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DETERMINATION OF THE FUNDAMENTAL PERIOD OF VIBRATION OF MULTI-STOREY RC BUILDINGS

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Abstract—*The period of vibration is the important parameter in the design of buildings as it governs the effect of earthquake. To design any building firstly fundamental period of vibrations is calculated. By using fundamental period of vibration spectral acceleration is calculated and then base shear is calculated. Many design codes provide simple empirical relationship relating the fundamental period of vibration of a building to its height. These relationships conservatively estimate the period of vibrations and consequently the resulted base shear force will be conservatively predicted.*

For the analysis of multi-storey reinforced concrete buildings ETABS software is used. The results obtained using ETABS software analysis and empirical formula given in IS 1893:2002 are compared . This comparison shows that the codes formula underestimate the fundamental period of vibration with large deviation from ETABS software results due to ignorance of major parameter influencing the period in the codes formula. A parametric study has been performed using ETABS software analysis to study the parameters influencing the fundamental period of vibration. And a new empirical relationship between fundamental period of vibration and its height, for multi-storey moment resisting frame and shear wall buildings has been done. the obtained using recommended formula show good agreement with the ETABS software results.

Keywords: *Empirical formulae, fundamental period of vibration, multi-storey reinforced concrete buildings,*

1. INTRODUCTION

For the determination of lateral loads, it is necessary to determine first the period of vibration. The fundamental period of vibration is one of the major factors which are having in accurately. But the accurate determination of fundamental period of vibration is not an easy task at the design stage. The present paper is aiming to determine the empirical formula to calculate fundamental period of vibration for multi-storey moment resisting and shear wall buildings. fluence on the earthquake induced lateral forces. So it is necessary to determine the fundamental period of vibration Using ETABS software the analysis of multi-storey reinforced concrete buildings and shear wall buildings has been done and then comparison of the results obtained by ETABS software analysis ,results obtained using empirical formula given in IS 1893:2001 and the results obtained using new empirical formula has been done.

2. PARAMETRIC STUDY

The fundamental period of vibration of motion of a system depend mainly on both the system mass and stiffness. These mass and stiffness factors can be detailed in some parameters for the case of reinforced concrete multistory frame buildings. These parameters can be identified as the height of frame (*H*), the width of the frame (*B*), the columns bending stiffness, beams bending stiffness and the total mass (total weight) of the frame including all acting vertical loads.

A parametric study has been carried out on several selected frames representing typical RC buildings without seismic resistant design. The considered buildings have been chosen to cover the most practical cases with number of floors 4,6,8, 10, 12,14,16,18 and 20 and floor height 3. 0 m (frames total height are 12,18,24,30,36 and 52 m respectively). The number of bays is ranging from six and eight with bay length 5. 0, and 6. 0 m. The cross section of the beams is a rectangle with 0. 25 m breadth and 0. 45m depth. The columns have rectangular section with dimensions230mm x 450mm, 300mm x 600mm,and 300mm x 750mm. In each model both beam section and column section are constant over the entire model.

2.1 PERIOD OF VIBRATION FOR MOMENT RESISTING FRAME STRUCTURE

- Following are the observations obtained for moment resisting frame structure having same loading conditions but different dimensions. Also the same structure for different height is also analysed.

Table 1

Building	Height of Buildin g	Column Size	H/√L	H/√ W	Period of Vibrations	
					X- Directio n	Y- Directio n
Building: 1 (42x20)	18	230x450	2. 77	4. 02	1. 55	1. 28
	24		3. 70	5. 36	2. 15	1. 77
	30		4. 62	6. 70	2. 76	2. 27
	12	300x600	1. 85	2. 68	0. 65	0. 53
	18		2. 77	4. 02	1. 00	0. 81

