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Parametric Study on Time Period of a RC Structure

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ABSTRACT
In order to understand the performance of the building under seismic effect and the effect of lateral loads on a structure, it is necessary to evaluate the time period of a structure. It is necessary to determine the significance of the time period before evaluating the time period of a structure. Time period plays an important role in estimating the lateral loads and hence contributes to the seismic assessment of a structure. Time period depends on mass and stiffness. Based on the time period which is purely dependent on stiffness and mass, the behavior of building under lateral loads can be evaluated. In this study an attempt is done to understand the various parameters which affect the time period of a RC building. The parametric study is done on time period of a structure as per the provisions of IS 1893(part I):2002. In this present work, a reinforced concrete special moment resisting frame building models are prepared and analyzed in ETAB software to illustrate the influence of various parameters of building such as building stiffness, mass, height of building and column orientation and unreinforced masonry infill on fundamental translational natural period.
Keywords – Equivalent static method, Time period, Infill panel, Etab , Stiffness of building

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I. INTRODUCTION

Buildings oscillate during earthquake shaking. The oscillation causes inertia force to be induced in the building. The intensity and duration of oscillation, and the amount of inertia force induced in a building depend on features of buildings, called their dynamic characteristics, in addition to the characteristics of the earthquake shaking itself. The important dynamic characteristics of buildings are modes of oscillation and damping. A mode of oscillation of a building is defined by associated Natural Period and Deformed Shape in which it oscillates.

1.1 Natural Period

Natural Period (T_n) of a building is the time taken by it to undergo one complete cycle of oscillation. It is an inherent property of a building controlled by its mass *m* and stiffness *k*. These three quantities are related by

$$T_n = \sqrt{\frac{m}{k}}$$ -------- eq (i)

its units are seconds (s). Thus, buildings that are heavy (with larger mass *m*) and flexible (with smaller stiffness *k*) have larger natural period than light and stiff buildings. Buildings oscillate by translating along X, Y or Z directions, or by rotating about X, Y or Z axes, or by a combination of the above. When a building oscillates, there is an associated shape of oscillation.

1.2 Fundamental Natural Period of Building

Every building has a number of natural frequencies, at which it offers minimum resistance to shaking induced by external effects (like earthquakes and wind) and internal effects (like motors fixed on it). Each of these natural frequencies and the associated deformation shape of a building constitute a Natural Mode of Oscillation. The mode of oscillation with the smallest natural frequency (and largest natural period) is called the Fundamental Mode; the associated natural period T1 is called the Fundamental Natural Period (Figure 2.5) and the associated natural frequency f1 the Fundamental Natural Frequency. Further, regular buildings held at their base from translation in the three directions, have
(1) three fundamental translational natural periods, *Tx1*, *Ty1* and *Tz1*, associated with its horizontal translational oscillation along X and Y directions, and vertical translational oscillation along Z direction, respectively, and (2) one fundamental rotational natural period *Tθ1* associated with its rotation about an axis parallel to Z axis.

Seismic analysis of most of the structures are still carried out on the basis of lateral force assumed to be equivalent to the actual loading the base shear which is the total horizontal force on the structure is calculated on the basis of structure mass

and fundamental period of vibration and corresponding mode shape. The base share is distributed along the height of structures in terms of lateral forces according to code formula. This method is usually conservative.
There are three methods of seismic analysis of structure i.e.

1. Equivalent static lateral force method
2. Response spectrum method
3. Time history method

Among these three methods we have adopted the Equivalent static lateral force method. The equivalent lateral force procedure is the simplest method of analysis and requires less computational effort because the forces depend on the code based fundamental period of structures with some empirical modifier. The design base shear shall first be computed as a whole, than be distributed along the height of the building based on simple formulas appropriate for building with regular distribution of mass and stiffness. The design lateral force obtained at each floor level then be distributed to individual lateral load resisting elements depending upon the floor diaphragm action. In the case of rigid diaphragm action, the total shear in any horizontal plane shall be distributed to various elements of the lateral force resisting on the system on the basis of relative rigidity (clause 7.7.2 of IS 1893(Part 1):2002).

