ANALYSIS OF FACTORS AFFECTING TIME PERIOD OF VIBRATION OF SYMMETRIC RC BUILDING

Prabhat K Soni [1], P Sangamnerkar [2], S K Dubey [3]

1. Maulana Azad Natonal Institute of Technology Bhopal, India
2. M.P. Housing & Infrastructure Development Board Bhopal, India
3. Maulana Azad Natonal Institute of Technology Bhopal, India

ABSTRACT. In the paper, analysis of symmetric reinforced concrete building is presented to evaluate the time period of vibration of building under seismic excitation. It is observed that seismic design codes provide empirical expressions to evaluate fundamental period of vibration of reinforced concrete (RC) buildings to derive design base shear. Empirical equations are given in the seismic code of the different countries for the calculation of the fundamental period of a framed structure. In the Indian Seismic Code also, these equations of time period are primarily either as a function of height or the number of storey. It is noted that the effect of stiffness of the structure and the beam thickness on time period is not included in these expressions. Time periods predicted by these equations are currently used in practice, although it has been observed by different researchers that there is further scope for improvisation in the expressions, as the height alone seems to be inadequate to explain the period variability. The aim of this study is to evaluate the effects of slab thickness and stiffness of the structure on time period of vibration performing dynamic analysis on structural configurations. The paper suggests that there is scope to incorporate these factors in time period formula given in Indian Standard Code IS1893 to find out more realistic values of the time period.

Keywords: Dynamic Analysis, Time Period, Vibration, Stiffness.

Prabhat K. Soni is a research scholar of civil engineering, Maulana Azad National Institute of Technology Bhopal (M.P.), India, has published on subject of Steel structures, Seismic Analysis. Telephone: (91)6263864049, Email Id: prabhatsoni15@gmail.com

Dr Prakash Sangamnerkar is Assistant Engineer in M.P. Housing & Infrastructure Development Board, Bhopal (M.P.), India, His research area of interest includes Vibration Analysis, Steel Framed Structures and High Rise Structures.
Telephone: (91)9406912035, Email Id: nerkar17@rediffmail.com

Dr S.K.Dubey, is Professor in Civil Engineering, Maulana Azad National Institute of Technology Bhopal (M.P.), India, His research area of interest includes Earthquake Engineering, R.C.C Structures, Composite Beam.
Telephone :(91)9424455828, Email Id: dubeysk2000@yahoo.com

LITERATURE STUDY

The fundamental period of vibration required for the simplified design of RC structures has been calculated for many years using a simplified formula relating the period to the height of the building.

Verderame et al. [7] pointed out that height alone seems inadequate to explain period variability. Nyrko et al. [8] proposed seven different equations in their study, in order to determine more accurate expressions for the elastic period they considered seven basic expressions as:

$$T = C_1 N^{C2} \tag{1}$$

$$T = C_1 N^{C2} B^{C3} \tag{2}$$

$$T = C_1 N^{C2} + C_3 B^{C4} \tag{3}$$

$$T = C_1 N^{C2} \left(\frac{B_x}{B_y} \right)^{KC3} \tag{4}$$

$$T = C_1 N^{C2} \left(B_x . B_y \right)^{C3} \tag{5}$$

$$T = C_1 N^{C2} + C_3 \left(B_x . B_y \right)^{C4} \tag{6}$$

$$T = C_1 N^{C2} + C_3 \left(\frac{B_x}{B_y} \right)^{C4} \tag{7}$$

Where, N is the number of stories, B is the number of bays of the building parallel to the considered direction, B_x is the number of bays in longitudinal direction, B_y is the number of bays in transversal direction, C_1, C_2, C_3 and C_4 are (unknown) parameters that need to be determined.

INTRODUCTION

The fundamental period of vibration depends upon the distribution of mass and stiffness along the height of the building and estimation of seismic base shear requires the fundamental natural period of vibration T of the building. Seismic induced dynamic forces and its directions vary substantially with time cause considerable inertia forces on the buildings. The approximate fundamental natural period of vibration (T_a) in second of a moment resisting frames building without brick infill panels may be estimated by empirical expression given in Indian seismic code IS1893 (Part-1) -2016 [5]

$$T_a = 0.075h^{0.75} \quad \text{for R.C. frame building} \tag{8}$$

$$= 0.085h^{0.75} \quad \text{for steel frame building} \tag{9}$$

$$T_a = 0.09\ h / \sqrt{d} \qquad \text{for all other buildings} \qquad (10)$$

The fundamental period can be evaluated using simplified expressions (1) to (3) found in codes, Building periods predicted by these expressions are widely used in practice, although it has been pointed out by Khan and Hoqueb [6], Verderame et.al. [7]. they discussed about scope for further improvement in these equations since the height alone is inadequate to explain period variability.