	24		3. 70	5. 36	1. 35	1. 10
	30		4. 62	6. 70	1. 71	1. 39
	36		5. 55	8. 05	2. 06	1. 69
	52		8. 02	11. 6	2. 41	1. 99
Building: 2 (56x30)	18	230x450	2. 77	4. 02	1. 55	1. 28
	24		3. 70	5. 36	2. 15	1. 77
	30		4. 62	6. 70	2. 76	2. 27
	12	300x600	1. 85	2. 68	0. 65	0. 53
	18		2. 77	4. 02	1. 00	0. 81
	24		3. 70	5. 36	1. 35	1. 10
	30		4. 62	6. 70	1. 71	1. 39
	36		5. 55	8. 05	2. 06	1. 69
	52		8. 02	11. 6	2. 41	1. 99
Building: 3 (42x30)	18	230x450	2. 77	3. 28	1. 36	1. 13
	24		3. 70	4. 38	1. 80	1. 50
	30		4. 62	5. 47	2. 25	1. 87
	12	300x600	1. 85	2. 19	0. 77	0. 70
	18		2. 77	3. 28	1. 18	1. 09
	24		3. 70	4. 38	1. 59	1. 48
	30		4. 62	5. 47	2. 00	1. 87
	36		5. 55	6. 57	2. 42	2. 26
	52		8. 02	9. 49	2. 83	2. 66

Period of vibration along both axes for three types of building

For above observations graph can be plotted and period of observations can be analyzed.

Fig. 3 shows graph of frame height vs. period of vibrations in X-direction. The equation obtained is given by,

$$T_x = 0.096\ H^{0.904}$$

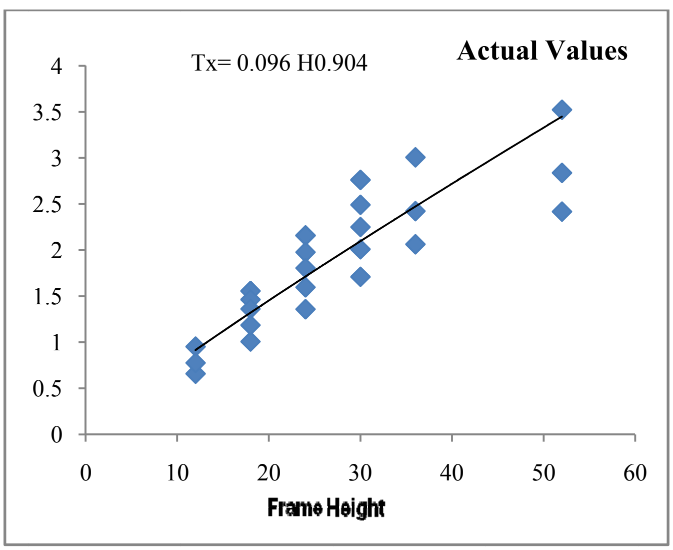


Fig. 4 shows graph of frame height vs. period of vibrations in Y-direction. The equation obtained is given by,

$$T_y = 0.077\ H^{0.922}$$

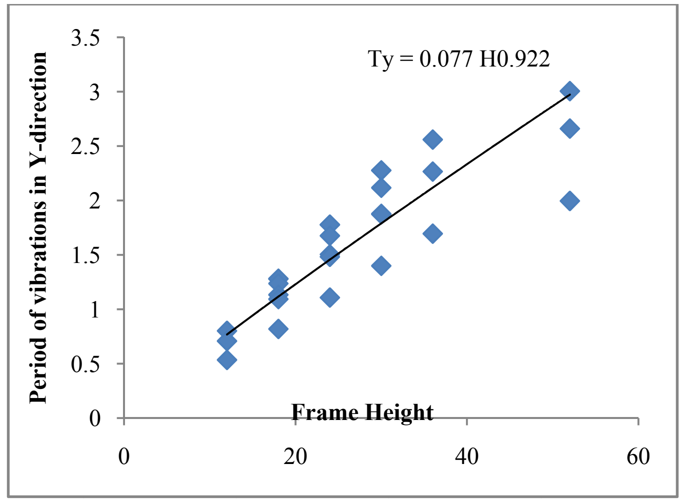


Fig. 5 shows graph of H/√L vs. Period of vibrations in X-direction. The equation obtained is

