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Comparative Study on Analysis and Design of Reinforced Concrete Building under Seismic Forces for Different Codal Guidelines

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ABSTRACT

Construction is a vital part of every developing country in this era. Every country has specific building design codes which provide the standards to engineers for the design of various structural components like the beam, column, and slab. Analysis and design Reinforcement concrete building of every country is based on their geographical location. Seismic forces are one of the major natural forces causing huge damage to lives and economy. So that one can understand the difference and can appropriate for best guidelines for safety to lives and economy. In today's world of globalization, an engineer must be efficient enough to understand and handle different codes. In this paper, a comparative study is presented for analysis and design of reinforced concrete building under seismic forces for four codal Guidelines (IS 1893:2002, Euro code 8, Japan-2007 and ASCE: 7-10) using Staad Pro. The comparative study includes the comparison building base shear, bending moment, shear force, percentage of steel, required area, displacement, and story-drift. For seismic Analysis and design, the building elements like beam and column is also compared using these countries RC building code.

Keywords: *Seismic analysis, Multi-storeyed RC building, IS, Euro code, ASCE, Japan*

INTRODUCTION

There is major earthquake have been recorded in India, Japan, Europe, and the U.S. The Bhuj earthquake in 2001 in India with the magnitude of 7.7 resulted in 20000 lives and around 339000 severe damage of building [2]. In India, 26 December 2004 Ocean earthquake of a magnitude of 9.1 to 9.3, resulted in more than 283,106 deaths [1]. Many earthquakes have accrued in Japan, the scientific research on seismology or earthquake engineering began only after the Meiji restoration in 1868.In 1923 Kanto (Tokyo) earthquake caused loss of life more than 14000, heavy damage in building and houses around 250000[1]. In 1908, the Messina earthquake occurred in Sicily, Italy, and Calabria with the magnitude of 7.1. The cities were destroyed and 200,000 lives were lost [4]. In 1989 Loma Prieta and 1994 Northridge earthquake led to a loss of 120 lives. To minimize these losses during earthquake seismic provision have been developed [2].

The Indian seismic code (IS-1893) published in 1962 for the purpose of Recommendation for earthquake resistant design of structures and this revised in 1966 first time. The sectional committee felt to revise these standards including the seismic zones and epicentre in 1970. The third revision in 1984, prepared with a new concept of the performance factor, base shear, and modal analysis was introduced. In 2002, the fifth revision of is 1893 deals with the seismic loads of various structure and earthquake resistant of the building [5].

The building standards law of Japan 1963 revision was removed the height limitation. The law required that the design and construction of high rise building should be approved by Minister of construction because of the severe damage of high rise building in the 1923 Kanto (Tokyo) earthquake disaster. The urban building law of enforcement order issued in 1920, limited to a building height of 65 feet of residential building and 100 feet of a non-residential building. The method of construction is required in the building of law of enforcement order, revised time to time by the technical development. Various standards and guidelines provided by the Architectural Institute of Japan (AIJ). The building law of Japan (BSLJ) was proclaimed in May 1950 to safeguard the life, health, and property of people. The (BSLJ) order was revised in July 1980 and was adopted from June 1981[6, 7].

The European standards EN 1998-1 Design of structure for earthquake resistance. Euro code consists of 10 sections that were developed by the European Committee for Standardization (CEN). EC-1998-8 concern the design of the structure for earthquake resistant, it is the eight standards of EC-1998 and it is an addition of six parts (EN1998-i: i=1, 2, 3, 4, 5, 6). EC8 was approved and published in 2013, it considers different factor like behavior factor, capacity design method, dissipative zones, importance factor etc[8,9].

The first modern code containing seismic provision is generally admitted to be the first edition of the uniform building code. National earthquake hazard reduction program recommended provisions developed by building science safety council in the USA (BSSC 1997). In 1937, the zonal map introduced with the concept of the different seismic resistant building. In 1988 UBC revised by structural engineering association of California (SEAOC). The (SEAOC) formed by Applied technology council, consider the introduction of site factor and occupancy importance factor. ASCE-7-10 utilize seismic design category (SDC) concept which differentiates the structure according to the seismic risk level [10, 11].

Ahmed M. EI Kholy at al. [3] compare the Egyptian code 2012 with EC 8-2013, IBC 2015 and UBC 1997; consider residential shear wall RC buildings in Egypt. Muhammad Mostafijur at al. [2] present seismic performance of reinforcement concrete buildings designed according to codes in Bangladesh, India, and the USA. The structures were modeled and design software ETABS NL (version 9.6). Masayoshi Nakashima [12] compares EC8 and the Japanese seismic design code (BCJ) for steel moment frames and braced frames. In this paper EC8 is 2.5 times larger force for his limit state. Marjan Faizan and Yuji Ishiyama [13] compare the seismic codes of Japan (BSLJ) 1981; USA (IBC) 2000 & Iran (ICS) 1999 are used for comparing the similarity and differences. C. Bhatt, R. Bento [14] compares the code of America and European, on the nonlinear static analysis of RC building. In this paper, five stories RC concrete building consider and result compare with nonlinear dynamic analysis. By Weizi Zhang and Bahram m. Shahrooz[15] present the comparison between ACI and AISC for concrete-filled tabular columns(CFTs), defined their potential capacity. Angelica Walsh at al. [16] compares three climatic zoning methodologies for structure and find out the difference in results for a small country climatic variation. Sameh A. EI-Betar [17] presents the seismic performance of existing RC framed building by nonlinear static pushover analysis. Ali Ergun at al. [18] presents the Premodern code (1998 Turkish earthquake code) to consider the seismic performance of RC building. Ali Ruzi Ozuygur [19] evaluates the structural design of a 50-story tall reinforcement concrete residential building, which was planned to be constructed in Istanbul. Its seismic performance has been checked by nonlinear time history analysis. Leonardo Avila at al. [20] presents the seismic performance of asymmetric masonry building. Mohsen Kohrangi [21] comparison consists of sequential steps for identifying and understanding the similarities of the Key elements informed the seismic hazards models. Kristijan Kolozvari [22] evaluates the seismic performance and behavior of high rise RC coupled wall building with the help of dynamic analysis by modeling approach. M. Mosleh et al.[23] in this research two existing RC irregular building analyzed with EC 8 and purposed for co-linear analysis at different levels Global and Local. Jose Barros [24] this paper evaluates a different procedure for the structural design that gives the behaviour of frequent and rare earthquakes. A two-story school building is considered for study case. S. Malekpour at all.[25] this paper introduces the steel moment resisting frames by using three country code, Iranian, European and Japanese codes. The seismic performances of these codes are almost identical but differ for high rise building. Gang Shi at all.[26] - present the paper which compares and design of steel moment resisting frame by the different country code and find that Chinese code designed steel moment resisting frame exhibit 20% to 150% larger resistance and stiffness than U.S. & Euro code.

This paper present comparison of four seismic codes (IS1893-2002, ASCE7-10, EC8-2013, BSLJ) and find out the difference and similarities of their codes. The analysis and design should be done by the software STAAD PRO V8i. The structure designed in India should be confirmed from the Indian standards code. The seismic design requirements of Indian standards and U.S. of the structure depends upon the seismic zoning system, site classification, fundamental period, response reduction factor, important factor, story drift and base shear are given in table 1. There are different parameter of Japan and Europe which are given table 2. Every code provides approximate formulas for estimating the time period and calculating base shear, lateral forces, and other required parameters.

