Study and Comparison of Seismic Assessment Parameters in Different International Codes

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Abstract: *This study aims towards the comparison of seismic assessment Parameters using different international standards. The chosen standards are Eurocode, ACI and Indian code i.e. IS 1893:2016. The study also leads to examine the main parameters which control the performance of Structure during the earthquake. The structure analyzed is symmetrical, G+20, Special RC moment-resting frame (SMRF). Modelling of the structure is done in ETABS 2015 software. The Lateral seismic forces are calculated per floor as per different codes in X direction. The analytical results of the model buildings are then represented graphically and in tabular form & it is compared and analyzed taking considering differences. This study focuses on exploring variations in the results of above three codes. A comparative analysis is performed in terms of Story Forces, Base shear, Design Force, Design Moments, Story Drift and also Reinforcement requirement as per different international codes.*

Key Words: (**ACI**) American Concrete Institute (**ASCE**) American Society of Civil Engineers

1. INTRODUCTION

The main earthquake hazard is the effect of ground shaking. Buildings are damaged by the shaking itself or by the ground beneath them settling to varying levels than it was before the earthquake.

Buildings can even sink into the ground if soil liquefaction occurs. When the water and soil are mixed, the ground becomes very soft and acts similar to quicksand. If liquefaction occurs under a building, it may start to lean, tip over, or sink several feet. Liquefaction is a hazard in areas that have groundwater near the surface and sandy soil.

Buildings may also be damaged by surface waves making the ground heave and lurch. Any buildings in the path of these surface waves can lean or tip over from all the movement. The ground shaking also results in landslides, and mudslides on steep hills which damages buildings and hurt people.

Such natural disasters are big challenges to the progress of development.

1.1 Overview

Civil Engineers play a major role in minimizing the hazards with efficient designs of the structures or constructions procedure or by quality control and taking other useful decisions. This includes examining the earthquakes, quality standards of the materials of construction.

Reinforced concrete Special Moment Resisting frames are used for seismic force resistance in buildings that are designed as Earthquake Resistant. Structural Elements in moment frames are proportioned and detailed in such a system that they must resist flexural, axial, and shearing actions that result through multiple displacement cycles during an earthquake. Effective proportioning and detailing are responsible for frame, capable of resisting earthquake shaking without loss of stiffness or strength. These moment-resisting frames are called "Special Moment Frames", which have improved seismic resistance in comparison with Intermediate and Ordinary Moment Frames.

Twist in buildings (Torsion), makes portions at the same level to displace horizontally by varying amounts. This induces more damage in the frames and walls on the side that moves more. Many buildings have been severely damaged by this excessive torsional behavior during past earthquakes. It is best to minimize if not completely avoided.

The Turkish Earthquake Code (TEC, 1998) was revised in 1997 and has been in effect since 1998. Unfortunately, two destructive earthquakes [Kocaeli and D'uzce] occurred in Turkey in 1999 one year after the enforcement of TEC. These earthquakes resulted in more than 18,000 recorded deaths and 50,000 serious injuries. More than 51,000 buildings were either heavily damaged or totally collapsed.

Seismic assessment codes are guidelines to design and construct. Seismic design has improved massively over the year due to the contribution of working engineers, as well as researchers.

1.2 Objective

The objective of this project is to differentiate between the main contributing factors which control the performance of the structures during the earthquake and make recommendations which should be taken into account while designing the multistoried reinforced concrete buildings so as to achieve their adequate safety. 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 updated in 2016 so as to address the various design issues brought out in the behavior of the RC Buildings during Earthquake.

1.3 Methodology

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

1. Modeling of the selected building in ETABS 2015 Software.

2.Retrieved data from the software.

3. Three models as per the codes i.e. Indian code, Eurocode, ACI specification were made.

1.3.2 Horizontal Seismic Forces (Distribution)

Different load calculations and base shear calculations has been used for different codes as mentioned in the codes. i.e. IS 1893-2016, Eurocode and ACI. The base shear is calculated and is distributed along the height of the building at each floor. The lateral seismic force (kN) induced at any level is determined as specified in the codes.

Indian Standards IS 1893:2016:

IS 1893:2016 is denoted as "Criteria for earthquake resistant Design of structures" Part 1 General provisions and buildings.

