Tuijin Jishu/Journal of Propulsion Technology
ISSN: 1001-4055
Vol. 45 No. 3 (2024)

Parametric Study of Time Period for RC Frame Structures with Infill walls.

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Abstract:- The seismic performance assessment of structures or buildings relies significantly on their time period, which is crucial for estimating lateral loads and evaluating seismic resistance. The time period is influenced not only by height and base dimensions but also by various other parameters. In this study, regression analysis is used and explored different combinations of models considering height of the structure, thickness of infill, modulus of elasticity of infill and aspect ratio of the infill. Through this comprehensive approach, an equation is derived for the time period, aiming to achieve more accurate predictions to enhance the assessment of the structure's seismic performance. Lastly, analyses were done to compare the values of equation this study proposed with those from the IS code.

Keywords*:* Period, Thickness of infill, Modulus of elasticity of infill, Modal analysis, RC frame structures

1. Introduction

When designing and assessing a structure, the assessment of its basic natural vibration period is essential. We can accurately evaluate the seismic performance of the structure and estimate the size of lateral loads by calculating the time period. The duration is influenced by the mass and stiffness of the building and offers important information about how it will respond to lateral loads. It can be difficult to pinpoint the exact time frame, though. Still, building structures that can efficiently survive earthquakes requires an understanding of the period. A. **Kocak *et.al* (2013)** Proposed a study to investigate how infill walls affect the stiffness of load-bearing and reinforced concrete (RC) framed buildings. The investigation also looked into how the infill walls apertures affected the buildings overall rigidity. Six possible configurations of outer and inner infill walls were examined by the researchers in order to conduct the analysis, which was precisely modeled using the ETABS software. The fundamental period of every model was found via modal analysis. Moreover, the fundamental periods were computed for comparison using different codes. The results of the investigation showed that adding infill walls decreased the fundamental period and increased the structure's overall stiffness. Specifically, the basic period was 78%–68% lower than that of a bare frame (without infill walls). Moreover, there was an 18%–13% reduction in the fundamental period between totally infilled frames and infilled frames with window–door apertures. These findings highlight the important impact that infill walls have on the dynamic behavior of buildings. By adding infill walls, the building's total stiffness was improved and the vibration period was successfully decreased**. A KrishnaSrinivas *et.al* (2008)** The primary goal was to compare the results with the period formula stated by the code and investigate the link between the height and fundamental period of Turkish RC moment resistant frames from ambient vibrations. Similar ambient testing were performed on five existing RC buildings using SAP2000, in their two primary directions. In order to calibrate the numerical models created for the project, a 12-story reinforced concrete structure underwent the first round of vibration testing during three distinct phases of construction. Relationships between building height and basic period were determined based on experimental and numerical study results. The analysis's findings, which gave rise to a connection for the rapid calculation of the infilled RC frame's fundamental period, agreed well with the suggested relationship. **Cinitha A *et.al* (2012)**. This study uses numerical investigations to determine the fundamental natural period of steel moment resisting frames. Regression analysis is then used to derive empirical equations for medium and low raise buildings. Examined are the standard steel moment-resisting frames without infill. Regression analysis is performed using parametric studies on 75 regular steel-framed structures based on the height and plan area to determine their basic period. The basic architectural phases of the structures had plan dimensions of 3 x 3, 3 x 4, 3 x 5, and 3 x 6, and varying heights of 3, 4, 5, and 6 meters. The formulas for the Low and Medium structures have been derived, based on the best fit. It is discovered that, regardless of the building's plan dimensions, the fundamental natural frequency falls as height and normalized stiffness increase. However, it is discovered that the fundamental frequency of the buildings is rising with an increase in plan area. **Guler *et.al* [2008]** The vibration period of an existing building was determined experimentally and compared with the period estimated by a numerical model, revealing a close match between the two results. The building was modelled with infill walls, which were represented as virtual strut frames. Considering the impact of infill walls, an equation was put forth for the fundamental time period of a structure as a function of building height. Nevertheless, the elasticity modulus and thickness of the infill walls were assumed to be constant when this equation was developed.They assumed that E = 6000 MPA and t = 150 mm. **Ali. Kocak *et.al* (2017)** The effect of infill walls on period and their contribution to lateral stiffness have been the subject of numerous studies. The empirical calculations are based on height, and the infill walls are considered according to coefficient. The building was evaluated using SAP2000, accounting for different wall thickness, modulus of elasticity, and aperture values. The necessary equations were then found using regression analysis. Similar compression struts with double end hinges and the axial stiffness advised by Ersin and Guler are used to model infill walls. The building's essential period is impacted by wall thickness by 9% to 27%. The periods decrease by 6%–35% as the modulus of elasticity rises. A higher wall opening ratio results in a higher time period. **Amanat and Hogue (2006)** demonstrated that the period obtained utilizing code formulas is lower than the basic period of an RC bare frame construction. On the other hand, they suggested that the era found for a building with an internal wall is about the same as the one found using code formulas. According to their investigation, the structure's infill wall distribution has no appreciable impact on the vibration period. For vibration period, the total number of inner walls matters rather than their distribution. They employed a constant inner wall thickness and elasticity modulus in these evaluations. **Zarnic *et al* (1998)** carried out a number of experiments comparing bare frame buildings with frame buildings with inner walls, and found that the inner walls' frames have more strength and durability than bare frames. On the basis of this finding, they recommended that the design process take the impact of the interior wall into account. Nevertheless, if the effects of the interior wall are disregarded, the interior wall and the structural system should be divided by an appropriate lap joint. **Pan *et al* (2014)** examined the connections between Singapore's high-rise public residential buildings' height and natural vibration period. They examined structures with four to thirty stories. They came to the conclusion that the buildings' aspect ratio had no appreciable impact on the basic vibration period. Regression analysis is used to determine the period-height connections while taking a building's site characteristics into account. Their study's findings indicate that the vibration periods calculated for structures at soft-soil sites using the proposed period-height connection are roughly 40% longer than those estimated for buildings at hard-soil sites. Numerous investigations were been out to look at how interior walls affected structural behavior. A fundamental vibration period equation for buildings was proposed by **NEHRP [25], UBC [26], EC8 [27], and TSC 2007 [28]**. A coefficient was included in some of these codes to account for the impact of interior walls. However, those codes' formulae and other researchers' studies do not take the thickness, elasticity modulus and aspect ratio of infill walls into account. A building's numerical model was created in ETABS20 using a variety of parameters such as building heights, wall thicknesses, infill wall elasticity modules and aspect ratio of infill. 500 distinct buildings were modelled for 5 different story numbers, 5 different elasticity moduli of the inside wall, 5 different thicknesses of the interior wall, 4 different aspect ratios of walls and fundamental periods of these buildings were established. Buildings numerical solution findings through modal analysis were used to do regression analysis and a function of building height, infill wall thickness, elasticity modulus of infill wall and aspect ratio of infill was given as an equation.

