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ANALYSIS AND COMPARISON OF TALL BUILDING USING INDIAN AND EURO CODE OF STANDARDS

Anupkumar S Karadi[1], B S Suresh Chandra[2]

[1]PG Student, Civil Engineering Department, Dr. AIT Bengaluru, Karnataka, India
[2]Associate Professor, Civil Engineering Department, Dr. AIT Bengaluru, Karnataka, India

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Abstract - *In Reinforced building, frames are major parts since it opposes Shear force, Bending moment ,torsion and furthermore subjected to variety of loads in which seismic loads are dominating. Developing nations like India we need to adopt some standards. The BIS recommended IS 456:2000 and IS 1893(Part-1)2002 likewise European standard recommended EC2 and EC8 for Design of concrete structures and Design of earthquake resistant structures respectively. An attempt is made to compare Indian standard and Euro standard in "ETABS 2016"*

Seismic plays gigantic part on life and property since the impact on structures is colossal, so it's essential to design the structures in the most ideal approach to withstand these impacts. Different seismic codes determines distinctive parameters so than clearly it's performance differs as per different codes. Hence, it is important to do a comparison in order to assess which building performs better'

Key Words: *Shear force, Bending moment, Torsion, IS 457-2000, IS 1893(Part-1), Euro code 2, Euro code 8.*

1. INTRODUCTION

In India the standard for RC buildings were presented in 1953, which was additionally revised and executed with the course of time. For Earthquake load, Indian Bureau Standard has recommended the criteria for earthquake resist design of structures in 1983. This paper incorporated the IS 456:2000: Code of Practice for Plain and Reinforced Concrete and IS 1983(Part-1):2002: Criteria for Earthquake Resistant Design of Structures. In the present situation there is a requirement for convergence of design philosophies to bring out structures with uniform danger of collapse and least level of harm or damage and need to look at the expected seismic performance of building designed on various codes. Indian codes are adequate for design but there are different parameters in some global norms which are not adopted in Indian code, so to improve our design there is requirement for selection for the best practice of design.

The developing nations like India it is desirable to adopt the standard like Euro standard. Comparison work is carried out by considering the design standards from both IS and Euro codes, under both static and dynamic forces in most reliable software tool "ETABS".

1.1 Brief on Euro codes

The European Committee for Standardization (**CEN**, French: Comité Européen de Normalization) is guidelines board. The main commitment of CEN is to provide an efficient and reliable structures for development of nation, to maintain a standard set of specifications.
The current CEN Members are:

- All member states of the European Union: Germany, Poland, United Kingdom, France, Italy etc.
- 3 of EFTA members: Iceland, Norway, Switzerland
- Other states: Macedonia, Turkey, Serbia.

2. OBJECTIVES AND SCOPE OF THE PROJECT

The research work was performed using ETABS 2016 software, the analysis is done under static and dynamic loads on structure using Indian and Euro code of standards for a 30 storey building.

The site conditions are as follows: Soil profile: Medium-Soil, Location-Bengaluru, Seismic Zone-II, Zone factor-0.1, Wind Speed-33 m/s

2.1 Importance of the Study

Despite the design principles and standards contained in both codes IS and Euro standards codes are same, but they vary in configuration, design criteria, detailing and also different seismic factors that governs the design strengths on the structure. The investigation focuses on the factors which contributes to the poor performance of structure during earthquake.

2.2 Objectives of the Study

i) To do the static and dynamic analysis on a 30 story building, using Indian and Euro code of standards.
ii)To compare the design standards in view of strength of building.

iii)To study the performance of building in view of two codes of standards and to measures which building performs better.
iv) To give comparison with the parameters like: Displacement, Base shear, Story displacement, Story drift, Time period, Shear force, Bending moments and Area of steel required.

3. METHODOLOGY

The current research is to compare the performance of 3D strengthened structure under both static and dynamic strategies. Modeling and research are done in ETABS. The structure is analysed under static and dynamic load cases.

Different seismic codes specifies different parameters so than clearly it's performance also varies. Thus it is important to do a relative report in order to conclude which building performs better. Results are organized by tables and relating graphs are plotted.

