Comparative Study of Various Design Codes for High Rise Building under Seismic Loads

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Abstract: -- The effective design and construction of earthquake resistance structure have a much greater importance all over the world. Hence, there is a need for comparative study of various codes. At present, there is various software available for earthquake analysis of buildings like STAAD. Pro, SAP 2000, ETABS and many more. The design criteria for different codes are also different. The aim of the paper is to compare the design results for high rise building (G+20) with various codes. The difference in the area of steel for column and beam by Euro code, IS code and ACI code are compared and respective graphs are plotted. A study shows variation in the section as well as reinforcement required to resist the same amount of design moments and shear force, whereas analysis of building is done as per IS 1893(part 1) -2016 .From the result, it is found that there are many similarities in main steel for ACI and Euro code as compared to IS code provision for design.

Key Words- Earthquake resistance design, Codal comparison, Design parameter.

I. INTRODUCTION

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.

The effective design and construction of earthquake resistance structure have very much importance all over the world. Thus, it is important to design building and comparing the result with different codes. In present study a G+20 storey residential building regular in plan are analyzed by IS 1893 part-1 (2016) and design is done by ACI 318,IS-456 and Euro code EC 1992-1-1 respectively.

II. OUTLINE

Given building is a G+20 storeyed residential building with the plan dimension of building are 37.39 in length and 20 m in width. Height of a building is 60 m with a storey height of 3 m. The column and beam is taken of reinforced concrete. Slab loading is directly applied on the frame structure. The architecture plan of building was already available, with the help of Auto Cad single line plan is made from double line plan then it is exported in STAAD.Pro for modelling
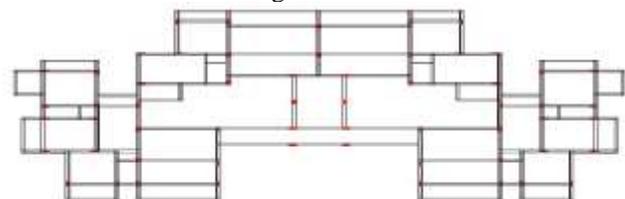

Fig. (a) Double line Auto cad plan with column position

III. LOAD CALCULATION

The probable loads acting on the structure are summarized below.

A. Dead load

Self-weight of the structural elements is automatically calculated by STAAD PRO. The other dead load are considered as per IS 875-part (1)

B. Imposed load

Imposed live load as per IS: 875: (Part 2) 1987 has been considered as given in table 1.

Table. 1 Imposed live load (IS: 875: (Part 2) 1987)

Sr. No	Occupancy	Imposed live load
1	All room & kitchen	$2\ kN/m^2$
2	Toilet & Bathroom	$3\ kN/m^2$
3	Corridor, Passage, Staircase	$3\ kN/m^2$
4	Balconies	$3\ kN/m^2$

C. Seismic load

1. Base shear and Seismic load calculation

As per the Indian seismic code IS: 1893, Design base shear is given by

$$V = A_h W = \frac{Z}{2} \frac{I}{R} \frac{S_a}{g} \quad (1)$$

2. Factors considered for Seismic calculation

The following factors given in table 2 below are used for the purpose of design base shear calculation

Table .2 Factors considered for Design of base shear calculation

Factors	Symbol	IS: 1893: 2016
Seismic Zone factor	Z	0.16
Importance factor	I	1
Response reduction factor	R	5
Fundamental Period		
RC frame	T_x	0.89
	T_y	1.22

3. Seismic weight calculation

To evaluate the design base shear, it is of importance to know the seismic weight of building. The seismic weight has been calculated by STAAD Pro by taking self weight, member weight, and floor weight command under seismic weight

IV. LOAD COMBINATION

To take the more uncertainties into considerations we need to use some factors that is why we need to consider some load combinations which is specified in IS1893 while going for seismic analysis.

Table. 3 Load combinations for seismic analysis (IS 1893 (Part 1): 2016.

SR. No	Load Combination
1	1.5 DL + 1.5 LL
2	1.5 DL + 1.5 EQX
3	1.5 DL - 1.5 EQX
4	1.5 DL + 1.5 EQZ
5	1.5 DL - 1.5 EQZ
6	1.2 DL+1.2 LL + 1.2EQX
7	1.2 DL+1.2 LL - 1.2 EQX
8	1.2 DL+1.2 LL+ 1.2 EQZ
9	1.2 DL+1.2 LL - 1.2 EQZ
10	0.9 DL + 1.5 EQX
11	0.9 DL - 1.5 EQX
12	0.9 DL + 1.5 EQZ
13	0.9 DL - 1.5 EQZ

V. ANALYSIS RESULT

A. Earthquake Analysis

Analysis of G +20 storied building with all the dimensions and the relevant data required for earthquake analysis of building is given below

