

# Effect of Shear Wall Location on the Response of Multi Story Buildings Under Seismic Loads

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**Abstract:-** Multi-story concrete buildings under the action of earthquake are analyzed by using time-history analysis. Base shear and floor displacements for different locations of shear wall are examined under the action of the well-known ground motion records of El Centro, California in 1940. The modelling and analysis are conducted by using the general purpose finite element software SAP2000 V14. cases of building height, which are 5, 10, 15, 20 and 25 stories, and seven arrangements of shear wall locations are explored. The total number of cases studies analyzed are 35 combinations of building, for each of them the story displacement, base shear, story drift, roof displacement and fundamental time period are determined and discussed.

It is found that, the natural period of a structure is highly affected by the height of the structure and the location of the shear walls. The minimum roof and floor displacements are obtained for the case when the shear walls are added in the corners and the core of the building. The effect of shear wall location is found to be noticed for buildings of more than ten stories. It is also concluded that the roof displacement and its maximum value at a specific moment does not give a clear indication for the behavior of building. Therefore, the full-time response of the building must be considered. Finally, it has been concluded that it is not necessarily when the stiffness of a building increases, the roof or any story displacement of the building decreases under earthquake load.

Keywords: Shear wall, Time History, Earthquake, Seismic Load, Free Vibration and Concrete Building.

safety 1.02 to 1.7 and were observed.

## 1 Introduction

In the world-wide scope and because of the people are more conscious of their life quality, comfort and safety, a special attention is recently given to study the effects of vibrations transmission through the ground to the neighboring structures. These vibrations are either produced by natural reasons like earthquake ground motion or by human made vibrations such as machine foundations, nearby roads or railway traffic, underground explosions and construction activities (such as pile driving and compaction of loose soil) ..etc. [1]. Earthquakes have two types of effects, direct and indirect. Direct effects cause damages directly and include ground motion and faulting. Indirect effects cause damages indirectly, as a result of the processes set in motion by an earthquake [2]. An earthquake is manifested as ground shaking caused by the sudden release of energy in the earth's crust.

## 2. Method of Study

### 2.1 Structural Modelling

In the present work, the concrete structure that investigated in ref. [3] was considered. The Indian standards IS 875-1 (1987) [4] and IS 875-2 (1987) [5] were utilized to estimate the applied dead and live loads. The studied models had been analyzed by linear time-history analysis technique. In this study seven buildings were considered. These Buildings have similar plan dimensions and different in the

number of stories. The number of stories examined are 5, 10, 15, 20 and 25. The considered concrete structure are provided with different position of reinforced concrete shear wall of 250 mm thick. As defined in Table (1), seven models were examined for each building of specific number of stories. The description of different models for five stories building are shown in Fig. (1). Similar configurations are examined for the other cases of buildings with different number of stories.

The dimensions in the plan of the studied buildings are 24.5m in x-direction and 22.5m in y direction. The bays are 3.5m in the x direction and 4.5m in the y-direction center to center with seven bays in x-direction and five bays in y-direction. Each building has concrete slab of 150 mm thick, beams of 0.6m×0.23m, and 3m floor height. The external columns are 0.4m×1.0m. The internal columns are 0.7m×0.7m. The columns have been modeled as fixed at the ground level. Element mass was assumed to be concentrated at the nodes. The mass of the structure included the applied dead load, including the self-weight, and live load. The mass was equal to the weight defined by the dead and live load divided by the gravitational acceleration (g). All the dead load and only 25 percent of the live load was considered as per IS 1893-1 (2002) [6].

**Table 1. Type of models.**

| Model number | Location of shear wall                                      |
|--------------|---|
| 1            | Without shear wall  |
| 2            | Shear wall at core  |
| 3            | Shear wall at corners in x direction & y direction          |
| 4            | Shear wall at periphery                                     |
| 5            | Shear wall at x diction                                     |
| 6            | Shear wall at y direction                                   |
| 7            | Shear wall at core and corners in x direction & y direction |

## 2.2 Applied loads

The concrete buildings are analyzed for dead, live, and earthquake loads. The Indian standards, IS 875-1 (1987) and IS 875-2 (1987) are utilized to calculate the applied dead and live load, respectively.

### 2.2.1 Dead loads:

Dead load of the floor has been taken as (2 kN/m<sup>2</sup>) and dead load of the roof has been taken (4 kN/m<sup>2</sup>) according to the IS 875-1 (1987).

