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The behavior of multi storey building considering Storey displacement, storey drift, and storey shear during the earthquake

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Abstract
The earthquake may cause serious failure of the building structure. There is a considerable effect on the building structure due to the earthquake. In the present work, considering IS 1893 (part I:2016) code [1] and zone factor 0.16 as per seismic zone 3 (i.e., Surat, Gujarat, India), a G+20 multi storey building is analyzed. Space framed structure using concrete is studied. Columns and beams are prismatic for the whole building. Thickness of the 2-way slab is taken as constant. Displacement of the building as well as storey shear load is analyzed for the earthquake within X direction. The effects of the amount of floor and weight of buildings are considered to find deflection, storey drift and storey shear. Mathematical calculations are considering different parameters like displacement of storeys at different floors, column width, and storey shear of specific columns. These results are verified using state of the art software (i.e. STAAD.Pro v8i). Time for the analysis for the different cross section of columns (i.e. 0. 33m x 0. 33m, 0. 66m x 0. 33m, and 0. 66m x 0. 66m) is considerably less due to application of the STAAD.Pro v8i. The result shows the effect of displacement on various floors base shear and storey drift.

Keywords: *Displacement, Storey drift, Base shear analysis, Storey shear analysis, STAAD.Pro v8i*

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I. Introduction

Considering economic aspects, Surat is an important city of Gujarat as well as India. Many projects, including government projects are under construction (i.e., diamond bourse and smart city). Considering the population density of the city, construction of multi-storey building that provides commercial and/or residential facilities is required. Hence, in the present work, the behavior of multi-storey building considering deflection, storey drift, and base shear during an earthquake is analyzed.

During the earthquake, seismic waves are produced because the energy stored in the earth's crust is quickly released. An unexpected shaking of the passage of seismic waves through earth's rocks occurs. It creates a seismic load that also acts as a lateral force to be transferred at the base of a column of the multi-storey building. As damage control and maintenance of building would become major issue in future therefore new materials structures and construction technology should be utilized. *S*eismic load estimation is studied multistory buildings as per IS: 1893-1984 and IS: 1893-2002 [2]. The lateral load is one of the important phenomena to be calculated to prevent column failure in a building having multiple numbers of storeys, stair and lifts and vertical circulation in of ramps. (I.e.,multi storey building). The proportional distribution of lateral forces, evolved through seismic action in each storey level, due to changes in mass and stiffness of building is investigated [3]. So, the seismic load is the vital consequence of the earthquake is significant in multi storey building to determine the column width. There are 4 Seismic zones in India as mentioned in Figure 1. It shows that Surat is under seismic zone III and the zone factor is to be taken as 0.16 for the structure analysis [1].

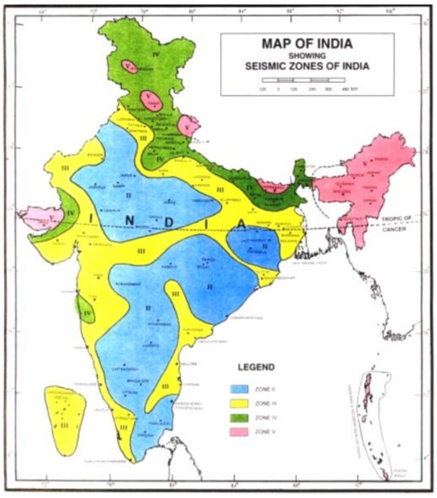

Fig1. Seismic map of India [1]

In the present work, a simple space framed structure, reinforcement concrete (RC) design for the building is proposed. The storey shear distribution of high rise reinforced concrete buildings for the purpose of the earthquake resistant design is studied [4]. Any type of shear wall outside is not provided to keep the structure design simple. Seismic analysis of high-rise building using program in STAAD.Pro v8i with various conditions of lateral stiffness system is described [5]. The Building is considered symmetric. So, displacements are the same in values for the X and Z direction for the load provided in the direction X-axis and Z-axis respectively. Cross-section of the column is varied (i.e., 0.33m x 0.33m, 0.66m x 0.33m, 0.66m x 0.66m) to compare displacement of the storey, lateral force (i.e. Storey shear) and storey drift. The displacement of the storey due to the earthquake is analyzed by the state of the art software (i.e. STAAD.Pro v8i). The lateral force is depending upon the numbers on the floor and related to the storey drift. So, it is needed to find the relation between the numbers of floor and storey drift. A maximum storey drift can be found by analyzing the difference between the deflections of the subsequent floors.

II. Methods

There are three methods to analyze the structure as per IS 1893 (part 1): 2016 [1]. The first method is known as Equivalent Static Analysis (ESA) or Seismic Coefficient Method (SCM) and used for the most of building structures [6]. This method is easy to use and based on the empirical time and distribution of the earthquake loads on each floor along with the height of the building. Another method is the Response Spectrum Analysis (RSA). Wherein, the structural model of the building, natural frequencies, and natural modes are obtained. For this purpose, free vibration is analyzed, by modeling the building structure [1]. The third method given in is Time History Analysis (THA). In this method, the dynamic response is obtained by using either the Modal Superposition Method (MSM) or Numerical Integration Method (NIM). A time history of ground acceleration is used to obtain a dynamic response in the form of time response in this method.

Amongst these three methods, ESA (i.e. First method) does not consider ground history to calculate base shear, deflection, and storey drift. Hence, in the present work, ESA is employed for the ease of calculations. The column configuration of the building is required to calculate base shear for the varied cross-section of a column, as stated in Figure 2. A Plan of a total of 64 columns having cross-section 0.33 m x 0.33m is mentioned in Figure 2 (a). Similarly, the plan to have cross-section 0.66 m x 0.33m and 0.66 m x 0.66m are mentioned in Figure 2 (b) and 2 (c) for the same amount of column respectively. As well as Figure 2 (d) shows 3 D modeling of the building having a cross-section of 0.33m x 0.33m to be analyzed for given configurations.

