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Time Period Analysis of Reinforced Concrete Framed Buildings

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Abstract - *The approximate fundamental natural period of vibration in seconds of a moment resisting frames building without brick infill panels may be estimated by the following empirical expressions of IS 1893:2016*

T_a	=	$0.075h^{0.75}$	*for R.C. frame building*
	=	$0.085h^{0.75}$	*for steel frame building*
T_a	=	$0.09\, h/\sqrt{d}$	*for all other buildings*

Computation of seismic base shear requires the fundamental natural period of vibration (T of the building. However, for the building configuration adopted and the construction material chosen, it is not always possible to exactly determine T from theoretical considerations, that is, through detailed dynamic analysis. Hence, empirical formulae obtained through experimentally observed behavior of buildings are utilized. A number of experimental studies were performed by various agencies of different countries and proposed period vs. height relationship for the estimation of the fundamental natural period of the building. Efforts are still being made by various researchers to improve the code based expressions, as current code equations are predicting period values on the lower side, which ultimately produce higher base shear. The aim of this study is to produce a period equation in order to predict the fundamental period of vibration of reinforced concrete buildings with moment resisting frames. Such buildings are considered in this study by analytically modeling 3D frames. For bare RC buildings, these 3D frames can be used adequately to estimate the period of vibration of the whole building in the principle direction in which these frames act. However, in a real building with infill panels, some of the frames are bare, some are fully in filled and some have infill panels with openings for windows and doors and it has been observed that infill masonry provides additional stiffness to the structure, but after a few second of earthquake shaking stiffness degradation is observed. Hence, the influence of infill panels is not considered.

***Key Words*:** Reinforced Concrete, Steel buildings, Moment Resisting Framed Buildings.

1.INTRODUCTION

The earthquake design and analysis of any reinforced concrete structure requires an essential procedure of the estimation of the fundamental period of vibration of the building. The fundamental period is the important property of the building/structure for determination of the elastic demand and, indirectly, the required inelastic performance of the structure. In the calculation of lateral forces and design base shear of a building, it is an important parameter to be considered. In the evaluation of the expected seismic load affecting the building, the estimated fundamental period is an essential parameter, that's why its precise estimation is important for the safety of the design procedure and consequently for the performance of the structure in the future. The Indian seismic code IS 1893(Part 1) 2016 provides the empirical expressions of *T* of the building taking its parameters; vertical dimension (*H*; height), types of structure, lateral force-resisting system, and infill walls, into prime consideration. These expressions are based on the recorded period of vibration of real buildings during the earthquake. Initially, the expressions were presented in terms of the number of stories(*N*) or height of the building (*H*), but later on, the same were developed in terms of other considerations also as mentioned above.

The use of an empirical expression, the rational method (referring to dynamic analysis) and the experimental techniques applied on similar buildings (which is probably not done in usual practice) are the primly available ways to estimation the value of *T*. In other words, in current provisions of seismic codes, the estimation of seismic forces with the help of design spectra requires either the use of available empirical equations for the fundamental period determination or more specifically detailed dynamic analysis.

But, the study of research works shows that the earlier attempts of the deriving formula of *T* was made using the recordings of the earthquakes and performing the study of vibration on a limited number of buildings of a set of locations. The derived empirical expressions of *T* based on these data were adopted by manydesign codes of different countries.

1.1 Objective of the study

- ✓ The characterization of the structural parameters of RC MRF buildings, affecting the fundamental period of reinforced concrete moment resisting frame building (RC MRF) comes under the preliminary objective of the study.

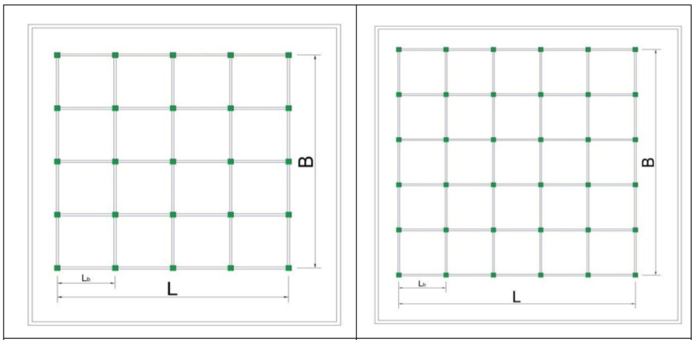
- ✓ The detailed analysis of the effect of the different parameters of structure including the characterized parameters is the intermediate goal of the study.
- ✓ The final objective of the work is to develop the expression of the time period(T) of the reinforced concrete framed building so that the expression may be capable enough to express the relation of T with the different structural members of the buildings in close vicinity of the results of the dynamic analysis.
- ✓ The sensitivity analysis has also been presented in the work to identify the weightage of the intensity of the effect of the considered parameters on time period.
- ✓ The validation analysis of the result of the developed expression is also performed by comparing them with the results of dynamic analysis.
- ✓ The comparative study of the results of the developed equation and the proposed equations of different researchers has also been presented.
- ✓ Based on the study of available research literature, the dependency of a fundamental time period (T) of the reinforced concrete(RC)-moment resisting framed (MRF) building on other structural parameters(other than height or number of storey) can easily be observed.