### 2.2.2 Live load:

Live load of the floor has been taken as (3 kN/m<sup>2</sup>) and live load of the roof has been taken as (1.5 kN/m<sup>2</sup>) according to the IS 875-2 (1987). According to the IS 1893-1 (2002) [6], in the seismic analysis, all dead load has been taken and only 25 percent of the live load has been taken when the imposed uniformly distributed floor load is less than or equal to (3 kN/m<sup>2</sup>).

### 2.2.3 Material properties

As in Ref. [3], Reinforced concrete has been utilized in modeling of the slabs, beams, columns and shear walls. Constant damping ratio has been assumed 0.05 ( $\zeta = 0.05$ ). The properties of material for the used steel and reinforced concrete as shown in Tables (2) and (3), respectively.

**Table 2. Properties of steel.**

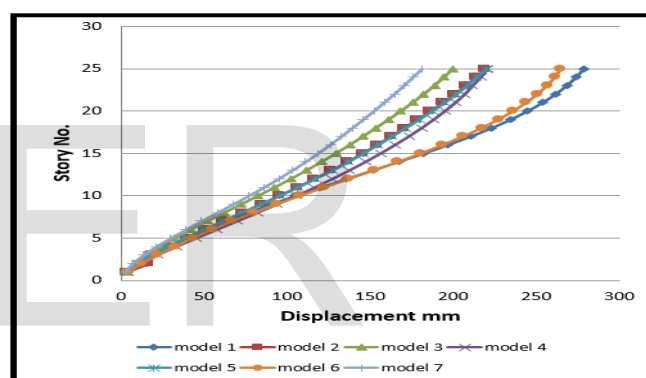
| Item  | Description             | Unit              | Value  |
|-------|-------------------------|-------------------|--------|
| $f_y$ | Minimum yield stress    | N/mm <sup>2</sup> | 414    |
| $F_u$ | Ultimate tensile stress | N/mm <sup>2</sup> | 620    |
| $E_s$ | Modulus of elasticity   | N/mm <sup>2</sup> | 210000 |
| $Q_s$ | Density                 | kN/m <sup>3</sup> | 78     |
| $v_s$ | Poisson's ratio         | ---               | 0.3    |

**Table 3. Reinforced concrete properties.**

| Item  | Description                         | Unit              | Value |
|-------|-------------------------------------|-------------------|-------|
| $f'c$ | Compressive strength of concrete    | N/mm <sup>2</sup> | 30    |
| $f_y$ | Yield stress of steel reinforcement | N/mm <sup>2</sup> | 420   |
| $E_c$ | Modulus of elasticity of concrete   | N/mm <sup>2</sup> | 25743 |
| $Q_c$ | Density                             | kN/m <sup>3</sup> | 24    |
| $v_c$ | Poisson's ratio                     | ---               | 0.2   |

## 1. Results

The response of the 25 - story building under the action of earthquake load is considered by using SAP 2000 V14. The results of analysis as shown in Tables 4 to 8 and Figs. 2 to 5.



**Fig 2. Story displacement of 25 story building.**

**Table 5. Fundamental time period and max base shear of 25 story building.**

| Model no. | Max base shear in X direction (kN) | Fundamental time period (sec) |
|-----------|------------------------------------|-------------------------------|
| 1         | 28160                              | 2.37402                       |
| 2         | 24250                              | 2.02469                       |
| 3         | 24590                              | 1.84151                       |
| 4         | 23470                              | 2.09257                       |
| 5         | 24390                              | 1.191943                      |
| 6         | 29480                              | 2.09529                       |
| 7         | 29560                              | 1.70574                       |

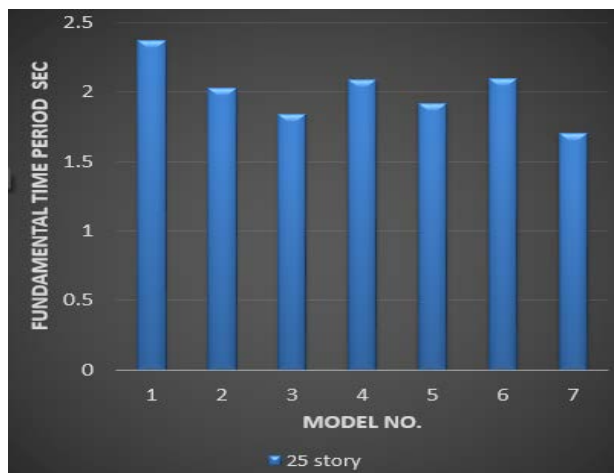


Fig 3. Fundamental time period for 25 story building.

