete frame structures designed to be earthquake resistant according to International Building Code (IBC 2009) and ACI 318-11 provisions applicable for Abu Dhabi city were studied. A major focus of this research was to establish specific distances beyond which a given blast would have minimal impact on a typical earthquake resistant concrete structure which can assist designers in choosing a safe standoff distance for a given load.**Yasser Alashker et. al. (5),** nonlinear pushover analysis was used to evaluate the seismic performance of three buildings with three different plans having same area and height. This method determines the base shear capacity of the building and performance level of each part of building under varying intensity of seismic force. **Nilanjan Tarafder et. al. (3),** in this research paper various seismic analysis methods such as Equivalent static analysis, Response spectrum analysis, Linear Dynamic Analysis, Nonlinear Static Analysis, Nonlinear Dynamic Analysis were discussed. Further Author described the Base Isolation technique, its types and workability. Soil Structure Interaction phenomenon is given in this paper. Thus it was concluded that asymmetrical tall building suffers more damages than the corresponding symmetrical buildings. It shows that the asymmetrical building is less seismic resistant than a symmetrical building during an earthquake. Also it was stated that if the damping is underestimated and the stiffness is overestimated then the assumption about higher buildings on an undone soil structure interaction rigid base does not represent the earthquake response. **T. Pokharel et. al. (7),** presented a summary of the reconnaissance survey of a major earthquake of magnitude 7.8 (on 25th of April, 2015) with epicentre in Gorkha District in Nepal, followed by a series of aftershocks including magnitude of 7.3 on the 12th of May 2015.**Rajat Srivastava et. al. (8),** presented paper to improve the efficiency of real time earthquake risk mitigation methods and its capability of protecting structures, infrastructures and people, to investigate a multistorey RCC building (G +9 Story) for Zone 2, to look at seismic conduct of multistorey RCC building for specific shaking power regarding reactions, to contemplate the impacts of various Seismic zones on execution of multi-story working as far as seismic, to know the connection between various techniques for seismic investigation and their seismic reactions, to accomplish functional learning on basic investigation, seismic examination, outlining and specifying of auxiliary segments utilizing standards of Earthquake Resistant Design.**A.C. Ragavan et. al. (9),** conducted seismic analysis of steel frame structure with the aid of SAP2000 software. Author selected three different types of steel frame structures like 10storey, 20storey and 30storey buildings and it analyzed with different loading conditions like dead load, live load, seismic load and wind load. Further Linear analysis (Time History Analysis) and Non - linear analysis (Push over analysis) was undertaken for the evaluation of seismic behavior of the different types of steel frame structures under examination.. **Swajit Singh Goud et. al.(10),** in this research paper Author compared the performance of structure designed considering non ductile detailing and ductile detailing, in terms of capacity, damage, response reduction factor and drift. A 5 storey building designed for Gravity loads as well as lateral load as per IS: 1893-2002 for seismic zone III was considered. Post damage yielding behavior of structure was estimated by Static Non Linear (Pushover) analysis and fragility analysis. Effect of assumed load patterns considered in non-linear static pushover analysis and the damages based on storey drift were described in the paper. Further Author provided important conclusions on seismic design provisions, response reduction factor and interstorey drift.

III. CASE CONSIDERATION

A. Problem Statement

No. of Floors: G+5.
Storey height: 3 m
Location of Site: Seismic zone II.
Type of Soil: Medium Soil.
Building frame system: Ordinary RC Moment Resisting Frame (OMRF).
Column Size: 230x530 mm

Beam Size: 230x450
Normal Loads: As per IS 456-2000
Earthquake Load: As per IS 1893-2002 (Part -1)

