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Estimation of Natural Period based on Dynamic Analysis for Regular Structures with Shear Wall

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Abstract: *Indian seismic code IS – 1893 (Part-1): 2016 provide guideline to calculate natural period of building with shear wall for static analysis. In the present paper, an attempt has been made to evaluate the natural period for regular building with shear wall and to develop a formula to calculate natural period of building with shear wall. In this work multi-storied RC frame symmetric building with different plan configuration, different storey height and different building height with different length of shear wall along with brick masonry infill panels has been considered. All the building have been analyzed and design as per Indian Codal Provision and Dynamic analysis has been performed using ETABS software and natural period of fundamental mode has been evaluated. Based on natural period results the new formula for calculating time period of building has been proposed by method of regression analysis using Microsoft-Excel.*

List of symbols

Symbol	**Explanation**
A_h	Design Horizontal Seismic Coefficient
A_{wi}	Effective Surface Area of Shear wall in wall i in first storey
d	Base Dimension of the Building at the Plinth Level (m), along the Considered Direction of Lateral Force
h	Height of Building (m)
L_{wi}	Length of Shear Wall
N_w	Number of Shear Wall
r	Correlation coefficient
S_a/g	Spectral Acceleration Coefficient
T	Natural period based on dynamic analysis in ETABS
T_a	Natural Period based on code formula
T_r	Natural period based on obtained formula
V_b	Design Seismic Base Shear

I. Introduction

Natural period of building is key parameter for seismic design of building. Most seismic codes provide empirical formula to estimate the fundamental vibration period of building. It is, however, shown that the code formulae provide period that are generally shorter than measured periods. Only few countries seismic codes provide formula to calculate the fundamental period of building with shear wall. Indian seismic code provides guideline to calculate Natural period of building with shear wall in IS – 1893 (Part-1): 2016. The formula given in Indian code predicts very lower value of time period. To develop a formula to calculate Natural period of building is area of research, so in this research work an attempt has been made to propose a new formula to calculate the natural period of building with shear wall.

Formula given in IS: 1893 (part-1) for calculating natural period of building is

$$T = \frac{0.075h^{0.75}}{\sqrt{A_w}} \qquad (1)$$

Where, area of shear wall A_w is,

$$A_w = \sum_{i=1}^{N_w}\left[A_{wi}\left\{0.2 + \left(\frac{L_{wi}}{h}\right)^2\right\}\right]$$

Where,

$$\frac{L_{wi}}{h} \leq 0.9$$

In the past, researchers have studied the effect of shear wall on natural period.
Goel and Chopra (1997,1998) Evaluated the formulas specified in present U.S. codes using the available data on the fundamental period of buildings "measured" from their motions recorded during eight California earthquakes, It is shown that current code formulas for estimating the fundamental period of RC and Steel MRF buildings improved better correlation with measured data. Subsequently, an improved formula is developed by calibrating a theoretical formula through regression analysis. Balkaya and Kalkan (2003) studied consistency of equations in Uniform Building Code and Turkish Seismic Code related to their dynamic properties are investigated and it is observed that the given empirical equations for prediction of fundamental periods of this special type of structures yield inaccurate results. The results of the analyses demonstrate that given formulas including new parameters provide accurate predictions for the broad range of different architectural configurations, roof heights and shear-wall distributions, and may be used as an efficient tool for the implicit design of these structures. Ghrib and Mamedov (2004) Estimated Period formulas of shear wall buildings with flexible bases. Results show that natural period formulas used by UBC-97 and NBCC-95 are inadequate since they do not include the effect of the foundation stiffness. Q. Wang and L.Y Wang(2005) Generated the resulting equation for natural vibration of buildings with uniform coupled shear walls is manual method for determining the first two periods of natural vibration of the buildings is presented to provide the centre of resistance and mass are coincided so that the structure does not twist. The method is accurate to within 2% for the fundamental mode of vibration and to within 15% for the second mode of vibration. Cinitha, umesha et.al (2012) Use a rational approach for fundamental natural period of low and medium rise steel building frames. It is found that the fundamental natural frequency decreases with increase in height and width increase in plan area the fundamental frequency of the buildings is found to be increasing. M.I Salama (2014) Improved formulas for estimating the fundamental period of vibration (T) of RC MRF buildings are developed by taking the effect of both building height (H) and number of stories together (N). The improved formula is based on regression analysis of the available data for the fundamental vibration period of RC MRF buildings measured from their motions recorded during eight California earthquakes.

II. Regression Analysis

Here in this case dependent variable is natural period (second) and independent variables are building height (m) and area of shear wall (m^2).