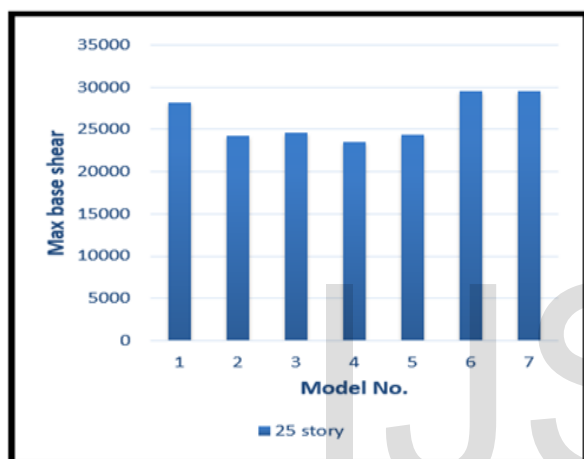


Fig 4. Max base shear of 25 story building.

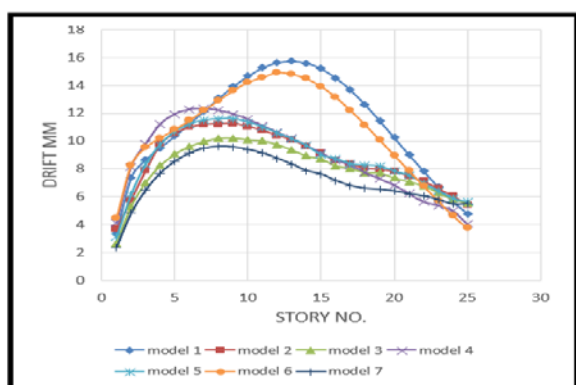


Fig 5. drift of 25 story building.

### 1.1. Static Analysis

The stiffness of (5, 10, 15 and 25) stories buildings have been investigated for all types of the models by applying a 48000 kN lateral static point load in the X direction at level of the roof (8000 kN at each beam-column connection point). This load is proposed as it represents approximately the max value of the base shear in the different studied models. The purpose of this analysis is to have an

estimation of the stiffness of the studied models in order to explain the stiffness effect on the response of the buildings in the cases of free vibration and earthquake loading. The model which gives less displacement is stiffer model. The results as shown in Table 6 and Figs. 6 to 11.

**Table 7. Displacement of roof subjected to lateral static point load in X direction.**

| Model No. | roof displacement (mm) |            |            |            |            |
|-----------|------------------------|------------|------------|------------|------------|
|           | 5 storeys              | 10 storeys | 15 storeys | 20 storeys | 25 storeys |
| 1         | 42.8                   | 177.7      | 293.6      | 429        | 589        |
| 2         | 29.4                   | 128.28     | 231.2      | 353.3      | 499.6      |
| 3         | 33.9                   | 114.7      | 211.5      | 321.1      | 412        |
| 4         | 32.3                   | 140.18     | 242        | 359.5      | 496.6      |
| 5         | 42.06                  | 131.12     | 237.6      | 360        | 502.1      |
| 6         | 43.11                  | 172.2      | 279.2      | 399.5      | 563        |
| 7         | 25.14                  | 93.78      | 180.5      | 280.6      | 365.8      |

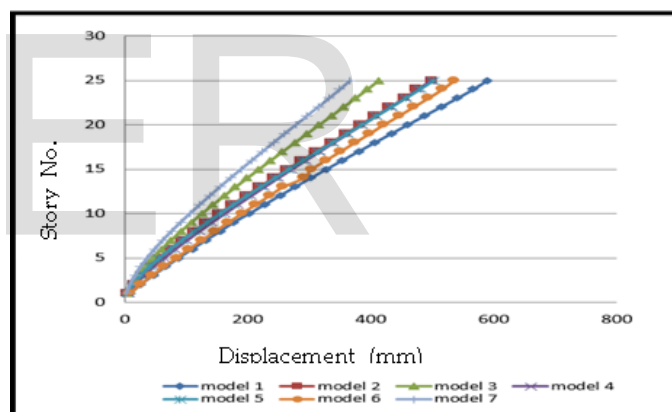


Fig. 6. Displacement of twenty-five story (25 story) buildings effected by lateral static point load in X direction.

## 4. Discussion of Results

### 4.1 Free Vibration Analysis

The free vibration analysis of any structure is very important to estimate the natural frequencies and mode shapes of the structure. The time period of undamped free vibration of structure is natural time period of that structure. The longest model time period of vibration is called fundamental time period. The fundamental natural time period of all studied models for all cases is shown in Table (8).