1.3 Objective of this work:
The objective of the parametric study is to determine the factors affecting the time period.
1. Evaluate effect of stiffness on time period of RC building
2. Evaluate effect of mass on time period of RC building
3. Evaluate effect of building height on time period of RC building
4. Evaluate effect of column orientation on time period of RC building.
5. Evaluate effect of unreinforced masonry infill walls on time period of RC building

II. METHODOLOGY

The equivalent static lateral load method is used to determine earthquake load on building along X-direction and Y-direction. The base shear is the horizontal force acting on the structure and is calculated on the basis of structure mass (seismic weight), fundamental period of vibration and types of soil, importance factor and response reduction factor. The following steps involved in calculating base shear i.e. lateral force acting on building.

Step 1: calculation of lumped masses to various floor level
Step 2: Determination of fundamental natural period.
Step 3: Determination of Base Shear
Step 4: Vertical Distribution of Base Shear
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II. PROBLEM FORMULATION

The Special RC moment resistant frame building models are prepared and analyzed in ETAB software to illustrate the influence of different factors affecting the fundamental natural time period of building. The following parameters were considered to analyze the special RC moment resistant frame building models. One of these buildings, namely a five storey building, is chosen as basis, and is hereinafter called Benchmark Building. It is bare frame with a plinth beam (and no slab) at ground floor level. The details of this benchmark building (figure 3.1) are as follows:

➢ **Structural Element Sizes:**
• Beams: 230mm x 450mm
• Columns: 400mm x 400mm
• Slab: 150mm thick

➢ **Material properties:**
• Grade of Concrete: M25
• Grade of Steel Reinforcement Bars: HYSD Fe 500.

➢ **Loading:**
• Dead load on beams from infill wall: 5.865 kN/m
(Density of Aerocon block, ρ=10 kN/m3)
• Floor Finish load on floor= 1 kN/m2
• Live load on floors: 2 kN/m2

➢ **Seismic Consideration:**
• Seismic Zone –IV (Zone factor, Z=0.24)
• Soil Type - II (Medium Soil)
• Importance Factor – 1 (Residential Building)
• Response Reduction Factor – 5 (special RC moment resistant frame)

➢ **Load Combinations**
In the limit state design of reinforced concrete structures, the following load combinations shall be accounted for:
Clause 6.3.1.2, IS: 1893-2002, Part 1:
a. 1.5(DL + IL)
b. 1.2(DL + IL±EL)
c. 1.5(DL±EL)
d. 0.9DL±1.5EL

➢ **Basic Assumptions**
• Rigid slab (Diaphragm-It is a horizontal system, which transmit lateral forces to the vertical resisting elements)

• Fixed base- The frames of building are assumed to be fixed at their base on an infinitely rigid foundation.
• Slab type-membrane

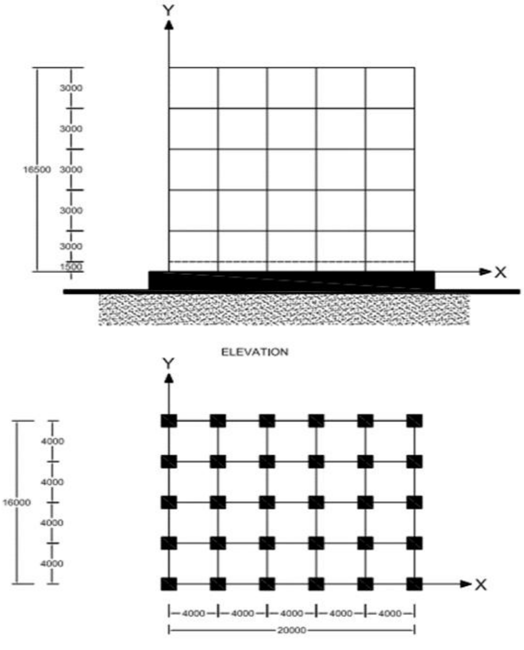


Figure4.1: Five-storey Benchmark Building: Elevation and plan of benchmark building showing the structural moment frame grid (all dimensions are in mm.