2. The Structure and Analysis

2.1 Material Property: In the following study, the material properties are kept standard throughout entire modelling process. The grade of concrete and reinforcing steel chosen is M25 and Fe-500 respectively. The modulus of elasticity of concrete is obtained as per the code provision i.e. Ec =$5000\sqrt{fck}$MPa.). In case of steel rebar, yield stress (fy) and modulus of elasticity (Es) is 500Mpa and 2 X10^5 N/mm2.Where characteristic compressive strength of concrete cube in MPa at 28-day.

Grade of Concrete	M30
Grade of Rebar	Fe 500
Slab thickness (in mm)	150
Storey Height (in m)	3

Table 2.1: Material property

2.2 Parameters Considered

2.2.1 Height of the Structure (H): Different values of height varying from low, medium and high-rise structures are considered with constant storey height of 3 meters. Grade of the concrete, Grade of steel rebar, thickness of slab are also not varying while the size of beam and size of column are the varying parameters for different height of the structures.

Height (in m)	Column size	Beam size
12 (G+3)	350 X 350	300 X 300
24 (G+7)	525 X 525	400 X 400
36 (G+11)	650 x 650	450 X 450
48 (G+15)	750 x 750	550 X 550
60 (G+19)	850 x 850	650 X 650

Table 2.2.1: Height of the structure

2.2.2 Thickness of Infill wall (t): The thickness of a brick masonry wall can vary based on factors such as the type of bricks, structural requirements, and local building codes

Minimum Thickness: For non-load-bearing walls, the minimum thickness is typically around 4 inches (100 mm), or the length of one brick. For load-bearing walls, the minimum thickness is usually around 8 inches (200 mm) or more, depending on the required support for the loads.

Maximum Thickness: The maximum thickness of a brick masonry wall is less defined and can depend on aesthetics, space constraints, and cost. Practically, the maximum thickness is often around 13 to 14 inches (330 to 355 mm), which is about one and a half brick lengths.

