IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 14, Issue 5 Ver. III (Sep. - Oct. 2017), PP 12-19
www.iosrjournals.org

Influence of Various Selected Parameters over Natural Frequencies & Natural Time Periods of R.C. Structures

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Abstract: *When a structure is subjected to Earthquake, The seismic forces drives the structure into motion & oscillates the structure into various directions. The time required for the structure for a single oscillation is called as Time Period. The longest of which is called as Natural Time period. Natural time period and the damping of the structure has phenomenal effect on the response of Structures.According to IS 1893(2002) the approximate natural time period (T) in sec, is influenced by two parameters, the height of the structure & secondly the base dimension of the building. In this study an investigation is made for Parameters which may elongate the natural time period of the RC structures apart from the height and base dimensions. The elongation of the natural time periods will result into improved Response of the RC structure. The Time History analysis of various R.C. Models using Imperial Valley (1940) Ground motions has been carried out using CSI Etabs 2016 & SAP 2000.*
Keywords*: Number of storeys,Natural Time period (T), Response, Natural Frequency (f_n), Storey height.*

Date of Submission: 20-09-2017 Date of acceptance: 02-10-2017

I. Introduction

1.1 General

All, the structures which are constructed with a lot of expenses and the structures with due importance specially situated in seismically activated areas demands safety for them. The design of such structures demands improved response when these structures come across a challenge to resist earthquakes. In this study we have investigated about how the response of the structure can be improved. Basically the parameters which has not been considered by IS 1893 (2002) whichgoverns the natural frequencies and Natural time periods are investigated. The influence of such parameters over natural frequency& the natural time of the structure was the primary concern of this investigation.The past historical earthquakes which has been faced by the earth has given us some hints about the dynamics of structure. According to some past earthquakes we came to know that the response of the structure depends upon the acceleration to which the structure is subjected which in turn depend on frequency. The response improves as the natural frequency of oscillation of the structures gets reduced due to various reasons. The Decrease in natural frequency means the increase of the natural time period (T). Increasing natural time period means the structure would become more flexible and it will not attract the lateral forces up to that extent which other structures with lesser value of (T) experienced. According to our Investigation the parameters which also plays significant role in the increase or decrease of frequency and the time period are No. of storeys (n) and Height of the storey (hi). According to IS 1893 the parameters which generally governs the Natural frequency (f_n) are the storey stiffness (K) and the Mass of the structure (M).

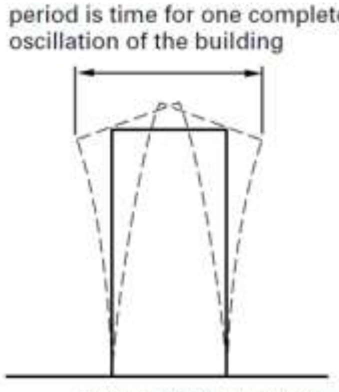

Figure 1: Period of a building

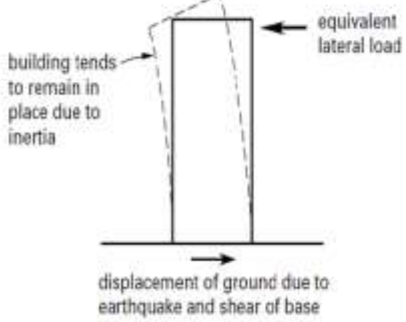

Figure 2: Response of a building to earthquake

$$\mathbf{f_n = \frac{1}{2\pi}\sqrt{K/M}}$$

And the natural period (T_a) (of a moment resisting frame), is the function of height of structure from the base (h), which excludes the basement storey if the basement walls are

$$\mathbf{T_a = 0.075h^{0.75}}$$

$$\mathbf{T_a = \frac{0.09}{\sqrt{d}}}$$

Connected to the ground floor deck and includes if they are no so connected, and base dimensions of the building at plinth level. It means that there is neither the consideration of storey height (h) nor the no of storeys (n) for the approximate calculation of these parameters. Natural frequency is the inverse of natural time period i.e. if the frequency decreases time period increases & vice versa.