Table 2.1: Buildings considered illustrating concept of natural period

Building	Description	No.of Storeys	Number of Bays X-Dir	Number of Bays Y-Dir	Column Dimension in (mm×mm)
A	2-Storey Building	2	5	4	400x 400
B	Benchmark 5-Storey Building	5	5	4	400x 400
C	Benchmark Building with Rectangular Columns oriented along X- direction	5	5	4	550x 300
D	Benchmark Building with Rectangular Columns oriented along Y - direction	5	5	4	300x550
E	10-Storey Building with varying Column Size along Building Height	10	5	4	Upper 5 storeys (400x400)
					Bottom 5 storeys (600x600)
F	10-Storey Building	10	5	4	600x600
G	25-Storey Building with varying Column Size along Building Height	25	5	4	Upper 5 storeys (400x400)
					Middle 10Storey (600x600)
					Bottom 10 storeys (800x800)
H	25-Storey Building	25	5	4	800x800
J	25-Storey Building with imposed mass 10% larger than Building H	25	5	4	800x800
K	25-Storey Building with imposed mass 20% larger than Building H	25	5	4	800x800
L	5-Storey Building with URM Infill	5	5	4	400x400
M	5-Storey Building with Partially URM Infill	5	5	4	400x400
N	5-Storey Building without URM Infill	5	5	4	400x400

Note:
1. Bay length in each plan direction is 4m (Centre to Centre).
2. All columns at each storey are of the same size.
3. All beams in all buildings are of the same size (230 mm x 450mm).
As per this above table, these are the 13 types of buildings.

III. RESULT ANALYSIS

3.1 Factors Affecting Natural Period of Building

3.1.1 Effect of Stiffness:

Increasing the column size increases both stiffness and mass of buildings. But, when the percentage increase in stiffness as a result of increase in column size is larger than the percentage increase in mass, the natural period reduces. Hence, the usual discussion that increase in column size reduces the natural period of buildings (motivated by Eq.(i)), does not consider the simultaneous increase in mass; in that context, buildings are said to have shorter natural periods with increase in column size(Graph 3.1 and 3.2).

The building F is stiffer than building E and building H is stiffer than building While increasing stiffness, the mass of building is also increased and because of that, from graph 3.1 and 3.2 it can be observed that increase in stiffness up to some extent, reduces natural period but later it increasing natural period.

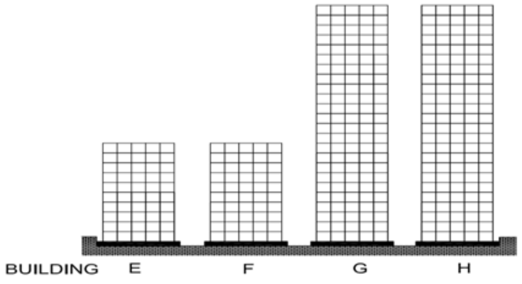
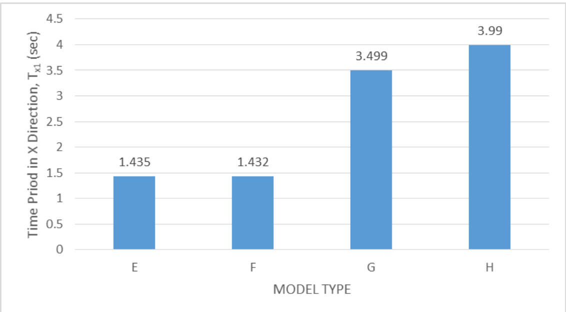


Figure.3.1: Effect of stiffness: Stiffer building have smaller natural period

Table.3.1: Effect of stiffness on Fundamental natural time period in X-Direction

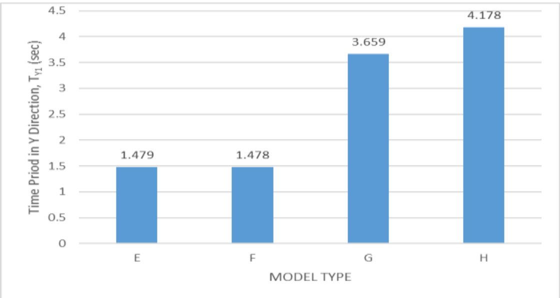
Model Type	Time Period In X-Direction, T_{x1} (sec)
E	1.435
F	1.432
G	3.499
H	3.99



Graph.3.1: Effect of stiffness on fundamental natural period in X- Direction

Table.3.2: Effect of stiffness on fundamental natural time period in Y Direction

Building Type	Time Period In Y-Direction, T_{y1} (sec)
E	1.479
F	1.478
G	3.659
H	4.178



Graph.3.2: Effect of stiffness on fundamental natural period in Y-Direction

5.1.2 Effect of Mass:

The comparative results of natural period in X and Y directions are shown in table 3.3 and table 3.4 respectively. From graphs 3.3 and graph 3.4, it is observed that, an increase in mass of a building increases its natural period. Let us consider that, model H have seismic mass of building equals to (m), while buildings J and K are 10% and 20% heavier than model H respectively.

