Seismic Analysis, Design and Comparative Study of RC Structure Using Different Codes

Amit B. Anwade[1], Shubham B. Aher[2], Akshay D. Barate[3], Shivam Raghuvanshi[4], Mrs. Smita Kuralkar[5]

[1,2,3,4] B.E. Student, Civil Engineering Department, G.H.R.C.E.M Pune, Maharashtra, India
[5]Professor, Civil Engineering Department, G.H.R.C.E.M Pune, Maharashtra, India

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Abstract - *This study focuses on comparison of International standards. The chosen standards are IS code, IBC and Canada code. The study also helps in understanding the main contributing factors which lead to poor performance of Structure during the earthquake, so as to achieve their adequate safe behavior under future earthquakes. In this project, a residential building of G+10, G+15, G+20 and G+25, Special RC moment-resting frame (SMRF) is taken for study. Modelling of the structure is done as per STAAD.pro V8i software. Time period of the structure in both the direction is taken from the software and as per the three standards 12 models are made i.e. 4 models for each code. The analytical results of the model buildings are then represented graphically and in tabular form, it is compared and analyzed taking note of any significant differences. This study focuses on exploring variations in the results obtained using the three codes i.e. IS code, IBC and Canada code. A comparative analysis is performed in terms of base shear, displacement and storey drift.*

Key Words: Base Shear, Displacement, Seismic Analysis, Storey Drift

1. INTRODUCTION

1.1 Overview

An earthquake may be defined as release of elastic energy by sudden slip on a fault and resulting ground shaking and radiated caused by slip. Earthquakes are one of the worst among the natural disasters. About 1 lakh earthquakes of magnitude more than three hit the earth every year. According to a conservative estimate more than 15 million human lives have been lost and damage worth hundred billions of dollars has been inflicted in the recorded history due to these.

Natural calamities such as earthquakes, Tsunamis, Landslides, Floods etc. causes severe damage and suffering to human being by collapsing many structures, trapping or killing persons, cutting off transport systems, blocking of navigation systems, animals hazards etc. Such natural disasters are big challenges to the progress of development. However, civil engineers play a major role in minimizing the damages by proper designing the structures or by proper material selections or proper Constructions procedure and taking other useful decisions. This includes understanding the earthquakes, behavior of the materials of construction and structures and the extent to which structural engineers make use of the knowledge in taking proper decisions in designing the structures made of reinforced concrete.

Earthquakes are defined as a vibration of the earth's surface that occurs after a release of energy in the earth's crust. Because the earth's crust is made up of numerous plates that are constantly moving slowly, vibrations can occur which result in small earthquakes. Most earthquakes are small but are not readily felt. Larger and violent earthquakes are those which occur in a release of energy as the plates slide past or collide into one another. The characteristics such as intensity, duration, etc. of seismic ground vibrations expected at any location depend upon the magnitude of earthquake, its depth of focus, distance from the epicenter, characteristics of the path through which the seismic waves travel, and the soil strata on which the structure stands. The predominant direction of ground vibration is usually horizontal. Reinforced concrete Special moment frames are used as part of seismic force resisting systems in buildings that are designed to resist earthquakes. Beams and columns in moment frames are proportioned and detailed in such a manner that they must resist flexural, axial, and shearing actions that result as a building sways through multiple displacement cycles during strong earthquake ground shaking. Special proportioning and detailing requirements are responsible for frame, capable of resisting strong earthquake shaking without significant loss of stiffness or strength. These moment resisting frames are called “Special Moment Frames” because of these additional requirements, which improve the seismic resistance in comparison with less detailed Intermediate and Ordinary Moment Frames.

Twist in buildings, called torsion, makes different portions at the same floor level to move horizontally by different amounts. This induces more damage in the frames and walls on the side that moves more. Many buildings have been severely affected by this excessive torsional behavior during past earthquakes. It is best to minimize if not completely avoid. This twist can be minimized by ensuring that buildings have symmetry in plan i.e., uniformly distributed mass and uniformly placed lateral load resisting systems. If this twist cannot be avoided, special calculations need to be done to account for this additional shear forces in the design of buildings; the Indian seismic code (IS 1893, 2002), Canada code and IBC has provisions for such calculations. But, for sure, these buildings with twist will perform poorly during strong earthquake shaking.

