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Derivation of Empirical Formula of Natural Period for Irregular Building with Shear Wall

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Abstract: *Indian seismic code IS – 1893 (Part-1): 2016 give rules to calculate the natural period of the building with the shear wall for static analysis, In the current paper, an endeavor has been made to assess the characteristic natural period for regular building with shear wall and stiffness Irregular building with shear wall to drive a formula to compute the natural period of building with the shear wall. In this work multi-storied RC frame symmetric and asymmetric building with different plan dimensions, different structure height, different shear wall dimensions with considering brick masonry. All the structures are analyzed and designed by Indian standard Codal Provision and Dynamic analysis has been performed using ETABS software to evaluate the natural period of the fundamental mode. Based on natural period results the new formula for calculating the period of the building has been proposed by the method of regression analysis using IBM SPSS.*

Keywords: *Natural Period, Regression Analysis, ETABS.*

I. INTRODUCTION

The natural period of building is a key parameter for the seismic design of buildings. Most seismic codes provide an empirical formula to estimate the fundamental vibration period of the building. It is, however, show that the code formulae provide a period that is generally shorter than measured periods. Only a few countries' seismic codes provide a formula to calculate the fundamental period of building with the shear wall. Indian seismic code provides guidelines to calculate the Natural period of building with the shear wall in IS – 1893 (Part-1): 2016.

$$T = \frac{0.075h^{0.75}}{\sqrt{A_w}}$$

Where, harean 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,

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

The formula given in the Indian code predicts a very lower value of the period. The basic concept of the Nature Period of the building is

1. Natural periods of buildings reduce with an increase in stiffness.

2. Natural periods of buildings increase with the increase in mass.

3. Taller buildings have larger fundamental translational natural periods.

4. Buildings tend to oscillate in the directions in which they are most flexible and have larger translational natural periods.

5. Natural periods of buildings depend on the amount and extent of the spatial distribution of unreinforced masonry infill walls.

To develop a formula to calculate the Natural period of building is the 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 the shear wall.

In the past, researchers have studied the effect of the shear wall on the natural period.

Chotaliya et al. (2018) It has been made to evaluate the natural period for regular buildings with shear walls and to develop a formula to calculate the natural period of building with the shear wall. In this work multi-storied RC frame symmetric building with different plan configuration, different story height and different building height with different length of the shear wall along with brick masonry infill panels has been considered. 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, the improved formula is developed by calibrating a theoretical formula through regression analysis. Velani and Ramancharla(2017) This is studying the reliability of empirical expression of the fundamental period for tall buildings in India. For this purpose, ambient vibration tests have been carried out for 21 RC buildings, located in Mumbai and Hyderabad cities, by placing vibration sensors on the topmost accessible floor. The measured periods have been compared with the code provisions. It is found in the study that as the height of the building increases, the natural period is not linearly proportional to the height; rather it is becoming flexible. Kewate and Murudi (2018) The review of previous literature shows that the code proposed expressions were based on regression analysis performed on the data set consisting of an experimentally determined period of few buildings located in a certain region. An extensive literature review suggested that code limits on the period are too conservative. The database must have been expanded to include the results of the new earthquake data. El-saad and Salama(2017) It is using the available data for the fundamental vibration period of reinforced concrete shear wall buildings measured from their motions recorded during eight California earthquakes, improved formulas for estimating the fundamental period of vibration (T) of concrete shear wall buildings are developed by regression analysis of the measured period data. The results indicate that the value of coefficient Ct in the current US and Egyptian building codes formula should be decreased from its present value of 0.02 to 0.014. Sudhir K Jain (1995) The provisions for seismic design of buildings contained in IS 1893-1984 need to be the view of many deficiencies that are currently being felt. This paper provided a detailed commentary to explain the proposed coal provision. In this study, many researchers conclude natural period mainly depends on the stiffness and height of the building. That way needs to develop new formulas is included height of building, stiffness, and width of the building.

A. Regression Analysis

Regression analysis is a statistical technique for investigating and modeling the relationship between variables. It is said that regression methods are used with the continuous response (dependent (y)) and explanatory (independent (x)) variables. It is a powerful and flexible procedure for analyzing associative relationships between a metric (quantitative) dependent variable and one or more independent variables. Here in this case the dependent variable is the natural period (second) and independent variables are building height (m), building width(m), and moment of inertia (m^4). For deriving a formula using regression analysis, a number of samples are required as input to the analysis. To generate a 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 variables, some random regular buildings and asymmetric 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 period of the buildings with optimum section have been investigated.