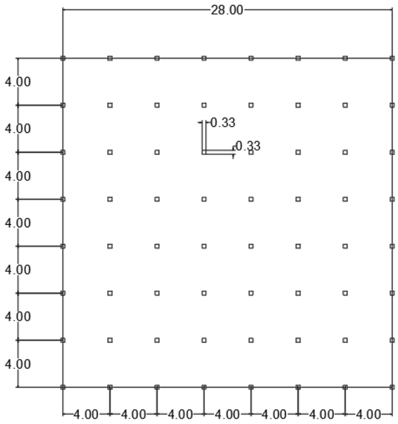

Fig 2 (a). Configuration of columns of 0.33m X0.33m in plan(dimensions are in m)

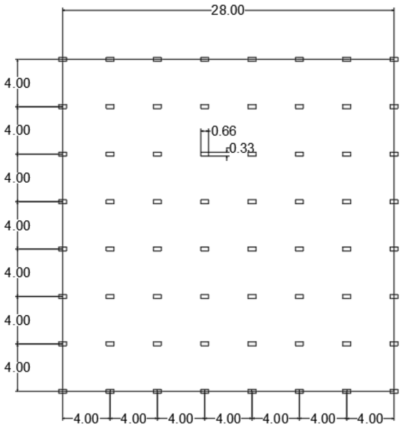

Fig2 (b) Configuration of columns of 0.66m X 0.33m in plan(dimensions in m)

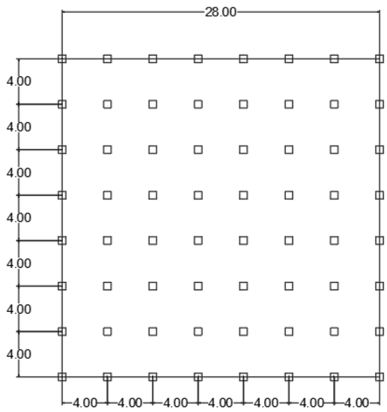

Fig 2 (c) Configuration of columns of 0.66m X0.66m in plan(dimensions in m)

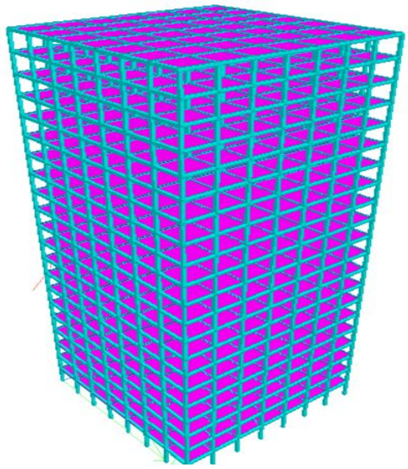

Fig 2(d). Modeling using STAAD.Pro v8i [10] for the building having column size 0.33 m x 0.33 m

The mathematical calculation of the base shear is carried for the column having column size 0.33 m x 0.33 m mentioned in Figure 2 (d). STAAD.Pro v8i is the basic software for analysis. STAAD.Pro v8i is the most popular structural engineering software product for 3D model generation, analysis, and multi-material design. So, in the present work, STAAD.Pro v8i is applied for the structural analysis of the building.

STRUCTURAL ANALYSIS

In the present work, multi-storey special moment resisting building frame, subjected to earthquake load is considered. An analysis is done for comparisons of lateral displacements and interstorey drift for G+20 storey building for the different columns having various cross-sectional areas. The analysis is based on the following modeling assumptions:

- Dead loads are assumed to be invariant with changes in member sizes.
- The material of concrete is assumed to be linearly elastic and force- deflection (P-Δ) effects are not considered.
- Structural members are straight and prismatic.
- To reflect the actual behavior of structures, all frames are assumed to be rigid in the plane. Hence, the horizontal shear deflection of all vertical bents to be related by the horizontal translations and floor slab rotations are constrained at floor levels.
- All connections between members of all building models are assumed rigid while the buildings are fixed at the base.
- The buildings are assumed to be residential complex types meant for general use.

According to these modeling assumptions, the shear force is analyzed by the conventional method and to be compared with the analysis done by STAAD.Pro v8i software.

ANALYSIS OF SHEAR FORCE

Building parameters [7] for the sample calculation of 0.33m X 0.33m column size (i.e. Cross-sectional area) is mentioned in Table 1.

Table1. Building parameters

Sr no	Particulars	Values
•	Unit weight of concrete (ρ_c)	25 kN/m^3
•	Unit weight of brick masonry (ρ_m)	19 kN/m^3
•	Length of the building (D)	28 m
•	Width of the building (B)	28 m
•	Cross sectional area of column(a_c)	0.33m x 0.33m
•	The thickness of the wall (t_w)	230 m
•	Height of floors(h)	3m
•	Slab thickness (ts)	0.15 m
•	Imposed floor load (P)	1.5 kN/m^2
•	Length of the beam (L)	4m
•	Cross sectional area of beam(a)	0.35m x 0.33m

In the present work, shear force analysis of the building is carried out by Equivalent Static Lateral ForceMethod. Dead load and live load (imposed load) are calculated considering the building parameter mentioned in Table 1. These calculated values of dead load and live load are added to find seismic weight. The calculated value of the seismic weight is multiplied by the horizontal seismic coefficient (A_h) to find the value of base shear. But, the value of the design acceleration coefficient is required to find the horizontal seismic coefficient (A_h). As the design acceleration coefficient $\left(\frac{s_a}{g}\right)$ the soil type [ed upon soil type[1] and time period. Hence, it is required to calculate time period. It is calculated by considering the height of the building and length of the building along the direction of the seismic load.

CALCULATION OF SEISMIC WEIGHT OF BUILDING

The deadload,liveload, andSeismicweight [9] arecalculatedto utilize to find base shear using STAAD.Pro v8i software asgivenbelow:

LOAD CALCULATION

- **DeadLoad:** It is calculated considering the self-weight of slab, wall, beam, columns.
- Due to the self-weight of the slab: Volume and unit weight of concrete () is multiplied to find the self-weight of the slab as per the value mentioned in Table 1.

Dead loadduetoSlab= ρ_cX B X DXt (1)

=25 X 0.15 X 28 X 28

= **2940kN**

- Dead Load due towall: Volume and unit weight of brick masonry (ρ_m) is multiplied to find the self-weight of the wall as per the value mentioned in Table 1. The number of walls (N) is considered 112 from the plan of the building.

Deadloadofwall (except roof)=N X ρ_mX h X t_WX L (2)

=120 X 19 X 3 X 0.23 X 4

=**5873.28 kN**

In the building, there is a parapet also so load due to parapet is also taken there are 28 walls in the parapet here N is 28. In the calculation, load due to parapet is also considered. As there is the number of walls are 28, So the number of the parapet (N) will be 28 (i.e. Same as the number of walls).