Objective of Study:-

The main purpose of this study is to bring out a detailed seismic analysis and structural design on simulation tool STAAD PRO of a rectangular plan of multi-storey building. This study is focused to carry out the advantage of seismic design of multi-storey building using different country code with STTAD PRO at global level with ease of use. This numerical study comprises of-

1. To understand the accuracy of software's for analysis and design of multi-storey building.
2. To compare the results and behaviour of structures using different country code.

Simulation Tool STAAD PRO:-

STAAD stands for Structural Analysis and Design. STAAD PRO is a general purpose structural analysis and design programme with applications primarily in the building industry-commercial buildings, bridges and highways structures etc. It was the first structural software which adopted for the analysis of matrix problems. The programme hence consists of the following facilities to enable this work. Graphical model generation utilities as well as text editor based commands for creating the mathematical model. Beam and column are represented using lines. Walls, slabs and panel type member are represents using triangular and quadrilateral finite elements. These utilities enable the users to create the geometry, assign properties, orient cross sections as desired, assign materials like steel, concrete, timber, aluminium, safety supports, and apply loads for desired loading case.

Results viewing, result verification and report generation tools for examining displacement diagrams, bending moment and shear force diagram, beam etc.

Comparison of seismic provision

The different seismic provisions and standards of different countries are shown in table in table 1 & 2 respectively. The factor of safety for different loading case for country code is represented in table 3.

Table 1: Comparison of seismic provisions of IS 1893-2002[5] and ASCE 7-10[2]

Parameters	IS 1893-2002[5]	ASCE 7-10[2]
Zoning system	The country divided into four zones (II, III, IV, and V) zone II $Z = 0.10$ zone III $Z = 0.16$ zone IV $Z = 0.24$ zone V $Z = 0.36$	i. Each region is assigned a location-specific mapped Spectral acceleration parameter (SS, short period and S1, 1sec). ii. SS & S1 are modified for Site Class effects to get Maximum Considered Earthquake (MCE) spectral Response acceleration parameters (SMS and SM1). iii. The design spectral acceleration SDS and SD1 parameters can be obtained by dividing SMS and SM1 parameters by 1.5.
Site classification	Classification of site depends upon standard penetration test (N).	Average shear wave velocity (υ_s), average field standard penetration resistance (n), and average undrained shear strength(S_u) for the top 30.5m are used to classify different sites.
Approximate fundamental period	The approximate fundamental period for "Reinforced Concrete Moment Resisting Frame" $T_a = 0.075 h_n^{0.75}$, h_n in meter.	The approximate fundamental period for "Reinforced Concrete Moment Resisting Frame" $T_a = 0.0466 h_n^{0.9}$, h_n in meter.
Response reduction factor	i. Ordinary moment resisting Frame (OMRF), R =3 ii. Special moment resistant Frame (SMRF), R = 5	i. Ordinary moment resisting Frame (OMRF), R = 3 ii. Intermediate Moment Resisting Frames (IMRF) R = 5
Important factor	i. Important service and community building I =1.5 ii. All other Buildings I = 1.0	Depends upon risk categories (I, ii, iii, iv)– ASCE 7 has four seismic important factor I = 1.0, 1.0, 1.25, 1.5 respectively.
Drift criteria	Allowable "elastic story drifts are $0.004H_{story}$ for all the structures irrespective of any structure under risk category.	Allowable "inelastic" story drifts are limited to $0.020H_{story}$ for a commercial building having risk category I or II.
Minimum design lateral force	Design lateral force calculated from the static analysis is $V = \frac{1}{2} x \frac{S}{g} \frac{I}{R} x W$ Where (S/g) = spectral response acceleration parameter for MCE response spectrum corresponding to Ta, And W = the seismic weight of the building. Story shear- $Q = V_B \frac{W i h_i^2}{\sum_{j=1}^{n} W j h j^2}$ Where Q_i = design lateral force at floor i, W_i = seismic weight of floor i, H_i = height of floor I measured from base N = number of story.	Design lateral force calculated from static analysis is $V = C_s \times W$ where C_s = the seismic response coefficient $C_S = \frac{S_{DS}}{\left(\frac{R}{I_e}\right)}$ W = the seismic weight of the building
Response spectrum	i. For rocky or hard soil sites, $S_a/g =$ $\{1 + 15T \quad 0.0 < T < 0.10 \quad 2.5 \quad 0.1 < T < 0.40 \quad \frac{1}{T} \quad 0.4 < T < 4.0$ ii. For medium soil sites, $S_a/g =$ $\{1 + 15T \quad 0.0 < T < 0.10 \quad 2.5 \quad 0.1 < T < 0.55 \quad \frac{1.36}{T} \quad 0.55 < T < 40$ iii. For soft soil sites, $S_a/g =$ $\{1 + 15T \quad 0.0 < T < 0.10 \quad 2.5 \quad 0.1 < T < 0.67 \quad \frac{1.67}{T} \quad 0.67 < T < 40$	i. Spectral Acceleration, For $T < T_0$, $Sa = S_{DS} (0.4 + 0.6T/T_0)$ $T_0 = 0.2 . S_{D1}/S_{DS}$ ii. $T_0 > T > T_S$, $Sa = S_{DS}$, $T_S = S_{D1}/S_{DS}$ iii. TS > T > TL, $Sa = S_{D1}/T$ where T_L=long period OR transition period iv. $T > T_L$, $Sa = S_{D1} T_L/T^2$

Table 2: Comparison of seismic provisions of EC 8 2004[26], BSLJ [6, 25]