In Fig. 7 shows the relationship between the height of buildings and fundamental time period for all models. The

fundamental natural time period for the building without shear wall is more than other models with shear wall and it reduces to largest magnitude for model (7) in all studied buildings.

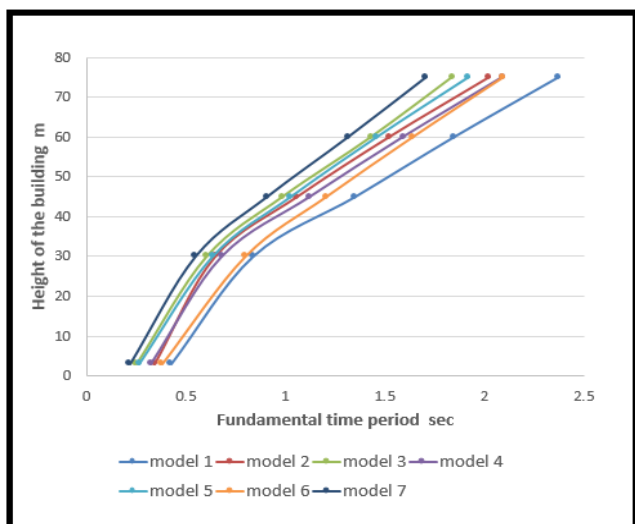


Fig 7. The relationship between the fundamental natural time period and the height of buildings.

There are two empirical expression in IS 1893-1 (2002) [41], to calculate the fundamental natural time period. The first one is  $T = 0.075 h^{0.75}$  for RC frame building and the second equation is  $T = 0.085 h^{0.75}$  for steely frame building, where  $h$  is the height of the building in meter and  $T$  in sec.

#### 4.2 Forced vibration analysis results

The dynamic response results of the buildings considered in this study under the action of the earthquake will be debated. In buildings (5, 10, and 25) the maximum roof displacement under the action of earthquake is maximum for the building without shear wall. The results signalize that when the stiffness of a building increases as shown in Table (6) the displacement of stiffened building is decreasing.

A comparison between the dynamic analysis and the static analysis results have been carried out for all buildings. Observed that the arrangement of the models from more to less stiffness in the static analysis, Table (9), is not match with the arrangement in the dynamic analysis under the earthquake, Table (10). The base shear ratios ( $R$ ) has been calculated relative to the magnitude of first model for the buildings as shown in Table (10).

Results of the base shear for different five story buildings showed that after putting the shear wall in different location, the response of the structure varies. The base shear

e ratio of second to seventh model are 1.06- 0.79- 1.06- 1.02- 0.62- 0.62, respectively.

In cases of 5 and 10 story the results show that the maximum roof displacement of the different models, having lesser displacement comparatively with model 1, and model 7, having the larger stiffness. The maximum roof displacement of the structure without shear wall is more than other models and the roof displacement of seventh model is less than other buildings.

In case of (15 story) building as in Table 9. The base shear ratio from second to seven model are 1.34, 1.43, 1.26, 1.45, 1.04, 1.67, respectively. The results for the case of (15) story building shown that the roof displacement for four models more than the first model as shown in Fig. 8. and story drift for this case as shown in Fig. 9. and also for model number seven as shown in Fig. (4-36) and story drift as shown in Fig. (11). From figure (8) the models number (2, 3, 4 and 5) have displacement more than first model at last five story. It is observed in Fig. (10) that the seventh model gives more displacement than first model just in the last story. Response of roof during the full time for the first model and seventh model are shown in Fig. (12). the results show that the displacement of roof for the seventh model is more than the first model in few seconds of time period of earthquake.

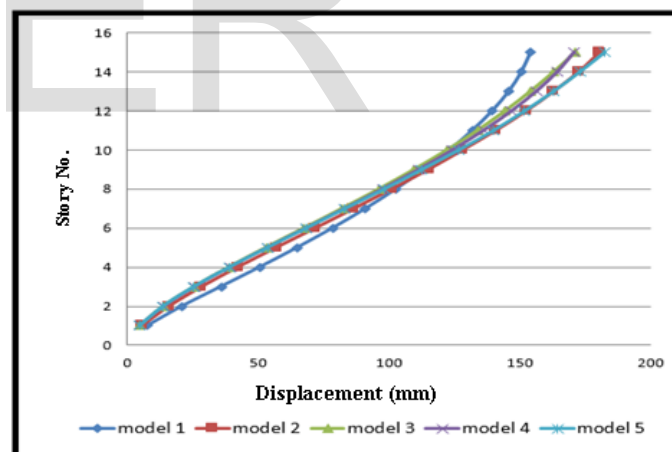


Fig. 8. Story displacement of 15 story for model (1, 2, 3, 4 and 5 model).