1.2 Factors on the fundamental period of the building

- ✓ Slab thickness.
- ✓ Dimensions of the building plan or width of the building in considered direction.
- ✓ Plan area of the building.
- ✓ Stiffness in terms of the total cross-sectional area of the columns.
- ✓ Dimensions of beam.
- ✓ The ratio of beam width to depth.
- ✓ The number of panels in the longitudinal and transverse direction.
- ✓ Length of panel/bay in longitudinal and transverse direction etc.
- ✓ The ratio of bay length to the total plan dimension in the considered direction.
- ✓ The ratio of the total cross-sectional area of the columns to the base area of thebuilding.

2. METHODOLOFY

In the previous study of literature, it has been already discussed thatthere is the scope of consideration of the structural elements other than the height of the building as the parameters in the analysis of *'T'* of building. The present code equation of *'T'* gives its conservative value, due to which, the base shear calculations produce its higher value, which tends for uneconomic construction due to higher sections of structural elements. The structural parameters discussed under the objectives of the study have been considered in the analysis of their effect on *'T'* to fulfil the objective of the development of a period formula incorporating these parameters along with *'H'*. To achieve this aim, the analysis has been done as per the following adopted methodology.



(a) 4×4 grid size (b) 5×5 grid size

Fig -1: Typical plans of considered building

Figure-1 represent the typical plans of the considered building models with bay sizes 4×4, 5×5, 6×6, 7×7, and 8×8. L and B represent the dimension of the plan in respective directions, and, Lb is the length of the bay(m) in the condered direction of the plan.

2.1 Parameters consideration for analysis

The considered RC frame buildings having square-shaped in the plan are analyzed using the analysis and design software of structure STAAD.Pro-V8i with the following assumption mentioned in Tables 3.1.

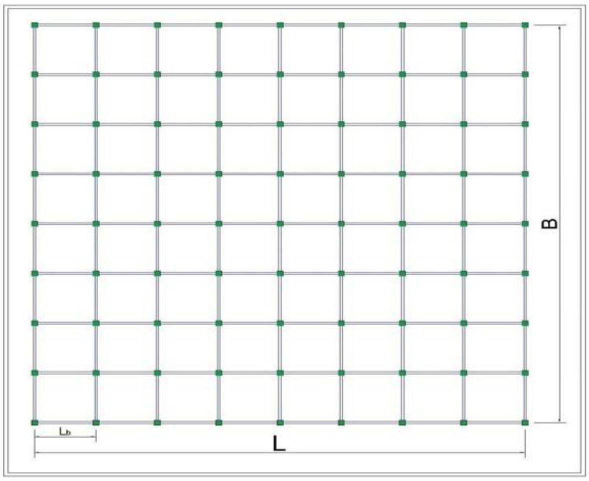


Fig -2: Typical plans with 8×8 grid size

Table -1: Structural configurations

Specifiions	Details
Type of structure	Multi-storey rigid-jointed frames
No. of storey	GF to G+5, G+6 to G+10
Floor height	3.6m
No. of grids	8×8, 7×7, 6×6, 5×5, 4×4
Thickness of slab	150mm, 175mm, 200mm, 225mm, 250mm
Bay length	4m, 5m, 6m, 8m
Size of columns	0.3m×0.3m,0.4m×0.4m, 0.5m×0.5m,0.6m×0.6m, 0.7m×0.7m,0.8m×0.8m,
Walls- **(a) External** **(b) Internal**	200mm 100mm
Beamwidth	300mm
Beam depth	600mm
Static analysis	Equivalent static lateral force method.
Dynamic analysis	Using response spectrum method.
Seismic code provisions	As per IS1893(Part 1):2016
Software used	STAAD.Pro-V8i