Dead load due to parapet = N X ρ_mX h X t_WX L (3)

= 28 X 19 X 1X 0.23 X 4

= **489.44 kN**

A cutting plane is passed from the mid part of the floor to calculate a dead load of the wall (roof) by adding a deadloadof the wall (excluding the roof) divided by 2 and dead load due to parapet.

Dead load of the wall (roof) = (Deadloadof the wall (except the roof)/2) + dead load due to parapet (4)

= (5873.28/2)+489.44

=**3426.08 kN**

- Dead Load due toBeam: Volume and unit weight of concrete (ρ_c) is multiplied to find the self-weight of the beam as per the value mentioned in Table 1. The number of beams (N) is considered 112 as per the plan of the building.

Dead Load of Beam = N X ρ_cX a X L (5)

= 120 X 0.3 X0.35 X 4

= **1176kN**

- Dead Load due toColumns: Volume and unit weight of concrete (ρ_c) is multiplied to find self-weight of the column as per the value mentioned in Table 1. The number of columns (N) is considered 64 from the plan of the building.

Dead Load due to column =N X ρ_cX a_cX L (6)

=64 X 0.33 X 0.33 X3

= **522.72 kN**

- **Live load:** It is also known as the Imposed floor load. This load is developed by trapezoidal pressure load.

Imposed floor load =P X D X B (7)

=1.5 X 28 X 28

=**1176 kN**

- **Summation of Dead Loads and Live load:** Dead loads due to self-weight of the slab, wall, beam, and column are added to the Imposed floor load (i.e. Live load) as per the following. It is noted that the Total dead load on the roof will be further added.

TotalDead Loadfrom 1to20storeys= Due to self-weight ofslab + Dead Load due towall (except roof) + Dead Load due toBeam + Dead Load due toColumns + Imposed floor load (8)

= 2940 + 5873.28 + 1176 + 522.72 + 1176

=**10806.84kN**

To find Total Dead load on roof= Dead load due to self-weight of the slab, wall, and beam are added to half of the Dead load due to column (according to position of cutting plane) and Imposed floor load (i.e. Live load).

TotalDead LoadonRoof =Due to self-weight ofslab + Dead Load due towall + Dead Load due toBeam + (Dead Load due toColumns)/2 + Imposed floor load (9)

= 2940 + 1223.6 + 1176 + (522.72) / 2 +1176

= **9959.45 kN**

- **The seismic weight of the building (W)**: It is a sum of Dead Load on each storey. It means to find seismic load, Number of floor are multiply with the value of total dead load from 1 to 20 storey and further added to Total dead load on roof as calculated above.

The seismic weight of the building (W) = sum of Dead Load of each story (10)

= (Number of floor x TotalDead Loadfrom 1to20storey) + TotalDead LoadonRoof

=(20 X 10806.84) + 9959.45

=263319.4 kN

- **Time Period (Ta):** The fundamental natural Time period (Ta, seconds) of a vibration of special moment resisting frame (i.e. Building withoutbricksinfillpanels)maybecalculatedbytheempiricalexpressionasgivenbelow:

Time Period (Ta) = 0.09h/√d (11)

=(0.09X 63)/√28

= 1.071sec

Where h is the height of the building in meters, and d is the base length of the building, at the plinth level along the X direction, assuming the earthquake is in the X-direction.

- **Horizontal acceleration coefficient ():** Value of Zone factor, Design acceleration coefficient, Response reduction factor, and Importance factors [11] are mention in Table 2.

Table 2 Seismic parameters

Sr no.	Seismic parameter	Values
•	Zone factor (Z)	0.16 (for zone III)[1]
•	Design acceleration coefficient (S_a/g)	1.27 (after calculating time period) [1]
•	Response reduction factor (R)	5 (RC special moment resisting structure)[1]
•	Importance factor(I)	1 (for other type of building)[1]

The value of the time period (Ta) is calculated 1.071 Sec for the medium stiff soil type. The value of the calculated Time period (Ta) is 1.071. It falls in between 0.55 seconds < T < 4.00 seconds mentioned in Table 3. Hence the value of the design acceleration coefficient (S_a/g)will be taken as(1.36/T).

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Table 3 Design acceleration coefficient IS 1893(part I):2016

$$\frac{S_a}{g} = \begin{cases} \text{For rocky or hard soil sites} & \begin{cases} 2.5 & 0 < T < 0.40 \text{ s} \\ \frac{1}{T} & 0.40 \text{ s} < T < 4.00 \text{ s} \\ 0.25 & T > 4.00 \text{ s} \end{cases} \\ \text{For medium stiff soil sites} & \begin{cases} 2.5 & 0 < T < 0.55 \text{ s} \\ \frac{1.36}{T} & 0.55 \text{ s} < T < 4.00 \text{ s} \\ 0.34 & T > 4.00 \text{ s} \end{cases} \\ \text{For soft soil sites} & \begin{cases} 2.5 & 0 < T < 0.67 \text{ s} \\ \frac{1.67}{T} & 0.67 \text{ s} < T < 4.00 \text{ s} \\ 0.42 & T > 4.00 \text{ s} \end{cases} \end{cases}$$

Design acceleration coefficient

$(Sa/g)=1.36/T$ (From Table 3) (12)

$= 1.36/ 1.071$

$=$**1.27**

Formula for horizontal acceleration coefficient as per [1]

(13)

Horizontal acceleration coefficient

$A_h=(S_a/g)(I/R)(Z/2) =(1.27)(0.16/2)(1/5)$

=0.02032

- **Determining design base shearV_B:** It is found by multiplying the Horizontal acceleration coefficient $A_h$calculated [8] from equation (13) with the seismic weight W calculated from equation (10).

$V_B=A_h$ X W (14)

=0.02032 X 263319.4

=5345.38 kN

- Vertical Distribution of base shear: The design base shear (VB) computed shall be distributed along with the height of the building as per expression the formula as per [1]

$$Q_i = \left(\frac{W_i h_i^{\,2}}{\sum_{i=1}^{n} W_i h_i^{\,2}} \right) \times V_B \quad (15)$$

Qi=Designlateralforcesatfloori,
Wi=Seismicweightsofthefloori
hi = height of the floor, measured from the base, and
n = Number of stories.
Using equation (15) mentioned above, Table 4 shows the distribution of storey shear.
The seismic weight of a particular floor (Wi) is multiplied with square of the height of that floor (hi) and divided the by summation of the Seismic weight of the same floor (Wi) is multiplied with square of height (hi) for the entire building and this ratio is multiplied with design base shear (V_B) to find design storey shear(Q_i).