Parameters	BSLJ [6,25]	EC-8 [26]
Zoning system	Z= seismic zone factor 0.7 to 1.0. The BSLJ seismic zoning dividing Japan into three zones. The seismic zoning coefficient Z is 1.0, 0.9,0.8 and 0.7	National territories shall be subdivided by the National Authorities into seismic zones, Depending on the local hazard. The hazard is described by a_g R, The parameter a_g R,is modified by the Importance Factor $\gamma_1$to become the design Ground acceleration (on type A ground) a_g = a_g R.γ_1 R= Reduction factor
Site classification	The Japanese procedure evaluates a kind of simplified period (T_G) of the upper part of the ground - above the engineering Base.	Classification of the site depends upon standard penetration (N) test and shear wave velocity (υ_s).
Approximate fundamental period	Ta = 0.1 N for moment resisting frame buildings not exceeding 12 stories and having a minimum story height of 3m is also permitted. (N is the number of stories) The natural period- T = (0.002+0.01α)H α= ratio of stories by steel and timber construction	The mean return period T_R is given by T_R = 1/V $T_R = T_L/\ln(1-P)$
Response reduction factor	R_t is the design spectral coefficient- R_t=1.0 $T<T_c$ $R_t=1.0-0.2\left\{\frac{T}{Tc}-1\right\}^2$ $T_c \leq T<2T_c$ $R_t=1.6T_c/T$ $2T_c \leq T$	-----
Important factor	Not available	Important factor divided into four class (I, ii, iii, iv) Class | Important factor | Buildings i | 0.8 | Agriculture building Ii | 1.0 | Ordinary building iii | 1.2 | Schools, assembly halls, culture hall. iv | 1.4 | Hospital, power plant, fire station
Drift criteria	Story drift limitations- In BSLJ, the drift of each story of the building caused by the moderate earthquake motions shall not exceed 1/200 of the story height. This value can be increased to 1/120 if the nonstructural members shall have no severe damage at increased story drift limitation.	i. for buildings having non-structural elements of brittle materials attached to the structure: $d_r v \leq 0.005h$ ii. for buildings having ductile non-structural elements: $d_r v \leq 0.0075h$ iii. for buildings having non-structural elements fixed in a way so as not to interfere with structural deformations, or without non-structural elements: $d_r v \leq 0.010h$
Minimum design lateral force	Story shear coefficient- Ci = Z R_t A_i C_0 story shear- $Q_{un} = D_S F_{es} C_i \sum_{j=1}^{n} W_j$ Where, Z is the seismic zoning coefficient, R_t is the design spectral coefficient, A_i is the lateral shear distribution factor and C_0 is the standard shear coefficient = 0.2 and for severe earthquake motions, D_s is the structural coefficient, F_{es} is the shape factor and C_0 = 1.0. $\sum_{j=1}^{n} W_j$= total dead load and live load above story i.	Base Shear - $V_B = S_d(T_1)W$ $S_d(T_1)$ is the ordinate of the design spectrum corresponding to fundamental Period T_1 of the structure and Wis the gravity load contributing W.
Response spectrum	Design response spectra at engineering bedrock $S_0(T)$ ={ 3.2 + 30 T < 0.162.5 0.16 ≤ T ≤ 0.645.12T 0.64 ≤ T Design response spectra at ground motion Sa(T) = Gs(T) Z S0(T) Where, S0 = basic design acceleration response spectra in m/s2 and T = natural period. Sa = design acceleration response spectra at ground surface m/s^2, G_S = surface soil layer amplification factor.	The elastic response spectrumis divided in 4 different branches defined by the following expressions: $0 \leq T \leq T_B$ $S_e(T)$ = $a_g S(1+T/T_B \eta 2.5-1)$ $T_B \leq T \leq T_C$ $S_e(T) = a_g S\eta 2.5$ $T_C \leq T \leq T_D$ $S_e(T) = a_g S(1+T/T_B \eta 2.5(T_C/T)$ $T_D \leq T \leq 4S$ $S_e(T) = a_g S\ \eta 2.5(T_C T_D/T)$

Table 3: Load combination of IS1893-2002, ASCE7-10, BSLJ and EC-2

IS875-2002 [5]	ASCE7-10 [2]	BSLJ [6,25]	EC-2 [29]
1.5(D+L)	1.4D	D+L+E	1.35D+1.5L
1.2(D+L±W)	1.2D+1.6L+0.5Lr	D+L+S+E	1.0D+1.5W
1.5(D±W)	1.2D+1.6Lr+(L OR 0.8W)		1.35D+1.5L+0.9W
0.9D±1.5W	1.2D+1.6W+1.0L+0.5Lr		
	0.9D + 1.6W		
	0.9D + 1.0W		
	0.9D + 1.0E		

Study Model:-

A geometrically similar 10 story included 4 -bay by 4- bay reinforcement concrete ordinary moment resting frame was considered for all the codes. The height of each story was 3 m and a total height of 30 m. The width and length of the structure were 24 and 24 m respectively. The selected building was to represent an office building. The D.L. per unit area of the floor, consisting of the floor slab finishes etc. is 4 KN /m2. The weight of the partition on the floor can be assumed to be 2 KN/m2. The intensity of live load on each floor is 3KN/m^2 and on the roof are 1.5 KN /m^2. The soil below the foundation is hard and the building is located in Delhi. The plan area is given in figure 1 & 2. The 3-D structural model is shown in figure 3. The site soil classification and the response acceleration parameters and zone factor for this building are shown in Table 4.

The load combination of dead load , live load, roof load and earthquake load, wind load for their four building code are given in Table 3.

1. Building parameter-

Size of beam= 300x600 mm
Size of column= 650x450 mm
Size of building= 24x24 mm
D.L. of slab including finishes 4 KN/m2
The weight of partition on floor 2 KN/m2
L.L. of each floor =3 KN/m2
L.L. on the roof =1.5 KN/m2
Soil below foundation is hard soil

Table 4 Site location and classification of seismic Design parameters

Code	Zone coefficient /response acceleration parameters	Site class
IS1893	Seismic zone: iv, (z) = 0.24 Importance factor (I) = 1 T = 0.96s	Type 2 (hard soil)
ASCE7-10	Spectrum response acceleration Ss= 1.893, S1= 0.85,	Site class D (stiff soil)
BSLJ	Seismic zone: iv, (z) = 0.75 Ta = 0.1N sec , α = 1	
EC-8	Seismic zone: iii ag = 0.15g Importance factor (γ) = 1	Soil type C

2. Seismic weight-

Floor area= 24x24 =576
Dead load =4 KN /m2
Weight of partitions = 2kN/m2
For live load up to and including =3KN/m2
Percentage of live load to be considered =2.5%
Effective weight at each floor except the roof = 4.0+2.0+0.25+3
= 6.75 KN/m2
And at the roof = 4.0 KN/m2

Fig.1. 4 @ 6.00 m = 24 m plan view of the structure

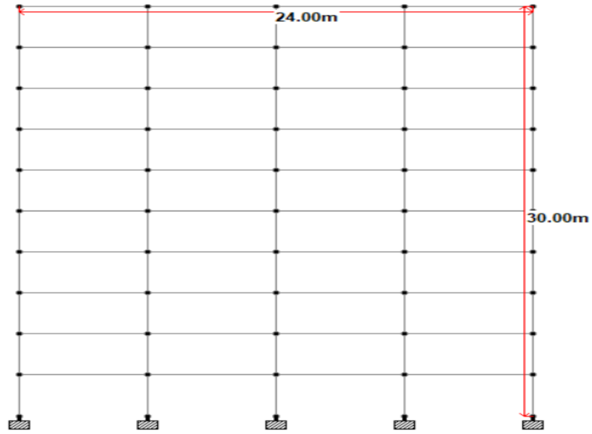

Fig.2. Front view of the structure

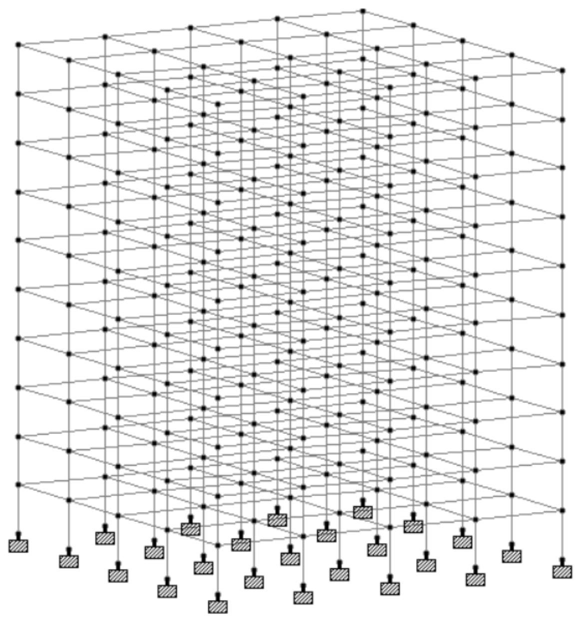

Fig.3. 3-D Structural Model of the structure

Modelling and design of the structure for analysis:-

The building should be consisting of three-dimensionally in the office purpose. Analysis, and design on software STAAD.pro V8 i. The column was considered as fixed support. Dead load, live load, and seismic load considered as per their code.
Code used for concrete design- IS45 -2002, ACI 318-2008, AIJ & EC-2
Code used for Seismic design- IS1893-2002, BS-8110, IBC-2006 & Japanese code.