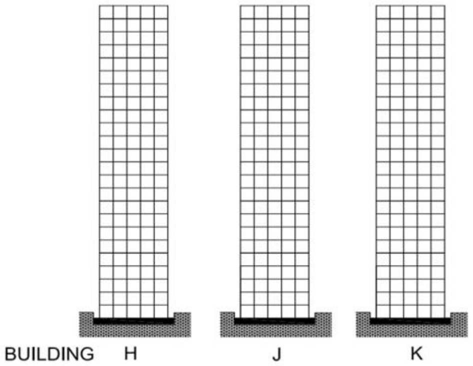
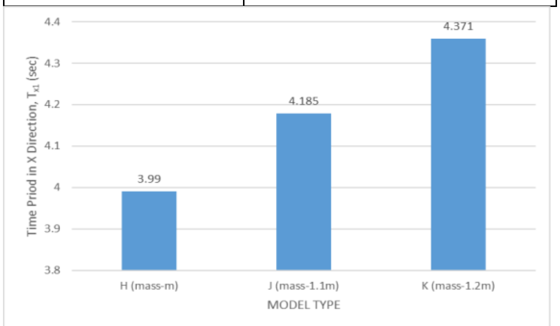


Figure.3.2: Effect of mass: Heavier buildings have larger natural period

Table.3.3: Effect of mass on fundamental natural time period in X-Direction

Building Type	Time Period In X-Direction, T_{x1} (sec)
H (mass=m)	3.99
J (mass=1.1m)	4.185
K (mass=1.2m)	4.371

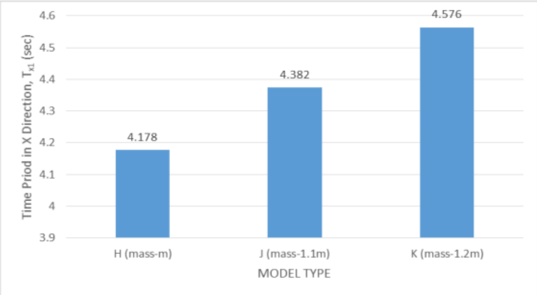


Graph.3.3: Effect of mass on fundamental natural period in X-Direction.

Table.3.4: Effect of mass on fundamental natural time period in Y-Direction

Building Type	Time Period In Y-Direction, T_{y1} (sec)
H (mass=m)	4.178

J (mass=1.1m)	4.382
K (mass=1.2m)	4.576



Graph.3.4: Effect of mass on fundamental natural period in Y-Direction

5.1.3 Effect of Building Height:

The comparative results of natural period in X and Y directions are shown in Table 3.5 and Table 3.6 respectively. From Graph 3.5 and Graph 3.6, it is observed that, as the height of building increases, its mass increases but its overall stiffness decreases. Hence, natural period of a building increases with increase in height.

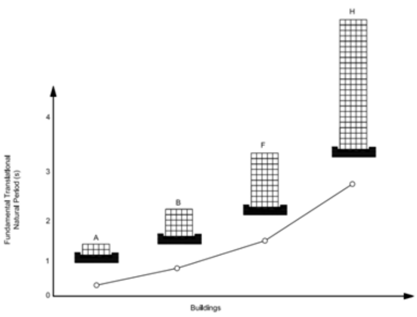
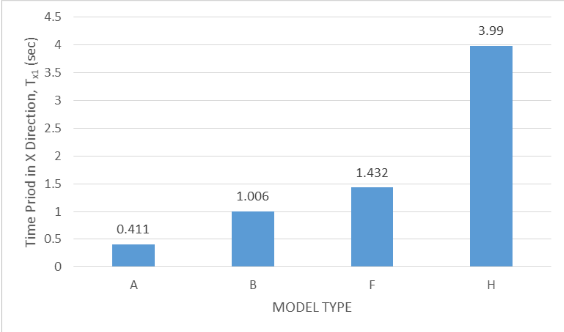


Figure.3.3: Effect of Building Height: Taller buildings have larger natural period.

