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Influence of infills on fundamental time period of RC structures

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Abstract - *The infill in RC framed building under study were modelled in ETAB software, with solid concrete blocks, aerated concrete block, common burnt clay brick, hollow open cavity concrete block and performed foam cellular concrete block infill masonry. A parametric analysis has been done by varying with height of building, young's modulus of infills and plan dimensions. The fundamental time period were compared by calculated using model analysis and design codes. From the study it is clear that, different infill buildings shows variations in fundamental time period with same height and plan dimensions due to the difference in young's modulus of infills. As the young's modulus of building infill increases the fundamental time period reduces. The fundamental time period is less for building having infill as performed foam cellular concrete block and more for solid concrete blocks. As the plan dimension increases, then fundamental time period reduces. The percentage reduction of the fundamental time period of infill buildings w.r.t the bare framed buildings varied by young's modulus as 26% to 80%. The fundamental time period in most empirical equations are related only with the height of buildings, which cannot be considered for general validity.*

***Key Words*: Solid concrete blocks (SCB), Aerated concrete block(ACB), Common burnt clay brick (CBB), Hollow open cavity concrete block (HCB) and Performed foam cellular concrete block(PCB), Fundamental time period.**

1. INTRODUCTION

Reinforced concrete (RC) frame buildings with unreinforced masonry (URM) infill walls are commonly built throughout the world, including in seismically active regions. URM infill walls are widely used as partitions throughout many places and despite often being considered as non-structural elements, they affect both the structural and non-structural performance of RC buildings. Structural engineers recognize that many buildings of this type have performed poorly and have even collapsed during recent earthquakes in Turkey, Taiwan, India, Algeria, Pakistan, China, Italy etc. Fundamental time period is a global characteristic which describes the behavior of building under seismic load. For the determination of the lateral loads, it is required to estimate first the fundamental vibration period of the building. It is unavoidable in seismic analysis and almost all code fundamental time period is function of building dimension. So it is necessary to study about the effect of infill on the fundamental time period. The studies conducted in last years allowed to define simplified relationship able to estimate the fundamental time period of buildings. The main parameters taken into account are the height and the typology of the buildings in terms of structural configuration and construction materials.

The empirical expression for T may be specific to each country. The approximate fundamental natural period of vibration (Ta) in second of a moment resisting frames building may be estimated by empirical expression given in codes. These technical codes provide expressions which depend on basic parameters such as building height or number of stories. There is scope for further improvement in these equations since the height alone is inadequate to explain period variability.

The present research basically aims to know about the influence of infills for finding the fundamental time period. Based on this it seems interesting to perform a parametric analysis taken into account the mechanical properties such as young's modulus of masonry infill panel which connected to surrounding RC frames. This study focused on seismic performance of buildings having bare framed RC buildings and buildings with infills such as solid concrete blocks, aerated concrete block, common burnt clay brick, and hollow open cavity concrete block and performed foam cellular concrete block. A parametric analysis has been done by varying with height of building, young's modulus of infills and plan dimension.

1.1 Objective

1. To compare different buildings having bare framed (BF) RC structures and with infills such as solid concrete blocks (SCB), aerated concrete block (ACB), common bur nt clay brick (CBB), hollow open cavity concrete block (HCB) and performed foam cellular concrete block (PCB) by seismic analysis.
2. A parametric analysis of infilled building structures has been performed considering height of building, young's modulus of infills and building plan dimension.
3. To compare the fundamental time period, obtained from empirical equations in design codes and from modal analysis.

1.2 Fundamental Time Period

Time period of buildings were determined by equations provided in design codes. The design codes used for earthquake resistant structures for calculating fundamental time period are IS 1893:2000 and ASCSE 7:2010.

The fundamental natural period of vibration, T_a (in seconds), of a RC moment resisting frame of overall height h (in meter) without brick infill, as per IS 1893:2002 is given by:

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

As per IS 1893 (Part 1) : 2002, the fundamental time period of vibration 'T_a' in seconds of all buildings including moment resisting frame buildings with brick infill panels may be estimated by,

$$Ta = 0.09\, h / \sqrt{d}$$

In a similar way as per ASCE 7:2010, the approximate fundamental period Ta (in second) of a structure with over all height h_n (in meter) for a RC moment resisting frame building is given by:

$$T_a = 0.0466(h_n)^{0.9}$$

ASCE 7:2010 permits to determine fundamental period T_a (in second) of RC buildings from the following equation for structures not exceeding 12 storey in height provided storey height to be at least 3 m. The equation is of the following form where, N is the number of storey:

$$T_a = 0.1N$$

2. MODELLING

2.1 Material Properties

The beams and slab in the modelled structures are of M_{20} grade of concrete and Fe-415 grade of steel rebar are used. For columns M_{30} grade of concrete and Fe-415 grade of steel rebar are used for modelling. The wall thickness of the infill taken as 200mm. The slab thickness of building is taken as 125mm. Material properties of infills are taken from IS 2185 are shown in the table 1.

