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A Review Study on Effect of Setback on Fundamental Period of RC Framed Buildings

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ABSTRACT:-Setback buildings are now increasingly encountered in modern urban construction. Many investigations have been performed to understand the behavior of setback structures and to ascertain method of improving performance.

METHODS: Based on modal analysis of 90 setback buildings with varying irregularity and height, the goal of this research is to investigate the accuracy of existing code-based equations for estimation of the fundamental period of setback buildings and provide suggestions to improve their accuracy.

KEYWORDS: Setback building, fundamental period, infill panels, ground motion, response spectrum analysis.

I.INTRODUCTION

The magnitude of lateral force due to an earthquake depends mainly on inertial mass, ground acceleration and the dynamic characteristics of the building. To characterize the ground motion and structural behavior, design codes provide a Response spectrum. The determination of the fundamental period of structures is essential to earthquake design and assessment. Masonry infill panels have been used in Reinforced Concrete (RC) frame structures as interior and exterior partition walls. Since they are usually considered as nonstructural elements, their interaction with the bounding frame is often ignored in design. If the properties of the infill wall like density and modulus elasticity of brick masonry are considered in structural design, it will help to improve the strength and stiffness of the structure. But in India infill wall is not considered as a structural element due to this, stiffness of infill wall is not estimated and not considered in design of structure.

Dynamic characteristics of setback buildings differ from the regular building due to changes in geometrical and structural property. Design codes are not clear about the definition of building height for computation of fundamental period.

The bay wise variation of height in setback building makes it difficult to compute natural period of such buildings. With this background it is found essential to study the effect of setbacks on the fundamental period of buildings. Also, the performance of the empirical equation given in Indian Standard IS 1893:2002 for estimation of fundamental period of setback buildings is matter of concern for structural engineers.

Wong and Tso (1999) studied the response of setback structures and they proposed a modification factor for adjusting the code period formulas so that it can more accurately determine the period of setback building[1].

Sarkar et al. (2015) proposes a new method of quantifying in stepped building frames, which accounts for dynamic characteristics i.e. mass and stiffness, addressing some of the key issues regarding analysis and design of stepped buildings[2].

Young (2017) presented a study in the determination of the fundamental period of vibration of structures with geometric irregularities. This study investigated the fundamental periods of three different types of steel earthquake-resistant building structures: moment resisting frames (MRF), concentrically braced frames (CBF), and eccentrically braced frames (EBF) with varying geometric irregularities[3].

As per IS 1893:2002 buildings having simpler regular geometry and uniformly distributed mass and stiffness in plan as well as in elevation, suffer much less damage than buildings with irregular configurations[4]. The applicability of code based empirical formulas for calculation of fundamental period of setback buildings was nowhere discussed in the literature, except Sarkar et al. (2015). Though much of the literature is available and many researchers have dealt with analysis in investigating the seismic behavior of vertically irregular buildings as per governing earthquake codes of respective countries, but less work has been done on the dynamic analysis of buildings with setbacks and infill walls. Hence, the present study aims to perform a parametric study on irregular buildings to find fundamental period of different types of reinforced concrete moment resisting frames (MRF) with varying number

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of stories, number of bays and configuration also with due consideration of infillwalls.

II. METHODOLOGY

A. 3D RC buildings with varying heights and widths were considered for the study. Different building geometries were taken for thestudy. These building geometries represent varying degree of irregularity or amount of setback. Three different bay widths, i.e. 5m, 6m and 7m (in both the horizontal direction) with a uniform three number of bays at base were considered for this study. Similarly, five different height categories were considered for the study, ranging from 6,12,18,24 and 30 storeys, with a uniform storey height of 3m.Altogether
90 building frames with different amount of setback irregularities due to the reduction in width and height were selected.