*The code BS-8110 is used for seismic design of European code on Staad- pro V8i.
*The code IBC-2006 is used for seismic design of American code on Staad- pro V8i.

The specification used for concrete design-
A grade of concrete -30 MPa
Grade reinforcement - 415 MPa
Concrete cover of the beam - 25mm
Concrete cover of the column- 40mm

Results and discussion-

1. The analysis and design of beam, column and storey drift at different level according to IS loading condition is evaluated in the terms of maximum axial force, maximum bending moment, maximum shear force, story drift and displacement as shown in Table 5,6 & 7. The graphical representation of the results is shown in figure from 4 to 11.

Table 5: Analysis of beam as per IS loading with different code

Code	Maximum axial force (kN)	Maximum Bending moment (kNm)	Maximum shear force (kN)
IS1893	111.384 (1.5DL+LL)	252.542 (1.5DL+LL)	252.083 (1.5DL+EQX)
EC-8	111.384 (1.5DL+LL)	252.542 (1.5DL+LL)	511.187 (1.5DL+EQX)
ASCE	110.9 (1.5DL+EQX)	233.25 (1.5DL+EQX)	505.186 (1.5DL+LL)
BSLJ	92.398 (1.5DL+LL)	233.25 (1.5DL+LL)	162.564 (1.5DL+LL)

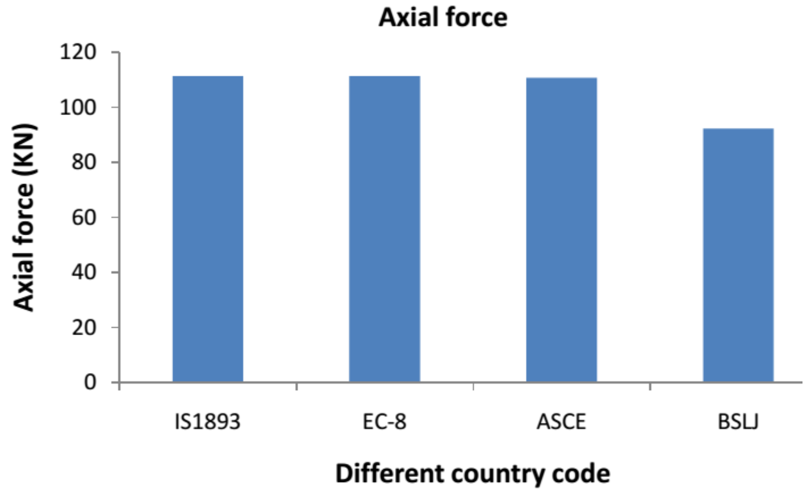

Fig.4. Axial force as per different code

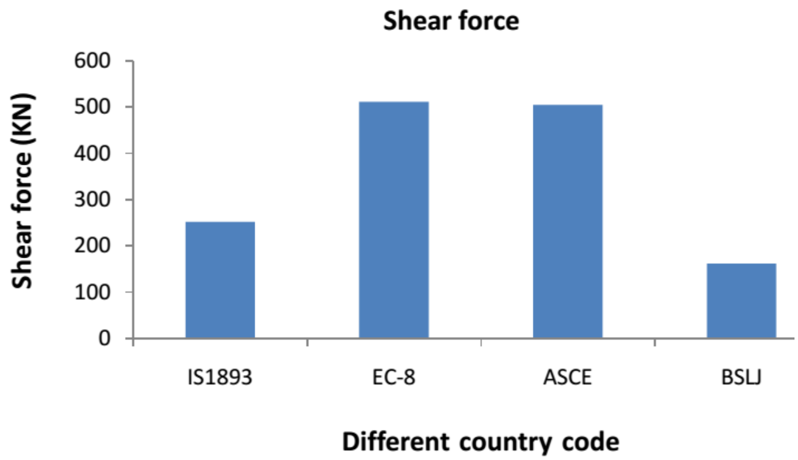

Fig.5. Bending moment as per different code

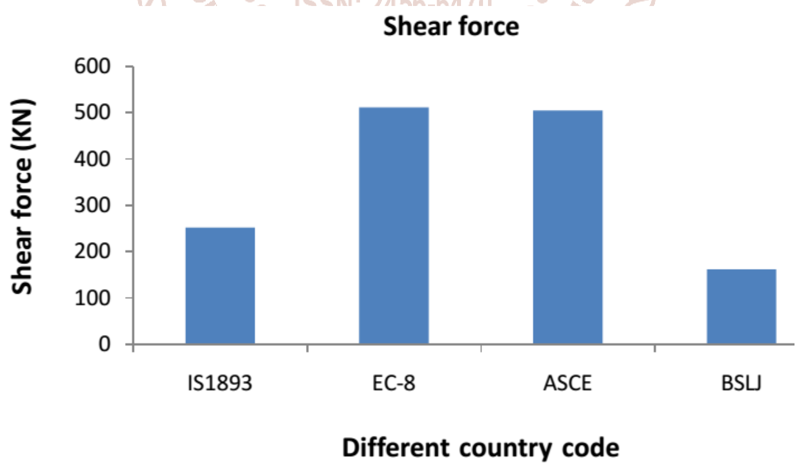

Fig.6. Shear force with different code

Analysis of beam in table 5 as per IS loading and its graphical results shows that the value of maximum axial force in beam is max for IS and EC but the min for BSLJ. The value of bending moment in beam is max for also IS and EC as compared to ASCE & BSLJ. The value of shear force in beam is max for EC but min for BSLJ.

Table 6: Analysis of column as per IS loading with different code

Code	Maximum axial force (kN)	Maximum Bending moment (KNm)	Maximum shear force (kN)	Base shear (kN)
IS1893	5358.35 (1.5DL+LL)	487.852 (1.5DL+EQZ)	285.706 (1.5DL+EQZ)	4294.75
EC-8	4781.278 (1.5DL+LL)	1065.58 (1.5DL+EQX)	684.447 (1.5DL+EQX)	4294.75
ASCE	5446.855 (1.5DL+LL)	1387.759 (1.5DL+EQX)	784.251 (1.5DL-EQX)	4124.012
BSLJ	5446.856 (1.5DL+LL)	202.681 (1.5DL+EQZ)	94.047 (1.5DL+EQZ)	4294.75

