

# A Work Paper on - Design of Earthquake Resistance Tall Structure with Lateral Force Method & Response Spectrum Analysis (Stadd. Pro)

Sanjay Singh Dang<sup>1</sup> Dr. Rakesh Patel<sup>2</sup>

<sup>2</sup>Professor & Head of the Department

<sup>1,2</sup>Department of Civil Engineering

<sup>1,2</sup>SIRTS, Bhopal, India

**Abstract**— The design of a building requires a detailed analysis to the building on which the structure is based. But somewhere it is not possible to do manual calculations which is why the need for editing tools was met. Built on several power tools, one of which was widely used by Stadd.Pro, which allows the processing of a structure preference to its construction. For high-rise buildings it is possible to use Stadd.Pro for consolidation and its integration as well as structural analysis and design-based design. Steel is the most widely used building materials in the world. In order to take advantage of these seismic resources, a design engineer must be familiar with the design features of the metal and the purpose for which they are coded. The basic formation of the building framework presented for this project is based on IS 1893-2002 and IS 800. such as IS 800: 2007 .The building contains six stories and has three biscuits on the straight side and five bays on the back side.

**Keywords:** FEM, ANSYS 15.0, Modal Hammer, Accelerometer, FFT Analyzer, Pulse Software, Instron, Tensile Strength

## I. INTRODUCTION

Seismic analysis is likely to be a groundbreaking factor that analyzes the structure and that is the calculation of the building's response to earthquakes. it is part of the

architectural approach, seismic engineering or structural testing and design in regions where earthquakes are prevalent.

The most important earthquakes are at the extremities of the earth's crust. These plates are usually at least partially aligned but are prevented from doing so by collision until the pressure between the plates below the epicenter point is so high that the movement occurs suddenly. this is usually an earthquake. Earthquakes cause waves inside the earth that fill the earth, causing movement in the foundations of buildings. The significance of the waves decreases with the space from the epicenter. Therefore, there is a planet region with a high or low earthquake risk, calculating its proximity to the tectonic plate border. Beside from the major earthquakes that occur along the boundaries of the tectonic plate, some have their origins within the innocent pairs. Called 'intra plates' earthquakes, these forces are small, but they can still destroy within the area known as the epicenter.

The following earthquake vibration parameters follows Seismic zone: 3

- Zone factor 'Z': 0.16
- Structure frame : steel moment performing frame designed as per IS 456:2000
- Calculation reduction factor : 5
- Importance factor : 1.5
- Damping ratio: 3%