Seismic building codes are guidelines to design and construct the buildings and civil engineering works in seismic regions. Reasons behind is to protect human lives from worst conditions which occurs during earthquake, to limit damage, and to sustain operations of important structures for civil protection. Seismic design has progressed significantly over the year due to the contribution of practicing engineers, as well as academic and governmental researchers. The progress depends on the improvement of the representation of ground motion, soil type and

1.2 Objective of the Project:

The main objective of this project is to bring out the main contributing factors which lead to poor performance during the earthquake and make recommendations which should be taken into account in designing the multi-storeyed reinforced concrete buildings so as to achieve their adequate safe behaviour under future earthquakes. Earthquake codes have been revised and updated depending on the improvements in the representation of ground motions, soils and structures. The Indian Standard Code IS: 1893 was suitably updated in 2002 so as to address the various design issues brought out in the earthquake behaviour of the RC Buildings.

The chosen standards are Indian Standard Code IS: 1893, Canada code and International building code (ASCE). A comparative analysis was performed in terms of Base shear, Displacement, for different codes.

1.3 Methodology:

The methodology worked out to achieve the mentioned objectives is as follows:

1. Modeling of the selected building in STAAD.pro V8i Software.
2. Retrieved time period of structure from the software.
3. Three models as per the codes i.e. Indian code, Canada code, IBC (ASCE) specification were made.
4. Applied manually calculated Lateral seismic forces and load combinations as per IS 1893-2002, Canada code and IBC (ASCE).
5. Analyzed the models and graphical and tabular representation of the data is presented.

2. MODELLING

A multi-storey building of G+10, G+15, G+20, and G+25, Special RC moment-resting frame (SMRF) is taken for study. The typical storey height is 3m for all storey.

The three codal provisions as mentioned above. A Linear Static analysis is done using STAAD.pro V8i Software. The model is studied for all three code for severe parameter with medium soil condition.

2.1 Plan and Specification of the Building

MODEL: Plan of the building

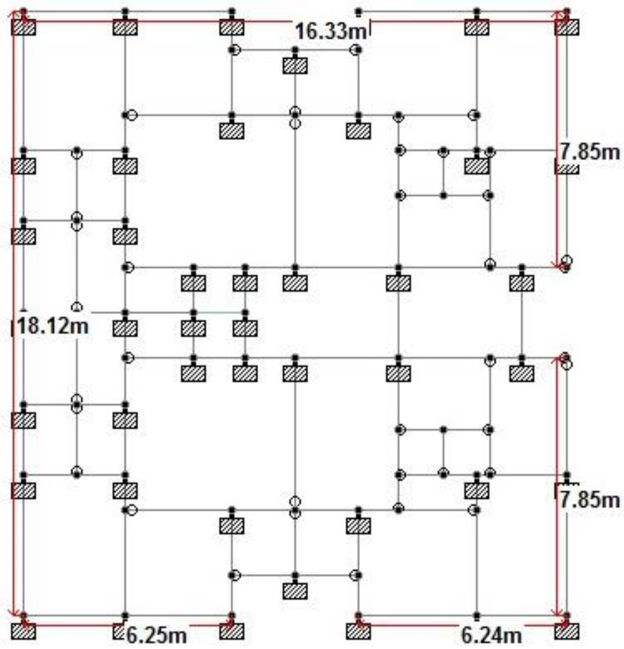

Fig (1). Plan of Building

Table -1: Specification of the Building

SR No.	PARAMETERS	DIMENSION / TYPE
1	Plan Dimension	16.33 m X 18.12 m
2	NO. of Stories	G+10,G+15,G+20,G+25
3	Height of Each Storey	3m
4	Grade of Concrete	M20
5	Frame Type	SMRF
6	Soil Type	Medium Soil
7	Inner Wall	125mm
8	Outer Wall	230mm
9	Slab Thickness	150mm
10	Unit Weight of Concrete	25 kN/cum

3. ANALYSIS AND RESULTS

3.1 Result obtained for Base Shear

Case (i). Result for Base Shear in X-Direction

Table -2: Base Shear in X-Direction (kN)