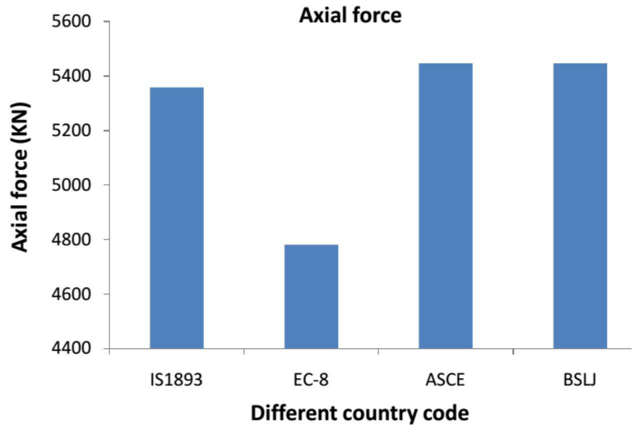

Fig.7. Axial force as per different code

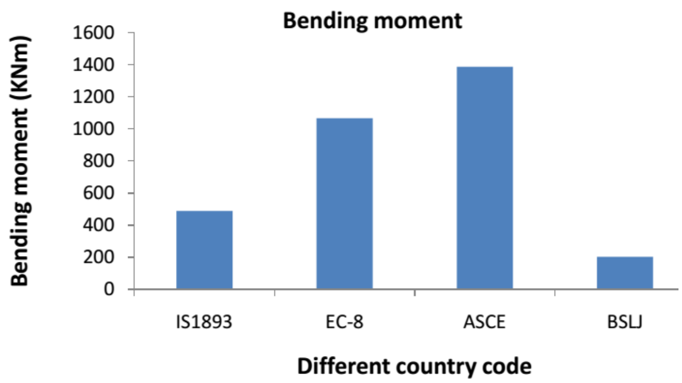

Fig.8. Bending moment as per different code

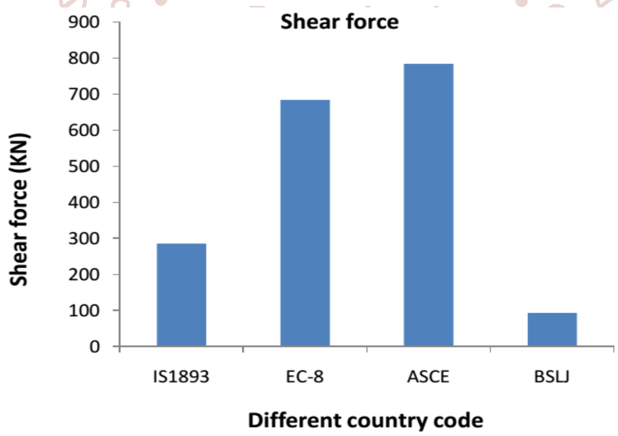

Fig.9. Shear force as per different code

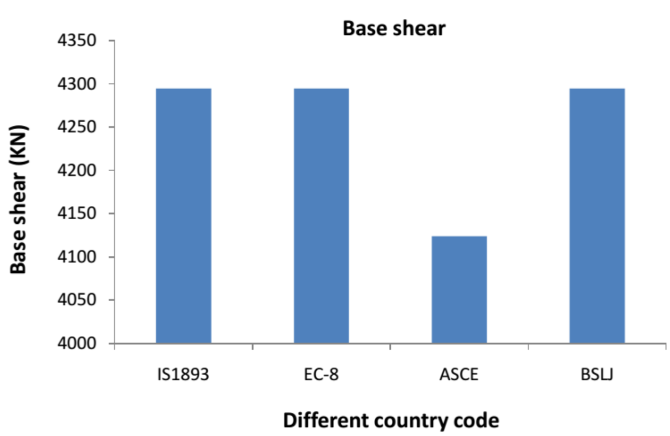

Fig.10. Base shear as per different code

Analysis of column in table 6 as per IS loading and its graphical results shows that the value of maximum axial force in column is max for ASCE & BSLJ but the min for EC. The value of bending moment in column is max for ASCE but min for BSLJ. The value of shear force in column is max for ASCE but min for BSLJ. The value of base shear is max for IS, BSLJ and EC but min for ASCE.

Table 7: Story drift and Displacement of building as per IS loading with different code

Height in m	IS1893		EC-8		ASCI		BSLJ	
	Drift	Displacement	Drift	Displacement	Drift	Displacement	Drift	Displacement
3	0.9688	9.688	0.7586	0.7586	2.6013	2.6013	0.6915	0.6915
6	1.5244	2.4932	1.1780	1.9366	4.0372	6.6385	1.0564	1.7479
9	1.6076	4.1008	1.2096	3.1462	4.1405	10.7791	1.0662	2.8141
12	1.6140	5.7147	1.1643	4.3106	3.9770	14.7561	1.0119	3.8261
15	1.5976	7.3123	1.0850	5.3955	3.6936	18.4497	0.9347	4.7608
18	1.5634	8.8757	0.9767	6.3722	3.3078	21.7575	0.8400	5.6007
21	1.5094	10.3851	0.8394	7.2117	2.8190	24.5764	0.7274	6.3281
24	1.4305	11.8157	0.6727	7.8843	2.2258	26.8023	0.5950	6.9232
27	1.3096	13.1253	0.4780	8.3623	1.5365	28.3388	0.4393	7.3625
30	1.0541	14.1794	0.2730	8.6354	0.8296	29.168	0.2644	7.6269

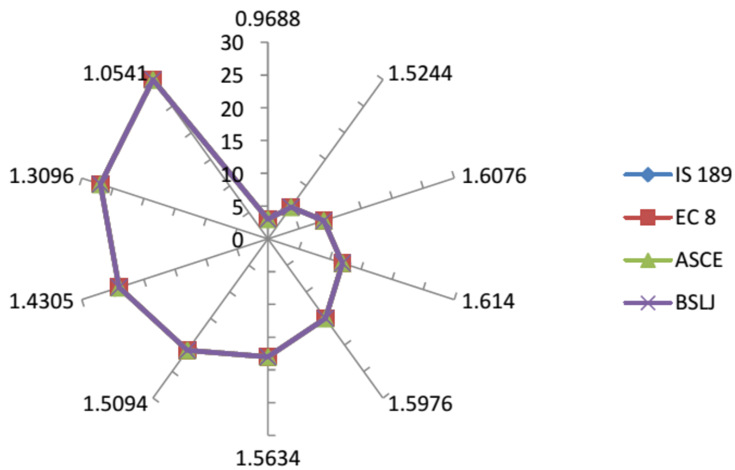

Fig.11. Value of drift at different level as per IS loading for different code

The above table and figure shows that the variation of storey drifts and displacement varies according to height of building. It is clearly shown in table that the value of drift is increasing slightly and then decreases.

2. The analysis and design of beam, column and storey drift at different level according to their loading condition is evaluated in the terms of maximum axial force, maximum bending moment, maximum shear force, story drift and displacement as shown in Table 8, 9 & 10. The graphical representation of the results is shown in figure from 12 to 19.

Table 8: Analysis of Beam as per their code loading

Code	Maximum Axial Force (kN)	Maximum Bending moment (KNm)	Maximum shear force (kN)
IS1893	111.384 (1.5DL+LL)	252.542 (1.5DL+LL)	252.083 (1.5DL+EQX)
EC-8	141.976 (1.4DL+1.6LL+1.6RFL)	331.976(1.4DL+1.6LL+1.6RFL)	240.174 (1.4DL+1.6LL+1.6RFL)
ASCE	122.556 (1.2DL+LL+1.6RFL)	282.111 (1.2DL+LL+1.6RFL)	493.048 (1.2DL+LL+RFL)
BSLJ	76.007 (DL+LL+EQX)	168.362 (DL+LL+EQX)	132.855 (DL+LL+RFL+EQX)