B. There are altogether six different building geometries, one regular and five irregular, for each height category are considered in the present study. Figure 1 to 6 presents the elevation of all six different geometries of a typical six storey building. The buildings are three dimensional, with the irregularity in the direction of setback, in the other horizontal direction the building is just repeating its geometric configuration. Setback frames are named as S1, S2, S3, S4 and S5 depending on the percentage reduction of floor area and height as shown in the Figure 1 to 7. The regular frame is named as R. The exact nomenclature of the buildings considered are expressed in the form of S-X-Y, where S represents the type of irregularity (i.e., S1 to S5 or R). X represents the number of storeys and Y represents the bay width in both the horizontal direction. For all the other setback buildings the reduction in height and reduction of width will be consistent with reductions as explained in Figures. For example a S3-18-5 will have plan dimension of 3 bay by 3 bay at the base and will continue up to 6th floor. Plan dimension will reduce to 2 bay by 2 bay from 7^{th} to 12^{th} floor, and it will further reduce to 1 bay by 1 bay from 13^{th} floor to 18^{th} floor. The setbacks are considered in one horizontal direction only; the building is made three dimensional by repeating these bays in other horizontaldirection.

C. The frames are designed with M-20 grade of concrete and Fe-415 grade of reinforcing steel as per prevailing Indian Standards. Gravity (dead and imposed) load and seismic load corresponding to seismic zone II of IS 1893:2002 are considered for thedesign.

The cross sectional dimensions of beams and columns are taken as shown in Table 1. The slab thickness is considered to be 120mm for all the buildings, Infill walls in the exterior faces of all the buildings are assumed as of 230mm thickness and of 120mm thickness for all the inner infillwalls.

D. The structures are modelled by using computer software ETABS. Modal analyses were performed to check if the selected frames represent realistic buildingmodels.

III.RESULTS ANDDISCUSSIONS

E. The fundamental time periods of all the 90 selected setback buildings were calculated using different methods available in literature including code based empirical formulas. Fundamental period of these buildings were also calculated using modal analysis. The fundamental periods presented here are computed as per different code empirical equations such as IS 1893:2002, ASCE 7-05 and period obtained from modalanalysis.

F. Figures 7, 9 and 11 presents the comparison of fundamental period of setback buildings (5m, 6m and 7m bay width) with that obtained from IS 1893:2002 equation. These figures show that the code empirical formula gives the upper-bound of the fundamental periods obtained from Modal Analysis. Therefore, it can be concluded that the Indian standard provides different expressions for the estimation of the natural period of the building structure considering or neglecting the stiffness of the infill wall. The consideration of stiffness of masonry infill increases the stiffness of the structure and hence reduces the natural period. Displacement decreases due to increase in strength and stiffness of the structure by infill walls for the investigated models. The base shear of the structure increases due to the introduction of infill walls because as the natural period decreases base shear increases. When the effect of infill wall is ignored this leads to the underestimation of base shear acting on a structure during earthquake. As the time period that are obtained from the code empirical formula is more base shear will be less. Finally, it can be said from the seismic design aspect that code equations yield lower base shear than actual, hence results in unsafe design of irregular structure. Figures 8, 10 and 12 presents the comparison of fundamental period of setback buildings with that obtained from empirical equation of ASCE 7-05 respectively. A similar conclusion to that of IS 1893:2002 can be made from the results presented in Figures 8, 10 and12.

It is instructive to note from these three figures that the fundamental period in a framed building is not only a function of building

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height, but also depends on various other factors. These three figures clearly show that buildings with same overall height may have different fundamental periods with a considerable variation which is not addressed in the code empirical equations. For a regular building there is no ambiguity as the height of the building is same throughout both the horizontal directions. However, this is not the case for setback buildings where building height may change from one end to other. Therefore, there is a need to define the irregularity for a setback building and relate the empirical equation of fundamental period of the setback building with its irregularity. Some of the previous works addressed this issue of defining irregularity and proposed some measure of quantifying the irregularity in setback buildings. Design codes do not directly quantify the irregularity in setback buildings but it gives a parameter to distinguish the regular and setback irregular buildings.

G. Figures 7 to 12 presented above show that the buildings with same maximum height and same maximum width may have different period depending on the amount of irregularity present in the setback buildings. This variation of the fundamental periods due to variation in irregularity is found to be more for taller buildings and comparatively less for shorter buildings. This observation is valid for the periods calculated from modalanalysis.

H. Parameters affecting fundamental timeperiod

I. One of the main objectives of the present study was to formulate an improved empirical relation to evaluate fundamental period of setback buildings considering the vertical geometric irregularity. It is, therefore, required to know the important parameters which control the fundamental period of a setback building. This section analyses the fundamental period computed using the Modal analysis against different possibleparameters.

