Effects of Various Parameters of Building on Natural Time Period

Prof. Shrikant R. Bhuskade
Department of Civil Engineering,
Prof. Ram Meghe Institute of Technology & Research,
Badnera, Amravati. (M.S.) (India)

Prof. Samruddhi C. Sagane
Department of Civil Engineering,
Prof. Ram Meghe Institute of Technology & Research,
Badnera, Amravati. (M.S.) (India)

***Abstract*—Indian standard recommended that the natural time period is a function of a building and the Base dimension of the building. Here in this work, the analysis is done to calculate variations of natural period according to various parameters of buildings. Details of total 10 buildings are considered. One of these buildings, namely a five storey building, is chosen as the basis, and is hereinafter called the Benchmark Building. It is a bare frame with a plinth beam (and no slab) at ground floor level. As per the different types of buildings, various effects are considered due to stiffness, mass, height of building and column orientation of building to study natural period. Analysis is done similarly as per book of C. V. R. Murty and with addition of this ETABS based shell and membrane based model.**

From the given study test results reveals that, as the stiffness, mass, storeys of building increases natural period increases. And for column orientation, natural period is larger for shorter direction of column size as compared to longer direction. Comparative analysis results shows that the natural period is more when it analyses by using ETABS. And from ETABS based model, values of natural period for membrane based model are more than shell based model.

Keywords-Building; Natural Time Period; Membrane; Shell

I. INTRODUCTION

The design of structures subjected to natural hazards such as earthquakes and typhoons demands safety of structures which is governed by the natural frequencies and the amount of damping in each mode of vibration. The dynamic behavior of structures is governed by the fundamental natural frequency and the amount of damping exhibited by each mode of vibration. Fundamental frequency of a building and its damping has a remarkable effect on the magnitude of its response. Fundamental natural period of vibration Tn of the building is an important parameter for evaluation of seismic base shear. It depends on basic parameters such as building height or number of stories. Building periods predicted by these expressions are widely used in practice although it has been observed that there is scope for further improvement in these equations since the height alone is inadequate to explain period variability. It is also known that the period of a RC frame structure differs depending on whether the longitudinal or transverse direction of the structure is considered.

The aim of this study is to analyze the effects of building due to natural period which is occurred during earthquake in both the directions i.e. X and Y. The various effects due to natural period on types of buildings are presented in this study. For this we have done case study from book "Earthquake Behavior of Buildings" of C.V.R. Murty. We have check the natural period for different types of buildings according to various effects. We have taken the same model as per C.V.R. Murty's book and at the same we have cross check the values of natural period for various effects as per book as well as by ETABS software also. In ETABS we have done analysis of natural period for various types of buildings by consideration of shell and membrane.

In the given paper, comparative results from book of C.V.R. Murty, ETABS shell based model and ETABS membrane based model for natural period have discussed.

II. DYNAMIC CHARACTISTICS OF BUILDING

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. In the given paper, study of natural period of a building is taken into account.

A. Natural Period

Natural Period Tn 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 its units are seconds (s).

$$T_n = 2\pi\sqrt{(m/k)}$$

The reciprocal (1/Tn) of natural period of a building is called the Natural Frequency fn; its unit is Hertz (Hz).

- 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

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 6 Issue 04, April-2017

axes, or by a combination of all. When a building oscillates, there is an associated shape of oscillation.

- The building offers least resistance when shaken at its natural frequency (or natural period). Hence, it undergoes larger oscillation when shaken at its natural frequency than at other frequencies.
- Usually, natural periods (Tn) of 1 to 20 storey normal reinforced concrete and steel buildings are in the range of 0.05 - 2.00s. In building design practice, engineers usually work with Tn and not fn. Resonance will occur in a building, only if frequency at which ground shakes is steady at or near any of the natural frequencies of building and applied over an extended period of time.

B. *Factors Influencing Natural Period*

Numerical results are used to explain the concept of natural period and the factors that influence it. Reinforced concrete moment resistant frame buildings are used to illustrate the concept; some properties of these buildings are listed in Table 1. Details of total 10 buildings considered. One of these buildings, namely a five storey building, is chosen as the basis, and is hereinafter called the Benchmark Building. It is a bare frame with a plinth beam (and no slab) at ground floor level. The details of this benchmark building are given in Figure 1.