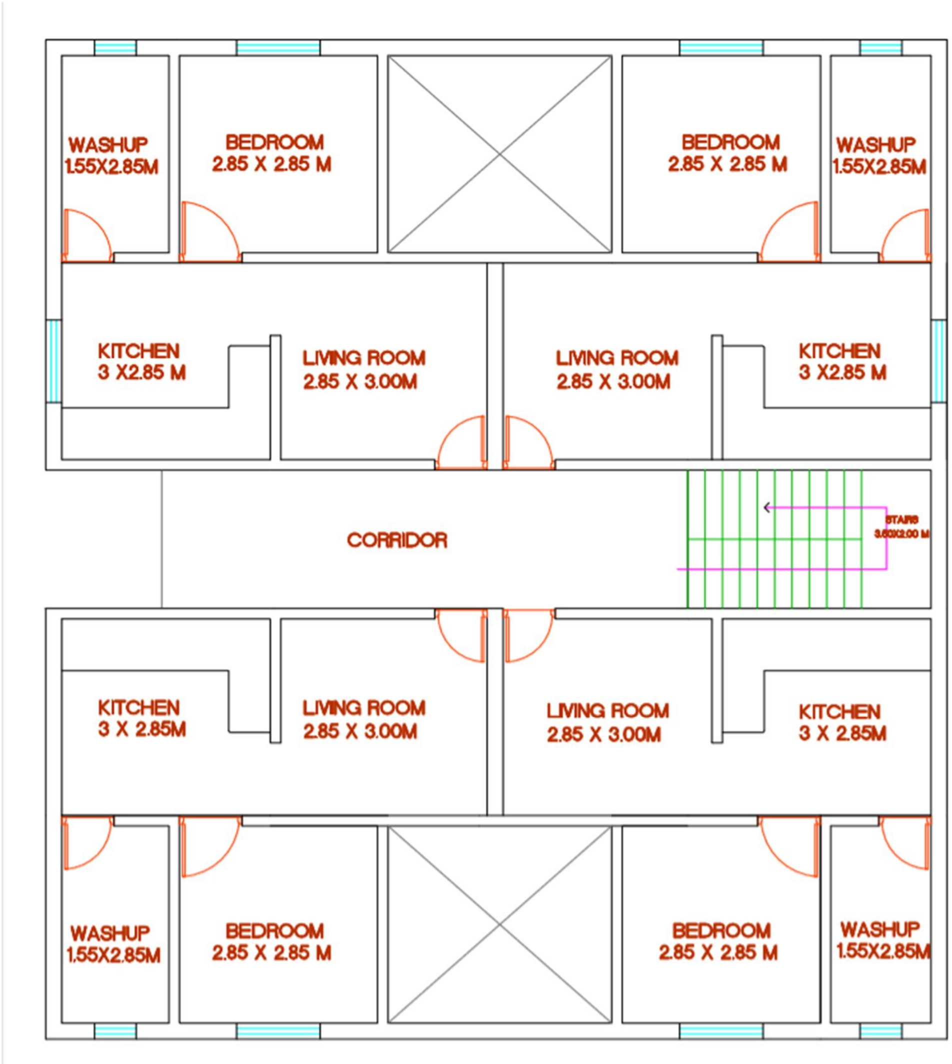

Fig 1: Plan of selected Building.

To study the effect on the structural members with the change in overlying water tank position the modeling and analysis is done for the three cases namely:

1) *Case I:* In this Case the water tank is placed on staircase Headroom.
2) *Case II:* In this Case the water tank is placed on Shaft position.
3) *Case III:* Here the water tank is placed on corner position.

IV. OBSERVATION & REMARK

On the basis of modeling and analysis the comparative observation tables are prepared for displacement of nodes and beams, water tank base plate stresses, support reactions at the base of water tank location, Beam end forces and Drift values.

The table no. 1 to 14 depicts the observations made for all three cases as shown below:

A. *Node Displacement*

Table 1: Node Displacement.