Model	IS	IBC	CANADA
G+10	1948.88	2151.73	2357.22
G+15	2845.53	2992.92	3025.28
G+20	3631.84	3883.64	3902.80
G+25	4837.12	5071.22	5279.21

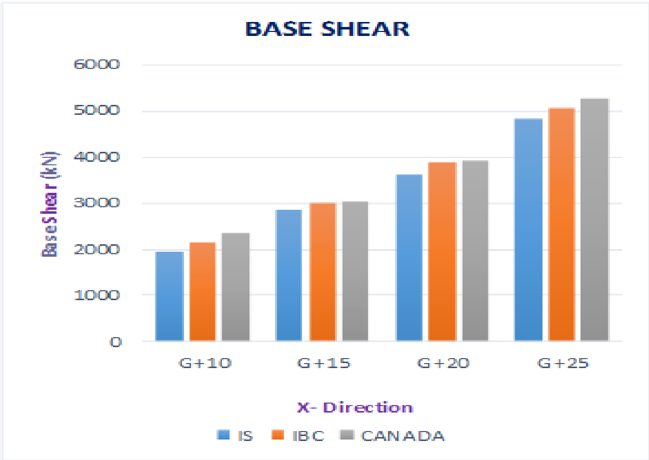

Fig (2). Base shear for earthquake in X-direction

Case (ii). Result for Base Shear in Z-Direction

Table -3: Base Shear in Z-Direction (kN)

MODEL	IS	IBC	CANADA
G+10	1706.980	1613.800	1657.147
G+15	2489.830	2212.210	2210.780
G+20	3181.880	2912.730	2896.613
G+25	4234.830	4043.140	4060.900

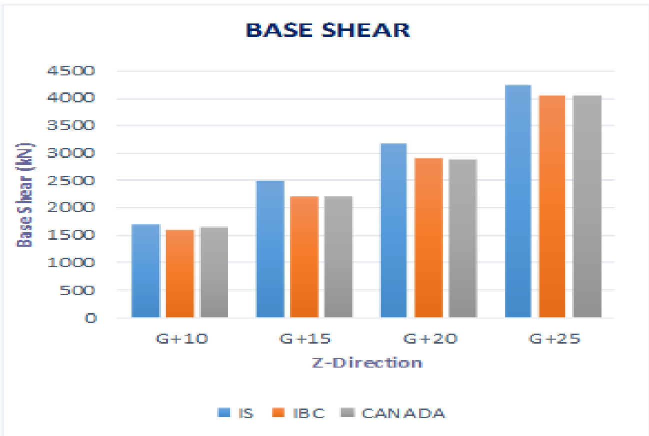

Fig (3). Base shear for earthquake in Z-direction

3.2 Result obtained for Displacement

3.2.1 Result for G+10

Table -4: Maximum Displacement (mm)

FLOOR	IS	CANADA	IBC
G	4.0560	3.9260	4.0150
1	5.3430	5.3990	5.3430
2	6.7240	6.8340	6.7610
3	7.9400	8.0350	7.5520
4	8.9530	9.0490	8.9360
5	9.7770	9.8640	9.7320
6	10.424	10.497	10.353
7	10.906	10.982	10.816
8	11.243	11.329	11.144
9	11.462	11.570	11.365
10	11.316	11.535	11.231

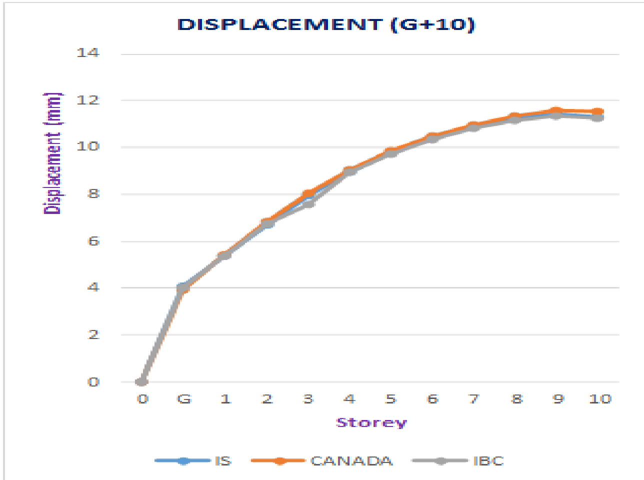

Fig (4). Comparing result of Displacement

3.2.2 Result for G+15

Table -5: Maximum Displacement (mm)