3.1 Factors Affecting the Lateral Seismic Forces

The total design lateral force acting at the base of the structure is depends on:

1.Time Period: The structure should be intended to oppose seismic forces acting up on structure. The fundamental natural period of structure is dependent on height, type of structural member, material property. The empirical formula as per codes are given below:
Fundamental natural period:

i) According to IS 1893 (Part-I) 2002

- With Infill: $Ta = 0.09 * h/\sqrt{d}$
- Without Infill: $Ta = 0.075*h^{0.75}$ for RC frame Buildings.

ii) According to BS EN 1998-1:2004

- $Ta = 0.075*h^{0.75}$ for RC outline.
- $Ta = 0.085*h^{0.75}$ for RC outline Buildings.
- $Ta = 0.050*h^{0.75}$ for every single other structure.

2. Zone Factor: Zone factors are derived on the basis of intensity of earthquakes in various zones. IS code characterized in view service life of structure. IS code has 4 zones from low to very severe seismic intensity with factors 0.10, 0.16, 0.24 and 0.36 for zones II, III, IV and V respectively. Where as in case of Euro code factors are based on peak ground acceleration (ag) from 0.02 to 0.18

3.Importance factor : Importance factor are introduced to represent level of significance for different structure. It relies upon the functional use and utilization of the structure in view of seismic constraints adopted. Also it depends upon the utilization of structure, risk factor, notable historic significance, number of occupants resides etc. In this case as per codes the importance factor is taken as 1.2 for both Indian and Euro codes, Since it's occupancy capacity of structure is high. i.e. 30 storey building.

4.Seismic Weight: In case of seismic design dead loads and partial proportions of live loads are considered along with the seismic forces are taken in to account for seismic design of structure.

The static design load combination for gravity loadings is given by IS 456:2000 and Eurocode2 are

$$w = 1.5gk + 1.5qk$$

$$w = 1.35gk + 1.5qk$$

Where: gk and qk are dead loads and imposed loads respectively. 1.5 and 1.35 are partial safety factors for loads for IS 456:2000 and Eurocode2 respectively.

5.Ductility Class: IS 1893:2002 (Part 1) specified the RC frame ductility as Ordinary Moment Resisting Frames (OMRF) and Special Moment Resisting Frames (SMRF) with factors 3 and 5 respectively. In case of Euro code 8 (EN 1998-1)specified the building ductility as Ductile Class Low (DCL), Ductile Class Medium (DCM) and Ductile Class High (DCH) with ductility factors 1.5, 3.9 and 5.85 respectively.

Table-1: Ductility Classes for IS and EC codes.

Class	Ductility Category	
	IS 1893	**EC 8**
Low dissipative structures.	OMRF	DCL
Medium dissipative structures.	SMRF	DCM
High dissipative structures.	-	DCH

6. Response Reduction Factor: Response reduction factor is the factor which reduces the actual base shear that would be generated, if the building were remain elastic and responded to a design basis earthquake, to get a design lateral force. According to IS codes the response reduction factors are 3 and 5 for OMRF and SMRF respectively. According to EN 1998 response reduction factors are1.5, 3.9, and 5.85 for DCL, DCM and DCH classes respectively.

7. Base Shear Calculation: The procedure to compute the base shear of the structure according to IS 1893 (Part 1): 2002, and BS EN 1998-1: 2004 are as follows.

IS 1893 (Part-1): 2002
a) $VB = Ah *W$

According to Clause 7.5.3 of IS 1893 (Part 1):2002
b) Ah = (Z/2* I/R* Sa/g)
According to Clause 6.4.2 of IS 1893 (Part 1):2002
c) For various kind of soil, Sa/g value is calculated according to Clause 6.4.5 of IS 1893 (Part1):2002

BS EN 1998-1: 2004

The seismic base shear force Fb, is given by:
Fb = Sd (T1) . m. λ
Where, T1 is time period, Sd is ordinate at T1, m is mass of building and λ is correction factor. According to Clause 4.3.3.2.2 (1) of BS EN 1998
Where Design Spectrum Sd(T1)shall be characterized from the following cases:

$0 \le T \le T_B$ $S_d(T_1)$ = ag. S [2/3+ T/T_B (2.5/q - 2/3)] according to Clause 3.2.2.5 of BS EN 1998

$T_B \le T \le T_C$: $S_d(T_1)$ = ag .S(2.5/q) according to Clause 3.2.2.5 of BS EN 1998

$T_C \le T \le T_D$: $S_d(T_1)$ = ag. S (2.5/q) . (T_C/T)
>/b ag. According to Clause 3.2.2.5 of BS EN 1998
TD ≤ T: Sd (T1) = ag. S.(2.5/q) (TC.TD)/(T^2)) .
>/b ag. According to Clause 3.2.2.5 of BS EN 1998

3.2 Modeling in ETABS

ETABS is a highly effective and reliable software developed by Computers and Structures Incorporation, USA, which is used for professional use in analysing and developing the models and components. It is easy, simple to use and compare and time saving software tool.

1. Materials Used:

Concrete: M 25 Grade of concrete for Slabs, M 30 Grade of concrete for Beams, M 40 Grade of concrete for Columns and Shear walls

- Concrete density is taken as 25 KN/m3 as per IS 456:2000 clause 19.2.1 and 24 KN/m3 as per EN 1991-1-1:2002:Annex A: Table A-1.
- Poisson's ratio is taken as 0.2 as per both respective codes.
- Modulus of elasticity for IS model is computed as per IS 456:2000 clause 6.2.3.1 is:

  $$E = 5000\sqrt{fck}$$

- Modulus of elasticity for EC model is taken from EN 1992-1: 2004 Table 3.1

Steel: Fe 500 HYSD bars for bending reinforcement, Fe 415 HYSD bars for shear reinforcement.

Walls: Poro-therm Blocks with density 6.8 KN/m3 – 7.68 KN/m^3

2. Defined Frame sections, Slab sections and Wall sections

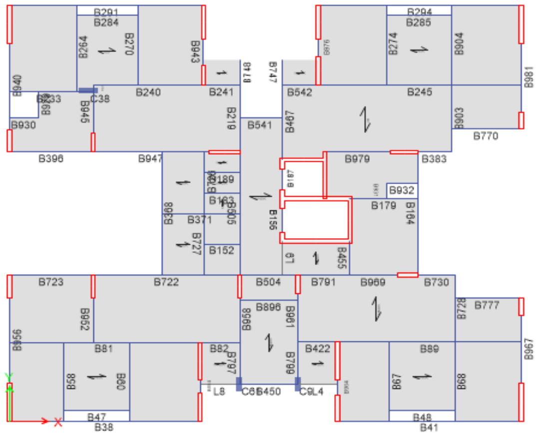


Fig-1: Typical plan layout of building model

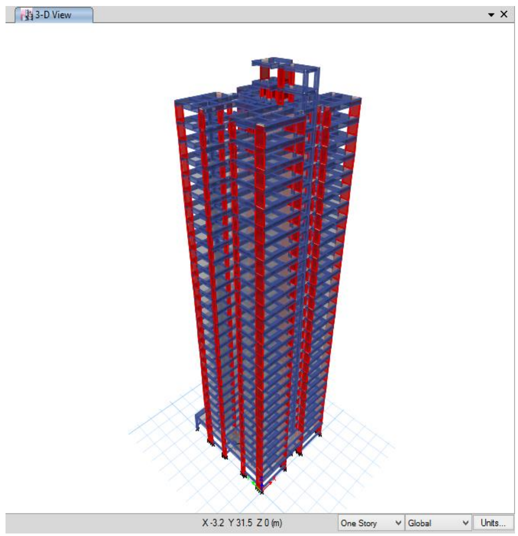


Fig-2: 3-D view of building model

3. Defining Load Patterns and Cases

1.Dead load, Floor finish, Wall loads.

- All these are defined under super dead and dead load cases.

2. Live Loads

- All imposed loads like uniformly or non-uniformly varying loads are defined under live load cases.

3. Earthquake Loads

- Earthquake loads are defined in both two horizontal directions X and Y from basement to top storey.