$$T_x = 0.597(H/\sqrt{L})^{0.838}$$

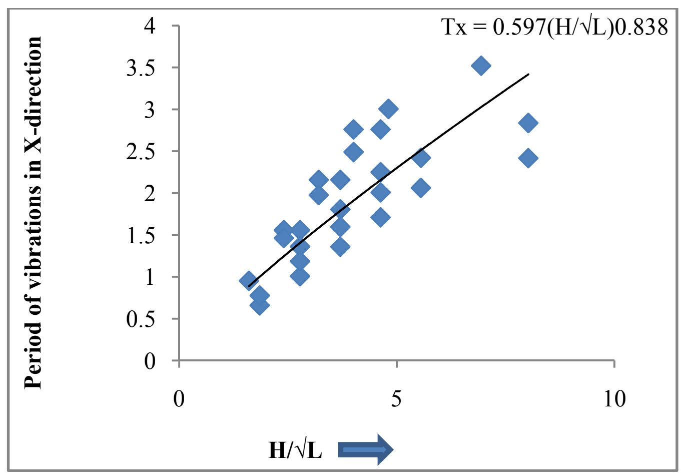
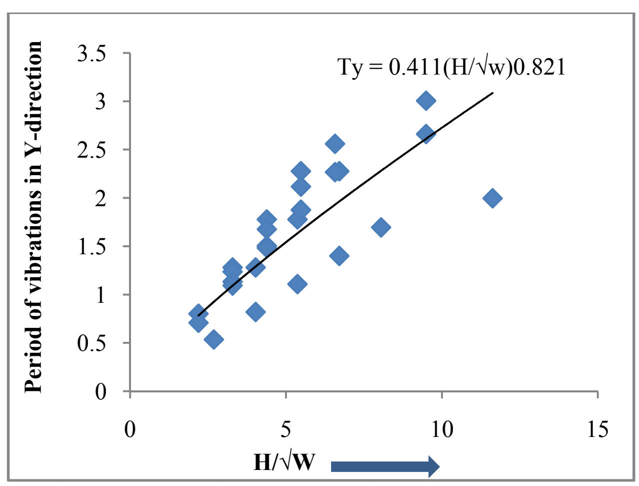


Fig. 6 shows graph of H/√W vs. Period of vibrations in Y-direction. The equation obtained is

$$T_y = 0.411(H/\sqrt{w})^{0.82}$$



PERIOD OF VIBRATION FOR SHEAR WALL DOMINANT STRUCTURES

- **Shear wall dominant structures with wall thickness 200mm,following observations are obtained-**

Table 2: Period of vibration along both axes for Shear wall dominating structures having wall thickness 200mm

Building	Height of Building	Column size	H/√L	H/√W	Period of vibration	
					X-Direction	Y-Direction
Building:1 (42x20)	18		2. 77	4. 02	0. 46	0. 38
	24		3. 70	5. 36	0. 67	0. 59
	30		4. 62	6. 70	0. 89	0. 82
	36		5. 55	8. 05	1. 12	1. 06
	42		6. 48	9. 39	1. 61	1. 57
	48		7. 40	10. 7	2. 13	2. 11
Building:2 (56x30)	18		2. 40	3. 28	0. 50	0. 41
	24		3. 20	4. 38	0. 78	0. 64
	30	300x750	4. 00	5. 47	1. 12	0. 93
	36		4. 81	6. 57	1. 49	1. 26
	42		5. 61	7. 66	2. 30	2. 02
	48		6. 41	8. 76	3. 17	2. 87
Building:3 (42x30)	18		2. 77	3. 28	0. 45	0. 44
	24		3. 70	4. 38	0. 68	0. 67
	30		4. 66	5. 47	0. 95	0. 93
	36		5. 55	6. 57	1. 23	1. 20
	42		6. 48	7. 66	1. 82	1. 77
	48		7. 40	8. 76	2. 61	2. 53

- For above observations graph can be plotted and period of observations can be analyzed.