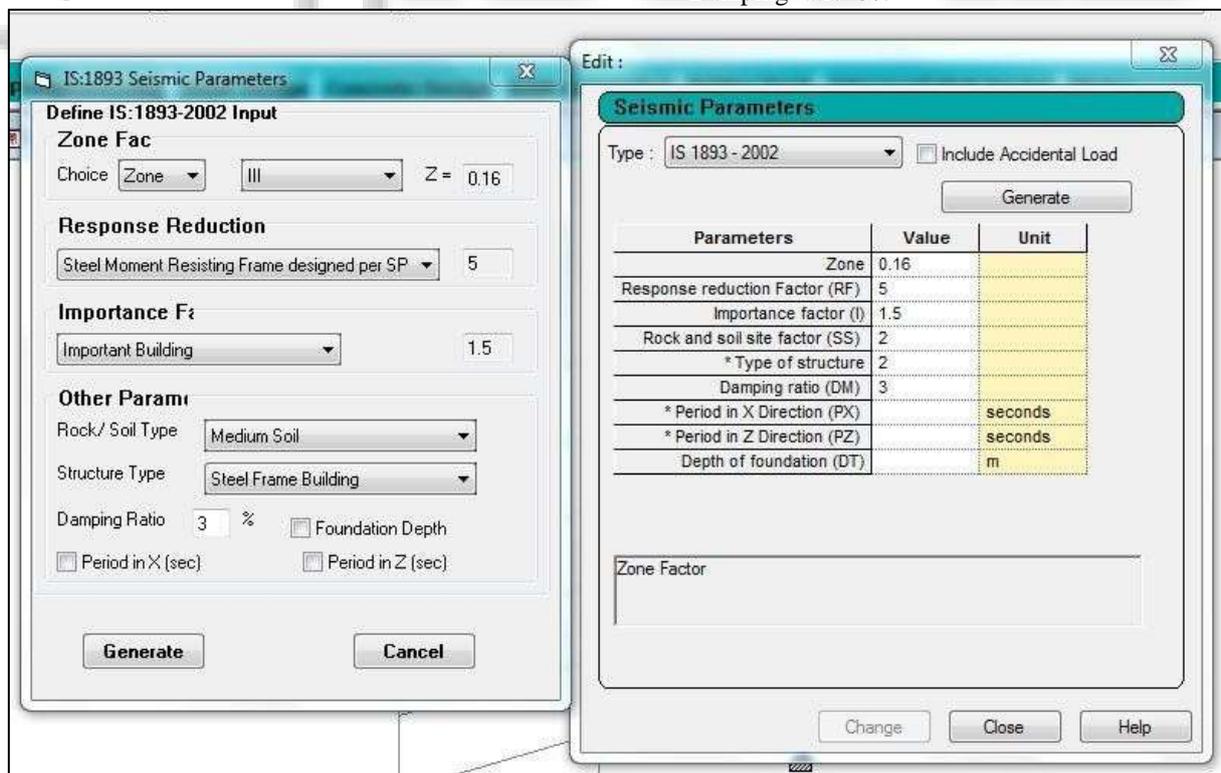


Fig. 1.1: Stadd pro. input of seismic parameter

## II. REVIEW OF LITERATURE

Literature reviews corresponding to the earthquake analysis of the multistorey structure were controlled. the target was to understand the strength of the various structural properties of different seismic zones. it has been noted that the majority of researchers, scholars and consultants have been active in the field of earthquakes, geography, the importance of seismic analysis, modern design methods, building methods, and so on.

[MVK. Satish et.al (2019)] evaluated and designed the G + 3 hospital building and the design of its land acquisition structure was studied using STAAD. NSP), this study recommends the use of standard NSP instead of the original NSP mode because it provides a better result when comparing building structures.

[Dr. Ashokkumar et.al (2018)] designed the G + 3 hospital building using a stand-alone stand at STAAD.Pro the efficiency of the analysis using software in addition to the written method was analyzed and a comparative analysis was performed.

[B. Gireesh (2016)] A study of the structure and earthquake of the G + 7 building was studied using the Stadd.Pro software. During this study planning was funded by the following general Indian codes: IS 1893 (Part 1) - 2007, in base shear planning. IS 1893: 2002 in terms of seismic resistance which identified various analytical methods supporting the local Zone, high building value and building value. After starting the project a heavy load, live load, air load, snow load and earthquake load was placed for further analysis.

[Mahesh et.al (2017)] This study focused on structural analysis within the effect of air load on a sloping surface with software Stadd.Pro. air conditioning was supported by India's standard code IS 875 part- III. Studies have shown that because height increases arrival time, shear strength and shared displacement all show a direct relationship with the higher value. It has therefore been concluded that zone IV is the most important because the rates of bending, shear strength and joint migration were the highest in the IV zone and the minimum within Zone I.

[D. Ramya et.al, (2015)] compared the planning and over-analysis of the multi-storey G + 10 structure with STAAD. Pro and other software's. the critical wind speed of this study was assumed to be 33.0 m / s so the shear strength and curvature above each part of the structure were calculated for a different combination of loads. This study shows that STAAD.Pro is flexible in co mparison to ETABS software in terms of architecture.