ANALYSIS

Design Parameters

Different values of the time period have been obtained by performing dynamic analysis on building / structural configurations for different parameters of the building and earthquake zone III, as per the provisions given in the Indian seismic code. Computer software STAAD [9] has been used to analyze the building model. General arrangement of beams and columns are depicted as figure below:

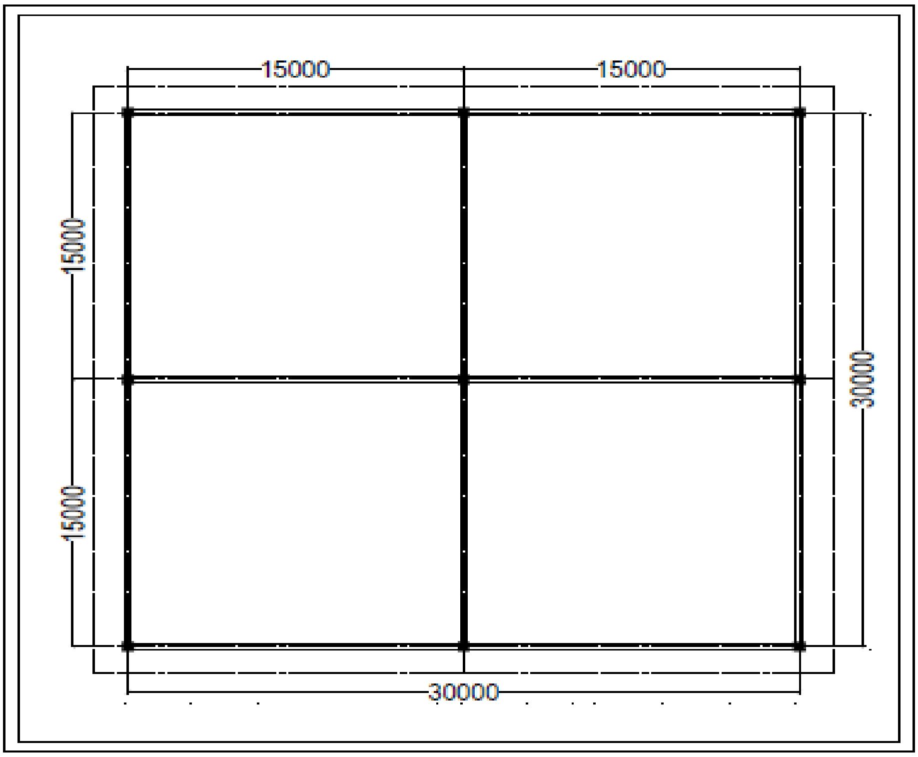

Figure 1 plan for 2 - Bay square shaped building.

Table 1 Details of building configuration, material used & structure

BUILDING CONFIGURATION		MATERIAL SPECIFICATION		STRUCTURAL DETAILS	
Type of structure	Multi-storey rigid jointed plane frames	Material used	Concrete M-25 and Reinforcement Fe-415.	Size of columns	0.5×0.5 m 0.4×0.4 m 0.3×0.3 m
No. of storey	GF to G+5.	Type of soil	Type -II, Medium soil as per IS-1893	Thickness of slab	150 mm
Floor height	3.6 m	E_c	$5000\sqrt{f_{ck}}$ N/mm^2	Imposed load	4.00 kN/m^2
				Floor finish	1.00 kN/m^2
Slab thickness	100 mm, 150 mm, 200 mm	F_{cr}	$0.7\sqrt{f_{ck}}$ N/mm^2	Water proofing	2.5 kN/m^2
				Specific wt. Of R.C.C.	25 kN/m^3

Table 2 Period values (sec) for column size 500×500 mm – 2 bays

BUILDING HEIGHT (m)	SLAB THICKNESS		
	100.00 mm	150.00 mm	200.00 mm
3.60	0.75	0.83	0.89
7.20	1.35	1.47	1.58
10.80	1.96	2.13	2.28
14.40	2.55	2.75	2.95
18.00	3.15	3.39	3.62
21.60	3.85	4.12	4.38

Table 3 Period values (sec) for column size 400×400 mm – 2 bays

BUILDING HEIGHT (m)	SLAB THICKNESS		
	100.00 mm	150.00 mm	200.00 mm
3.60	0.93	1.02	1.01
7.20	1.61	1.76	1.89
10.80	2.30	2.49	2.66
14.40	2.95	3.18	3.40
18.00	3.60	3.88	4.14
21.60	4.38	4.69	4.99