Fig. 7 shows graph of frame height vs. period of vibrations in X-direction. The equation obtained is given by,

$$T_x = 0.013H^{1.449}$$

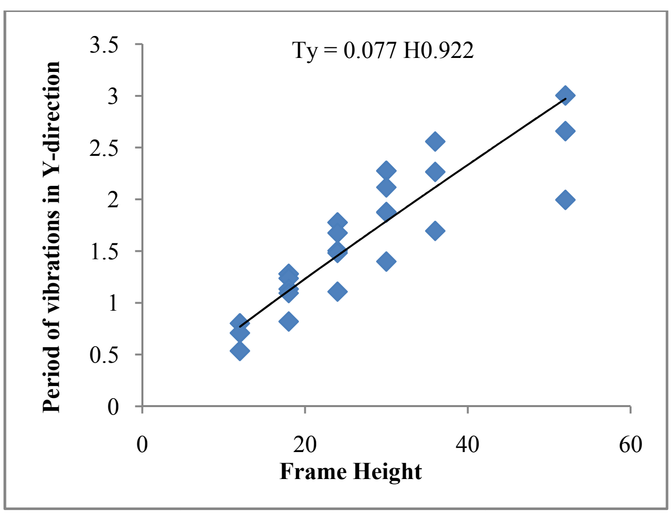


Fig. 7

Graph of frame height vs period of vibrations in X-direction

Fig. 8 shows graph of frame height vs period of vibrations in Y-direction. The equation obtained is given by,

$$T_y = 0.013H^{1.449}$$

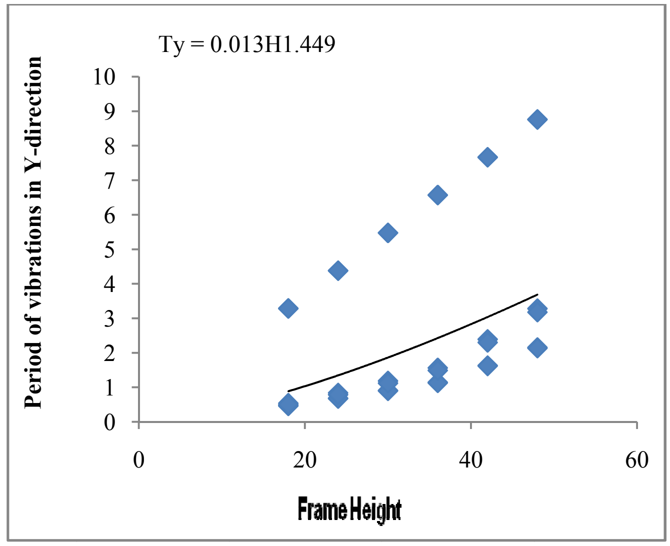


Fig. 8

Graph of frame height vs. period of vibrations in Y-direction

Fig. 9 shows graph of H/√L vs Period of vibrations in X-direction**.** The equation obtained is

obtained is given by,

$$T_x = 0.184(H/\sqrt{L})^{1.556}$$

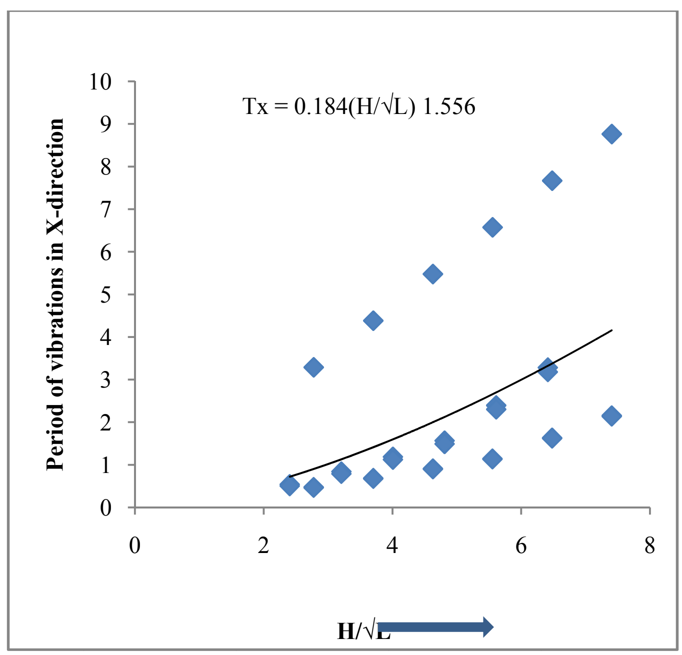


Fig. 9

Graph of H/√L vs Period of vibrations in X-direction

Fig. 10 shows graph of H/√W vs Period of vibrations in Y-direction. The equation obtained is obtained is given by