Table 3.5: Effect of building height on fundamental natural time period in X-Direction

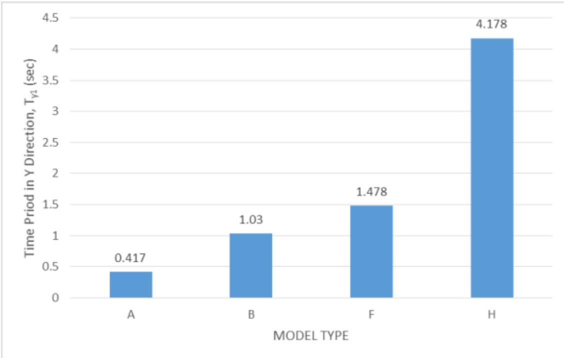
Building Type	Time Period In X-Direction, T_{x1} (sec)
A	0.411
B	1.006
F	1.432
H	3.99



Graph 3.5: Effect of height of building on fundamental natural period in X-Direction

Table 3.6: Effect of building height on fundamental natural time period in Y-Direction

Building Type	Time Period In Y-Direction, T_{y1} (sec)
A	0.417
B	1.030
F	1.478
H	4.178



Graph.5.6: Effect of height of building on fundamental natural period in Y-Direction

5.1.4 Effect of Column Orientation:

The comparative results of natural period in X and Y directions are shown Table 3.7 and Table 3.8 respectively. From graph 3.7 and graph 3.8, it is observed that, orientation of rectangular columns influences lateral stiffness of buildings along two horizontal directions. Hence, changing the orientation of columns changes the translational natural period of buildings. Building C and D are two 5-storey buildings with same column area, but different orientation of rectangular column. Longer side 550mm×300mm columns is oriented along X-direction in building-C, and along Y-direction in building-D. Lateral stiffness of columns along longer direction is more.

Hence, natural period of buildings along longer direction of column cross section is smaller than that along the shorter direction.

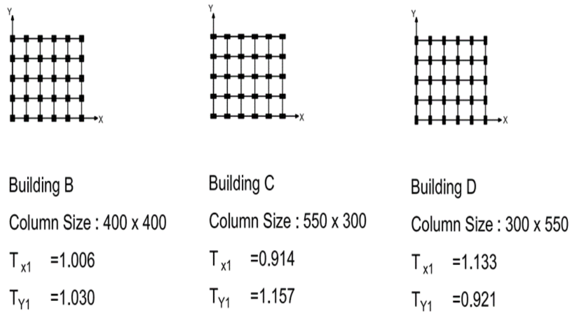
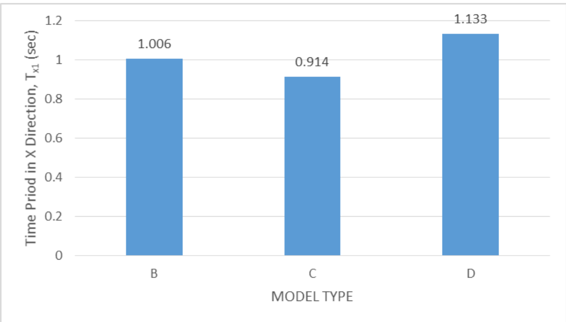


Figure.3.4: Effect of column orientation: Buildings with larger column dimensions oriented in the direction reduces the translational natural period of oscillation in that direction.

Table 3.7: Effect of column orientation on fundamental natural time period in X-Direction

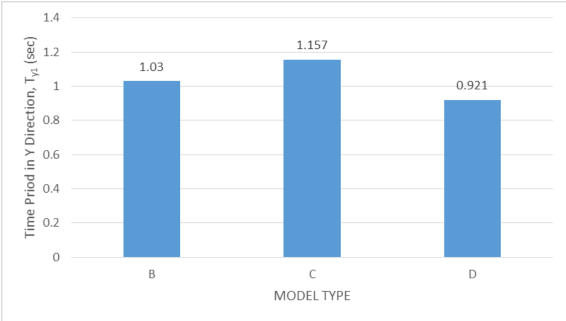
Building Type	Time Period In X-Direction, T_{x1} (sec)
B	1.006
C	0.914
D	1.133



Graph 5.7: Effect of column orientation on fundamental natural period in X-Direction

Table 5.8: Effect of column orientation on fundamental natural time period in Y-Direction

Building Type	Time Period In Y-Direction, T_{y1} (sec)
B	1.030
C	1.157
D	0.921



Graph 5.8: Effect of column orientation on fundamental natural time period in Y-Direction