FLOOR	IS	Canada	IBC
G	3.2210	3.6060	3.3250
1	4.4770	5.2430	4.8310
2	5.7310	6.7030	6.1760
3	6.8350	7.9570	7.3350
4	7.5680	9.1200	8.4170
5	8.9310	10.308	9.5350
6	9.8780	11.543	10.504
7	10.689	12.225	11.324
8	11.355	12.916	11.982
9	12.130	13.670	12.716
10	12.797	14.298	13.265
11	13.338	14.791	13.815
12	13.759	15.161	14.186
13	14.076	15.430	14.461
14	14.290	15.563	14.614
15	14.170	15.102	14.236

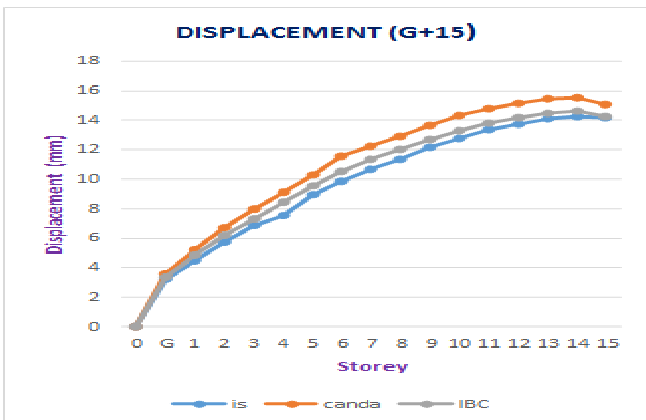

Fig (5). Comparing result of Displacement

3.2.3 Result for G+20

Table -6: Maximum Displacement (mm)

FLOOR	IS	CANADA	IBC
G	6.3820	6.3360	6.3720
1	8.4550	8.7580	8.7610
2	11.161	11.317	11.093
3	13.369	13.560	13.482
4	15.240	16.103	15.962
5	17.596	17.837	17.509
6	19.207	19.461	19.094
7	20.590	20.940	20.621
8	21.971	22.252	21.860
9	23.129	23.359	22.962
10	24.157	24.493	23.934
11	25.055	25.424	24.783
12	25.828	26.236	25.505
13	26.413	26.894	26.049
14	26.781	27.378	26.389
15	27.080	27.722	26.668
16	27.261	28.041	26.843
17	27.385	28.403	26.981
18	27.836	28.939	27.432
19	28.133	29.350	27.74
20	27.354	29.200	27.018

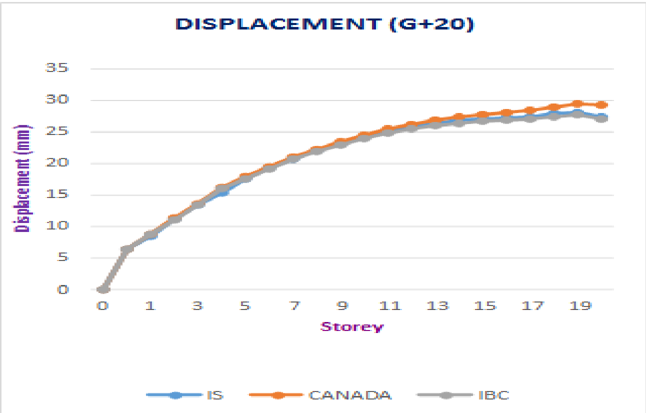

Fig (6). Comparing result of Displacement

3.2.4 Result for G+25

Table -7: Maximum Displacement (mm)