Node	L/C	Max Displacement(resultant)		
		Case I	Case II	Case III
Staircase headroom 292	1.5(DL-EQ Z)	17.105	17.256	16.847
291	1.5(DL-EQ Z)	17.081	17.242	16.836
293	1.5(DL-EQ Z)	17.099	17.184	16.775
294	1.5(DL-EQ Z)	17.081	17.171	16.770
Shaft position 260	1.5(DL-EQ Z)	16.284	16.721	16.286
261	1.5(DL-EQ Z)	16.188	16.509	16.188
Corner position 276	1.5(DL-EQ Z)	16.102	16.155	16.177
282	1.5(DL-EQ Z)	16.067	16.124	16.025

1) *Remark:* From table 1 that is maximum Nodal Displacement table it can be seen that the nodal displacement value is maximum for the combination of 1.5(DL-EQ Z). When the water tank is resting on staircase headroom the displacement value is 17.105, while when it is resting on shaft the nodal displacement is 16.721. Similarly when the water tank is at corner position of the building the nodal displacement value is 16.77.From the above table 1 it can be marked that with the change in resting position of water tank, the change in nodal displacement value is negligible.

B. *Beam Maximum Relative Displacement*

Table 2: Beam Maximum Relative Displacement

Location	Beam	Displacement
Headroom Location (Case I)	664	0.267
	665	0.257
	666	0.928
	667	0.923
Shaft location (Case II)	668	0.559
	609	1.546
	671	0.497
	670	1.442
Corner (Case III)	623	0.505
	670	1.432
	627	1.645
	628	0.023

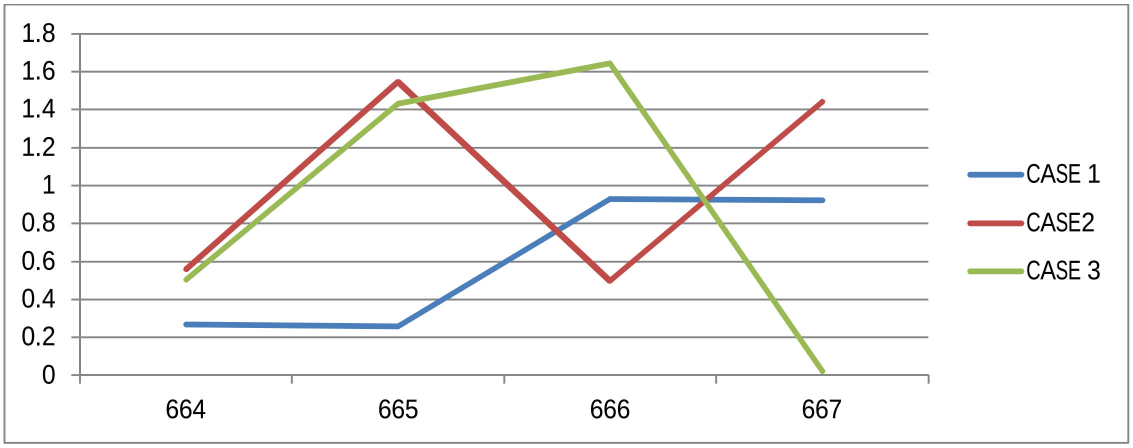

Fig 2: Comparison of Beam Maximum Relative Displacement.

1) *Remark:* From table no 2 the observations are marked for beam displacement when the water tank is resting at different positions. The Beam Displacement is maximum when the water tank is resting on shaft and minimum when it is resting on headroom of the building, this can be clearly seen from graph 2.

C. Plate Center and Corner Stresses

Table 3: Plate Corner and Center Stress for Case I.

Plate no.777 Node no.	Corner Stress				
	Shear		BM		
	X	Y	Mx	My	Mxy
291	-0.006	0.003	1.768	1.828	-0.358
292	-0.006	0.003	1.697	1.766	0.340
293	-0.006	0.004	2.162	1.925	0.353
294	-0.006	-0.003	2.090	1.845	-0.346

Plate no	L/C	Center Stress				
		Shear		BM		
		X	Y	Mx	My	Mxy
777	1.5(DL+EQX)	-0.006	-0.000	1.545	1.467	-0.003

Table 4: Plate Corner and Center Stress for Case II.

