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DETERMINATION OF TIME PERIOD AND EVALUATION OF SEISMIC RESPONSE OF FRAMED STRUCTURE WITH DIFFERENT APPROACHES

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Abstract – *This paper represents the study of the seismic performance of multistory building to identify the most influential structural parameters. The dynamic property such as time period of multistory building is determined analytically and experimentally. The analytical results are compared with experimental results. The effect of experimental results (time period) on dynamic property and design of building elements also evaluated.*

Key Words: Time period, multistory building, experimental, analytical, design

1.INTRODUCTION

Attention in late 1930s. The time period of structure being the important factor affecting the seismic performance of the building frame. Different methods of estimating time period of structure are there namely by using standard codes, by regression analysis, by using application software (ABACUS) and by experimental approach (Shake Table). So there is a need to assess the impact of each approach for estimation of time period on structure. The calculation of time period can be tried by different approaches. The effect of variation of each time period on seismic response parameters i.e. base shear, displacement, storey drift can be attempted. Effect of above parameter affects ultimately on beam, column section design of frame. So the calculation of time period, base shear, displacement, storey drift and design of beams and columns will be tried by different approaches.

2. Analytical study

Analytical study includes following two types

2.1 Codal Based Method (IS 1893)

This standard contains provisions that are general in nature and applicable to all structures. Also, it contains provisions that are specific to buildings only. It covers general principles and design criteria, combinations, design spectrum, main attributes of buildings, dynamic analysis, apart from seismic zoning map and seismic coefficients of important towns, map showing epicenters, map showing tectonic features and lithological map of India.

Fundamental Natural Period

The approximate fundamental natural period of vibration (T), in seconds, of a moment-resisting frame building without brick in filled panels may be estimated by the empirical expression

$T = 0.075h^{0.75}$ ...for RC frame building
$T = 0.085h^{0.75}$ ...for steel frame building
$T = 0.09h/d^{1/2}$ ...for all other buildings

2.2 Application Software Based Method

Time period of proposed structures is estimated in the application software i.e. ETABS. The model of prototype structure of given geometry and sizes of elements is prepared in the ETABS. Analysis provids the time period of the structure.

Table-1: Geometric and material properties of building frames

Sr. No	Contents	Description
1	Structure	OMRF
2	No. of stories	G+5
3	Storey Height	3.5 m
4	Grade of Concrete	M 25
5	Grade of Steel	Fe415
6	Bay width(Both Direction)	4 m.
7	Slab thickness	0.15 m
8	Size of Column	0.40m x 0.25m (Top three storey)
		0.45m x 0.45m (Bottom three storey)
9	Size of Beam	0.4m x 0.23m
10	Floor finish	0.6 kN/m²
11	Live load	4 kN/m²
12	Seismic Zone	III
13	Importance Factor	1
14	Response Reduction Factor	3

Fig -1: G+5 model of Structure in ETABS-2015

2.3 Experimental Based Method

Fig -2: Model fixed on Shake Table

Models are prepared and tested using shake table which provides the frequency of the scale down model. This will be then converted to the prototype frequency by using similitude laws. This will give the time period of corresponding structure.

The present study aims to evaluate the experimental performance of RC building frame. A steel scale-down model is designed using similitude laws which replicates the prototype RC Building frame. The performance of the prototype structure is evaluated based on the performance of the scaled down model in the laboratory.

Scale Factor (S)

A Scale Factor is the ratio of linear dimension of prototype to the linear dimension of model. Following scaling relations are established using Geometric scale factor.

Table -2: Scaling Relations in Terms of Geometric Scaling Factor (S)

PARAMETERS	SCALE FACTOR
Mass Density ⍰	1
Stiffness	S^2
Force	S^3
Modulus	S
Acceleration	1
Frequency	$S^{-1/2}$
Time	$S^{1/2}$
Shear Wave Velocity	$S^{1/2}$
Length	S
Stress	S
Strain	1
EI	S^5

Table-3: Geometric and material properties of scale down steel model

Sr. No	Contents	Description
1	No. of stories	G+5
2	Storey Height	280mm
3	Grade of Steel	Fe250
4	Bay width	320mm.
5	Slab thickness	3mm
6	Size of Column	12mm X 12mm
7	Size of Plinth Beam	12mm X 12mm

G+5 STEEL MODEL

The G+5 steel scale down model is fixed on Shake Table to simulate fixed base condition. The sine sweep test is conducted to know the natural frequency of the model. The FRF and FFT plots are obtain for each individual accelerometer and also for all combined accelerometers. The results of combine FRF and FFT are given in Figure.