$$T_Y = 0.061(H/\sqrt{W})^{1.574}$$

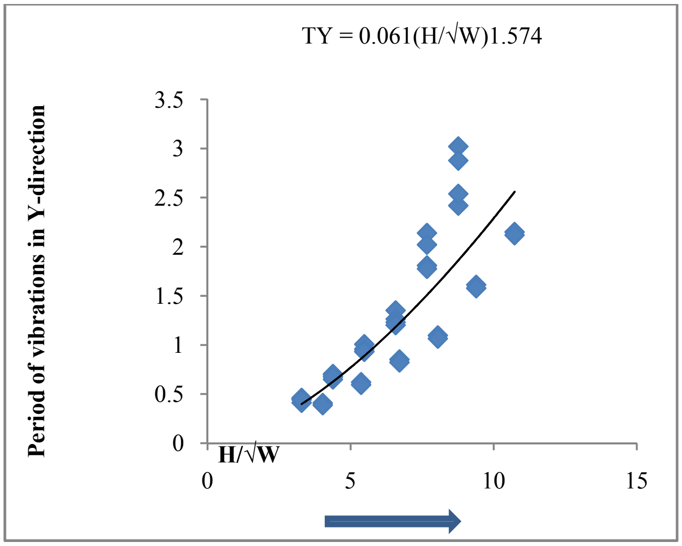


Fig. 10

Graph of H/√W vs Period of vibrations in Y-direct

- **Following tables gives the comparison of is code values, empirical values**

COMPARISION OF IS CODE VALUES AND VALUES USING EMPIRICAL FORMULA				
Building	**Height of Building**	**Period of Vibrations X-Direction**	**IS CODE VALUES Tx= 0. 075 H0. 75**	**Using Empirical formula Tx= 0. 096 H0. 904**
Building No:1	18	1. 55	0. 65	1. 30
	24	2. 15	0. 81	1. 69
	30	2. 76	0. 96	2. 07
	12	0. 65	0. 48	0. 90
	18	1. 00	0. 65	1. 30
	24	1. 35	0. 81	1. 69
	30	1. 71	0. 96	2. 07
	36	2. 06	1. 10	2. 45
	52	2. 41	1. 45	3. 41
Building No:2	18	1. 55	0. 65	1. 30
	24	2. 15	0. 81	1. 69
	30	2. 76	0. 96	2. 07
	12	0. 65	0. 48	0. 90
	18	1. 00	0. 65	1. 30
	24	1. 35	0. 81	1. 69
	30	1. 71	0. 96	2. 07
	36	2. 06	1. 14	2. 45
	52	2. 41	1. 45	3. 41
Building No:3	18	1. 36	0. 65	1. 30
	24	1. 80	0. 81	1. 69
	30	2. 25	0. 96	2. 07
	12	0. 77	0. 48	0. 90
	18	1. 18	0. 65	1. 30
	24	1. 59	0. 81	1. 69
	30	2. 00	0. 96	2. 07
	36	2. 42	1. 10	2. 45
	52	2. 83	1. 45	3. 41

COMPARISION OF IS CODE VALUES AND VALUES USING IS CODE				
Building	**Height of Building**	**Period of Vibrations X-Direction**	**IS CODE VALUES**	**Using Empirical formula Tx = 0. 013H1. 449**
Building No:1	18	0. 40	0. 65	0. 85
	24	0. 61	0. 81	1. 29
	30	0. 85	0. 96	1. 79
	12	1. 09	0. 48	0. 47
	18	1. 61	0. 65	0. 85
	24	2. 14	0. 81	1. 29
	30	0. 38	0. 96	1. 79
	36	0. 59	1. 10	2. 33
	52	0. 82	1. 45	3. 98
Building No:2	18	1. 06	0. 65	0. 85
	24	1. 57	0. 81	1. 29
	30	2. 11	0. 96	1. 79
	12	0. 45	0. 48	0. 47
	18	0. 70	0. 65	0. 85
	24	1. 00	0. 81	1. 29
	30	1. 35	0. 96	1. 79
	36	2. 13	1. 10	2. 33
	52	3. 02	1. 45	3. 98
Building No:3	18	0. 41	0. 65	0. 85
	24	0. 64	0. 81	1. 29
	30	0. 93	0. 96	1. 79
	12	1. 26	0. 48	0. 47
	18	2. 02	0. 65	0. 85
	24	2. 87	0. 81	1. 29
	30	0. 46	0. 96	1. 79
	36	0. 69	1. 10	2. 33
	52	0. 95	1. 45	3. 98