Table -2: Material properties and design parameters

Specifications	Details
Material used	Concrete M-25 and Reinforcement Fe-415.
Ec	5000√fck N/mm²
fcr	0.7√fck N/mm²
Specific weight (R.C.C.)	25 kN/ m³
Floor finish	1 kN/ m²
Imposed load	4 kN/ m²
Type of soil	Type-II, (medium soil) {as per IS1893 (Part1) : 2016}
Load of waterproofing	2.5 kN/ m²
Specific weight of infill	20.00 kN/m³
Seismic zone	III
Zone factor, Z	0.16, As per IS1893 (Part 1) :2016.
Importance factor, I	1
Response reduction factor, R	5
Damping	5%

2.2 Structural Parameters

432 building models have been analysed to characterize the different considered structural parameters, which influence the fundamental period of the building. Three building plans with grid size 7×7, 5×5, 4×4 are analyzed with column sizes 0.3m×0.3m, 0.4m×0.4m, 0.5m×0.5m, 0.6m×0.6m, 0.7m×0.7m, 0.8m×0.8m. For above-mentioned building plans and column sizes, considered the length of the bay are 4m, 5m, 6m and 8m. Height of building is also varied from 5.6m to 41.6m, and slab thickness varies from 150mm to 250mm at the interval of 25mm. The variation of the ratio of depth to width of the beam is done from 1.5 to 2.0 at interval 0.1. Thus, the total cases of buildings for characterization study come out as 432. Each parameter has been analysed bringing variation in it,

keeping other parameters constant at the same time, to study the effect of that parameter on *'T'*.

2.3 Assumptions for analysis

- ✓ It is considered for analysis that earthquake is not likely to occur simultaneously with high wind, maximum flood.
- ✓ The symmetrical square-shaped building plans have been considered to performthe analysis.
- ✓ RC buildings have been considered with special moment-resisting frame.
- ✓ The symmetry is also maintained in the vertical geometry of the building modeland the applied loadings.
- ✓ Sizes of the structural elements like beams and columns were also kept constantfor a particular model.
- ✓ The soil-structure interaction has not been taken into consideration of analysis.
- ✓ The joints of the beams and the columns are kept as rigid joints.
- ✓ The nodes at the footing level are assigned as fixed supports.
- ✓ The gross moment of inertia of the sections is considered for performing theanalysis.
- ✓ The loading of slabs is applied using floor load command of the software.
- ✓ The uniformly distributed load of brick masonry is applied as a member load onthe beams.
- ✓ In the frames, no infill walls are modelled in the software for the analysis.

3. STUDY OF STRUCTURAL PARAMETERS

In this study report 432 different models of building configurations have been analysed to characterize the different considered structural parameters to identify them with capacity to affect the fundamental period (*T*) of the building. The elements of building frame; slab thickness, column size, grid size, beam size, plan area and bay length in considered direction of plan have been taken as parameters into analysis. The analysis has been carried out as per the configurations described in parametric specification and adopted computational methodology as described. The followings are the tabulated results of time period values.

Table -3: Time Period(*T*) :- Grid Size 7×7, Slab Thickness = 150 mm

	Columns Size			
Floors/ Height	0.6m×0.6m		0.3m×0.3m	
	Bay length			
	5m	4m	5m	4m
	Plan Area			
	35m×35m	28m×28m	35m×35m	28m×28m
	T(sec)			
G+5/(23.6m)	1.227	0.988	2.617	2.181
G+4/(20m)	1.026	0.826	2.208	1.838
G+3/(16.4m)	0.826	0.665	1.802	1.497
G+2/(12.8m)	0.627	0.505	1.397	1.159
G+1/(9.2m)	0.432	0.348	0.995	0.823
G.F./(5.6m)	0.247	0.198	0.602	0.495

Table -4: Time Period(*T*): - Grid Size 8×8, Slab Thickness = 150 mm

Floors/Height	Columns Size			
	0.5m×0.5m		0.4m×0.4m	
	Bay length			
	5m	4m	5m	4m
	Plan Area			
	35m×35m	28m×28m	35m×35m	28m×28m
	T(sec)			
G+5/(23.6m)	1.45	1.17	1.817	1.486
G+4/(20m)	1.218	0.982	1.531	1.251
G+3/(16.4m)	0.988	0.796	1.247	1.017
G+2/(12.8m)	0.758	0.61	0.964	0.785
G+1/(9.2m)	0.531	0.427	0.683	0.555
G.F./(5.6m)	0.311	0.249	0.408	0.33

The variation of the ratio of depth to width of the beam is done from 1.5 to 2.0 at interval 0.1. Thus, the totalcases of buildings for characterization. Each parameter has been analysed bringing variation in itself, keeping other parameters constant at the sametime, to study the effect of that parameter on *'T'*. The above characterization process confirms the significant contribution of considered parameters affecting *'T'* of building. Hence it supports for further detailed analysis of building models to study the intensity of effect of all considered parameters and its pattern.