For deriving a formula using regression analysis, number of samples are required as input to analysis. To generate generalized formula lot of samples would be required and the size of the problem will also become very large to be dealt with. To incorporate these all variables, some random regular buildings are modeled, analyzed and designed in ETABS. All the buildings are designed as per Indian codal provision as per IS 456 and IS 1893, based on the actual design requirements, the time period of the buildings with optimum section have been investigated.

figure 1: Plan view of building with shear wall

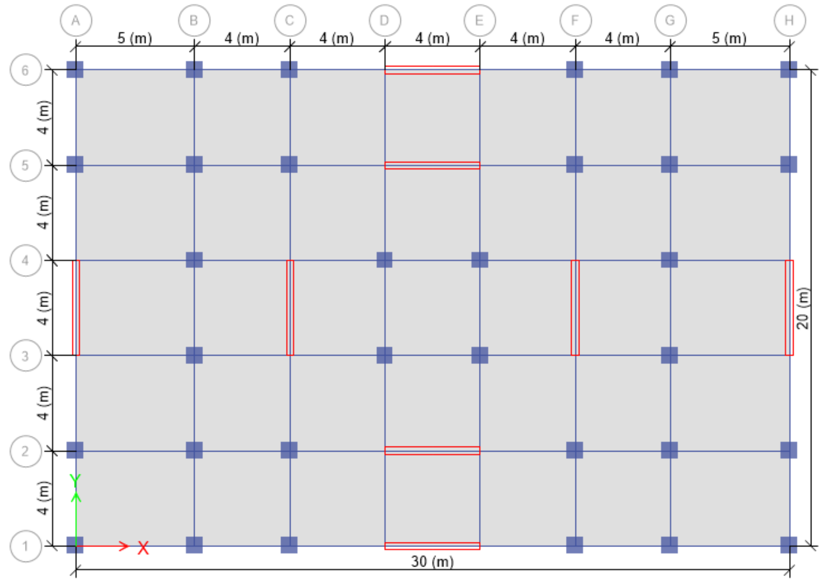

Figure 2: 3D view of building with shear wall

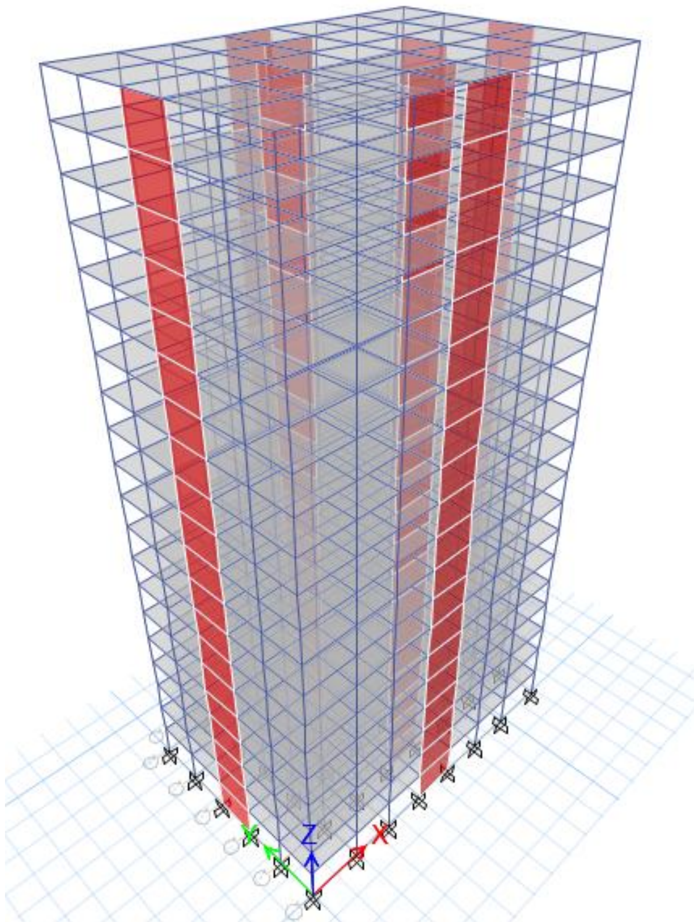

Table 1: Results of natural period from dynamic analysis in ETABS

Plan Dimension (m)	Height H (m)	Area of Shear Wall A_w (m^2)	ETABS Natural Period (second)
17 X 9	39	0.243	2.22
16 X 16	46.5	0.664	2.457
37 X 37	48	11.947	1.871
20.5 X 20.5	67.2	1.028	3.185
25 X 25	49.5	1.288	3.088
28.5 X 28.5	60	8.549	2.286
37 X 37	86.4	8.997	3.619
19.5 X 19.5	45	3.136	1.755
30 X 20	93	1.991	2.862
32.5 X 18.5	66	1.0287	3.02
39 X 21	54	4.788	2.663
20X10	57	0.935	2.675
40 X20	60	4.987	2.987
16 X 16	93	0.646	4.218
25 X 25	46.2	1.301	2.977

Format of proposed equation for multi linear regression analysis,

$$T_r = \frac{ah^b}{Aw^c} \quad (2)$$

Table 2 shows the results of dynamic analysis of selected models for the regression analysis which analysed and designed in ETABS.