Values of thickness of infill considered are as mentioned in the table:

t1	t2	t3	t4	t5
115mm	150mm	200mm	230mm	300mm

Table 2.2.2: Thickness of infill

2.2.3 Modulus of Elasticity of Infill walls (E) The modulus of elasticity (E) of masonry infill walls, also known as the elastic modulus, is a measure of the stiffness of the material. It represents the ratio of stress (force per unit area) to strain (deformation) in a material when subjected to loading. For infill walls, this property can vary widely depending on several factors, including the type of masonry units (bricks or blocks), the type of mortar, and the quality of construction.As per IS 1893:2016 (Part 1) the elasticity modulus is given by:

$$E_{\mathrm{m}} = 550 f_{\mathrm{m}}$$

The modulus of elasticity *E* (in MPa) of masonry infill where *f* is the compressive strength of masonry prism (in MPa) obtained as per IS 1905.

Avg comp strength of brick (in MPa)	Modulus of elasticity (in MPa)
5	2750
6	3300
7	3850
7.5	4125
10	5500

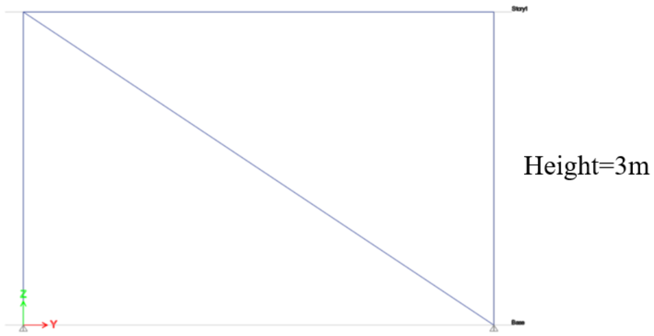
Table 7.3.3: Modulus of elasticity of infill

2.2.4 Aspect Ratio of Infill wall (AR): Aspect ratio of an infill wall is the ratio of its length to its height. This ratio is significant in structural engineering as it affects the wall's behavior under loads, particularly in seismic zones. Here’s how to determine and understand the aspect ratio of an infill wall:

Aspect Ratio = Length of the wall / Height of the wall.

Aspect ratio impacts the stiffness and strength of the infill wall. Walls which have high aspect ratios (short and wide) tend to be more rigid, while walls with less aspect ratios (tall and narrow) are more flexible but can be more susceptible to buckling under lateral loads.

Four values of aspect ratio are considered in the study, height of the infill is taken as constant 3m while the grid spacing is varied to vary the length of the infill



Grid spacing – 1.5m,3m,4.5m,6m.

AR1	AR2	AR3	AR4
0.5	1	1.5	2

Fig 2.2.4: Aspect ratio of infill

2.3 Regression Analysis: Regression analysis is a statistical technique that examines the relationship between one or more independent variables—also referred to as predictors or explanatory variables—and a dependent variable, or response variable. The main goals of regression analysis are to comprehend how the independent factors affect the dependent variable and to create a prediction model that can estimate the value of the dependent variable based on the values of the independent variables.

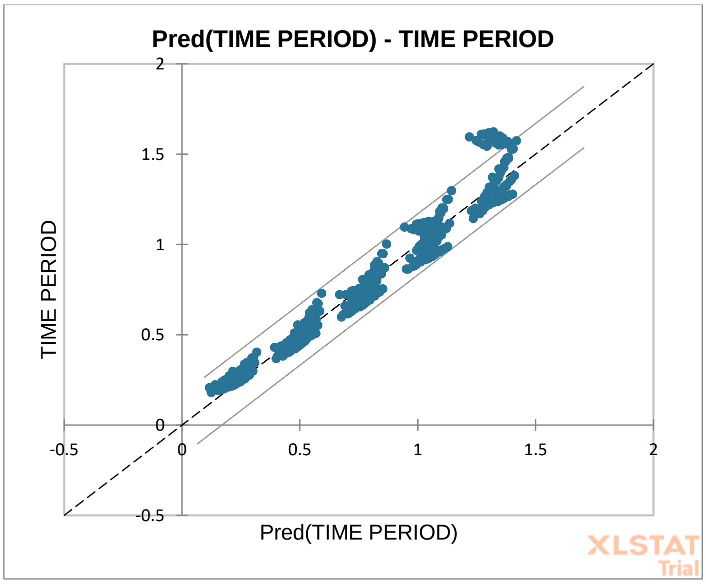


Fig 2.3: Observed time period vs Predicted time period.

The period is well approximated by the suggested equation as the dispersion of the equation is between ±%10, as shown in Figure 2.3, indicating that the equation provides adequate results

3. Results and Discussions.

The models under investigation were subjected to modal Eigen value analysis using ETABS 2020 to calculate the time periods of each structure. The various combination of 500 models were generated and analyzed. Regression analysis was performed on the obtained data using the MS XLSTAT tool for the multivariate data. The equation obtained through the regression analysis is given below:

$$T = 0.157 + 0.023*H - 0.00004*E - 0.402*t - 0.016*AR$$

Where,

T – Time period in seconds.