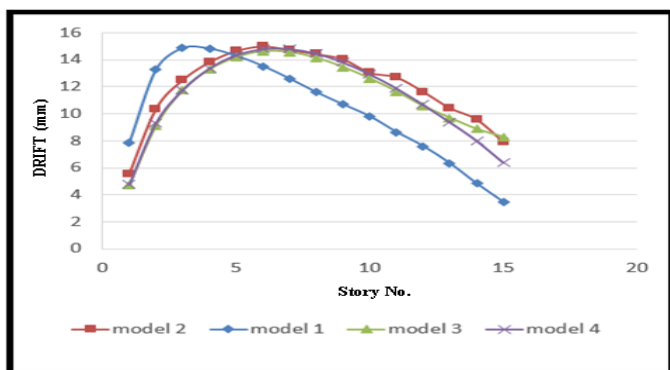


Fig 9. Story drift of 15 story for model (1, 2, 3 and 4).

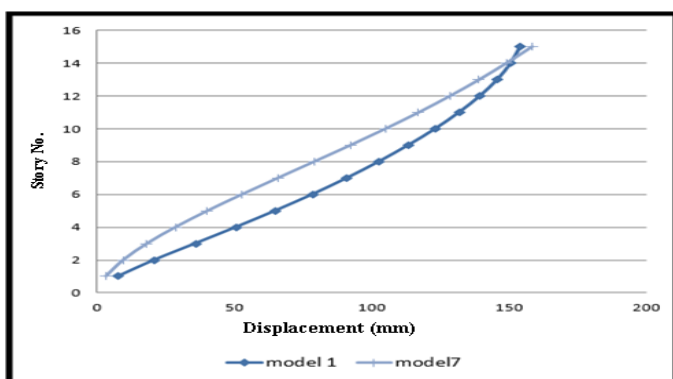


Fig. 10 Story displacement for 15 story for the first model and seventh.

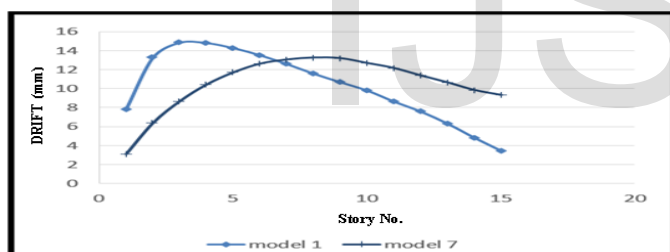


Fig. 11 Story drift of 15 story for first model and seventh.

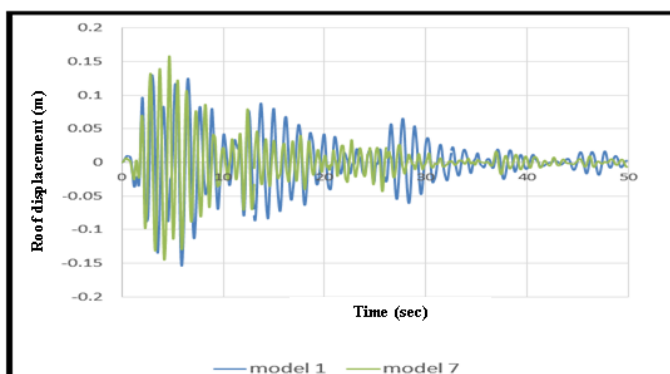


Fig. 12 Response of roof during full earthquake time for the first and seventh model of 15-story building.

### 5. Conclusion

The results show that, the height of the concrete structures increases as the natural time period increases. Using shear wall in concrete structure increase the stiffness of the structures. The response of the structures under seismic load is affected by shear wall locations, where the presence of shear walls was useful in some places and not useful in the other places. The base shear values increase due to using different locations of shear wall in most of cases. The full-time response of the structure must be taken not just maximum roof displacement to give a clear indication on the behavior of the structure not always when the roof displacement of the structure increases, the stiffness of that structure decreases under seismic load.

