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
The first modern code containing seismic provision is generally admitted to be the first edition of the Uniform Building Code 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. El 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 (BSSL) 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. Shahrroz [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. El-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 al. [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, BSSL) 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 STAAD 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.

1. Graphical model generation utilities as well as text 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.
| Parameters                  | IS 1893-2002 [5]                                                                 | ASCE 7-10 [2]                                                                 |
|-----------------------------|---------------------------------------------------------------------------------|--------------------------------------------------------------------------------|
| Zoning system               | The country divided into four zones (II, III, IV, and V)                        | i. Each region is assigned a location-specific mapped Spectral acceleration parameter (SS, short period and S1, 1sec). |
| zone II Z = 0.10            |                                                                                 | ii. SS & S1 are modified for Site Class effects to get Maximum Considered Earthquake (MCE) spectral Response acceleration parameters (SMS and SM1). |
| zone III Z = 0.16           |                                                                                 | iii. The design spectral acceleration SDS and SD1 parameters can be obtained by dividing SMS and SM1 parameters by 1.5. |
| zone IV Z = 0.24            |                                                                                 |                                                                                   |
| zone V Z = 0.36             |                                                                                 |                                                                                   |
| Site classification         | Classification of site depends upon standard penetration test (N).             | Average shear wave velocity ($v_o$), 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” $T_a = 0.075h_0^{0.75} \cdot h_o$ in meter. | The approximate fundamental period for “Reinforced Concrete Moment Resisting Frame” $T_a = 0.0466h_0^{0.9} \cdot h_o$ in meter. |
| Response reduction factor   | i. Ordinary moment resisting Frame (OMRF), R = 3                                | i. Ordinary moment resisting Frame (OMRF), R = 3                                    |
|                             | ii. Special moment resistant Frame (SMRF), R = 5                                | ii. Intermediate Moment Resisting Frames (IMRF) R = 5                               |
| Important factor            | i. Important service and community building I = 1.5                             | 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. |
|                             | ii. All other Buildings I = 1.0                                                 |                                                                                   |
| Drift criteria              | Allowable “elastic story drifts are 0.004Hstory for all the structures irrespective of any structure under risk category. | Allowable “inelastic” story drifts are limited to 0.020Hstory for a commercial building having risk category I or II. |
| Minimum design lateral force | Design lateral force calculated from the static analysis is V = $S_o/g \times W$ | Design lateral force calculated from static analysis is V = $C_s \times W$ |
|                             | Where ($S/g$) = spectral response acceleration parameter for MCE response spectrum corresponding to $T_a$, |
|                             | And $W$ = the seismic weight of the building. Story shear- $Q = V \frac{W_i}{H_i}$ | where $C_s$ = the seismic response coefficient $C_S$ |
|                             | 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. |
| Response spectrum           | i. For rocky or hard soil sites, $S_o/g =$                                                                 | i. Spectral Acceleration, For $T < T_h$                                                                 |
|                             | $\begin{array}{ll} (1 + 19T) & 0.0 < T < 0.20 \frac{1}{T} \\ 0.4 < T < 0.7 \end{array}$ | $S_o = S_{DS} \left(0.4 + 0.6T/T_0 \right)$ |
|                             | $T_0=0.2S_{DS}/S_{DS}$                                                         | $T_o=S_{DS}/S_{DS}$                                                                 |
|                             | ii. For medium soil sites, $S_o/g =$                                                                                            | ii. $T_o > T_s$ $S_o = S_{DS}$ |
|                             | $\begin{array}{ll} (1 + 19T) & 0.0 < T < 0.30 \frac{1}{T} \\ 0.1 < T < 0.5 \frac{1}{T} \end{array}$ | $T_o=S_{DS}/S_{DS}$ |
|                             | $0.59 < T < 0.9$                                                                | iii. $T_s < T < T_L$, $S_o = S_{DS}/T$ |
|                             | $i. T_o = long period OR transition period$                                      | $T_o=S_{DS}/S_{DS}$                                                                 |
|                             | iv. $T > T_L$ $S_o = S_{DS}/T$                                                 | $T_o=S_{DS}/S_{DS}$                                                                 |
|                             | $T_o=S_{DS}/S_{DS}$ |
|                             |                                                                                   | $T_o=S_{DS}/S_{DS}$                                                                 |
|                             |                                                                                   | $T_o=S_{DS}/S_{DS}$                                                                 |