Vertical Distribution of Base Shear to Different Floor Levels is mentioned in IS 1893:2016. The design lateral force shall first be computed for the building as a whole. The force thereafter be distributed to the various floor levels. This overall design seismic force thus obtained at each floor level is distributed to individual lateral load resisting elements. The design base shear calculated shall be distributed along the height of the building as per the following expression:

$$Q_i = V_B \frac{W_i h_i^k}{\sum_{j=1}^{n} W_j h_j^k}$$

Euro Code 8 EN 1998-1:2004:

Eurocode 8 is denoted as EN 1998: "Design of structure for earthquake resistance", which is used in design and construction of buildings and civil engineering works in seismic regions. Base shear of the structure calculated as stated by expression (EN 1998-1/4.5). Distribution of the horizontal seismic forces can be calculated by two ways

a) Depends on height of masses

b) Depend on absolute horizontal displacement of masses

Distribution of the horizontal seismic forces is calculated as per height of masses and is computed as per the following expression:

$$F_i = F_b \cdot \frac{z_i \cdot m_i}{\Sigma z_j \cdot m_j}$$

Where, z terms are the heights of the masses (m terms) above the level of the seismic action.

F_b is the force calculated by the expression (4.5) of the Eurocode specified.

ACI Code 318-08:

ACI 318-08 is denoted as "Building Code Requirements for Structural Concrete" in which Chapter 21 deals with the "Earthquake Resistant Structures".

ACI 318-08 recommends "ASCE 7-10" to adopt data for Design of Earthquake Resisting structure such as Soil Type, Site Classification, Design Acceleration Parameters,

In this case, the lateral seismic force (*Fx*) (kip or kN) induced at any level shall be determined from the following equations:

$$F_x = C_{vx} V$$

and

$$C_{vx} = \frac{w_x h_x^k}{\sum_{i=1}^{n} w_i h_i^k}$$

where

C_{vx} = vertical distribution factor,

It can be seen that mathematically the above expression is similar to the expression of IS 1893:2016.

Even if the expression is similar, values of other constants are different.

Table-1: Lateral seismic forces in X direction in KN

Story	IS	EN	ACI
1	3741	4366	3366
2	3741	4366	3366
3	3740	4343	3361
4	3733	4297	3347
5	3720	4229	3321
6	3695	4137	3281
7	3657	4022	3225
8	3602	3885	3151
9	3527	3724	3058
10	3429	3541	2944
11	3305	3335	2808
12	3152	3106	2648

13	2967	2853	2464
14	2746	2578	2254
15	2488	2281	2017
16	2188	1960	1752
17	1844	1616	1458
18	1452	1249	1133
19	1010	860	778
20	514	447	391

1.3.3 Numeric Data

The data used in modeling is

Table 2: Numeric Data for case study

	Parameters	Dimensions/Type
1	Plan dimension	(15 x 15) m.
2	Number of stories	G+20
3	Total height of building	64 m
4	Height of each storey	3 m
5	Column size	750 x 750 mm
6	Beam size	450 x 600 mm
7	Grade of concrete	M35
8	Frame type SMRF	SMRF
9	Soil type Medium soil	Medium Soil
10	Live load	2.5 KN/m
11	Inner wall	150 mm
12	Outer wall	250 mm
13	Slab thickness	150 mm
14	Unit weights of Concrete	25KN/CuM
15	Unit weights of brick work	19 KN/CuM

1.3.4 Modelling

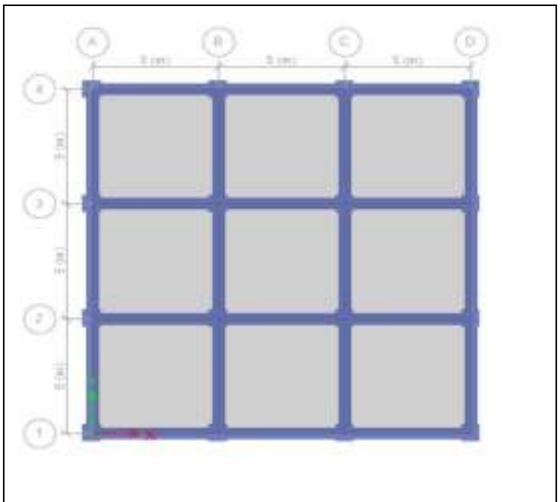

Fig-1: Plan of the selected building

Fig-2: 3D View of the selected building

2 ANALYSIS AND RESULTS

2.1 OVERVIEW

A G+20 building is examined and analyzed with three different code specifications during the earthquake. Parameters like base shear, Story Drift, axial force, bending moments, for column is calculated and shear, moment for beam is calculated. Graphical and Tabular representation of data is shown in this chapter.