Table 4 Manual analysis

Floor	hi (m)	Wi (kN)	Wihi^2 (kNm^2)	Qi (kN)	shear force (kN)
21	63	9959.44	39529017	576.14	576.15
20	60	12668	45604800	664.70	1240.85
19	57	12668	41158332	599.89	1840.74
18	54	12668	36939888	538.41	2379.15
17	51	12668	32949468	480.25	2859.40
16	48	12668	29187072	425.41	3284.81
15	45	12668	25652700	373.89	3658.70
14	42	12668	22346352	325.70	3984.41
13	39	12668	19268028	280.84	4265.24
12	36	12668	16417728	239.29	4504.54
11	33	12668	13795452	201.07	4705.60
10	30	12668	11401200	166.18	4871.78
9	27	12668	9234972	134.60	5006.39
8	24	12668	7296768	106.35	5112.74
7	21	12668	5586588	81.426	5194.16
6	18	12668	4104432	59.823	5253.99
5	15	12668	2850300	41.544	5295.53

4	12	12668	1824192	26.588	5322.12
3	9	12668	1026108	14.955	5337.07
2	6	12668	456048	6.6470	5343.72
1	3	12668	114012	1.6618	5345.38
		Σ $Wihi^2$	**366743457**		

Figure 3 shows the diagram of the shear force mentioned in Table 4.From Figure 3 it is seen that storey shear is increasing with the number of storey.

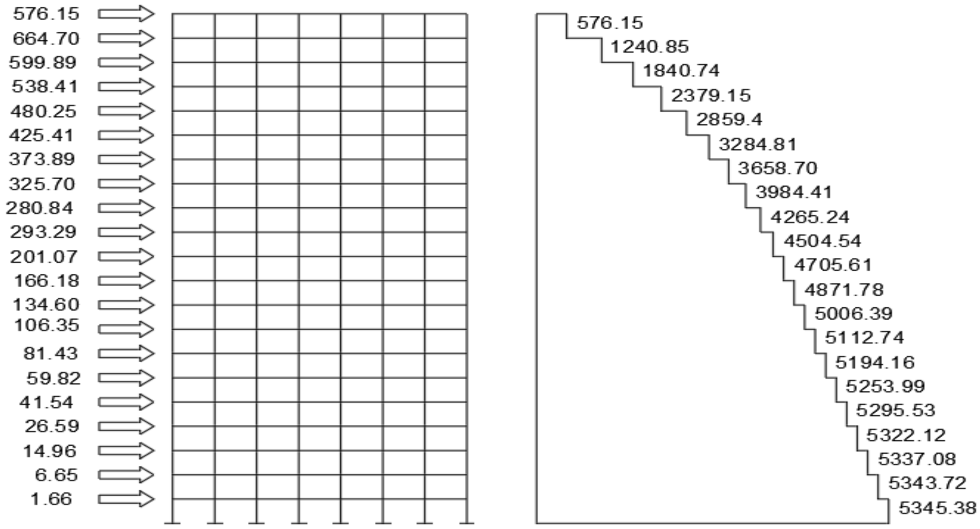


Fig 3. Base shear acting on the base of the floor and cumulative force(in KN)

III. Result And Discussion

The values of parameters like Dead Load, Live Load, Seismic weight, Time period, Design acceleration coefficient, Horizontal acceleration coefficient, and base shear are calculated and mentioned in Table 5.

Table 5 Calculated parameter and values

Sr no.	Calculated parameters	Values
•	Weight of slab	2940 kN
•	Dead Load due to wall, excluding roof	5873.28 kN
•	Dead Load due to wall roof	3426.08 kN
•	Dead Load of beam	1176 kN
•	Dead Load of column	522.72 kN.
•	Seismic weight	10806.84kN
•	Imposed Floor load	1176 kN.
•	Time period	1.071 Sec
•	Design acceleration coefficient	1.27
•	Horizontal acceleration coefficient	0.02032
•	Base shear	• **Kn**

For the storey shear force, the ratio of a result obtained by the mathematical method minus the result obtained by STAAD.Pro v8i with the result obtained by the mathematical method is stated as percentage deviation. Distribution of storey shear force (Qi) calculated in Table 6 further compared with the result obtained from STAAD.Pro v8i.

Table 6 Comparison between Mathematical software and STAAD.Pro v8i

Numbers of floors	Qi (calculated) kN	Qi (STAAD.Pro v8i) kN	% Deviation
Roof	**576.14**	**397.822**	**30.95**
20	664.7	663.397	0.20
19	599.89	598.716	0.20

18	538.41	537.351	0.20
17	480.25	479.304	0.20
16	425.41	424.574	0.20
15	373.89	373.161	0.19
14	325.7	325.064	0.20
13	280.84	280.285	0.20
12	239.29	238.823	0.20
11	201.07	200.678	0.19
10	166.18	165.849	0.20
9	134.6	134.338	0.19
8	106.35	106.143	0.19
7	81.426	81.266	0.20
6	59.823	59.706	0.20
5	41.544	41.462	0.20
4	26.588	26.536	0.20
3	14.955	14.926	0.19
2	6.647	6.634	0.20
1	1.6618	1.658	0.23

It is noted that the value of the deviation is from 0.19 % to 0.23%. Hence, it can be said that the results found with STAAD.Pro v8i is matched very well. Further, it is noteworthy that, percentage deviation of the storey shear of the roof mentioned in Table 6 is considered high because in the case of the roof, while following the mathematical procedure, the cutting plane cut the wall at half. So, the half weight of the wall is considered. But in the case of STAAD.Pro v8i, the uniformly distributed load is considered acting upon the beam. STAAD.Pro v8i doesn't consider the half wall weight. Hence, the percentage deviation is more.