J. From the Figures 13 to 18, it can be seen that the fundamental period of the building increases as the building height increases. It can also be seen that the time period is inversely proportional to the bay width, as the bay width increases the fundamental period decreases. This difference is more for high rise buildings. From Figures 19 to 23, it can be seen that the variation in fundamental period with the change in bay width of the setback building, it is observed from these figures that, the change in bay width affects the fundamental period of the setback buildingconsiderably.

K. This change in fundamental period due to change in bay width is found to be considerable and it cannot be ignored. The code based empirical equation for the estimation of fundamental period does not take in account the bay width of the building for RC moment resisting frames without brick infill. However, in design codes, the empirical equations considering the brick infill does depend on bay width. Therefore, it is concluded that the bay width or the plan dimension of the building affects the fundamental period of building, and it should be accounted for in the code based empirical equations for the calculation of fundamental period of RC frame buildings without infillalso.

IV.MODIFIED FORMULA FOR TIMEPERIOD

L. Based on the analytical studies, an empirical formula for modification of expression of the time period proposed by existing code is proposed. The results obtained from the proposed equation of the fundamental period of vibration is compared with the results of modal analysis for building models with different location of setbacks. Results of the study obtained using proposed equation and modal analysis are found to be in closeagreement.

M. The modified formula for finding out the Time Period of irregular buildings with brick infills is given by the equation.

N. $T = aH^{1.34}$

O. Where $a = 0.0038$ for $0.25 < A/L \leq 0.66$

Table 1.
Dimensions of beams and columns for different buildings

Building Type according to number to stories	Column dimension	Beam dimension
Six-storey building	400 mm × 400 mm	300 mm × 450 mm
Twelve-storey building	600 mm × 600 mm	450 mm × 600 mm

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Eighteen storey building	800 mm × 800 mm	450 mm × 600 mm
Twenty four-storey building	1000 mm × 1000 mm	450 mm × 750 mm
Thirty-storey building	1200 mm × 1200 mm	600 mm × 750 mm

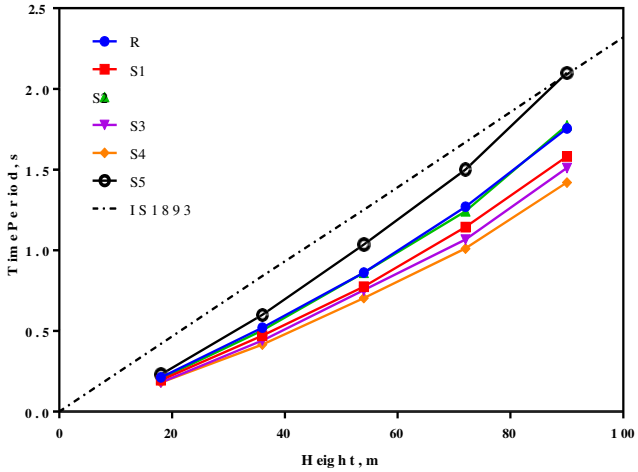

Figure 7.Comparison of fundamental period versus height of setback buildings of 5m bay width with that obtained from IS 1893

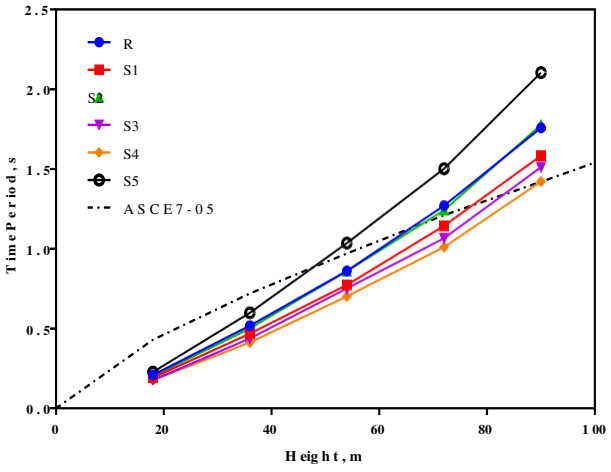

Figure 8.Comparison of fundamental period versus height of setback buildings of 5m bay width with that obtained from ASCE 7-05