Table 2: Data considered for regression analysis

Plan Dimension (m)	Height H (m)	Area of Shear Wall A_w (m^2)	ETABS Natural Period T (second)
17 x 9	39	0.243	2.22
16 X 16	46.5	0.663	2.457
37 X 37	48	11.946	1.871
20.5 X 20.5	67.2	1.027	3.185
30 X 20	60	8.549	2.286
20X10	57	0.934	2.675
r	**0.045**		

For multi linear regression analysis taking natural log both side,

$\ln T_r = \ln a + \ln h^b - \ln A_w^c$

$\ln T_r = \ln a + b \ln h - c \ln A_w$

III. Result

Table 3: Regression analysis output using ANOVA

SUMMARY OUTPUT		Explanation
Regression Statistics		
Multiple R	0.992	R = square root of R^2
R Square	0.984	R^2
Adjusted R Square	0.974	Adjusted R^2 used if more than one x variable
Standard Error	0.028	This is the sample estimate of the standard deviation of the error
Observations	6	Number of observations used in the regression (n)

Table 4: Regression analysis output using ANOVA

ANOVA					
	df	*SS*	*MS*	*F*	*Significance F*
regression	2	0.160	0.080	98.42	0.001
residual	3	0.002	0.001		
total	5	0.162			

Here, Correlation Coefficient between H and A_w = 0.045 So multi co-linearity is almost zero, it means there is no relation exist between height of building and area of shear wall, so these two can be taken as two independent variable. So Multi collinear regression analysis in this case gives best results. If R^2 value closer to 1, the better the regression line fits the data. Here the R^2 = 0.984, which shows that regression line give the best fit for the given data.

ANOVA analysis give value like degree of freedom (df), sum of square (SS), mean sum of square (MS) and significance F. To check our results are reliable (statistically significant),

To check the results are reliable or not (statistically significant), look Significance F value. If this value is less than 0.05, then it's ok. If Significance F is greater than 0.05, it's probably better to stop using this set of independent variables. In our case F = 0.001 which is less than the specified value 0.05 which shows that it may give reliable results.

Through regression analysis in ANOVA analysis tool for developing formula for regular buildings, results are as below.

Table 5: Coefficients for formula

	Coefficients	Standard Error	t Stat	P-value
a	-2.468	0.272	-9.058	0.003
b	0.859	0.069	12.401	0.001
c	-0.096	0.009	-10.664	0.002

So, a = exp (-2.468) = 0.084772

Equation (3) is the propose equation obtained through regression analysis which gives the natural period

$$T_f = \frac{0.084h^{0.859}}{Aw^{0.096}} \tag{3}$$

Table 6: Results of obtained equation through regression analysis for considered data

H (m)	A_w (m^2)	T (sec)	T_r (sec)	ERROR w.r.t dynamic analysis (%)
39	0.243	2.22	2.254	-1.55265
46.5	0.663	2.457	2.381	3.073115
48	11.946	1.871	1.855	0.835367
67.2	1.027	3.185	3.133	1.635373
60	8.549	2.286	2.320	-1.50201
57	0.934	2.675	2.744	-2.61104
r =	0.045		Average Error =	1.868

Table 7: Results of obtained equation through regression analysis for other models

H (m)	**A_w (m^2)**	**T (sec)**	**T_r (sec)**	ERROR w.r.t dynamic analysis (%)
93	0.646	4.218	4.330	-2.639
32	1.122	1.628	1.643	-0.927
71.3	0.650	3.583	3.444	3.874

Limitations for obtained formula of natural period for regular structures,

(a) Building longest plan dimension should not be more than 40m.

(b) Building should not have length of span more than 6m.

(c) Dimension of all columns and beams for particular storey should be same.

(d) Formula is valid for building height up to 90m.

IV. Conclusion

It is observed that Natural period given by code formula is much lesser than the natural period obtain by dynamic analysis. Natural period is less then Sa/g will be higher and due to that seismic coefficient A_h will be higher. If A_h will higher it will give higher value of base shear v_b and structure need to design for that higher force and it makes uneconomical structural design. In the present research work the exclusive formula has been developed which gives directly the natural time period of building which is otherwise to be obtained through actual dynamic analysis

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