1. Dimensions of building

       Length = 37.39 m
       Width = 20 m

2. Life of building = 50 years
3. City = Mumbai
4. Seismic zone = Zone III (Soil is medium)
5. No of stories = 20
6. Storey Height = 3 m
7. Building Height = 60 m
8. Dimensions of component of RCC Building
   Beam   B1 300 X 450 mm
                  B2 300 X 500 mm
   Column   C1 400 X 850 mm
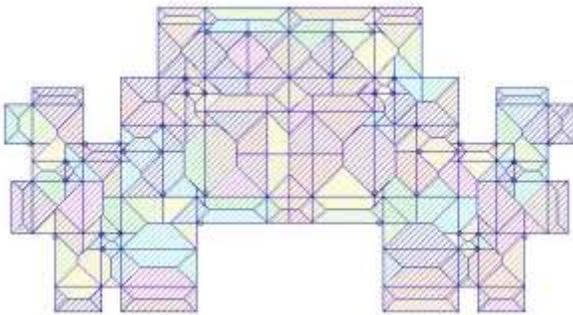   C2 450 X 1200 mm

Fig. (b) Load distribution

After doing the analysis if the base shear values we got from response sprectrum is less than the base shear calculated using empirical formula for fundamental natural period then we need to use the multiplying factor (Vb/VB) for the response spectra factor given by STAAD when we enter the value of fundamental time period then go for analysis again in software which gives the peak shear values at each floor. Fig.(b) shows the load distribution in STAAD.Pro and table.4 shows the peak storey shear.

Table. 4 Peak story shear

STOREY NO	STOREY LEVEL IN m	PEAK STOREY SHEAR IN kN
20	60	500.27
19	57	1193.56
18	54	1818.91
17	51	2362.03
16	48	2816.35
15	45	3180.84
14	42	3463.00
13	39	3678.79
12	36	3851.20
11	33	4006.89
10	30	4170.98
9	27	4361.02

8	24	4582.48
7	21	4827.93
6	18	5082.83
5	15	5322.87
4	12	5524.58
3	9	5674.32
2	6	5765.51
1	3	5788.04
Base	0	5788.04

Summary of all the forces and moment are given in table.5 for the various load combination specified in IS 1893-part (1). The worst combination is selected for the members and gone for design of member.

Table .5 Maximum value of forces and moments

Beam	Load combination	Node	Fx kN	Fy kN	Fz kN	Mx kN m	My kN m	Mz kN m
125	1.5(DL + EQX)	100	10550.4	385.14	25.602	18.50	176.48	2234.4
3245	1.5(DL + EQX)	171	-1532.31	269.11	99.484	7.842	12.4	727.02
3332	1.5(DL + EQX)	1805	28.001	533.86	6.688	3.137	5.202	344.23
3332	1.5(DL + EQZ)	1829	-21.89	552.08	6.883	2.749	3.872	332.08
3373	1.5(DL + EQZ)	1805	5244.45	170.55	244.54	9.199	252.05	258.83
5082	1.5(DL + EQZ)	1866	2948.94	110.01	263.18	10.35	377.58	148.21
3185	1.5(DL + EQX)	1733	6.613	36.918	4.396	107.6	4.167	0
36	1.5(DL + EQX)	59	-2.593	-36.918	3.68	-107.1	-4.526	0
3255	1.5(DL + EQX)	1757	5580.61	244.52	220.85	5.596	498.23	1503.4
3255	1.5(DL + EQZ)	1757	1601.16	-264.69	206.05	-5.117	486.90	-1475.8
3244	1.5(DL + EQZ)	1746	3326.78	482.04	86.543	3.775	234.8	2331.4
3244	1.5(DL + EQX)	1746	3467.93	-473.25	-82.123	-11.29	-228.49	-2362.5

VI. ANALYSIS OF BUILDING FOR EARTHQUAKE LOADING

After analysis the building as per IS 1893-part1 (2016) the design of given residential (G+20) story building is done by three different codes. The area of main longitudinal steel for column and beam with different sizes and codes are presented in tabular form and graphs are also plotted. In addition the percentage variation in main steel with reference with IS 1893 part-1 also presented.

A. Design calculation for beam

For study purpose four sample beam are consider. All the four selected beams are ground floor beam namely B1, B2, B3 and B4.The beam B1and B4 are peripheral external beam and B2 and B3 are internal beams. Table. 6 shows the area of main longitudinal steel as per specified three different codes. Area of main steel all the four beam are graphically shown in fig. c. Difference in the area of steel can easily observed from the given figure.

Table. 6 Area of main steel for beam

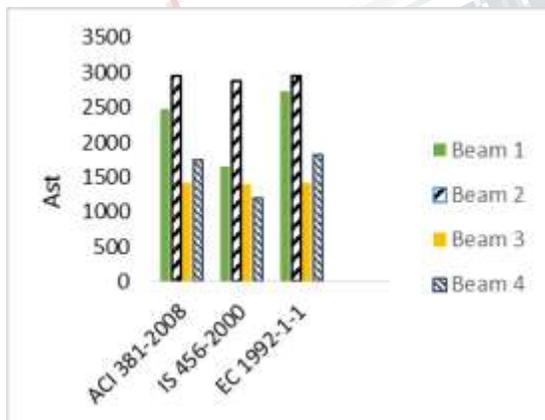| Beam	Area of main steel mm^2	Code
B1	1655.61	IS 456-2000
	2477.93	ACI 318 2008
	2729.25	EN 1992-1-1
B2	2877.69	IS 456-2000
	2945.24	ACI 318 2008
	2945.24	EN 1992-1-1
B3	1388.58	IS 456-2000
	1407.43	ACI 318 2008
	1407.43	EN 1992-1-1
B4	1203.23	IS 456-2000
	1746.73	ACI 318 2008
	1809.55	EN 1992-1-1