2.2 Story Forces

2.2.1 In X Direction

Table 3: Story Forces (KN)

Height (m)	IS	EC	ACI
64	513.95	447.03	390.92
61	495.78	412.53	387.25
58	442.22	389.62	355.26

55	391.73	366.70	324.21
52	344.29	343.78	294.13
49	299.92	320.86	265.06
46	258.60	297.94	237.02
43	220.35	275.02	210.06
40	185.15	252.10	184.22
37	153.02	229.19	159.55
34	123.95	206.27	136.11
31	97.93	183.35	113.95
28	74.98	160.43	93.16
25	55.09	137.51	73.83
22	38.25	114.59	56.08
19	24.48	91.67	40.05
16	13.77	68.76	25.95
13	6.12	45.84	14.08
10	1.53	22.92	4.95
7	0.00	0.00	0.00
0	0.00	0.00	0.00

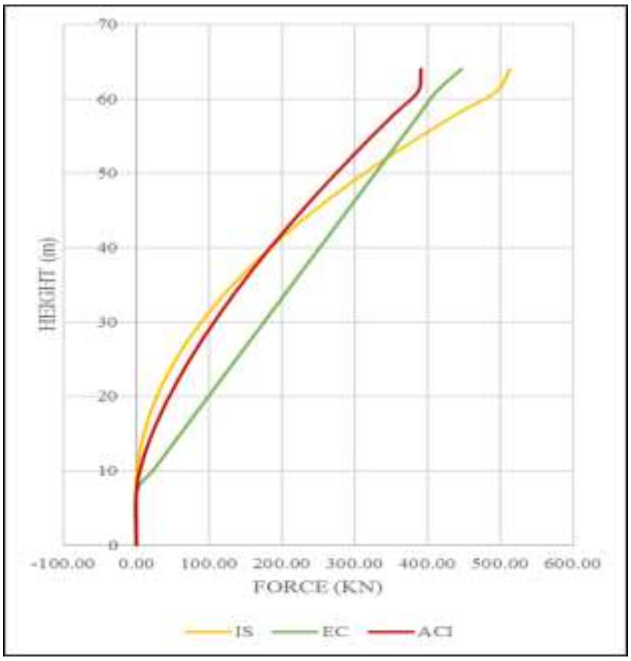

Chart 1: Story Forces (KN)

2.3 Base Shear

2.3.1 In X Direction

Table 4: Base Shear for earthquake in X-direction in KN

IS	EN	ACI
3741	4366	3365

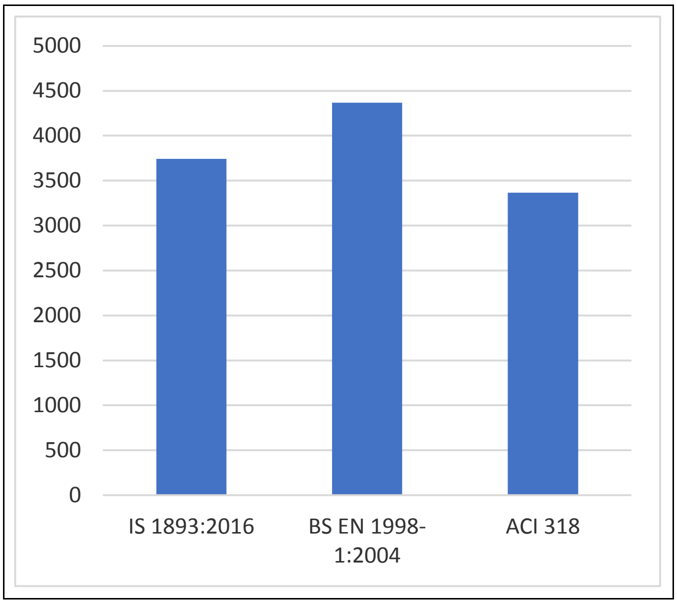

Chart 2: Base Shear for earthquake in X-direction

2.4 Column

2.4.1 Design axial force (KN) (C1)

Table 5: Design Axial Force (KN)