Plate no-675 Node no.	Corner Stress				
	Shear		B.M		
	X	Y	Mx	My	Mxy
295	-0.062	-0.005	9.875	4.672	2.086
260	-0.062	-0.011	-3.344	4.066	1.525
261	-0.062	-0.011	3.787	2.571	-2.123
296	-0.062	-0.005	9.423	4.394	-1.483

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Plate No	L/C	Center Stress				
		Shear		BM		
		X	Y	Mx	My	Mxy
675	1.5(DL+EQX)	-0.062	-0.005	3.042	3.592	-0.042

Table 5: Plate Corner and Center Stress for Case III.

Plate no-672 Node no.	Corner Stress				
	Shear		B.M		
	X	Y	Mx	My	Mxy
282	0.008	0.010	0.560	3.698	-2.879
295	0.008	0.028	0.790	0.828	-0.410
296	0.083	0.029	12.763	7.266	-2.183
276	0.083	0.012	-6.505	2.969	-0.549

Plate no.	Center Stress				
	Shear		B.M		
	X	Y	Mx	My	Mxy
672	0.043	0.021	2.163	3.460	-0.425

1) *Remark:* From table no. 3, 4 & 5 it can be seen that the corner B.M values are maximum for case II i.e in table no. 4. While for Case I and Case III the moment values are comparatively less and it is minimum for Case I. The plate shear values in all the three cases are similar upto third decimal and thus negligible. The Plate Center shear stress values are negligible while B.M values are more when the plate is kept at shaft position that is Case II, table no 4. The values for shear stress and B.M are minimum for case I that is when water tank is located over headroom.

D. Support Reactions:

Table 6: Support Reactions for Case I.

Node No.	Fx	Fy	Fz	Mx	My	Mxy
23	-16.221	855.946	-0.127	-0.118	0.021	19.702
6	-12.624	781.527	0.921	0.448	0.019	17.794
7	-12.778	783.172	-1.409	-0.917	0.021	18.037
9	-16.443	858.390	-0.106	-0.104	0.019	19.982

Table 7: Support Reactions for Case II.

Node No.	Fx	Fy	Fz	Mx	My	Mz
13	-15.105	879.605	14.291	14.445	-0.023	19.245
14	-17.068	568.507	-15.058	-14.877	0.017	20.416

Table 8: Support Reactions for Case III.

Node No.	Fx	Fy	Fz	Mx	My	Mz
41	12.448	678.340	14.988	14.775	-0.024	-18.252
35	16.604	907.638	15.833	15.276	-0.019	-20.192

1) *Remark:* When the support reaction value under water tank is observed it is seen that the reaction values in the direction of gravitation that is F_y are far greater than reaction values Fx and Fz. The reaction values in X and Z direction are more when tank is resting on shaft and corner i.e table no. 7 and 8. While the moment values Mx is maximum for corner location of water tank.

E. *Maximum Shear Force & B.M*

Table 9: Max Shear Force & B.M for Case I.

Beam	Max Shear Force				Max B.M			
	Fy		Fz		Mz		My	
	Max+	Max -	Max +	Max -	Max +	Max-	Max+	Max -
Beams 666	120.833	123.842	0.003	0.003	59.730	50.423	0.004	0.053
664	71.508	72.311	0.015	0.008	16.255	27.55	0.005	0.088
667	121.316	123.539	0.004	0.003	59.438	50.261	0.056	0.000
665	72.499	72.867	0.016	0.008	17.604	27.091	0.005	0.087
Columns 660	34.056	-	-	8.163	16.307	58.615	9.728	12.641
661	33.914	-	10.862	2.901	15.819	58.792	13.394	10.502
662	-	34.917	11.632	3.240	53.431	23.385	13.898	11.692
663	3.841	37.139	0.489	12.445	54.472	27.233	12.963	14.416

Table 10: Max Shear Force & B.M for Case II.