COMPARISION OF IS CODE VALUES AND VALUES USING IS CODE					
Building	**Height of Building**	**Value of H/ √W**	**Period of Vibrations X-Direction**	**IS CODE VALUES Tx = 0. 09(H/√W)**	**Using Empirical formula Ty = 0. 411(H/√w) 0. 821**
Building No:1	18	4. 02	1. 28	0. 36	1. 28
	24	5. 3	1. 77	0. 48	1. 63
	30	6. 70	2. 27	0. 60	1. 96
	12	2. 68	0. 53	0. 24	0. 92
	18	4. 02	0. 81	0. 36	1. 28
	24	5. 36	1. 10	0. 48	1. 63
	30	6. 70	1. 39	0. 60	1. 96
	36	8. 05	1. 69	0. 72	2. 27
	52	11. 62	1. 99	1. 04	3. 08
Building	18	4. 02	1. 28	0. 36	1. 28

No:2	24	5. 36	1. 77	0. 48	1. 63
	30	6. 70	2. 27	0. 60	1. 96
	12	2. 68	0. 53	0. 24	0. 92
	18	4. 02	0. 81	0. 36	1. 28
	24	5. 36	1. 10	0. 48	1. 63
	30	6. 70	1. 39	0. 60	1. 96
	36	8. 05	1. 69	0. 72	2. 27
	52	11. 62	1. 99	1. 04	3. 08
Building No:3	18	3. 28	1. 13	0. 29	1. 09
	24	4. 38	1. 50	0. 39	1. 38
	30	5. 47	1. 87	0. 49	1. 66
	12	2. 19	0. 70	0. 19	0. 78
	18	3. 28	1. 09	0. 29	1. 09
	24	4. 38	1. 48	0. 39	1. 38
	30	5. 47	1. 87	0. 49	1. 66
	36	6. 57	2. 26	0. 59	1. 92
	52	9. 49	2. 66	0. 85	2. 60

COMPARISION OF IS CODE VALUES AND VALUES USING EMPIRICAL FORMULA

Building	Height of Building	H/√L	Period of Vibrations X-Direction	IS CODE VALUES Tx = 0. 09(H/√L)	Using Empirical formula Tx = 0. 597(H/√L)0. 838
Building No:1	18	2. 77	1. 55	0. 24	1. 40
	24	3. 70	2. 15	0. 33	1. 78
	30	4. 62	2. 76	0. 41	2. 15
	12	1. 85	0. 65	0. 16	1. 00
	18	2. 77	1. 00	0. 24	1. 40
	24	3. 70	1. 35	0. 33	1. 78
	30	4. 62	1. 71	0. 41	2. 15
	36	5. 55	2. 06	0. 49	2. 51
	52	8. 02	2. 41	0. 72	3. 41
Building No:2	18	2. 77	1. 55	0. 24	1. 40
	24	3. 70	2. 15	0. 33	1. 78
	30	4. 62	2. 76	0. 41	2. 15
	12	1. 85	0. 65	0. 16	1. 00
	18	2. 77	1. 00	0. 24	1. 40
	24	3. 70	1. 35	0. 33	1. 78
	30	4. 62	1. 71	0. 41	2. 15
	36	5. 55	2. 06	0. 49	2. 51
	52	8. 02	2. 41	0. 72	3. 41
Building No:3	18	2. 77	1. 36	0. 25	1. 40
	24	3. 70	1. 80	0. 33	1. 78
	30	4. 62	2. 25	0. 41	2. 15
	12	1. 85	0. 77	0. 16	1. 00
	18	2. 77	1. 18	0. 25	1. 40
	24	3. 70	1. 59	0. 33	1. 78
	30	4. 62	2. 00	0. 41	2. 15
	36	5. 55	2. 42	0. 5	2. 51
	52	8. 02	2. 83	0. 72	3. 41