[Bandipati Anup et al., (2014)] This paper discusses by examining and planning a multi-storey structure [G + 5 (3-dimensional frame)] adopting STAAD Pro. The process used in STAAD.Pro is a custom method. Initially they need 2-D frames created and tested for physical calculations. The exact result must be proven. We inspected and constructed a building with G + 5 [2-D Frame] structures instantly in all possible load combinations. The work is completed with many other 2-Dimensional and 3-Dimensional frames under different load combinations.

## III. FORMULATION & LOAD CALCULATION

The parameters to be used for this section are determined initially using two checks: Moment Resistance check and Deflection criteria.

Checks the deflection limit of Beam in x motion. Selecting the Beam category:

Total Dead load + Live load = 51 KN/m = gravity load.

Now the code specifies maximum deflection limit as  $\frac{1}{300}$  where, l is the effective length of the section.

$$\text{So, } \frac{1}{300} = \frac{Pl^4}{384EI}$$

$$I_{\text{Required}} = \frac{300Pl^3}{384E}$$

$$= \frac{300 \times 51 \times 83}{384 \times 2.1 \times 10^8}$$

$$= 9714.3 \text{ cm}^4$$

So section selected is ISMB 350

$$I_{zz} = 13630 \text{ cm}^4 \text{ Area } 66.7 \text{ cm}^2$$

Depth of section = 350 mm Breadth of flange = 140 mm

Thickness of flange = 14.2 mm Thickness of Web = 8.1 mm

Definition of Column Sections checking the 'weak beam strong column criteria'

Mc : moment of column

Mg : moment of beam

$$\Sigma Mc = Mc1 + Mc2$$

$$\Sigma Mg = Mg1 + Mg2$$

$$\Sigma Mc \geq 1.2 \Sigma Mg \text{ (as per IS 800:2007)}$$

$$\Sigma f_{yc} \times \Sigma Z_{\text{column}} > 1.2 \Sigma f_{yb} \times Z_{\text{beam}}$$

So,

$$2 \times 250 \times Z_{\text{req.}} = 1.2 \times 250 \times 1094.8 \times 1000$$

$$Z_{\text{req.}} = 656.88 \text{ cm}^3$$

So, therefore the selection of section is: I80012B50012.

There for calculation of the moment using the shown equations & the section of all column is found to be: I80012B50012

Check compression & buckling at ground floor level with under gravity loading.

$$\text{Formatted loaded area} = 8 \times 6 = 48 \text{ m}^2.$$

Floor weight is taken as 5KN/m<sup>2</sup>, all included.

$$G_{\text{floor}} = 48 \times 5 = 240 \text{ KN/storey}$$

$$G_{\text{walls}} = (8+6) \times 3 = 42 \text{ KN/storey}$$

$$G_{\text{frame}} = 18.5 \text{ KN/storey}$$

$$Q = 3 \text{ KN/m}^2 \times 48 = 144 \text{ KN}$$

$$1.35 \times G + 1.5 \times Q = 1.35 \times 300.5 + 1.5 \times 144 = 622 \text{ KN/storey}$$

$$\text{Compression in column for basement level: } 6 \times 622 = 3732 \text{ KN.}$$

Approx. buckling length should = 3.0 m

(equal to each storey height)

Now calculation for the column section of I80012B50012

$$\text{Sectional area} = 387 \text{ cm}^2$$

$$\text{And } I_{zz} = 494454 \text{ cm}^4$$

$$R_{zz} = 35.744 \text{ cm}$$

$$\lambda = 48$$

$\chi = 0.85$

$F_{cd} = \chi \cdot f_y / \gamma_{m0} = 0.85 \times 250 / 1.1 = 193.18 \text{ N/mm}^2$

$P_d = F_{cd} \times A = 193.18 \times 38700 = 7476.136 \text{ kN} > 3732 \text{ kN}$

Where;  $F_{cd}$  is calculated as design compressive stress.

Where;  $P_d$  is calculated as design compressive strength.