H – Height of the structure in meters.

E – Modulus of elasticity of infill in MPa.

t – Thickness of infill in meters.

AR – Aspect ratio of infill.

The outcomes of the models created using the specified parameters were contrasted with the codal formula given in IS 1893(Part I):2016 For Infilled Moment resisting Frame, given by:

$$T = \frac{0.09h}{\sqrt{d}}$$

Where,

h=height of the structure.

d=base dimension of the building at the plinth level along the considered direction of earthquake shaking.

3.1 Variation Of Time Period With Respect To Modulus Of Elasticity Of Infill.

Table 3.1.1: Comparison of time period with IS code and proposed equation, for various Modulus of Elasticity of infill for aspect ratio 0.5

HEIGHT	BASE DIMENSION	TIME PERIOD					
(in meters)	(in meters)	IS Code formula	2750 MPa	3300 MPa	3850 MPa	4125 MPa	5500 MPa
12	4.5	0.509	0.269	0.247	0.225	0.214	0.159
24	4.5	1.021	0.545	0.523	0.501	0.489	0.435
36	4.5	1.527	0.821	0.799	0.777	0.766	0.711
48	4.5	2.036	1.097	1.075	1.053	1.042	0.987
60	4.5	2.545	1.373	1.351	1.329	1.318	1.263

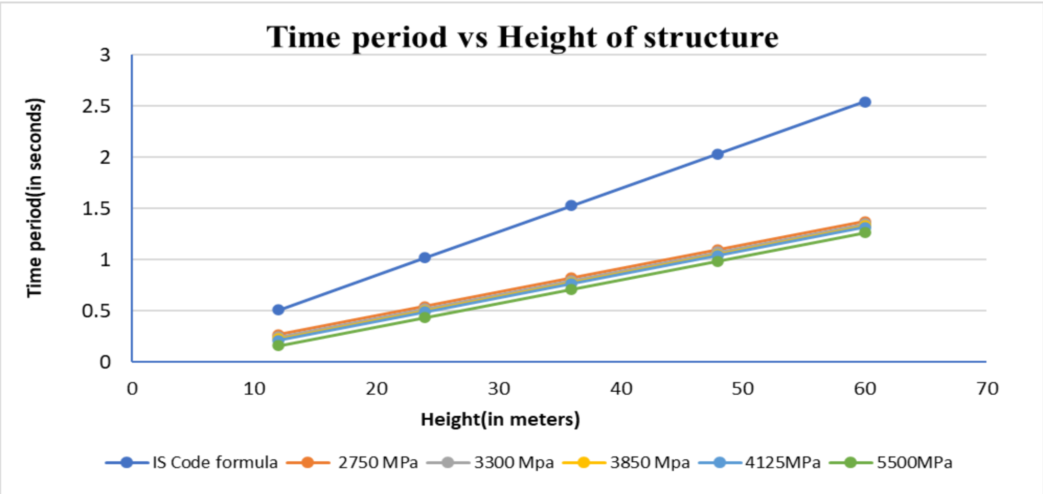


Fig 3.1.1: Comparison of time period with IS code and proposed equation, for various Modulus of Elasticity of infill for aspect ratio 0.5

Table 3.1.2: Comparison of time period with IS code and proposed equation, for various Modulus of Elasticity of infill for aspect ratio 1

HEIGHT	BASE DIMENSION	TIME PERIOD					
(in meters)	(in meters)	IS Code formula	2750 MPa	3300 MPa	3850 MPa	4125 MPa	5500 MPa
12	9	0.361	0.261	0.239	0.217	0.206	0.151
24	9	0.721	0.537	0.515	0.493	0.482	0.427
36	9	1.081	0.813	0.791	0.769	0.758	0.703
48	9	1.441	1.089	1.067	1.045	1.034	0.979
60	9	1.801	1.365	1.343	1.321	1.309	1.255