Element	Max Shear Force				Max B.M			
	Fy		Fz		Mz		My	
	Max +	Max -	Max +	Max -	Max +	Max -	Max +	Max -
Beam 609	119.294	127.502	0.015	0.002	38.904	71.251	0.069	0.002
668	20.880	141.979	0.008	0.094	65.872	65.683	0.069	0.166
670	119.481	119.909	0.003	0.001	36.495	67.766	0.005	0.008
671	10.800	132.614	0.162	0.005	65.335	63.618	0.184	0.141
Column 572	35.319	-	12.819	3.376	35.259	70.699	25.187	13.272
573	31.749	-	17.625	0.029	30.509	64.738	20.202	32.674

Table 11: Max Shear Force & B.M for Case III.

Beam	Max Shear Force				Max B.M			
	Fy		Fz		Mz		My	
	Max +	Max-	Max +	Max-	Max +	Max-	Max +	Max-
Beam 627	137.459	133.316	0.097	0.011	44.911	75.076	0.185	0.099
670	130.617	109.218	0.084	-	54.089	67.419	0.112	0.140
623	160.706	1.792	0.078	0.040	93.221	92.839	0.093	0.065
628	41.396	75.149	2.761	0.390	24.448	7.933	2.105	1.736
Column 594	0.369	9.156	18.870	2.805	18.512	9.666	35.331	21.279
588	2.521	35.581	2.418	13.609	82.813	23.930	15.977	24.850

1) *Remark:* The table no. 9, 10, 11 represent the beam maximum Shear Force and B.M values with the change in water tank position. From table no 9 it is clear that the Shear Force in Z-direction is negligible and also B.M My for beams, while the Shear Force Fy are prominent. The same observation is marked when water tank is resting over shaft. Overall B.M values are maximum for water tank resting on corner position and minimum for headroom location of the tank.

F. *Drift Value*

Table 12: Drift value for Case I.

Node	L/C	Displacement	Drift
293	1.5(DL-EQ Z)	17.099	-
256	1.5(DL-EQ Z)	16.499	0.6
216	1.5(DL+EQ Z)	14.602	1.897
176	1.5(DL+EQ Z)	11.816	2.786
136	1.5(DL+EQ Z)	8.399	3.417
96	1.5(DL+EQ Z)	4.674	3.725
56	1.5(DL-EQ Z)	1.021	3.653

Table 13: Drift Value for Case II.

Node No.	L/C	Displacement	Drift
260	1.5(DL-EQ Z)	16.721	-
220	1.5(DL-EQ Z)	14.776	1.945
180	1.5(DL-EQ Z)	11.916	2.860
140	1.5(DL-EQ Z)	8.457	3.459
100	1.5(DL-EQ Z)	4.701	3.756
60	1.5(DL-EQ Z)	0.958	3.743

Table 14: Drift Value for Case III.

Node	L/C	Displacement	Drift
282	1.5(DL-EQ Z)	16.025	-
242	1.5(DL-EQ Z)	14.342	1.683
202	1.5(DL-EQ Z)	11.591	2.751
162	1.5(DL-EQ Z)	8.220	3.371
122	1.5(DL-EQ Z)	4.543	3.677
82	1.5(DL-EQ Z)	0.942	3.601

1) Remark: The study of the drift pattern for the node underlying water tank is done in observation table 12, 13, 14. From table no.12 it is clear that the drift value is maximum at 1st floor and gradually reduces upto top. The drift value for Case II is greater On the basis of these observations and remarks the conclusion is drawn.

V. CONCLUSION

To study Seismic Analysis of RCC Slab with Overlying Water Tank at Different Position the dissertation work was undertaken. The G+5 storey RCC structure of Ordinary Moment Resistive Frame (OMRF) in zone III resting on medium soil is analyzed for three different position of water tank on RCC slab.