III. PROBLEM FORMULATION

Structural Element Sizes:
Beams: 300 × 400 mm
Columns: 400 × 400 mm
Slab: 150 mm thick
Material Properties:
Grade of Concrete: M30
Grade of Steel Reinforcement Bars: Fe 415
Loading:
Dead Load on beams from infill wall: 10 kN/m
Openings in walls: 20%
Live load on floor: 3 kN/m^2

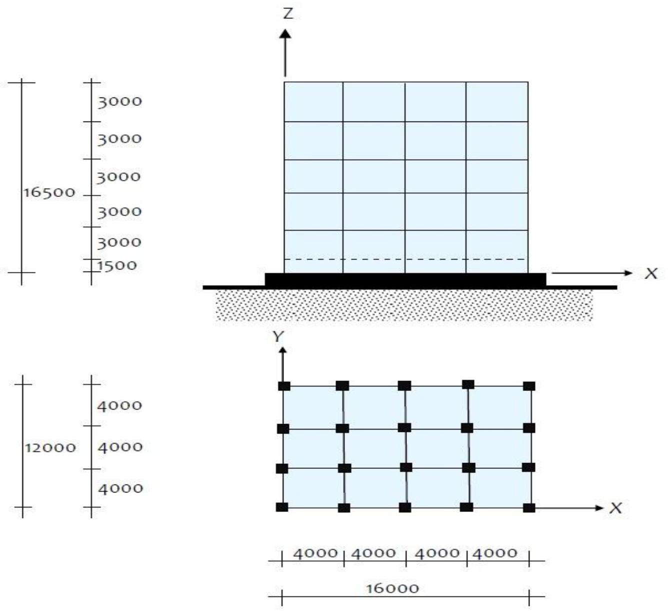

Fig. 1. Five-storey Benchmark Building: Elevation and plan of benchmark building showing the structural moment frame grid
(All dimensions are in mm)

Table 1: Buildings considered to illustrate concept of natural period

Build	Description	No. of Storeys	Number of Bays		Column Dimension (mm x mm)
			X Dir.	Y Dir.	
A	2 Storey Building	2	4	3	400 x 400
B	Benchmark 5 Storey Building	5	4	3	400 x 400
C	Benchmark Building with Rectangular Columns oriented along X - direction	5	4	3	550 x 300
D	Benchmark Building with Rectangular Columns oriented along Y - direction	5	4	3	300 x 550
E	10 Storey Building with varying Column Size along Building Height	10	4	3	Upper 5 Storeys: (400 x 400) Bottom 5 Storeys: (600 x 600)
F	10 Storey Building	10	4	3	600 x 600
G	25 Storey Building with varying Column Size along Building Height	25	4	3	Upper 5 Storeys: (400 x 400) Middle 10 Storeys: (600 x 600) Bottom 10 Storeys: (800 x 800)
H	25 Storey Building	25	4	3	800 x 800
J	25 Storey Building with imposed mass 10% larger than Building H	25	4	3	800 x 800
K	25 Storey Building with imposed mass 20% larger than Building H	25	4	3	800 x 800

Note:
- Bay length in each plan direction is 4m (Centre to Centre).
- All columns at each storey are of the same size.
- All beams in all buildings are of the same size (300 mm x 400 mm).

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 6 Issue 04, April-2017

As per this above table, these are the 10 types of buildings as per C.V.R. Murty's book. According to this classification of buildings the various effects due to natural period are as follows:

A. Effect of Stiffness :

To check this effect of stiffness building types E, F, G and H have considered from above 10 types of buildings. 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 increase in column size reduces the natural period of buildings.

Buildings E and F are two 10-storey buildings. From which building E is with different column sizes along the elevation and building F has column size of 600×600 throughout the height, while building E has smaller column size of 400×400 in the upper 5 storeys. Thus, building F with 600×600 column throughout is relatively stiffer than Building E and the fundamental period of the stiffer building F is only marginally smaller than that of the building E.

The most of the deformation is occurring only in the lower storeys because of shear-type of lateral deformation in the building, where the columns size is same. Hence, the influence on the overall natural period is not perceptible. But, if column sizes are changed in the lower storeys also, the natural period will differ significantly. Between buildings G and H, building H is much stiffer. But, while increasing stiffness, the mass is also increased.