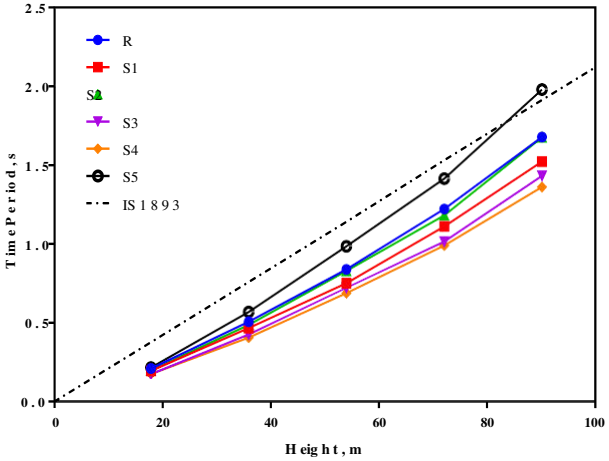

Figure 9. Comparison of fundamental period versus height of setback buildings of 6m bay width with that obtained from IS 1893

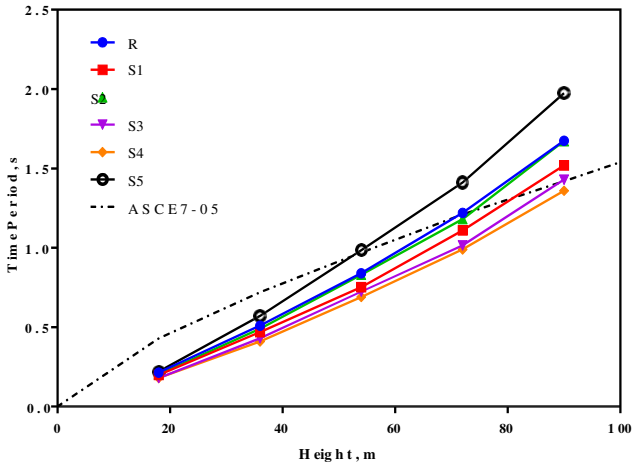

Figure 10.Comparison of fundamental period versus height of setback buildings of 6m bay width with that obtained from ASCE 7-05

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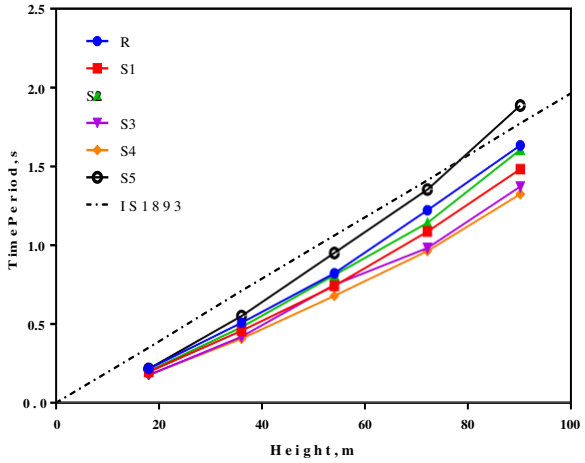

Figure 11.Comparison of fundamental period versus height of setback buildings of 7m bay width with that obtained from IS 1893

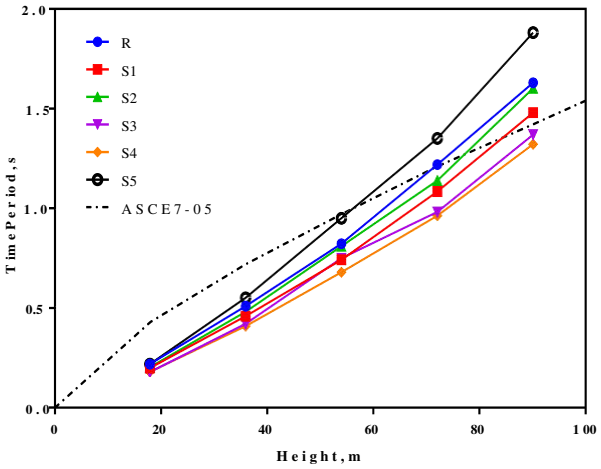

Figure 12.Comparison of fundamental period versus height of setback buildings of 7m bay width with that obtained from ASCE 7-05