Table -1: Material properties of infills used in the structural models

Infill materials	Compressive strength (MPa)	Young's modulus (MPa)
Solid concrete blocks (SCB)	4	3600
Aerated concrete block (ACB)	7	6300
Common burnt clay brick (CBB)	12.5	17588
Hollow open cavity concrete block (HCB)	15	13500
Performed foam cellular concrete block (PCB)	25	22500

2.2 Loading Conditions

When earthquake forces are considered on a structure following loads are considered for analysis.

1. Dead load (DL): It is taken by software itself.
2. Live load (LL) of slab = 3kN/m^2
3. Earthquake loading (EL): Loading is done as per IS 1893 (Part I): 2002[18]
   Building is considered in Calicut and seismic zone: III
   Z, Zone factor = 0.16
   I, Importance factor = 1
   Special R C moment resisting frame
   R, Response reduction factor = 5

Load combination: In the limit state design of reinforced and prestressed concrete structure, the following load combinations are taken into account which is already designed in ETAB software,

1. 1.5 (DL+LL)
2. 1.2 (DL+LL+EL)

2.3 Building Geometry

Solid concrete block (SCB), aerated concrete block (ACB), common burnt clay brick (CCB), hollow open cavity concrete block (HCB) and performed foam cellular concrete block (PCB) infills are used in modelling. Three different height categories were considered for the study such as 10 storey, 20 storey and 30 storey with storey height as 3m and bay width as 4m. The size of beams and columns are selected as 300mm x 600mm and 500mm x 500mm.The building plan dimensions selected for modelling are 12m x 12m, 24m x 24m and 36m x 36m.There are altogether 54 building models were analyzed. The buildings were fixed at bottom and all the degrees of freedom of the displacement are restrained against movement.

3. RESULTS AND DISCUSSIONS

According to the objectives of the present study, the result presented here are focused on fundamental time period of building models with different infills.

3.1 Variation of fundamental time period by different infills

The following graphs shows the variation of fundamental time period, the fundamental time period of different infilled buildings as a function of height are compared by model analysis, IS1893 and ASCE.7.