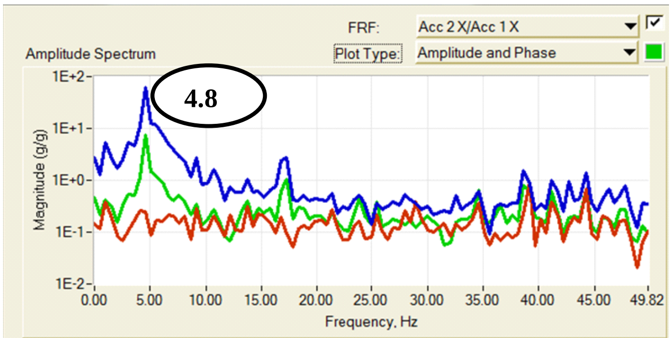

Fig -3: Combine FRF

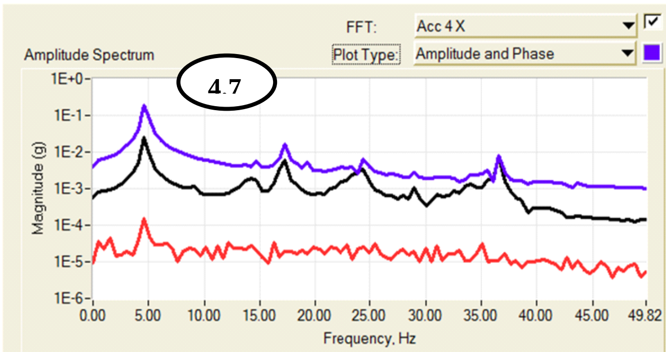

Fig -4: Combine FFT

The FRF and FFT results are averaged and converted to the time period of prototype using scale factor and similitude laws. Analytical and experimental evaluation of time period of structures is carried out and the corresponding results are tabulated as below.

Table-4: Comparison of time period by different approach

Model	Time Period (sec) Using		
	IS1893-2002	Application Software-Response Sptcturm	Experimental Approach-Shake Table
G+5	0.768	0.954	0.745

3. RESULT

The results obtained are used for structural analysis and design using application software. For different values of time period obtained by different approaches are analyzed using application software to study the effect of time period on the behavior of structure. The results again tabulated as below.

Following table shows the results obtained for mentioned frame with different approaches.

Table-5: Seismic Response Parameters for Calculation of Time Period with Different Approaches for frame Along X and Y Directions

Approach	Time period (sec)		Base shear (KN)		Displacement (mm)		Storey Drift (mm)	
	X	Y	X	Y	X	Y	X	Y
IS 1893 2002	0.768	0.768	65.01	65.01	18.2	23.13	3.81	6.04
Appl. Software	0.877	0.954	48.39	43.22	15.93	18.61	3.34	4.86
Exp. Approach	0.745	0.745	67.02	67.02	18.76	23.84	3.93	6.23