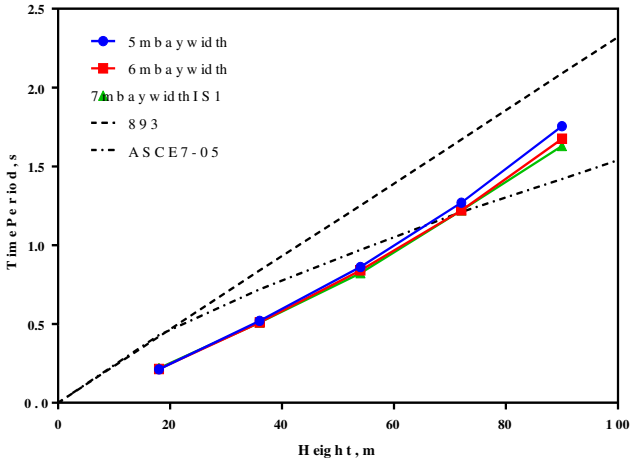

Figure 13.Variation of fundamental time period with bay width for Type – R building.

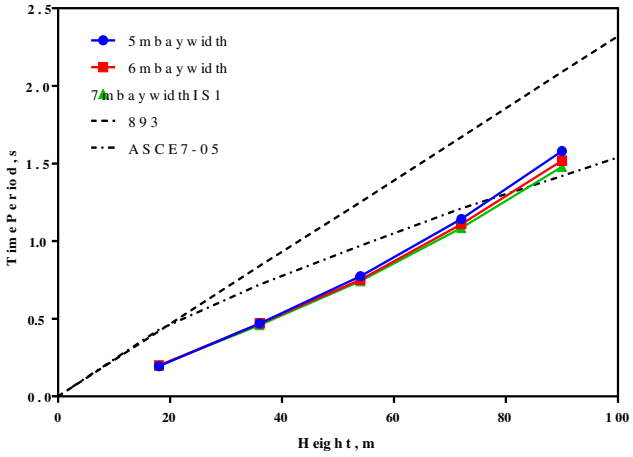

Figure 14,Variation of fundamental time period with bay width for Type – S1 setback building

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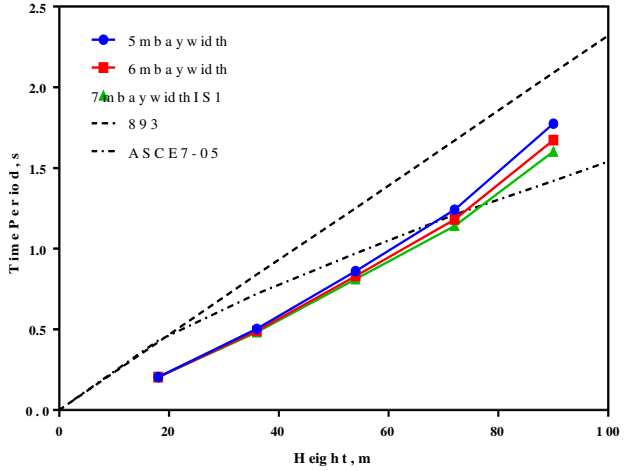

Figure 15.Variation of fundamental time period with bay width for Type – S2 setback building

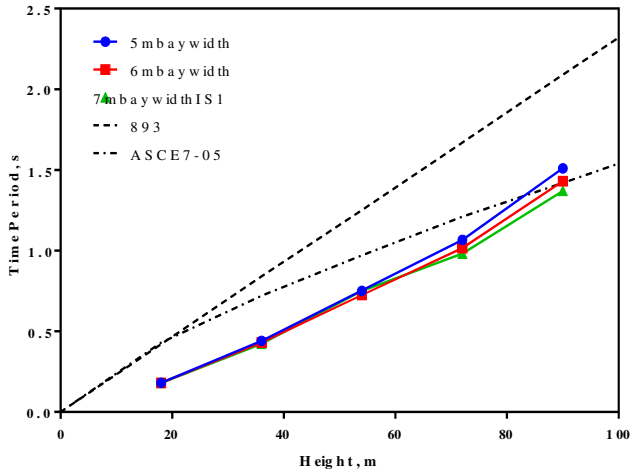

Figure 16. Variation of fundamental time period with bay width for Type – S3 setback building