### References

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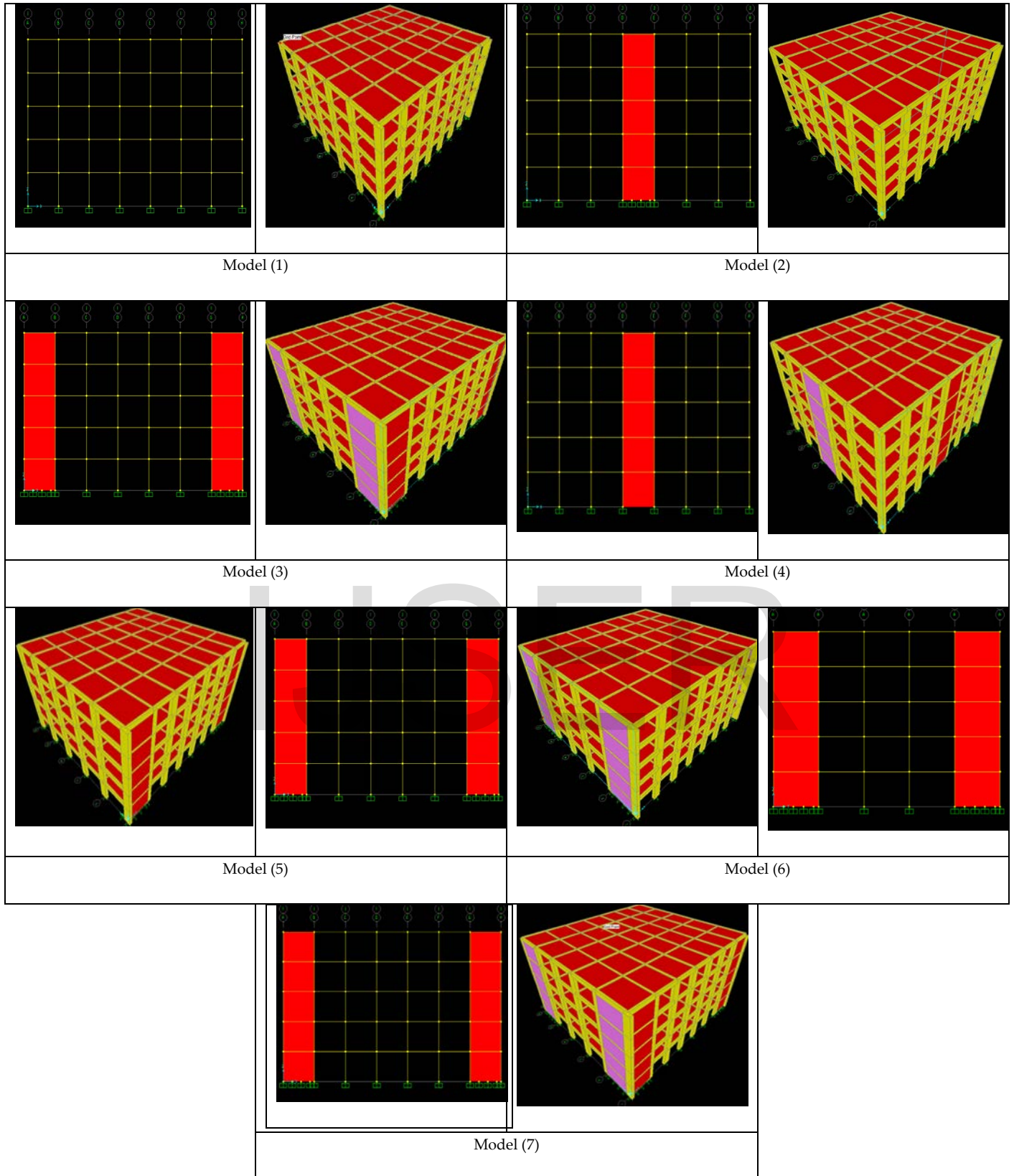