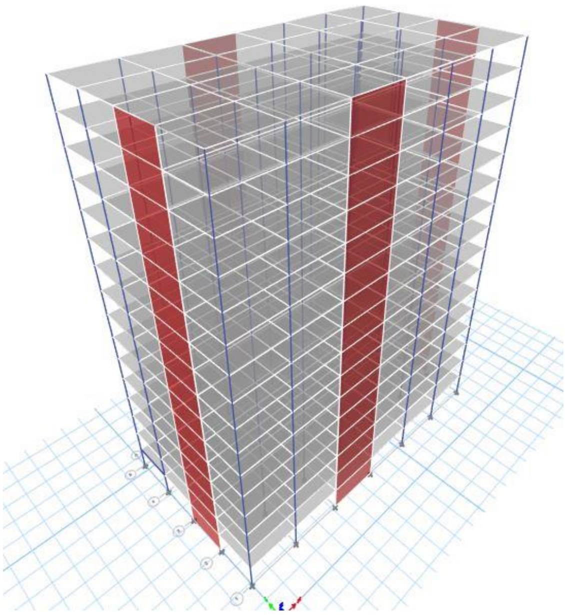

Fig -1: Isometric view of ETABS Model

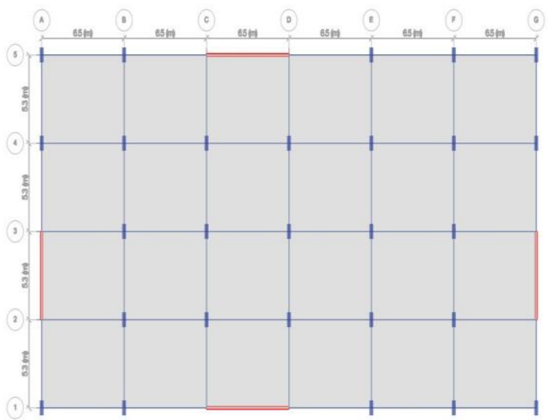

Fig -2: Plan view of ETABS Model

Table -1
Final Data consider for Regression Analysis

ETABS Natural Period (second)	Building Height H(m)	Building Width D(m)	Moment of Inertia $I(m^4)$
0.805	18	22.5	1.57215
1.425	44	33.8	1.4947
1.97	52.8	39	5.848569
2.111	48	21.2	5.848569
2.213	46.2	18	5.457375
1.818	39.6	25	4.855806
1.943	46.2	47.1	4.513306
0.995	25.2	30	4.149438
0.808	21.6	54	4.149438
1.559	33	18	3.6459
1.789	50.4	41.5	3.387013
2.255	48	23.5	3.259438
1.421	33	35	3.181813
0.785	25.2	45	2.829094
1.118	25.2	22.5	2.350856
1.816	42.9	26.5	2.326516
2.35	46.5	23.5	2.148967
0.666	16	33.5	1.9467
1.978	46.2	33.8	1.919363
1.177	27	48	1.65535
1.022	24	22	1.6441
2.083	44	21	1.3003
2.4	50.4	18.8	1.154844

Here shows table: - 1 is building modeling in ETABS this analysis and design. Then consider 1st mode natural period is noted and width of building and height of the building is noted this data sheet are generated show many models are used. This data shows the final regression used in SPSS Modeling. Then set all variables in the below formula form used in final regression.

Format of the proposed equation for multilinear regression analysis,

$$\mathbf{T} = \frac{\mathbf{ah^b}}{\mathbf{D^c I^d}}$$

For multi linear regression analysis taking natural log both side,

$\ln T = \ln a + \ln h^b – \ln D^c - \ln I^d$

$\ln T = \ln a + b \ln h - c \ln D – d \ln I$

II. RESULT AND DISCUSSION

A. RESULTS

Table -2
Regression analysis output using SPSS

SUMMARY OUTPUT		Explanation
Regression Statistics		
Multiple R	0.971	R = square root of R^2
R Square	0.944	R^2
Adjusted R Square	0.934	Adjusted R^2 used if more than one x variable
Standard Error	0.09942	This is a sample estimate of the standard deviation of the error
Observations	25	Number of observations used in the regression(n)