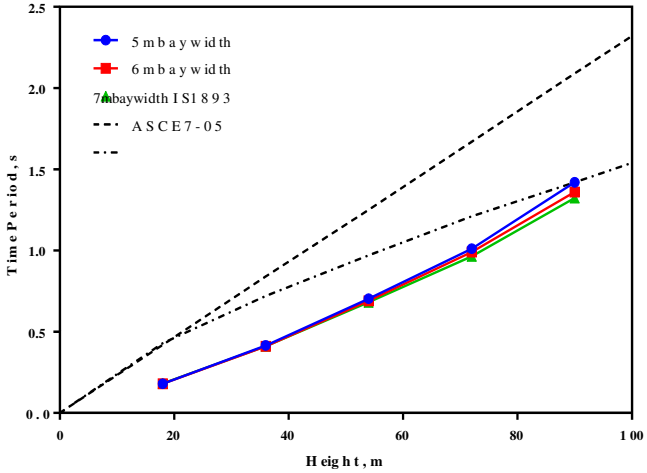

Figure 17.Variation of fundamental time period with bay width for Type – S4 setback building

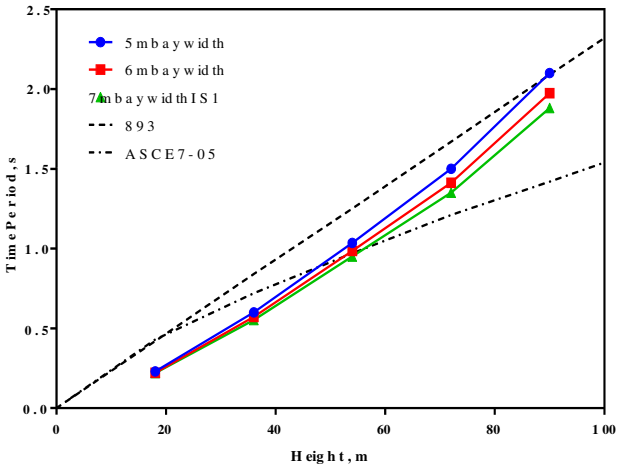

Figure 18.Variation of fundamental time period with bay width for Type – S5 setback building

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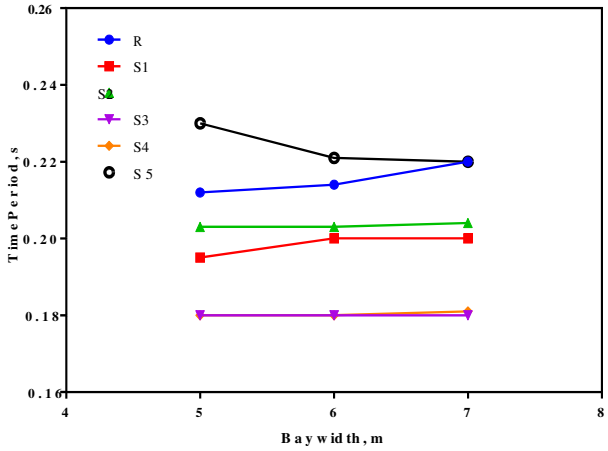

Figure 19. Variation of fundamental time period with bay width for 6-storey setback buildings

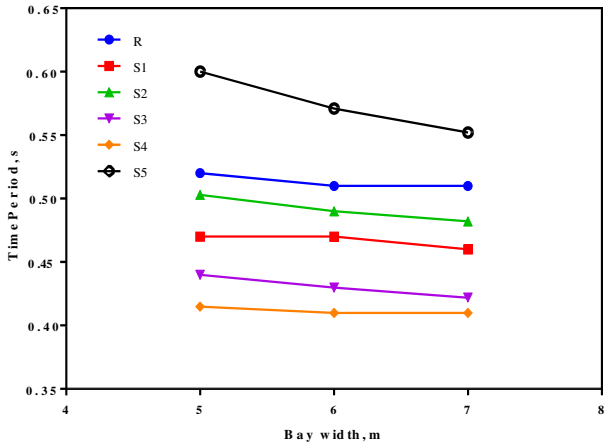

Figure 20.Variation of fundamental time period with bay width for 12-storey setback buildings