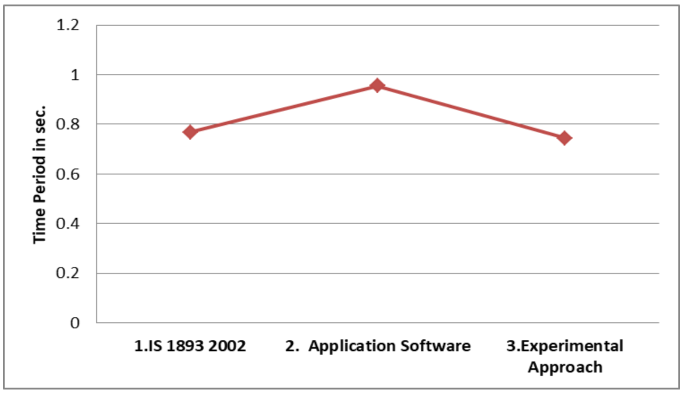

Fig -5: Time Period of Structure

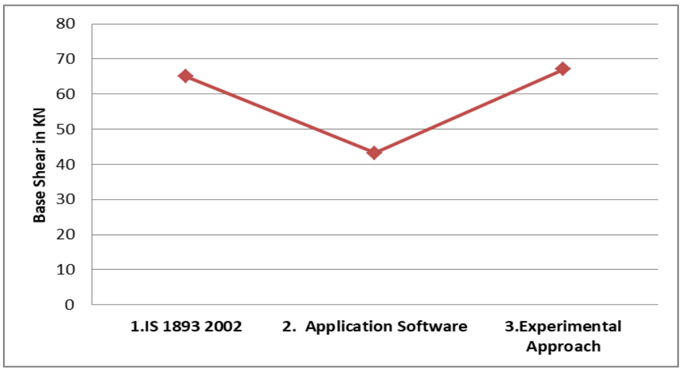

Fig -6: Base shear of Structure

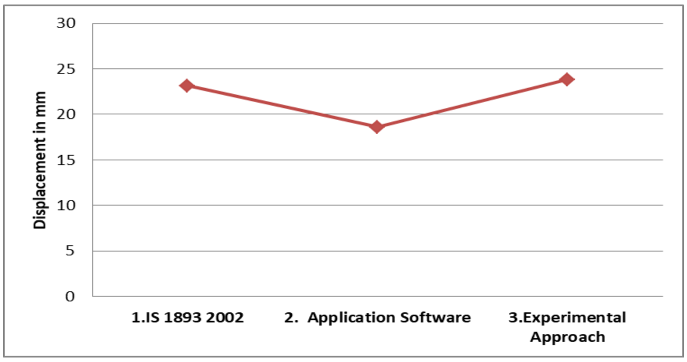

Fig -7: Displacement at Top of Structure

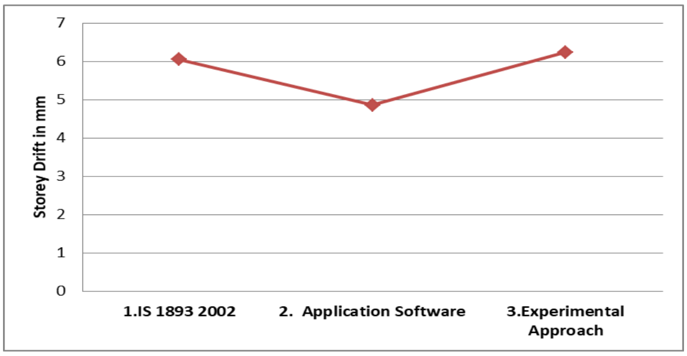

Fig -8: Maximum Storey Drift of Structure

3.1 Time period

a) The time period calculated by application software is highest.
b) The time period calculated by shake table is lowest.
c) The time period calculated by IS 1893 lies in between application software and shake table.

3.2 Base shear

a) The analyzed base shear magnitude w.r.t time period by shake table approach is highest.
b) The analyzed base shear magnitude w.r.t time period by application software is lowest.
c) The analyzed base shear magnitude w.r.t time period by IS 1893 approach lies between shake table approach and application software.

3.3 Displacement

a) The analyzed displacement magnitude w.r.t time period by shake table approach is highest.
b) The analyzed displacement magnitude w.r.t time period by application software is lowest.
c) The analyzed displacement magnitude w.r.t time period by IS 1893 approach lies between shake table approach and application software.

3.4 Storey drift

a) The analyzed storey drift magnitude w.r.t time period by shake table approach is highest.
b) The analyzed storey drift magnitude w.r.t time period by application software is lowest.
c) The analyzed storey drift magnitude w.r.t time period by IS 1893 approach lies between shake table approach and application software.

Analytical and Design parameters for frame are tabulated and discussion of results is also mentioned below.