The impact and effect of water tank with change in its location is shown in chapter III and on the basis of observations, remark are drawn in the same chapter. On the basis of the values for the resultant displacement, Beam end forces, reaction values, drift value the three different cases are compared.

The following things can be concluded from the observations:

A. For cases under consideration the displacement values are almost same in all the three cases. While the values are more for the corner nodal locations that is Case III.

B. The Drift profile shows that the pattern does not change with change in location of Water tank and is maximum at 1st floor level.

C. The Shear Forces in the X and Z direction are negligible while prominent for vertical Y direction. The B.M values are more for the beams and the columns when rested over the Shaft.

D. The reaction values does not show the considerable changes in the forces values in X and Z direction with the change in location of water tank.

E. Out of all three locations for the considered case the displacement, Shear Force and Bending Moment values are more for the location of water tank over shaft, while the values are minimum for the water tank location over the headroom.

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REFERENCES

[1] B. Gireesh Babu, "Seismic Analysis and Design of G+7 Residential Building Using STAADPRO" International Journal of Advance Research, Ideas and Innovations In Technology, ISSN: 2454-132X, Volume3, Issue3.

[2] Atul Jadhav et. al.: Analysis Of Elevated Water Tank In High Seismic Zone By Using STAAD PRO Software, International Journal of Research in Advent Technology (IJRAT) Special Issue E-ISSN: 2321-9637.

[3] Furquan Elahi Shaikh et. al.: Performance Study of Elevated Water Tanks under Seismic Forces, International Research Journal of Engineering and Technology (IRJET), Volume: 04, Issue: 07 July -2017, pp 1531- 1537.

[4] Zubair I. Syed, Osama A. Mohamed, Kumail Murad, Manish Kewalramani, "Performance of Earthquake-resistant RCC Frame Structures under Blast Explosions", International High- Performance Built Environment Conference – A Sustainable Built Environment Conference 2016 Series (SBE16), iHBE 2016.

[5] Yasser Alashker, Sohaib Nazar, Mohamed Ismaiel: Effects of Building Configuration on Seismic Performance of RC Buildings by Pushover Analysis, Open Journal of Civil Engineering, 2015.
[6] Nilanjan Tarafder, SM ASCE, Kamalesh Bhowmik, SM ASCE1 K. V. Naveen Kumar: Earthquake Resistant Techniques and Analysis of Tall Buildings, IJRET: International Journal of Research in Engineering and Technology, Volume: 04, Dec-2015.
[7] T. Pokharel and H.M. Goldsworthy: Lessons Learned from the Nepal Earthquake 2015, Proceedings of the Tenth Pacific Conference on Earthquake Engineering Building an Earthquake-Resilient Pacific 6-8 November 2015, and Sydney, Australia.
[8] Rajat Srivastava, Sitesh Kumar Singh, "Seismic Analysis and Design of G+9 RCC Residential Building in STAAD.PRO for Zone II Region" International Journal of Innovative Research in Science, Engineering and Technology, Vol. 7, Issue 5, May 2018, ISSN(Online): 2319-8753.
[9] A.C. Ragavan, J .B. Nithin, M.P. Sunandha and K. Srinivasan, "Seismic analysis of steel structure", Conference Paper January 2018.
[10] Swajit Singh Goud and Ramancharla Pradeep Kumar, "Seismic Design Provisions For Ductile Detailed Reinforced Concrete Structures", 15th Symposium on Earthquake Engineering (15SEE), Report No: IIIT/TR/2014/-1. IS 456:2000 "Plain And Reinforced Concrete- Code Of Practice".
[11] IS 1893 (Part 1):2002 "Criteria for Earthquake Resistant Design of Structures".
[12] IS 13920:1993 "Ductile Detailing of Reinforced Concrete Structures Subjected to Seismic Forces- Code of Practice"