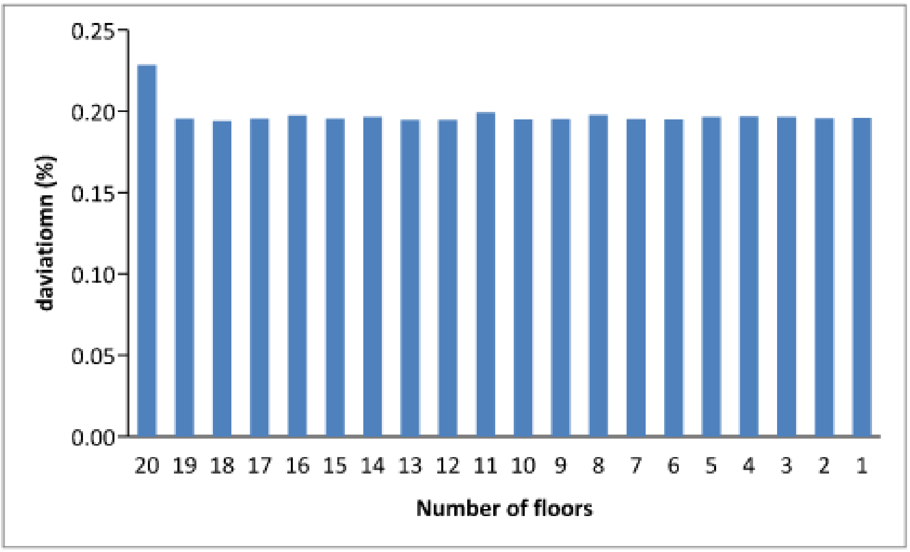


Fig 4. Deviation of the value of storey shear

Figure 4 shows that the percentage deviation of storey shear for each floor is less than 0.25. So, it can be concluded that STAAD.Pro v8i can be employed to find base shear using the value of shear force. Table 7 denotes the shear force obtained by storey shear (Qi) using STAAD.Pro v8i.

Table 7 Shear force in floors

Numbers of floors	Qi(STAAD.Pro v8i)	shear force(kN)
Roof	397.822	397.82
20	663.397	1061.22
19	598.716	1659.94
18	537.351	2197.29
17	479.304	2676.59
16	424.574	3101.16
15	373.161	3474.33
14	325.064	3799.39
13	280.285	4079.67
12	238.823	4318.50
11	200.678	4519.18
10	165.849	4685.02
9	134.338	4819.36
8	106.143	4925.51
7	81.266	5006.77
6	59.706	5066.48
5	41.462	5107.94
4	26.536	5134.48
3	14.926	5149.40
2	6.634	5156.04
1	1.658	**5157.69**

The shear force acting upon the ground floor is considered as a base shear. It is required to calculate the percentage deviation calculated base shear (Table 4) and analyzed by STAAD.Pro v8i. The base shear from Table 4 is 5345.38 kN.While base shear from Table 7 is equal to 5157.69 kN. As a percentage deviation is a ratio of the result obtained by the mathematical method minus the result obtained by STAAD.Pro v8i with the result obtained by the mathematical method. So, the percentage deviation for base shear is (5345.38-5157.693)/5345.38)x100 is equal to 3.51%. It is quite less (i.e. than 5%). After calculating Base shear, storey shear is analyzed. Fig 5.shows the storey shear with the varying number of floors for the different cross-sectional areas (i.e. 0.33 m x 0.33 m, 0.66 m x 0.33 m, and 0.66 m x 0.66 m) of columns using STAAD.Pro v8i.

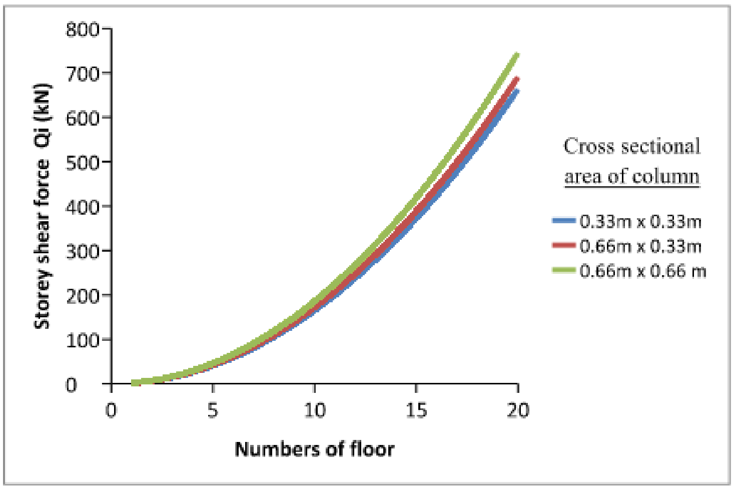


Fig 5. Comparison of storey shear

Figure 5 mentions storey shear force (Q_i) for the number of the floor from the spreadsheet of the result obtained using STAAD.Pro v8i for various cross-sectional of the column. From the graph, it can be said that storey shear (Q_i) of the column having a cross-sectional area 0.33m x 0.33m is increasing with the number of floors. Similarly, storey shear (Qi) of the column having a cross-sectional area 0.66m x 0.66m is increasing with the number of floors. It is noted that the column area for the column having a cross-section 0.66 m x 0.66m is 4 times more than the column having a cross-section 0.33 m x 0.33m. But, the deviation of the storey shear force of column having a cross-sectional area 0.66 m x 0.66m, is only approximately 11% more than a column having a cross-sectional area 0.33m x 0.33m as shown in Table 8. The percentage deviation of storey shear is very negligible compared to the increment of the area of column cross-section.

Table 8 Percentage deviation of storey shear

Number of floors	Column cross-sectional area		% deviation of storey shear
	0.33m x 0.33m	0.66m x 0.66m	
1	1.66	1.86	11.00
2	6.63	7.45	10.95
3	14.93	16.76	10.96
4	26.54	29.80	10.95
5	41.46	46.56	10.96
6	59.71	67.05	10.95
7	81.27	91.26	10.95
8	106.14	119.20	10.95
9	134.34	150.00	10.44
10	165.85	186.25	10.95
11	200.68	225.36	10.95
12	238.82	268.20	10.95
13	280.29	314.76	10.95
14	325.06	365.05	10.95
15	373.16	419.06	10.95
16	424.57	476.80	10.95
17	479.30	538.26	10.95
18	537.35	603.45	10.95
19	598.72	672.36	10.95
20	663.40	745.00	10.95

Again, it is noteworthy from Table 8 that the percentage deviation is almost constant with increasing in the number of floors. As per modeling assumption, Dead loads are assumed to be invariant with changes in member (i.e. Column) sizes, Dead load due to beam, slab, and wall and Live load is constant. Only the weight of the column will be increased. The increment of the weight of the column is very negligible compared to seismic weight. After calculating storey shear force. Shear force is attempted. Figure 6.shows the output of shear force along X direction during an earthquake using STAAD.Pro v8i.