Following Figure 2 and Figure 3 shows comparative results of natural period as per book and as per ETABS shell based and membrane based model in X and Y directions respectively. From both the figures it states that, as the building F is stiffer than building E and building H is also stiffer than building G natural period increases as the stiffness of building increases. Comparative analysis results shows that the natural period is more when it analyses by using ETABS. And from ETABS based model, values of natural period for membrane based model are more than shell based model.

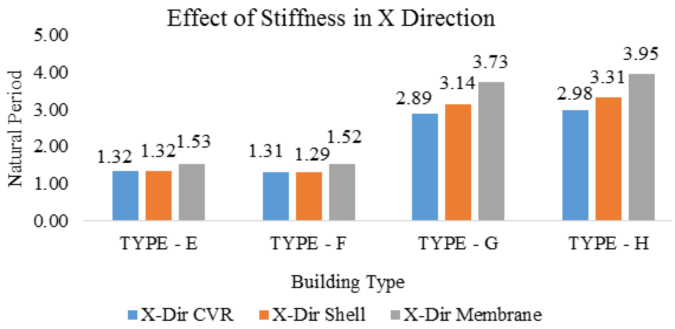

Fig. 2. Effect of Stiffness on Natural Period in coordinate X – Direction

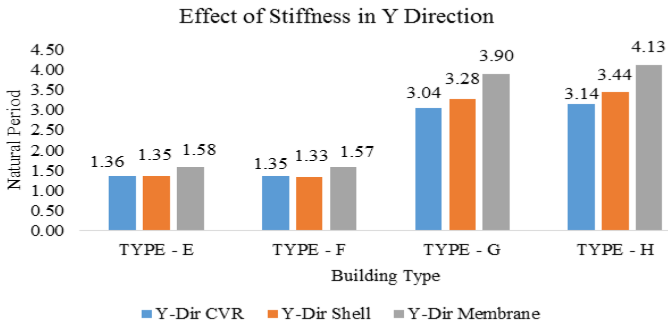

Fig. 3. Effect of Stiffness on Natural Period in coordinate Y - Direction

B. Effect of Mass :

To check this effect of mass building types H, J and K have considered from above 10 types of buildings. Mass of a building that is effective in lateral oscillation during earthquake shaking is called the seismic mass of the building. It is the sum of its seismic masses at different floor levels. Seismic mass at each floor level is equal to full dead load plus appropriate fraction of live load. The fraction of live load depends on the intensity of the live load and how it is connected to the floor slab. An increase in mass of a building increases its natural period. Buildings H, J and K are all 25-storey buildings with same plan size, elevation and column sizes, but with different floor mass. Imposed floor mass in building H is 2,150kN, while that in buildings J and K are 10% and 20% larger, respectively. Fundamental translational natural periods of heavier buildings K and J are larger than that of building H.

Figure 4 and Figure 5 shows comparative results of natural period as per book and as per ETABS shell based and membrane based model in X and Y directions respectively. From both the figures it states that, building K is heavier than building H and J. As the mass of building increases natural period of building increases. Comparative analysis results shows that the natural period is more when it analyses by using ETABS. And from ETABS based model, values of natural period for membrane based model are more than shell based model.