Table-6: Analytical and Design Parameters for Calculation of Time Period by different Approaches for G+5 frame

Floors	Frame Elements	Parameters	Approaches		
			IS Approach	Application Software	Experimental
Ground Floor	Beam (400x230)	Max BM (KN-m)	48.79	43.63	50.06
		Max S.F. (KN)	47.49	45.5	48.48
		Long. Reinf. (mm2)	477	428	489
		Shear Reinf. (mm2/m)	673	598	738
	Column (450x450)	Max BM (KN-m)	57.63	50.96	59.28
		Max S.F. (KN)	28.21	25.14	28.97
		Long. Reinf. (mm2)	1620	1620	1620
		Shear Reinf. (mm2/m)	500	500	500
1st Floor	Beam (400x230)	Max BM (KN-m)	50.61	45.13	51.92
		Max S.F. (KN)	48.65	44.43	49.66
		Long. Reinf. (mm2)	495	442	508
		Shear Reinf. (mm2/m)	751	624	775
	Column (450x450)	Max BM (KN-m)	55.24	49.75	56.6
		Max S.F. (KN)	30.17	27.16	30.92
		Long. Reinf. (mm2)	1620	1620	1620
		Shear Reinf. (mm2/m)	500	500	500
2nd Floor	Beam (400x230)	Max BM (KN-m)	46.85	41.97	47.92
		Max S.F. (KN)	46.14	42.36	47.08
		Long. Reinf. (mm2)	452	403	464
		Shear Reinf. (mm2/m)	674	564	696
	Column (450x450)	Max BM (KN-m)	49.19	44.36	50.38
		Max S.F. (KN)	29.08	26.27	29.78
		Long. Reinf. (mm2)	1620	1620	1620
		Shear Reinf. (mm2/m)	500	500	500
3rd Floor	Beam (400x230)	Max BM (KN-m)	40.13	35.71	41.11
		Max S.F. (KN)	40.77	37.66	41.54
		Long. Reinf. (mm2)	366	327	375
		Shear Reinf. (mm2/m)	499	413	514
	Column (400x250)	Max BM (KN-m)	40.1	35.95	41.13
		Max S.F. (KN)	23.93	21.47	24.54
		Long. Reinf. (mm2)	904	801	996
		Shear Reinf. (mm2/m)	444	444	444
4th Floor	Beam (400x230)	Max BM (KN-m)	29.96	27.11	30.65
		Max S.F. (KN)	33	30.88	33.52
		Long. Reinf. (mm2)	275	266	282
		Shear Reinf. (mm2/m)	370	321	378
	Column (400x250)	Max BM (KN-m)	33.26	30.19	34.02
		Max S.F. (KN)	19.99	18.09	20.47
		Long. Reinf. (mm2)	837	800	850
		Shear Reinf. (mm2/m)	444	444	444
5th Floor	Beam (400x230)	Max BM (KN-m)	18.16	13.33	18.16
		Max S.F. (KN)	23.51	22.78	32.69
		Long. Reinf. (mm2)	266	266	266
		Shear Reinf. (mm2/m)	254	254	254
	Column (400x250)	Max BM (KN-m)	24.24	22.46	24.68
		Max S.F. (KN)	14.97	13.9	15.24
		Long. Reinf. (mm2)	800	800	800
		Shear Reinf. (mm2/m)	444	444	444