$$\mathbf{\frac{1}{T_n} = f_n}$$

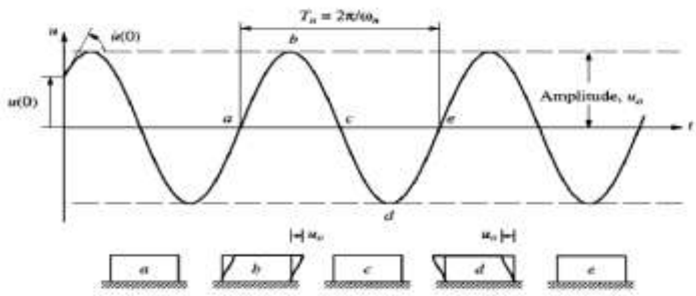

Figure 3: Amplitude of vibration of a structure

1.2Literature Review

Nilesh V. Prajapati [1].Presented a work study on seismic analysis of a structure. In his study they stated that there has not been any consideration of no of storeys in IS 1893 (2002) for the calculation of natural time period and frequency of the structure. In his study he analysed a 70m X 70m plan dimensioned building with height varying from 60m to 90m. All the modelling works were done using Staad pro analytical software. He made various models of varying height starting from 3m and an increment of 0.25m in each model also an increment of one floor is made in each model as the number of floor increases and the floor height increases ultimately the total height of the structure increases, Hence resulting in elongation of the Natural time period. Lastly the natural time period calculated from Staad pro and from empirical formula from IS 1893 has been compared.

L.Lin, N. Naumoski, S. Foo and M. Saatciogl [2].Did an investigation on elongation of the natural periods of Reinforced concrete structures during nonlinear seismic response. In their study they analysed three type of structures i.e. Low rise structures, medium rise structures and high rise structures. Pushover analysis was done for these structures. The Vancouver earthquake ground motions were taken into account for the study. A set of 40 pre-recorded accelerograms were usedwhich represented the seismic motions of Vancouver region. Each structure was forced to experience a series of seismic excitations which produced a responses that ranged from elastic to inelastic responses. The undamped vibrations of the structure, after the end of each excitation motion were analysed to calculate the first modal period of the structure. The computed periods were then statically analysed to prepare a relationship between the elongation of the natural time period and the intensity of the seismic excitations. It was then found that mean elongation of the period is almost linearly proportional to the intensity of the motions. They also concluded that for the intensity producing global ductility of 5.0, the mean elongated period is 55% higher than the corresponding elastic first mode which enables the one to determine the period elongation for any global ductility level that would be considered.

Abbas Ali Dhundasi[3]. This paper dealt basically with the estimation of natural time period of various type Reinforced Concrete Elevated water tanks. In this study the investigator did the investigation over the natural periods of Intze and Funnel type of tanks. The investigator modelled Intze and Funnel type of tanks with varying staging height in three sets i.e. 16m, 20m & 24m. The type of staging is also varied i.e. framed staging & shaft staging. In all 27 models were prepared and analysed for Full water, half full & empty water condition. Also the capacity of the water tank has been kept as a variant in the study for 10 lakh, 15 lakh & 20 lakh litre of water. The analysis of every structure was carried out on SAP 2000 analytical software. The important findings were that the time period for the full condition is more than that of the empty tank. Secondly the time period increases with staging height of the same.Also with increase in capacity the time period goes on increasing and Intze tanks with shafts are preferable for use. The study led to a simplified period height based equation which has been proposed for use. The equation proposed being, $\mathbf{T_{a=0.00013H^{2.43}}}$, H being the staging height in metres.