Fig 1. Different models for five stories building

**Table 4. Story displacement in X-direction of 25-story building.**

| Story No. | Displacement (mm) |         |        |        |        |        |        |
|-----------|-------------------|---------|--------|--------|--------|--------|--------|
|           | Model No.         |         |        |        |        |        |        |
|           | (1)               | (2)     | (3)    | (4)    | (5)    | (6)    | (7)    |
| 25        | 278.89            | 218.84  | 199.94 | 220.67 | 219.63 | 265.07 | 181.46 |
| 24        | 274.08            | 213.14  | 194.41 | 216.6  | 213.99 | 261.32 | 175.95 |
| 23        | 268.42            | 207.33  | 188.59 | 211.6  | 208.08 | 256.66 | 170.48 |
| 22        | 261.72            | 200.74  | 182.28 | 206.88 | 201.65 | 250.96 | 167.67 |
| 21        | 253.87            | 193.62  | 175.49 | 201.23 | 194.66 | 244.18 | 158.6  |
| 20        | 244.85            | 186.14  | 168.4  | 194.99 | 187.13 | 236.3  | 152.58 |
| 19        | 234.61            | 178.306 | 161.05 | 188.15 | 197.29 | 227.32 | 145.96 |
| 18        | 223.15            | 170.35  | 153.33 | 180.6  | 171.09 | 217.23 | 139.42 |
| 17        | 210.53            | 162.29  | 145.59 | 173.11 | 162.82 | 206.05 | 132.81 |
| 16        | 196.86            | 153.93  | 137.55 | 164.83 | 154.45 | 193.83 | 126    |
| 15        | 182.32            | 145.32  | 129.32 | 156.19 | 157.7  | 180.67 | 118.84 |
| 14        | 167.12            | 136.2   | 120.6  | 147.06 | 136.7  | 166.74 | 111.21 |
| 13        | 151.52            | 126.57  | 111.65 | 137.39 | 127.03 | 152.25 | 103.34 |
| 12        | 135.78            | 116.48  | 102.28 | 127.21 | 116.88 | 137.44 | 95.00  |
| 11        | 120.15            | 106.08  | 92.52  | 116.6  | 106.31 | 122.5  | 86.24  |
| 10        | 104.89            | 95.31   | 82.5   | 105.5  | 95.31  | 107.92 | 77.11  |
| 9         | 90.22             | 84.25   | 72.39  | 93.96  | 83.96  | 93.69  | 67.72  |
| 8         | 76.29             | 72.98   | 62.16  | 82.04  | 72.37  | 80.05  | 58.15  |
| 7         | 63.21             | 61.74   | 51.94  | 69.85  | 60.79  | 67.11  | 48.54  |
| 6         | 51.06             | 50.53   | 41.96  | 57.53  | 49.3   | 54.89  | 39.06  |
| 5         | 39.81             | 39.52   | 32.33  | 45.26  | 38.08  | 43.39  | 29.93  |
| 4         | 29.45             | 28.96   | 23.25  | 33.33  | 27.4   | 32.54  | 21.38  |
| 3         | 19.93             | 19.18   | 15.00  | 22.11  | 17.64  | 22.31  | 13.68  |
| 2         | 11.27             | 16.57   | 7.96   | 12.3   | 9.3    | 12.76  | 7.2    |
| 1         | 3.39              | 3.69    | 2.66   | 4.13   | 3.11   | 4.48   | 3.38   |

**Table 6. Drift of 25 story building.**

| Story No. | Drift (mm) |      |      |      |      |      |      |
|-----------|------------|------|------|------|------|------|------|
|           | Model No.  |      |      |      |      |      |      |
|           | (1)        | (2)  | (3)  | (4)  | (5)  | (6)  | (7)  |
| 25        | 4.81       | 5.44 | 5.53 | 4.07 | 5.64 | 3.75 | 5.51 |
| 24        | 5.66       | 6.07 | 5.81 | 5    | 5.91 | 4.66 | 5.47 |