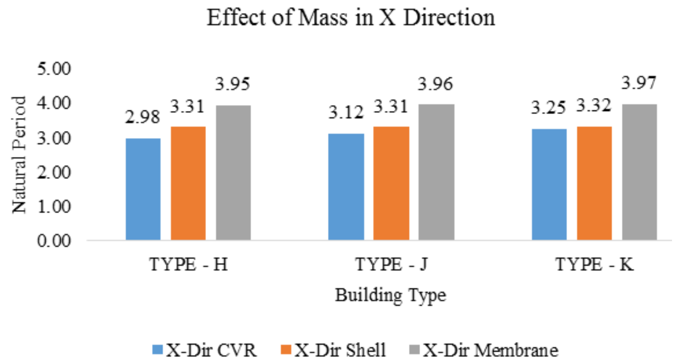

Fig. 4. Effect of Mass on Natural Period in coordinate X – Direction

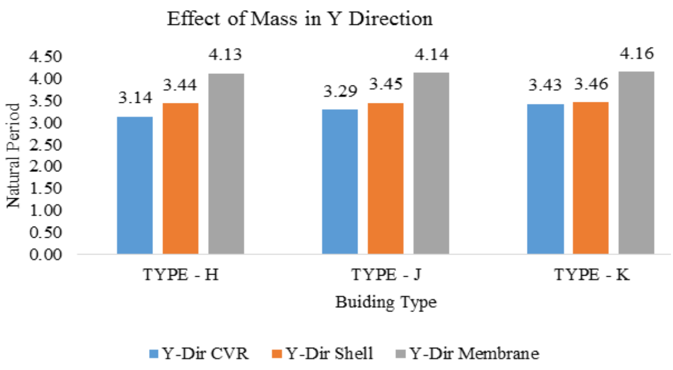

Fig. 5. Effect of Mass on Natural Period in coordinate Y – Direction

C. *Effect of Building Height :*

To check this effect building types A, B, F and H have considered. 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. Buildings A, B, F and H have same plan size, but are of different heights. Taller buildings have larger fundamental natural period than shorter ones, the fundamental translational natural periods for base model of 25-storey building H, 10-storey building F, 5-storey building B and 2-storey building are 3.14s, 1.35s, 0.89s and 0.45s, respectively.

Comparative results of natural period for this effect as per book and as per ETABS shell based and membrane based model in X and Y directions are shown in Figure 6 and Figure 7 respectively. From both the figures it shows that, building H is tallest one as compare to other buildings. As the height of building increases natural period of building increases. For building type A, B, and F there is slight difference of natural period but for building type H there is a vast difference in natural period values. Comparative analysis results shows that the natural period is more when it analyses by using ETABS. And from ETABS based model, values of natural period for membrane based model are more than shell based model.

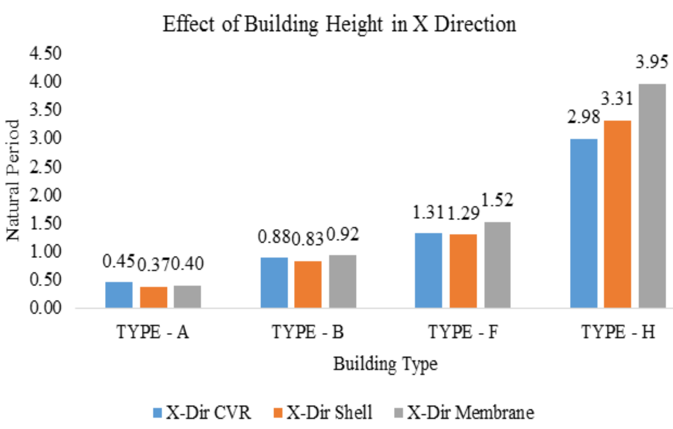

Fig. 6. Effect of Building Height on Natural Period in coordinate X – Direction

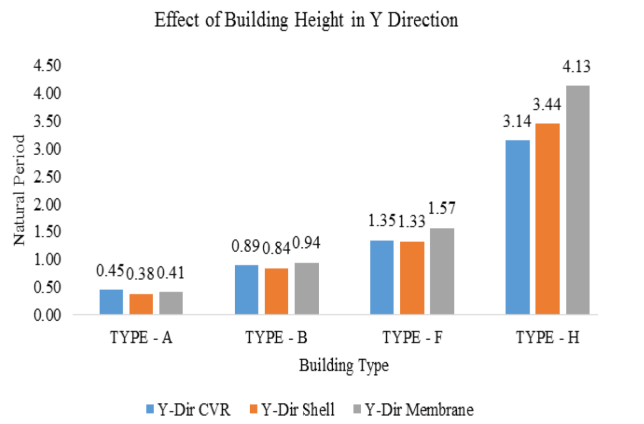

Fig. 7. Effect of Building Height on Natural Period in coordinate Y – Direction

D. *Effect of Column Orientation :*

To check this effect building types B, C and D have considered. 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 type B is 5 storey building having square columns of size 400 mm x 400 mm size. Buildings C and D are two 5-storey buildings with same column area, but with different orientation of rectangular columns. Longer side of 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 the longer direction of column cross-section is smaller than that along the shorter direction.