Fig. (c) Area of main steel for beam

B. Design calculation for column

Three columns from ground floor and one from above floor are selected namely C1, C2, C3 and C4. The column C1 and C2 are exterior column where as C3 and C4 are interior one. Tables 7 shows the area of main steel for column as per specified three codes. Area of main steel for all the four column are graphically shown in fig. d. Difference in the area of steel can easily observed from the given figure.

Table. 7 Area of main steel for column

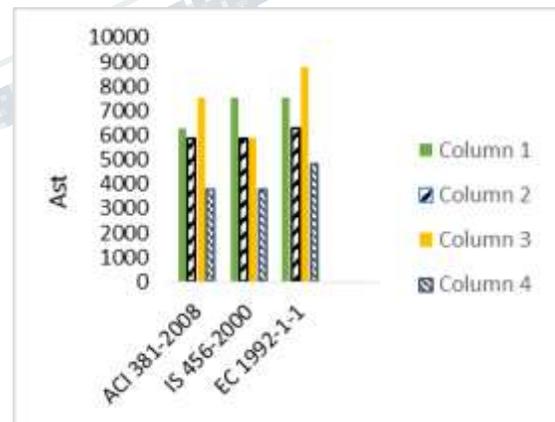| Column	Area of main steel mm^2	Code
C1	7539.82	IS 456-2000
	6283.18	ACI 318 2008
	7539.82	EN 1992-1-1
C2	6283.18	IS 456-2000
	5890.48	ACI 318 2008
	5890.48	EN 1992-1-1
C3	8796.46	IS 456-2000
	7539.82	ACI 318 2008
	5890.486	EN 1992-1-1
C4	4825.48	IS 456-2000
	3769.911	ACI 318 2008
	3769.911	EN 1992-1-1

Fig. (d) Area of main steel for column

C. Percentage variation in main steels

Below are the graphical representation for the percentage variation in main steel for column and beam for ACI and Euro code with respect to the IS code and conclusions are drawn by comparative study. Fig. e shows the percentage variation for beam and fig. f shows percentage variation for column respectively.
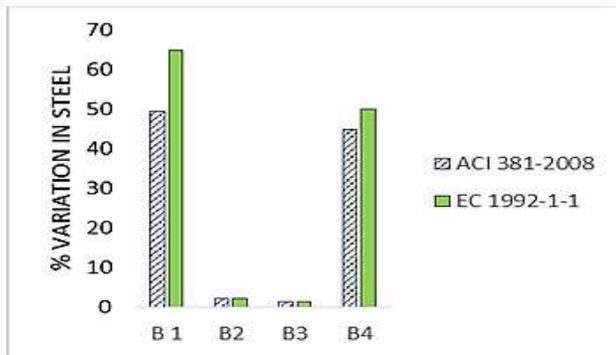
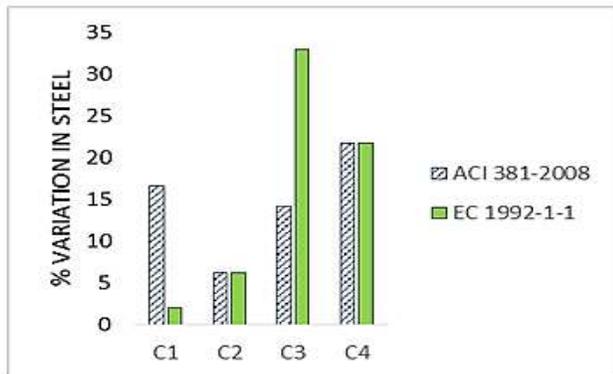*Fig. (e) Percentage variation in main steel for beam*

Fig. (f) Percentage variation in main steel for column

VII. RESULT AND DISCUSSION

From the above study of comparison of various codes the following conclusions has drawn,

1.   From four beam results it has been found that ACI and Euro code having almost similar result in main steel and considerable difference in main steel as par IS codal provision

2.   For beam B1 and B4 which are peripheral external beam the percentage decrease in main steel has found to be around 45 %. Whereas for beam B2 and B3 which are interior once the percentage decrease in main steel is very less around 1%.

3.   Result of column also shows that the main steel as per ACI and Euro code has almost same.

4.   As per IS the main steel in column is coming out to be more as compare to other code

5.   For external column C1 and C2 the percentage increase in main steel with respect to IS code has less whereas for column C3 and C4 is about 20%.

6. From the above study it may be concluded that the concept of strong column and weak beam has most probably followed by IS code.

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