The factors used as per IS 1893 (Part 1) 2002

Seismic Zone factor=0.1: Ductility class= OMRF: Soil type=Type II (Medium Soil): Response reduction factor=3: Importance factor, γ= 1.2 (as per revised IS 1893 (Part 1) 2016): Height of structure=93.35 m: Time period: 0.075 X H ^ 0.75 = 0.075 X 93.35 ^ 0.75 = 2.252

The factors used as per EN 1998-1 (2004)

Ground acceleration , ag = 0.153 (As per study mentioned in reference[1]):
Spectrum Type : 2 (Surface wave magnitude Ms < 5.5 as per clause 3.2.2.2, Page- 38)[1]
Ground Type: C (Table-3.1 , Page-34 with respect to Value N_{SPT})
Soil factor, S = 1.5
Spectrum Period Tb,= 0.1
Spectrum Period Tc,= 0.25 (for Spectrum Type-2, Table 3.3)
Spectrum Period Td,= 1.2
Lower bound factor, b= 0.2 (Clause 3.2.2.5)
Behavior factor, q =1.5 (Clause 5.2.2.2, Table-5.1)
Correction factor, λ = 1 (Clause 3.2.2.2 Eqn:-3.6)
Height of structure: 93.35 m
Time period = Ct x H $^{3/4}$ (Clause 4.3.3.2.2)
= 0.075 x 93.35 x 0.75 = 2.252

4. Response Spectrum Function

Response spectrum functions are defined along spectrum X and Y.

According to IS 1893:2002

Damping ratio: 5%
Modal combination method used : SRSS
Scale Factor = I . g/2R = 1.2 (9.81/(2 x 3) = 1.962 (Rescaling has done to match spectral base shear with static base shear up to 90%)

According to EN 1998-1:2004

Type of response spectrum: Horizontal
Ground acceleration, ag/g = γ. ag_R = 1.2 x 0.153 = 0.184 (Clause 3.2.2.2,Page-37)
Damping ratio: 5 %
Modal combination method used : SRSS
Scale Factor = 9.81m/sec^2 or 9806.65 mm/ sec^2(Rescaling has done to match with spectral base shear with static base shear up to 90%)

5. Assignment of loads : Live loads, Wall load, Finishes, Fill as per plan layout with reference to IS 875 (Part-1)

6. Defined : Mass Source, Diaphragms, Load combinations and Live load reduction factors

7. Design of structural elements: Beams, columns, walls and slabs are designed as per preferences of codes.

i) IS 456:2000: Plain and Reinforced concrete code of practice
ii) EN 1992-1-1 (2004): Design of concrete structures – Part 1-1: General rules and rules for buildings.

4. RESULTS AND ANALYSIS

4.1 Static Analysis Results

Table-2 : Bending Moments for selected beams

Bending Moment, KN.m	2nd Floor		15th Floor		Terrace	
Beam ID	**IS**	**EC**	**IS**	**EC**	**IS**	**EC**
B164(200X 850)M30	113.4	98.33	108.9	95.76	100.1	88.24
B368(200X 850)M30	219.5	196.85	220.0	199.9	158.3	144.8
B505(200X 650)M30	231.9	211.0	317.0	291.3	243.6	221.4
B294(200X 850)M30	541.28	487.9	539.0	488.6	385.9	348.4