Table -3
Regression analysis output using SPSS in Model Summery

Model Summary									
					Change Statistics				
Model	R	R Square	Adjusted R Square	Std. The error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change
1	.971[a]	.944	.936	.09942	.944	117.339	3	21	.000
a. Predictors: (Constant), I, D, H									
b. Dependent Variable: T									

Table -4
Regression analysis output using SPSS in ANOVA

ANOVA						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	3.479	3	1.160	117.339	.000[b]
	Residual	.208	21	.010		
	Total	3.687	24			
a. Dependent Variable: T						
b. Predictors: (Constant), I, D, H						

Here, Correlation Coefficient between H and D = -0.158, H and I = 0.229 and I and D = 0.150. So multi co-linearity is nearer to zero, it means there are no relationships exist between the height of building and width of the building, the relationship between height and in the direction of moment of inertia not exist, also between depth and in this direction of moment of inertia no relationship exists. so, there can be taken as three independent variables. So Multi collinear regression analysis, in this case, gives the best results. If the R2 value is closer to 1, the better the regression line fits the data. Here the R2 = 0.944 (table: - 2&3), which shows that the regression line gives the best fit for the given data.

ANOVA analysis gives value like a degree of freedom (df), the 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 = 0.000 nearest to zero. (table: - 4) 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 a formula for regular buildings, results are as below.

Table -5
Regression analysis output using SPSS in Coefficients

Coefficients									
		Unstandardized Coefficients		Standardized Coefficients			Correlations		
Model		B	Std. Error	Beta	t	Sig.	Zero-order	Partial	Part
1	(Constant)	-2.467	.323		-7.644	.000			
	H	1.031	.060	.925	17.049	.000	.950	.966	.883
	D	-.233	.063	-.197	-3.686	.001	-.348	-.627	-.191
	I	-.020	.038	-.028	-.516	.611	.154	-.112	-.027
a. Dependent Variable: T									

B. Formula Derived

So, a = exp (-2.467) = 0.085

It is the proposed equation obtained through regression analysis that gives the natural period

$$\mathbf{T} = \frac{\mathbf{0.085h}}{\mathbf{D^{0.23} I^{0.02}}}$$

Where,

H= Hight of Building (m)

D= Width of Building(m)

I= in direction of MOI(m^4)

I=$\frac{bd^3}{12}$x(nos. of column/shear wall in the direction)

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

Height of Building H(m)	Width of Building D(m)	Moment of inertia I(m^4)	The period from ETABS T(sec)	The period from Formula T (sec)	Error (%)
18	22.5	1.57215	0.805	0.777189	3.454791
28.8	22.8	1.020467	1.206	1.250432	3.684275
52.8	39	5.848569	1.97	1.953518	0.836657
48	21.2	5.848569	2.111	2.046947	3.034271
46.2	18	5.457375	2.213	2.049587	7.384239
25.2	22.5	2.350856	1.118	1.079344	3.457576
42.9	26.5	2.326516	1.816	1.769088	2.58327
25.2	30	4.149438	0.995	0.997962	0.29769
21.6	54	4.149438	0.808	0.745914	7.683917
33	18	3.6459	1.559	1.475849	5.333625
50.4	41.5	3.387013	1.789	1.85811	3.863072
16	33.6	1.9467	0.666	0.626527	5.926949
24	22	1.6441	1.022	1.04076	1.835642
44	21	1.3003	2.083	1.937926	6.96466
50.4	18.8	1.154844	2.471	2.283199	7.600195
Average Error = 4.27 %					

C. Formulas Limitations

Limitations for this formula.

[1] The building plan dimension should not be more than 50m.
[2] The building should not have a single bay length of the span of more than 8m.
[3] All story dimensions should be the same.
[4] This formula validates ab to 50-meter height

III. CONCLUSIONS

This investigation on the evaluation of code formula for a natural period of building leads to the following conclusion:

[1] For high-rise, building evaluated value of natural period using codal formula gives less value compere to period evaluated from dynamic analysis in ETABS.

[2] The code formulas for estimating the periods of RCC buildings with a shear wall almost always give to higher values of seismic coefficients compared to the values based on measured periods in ETABS.

[3] For less value of natural period gives a higher value of Sa/g which results in higher value seismic coefficient. So, ultimately the value of base shear V_b becomes more which leads to that higher force and it makes the uneconomical structural design.

[4] In the present research work, the exclusive formula has been developed which gives directly the natural periods of the building which is otherwise to be obtained through actual dynamic analysis.

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