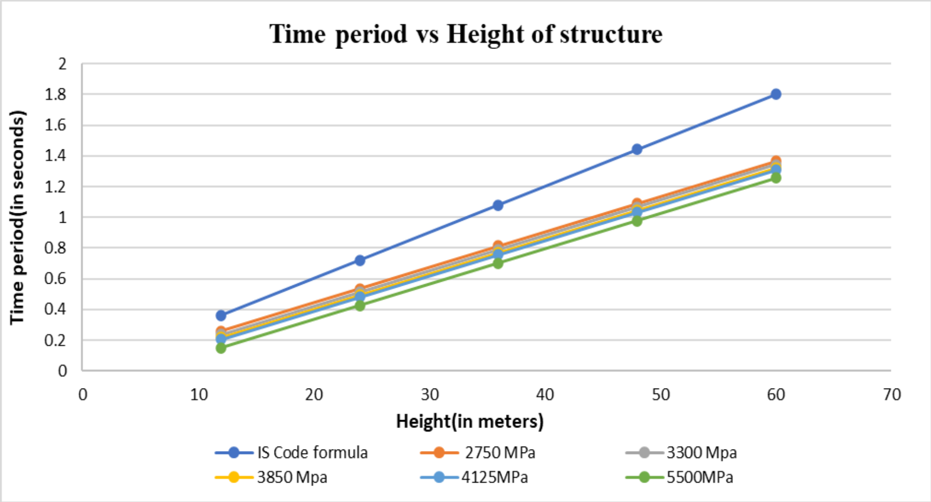


Fig 3.1.2: Comparison of time period with IS code and proposed equation, for various Modulus of Elasticity of infill for aspect ratio 1

Table3.1.3: Comparison of time period with IS code and proposed equation, for various Modulus of Elasticity of infill for aspect ratio 1.5

HEIGHT	BASE DIMENSION	TIME PERIOD					
(in meters)	(in meters)	IS Code formula	2750 MPa	3300 MPa	3850 MPa	4125 MPa	5500 MPa
12	13.5	0.293	0.253	0.231	0.209	0.198	0.143
24	13.5	0.588	0.529	0.507	0.485	0.474	0.419
36	13.5	0.882	0.805	0.783	0.761	0.749	0.695
48	13.5	1.176	1.081	1.059	1.037	1.026	0.971
60	13.5	1.469	1.357	1.335	1.313	1.302	1.247

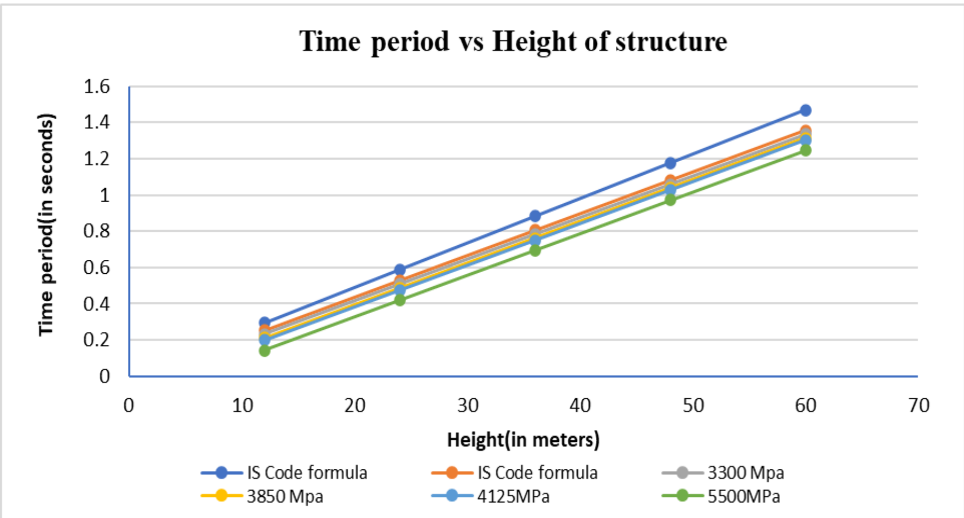


Fig 3.1.3: Comparison of time period with IS code and proposed equation, for various Modulus of Elasticity of infill for aspect ratio 1.5

Table 3.1.4: Comparison of time period with IS code and proposed equation, for various Modulus of Elasticity of infill for aspect ratio 2

HEIGHT	BASE DIMENSION	TIME PERIOD					
(in meters)	(in meters)	IS Code formula	2750 MPa	3300 MPa	3850 MPa	4125 MPa	5500 MPa
12	18	0.254	0.245	0.223	0.201	0.189	0.135
24	18	0.509	0.521	0.499	0.477	0.466	0.411
36	18	0.763	0.797	0.775	0.753	0.742	0.687
48	18	1.018	1.073	1.051	1.029	1.018	0.963
60	18	1.273	1.315	1.293	1.271	1.259	1.205