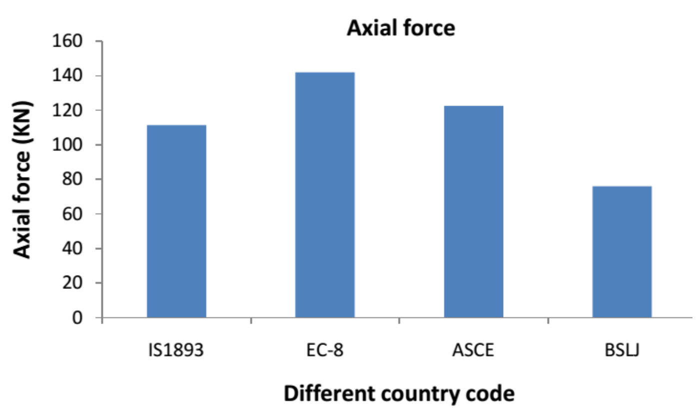

Fig.12. Axial force as per different code

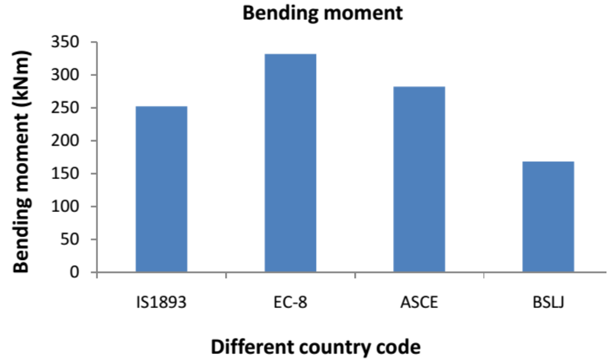

Fig.13. Bending moment as per different code

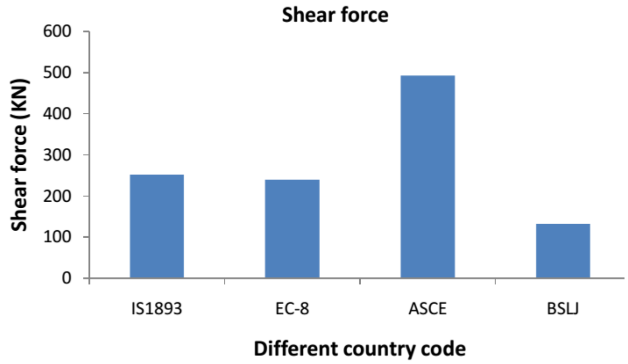

Fig.14. Shear force as per different code

Analysis of beam in table 8 as per their loading and its graphical results shows that the value of maximum axial force in beam is max for EC but the min for BSLJ. The value of bending moment in beam is max for EC but min for BSLJ. The value of shear force in beam is max for ASCE but min for BSLJ.

Table 9: Analysis of Column as per their loading condition

Code	Maximum axial force (KN)	Maximum Bending moment (KN-m)	Maximum shear force (KN)	Base shear (KN)
IS1893	5358.35 (1.5DL+LL)	487.852 (1.5DL+EQZ)	285.706 (1.5DL+EQZ)	4294.75
EC-8	4781.278 (1.5DL+LL)	1065.58 (1.5DL+EQX)	684.447 (1.5DL+EQX)	4294.75
ASCE	5446.855 (1.5DL+LL)	1387.759(1.5DL+EQX)	784.251 (1.5DL-EQX)	4124.012
BSLJ	5446.856 (1.5DL+LL)	202.681 (1.5DL+EQZ)	94.047 (1.5DL+EQZ)	4294.75

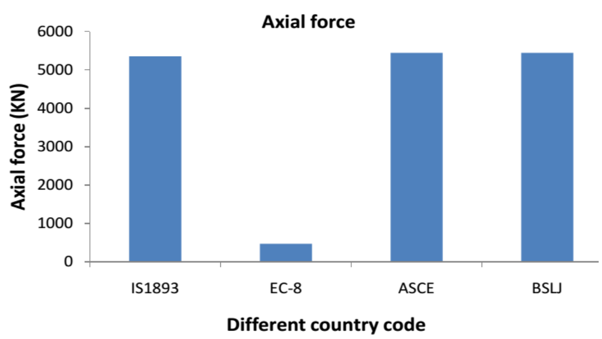

Fig.15. Axial force with different code

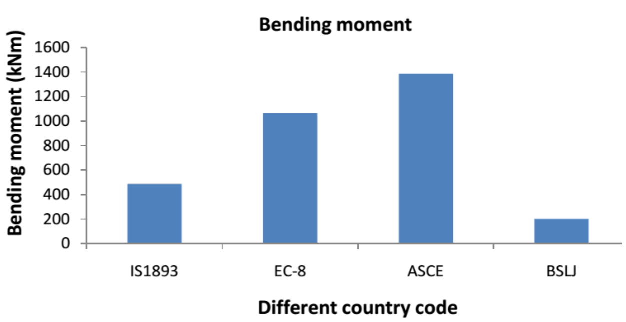

Fig.16. Bending moment as per different code

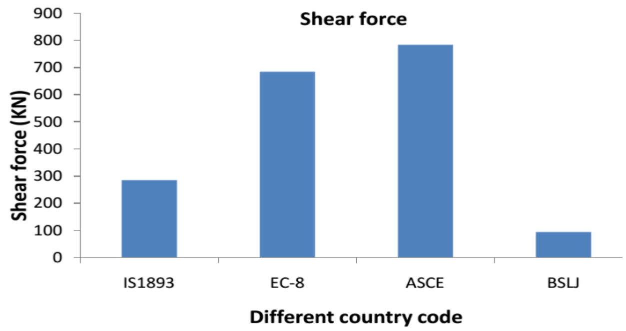

Fig.17. Shear force as per different code

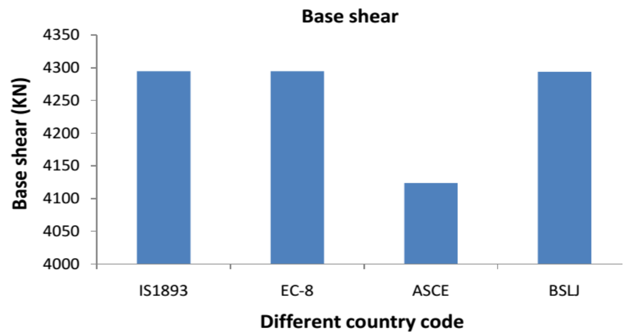

Fig.18. Base shear as per different code

Analysis of column in table 9 as per their loading and its graphical results shows that the value of maximum axial force in column is max for ASCE and BSLJ but the min for EC-8. The value of bending moment in column is max for ASCE but min for BSLJ. The value of shear force in column is max for ASCE but min for BSLJ. The value of base shear is max for IS, BSLJ and EC but min for ASCE.

Table 10: Story drift and Displacement of building as per their code loading

Height in m	IS1893		EC-8		ASCE		BSLJ	
	Drift	Displacement	Drift	Displacement	Drift	Displacement	Drift	Displacement
3	0.9688	9.688	0.9688	9.688	2.6931	2.6931	0.3112	....
6	1.5244	2.4932	1.5244	2.4932	4.1963	6.8894	0.7865	....
9	1.6076	4.1008	1.6076	4.1008	4.3324	11.2218	1.2664	....
12	1.6140	5.7147	1.6140	5.7147	4.1968	15.4186	1.7217	....
15	1.5976	7.3123	1.5976	7.3123	3.9353	19.3539	2.1423	....
18	1.5634	8.8757	1.5634	8.8757	3.5601	22.9140	2.5203	....
21	1.5094	10.3851	1.5094	10.3851	3.0651	25.9791	2.2781	....
24	1.4305	11.8157	1.4305	11.8157	2.4444	28.4235	3.1154	....
27	1.3096	13.1253	1.3096	13.1253	1.7025	30.1260	3.3131	....
30	1.0541	14.1794	1.0541	14.1794	0.964	31.055	3.4321	....