3. CONCLUSION

A) The above analysis gives the empirical formula:

1) For moment resisting frames

$\mathbf{T_x = 0.597(H/\sqrt{L})^{0.838}}$

H/√L vs. Period of vibrations in X-direction

$\mathbf{T_y = 0.411(H/\sqrt{w})^{0.821}}$

H/√W vs. Period of vibrations in Y-direction

2) For shear wall dominant structures

$\mathbf{T_x = 0.013H^{1.449}}$

Height vs. period of vibrations in X-direction

$\mathbf{T_y = 0.077\ H^{0.922}}$

Height vs. period of vibrations in Y-direction

$\mathbf{T_x = 0.184(H/\sqrt{L})^{1.556}}$

H/√W vs. Period of vibrations in X-direction

$\mathbf{T_Y = 0.061(H/\sqrt{W})^{1.574}}$

H/√W vs. Period of vibrations in Y-direction

B) These empirical formulae gives base shear closer to exact base shear of building.

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COMPARISION OF IS CODE VALUES AND VALUES USING EMPIRICAL FORMULA

Building	Height of Building	Period of Vibrations X-Direction	ISCODE VALUES Ty= 0. 075 H0. 75	Using Empirical formula Ty = 0. 077 H0. 922
Building No:1	18	1. 28	0. 65	1. 10
	24	1. 77	0. 81	1. 44
	30	2. 27	0. 96	1. 77
	12	0. 53	0. 48	0. 76
	18	0. 81	0. 65	1. 10
	24	1. 10	0. 81	1. 44

	30	1. 39	0. 96	1. 77
	36	1. 69	1. 10	2. 09
	52	1. 99	1. 45	2. 94
Building No:2	18	1. 28	0. 65	1. 10
	24	1. 77	0. 81	1. 44
	30	2. 27	0. 96	1. 77
	12	0. 53	0. 48	0. 76
	18	0. 81	0. 65	1. 10
	24	1. 10	0. 81	1. 44
	30	1. 39	0. 96	1. 77
	36	1. 69	1. 10	2. 09
	52	1. 99	1. 45	2. 94
Building No:3	18	1. 13	0. 65	1. 10
	24	1. 50	0. 81	1. 44
	30	1. 87	0. 96	1. 77
	12	0. 70	0. 48	0. 76
	18	1. 09	0. 65	1. 10
	24	1. 48	0. 81	1. 44
	30	1. 87	0. 96	1. 77
	36	2. 26	1. 10	2. 09
	52	2. 66	1. 45	2. 94

COMPARISION OF IS CODE VALUES AND VALUES USING IS CODE				
Building	**Height of Building**	**Period of Vibrations X-Direction**	**IS CODE VALUES**	**Using Empirical formula Tx = 0. 013H1. 449**
Building No:1	18	0. 47	0. 65	0. 85
	24	0. 68	0. 81	1. 29
	30	0. 91	0. 96	1. 79
	12	1. 14	0. 48	0. 47
	18	1. 63	0. 65	0. 85
	24	2. 15	0. 81	1. 29
	30	0. 46	0. 96	1. 79
	36	0. 67	1. 10	2. 33
	52	0. 89	1. 45	3. 98
Building No:2	18	1. 12	0. 65	0. 85
	24	1. 61	0. 81	1. 29
	30	2. 13	0. 96	1. 79
	12	0. 54	0. 48	0. 47
	18	0. 84	0. 65	0. 85
	24	1. 18	0. 81	1. 29
	30	1. 56	0. 96	1. 79
	36	2. 39	1. 10	2. 33
	52	3. 28	1. 45	3. 98
Building No:3	18	0. 50	0. 65	0. 85
	24	0. 78	0. 81	1. 29
	30	1. 12	0. 96	1. 79
	12	1. 49	0. 48	0. 47
	18	2. 30	0. 65	0. 85
	24	3. 17	0. 81	1. 29
	30	3. 28	0. 96	1. 79
	36	4. 38	1. 10	2. 33
	52	5. 47	1. 45	3. 98