Calculation of seismic mass

For the steel structure frame considered, the seismic calculation of mass in terms of joint weight & for the member weight of the steel frame:

Dead load is =  $5 \text{ kN/m}^2$ ,

Live load is =  $3 \text{ kN/m}^2$

Area load calculated for each beam is  $30 \text{ m}^2$ , & there are 3 beams in each storey. Therefore total DL +LL for per each storey is calculated to be:

$= 3 \times 30 \times (5 + 3) = 720 \text{ kN}$

Nodal loads apply as  $144 \text{ kN}$  on both interior nodes & a nodal load apply as  $72 \text{ kN}$  on the exterior nodes. Thus the total nodal load are contribution for the seismic mass calculation is:

$= 144 \times 2 + 72 \times 2 = 432 \text{ kN}$

Weight of wall (Dead Load) is also contributes as for the seismic mass.

Weight of the wall (Dead Load) is  $3 \text{ kN/m}$ .

Thus total wall weight per storey is calculated as:

$= 3 \times 24 = 72 \text{ kN}$

So far; There for total seismic mass for calculation as per storey is given by

$= 720 + 432 + 72 = 1224 \text{ kN}$

#### IV. DESIGN ANALYSIS

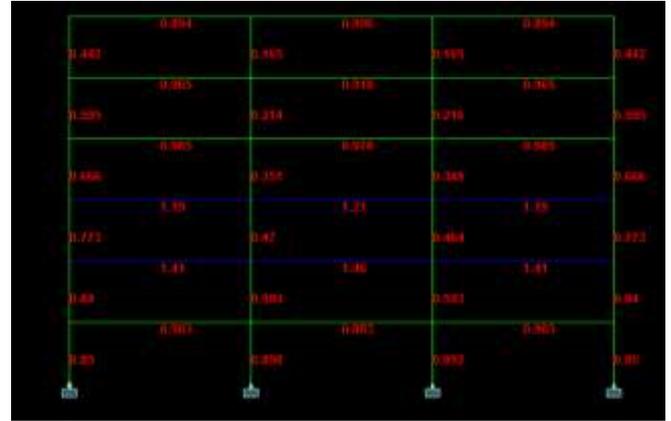


Fig. 4.1: Diagram showing failed members

Sl no.	Failed member no:	Failed section	Critical condition	Staad design section (passed)
1	1	ISMB350	IS 6.2	ISWB500
2	3,8,11,14,15	ISMB350	IS 6.2	ISLB550
3	10,12,17	ISMB350	IS 7.1.2	ISWB600
4	13	ISMB350	IS 6.2	ISHB450A
5	4,5,6,7,9,16,18	ISMB350	IS 7.1.2	ISWB600A
6	2	ISMB350	IS 6.2	ISHB450

Table 4.1: Table of members failed and modified sections (by lateral force method)

Sl no.	Failed member no:	Failed section	Critical condition	Staad design section (passed)
1	1,13	I80012B50012	IS 7.1.2	I80012B50016
2	2,14	I80012B50012	IS 7.1.2	I0012B55012
3	3,15	I80012B50012	IS 7.1.2	ISWB550
4	7,8,9,40,42	ISMB350	IS 6.2	I100012B50012
5	21	I80012B50012	IS 7.1.2	I100012B50012
6	27	I80012B50012	IS 7.1.2	ISWB600A

Table 4.2: Table of members failed and new modified sections (by response spectrum analysis)

#### V. CONNECTION DESIGN:

Considering node 16, a connection is built between the components ISWB600A and I80012B50012 as described below