Mehmet Metin Kose[4]. The performance of the buildings largely depends on the strength and deformability of constituent members. A study has been done by investigating those parameters which may affect the natural period of RC buildings with in-filled walls. Various selected parameterswere building height, number of bays, ratio of area of shear walls to floor area, ratio of infilled panels to total number of panels, type of frame. Around 190 models of various properties were modelled and the effect of the selected parameters in an infilled RC frame were investigated. Generally the natural time period is calculated by discarding the infills, but the infills have a nonlinear behaviour. 3D Finite element modelling was done for the sake analysis. It was found that RC frames with infilled walls had lower periods about 5%-10%, as the stiffness of the structures gets increased. The presence of shear walls also lowered the time period about 6%-10% with or without infilled walls. It was also concluded that the natural time period of various structures calculated by code is less than that of the software suggested time periods which were calculated by exact Eigen values.

1.3 Objective

The primary objective of this study is to investigate the influence of the selected parameters over the natural period of the structure. The selected parameters being Height of the storey and the No of storeys. This paper over views the effect of these two parameters on natural frequency as well as the natural time period of the structure.

In this paper work, various RCC models have been prepared and compared for the natural frequency as well as the natural time period for each structure. The no of storeys as well as the height of each storey has been varied. In all seven models were prepared for the analysis. Non-linear Time history analysis with direct integration method has been used. The Ground motions of Imperial valley Earthquake has been used both for X as well as Y direction.

II. System Development

In all seven no. of RCC models were prepared using the analytical software Etabs 2016. In all the models the plan dimension as well as the height was also approximately kept constant. The building which was analysed was an existing apartment structure which had a plan dimension of 54.60m X 22.80 m and a height of approximately 80m. The height of the storey for the first model has been kept as 3.0 m later on in the subsequent models an increment of 0.25 m was made in floor height for each model till the height reached the value of 4.5 m at each floor. The height of each floor was kept constant in one model. As the height of the storey was increased by 0.25 m in each model the number of floors in each model decreased. The impact of increase in floor height on time period in each model was checked. The plan of the structures which was constant for each model is shown below:

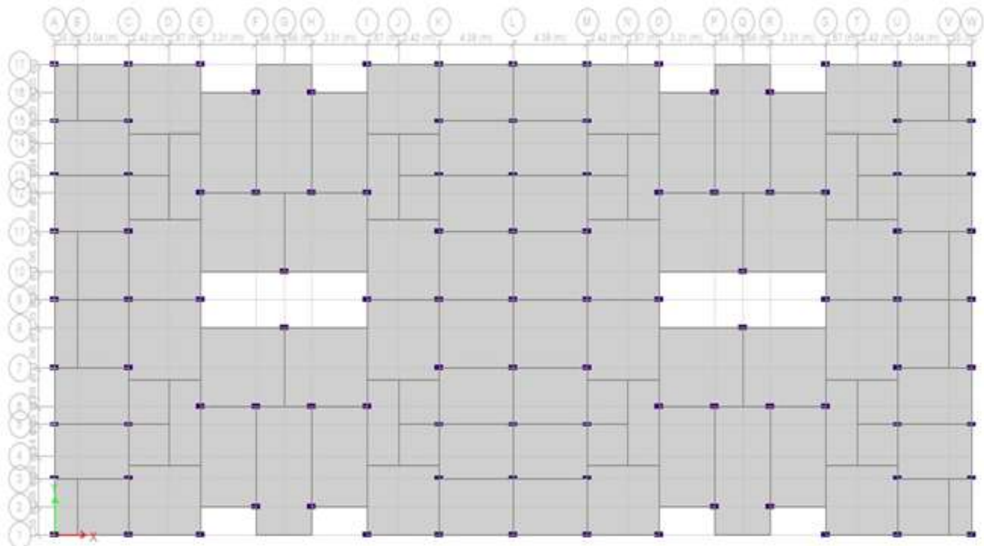

Figure 4: Plan of the Structural Model

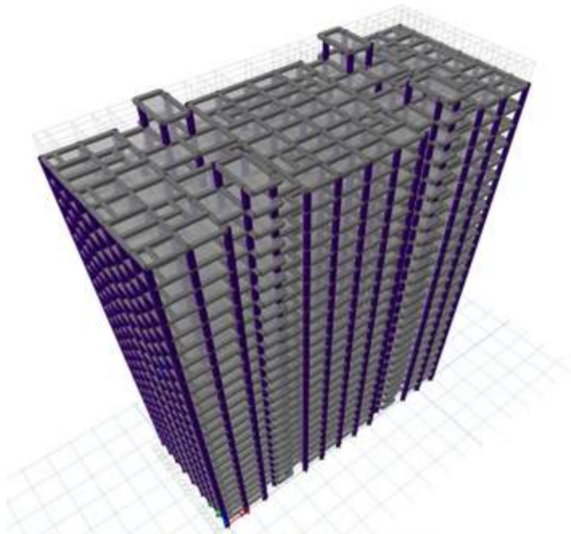

Figure 5: 3D extruded view

The Material properties, general specification of buildings, Structural specifications, loading specifications and Load Combinations has been stated in table no. 1, 2, 3, 4 and 5respectively.

Table 1: Material Properties

1.	Grade of concrete	M25
2.	Grade of reinforcing steel	Fe 500
3.	Grade of steel	Fe 345
4.	Density of concrete	25 KN/m^3
5.	Density of brick masonry	19 KN/m^3
6.	Damping ratio	5%

Table 2 : General Specification of buildings

1.	Plan Dimensions	54.60m X 22.80m
2.	Height of the structure	80m
3.	Height of storeys	3m - 4.5m
4.	Interval of storey height in each model	0.25m
5.	Thickness of Slabs	150 mm
6.	Internal Wall thickness	150 mm
7.	External wall thickness	150 mm
8.	Waist slab thickness	150 mm
9.	Depth of footings	3 m

Table 3: Structural Specifications of Buildings

1.	Type of sections	R.C.C.
Sizes of Column sections		
2.	Columns (C1)	230 X 380
3.	Columns (C2)	230 X 450
4.	Columns (C3)	230 X 530
Sizes of beam sections		

5.	Primary Beams	230 X 530
6.	Secondary beams	230 X 450
7.	Tertiary beams	230 X 380

Table 4: loading Specifications

1.	Floor load	1.0 KN/m^2
2.	Live load	3.5 KN/m^2
3.	Live load on Staircase tower	2.0 KN/m^2
4.	External wall load	10 KN/m
5.	Internal wall load	10 KN/m
6.	Code for RCC	IS 456 (2000)
7.	Code for Earthquake analysis	IS 1893 (2002)
8.	Zone	V (very severe)
9.	Zone factor (Z)	0.36
10.	Importance factor	1.0
11.	Moment resisting frame type	OMRF
12.	Response reduction factor	3.0
13.	Site soil type	Medium (II)

Table 5: Load Combinations

1.	0.9DL+1.5EQX
2.	0.9DL-1.5EQX
3.	0.9DL+1.5EQY
4.	0.9DL-1.5EQY
5.	1.2(DL+LL+EQX)
6.	1.2(DL+LL+EQY)
7.	1.2(DL+LL-EQY
8.	1.5(DL+EQX)
9.	1.5(DL+EQY)
10.	1.5(DL+LL)
11.	1.5(DL-EQX)
12.	1.5(DL-EQY)
13.	1.2(DL+LL-EQY)

III. Results And Discussion

The modelling and analysis of the all the RCC structures has been done finite element based software ETABS 2016. For comparative study of various parameters total sevenRCC structures were modelled. The parameters such as natural frequency,natural time period and response acceleration has been compared. All the seismic parameters which were necessary for the analytical purpose were considered from IS 1893-(2002).

3.1 Natural Frequency:

The Natural frequency of each model having different floor heights has been evaluated and compared for four different modes. It has been compared in (Figure 5).It can be clearly seen that as the storey height goes on increasing the Natural frequency goes on decreasing. The values frequency values for different modes to the respective floor height has been stated in table.