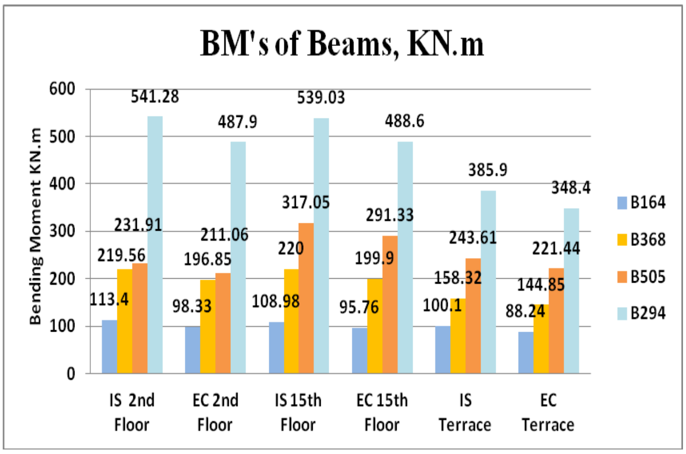


Fig-3: Bending moments for selected beams

Table-3: Shear Forces for selected beams

Shear Force, KN	2nd Floor		15th Floor		Terrace	
Beam ID	**IS**	**EC**	**IS**	**EC**	**IS**	**EC**
B164(200X850) M30	92.14	83.95	82.23	72.50	73.00	64.50
B368(200X850) M30	106.9 1	95.83	107.0 4	96.76	82.36	74.50
B505(200X650) M30	173.2 5	159.1 6	205.2 3	191.4 2	151.5 3	141.0 0
B294(200X850) M30	267.6 4	238.2 5	285.4 8	254.6 7	185.0 7	164.7 2

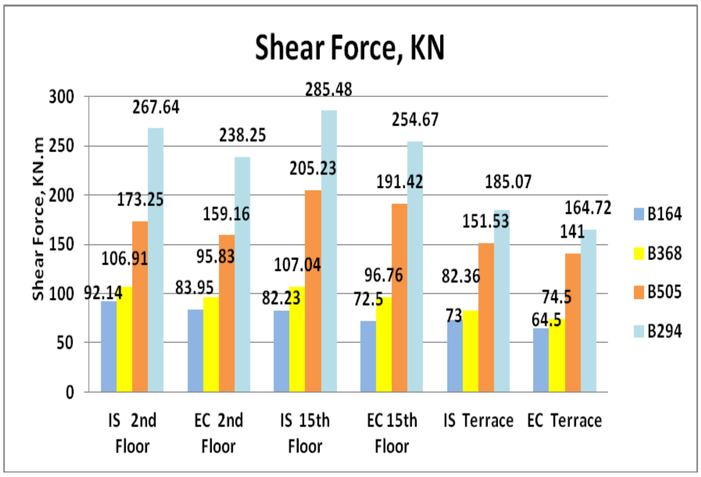


Fig-4: Shear force for selected beams

Table-4: Axial Force for selected Columns

Axial Force, KN	Basement		Terrace	
Column ID	**IS**	**EC**	**IS**	**EC**
C9-200X750M40	4678.22	4223.57	385.68	345.8
C38-300X900M40	8205.25	7278.88	197.36	172.13
PT1-200X2000M40	10854.56	9699.92	305.26	271.22
PT21-200X2000M40	12603.43	11256.43	377.85	336.35

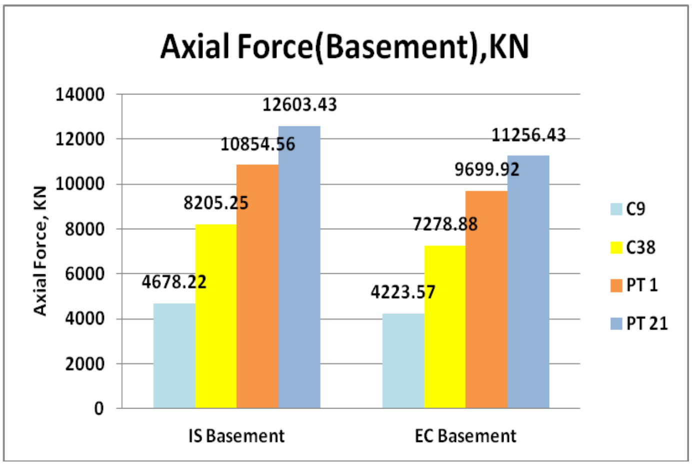


Fig-5: Axial force for selected columns at basement

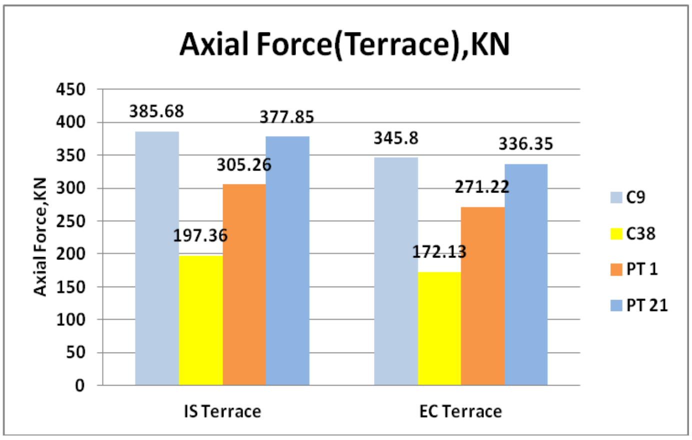


Fig-6: Axial force for selected columns at terrace floor

Table-5. Design Reaction at basement for selected columns.