The results for this effect are shown in Figure 8 and in Figure 9 as per book and as per ETABS shell based and membrane based model in X and Y directions respectively. From Figure 8 it shows that, natural period is more for type D building than B and C. But from Figure 9 it states that, natural period of type C is more than type B as well as type D. For this effect the results of natural period are not relevant. Comparative analysis results shows that the natural period is more when it analyses by using ETABS. And from ETABS based model, values of natural period for membrane based model are more than shell based model.

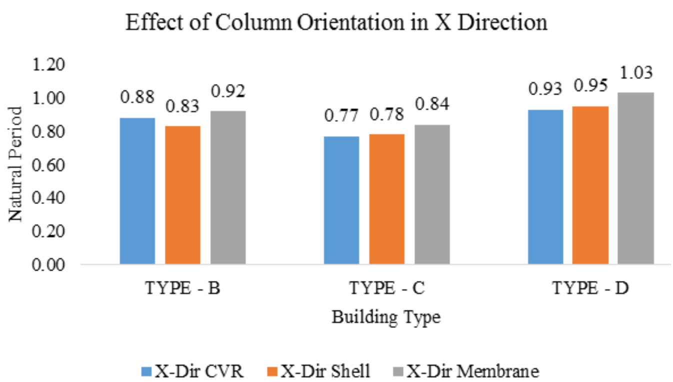

Fig. 8. Effect of Column Orientation on Natural Period in coordinate X – Direction

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 6 Issue 04, April-2017

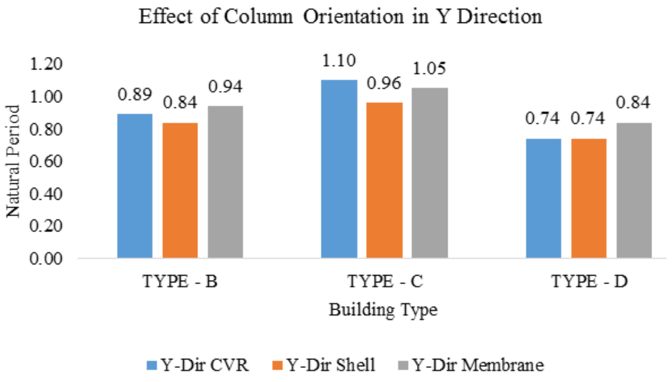

Fig. 9. Effect of Column Orientation on Natural Period in coordinate Y – Direction

IV. CONCLUSION

1. All the test results of this case study which are taken from the book "Earthquake Behaviour of Buildings" of C.V.R. Murty are get verified.
2. As per the various effects, natural period of a building increases when the stiffness of building increases.
3. With the increasing mass of building, natural period is also increases.
4. As the height of building increases, natural period is increases.
5. As per the column orientation of a building, natural period of buildings along the longer direction of column cross-section is smaller than that along the shorter direction.
6. We have plotted two consecutive graphs for each effect showing variation in natural period as per the various types of buildings, in X and Y Direction. So natural period is more in all graphs of Y direction as compare to graphs in X direction.
7. As we have considered here ETABS based model for shell and membrane type and the results of them are compared with the base model it is shown that, for every effect of natural period, values of natural period for base model are lesser than ETABS based membrane and shell model.
8. And the values of membrane based model are more than shell based model.

REFERENCES

[1] C. V. R. Murty, Rupen Goswami, A. R. Vijayanarayanan and Vipul V. Mehta, "Earthquake Behaviour of Buildings".
[2] Sudhir K. Patel, Prof. A. N. Desai, Prof V. B. Patel, "Effect of Number of Storeys to Natural Time Period of Building", National Conference on Recent Trends in Engineering & Technology.
[3] Nilesh v prajapati, Prof. A.N.Desai, "Effect of Height and Number Floors to Natural Time Period of a Multi- Storey Building", International Journal of Emerging Technology and Advanced Engineering, ISSN 2250-2459, Volume 2, Issue 11, November 2012.
[4] Rakesh K. Goel, and Anil K. Chopra, "Period Formulas for Moment-Resisting Frame Buildings".