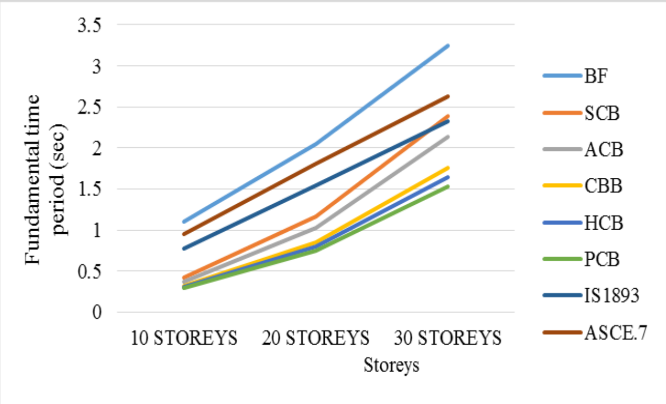

Chart -1: Fundamental time period of buildings for 12m x 12m plan dimension

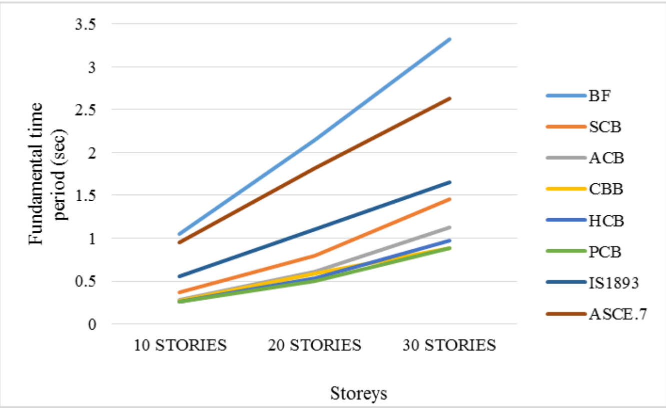

Chart -2: Fundamental time period of buildings for 24m x 24m plan dimension

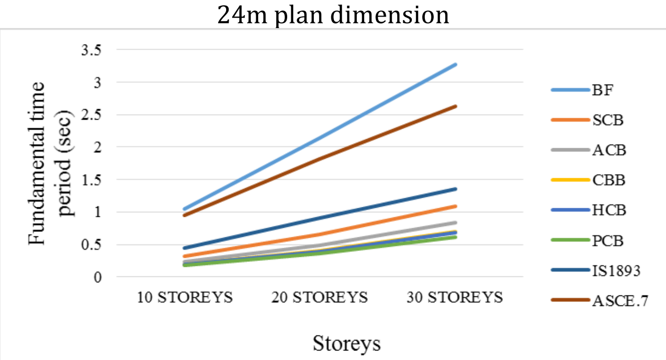

Chart -3: Fundamental time period of buildings for 36m x 36m plan dimension.

In table 2 the result obtained for buildings designed with plan dimension 12m x 12mm and these similar variations are also shown by other plan dimensions. The percentage reduction of the fundamental time period of infill buildings w.r.t the bare framed buildings is shown in table2.

Table -2: Percentage reduction of the time period of infill buildings to the bare framed

Infill materials	Young's modulus, E (MPa)	% reduction of time period of infill buildings w.r.t bare framed building		
		28.5m height	58.5m height	88.5m height
Solid concrete blocks (SCB)	3600	61	43	26
Aerated concrete block (ACB)	6300	66	58	34
Common burnt clay brick (CBB)	17588	71	61	46
Hollow open cavity concrete block (HCB)	13500	72	64	49
Performed foam cellular concrete block (PCB)	22500	74	68	53

From chart 1-3 and table 2, we can observe that,

1. Different infilled building shows variations in fundamental time period with same height and plan dimensions due to the difference in young's modulus of infills.
2. As the young's modulus of building infill increases the fundamental time period reduces. The fundamental time period is less for building having infill as performed foam cellular concrete block (PCB) and more for solid concrete blocks (SCB). The PCB have more young's modulus compared to other infills.
3. For the building with height equal to 28.5 m, the fundamental time period of infilled building compared to the period of bare frames decreases of 61% and 74%, for E_w = 3600 MPa and E_w = 22500 MPa, respectively. For frames with a height of 88.5 m the decrease of period in percentage is between 26% and 53%, at the same E_w values. These variations are also shown by other models.
4. The bare framed building shows more time period than infilled buildings. The percentage reduction of the fundamental time period of infill buildings w.r.t the bare framed buildings varied by young's modulus as 26% to 74%.

5. The variations has been observed between the fundamental time period obtained from empirical equations and modal analysis.
6. As building height increases, fundamental time period increases. The percentage reduction of the fundamental time period of infill buildings w.r.t the bare framed buildings, reduces as height of building. For building having E_w = 3600 MPa, time period reduces as 61% to 26%, when height increases. For building having E_w = 22500 MPa, time period reduces as 74% to 53%, when height increases.
7. The variation in fundamental time period due to variation in infills is found to be significant for taller building. The percentage reduction of the fundamental time period of infill buildings w.r.t the bare framed buildings, variation is shown more for height 88.5m as 61% to 74% than for height 28.5m 26% to 53%.

3.1 Variation of fundamental time period by plan dimension

The following graphs shows that fundamental time period in a buildings depend upon the plan dimensions.

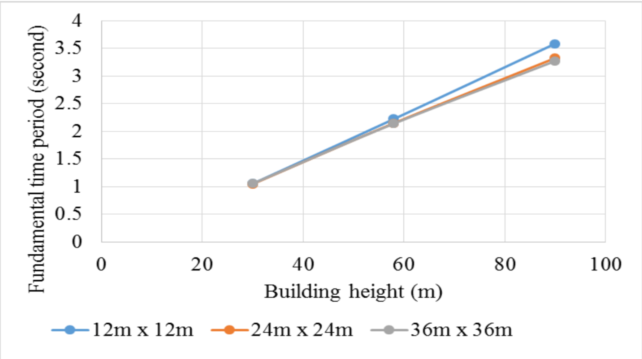

Chart -4: Variation of fundamental time period with plan dimension for bare frame