Table 6: Natural frequencies

Sr. no	Storey height (m)	Natural Frequency (Etabs)			
		Mode 1	Mode 2	Mode 3	Mode 4
1.	3.00	0.128	0.153	0.201	0.392
2.	3.25	0.121	0.145	0.191	0.367
3.	3.50	0.114	0.137	0.182	0.346
4.	3.75	0.113	0.136	0.180	0.343
5.	4.00	0.109	0.132	0.179	0.331
6.	4.25	0.106	0.128	0.175	0.321
7.	4.50	0.104	0.126	0.168	0.305

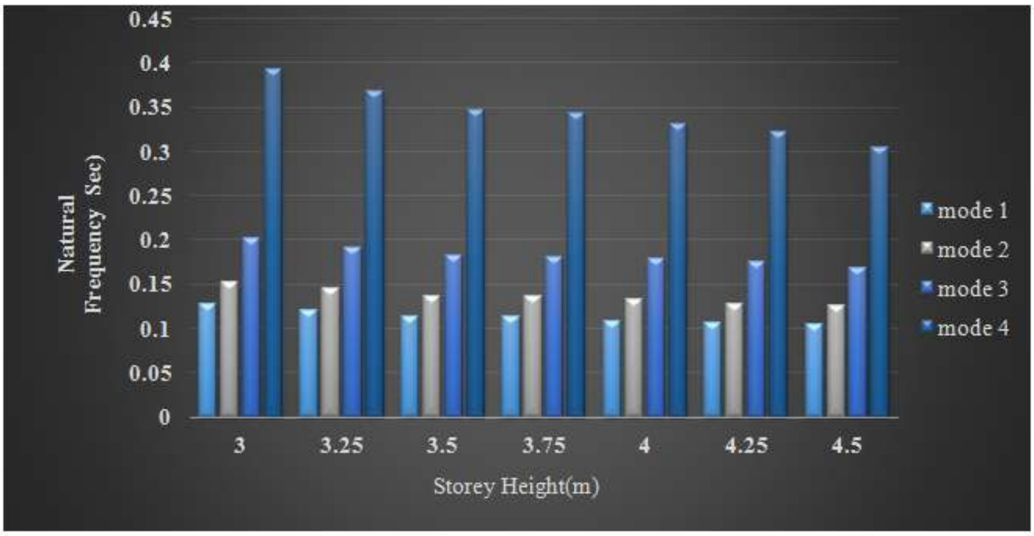

Figure 5: Natural Frequency for different floor heights

3.2 Natural Time Period:

The basic objective of this study was to evaluate the effect of increase in storey heights and no. of storeys on natural time period. The results has been shown in Table 7. The time period has been compared for different modes for different storey heights. It is clear from this that as the storey height and no. of storeys will increase the time period of the structure would also linearly gets increased. Increase in Natural time period will ultimately lead to an improved response of the structure.

Table 7: Natural time periods

Sr. no	Story height (m)	Natural Time Period (Etabs)			
		Mode 1	Mode 2	Mode 3	Mode 4
1.	3.00	7.754	6.495	4.986	2.552
2.	3.25	8.274	6.912	5.247	2.726
3.	3.50	8.771	7.305	5.492	2.892
4.	3.75	8.775	7.312	5.537	2.897
5.	4.00	9.133	7.580	5.598	3.017
6.	4.25	9.433	7.812	5.725	3.119
7.	4.50	9.567	7.879	5.931	3.284

3.3 Response Acceleration

The Response acceleration graph of various structures for various time periods has been given in Fig. 7. It can be seen in the graph that as the natural time period goes on increasing the acceleration simultaneously gets decreased.