Table 4 Period values (sec) for column size 300×300 mm – 2 bays

BUILDING HEIGHT (m)	SLAB THICKNESS		
	100.00 mm	150.00 mm	200.00 mm
3.60	1.29	1.42	1.54
7.20	2.16	2.35	2.53
10.80	3.01	3.26	3.49
14.40	3.84	4.14	4.42
18.00	4.68	5.04	5.37
21.60	5.68	6.08	6.46

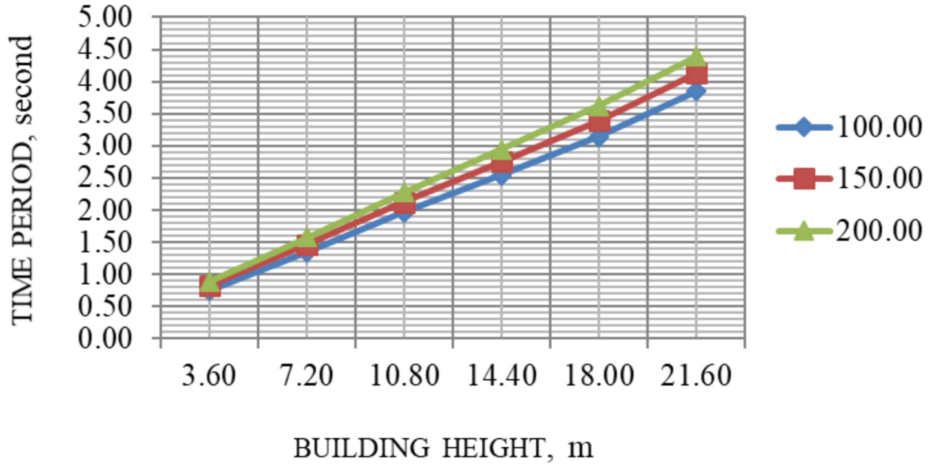

Figure 2 variation of period values(sec),column size 0.5×0.5m

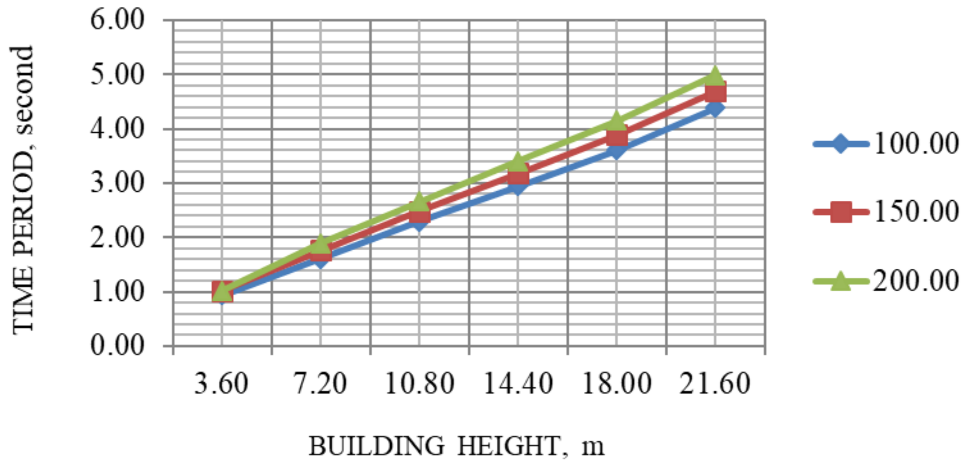

Figure 3 variation of period value(sec),column size 0.4× 0.4 m

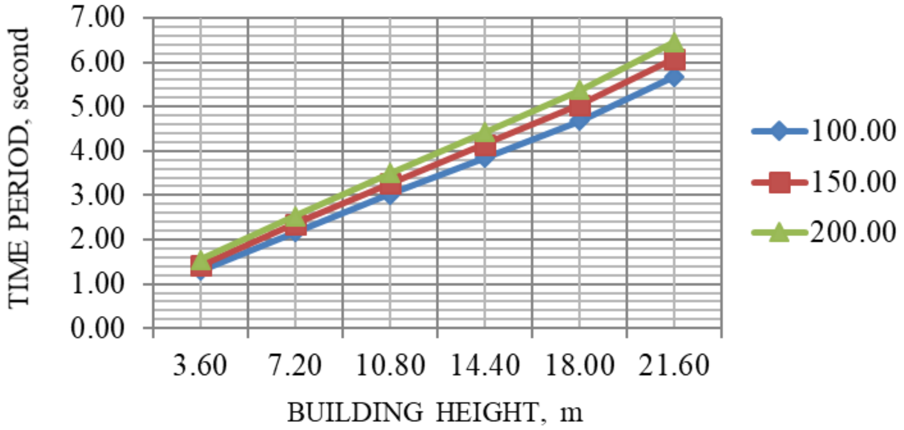

Figure 4 variation of period value(sec),column size 0.3×0.3 m

Tables (2) – (4) and Figures (2) – (4) show that time period is also increasing with increase in thickness of the slab, and hence the effect of the same cannot be ignored. For slab thickness 100mm & 200mm, fig (2) shows that there is increment in time period as 18.7% & 13.8% with column size 500mm×500mm for building height 3.6m & 21.6m respectively. From fig (3), it can be observed, the variation in time period comes out as 8.6% &13.9% with column size 400mm×400mm. similarly, time period increase to 19.4% & 13.7% with column size 300mm×300mm(fig.4) for beam thickness 100mm & 200mm for building height 3.6m and 21.6 m.

CONCLUDING REMARKS

It can be observed from Figs. (2) to (4), with variation of slab thickness, time period is also showing variation in its values. Hence, the effect of the same cannot be ignored. Therefore, height alone seems inadequate to evaluate period of vibration and the results of this study suggest that thickness of slab along with stiffness of the structure also affect the time period of vibration. Hence there is need to incorporate these factors in simplified relationships given in IS 1893,for evaluation of time period of vibration in seismic analysis.

REFERENCES

1. PANZERA F, LOMBARDO G, MUZZETTA I, Evaluation of building dynamic properties through in situ experimental techniques and 1D modeling: The example of Catania, Itly, Physics and Chemistry of the Earth, Elsevier, 2013, 63, pp. 136 - 146.
2. SHA J, SHI W, WANG J, Regional study on structural dynamic property of buildings in China, Earthquake Engineering and Structural Dynamics, John wiley publ.,2013, 42, pp. 1013-1029.

3. OLIVERIA C S, NAVARRO M, Fundamental period of vibration of RC buildings in Portugal in-situ experimental and numerical techniques, Bull Earthquake Engineering, Springer, 2010, 8, pp. 609 – 642.