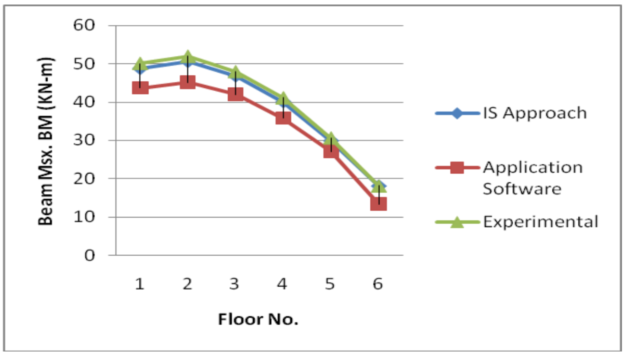

Fig -9: Beam Maximum BM Storeywise

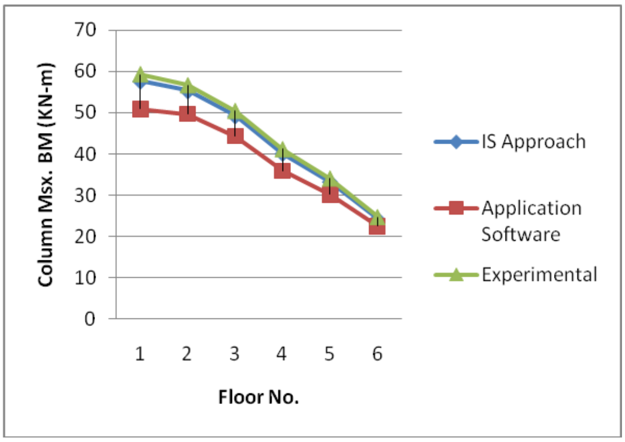

Fig -10: Column Maximum BM Storeywise

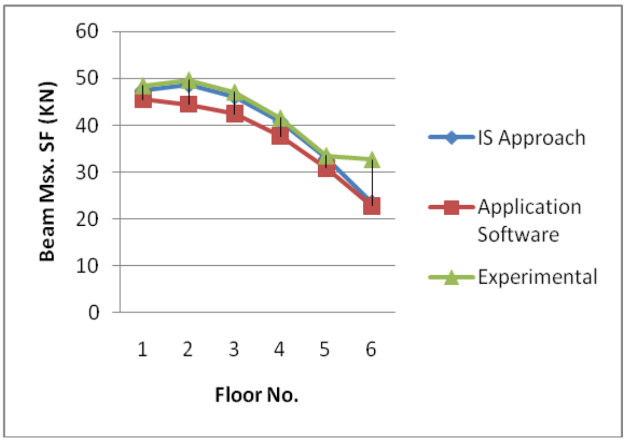

Fig -11: Beam Maximum SF Storeywise

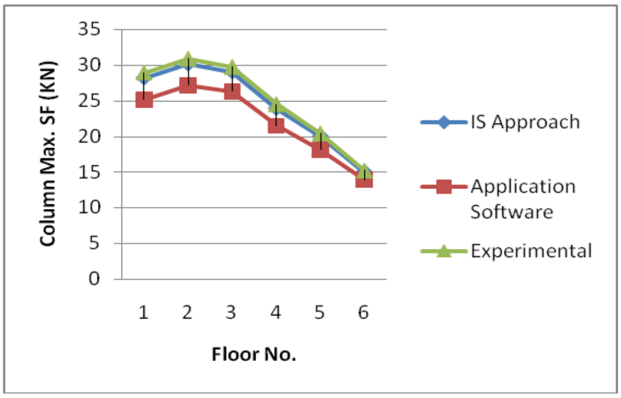

Fig -12: Column Maximum SF Storeywise

3.5 Analytical and Design Results

Analysis parameters for calculation of time period with different approaches for frames.

a) The difference in magnitude of maximum shear force and maximum bending moment by different approaches in columns and beams are not significant in all floors.

b) Whereas, magnitude of shear force and bending moment w.r.t calculation of time period by experimentally are highest.

Design parameters for calculation of time period with different approaches for frames.

a) The flexural main reinforcement of beam of ground, first, second, third floor has increased in around 13-14% w.r.t calculation of time period by shake table approach.
b) The flexural main reinforcement of beam of fourth floor has increased in around 8.5% w.r.t calculation of time period by shake table approach.
c) The flexural main reinforcement of beam of fifth floor has no change w.r.t calculation of time period by shake table approach.
d) The shear reinforcement of beam of ground, first, second, third floor has increased in around 23-24.5% w.r.t calculation of time period by shake table approach.
e) The shear reinforcement of beam of fourth floor has increased by 18% w.r.t calculation of time period by shake table approach.
f) The shear reinforcement of beam of fifth floor has no change w.r.t calculation of time period by shake table approach.

4. CONCLUSION

Maximum bending moment, maximum shear force, longitudinal reinforcement and shear reinforcement of beam and column are comparative parameters.

The results of above parameters by IS-1893 approach are closer to application software-Response Spectrum analysis for G+3 and G+5 frames. Highest parameters of above parameters are given by Experimental-Shake Table Approach

1. The beam longitudinal reinforcement is increased by 14% when compared to Response Spectrum analysis.

2. The beam shear reinforcement is increased by approximately 23% when compared to Response Spectrum Analysis.

3. There is no much difference in column longitudinal and shear reinforcement.

For medium rise building like G+5 there is no considerable difference in the reinforcement when used experimental shake table approach and Response Spectrum analysis using Application Software. So for such building frames Response Spectrum analysis proves to be economical as compared to Experimental Shake Table approach where equipment and model making can be costlier.

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