Base Reactions, KN		
Column ID	**IS**	**EC**
C9	4678.22	4223.57
C38	8205.24	7278.88
PT1	10854.55	9700.00
PT21	12603.44	11256.43

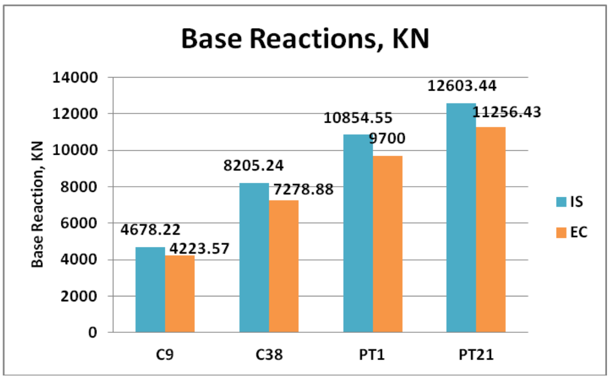


Fig-7: Design base reactions at base points of selected columns

4.2 Dynamic Analysis Results

Table-6: Base Shear due to Earthquake Forces

Static Base Shear, KN	Direction, X		Direction, Y	
	IS	**EC**	**IS**	**EC**

EQ X	2008.69	5017.70	0	0
EQ Y	0	0	2008.69	5017.70

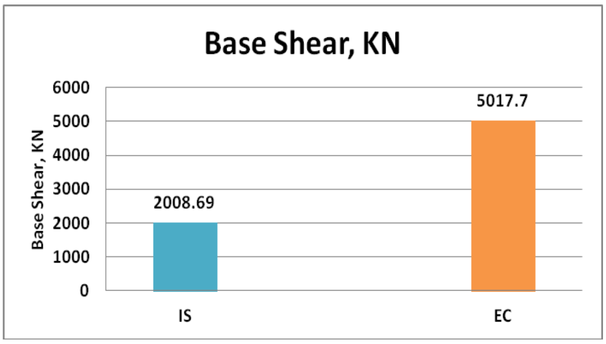
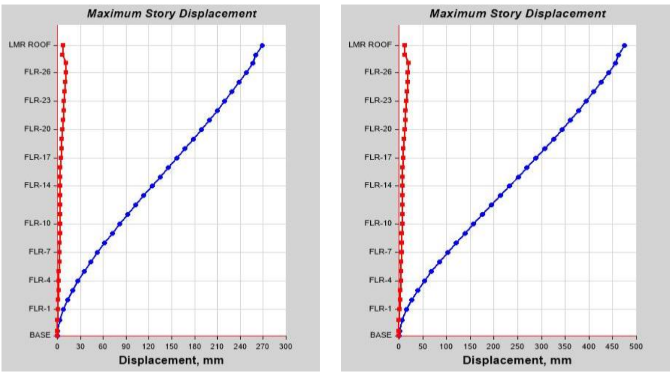