The connection of the heating plate to the column piles is eliminated using a full entry weld, the positive pressure can also be,  $P_b = 150 \text{ Mpa}$  and weld size 't'=10mm

$$\text{Length of the weld required: } = \sqrt{\frac{6 \times M}{t \times P_b}} = \sqrt{\frac{6 \times 278.682 \times 1000 \times 1000}{10 \times 150}} = 1055 \text{ mm}$$

$$\text{Max. bending stress in the weld } P_b = \frac{M \times y}{I} = \frac{6 \times M}{t \times d^2} = \frac{6 \times 278.682 \times 300 \times 1000000}{850 \times 300 \times 300 \times 300} = 21.85 \text{ Mpa}$$

$$\text{Shear stress at weld } = \frac{W}{d \times t} = \frac{120 \times 1000}{10 \times 1294} = 9.27 \text{ Mpa}$$

$$\text{Final condition: } P_e = \sqrt{P_b^2 + 3P_s^2} = \sqrt{21.85^2 + 3 \times 9.27^2} = 27.114 \text{ Mpa} < 225 \text{ Mpa}$$

Design is OK (so assumed steel plate of  $824 \times 850 \text{ mm}$  is welded to the flanges of the column)

#### A. Connection of Beam to The Steel-Plate:

Consider 2 angle sections of ISA  $100 \times 100 \times 8$  and 20mm dia close tolerance turned bolts

$$n = \sqrt{\frac{6 \times M}{m \times p \times R}} \quad (\text{no. of bolts required}) = \sqrt{\frac{6 \times 278.682}{4 \times 0.06 \times 108.915}} = 7.997 \approx 8 \text{ bolts}$$

R = bolt value (area  $\times \sigma_{tf}$ )

m= 4 lines, M= 278.682kN, W=120kN

After calculation  $n = 7.997 \approx 8$  no.s bolts per line

Check for stresses:

$$\sigma_{tf \text{ cal}} = \frac{6 \times M}{m \times p \times n^2 \times A_b} = \frac{6 \times 278.682 \times 100}{4 \times 6 \times (8 \times 8) \times \frac{\pi}{4} \times (21.5)^2} = 299.8 \text{ Mpa}$$

$$\text{Shear stress on each bolt} = \frac{W}{m \times n \times Ab} = \frac{120 \times (10)3}{32 \times \frac{\pi}{4} \times (21.5)2} = 1.03 \text{Mpa}$$

Permissible combined shear and tensile stress :

$$\frac{\tau_{vf} \text{ cal}}{\tau_{vf}} + \frac{\sigma_{vf} \text{ cal}}{\sigma_{vf}} \leq 1.4$$

$$= \frac{299.8}{300} + \frac{1.03}{100}$$

1.00963 ≤ 1.4 (OK)

### B. Unstiffened Seat Connection:

Assume 2 angle sections ISA 150×115×8

$$\text{Strength of bolts in single shear} = \frac{300}{1000} \times \frac{\pi}{4} \times (21.5)^2 = 108.9 \text{KN}$$

$$\text{Strength of bolts in bearing 12mm plate} = \frac{300}{1000} \times 21.5 \times 12 = 77.4 \text{KN}$$

$$\text{No. of bolts} = \frac{120}{77.4} = 1.55 \approx 2$$

$$\text{Bearing length } a = \frac{R}{tw \times \sigma_p} - h_2 \sqrt{3} = \frac{120 \times (10)3}{11.8 \times 187.5} - 46.05 \times \sqrt{3} = -25.52 \text{ (negative)}$$

$$\text{But bearing length } a \geq \frac{R}{2 \times tw \times \sigma_p} = \frac{120 \times (10)3}{11.8 \times 187.5} = 27.11 \text{mm}$$

### C. Base Plate Design:

For I80012B50012 column

The base plate has to carry additional stress due to bending moment in the column as it is eccentrically loaded. Stress due to vertical load 'P' and moment 'M' at the extreme fibre is given by:

$$\frac{P}{b \times l} \pm \frac{6M}{b \times l^2}$$

obs = 185Mpa

$$\text{In single shear} = \tau_{vf} \times \frac{\pi}{4} \times d^2 = \frac{100}{1000} \times \frac{\pi}{4} \times 25.52 = 51.05 \text{KN}$$

Therefore bolt value= 51.05KN

$$\text{Force due to moment} = \frac{\text{moment}}{\text{lever arm between flanges}} = \frac{480093}{824} = 582.63 \text{KN}$$

Assume 50% of the axial load is transferred by direct bearing and 50% on both flanges. If the end of the calculation is faced for total bearing on base plate.