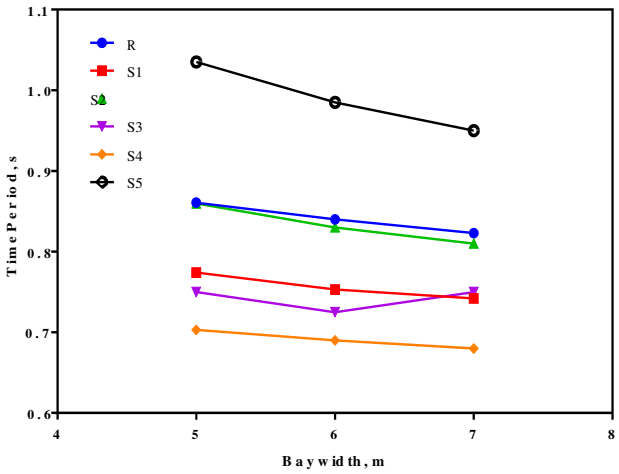

Figure 21.Variation of fundamental time period with bay width for 18-storey setback buildings

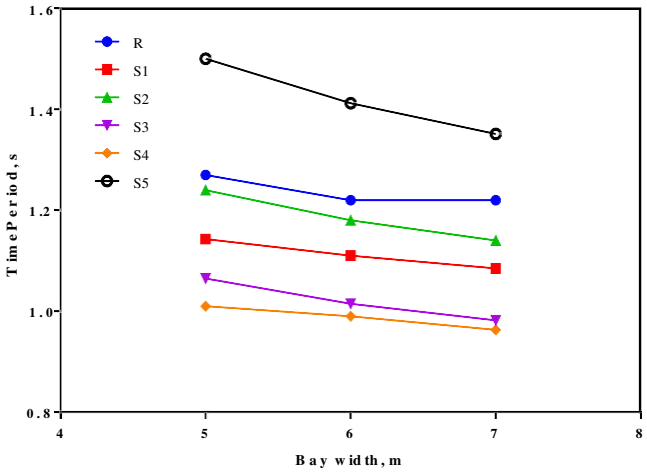

Figure 22.Variation of fundamental time period with bay width for 24-storey setback buildings

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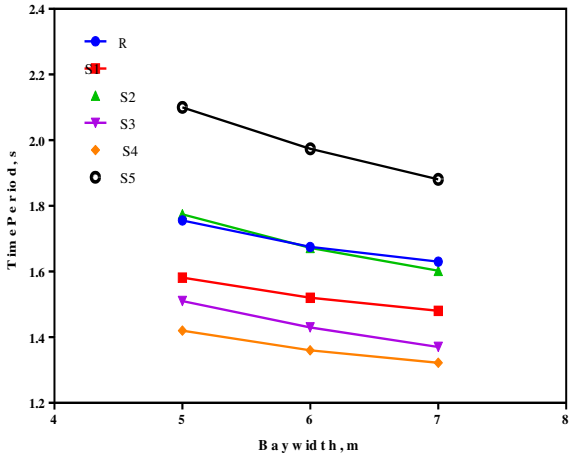

Figure 23.Variation of fundamental time period with bay width for 30-storey setback buildings

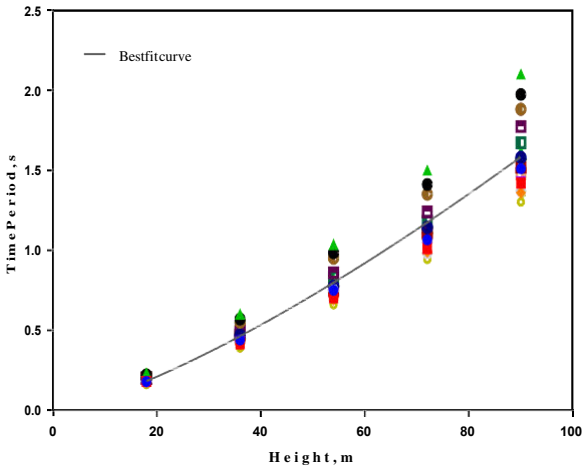

Figure 24. Regression analysis for Fundamental time period for models

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