### 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 $\zeta_R$. The parameter $\zeta_R$ modified by the Importance Factor $I$ to become the design Ground acceleration (on type A ground) $a_0 = \zeta_R R I$ |
| **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 ($v_s$). |
| **Approximate fundamental period**       | $T_a = 0.1 \, N$ 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 $T = (0.002 + 0.01H)$ $\alpha$ = ratio of stories by steel and timber construction | The mean return period $T_R$ is given by $T_R = T_i/\ln(1-P)$ |
| **Response reduction factor**            | $R_s$ is the design spectral coefficient- $R_s = 1.0$ $T < T_c$ $R_s = 1.0 - 0.2 T_c \leq T < 2 T_c$ $R_s = 1.6 T_c / T$ $2T_c \leq T$ | ----- |
| **Important factor**                     | Not available                                                                | Important factor divided into four class (I, ii, iii, iv) |
| **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: $d_{lv} \leq 0.005 h$
ii. for buildings having ductile non-structural elements: $d_{lv} \leq 0.0075 h$
iii. for buildings having non-structural elements fixed in a way so as not to interfere with structural deformations, or without non-structural elements: $d_{lv} \leq 0.010 h$

**Minimum design lateral force**

| Story shear coefficient- $C_i = Z R_s A_i C_0$ story shear- $Q_{re} = D_s F_s C_i S_0(T)$ | $S_0(T) = 1.0$ $F_{S0} = 0.005$ $F_{S1} = 0.010$ $F_{S2} = 0.015$ $F_{S3} = 0.020$ |
| Where, $Z$ is the seismic zoning coefficient, $R_s$ 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, $F_s$ is the shape factor and $C_0 = 1.0$. $S_0(T)$ = total dead load and live load above story |

**Base Shear**

$V_B = S_0(T_i) W$

$S_0(T_i)$ is the ordinate of the design spectrum corresponding to fundamental Period $T_i$ of the structure and $W$ is the gravity load contributing $W$. The elastic response spectrum is divided in 4 different branches defined by the following expressions:

$0 \leq T S_0(T_s) S_a(T) = a_0 S(1 + T/T_s 0.25 - 1)$

$T_s \leq T S_0(T_s) S_a(T) = a_0 S 2.5$

$T_c \leq T \leq T_s S_a(T) = a_0 S(1 + T/T_s 0.25(T_c/T))$

$T_s \leq T \leq 4S S_a(T) = a_0 S 2.5(T_c/T)$

**Response spectrum**

$G_s = \text{surface soil layer amplification factor}$

$S_0(T)$ = design response spectra at engineering bedrock $S_a(T)$ = design response spectra at ground motion $S_a(T) = G_s(T) Z S_0(T)$

Where, $S_0 = \text{basic design acceleration response spectra in } m/s^2$ and $T = \text{natural period}$. $S_a = \text{design acceleration response spectra at ground surface in } m/s^2$, $G_s = \text{surface soil layer amplification factor}$.
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/m² and on the roof are 1.5 KN/m². 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 = 0.96sec | Type 2 (hard soil) |
| ASCE7-10| Spectrum response acceleration SS= 1.8933, S1= 0.85, Site class D (stiff soil) |
| BSLJ  | Seismic zone: iv, (z) = 0.75 Ta = 0.1N sec , α = 1 | Soil type C |
| 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 = 2 KN/m²
For live load up to and including = 3 KN/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
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.

| 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 Drift | IS1893 Displacement | EC-8 Drift | EC-8 Displacement | ASCE Drift | ASCE Displacement | BSLJ Drift | BSLJ 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            |

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, storey 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+1.6RFL)  |
| BSLJ      | 76.007 (DL+LL+EQX)       | 168.362 (DL+LL+EQX)        | 132.855 (DL+LL+RFL+EQX) |

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.
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 (1.5 DL+EQZ)     | 4294.75       |
| EC-8   | 4781.278 (1.5DL+LL)       | 1065.58 (1.5DL+EQX)         | 684.44  (1.5DL+EQX)      | 4294.75       |
| ASCE   | 5446.855 (1.5DL+LL)       | 1387.759 (1.5DL+EQX)        | 784.25  (1.5DL-EQX)      | 4124.012      |
| BSLJ   | 5446.856 (1.5DL+LL)       | 202.681 (1.5DL+EQZ)         | 94.047  (1.5DL+EQZ)      | 4294.75       |
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 | ............ |

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.

| 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                |

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.

| 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                   |
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                |

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 (mm²) | 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 |

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.

**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.

(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.
(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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