Fig-8: Base Shear due to Earthquake Forces

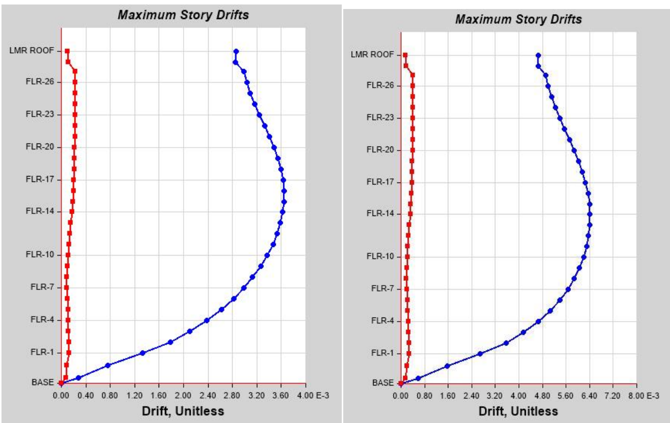
Storey Displacement



IS EC

Fig-9: Storey Displacement due Earthquake loads

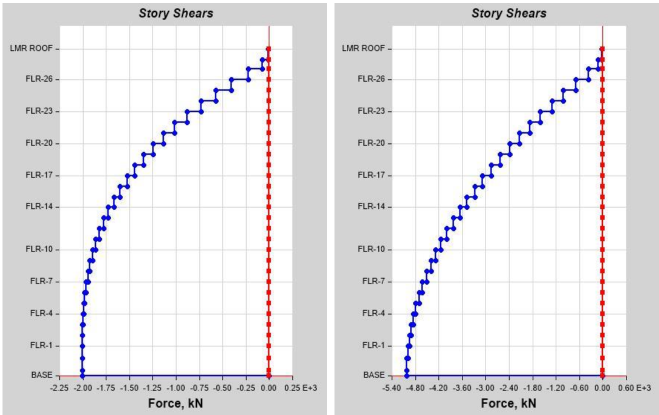
Storey Drift



IS EC

Fig-10: Storey Displacement due Earthquake loads

Storey Shear



IS EC

Fig-11: Storey Shear due Earthquake loads

Table-7: Longitudinal Reinforcement for selected columns due to Dynamic loading

Longitudinal Reinforcement, (%)	Basement		Terrace	
Column ID	IS	EC	IS	EC
C9	3.13%	2.32%	2.10%	2.42%
C38	4.97%	3.25%	0.80%	0.81%
PT1	2.10%	1.85%	0.80%	0.80%
PT21	2.35%	1.14%	1.30%	1.45%

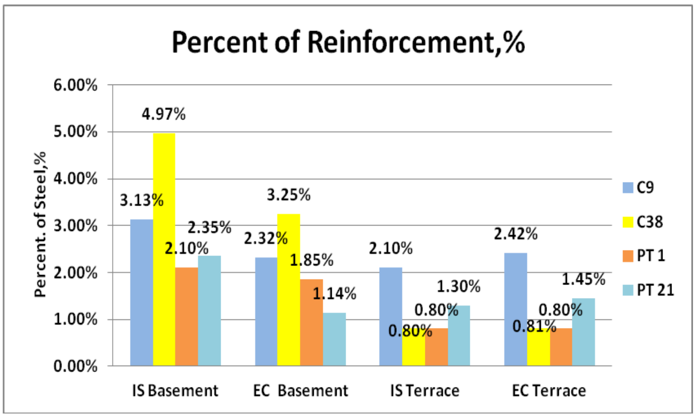


Fig-12: Longitudinal Reinforcement for selected columns due to Dynamic loading

5. CONCLUSIONS

5.1 Static Analysis:

Due to varied partial safety factors for dead and live loads and unit weight of concrete as indicated in both IS and

EC codes, there are numerous variations in design parameters like Bending moment, Shear force, Axial force and Base design reactions.

•Bending moment, Shear force, Axial forces and Base design are reduced in Euro code based design values by 8-13%

•Storey displacement is decreased by 22.5% for static loads

5.2 Dynamic Analysis:

Design base shear calculated according to EC 8 is higher than IS 1893 by up to 60% on account of high values of response reduction factors specified by IS code.

•Due to higher design base shear, the storey displacement at top and storey drifts are high for Euro code based design, but these parameters are within the safe confinements specified by the codes.

•Percentage of steel for column as per Euro standards is relatively lower. It's because of higher values of modulus of elasticity of concrete specified by Euro code2 due to this the ductility of columns are enhanced by the concrete and axial force is less comparing to IS values because of low partial factor of safety for the dead loads.

•The minimum and maximum percentage of reinforcement for columns as per IS is 0.8% and 6% respectively, where as per EC 2 is 0.2 % and 4%. So, this also makes impact while giving minimum reinforcement.

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