IS	EN	ACI
3719.593	1779.059	3142.087

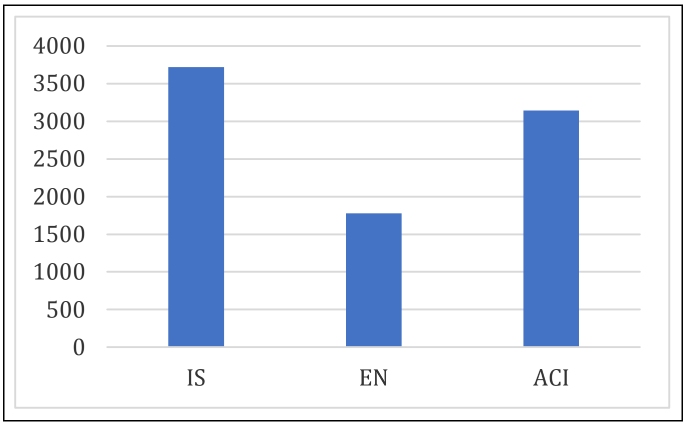

Chart 3: Design Axial Force

2.4.2 Design Bending Moment (KN-m) (C1)

Table-6: Design Bending Moment (KM-m)

IS	EN	ACI
1526.40	1162.96	1344.68

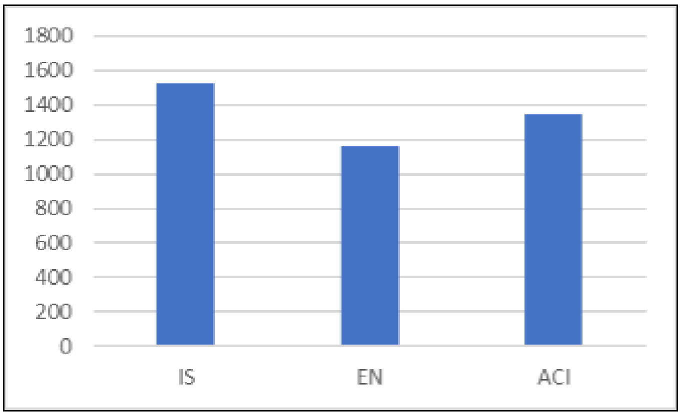

Chart 4: Design Bending Moments

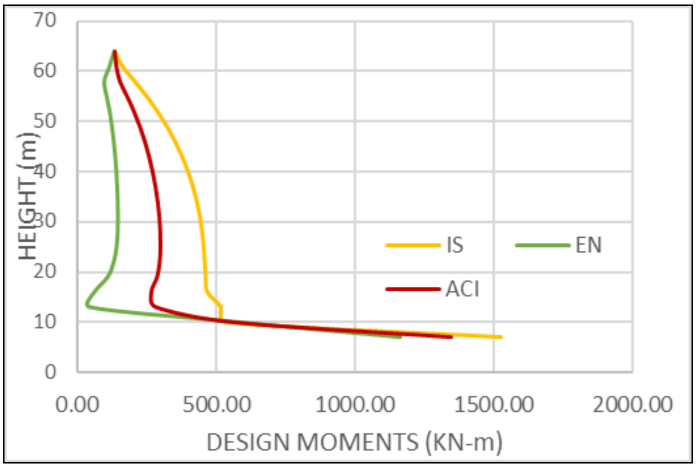

Chart 5: Design Bending Moment (KN-m) (C1)

2.4.3 Story Drift

Table 7: Story Drift

Story	IS	EN	ACI
1	0.001403	0.001374	0.00126
2	0.001621	0.002394	0.001451
3	0.001891	0.003525	0.001689
4	0.002001	0.004014	0.001781
5	0.002059	0.004206	0.001825
6	0.002096	0.004252	0.001847
7	0.002119	0.004218	0.001856
8	0.002128	0.004135	0.001851
9	0.002124	0.004014	0.001833
10	0.002105	0.003863	0.001802
11	0.00207	0.003683	0.001757
12	0.002017	0.003478	0.001698
13	0.001945	0.003246	0.001624
14	0.001854	0.00299	0.001536
15	0.001742	0.002709	0.001432
16	0.001608	0.002407	0.001313
17	0.001451	0.002087	0.00118
18	0.001273	0.001757	0.001032
19	0.001079	0.001437	0.000876
20	0.000894	0.001167	0.000731