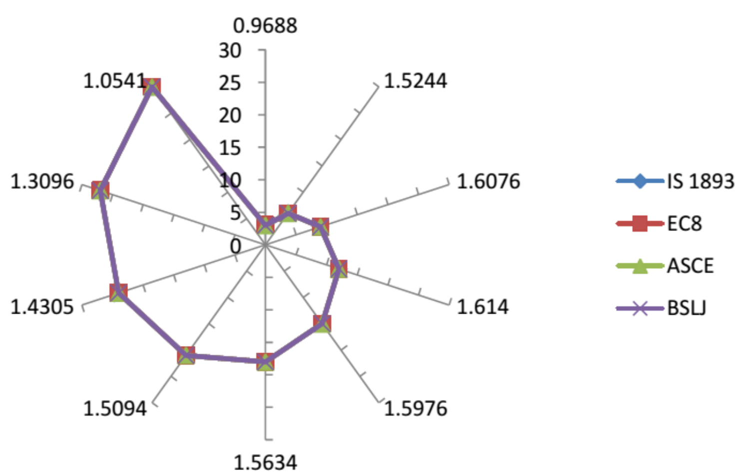

Fig.19. Value of drift as different code

The above table and figure shows that the variation of storey drifts and displacement varies according to height of building. It is clearly shown in table that the value of drift is increasing slightly and then decreases.

3. Now the concrete design of beam and column according to IS loading condition is evaluated in the terms of required area and percentage of steel as shown in Table 11 & 12. The graphical representation of the results is shown in figure from 20 to 23.

Table 11: Concrete design of beam as per IS code loading

Code	Required area	Percentage of steel
IS456	4061.970	1.76
EC-2	4321.083	1.10
ACI	4452.23	1.29
AIJ	4224.11	1.02

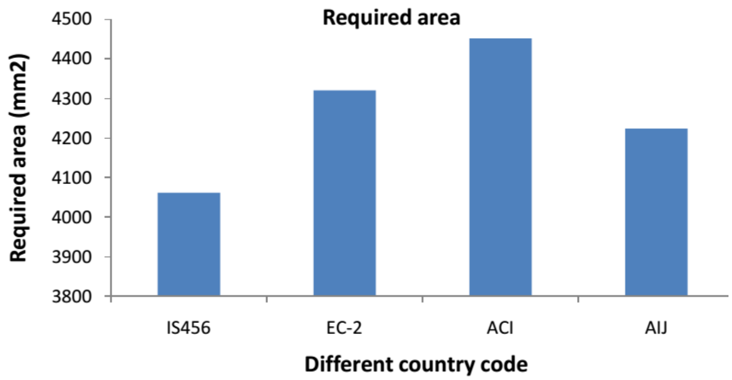

Fig.20. Required area as per different code

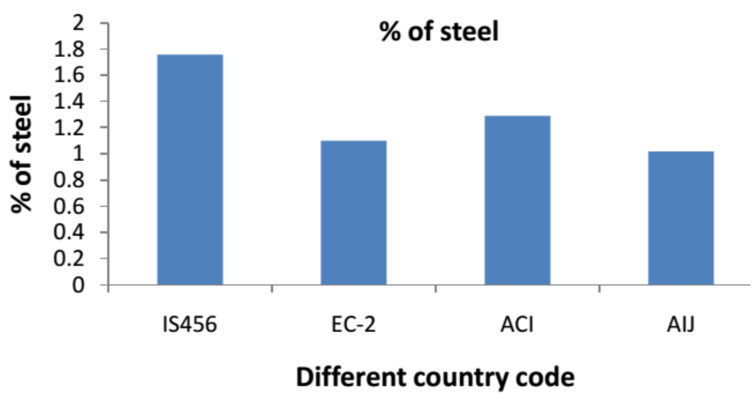

Fig.21. Percentage of steel as per different code

The concrete design of beam in table 11 as per IS loading condition and its graphical results shows that the value of required area in beam is max for ACI but the min for IS. The value of % steel in beam is max for IS but min for AIJ.

Table 12: Concrete design of column as per IS code loading

0.1	Main reinforcement	Tie reinforcement	Required area (mm²)	Percentage of steel (%)
IS456	24#20Ø	8mm@300mm c/c	7539.82	2.58
EC-2	36#25Ø	8mm@180mm c/c	9754	3.219
ACI	12#32Ø	12mm@110mm c/c	8862.8	0.528
AIJ	12#13Ø	10mm@320mm c/c	1470.265	3.299

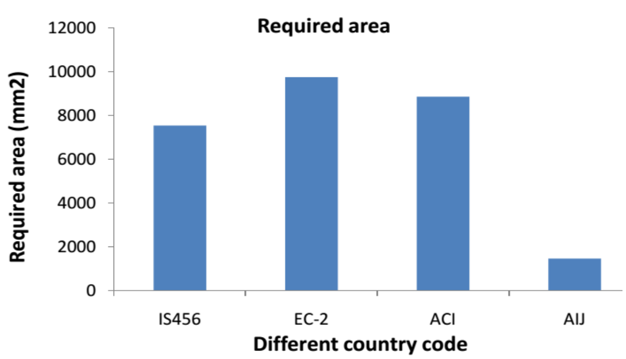

Fig.22. Required area as per different code

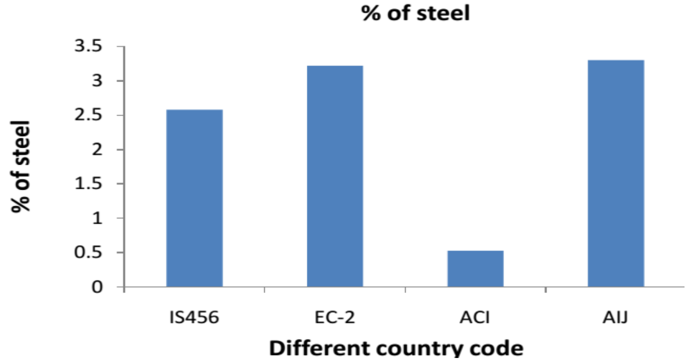

Fig.23. % of steel as per different code

The concrete design of column in table 12 as per IS loading condition and its graphical results shows that the value of required area in column is max for EC but the min for AIJ. The value of % steel in column is max for AIJ but min for ACI.

4. Now the concrete design of beam and column according to their loading condition is evaluated in the terms of required area and percentage of steel as shown in Table 13 & 14. The graphical representation of the results is shown in figure from 24 to 27.