4. ANIL O, ALTIN S, An experimental study on reinforced concrete partially infilled frames. Eng Struct, 2007, 29(3), pp.449-60.

5. BUREAU OF INDIAN STANDARDS. Criteria for Earthquake resistant design of structures-Part-1, General Provisions and Buildings, IS 1893(Part 1):2016, Bureau of Indian Standards, New Delhi.

6. KHAN M A, HOQUEB E, A rational for determining the natural period of RC building frames having infill, Engineering Structures, Elsevier, 2006, 28, pp 495-502.

7. VERDERAME G M, IERVOLINO I, MANFREDI G, Elastic period of existing RC-MRF buildings, Eurocode 8 Perespectives from Indian standpoint Workshop, Napoli, Italy, 2009, pp 79-94.

8. NYRKO M H, MORIE D, DRAGANIC H, NYARKO E K, New direction based (Fundamental) periods of RC frames using Genetic Algorithms, 15th World Conference on earthquake engineering, Lisboa ,2012.

9. KWON O S, KIM E S, Evaluation of building period formulas for seismic design,Earthquake Engineering and Structural Dynamics, 2010, 39, pp.1569-1583.

10. GOEL R K, CHOPRA A K, Period formulas for moment-resisting frame buildings, Structure Eng Div ASCE, 1997, 123 pp 1454-1461.

11. GONG M, SUN J, XUE L, Emperical Formula of Fundamental Period for Steel Structure Based on Seismic Response Record. International Conference on Civil Engineering (ICETCE), Lushan, China, 2011, pp. 283-286.

12. GULER K, YUKSEL E, KOCAK A, Estimation of the fundamental vibration period of existing RC buildings in Turkey utilizing ambient vibration records, Journal of Earthquake Engineering 12(SUPPL. 2), 2008, pp. 140–150.

13. HONG L L, HWANG W L, Empirical formula for fundamental vibration periods of reinforced concrete buildings in Taiwan, Earthquake Engineering and Structural Dynamics, 2000, 9(3), pp. 327–337.

14. CROWLEY H, PINHO R, Simplified equations for estimating the period of vibration of existing buildings. First European Conference on Earthquake Engineering and Seismology, Geneva, Switzerland, 2006.

15. GALLIPOLI M R et al, Empirical estimates of dynamic parameters on a large set of European buildings, Bulletin of Earthquake Engineering, 2010, 8(3), pp. 593–607.

16. INGLE R K, Time Period of elevated water tower, Indian Concrete Journal, 1997, 71, pp. 497.

17. STAAD PRO-V8i –Structural analyses and designing software by Bentely.

18. BUREAU OF INDIAN STANDARDS. Code of practice for structural safety loadings standards IS-875-1987 Part-1, 2 Bureau of Indian Standards, New Delhi.