|    |       |       |       |       |       |       |      |
|----|-------|-------|-------|-------|-------|-------|------|
| 23 | 6.7   | 6.59  | 6.31  | 5.4   | 6.43  | 5.7   | 5.81 |
| 22 | 7.85  | 7.12  | 6.79  | 5.65  | 6.99  | 6.78  | 6.07 |
| 21 | 9.02  | 7.48  | 7.09  | 6.24  | 7.53  | 7.88  | 6.22 |
| 20 | 10.42 | 7.83  | 7.35  | 6.84  | 7.84  | 8.98  | 6.42 |
| 19 | 11.46 | 7.95  | 7.72  | 7.29  | 8.20  | 10.09 | 6.54 |
| 18 | 12.62 | 8.06  | 7.74  | 7.75  | 8.27  | 11.18 | 6.61 |
| 17 | 13.67 | 8.36  | 8.04  | 8.28  | 8.37  | 12.22 | 6.81 |
| 16 | 14.54 | 8.61  | 8.23  | 8.64  | 8.75  | 13.16 | 7.16 |
| 15 | 15.2  | 9.12  | 8.72  | 9.13  | 9     | 13.93 | 7.63 |
| 14 | 15.6  | 9.63  | 8.95  | 9.67  | 9.67  | 14.49 | 7.87 |
| 13 | 15.74 | 10.03 | 9.37  | 10.18 | 10.15 | 14.81 | 8.34 |
| 12 | 15.63 | 10.4  | 9.76  | 10.61 | 10.57 | 14.94 | 8.76 |
| 11 | 15.26 | 10.77 | 10.02 | 11.1  | 11    | 14.58 | 9.13 |
| 10 | 14.67 | 11.06 | 10.11 | 11.54 | 11.35 | 14.23 | 9.39 |
| 9  | 13.93 | 11.27 | 10.23 | 11.92 | 11.5  | 13.64 | 9.57 |
| 8  | 13.08 | 11.24 | 10.2  | 12.19 | 11.58 | 12.94 | 9.61 |
| 7  | 12.15 | 11.21 | 9.98  | 12.32 | 11.49 | 12.22 | 4.48 |
| 6  | 11.25 | 11.01 | 9.63  | 12.27 | 11.22 | 11.5  | 9.13 |
| 5  | 10.36 | 10.56 | 9.08  | 11.93 | 10.68 | 10.85 | 8.55 |
| 4  | 9.52  | 9.78  | 8.25  | 11.22 | 9.76  | 10.23 | 7.7  |
| 3  | 8.66  | 7.9   | 7.04  | 9.81  | 8.34  | 9.55  | 6.48 |
| 2  | 7.37  | 5.8   | 5.3   | 8.17  | 6.19  | 8.28  | 4.82 |
| 1  | 3.39  | 3.69  | 2.66  | 4.13  | 3.11  | 4.48  | 2.38 |

**Table 8. Fundamental natural period (sec) of all studied models for all case**

| No. of stories | Fundamental natural period (sec) |         |         |         |        |         |         |
|----------------|----------------------------------|---------|---------|---------|--------|---------|---------|
|                | Model No.                        |         |         |         |        |         |         |
|                | (1)                              | (2)     | (3)     | (4)     | (5)    | (6)     | (7)     |
| 5              | 0.42387                          | 0.34263 | 0.25081 | 0.32322 | 0.2673 | 0.37877 | 0.21782 |
| 10             | 0.83651                          | 0.64748 | 0.60413 | 0.68056 | 0.6359 | 0.79741 | 0.54703 |
| 15             | 1.35109                          | 1.06038 | 0.98724 | 1.1244  | 1.0287 | 1.20536 | 0.90725 |
| 20             | 1.84887                          | 1.52307 | 1.43377 | 1.59312 | 1.4599 | 1.6404  | 1.31460 |
| 25             | 2.37402                          | 2.02469 | 1.84151 | 2.09257 | 1.9194 | 2.09529 | 1.70574 |



**Table 10. Base shear ratio for (5, 10, 15, 20, and 25) story.**

| Model No. | No. of stories |                  |               |                  |               |                  |               |                  |               |                  |
|-----------|----------------|------------------|---------------|------------------|---------------|------------------|---------------|------------------|---------------|------------------|
|           | 5 st           |                  | 10 st         |                  | 15 st         |                  | 20 st         |                  | 25 st         |                  |
|           | Base Shear kN  | Base shear ratio | Base Shear kN | Base shear ratio | Base Shear kN | Base shear ratio | Base Shear kN | Base shear ratio | Base Shear kN | Base shear ratio |
| (1)       | 29900          | 1.00             | 29960         | 1.00             | 25180         | 1.00             | 19950         | 1.00             | 28160         | 1.00             |
| (2)       | 31850          | 1.06             | 34520         | 1.15             | 33800         | 1.34             | 22990         | 1.15             | 24250         | 0.86             |
| (3)       | 23830          | 0.79             | 40710         | 1.35             | 36110         | 1.43             | 23210         | 1.16             | 24590         | 0.87             |
| (4)       | 31880          | 1.06             | 32640         | 1.08             | 31930         | 1.26             | 21670         | 1.08             | 23470         | 0.83             |
| (5)       | 30740          | 1.02             | 34060         | 1.13             | 36670         | 1.45             | 22460         | 1.12             | 24390         | 0.86             |
| (6)       | 18620          | 0.62             | 31060         | 1.03             | 26290         | 1.04             | 20790         | 1.04             | 29480         | 1.04             |
| (7)       | 18660          | 0.62             | 47330         | 1.57             | 42270         | 1.67             | 28060         | 1.406            | 29560         | 1.05             |

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