FLOOR	IS	CANADA	IBC
G	5.0090	5.1460	5.1240
1	7.5760	7.7960	7.7500
2	9.9790	10.275	10.203
3	12.173	12.536	12.441
4	14.370	14.795	14.578
5	16.721	17.310	17.172
6	19.105	19.653	19.495
7	21.254	21.856	21.678
8	23.236	23.890	23.691
9	25.075	25.779	25.557
10	26.781	27.536	27.287
11	28.370	29.122	28.898
12	29.831	30.697	30.378
13	31.134	32.129	31.696
14	32.253	33.256	32.827
15	33.226	34.304	32.806
16	34.033	35.199	34.619
17	35.014	36.132	35.602
18	35.932	37.362	36.520
19	36.708	38.288	37.299
20	37.325	39.062	37.914
21	37.796	39.694	38.381
22	38.136	40.195	38.717
23	38.379	40.576	38.878
24	38.553	41.077	39.121
25	38.338	40.879	38.890

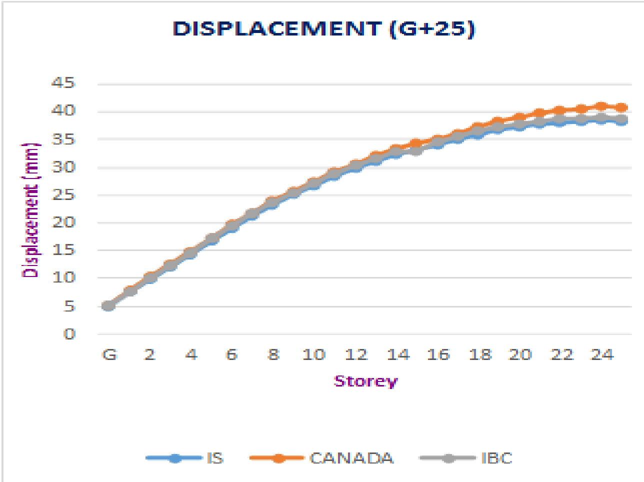

Fig (7). Comparing result of Displacement

3.3 Result obtained for Storey Drift

3.3.1 Result for G+10

Table -8: Storey Drift (mm)

FLOOR	IS	CANADA	IBC
1	0.0437	0.0520	0.0481
2	0.1604	0.2006	0.1855
3	0.2415	0.2855	0.2658
4	0.2837	0.3302	0.3108
5	0.3017	0.3429	0.3268
6	0.2924	0.3129	0.3086
7	0.2749	0.2857	0.2841
8	0.2379	0.2497	0.2501
9	0.1478	0.1703	0.1409
10	0.0627	0.0955	0.0563

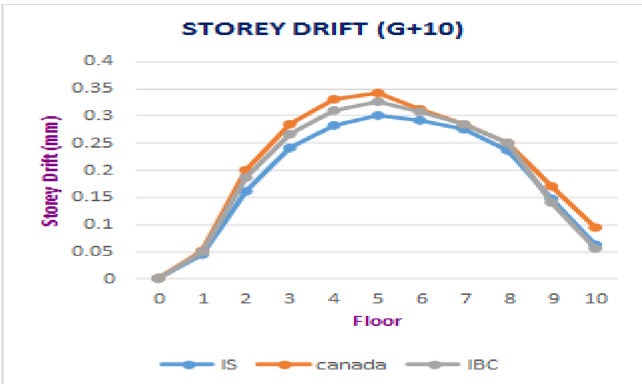

Fig (8). Comparing result of Storey Drift

3.3.2 Result for G+15

Table -9: Storey Drift (mm)

FLOOR	IS	CANADA	IBC
1	0.0553	0.0418	0.0477
2	0.2216	0.1677	0.1911
3	0.3311	0.2508	0.2859
4	0.4358	0.3286	0.3765
5	0.5101	0.3811	0.4403
6	0.5508	0.4060	0.4856
7	0.5646	0.3943	0.4783
8	0.5368	0.3682	0.4591
9	0.5037	0.3317	0.4295
10	0.5076	0.3172	0.4301
11	0.4855	0.2807	0.4085
12	0.4627	0.2407	0.3861
13	0.3759	0.1901	0.2993
14	0.2646	0.1253	0.2128
15	0.1211	0.0662	0.0917