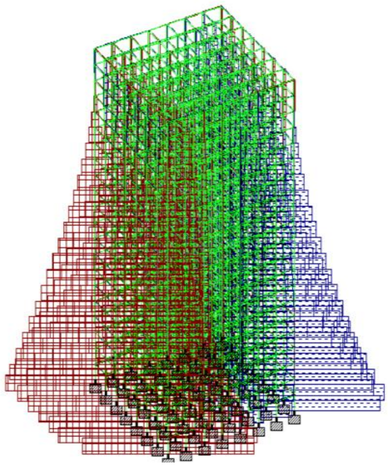


Fig 6. Shear force along x direction

The geometry of the diagram of the shear force mentioned in Figure 6 is similar to Figure 3. so it can be said that the ESA method gives a similar result to the analysis of shear force using STAAD.Pro v8i. In the present work storey displacement and storey drift are also attempted. As mentioned in Figure 7, storey drift is the displacement of one storey concerning the other storey.

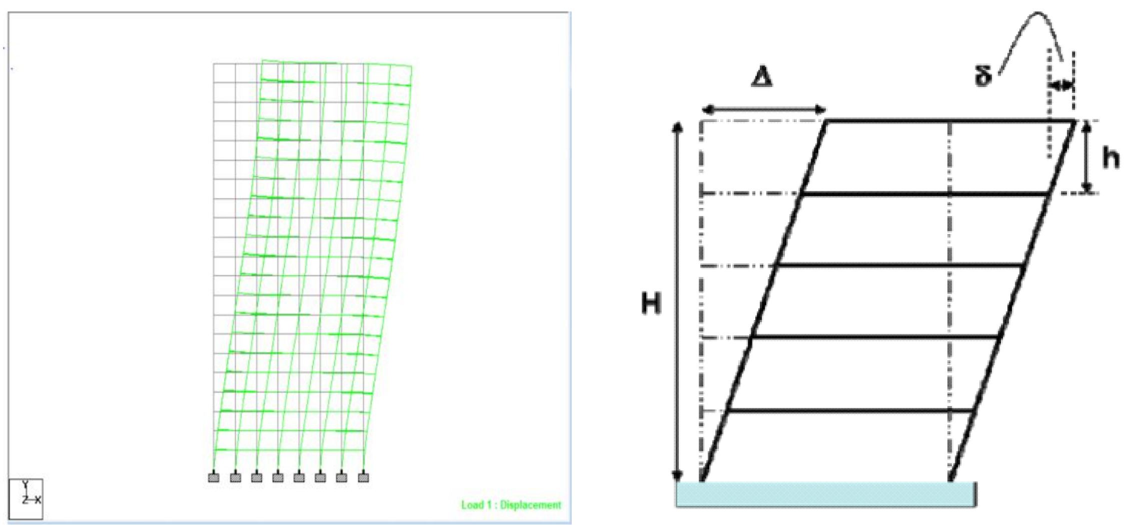
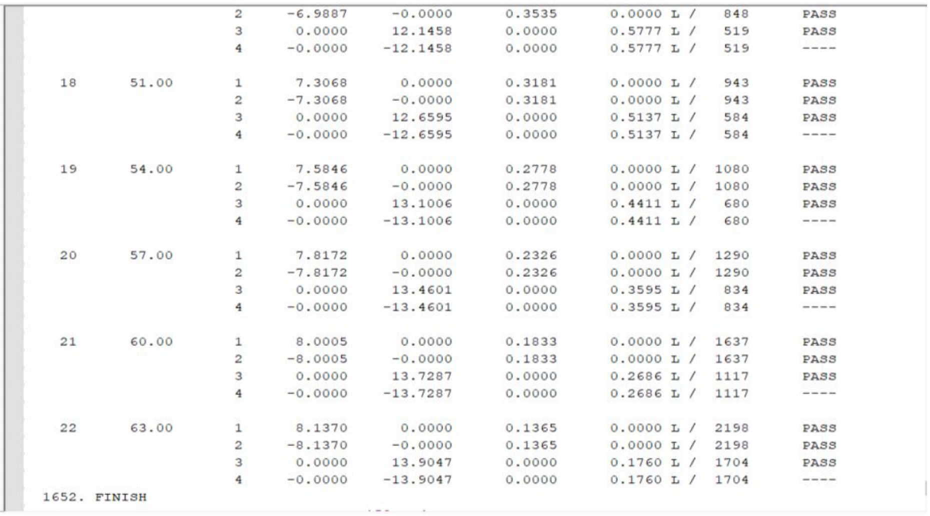


Fig 7 (a) [12], (b) Storey drift and storey displacement(not to scale)

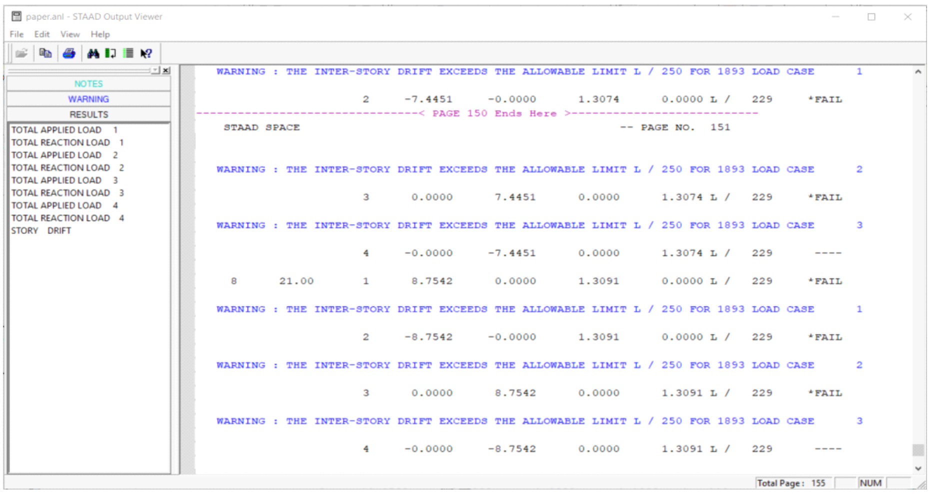
Figure 7 (a) [12], (b) shows the difference between storey drift and storey displacement here Δ denotes storey displacement and δ denotes drift. The building can be failed by storey drift and storey displacement. Storey drift and storey displacement are shown in Figure 8(a). It is a report generated using STAAD.Pro v8i. In this report, drift, and displacement along X direction (direction of earthquake load) denoted by '1'. Hence, storey drift and storey displacement also have to be considered as mentioned in Figure 8(b) and (c) from the results obtained using STAAD.Pro v8i.