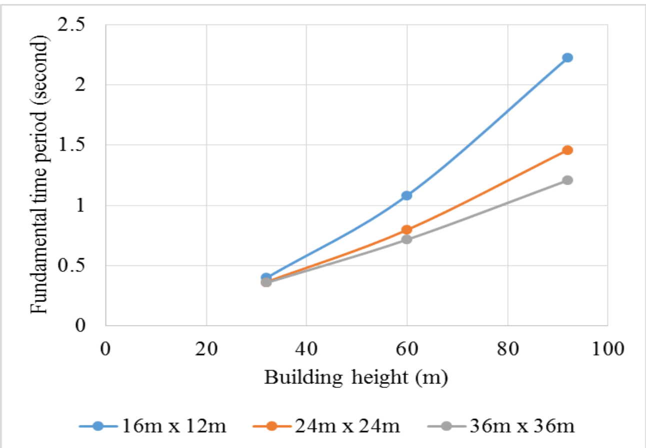

Chart -5: Variation of fundamental time period with plan dimension for solid concrete block (SCB)

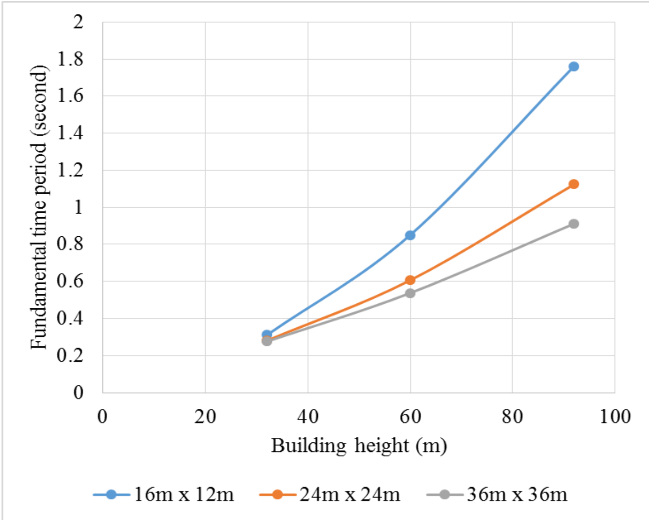

Chart -6: Variation of fundamental time period with plan dimension for aerated concrete block (ACB)

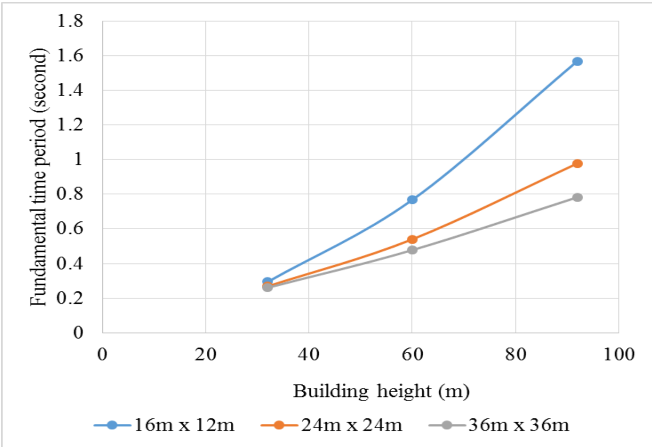

Chart-7: Variation of fundamental time period with plan dimension for common burnt clay brick (CCB)

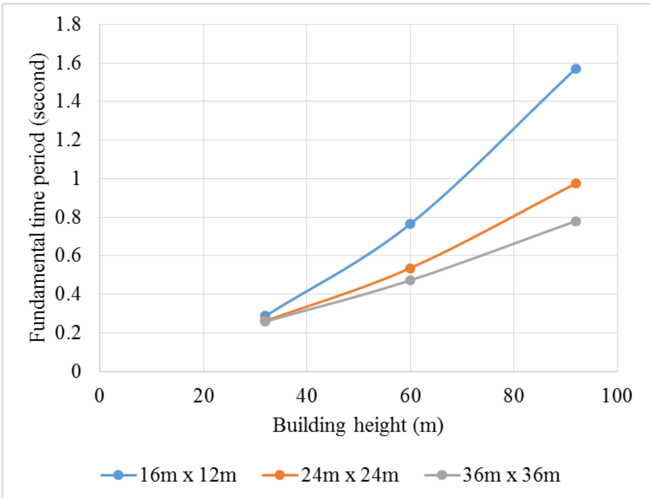

Chart -8: Variation of fundamental time period with plan dimension for hollow open cavity concrete block (HCB)