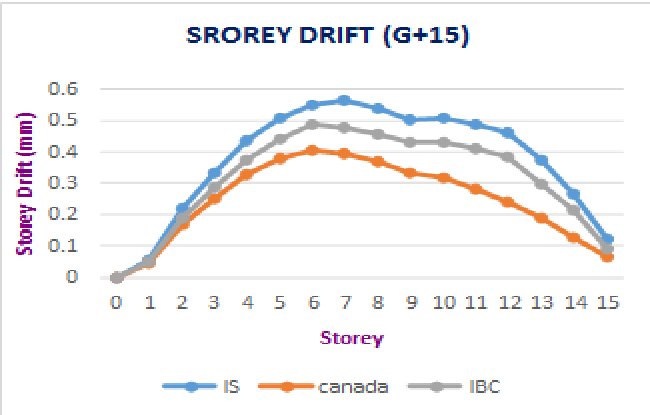

Fig (9). Comparing result of Storey Drift

3.3.3 Result for G+20

Table -9: Storey Drift (mm)

FLOOR	IS	CANADA	IBC
1	0.0794	0.0848	0.0844
2	0.3440	0.3681	0.3616
3	0.5595	0.5989	0.5942
4	0.7565	0.7875	0.7813
5	0.8626	0.9186	0.9118
6	0.9406	0.9961	0.9901
7	0.9631	1.0158	1.0105
8	0.9810	1.0166	1.0231
9	0.9585	1.0174	1.0161
10	0.9223	0.9838	1.0056
11	0.8736	0.9355	0.9416
12	0.8692	0.8737	0.8858
13	0.8357	0.8522	0.8722
14	0.7741	0.7825	0.8293
15	0.7238	0.6923	0.7699
16	0.6607	0.6368	0.7039
17	0.5844	0.5674	0.6239
18	0.3660	0.3994	0.3327
19	0.3356	0.3854	0.3178
20	0.1422	0.0908	0.1120

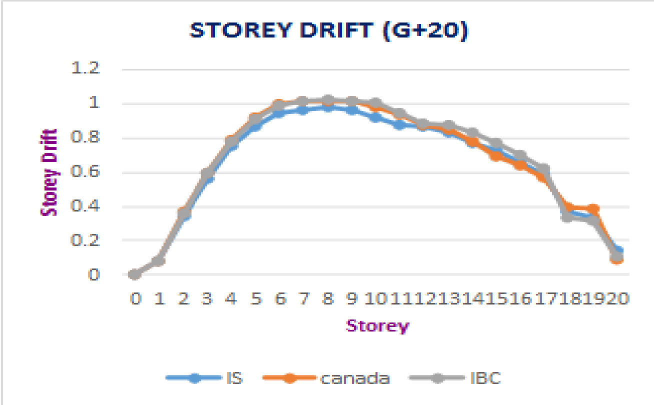

Fig (9). Comparing result of Storey Drift

3.3.4 Result for G+25

Table -10: Storey Drift (mm)

FLOOR	IS	CANADA	IBC
1	0.0593	0.0645	0.0621
2	0.2410	0.2624	0.2525
3	0.3652	0.3982	0.3826
4	0.4876	0.5313	0.5107
5	0.5823	0.6331	0.6098
6	0.6452	0.6993	0.6756
7	0.6851	0.7394	0.7172
8	0.7062	0.7586	0.7392
9	0.7183	0.7673	0.7517
10	0.7165	0.7607	0.7496
11	0.7075	0.7462	0.7402
12	0.6934	0.7257	0.7252
13	0.7054	0.7300	0.7368
14	0.7009	0.7185	0.7330
15	0.6793	0.6877	0.7103
16	0.6465	0.6444	0.676
17	0.6371	0.6083	0.6666
18	0.6229	0.5781	0.6519
19	0.6023	0.5110	0.6253
20	0.5820	0.4907	0.6093
21	0.5529	0.4306	0.5719
22	0.5166	0.3568	0.5413
23	0.4708	0.2672	0.4937
24	0.4117	0.1591	0.3485
25	0.3310	0.1134	0.2383