Total load carried through one flange to different angle

$$\text{section} = \frac{1}{2} \times \frac{1963.83}{2} + 582.63 = 1073.59 \text{KN}$$

$$\text{No. of bolts} = \frac{1073.59}{51.07} = 21.02 \approx 22 \text{ bolts}$$

We took the 22 of 24mm dia bolts to connect the column for base plate

Take now length of the base plate= 824+300=1124mm, take 1150mm

$$\text{Since, } \frac{M}{P} = \frac{480093}{1963.83} = 244.46 \text{mm} > \frac{1150}{6} = \frac{1}{6}$$

Thus the stress calculation will be;

$$\approx \frac{x}{3} = \frac{1}{2} - \frac{M}{P} = \frac{824}{2} - 244.46$$

$$X=502.62 \text{mm}$$

The extreme fibre stress 'σ' is negative & a part of base plate is quit lifted up. Thus the resultant upward pr. R should be as equal to the downward load P

$$\text{Therefore; } R = \frac{\sigma \times x \times b}{2} = P$$

$$b = \frac{P \times 2}{\sigma \times x} = \frac{2 \times 1963.83 \times 1000}{8 \times 502.62} = 976.796 \approx 980 \text{mm}$$

Assume = 1150 X 980mm base plate

Thickness of base plate:

Bending moment at section Z-Z

$$M_z = 5.33 \times (151 \times 980) \times \frac{151}{2} + \frac{8-5.33}{2} \times (151 \times 980) \times \frac{2}{3} \times 151 = 79436403.9$$

Equating the above equations; bending moment to the moment of resistance

$$\left(\frac{1}{6}\right) \times 980 \times t^2 \times 185 = 79436403.9$$

$$T = 51.27 \text{mm}$$

Thickness of the base plate = t- thickness of the angle = 51.27 - 12 = 39.27 ≈ 40mm

## VI. RESULT AND DISCUSSION

Storey no.	Storey height	LSM(cm)	RSA(cm)
1	3	0.3869	0.491
2	6	1.2595	1.15
3	9	2.3837	1.61
4	12	3.5892	1.96
5	15	4.7566	2.19
6	18	5.8123	2.34

Comparison analysis of the absolute storey drift in both methods: (table 6.1)

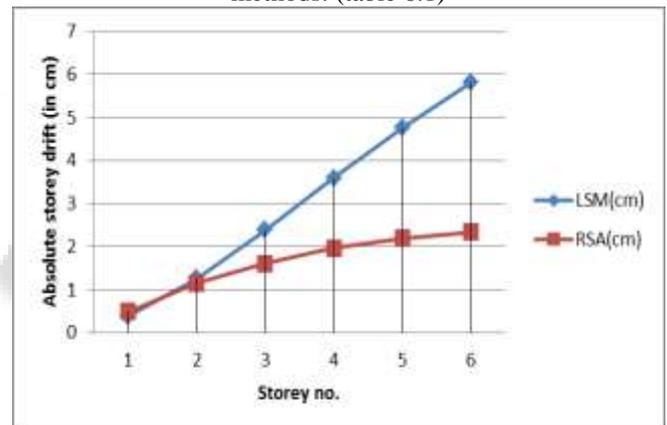


Fig. 6.1: Graph of comparison no of absolute storey drift

Storey no.	Storey height	LSM (KN)	RSA (KN)	Difference in %
1	3	179.201	120.981	28.91
2	6	177.232	119.104	32.79
3	9	169.281	112.992	33.25
4	12	151.451	102.341	32.42
5	15	119.794	85.01	28.99
6	18	70.582	55.03	22.033

Table 6.2: Comparison analysis of the storey shear: (using both LSM and RSA)

It is found that the extreme shear difference of these methods is approximately 29.73% somewhere in each yard.