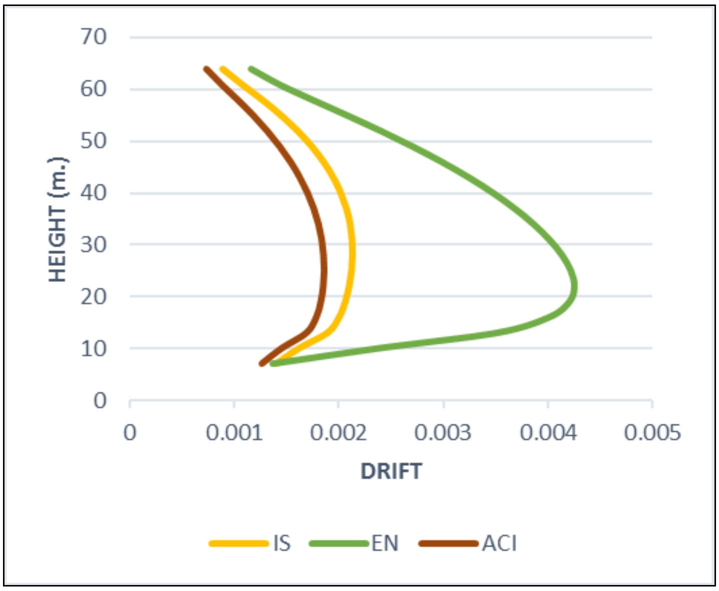

Chart 6: Story Drift

2.4.4 Column Reinforcement (mm2) (C1) (Story 1)

Table-8: Reinforcement (C1) mm²

IS	EN	ACI
12933	24517	18000

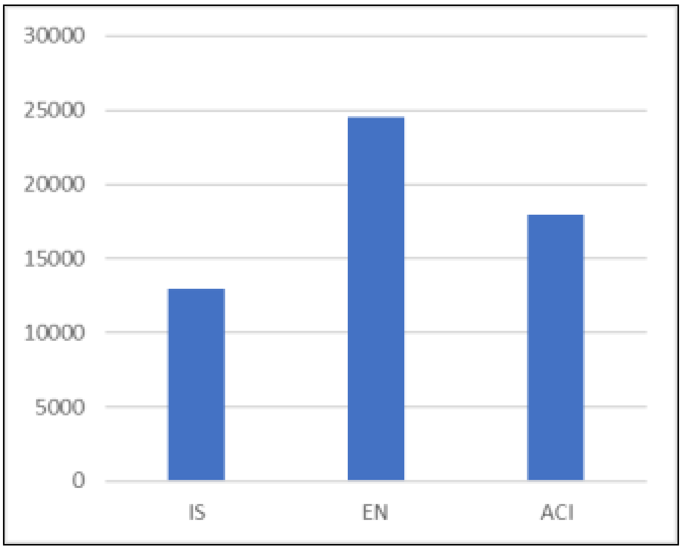

Chart 7: Column Reinforcement (mm2) (C1) (Story 1)

3. CONCLUSIONS

1. **Story Forces**

- It can be observed in Chart 1 that; story forces vary as per different international codes.
- It can be concluded that; Story forces obtained from Eurocode has larger range than the same obtained from Indian Standard and ACI.

2. **Base Shear**

- Calculated Base shear in X direction, Compared to Indian code, Eurocode shows 16.70 % more base shear and ACI shows 10.05 % less base shear.

3. **Axial load, Moment for selected columns**

- Axial force as per Indian code is maximum compared to other codes, Axial force as per Eurocode is less by 52.16 % and Axial force as per ACI is less by 15.52 % as compared to Indian code.
- Design Moment as per Indian code is maximum compared to other codes, Moment is 23.81% less of Eurocode as compared to Indian code and 11.90% less of Eurocode as compared to Indian code.

4. **Story Drift**

- Story Drift as seen in the graph, in the case of Eurocode has fluctuating values with a drastic heave. And Indian Code, ACI represent a graph having lesser fluctuating values than the former one.

5. **Reinforcement**

- Column Reinforcement (mm2) required for C1 at Story 1 can be observed in Chart 6 & the variation in different codes is large. In this case Eurocode result surpasses other two codes.
- As compared to Eurocode, IS code recommends 47.24% less reinforcement and as compared to ACI, it recommends 28.15% less reinforcement.
- From the observations made it can be concluded that, IS code recommends the reinforcement lesser than Eurocode and ACI in this specific case.
- Though recommending largest amount of reinforcement, Eurocode extracts safer results than IS and ACI due to its heavier Load Combinations, Factors of Safety, Reduction Factors etc.
- This maRkes the structure safest and able to withstand the loads with longer durability yet being heaviest.

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