		2	-6.9887	-0.0000	0.3535	0.0000 L / 848	PASS
		3	0.0000	12.1458	0.0000	0.5777 L / 519	PASS
		4	-0.0000	-12.1458	0.0000	0.5777 L / 519	----
18	51.00	1	7.3068	0.0000	0.3181	0.0000 L / 943	PASS
		2	-7.3068	-0.0000	0.3181	0.0000 L / 943	PASS
		3	0.0000	12.6595	0.0000	0.5137 L / 584	PASS
		4	-0.0000	-12.6595	0.0000	0.5137 L / 584	----
19	54.00	1	7.5846	0.0000	0.2778	0.0000 L / 1080	PASS
		2	-7.5846	-0.0000	0.2778	0.0000 L / 1080	PASS
		3	0.0000	13.1006	0.0000	0.4411 L / 680	PASS
		4	-0.0000	-13.1006	0.0000	0.4411 L / 680	----
20	57.00	1	7.8172	0.0000	0.2326	0.0000 L / 1290	PASS
		2	-7.8172	-0.0000	0.2326	0.0000 L / 1290	PASS
		3	0.0000	13.4601	0.0000	0.3595 L / 834	PASS
		4	-0.0000	-13.4601	0.0000	0.3595 L / 834	----
21	60.00	1	8.0005	0.0000	0.1833	0.0000 L / 1637	PASS
		2	-8.0005	-0.0000	0.1833	0.0000 L / 1637	PASS
		3	0.0000	13.7287	0.0000	0.2686 L / 1117	PASS
		4	-0.0000	-13.7287	0.0000	0.2686 L / 1117	----
22	63.00	1	8.1370	0.0000	0.1365	0.0000 L / 2198	PASS
		2	-8.1370	-0.0000	0.1365	0.0000 L / 2198	PASS
		3	0.0000	13.9047	0.0000	0.1760 L / 1704	PASS
		4	-0.0000	-13.9047	0.0000	0.1760 L / 1704	----

1652. FINISH

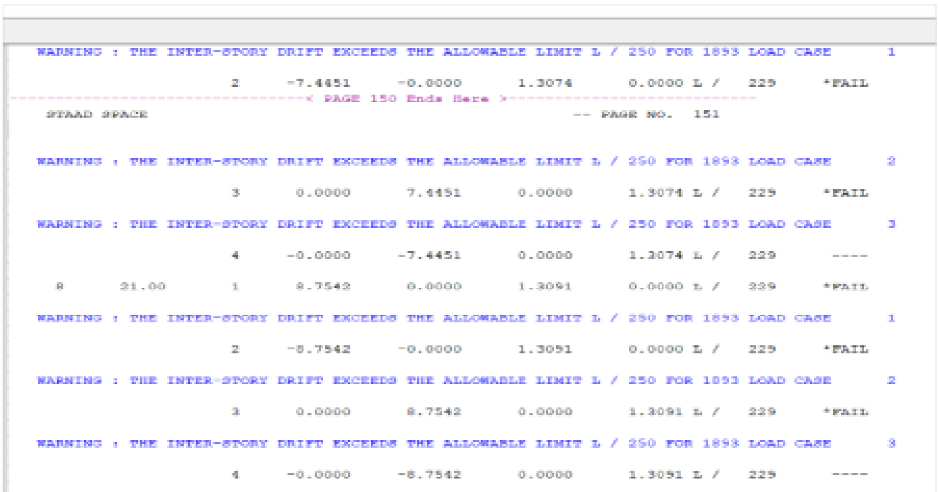
Fig 8(a). Displacement of building having column cross-sectional area 0.33m x0.33m




```
WARNING : THE INTER-STORY DRIFT EXCEEDS THE ALLOWABLE LIMIT L / 250 FOR 1893 LOAD CASE    1
                          2    -7.4451     -0.0000     1.3074     0.0000 L /   229    *FAIL
-----------------------------< PAGE 150 Ends Here >-----------------------------
 STAAD SPACE                                              -- PAGE NO.  151

WARNING : THE INTER-STORY DRIFT EXCEEDS THE ALLOWABLE LIMIT L / 250 FOR 1893 LOAD CASE    2
                          3     0.0000      7.4451     0.0000     1.3074 L /   229    *FAIL
WARNING : THE INTER-STORY DRIFT EXCEEDS THE ALLOWABLE LIMIT L / 250 FOR 1893 LOAD CASE    3
                          4    -0.0000     -7.4451     0.0000     1.3074 L /   229    ----
   8      21.00           1     8.7542      0.0000     1.3091     0.0000 L /   229    *FAIL
WARNING : THE INTER-STORY DRIFT EXCEEDS THE ALLOWABLE LIMIT L / 250 FOR 1893 LOAD CASE    1
                          2    -8.7542     -0.0000     1.3091     0.0000 L /   229    *FAIL
WARNING : THE INTER-STORY DRIFT EXCEEDS THE ALLOWABLE LIMIT L / 250 FOR 1893 LOAD CASE    2
                          3     0.0000      8.7542     0.0000     1.3091 L /   229    *FAIL
WARNING : THE INTER-STORY DRIFT EXCEEDS THE ALLOWABLE LIMIT L / 250 FOR 1893 LOAD CASE    3
                          4    -0.0000     -8.7542     0.0000     1.3091 L /   229    ----
```