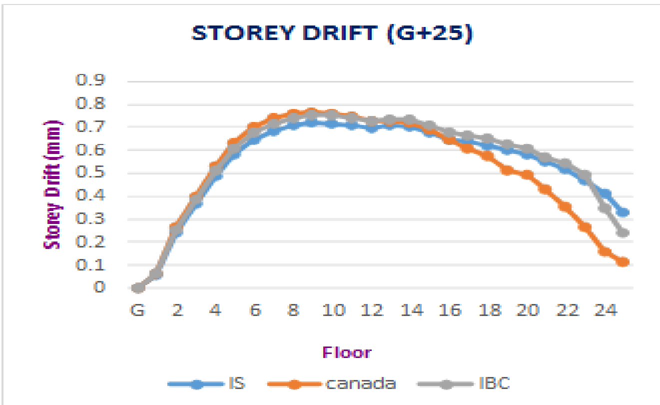

Fig (10). Comparing result of Storey Drift

4. CONCLUSIONS

1. Conclusions for Base Shear

- For G+10

Calculated base shear in X-direction, compared to Indian code, Canada code shows 17.32% more base shear and IBC shows 9.42% more base shear.

Calculated base shear in Z-direction, compared to Indian code, Canada code shows 11.20% less base shear and IBC shows 11.15% less base shear.

- For G+15

Calculated base shear in X-direction, compared to Indian code, Canada code shows 5.94% more base shear and IBC shows 4.32% more base shear.

Calculated base shear in Z-direction, compared to Indian code, Canada code shows 2.92% less base shear and IBC shows 5.46% less base shear.

- For G+20

Calculated base shear in X-direction, compared to Indian code, Canada code shows 6.94% more base shear and IBC shows 6.48% more base shear.

Calculated base shear in Z-direction, compared to Indian code, Canada code shows 8.97% less base shear and IBC shows 8.45% less base shear.

- For G+25

Calculated base shear in X-direction, compared to Indian code, Canada code shows 8.37% more base shear and IBC shows 4.61% more base shear.

Calculated base shear in Z-direction, compared to Indian code, Canada code shows 4.10% less base shear and IBC shows 4.53% less base shear.

2. Conclusions for Displacement

- For G+10

Displacement as per Canada code is 6.52% less than IS code for 10th floor and difference between them is gradually increases up to 3rd floor and for 3rd floor, displacement as per Canada code is 6.72% less than IS code and from 2nd floor it is decreases gradually toward ground floor.

- For G+15

Displacement as per Canada code is 3.57% less than IS code for 15th floor and difference between them is gradually increases up to 6th floor and for 6th floor, displacement as per Canada code 5.85% less than IS code and from 5th floor it is decreases gradually toward ground floor.

- For G+20

Displacement as per Canada code is 6.65% less than IS code for 20th floor and difference between them is gradually increases up to 10th floor and for 10th floor, displacement as per Canada code is 17.72% less than IS code and from 9h floor it is decreases gradually toward ground floor.

- For G+25

Displacement as per Canada code is 7.75% less than IS code for 25th floor and difference between them is gradually increases up to 11th floor and for 11th floor, displacement as per Canada code is 15.48% less than IS code and from 10h floor it is decreases gradually toward ground floor.

3. Conclusions for Storey Drift

- For G+10

For IS code, storey drift increase at an average value of 17.67% up to 5th floor and then it decrease at an average value of 18.67%.

For Canada code, storey drift increase at an average value of 15.33% up to 5th floor and then it decrease at an average value of 18.10%.

For IBC, storey drift increase at an average value of 16.33% up to 5th floor and then it decrease at an average value of 19.23%.

- For G+15

For IS code, storey drift increase at an average value of 25.25% up to 7th floor and then it decrease at an average value of 19.30%.

For Canada code, storey drift increase at an average value of 19.5% up to 6th floor and then it decrease at an average value of 18.94%.

For IBC, storey drift increase at an average value of 19.83% up to 6th floor and then it decrease at an average value of 16.52%.

- For G+20

For IS code, storey drift increase at an average value of 17.20% up to 8th floor and then it decrease at an average value of 19.34%.

For Canada code, storey drift increase at an average value of 19.50% up to 9th floor and then it decrease at an average value of 19.59%.

For IBC, storey drift increase at an average value of 18.24% up to 8th floor and then it decrease at an average value of 17.24%.

- For G+25

  For IS code, storey drift increase at an average value of 18.15% up to 9th floor and then it decrease at an average value of 17.17%.

  For Canada code, storey drift increase at an average value of 17.46% up to 9th floor and then it decrease at an average value of 17.75%.

  For IBC, storey drift increase at an average value of 17.87% up to 9th floor and then it decrease at an average value of 17.08%.

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