3.1 Fundamental parameters

Various parameters affecting the fundamental period of vibration in seismic analysis have been characterized in previous chapter, and it has been observed through dynamic analysis on various building configurations, that, the height of the building is not only the parameter, but following parameters also influence the period of vibration:

- ✓ Plan area of the building
- ✓ Total cross sectional area of the columns of the structure
- ✓ Bay length
- ✓ Number of bay
- ✓ Slab thickness
- ✓ Bay size
- ✓ Beam sections

To observe the effects of these various parameters, 1768 various building configurationshave been analyzed keeping above mentioned parameters as variables.

3.2 Effect of column size on time period

Table -5: Time Period (*T*):- for grid size 8×8, plan area (m) = 48×48,Slab thickness (mm) = 150, bay length (m) = 6m

S. No	Floors/ Building height	Time Period	Columns Size			
		as per IS1893	0.5m×0.5m	0.6m×0.6m	0.7m×0.7m	0.8m×0.8m
			T(sec)			
1	G+10/(41.6m)	1.229	2.814	2.531	2.387	2.302
2	G+9 /(38m)	1.184	2.566	2.305	2.171	2.089
3	G+8/(34.4m)	1.065	2.32	2.081	1.956	1.876
4	G+7/(30.8m)	0.981	2.075	1.857	1.741	1.665
5	G+6/(27.2m)	0.893	1.829	1.634	1.526	1.459

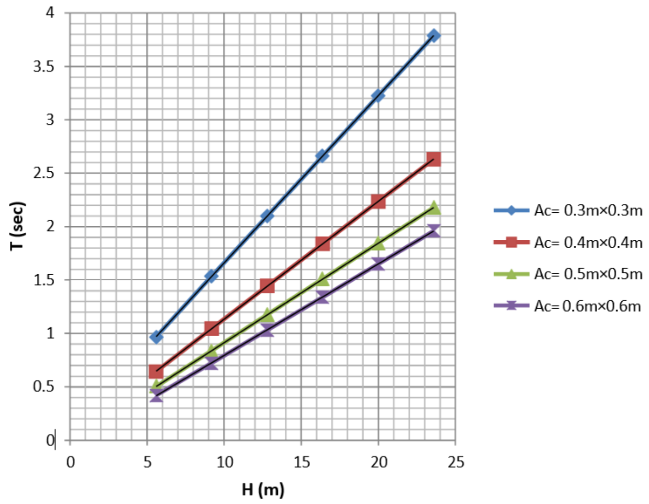


Chart -1: Variation of T for grid size 8×8

4. CONCLUSIONS

1. It can be concluded that the present work explores the scope of improvisation in expressions of time period of vibration given in seismic design code IS1893-2016 and presents the study to show that the height alone, as a primary factor, seems to be inadequate to evaluate the timeperiod of vibration accurately.

2. Further, it can be suggested that the different structural parameters other than the height of the building, also with respect to the parameters characterized in this analysis.

3. The affect the period and can be incorporated in the simplified expressions of the time period of vibration illustrated in the design codes, which are commonly used in seismic analysis.

4. In this work, the analysis has been done for buildings considering different bay sizes, column sizes, slab thickness, bay length, plan area, beam sizes etc. This improvement can provide better assessment of the time period supporting to economy in the structural design.

5. Multiple non linear regression analysis was performed over 2200 period values obtained through dynamic analysis with various considered combinations of different parameters.

6. The different empirical expressions have been developed by non-linear regressionand sensitivity analysis has also been presented.

7. It is suggested that there is scope to incorporate these considered structural parameters in time period

formula given in Indian Standard Code IS1893 to estimate the value of *'T'* closer to results of dynamic analysis.

8. So, for the enhancement of the capacity of available approximate formula, the work presents with the results of dynamic analysis, which can be useful for the researchers, academicians as well as for the professionals.

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