Fig 8 (b). Displacement of building with the variation of floors




```
WARNING : THE INTER-STORY DRIFT EXCEEDS THE ALLOWABLE LIMIT L / 250 FOR 1893 LOAD CASE    1
                          2    -7.4451     -0.0000     1.3074     0.0000 L /   229    *FAIL
-----------------------------< PAGE 150 Ends Here >-----------------------------
 STAAD SPACE                                              -- PAGE NO.  151

WARNING : THE INTER-STORY DRIFT EXCEEDS THE ALLOWABLE LIMIT L / 250 FOR 1893 LOAD CASE    2
                          3     0.0000      7.4451     0.0000     1.3074 L /   229    *FAIL
WARNING : THE INTER-STORY DRIFT EXCEEDS THE ALLOWABLE LIMIT L / 250 FOR 1893 LOAD CASE    3
                          4    -0.0000     -7.4451     0.0000     1.3074 L /   229    ----
   8      21.00           1     8.7542      0.0000     1.3091     0.0000 L /   229    *FAIL
WARNING : THE INTER-STORY DRIFT EXCEEDS THE ALLOWABLE LIMIT L / 250 FOR 1893 LOAD CASE    1
                          2    -8.7542     -0.0000     1.3091     0.0000 L /   229    *FAIL
WARNING : THE INTER-STORY DRIFT EXCEEDS THE ALLOWABLE LIMIT L / 250 FOR 1893 LOAD CASE    2
                          3     0.0000      8.7542     0.0000     1.3091 L /   229    *FAIL
WARNING : THE INTER-STORY DRIFT EXCEEDS THE ALLOWABLE LIMIT L / 250 FOR 1893 LOAD CASE    3
                          4    -0.0000     -8.7542     0.0000     1.3091 L /   229    ----
```


Fig 8(c). Failure of column cross sectional area 0.33m x0.33m

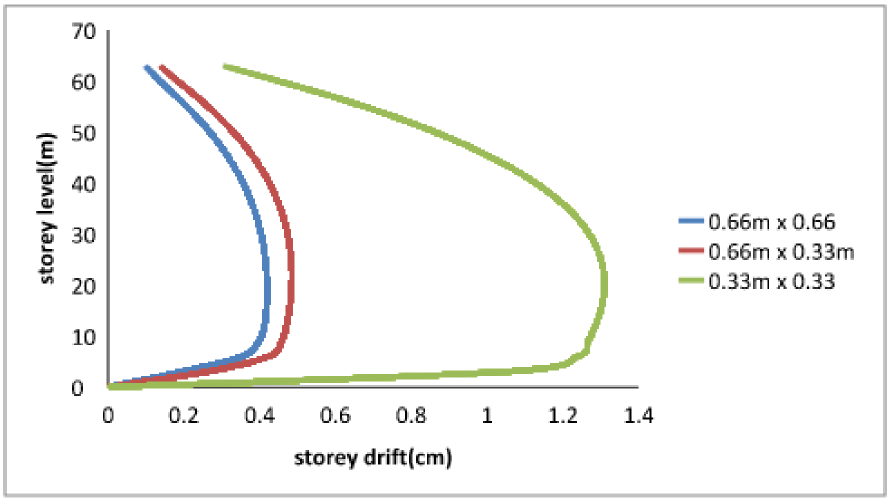


Fig 8 (d). Storey drift

Figure 8 (b) shows the comparison of the lateral displacement with a drift of the storey. It illustrates the lateral displacement of building with varying the dimension of the cross-section of the column. Lateral displacement of the building for a cross-section of column 0.33m x 0.33m storey increases as the story increases. It can be noted that, for the column having a cross-sectional area 0.33m x 0.33m, the displacement of the building drastically increased compared to the other two cross-sectional areas (i.e. 0.66m x 0.33m and 0.66m x 0.66m). Figure 8 (b) suggests that columns having cross-section area of 0. 66m x 0.66m and 0.66m x 0.33m are not having a considerable displacement. Here, building with columns having a cross-section area 0.33m x 0.33 having more displacement. It would be failed as stated in Figure 8(c) according to STAAD.Pro v8i analysis.

Figure 8(d) mentions that the storey drift is increased up to storey level of 6m drastically. After it would be stable for 9m to 24m and after storey level of 24m to 63m it would be decreased for all types of cross-sectional area (i.e. 0.33m x 0.33m, 0.66m x 0.33m, and 0.66m x 0.66m). Again, it can be said from STAAD.Pro v8i analysis (i.e. Figure 8(b)), that the failure would have occurred in the middle part of the building. It is analyzed that the storey drift should not be excess L/250. Where L is a height of one floor in mm. From the above result and discussion, the following important conclusions could be narrated.

IV. Conclusions

In the present work, Shear force, storey drift, and storey displacement of the G+20 multi-story building is analyzed using STAAD.Pro v8i and compare with various cross-sectional area of columns (i.e. 0.33m x 0.33m, 0.66m x 0.33m and 0.66m x 0.66m). It is concluded that,

- Base shear is mathematically calculated using the Seismic Coefficient Method (SCM) to validate related outcomes of STAAD.Pro v8i software. Constant, Dead loads are assumed with changes in column sizes. An increment in the weight of the column is very negligible compared to seismic weight. Hence, the percentage deviation of storey shear is almost the same (i.e. 11%) for all the floors.
- The value of the storey shear is maximum at the floor just below the roof, but not on the roof. This is because results obtained from the mathematical calculation as well as STAAD.Pro v8i software shows that seismic weight on the roof is lower than on the floor just below the roof.
- Analysis using STAAD.Pro v8i software shows that the value of the storey displacement is maximum at the roof of the building while storey drift is maximum at 24 m in all considered cross-sectional area of the column (i.e. 0.33m x 0.33m, 0.66m x 0.33m, and 0.66m x 0.66m).
- For the given variety of columns, the column having a cross-sectional area 0.66m x 0.33 is preferable. This is because a column having a cross-sectional area 0.66m x 0.66m is not preferable due to the higher value of base shear than the other two types. The column having a cross-sectional area 0.33m x 0.33m is not preferable due to the higher value of deflection and drift than the other two types.
- STAAD.Pro v8iisversatilesoftwarehavingtheabilityto analyze base shear, the storey drift, and storey displacement. These outcomes might be useful to determinethereinforcementforconcretesections considering earthquake loadingand to determinethenodaldeflectionsagainstlateralforces as future scope.

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