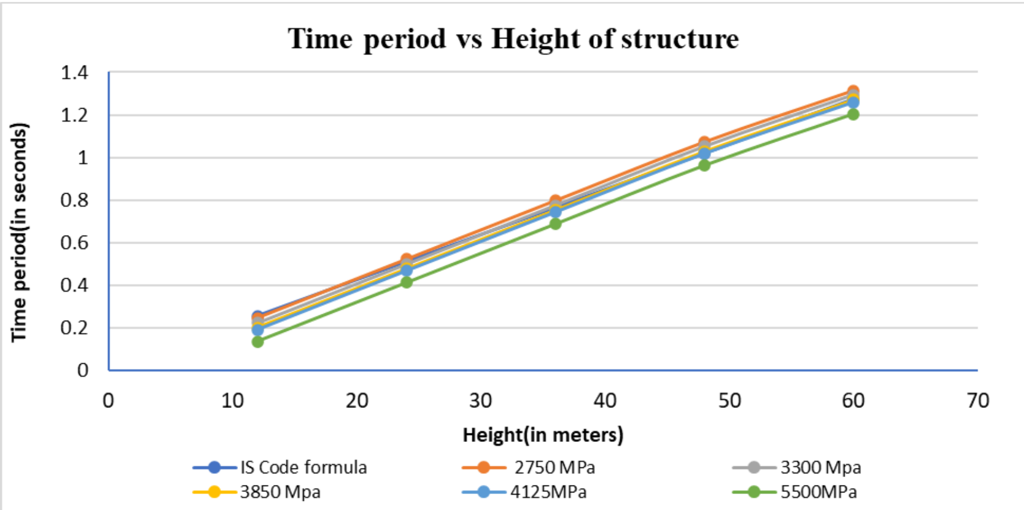


Fig 3.1.4: Comparison of time period with IS code and proposed equation, for various Modulus of Elasticity of infill for aspect ratio 2

3.2 Variation Of Time Period With Respect To Thickness Of Infill.

Table 3.2.1: Comparison of time period with IS code and proposed equation, for various thickness of infill for aspect ratio 0.5

HEIGHT	BASE DIMENSION	TIME PERIOD					
(in meters)	(in meters)	IS Code formula	115 mm	150mm	200mm	230mm	300mm
12	4.5	0.509	0.269	0.255	0.235	0.223	0.194
24	4.5	1.021	0.545	0.531	0.511	0.498	0.471
36	4.5	1.527	0.821	0.807	0.787	0.774	0.746
48	4.5	2.036	1.097	1.083	1.063	1.051	1.022
60	4.5	2.545	1.373	1.359	1.339	1.326	1.298

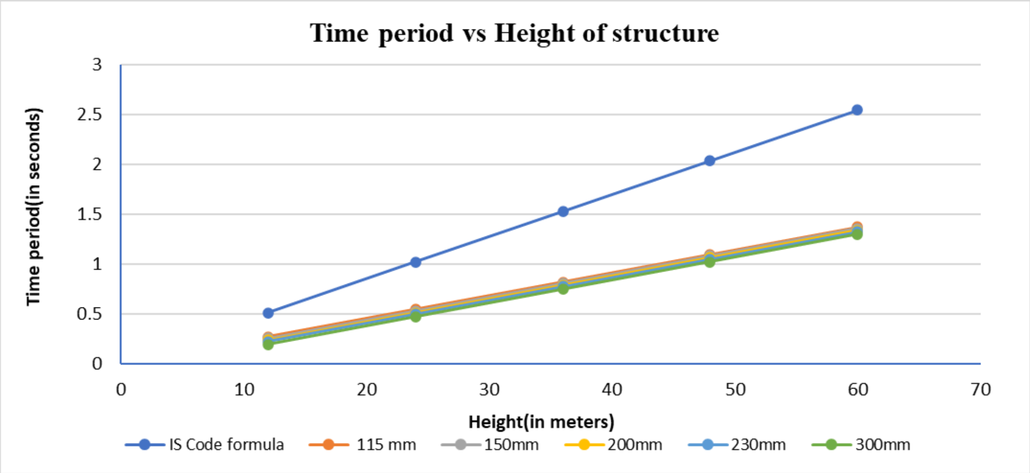


Fig 3.2.1: Comparison of time period with IS code and proposed equation, for various thickness of infill for aspect ratio 0.5

Table 3.2.2: Comparison of time period with IS code and proposed equation, for various thickness of infill for aspect ratio 1

HEIGHT	BASE DIMENSION	TIME PERIOD					
(in meters)	(in meters)	IS Code formula	115 mm	150mm	200mm	230mm	300mm
12	9	0.361	0.261	0.247	0.227	0.214	0.186
24	9	0.721	0.537	0.523	0.503	0.491	0.462
36	9	1.081	0.813	0.799	0.779	0.766	0.738
48	9	1.441	1.089	1.075	1.055	1.042	1.014
60	9	1.801	1.365	1.351	1.331	1.318	1.291