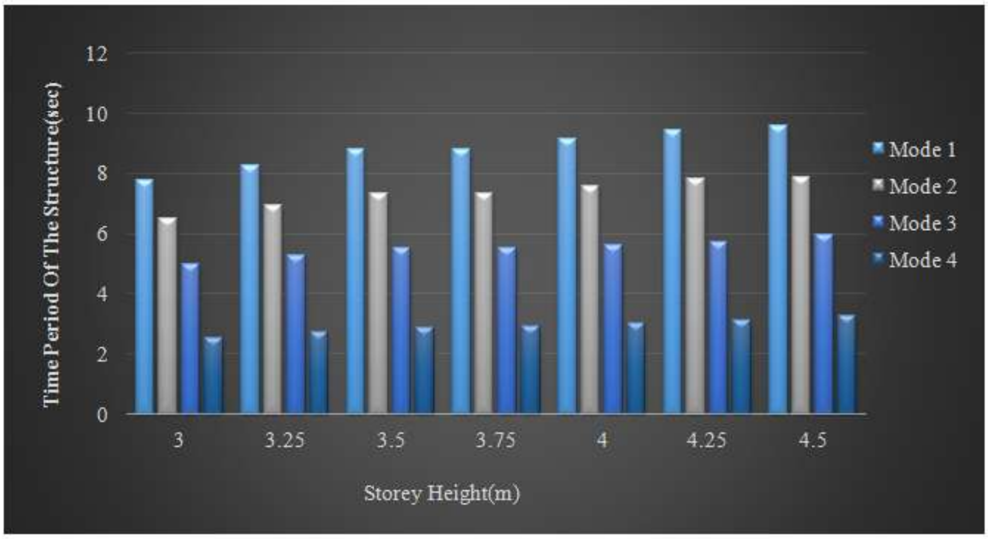

Figure 6: Time Period for different floor heights

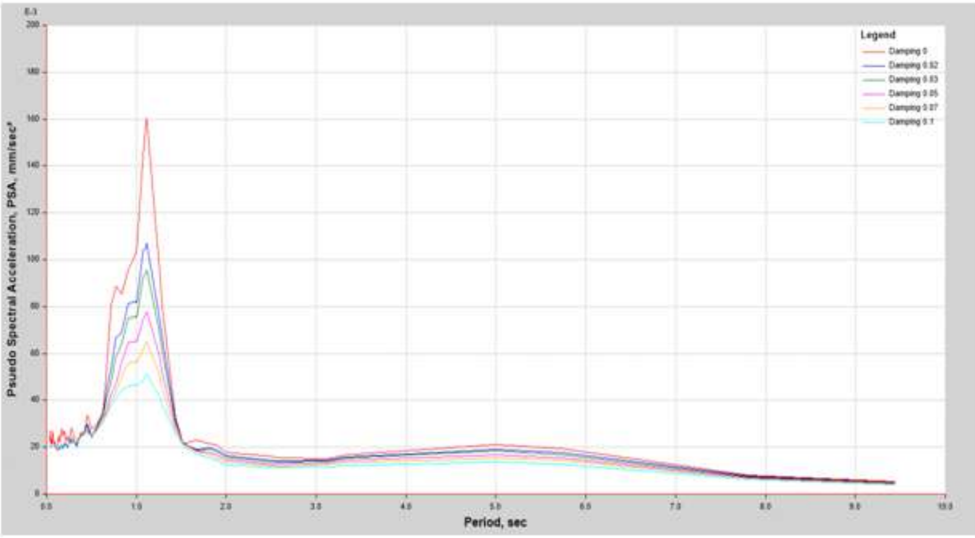

Figure 7: Response Acceleration graph

IV. Conclusions

This comparative study presented comparison of various structures with varying floor height as well as varying number of storeys. By observing all the models, results, tables as well as graphs following conclusions has been made:

- The variation in floor height for the same structure in different model shows that the natural frequency for the structures with less floor height is more and the frequency for the structures with greater floor height is less.
- As the storey height increases the time period of the structure increases even if the total height of the structure remains same.
- As the number of floors in the structure increases the time period also gets increased.
- It means that Natural time period is also a function of storey height and number of storeys.
- As the natural time period of structure increases, the response of the structure gets improved becauseof minimised spectral accelerations of the structure.

- It is also suggested that the effect of Storey height and number of storeys must be considered in IS-1893 for calculating the natural time periods of the structures

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