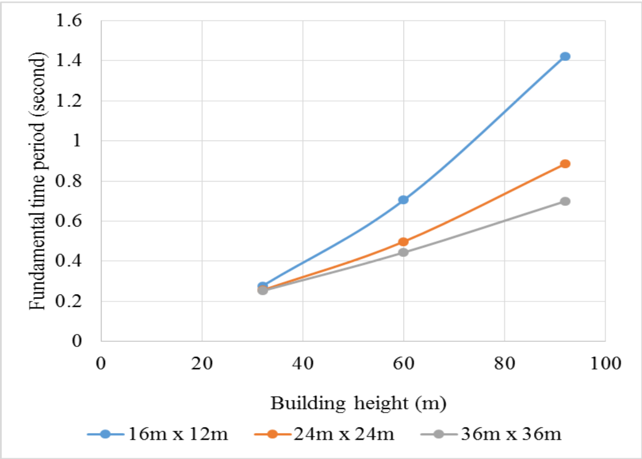

Chart -9: Variation of fundamental time period with plan dimension for performed foam cellular concrete block

In table 3 are the result obtained for buildings designed with height as 58.5m and is similar for all other height. The percentage reduction of the fundamental time period of infill buildings to the bare framed buildings is shown in table 3.

Table -3: Percentage reduction of the time period of infill buildings to the bare framed

Infill materials	Young's modulus, E (MPa)	% reduction of time period of infill buildings w.r.t bare framed building		
		12m x 12m Plan dimension	24m x 24m Plan dimension	36m x 36m Plan dimension
Solid concrete blocks (SCB)	3600	43	63	66
Aerated concrete block (ACB)	6300	58	72	75
Common burnt clay brick (CBB)	17588	61	73	77
Hollow open cavity concrete block (HCB)	13500	64	75	78
Performed foam cellular concrete block (PCB)	22500	68	77	79

From chart 4 – 9 and table 3, we can observe that,

1. Different infilled building shows variations in fundamental time period with same height and plan dimensions due to the difference in young's modulus of infills.
2. The plan dimension increases, then fundamental time period reduces. For the buildings with infill as E_w = 3600 MPa, the percentage decrease in time period of infilled building compared to the period of bare frames as 43% to 66%, for plan dimension 12m x 12m and 36m x 36m respectively. For buildings with infill as E_w = 22500 MPa , the percentage decrease in time period of infilled building compared to the period of bare frames as 68% to 79%, at the same plan dimensions. As plan dimension increases, percentage reduction of the time period of infill buildings to the bare framed increases.
3. For the buildings with plan dimension equal to 12m x 12m, the time period of infilled building compared to the period of bare frames decreases of 43% and 68%, for E_w = 3600 MPa and E_w = 22500 MPa, respectively. For frames with plan dimension 36m x 36m, the decrease of period in percentage is between 66% and 79%, at the same E_w values. As plan dimension increases, percentage reduction of the time period of infill buildings to the bare framed increases. As young's modulus increases, time period increases.

4. CONCLUSIONS

Based on the analyses of building models, the following conclusions are drawn.

1. The results obtained underline as the properties of infills are not negligible; the young's modulus considerably modifies the period of frames; this analysis empathizes the importance of evaluating the mechanical properties of materials in the assessment of seismic vulnerability of existing structures.
2. Different infilled building shows variations in fundamental time period with same height and plan dimensions due to the difference in young's modulus of infills.
3. As the young's modulus of building infill increases the fundamental time period reduces. The fundamental time period is less for building having infill as performed foam cellular concrete block (PCB) and more for solid concrete blocks (SCB). The PCB have more young's modulus compared to other infills.
4. The percentage reduction of the fundamental time period of infill buildings w.r.t the bare framed buildings varied for young's modulus E_w = 3600 MPa to E_w = 22500 MPa ,as 61% to 74% to 28.5m height, 43% to 68% to 58.5m height and 26% to 53% to 88.5m height buildings.

5. The bare framed building shows more time period than infilled buildings. The percentage reduction of the fundamental time period of infill buildings w.r.t the bare framed buildings varied by young's modulus as 26% to 80%.
6. The plan dimension increases, then fundamental time period reduces. The percentage reduction of the fundamental time period of infill buildings w.r.t the bare framed buildings varied for young's modulus E_w = 3600 MPa to E_w = 22500 MPa ,as 43% to 68% (12m x 12m plan dimension), 63% to 77% (24m x 24m plan dimension) and 66% to 79% (36m x 36m plan dimension).
7. The fundamental time period in empirical equations are related only with the height of buildings, which cannot be considered for general validity. Some other parameters are also considered for the evaluation of fundamental time period such as young's modulus of infills and plan dimensions were need to be considered.

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