Final results with compared to initial design result:

Storey no.	Pre design drift (cm)	Post design drift(cm)	Difference in %
1	0.3869	0.2056	46.85
2	1.2595	0.5472	56.55
3	2.3837	0.9052	68.11
4	3.5892	1.2561	65
5	4.7566	1.5729	66.93

6	5.8123	1.8012	69.05
---	--------	--------	-------

Table 6.3: Drift: By Lateral Force Method

It is evident that the variability in design and pre-delivery variations is approximately 62.08% in the individual retail space.

The total amount of metal required within the type of connection with the parts of the members is more than the analysis and support style of the support system used rather than the dynamic strength method.

## VII. CONCLUSION

- 1) Inter-storey Drift was identified using the power team method and response method and it was found that the downside of the response system is not only visual but also a lateral force method.
- 2) The shear obtained by the physical means of the method is smaller than that obtained by the lateral force method.
- 3) As seen within the above results the values obtained according to the force analysis are smaller than those of the lateral force method. this is very common because the duration of the main mode with a powerful analysis is 0.62803 is greater than the 0.33 s estimate of the lateral force method.
- 4) The analysis also shows that the basic modal weight is 85.33% of the seismic weight. The second modal is 8.13% of the total seismic mass  $m$  so the time frame is 0.19s.
- 5) within the design analysis submitted the inter storey Drift and base shear are both significantly reduced due to the heavy component parts leading to safe construction. For example the previously used categories (eg: ISMB 350) failed and Stead Pro reset and accepted the higher category (eg: ISWB 600 A)

## REFERENCES:

- [1] Subramanian N., Design of steel structures, Oxford University Press, 7<sup>th</sup> edition, 2011, 173- 209
- [2] Negi LS, Design of Steel Structures, Tata Mc-Graw Hill Publishing Company Limited, 2<sup>nd</sup> edition, 1997,
- [3] India's custom code for project loads (excluding earthquakes) for construction and structural load (Second Revision) IS 875: 1987 (Part II). Bureau of Indian Standards. 2002
- [4] Indian Land Standards for Land Standards (5th Review) IS 1893 (Part 1) Bureau of Indian Standards. 2002
- [5] Establishing Limitations and Practical Issues in the Opposition and Response to Earthquakes. INTERNATIONAL ASSEMBLY FOR ENERGY ENGINEERING AND ENGINEERING (IJCIET), Volume 5, Complaint 6, June (2014), p. 89-93
- [6] A Comparison of the Impact of Building Structures Using the STAAD Software and ETABS, WORLD CONSTITUTION OF CONSTRUCTION AND PLANNING, Volume 2, No 3, 2012
- [7] Analysis of multi-storey building with full wall. INTERNATIONAL DEPARTMENT OF CONSERVATION AND SKILLS DEVELOPMENT, Volume 4, No 2, 2013
- [8] Analysis and height of stores against a certain level of energy. INTERNATIONAL JOURNAL OF

RESPONSIBLE engineering, Volume 3 Complaint 4 April 2014.

- [9] Review of Shear Wall Lateral and Concrete Braced Multi-Storey Muly-Storey Multi-Storey for Athor of Ground Soft Storey. INTERNATIONAL CYCLE OF INFORMED SCIENCE AND HIGHER LEARNING, Vol. 2, Index 09, 2014.
- [10] Behavior of a multi-material structure under air capacity. INTERNATIONAL CYCLE OF INFORMED SCIENCE AND HIGHER LEARNING, Vol. 1, Figure 4, 2012.
- [11] IS 875 (Part 2): Code of Practice for Building Structures (Except for Earthquakes) for Buildings and Buildings. Part 2: Released Loads (Second Review) (1987)
- [12] D.Ramya, A.V.S.Sai Kumar "Comparative Study of Construction and Analysis of Multiple Complete Buildings (G + 10) By STAAD.Pro and Etabs Software's." IJESRT, ISSN: 2277-9655 (I2OR), (October, 2015)