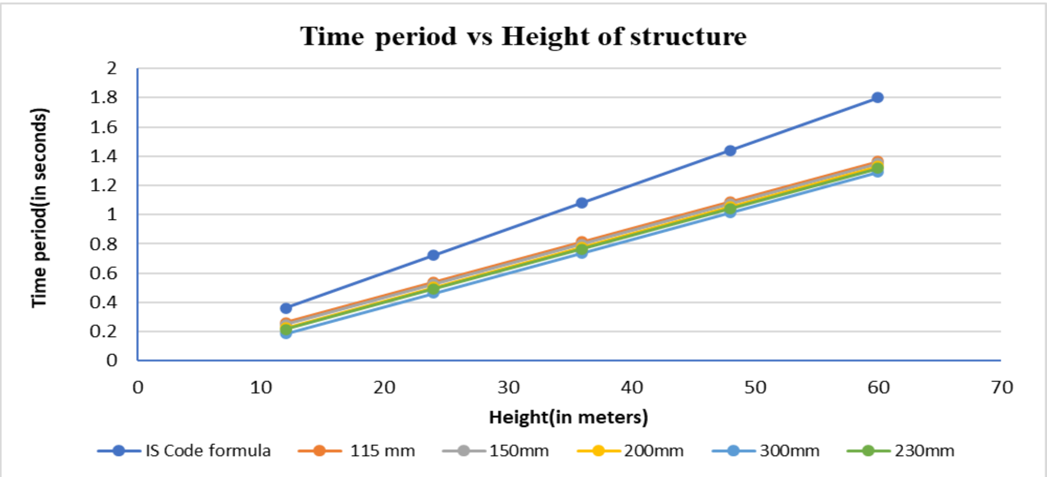


Table 3.2.2: Comparison of time period with IS code and proposed equation, for various thickness of infill for aspect ratio 1

Table 3.3.3: Comparison of time period with IS code and proposed equation, for various thickness of infill for aspect ratio 1.5

HEIGHT	BASE DIMENSION	TIME PERIOD					
(in meters)	(in meters)	IS Code formula	115 mm	150mm	200mm	230mm	300mm
12	13.5	0.293	0.253	0.239	0.219	0.206	0.178
24	13.5	0.588	0.529	0.515	0.495	0.482	0.454
36	13.5	0.882	0.805	0.791	0.771	0.758	0.731
48	13.5	1.176	1.081	1.067	1.047	1.034	1.006
60	13.5	1.469	1.357	1.343	1.323	1.311	1.282

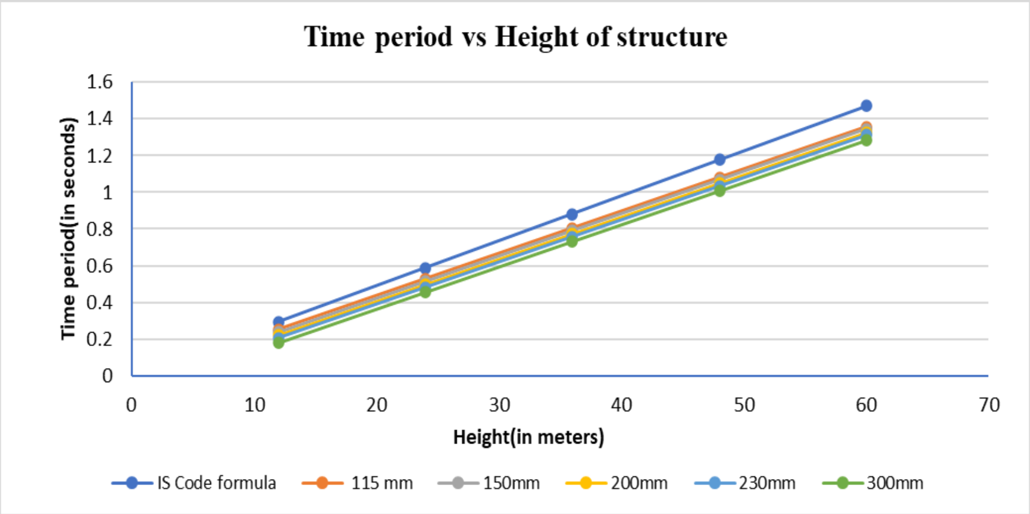


Fig 3.3.3: Comparison of time period with IS code and proposed equation, for various thickness of infill for aspect ratio 1.5

Table 3.3.4: Comparison of time period with IS code and proposed equation, for various thickness of infill for aspect ratio 2