Table 13: Concrete design of beam according as per their code loading

Code	Required area	Percentage of steel
IS456	4061.970	1.76
EC-2	2033	1.10
ACI	493.048	1.19
AIJ	223.19	1.02

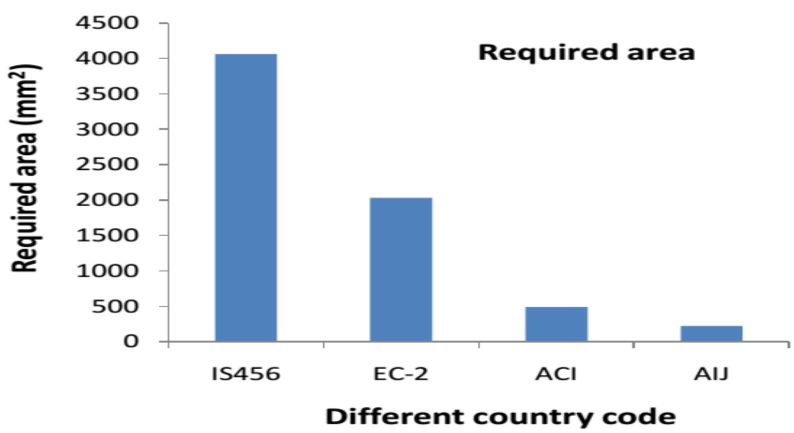

Fig.24. Required area as per different code

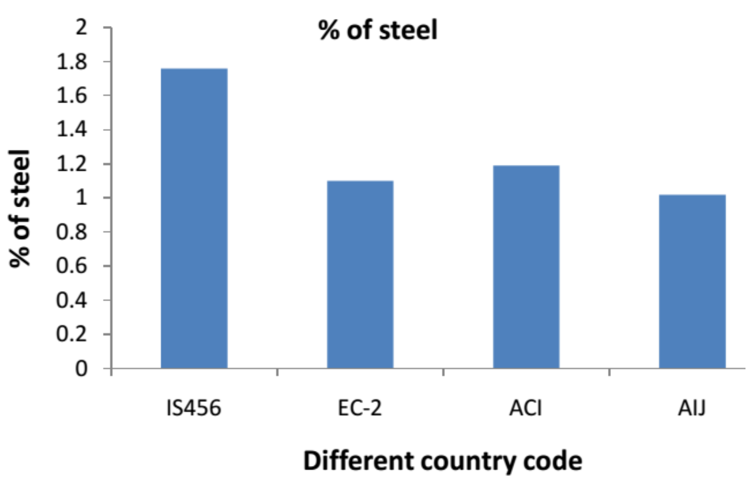

Fig.25. % of steel with different code

The concrete design of beam in table 13 as per their loading condition and its graphical results shows that the value of required area in beam is max for IS but the min for AIJ. The value of % steel in beam is max for IS but min for AIJ.

Table 14: Concrete design of column according as per their code loading

Code	Main reinforcement	Shear reinforcement	Required area (mm^2)	Percentage of steel
IS456	24#20Ø	2 legged 8 Ø@280mmc/c	7539.82	1.23
EC-2	4#20Ø(TOP) 4#12Ø(BOTTOM)	1 legged 8 Ø@157mmc/c	223.19	1.25
ACI	5#20Ø(TOP) 6#16Ø(BOTTOM)	2 legged 8 Ø@245mmc/c	1474	1.00
AIJ	3#20Ø(TOP) 5#16Ø(BOTTOM)	2 legged 12 Ø@245mmc/c	1470.265	1.31

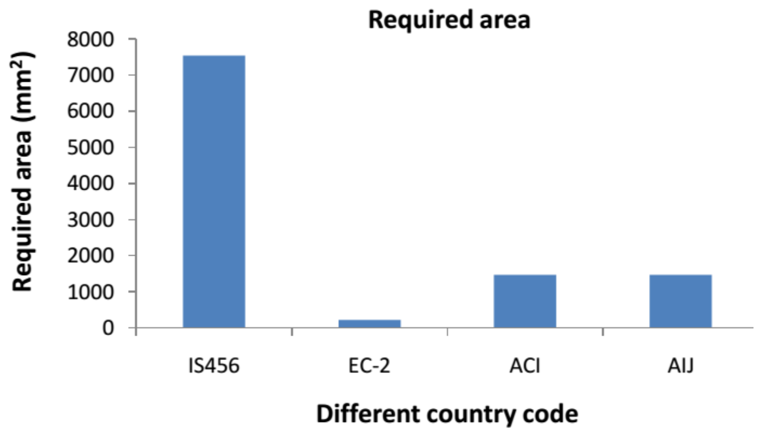

Fig.26. Required area as per different code

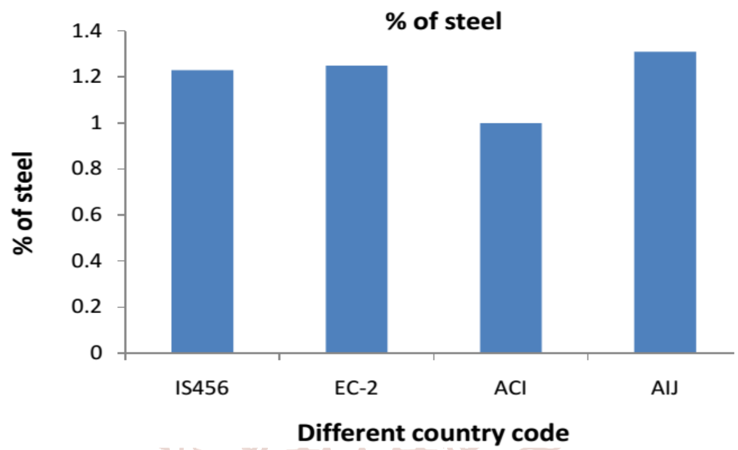

Fig.27. % of steel as per different code

The concrete design of column in table 12 as per their loading condition and its graphical results shows that the value of required area in column is max for IS but the min for EC. The value of % steel in column is max for AIJ but min for ACI.

Conclusion:-

The following conclusions are drawn from the computer simulation program carried out in this investigation:

A. For Beam:-

(i) Analysis as per IS loading-

1. Axial force is maximum as per IS & EC and minimum as per BSLJ.
2. Bending moment is maximum as per IS & EC and minimum as per ASCE & BSLJ.
3. Shear force is maximum as per EC and minimum as per BSLJ.

(ii) Analysis as per their loading-

1. Axial force is maximum as per EC and minimum as per BSLJ.
2. Bending moment is maximum as per EC and minimum as per BSLJ.
3. Shear force is maximum as per ASCE and minimum as per BSLJ.

(iii) Concrete design as per IS loading

1. Required area is maximum as per ACI and minimum as per IS.
2. Percentage of steel is maximum as per IS and minimum as per AIJ.

(iv) Concrete design as per their loading

1. Required area is maximum as per IS and minimum as per BSLJ.
2. Percentage of steel is maximum as per IS and minimum as per AIJ.

B. For Column:-

(i) Analysis as per IS loading-

1. Axial force is maximum as per ASCE & BSLJ and minimum as per EC.
2. Bending moment is maximum as per ASCE and minimum as per BSLJ.
3. Shear force is maximum as per ASCE and minimum as per BSLJ.
4. Base shear is maximum as per IS, EC & BSLJ and minimum as per ASCE.

(ii) Analysis as per their loading-
1. Axial force is maximum as per ASCE & BSLJ and minimum as per EC.
2. Bending moment is maximum as per ASCE and minimum as per BSLJ.
3. Shear force is maximum as per ASCE and minimum as per BSLJ.
4. Base shear is maximum as per IS, BSLJ & EC and minimum as per ASCE.

(iii) Concrete design as per IS loading
1. Required area is maximum as per EC and minimum as per AIJ.
2. Percentage of steel is maximum as per AIJ and minimum as per ACI.

(iv) Concrete design as per their loading
1. Required area is maximum as per IS and minimum as per EC.
2. Percentage of steel is maximum as per AIJ and minimum as per ACI.

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