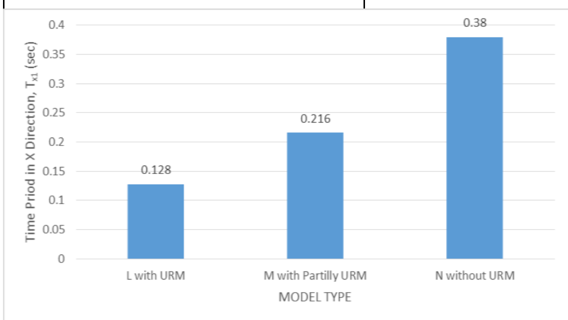
3.1.5 Effect of Unreinforced Masonry infill walls in RC Frames:

The comparative results of fundamental natural period in X-direction are shown in Table 3.9. The interaction between the masonry infill walls and the frame strongly influence the global performance of the framed structures. The performance of the bare frame does significantly vary from the other various infill panels configuration (i.e. partially or fully infilled) under lateral loading. From Graph 4.9, it is observed that, partially or fully infilled framed structures have higher stiffness than the bare framed structure and also, lateral stiffness of buildings increases when URM infill walls are included in the analysis models.

Thus, natural period of building is lower, when stiffness of URM infill is considered (i.e. Model L and Model-M), than when it is not considered (i.e. Model-N).

Table 3.9: Effect of unreinforced masonry infill wall on fundamental natural time period in X-Direction

Building Type	Time Period In X-Direction, T_{x1} (sec)
Model L (with URM)	0.128
Model M (with partially URM. i.e. with soft storey)	0.216
Model N (without URM)	0.38



Graph.5.9: Effect of URM infill on fundamental natural period in X-Direction

IV. CONCLUSIONS

1. Increasing the column size increases both stiffness and mass of buildings. But, when the percentage increase in stiffness as a result of increase in column size is larger than the percentage increase in mass, the natural period reduces. It can be observed that increase in stiffness up to some extent, reduces natural period but later it increasing natural period.
2. Increasing the column size increases both stiffness and mass of buildings. But, when the percentage increase in stiffness as a result of increase in column size is larger than the percentage increase in mass, the natural period reduces.
3. With the increasing mass of building, natural period is also increased.
4. As the height of building increases, its mass increases but its overall stiffness decreases. Hence, the natural period of a building increases with increase in height.
5. Natural period of buildings along the longer direction of column cross-section is smaller than that along the shorter direction.
6. Natural period of a building is lower, when stiffness of URM walls are considered in the analysis models, then when it is not considered.
7. The extent of stiffness enhancement and change in natural period due to URM infills depends on the extent and spatial distribution of URM infills.

REFERENCES

[1]. D. Guney and A.O. Kurusu,(2011) "optimization of the configuration of infill wall in order to increase seismic resistance of building structure"., international journal of physical sciences vol -6(4) pages 698 to 706
[2]. Jaswant N. Arlekar, et al (1997), “Seismic Response of RC Frame Buildings with Soft First Storeys” Proceedings of the CBRI Golden Jubilee Conference on Natural Hazards in Urban Habitat, 1997, New Delhi.
[3]. Arlekar, J.N.; S. K. Jain and C.V.R Murty (1997) Seismic response of RC frame buildings with soft first storeys. Proceedings of CBRI golden jubilee conference on natural hazards in urban habitat New Delhi
[4]. Jawid Ahmad Tajzadah and Proff. Vimlesh V. Agrawal”Effect of Column Size, Shape and Orientation on Seismic Performance of RC Building”.
[5]. Poncet, L. and Tremblay, R.”Influence of mass irregularity on the seismic design and Performance of multi-storey braced steel frames”.
[6]. C. V. R. Murty, Rupen Goswami, A. R. Vijayanarayanan and Vipul V. Mehta, “Earthquake Behaviour of Buildings”.
[7]. Murty C.V.R. and Sudhir K.J., Beneficial influence of masonry infill walls on seismic performance of RC frame th buildings, The 12 World Conference on Earthquake Engineering, January 30–February 4, 2000, Paper No. 1790, Auckland, New Zealand
[8]. IS:1893 (Part 1), (2007), Indian Standard Criteria for Earthquake Resistant Design of Structures, Bureau of Indian Standards, New Delhi
[9]. IS:456, (2000), Indian Standard Code of Practice for Plain and Reinforced Concrete, Bureau of Indian Standards, New Delhi