HEIGHT	BASE DIMENSION	TIME PERIOD					
(in meters)	(in meters)	IS Code formula	115 mm	150mm	200mm	230mm	300mm
12	18	0.254	0.245	0.231	0.211	0.198	0.171
24	18	0.509	0.521	0.507	0.487	0.474	0.446
36	18	0.763	0.797	0.783	0.763	0.751	0.722
48	18	1.018	1.073	1.059	1.039	1.026	0.998
60	18	1.273	1.349	1.335	1.315	1.302	1.274

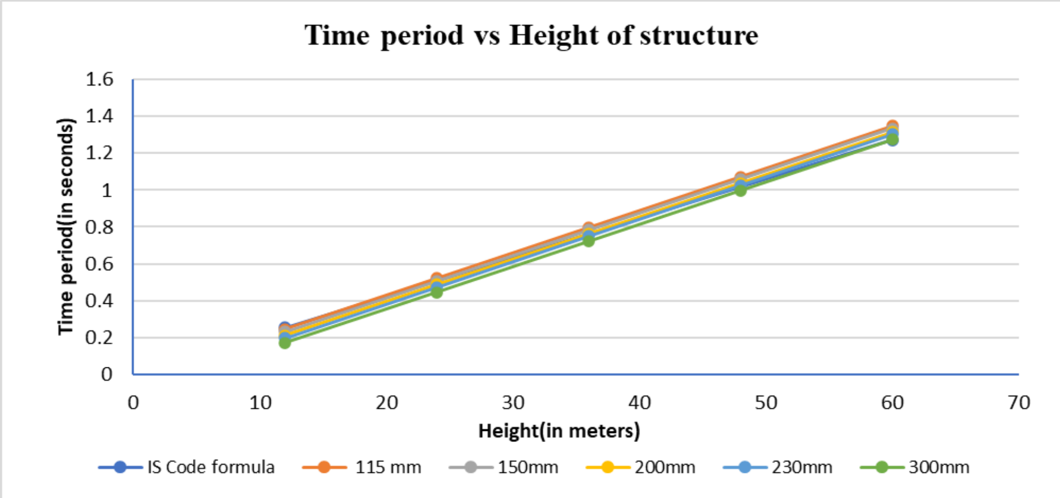


Fig 3.3.4: Comparison of time period with IS code and proposed equation, for various thickness of infill for aspect ratio 2

Findings from the Graphs: The infill walls' modulus of elasticity (E) has a major impact on how long a building lasts. The stiffness of a substance is gauged by its modulus of elasticity. Infill walls with a higher modulus of elasticity are more rigid. Stiffer walls make the structure more rigid overall, which usually results in a shorter building's fundamental time period. As a result, the infill with a modulus of elasticity of 5500 MPa took less time to complete than the 2750 MPa, as seen in graphs (Fig 3.1.1- Fig 3.1.4). The mass and rigidity of a structure are influenced by the thickness (t) of the infill wall. In general, thicker infill walls enhance the bulk and stiffness of the structure. As a result, the time acquired for the 300 mm thick infill is shorter than the 115 mm, as shown in graphs (Fig 3.2.1- Fig 3.2.4).

Height has a major influence on how long a structure lasts, especially for towering buildings and constructions. The flexibility of a building tends to grow with its height. Taller buildings hence typically show longer time periods. As a result, the time period grows with height and is greater for heights of 60 meters than for those of 12 meters. The suggested equation accounts for the infill parameter even though the IS code is independent of it. Time period values are thus often lower than IS code values, as can be observed. The graphs demonstrate how the time period values from the proposed equation typically match the IS code values and overlap in the graph as the structure's height increases.

4. Conclusion.

This study investigated the effects of the thickness, aspect ratio, and elastic modulus of an infill wall on the fundamental vibration period of a building. In addition, a new formula was proposed to determine the basic vibration period as a function of building height, modulus of elasticity, and infill wall thickness. This equation was developed after a comprehensive statistical analysis using regression in XLSTAT.

The infill has a major effect on the overall stiffness of the building and influences its basic time period. The amount of time needed for one full vibration cycle is largely dependent on how stiff the infill makes the structure. Consequently, the basic period of the structure is affected by the stiffness that the infill material provides.

The study found that a structure's time duration depends on a number of other factors in addition to its height and base measurements. A building's lifespan is greatly impacted by a number of infill wall factors, including thickness, aspect ratio, and modulus of elasticity.

This paper proposes an equation for the regression analysis-based fundamental vibration period calculation in XLSTAT. When compared to the time period derived from the suggested equation from modal Eigenvalue analysis for infilled frames, the time period computed in accordance with code provisions is typically longer.

Comparing the proposed equation with the IS code, it is successful in forecasting the time period since it considers all the factors mentioned in the current study.

Acknowledgements:

Declarations:

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