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Design and Seismic Evaluation of the Six Storey RC Residential Building

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Abstract: Seismic evaluation of buildings take many forms and is used to project probable damage level, develop economic losses, set priorities for mitigation and do determine specific deficiencies in individual buildings. The objective of research work is to design and seismic evaluation of the six storey reinforced concrete residential building by Code-compliance Approach based on IS 1893:2002 Critical for Earthquake Resistance Design of Structures (5th Revision) Part 1: General Provision and Building with the help of Structural Analysis Program (SAP2000 Ultimate 16.0.0).
Index Terms: Code-compliance approach, Earthquake, Eveluation, Design, RC building, Seismic vulnerability.

I. INTRODUCTION

Earthquake is sudden, rapid shaking of the earth caused by the release of the energy stored in the rocks. Energy released from the source of disturbance, inside the earth is transferred to adjacent land/water to vibrate. It affect on the entire built environment. It doesn't kill people but buildings do. We are heavily dependent upon the civic amenities or life lines like water supply, electric power supply, drainage. It disturbs civic amenities in a major way. Lifeline facilities like hospital, health care centres have a major role in natural catastrophe like earthquake. Hence additional care while designing such structures is needed. Damage of heritage buildings can make us root less. A severe earthquake can have very damaging consequences upon a reign's development and economy.

Damage in reinforced concrete frame building becomes massive if they are not design to behave elastically during earthquake. The 2001 Bhuj earthquake has confirmed that the Indian multi-storey reinforced concrete building with open ground storey are highly vulnerable to strong seismic ground motion.

Indian buildings built over the past two decades are deficient because of existing building can become seismically deficient when the seismic design requirements are up-graded since the design of these buildings with an older version of the code, seismic design codes used in their design are deficient, engineering knowledge makes advances rendering insufficient the previous understanding used in their design and designer lack understanding of the seismic behaviour of structures.

A. *Code-Compliance Approach*

1) *Step 1:* Data for Design

As per IS: 1893 (Part 1): 2002

The design data shall be as follows

Live load	3 kN/m^2 at typical floor
Live Load:	1.5 kN/ m^2 on terrace
Floor finish	1 kN/ m^2
Water proofing	2 kN/ m^2
Terrace finish	1 kN/ m^2
Location	Surat city, Gujrat
Wind load	As per IS: 875-Not design for wing load, since earthquake load exceed the wind load
Earthquake load	As per IS1893 (part 1)-2002
Depth of foundation below ground	3m

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Type of soil	Type II, Medium as per IS1893
Allowable bear-ing pressure	200 kN/ m^2
Allowable thick-ness of footing	0.9 m, assume isolated footing
Storey Height	Typical 3m and Ground Floor 3m
Floors	G.F. +5 upper floors
Ground beam	to be provided at 100 mm below G.L.
Plinth level	0.6 m
Wall	130mm thick brick masonry wall

B. Material Properties

Concrete

All components unless specified in design: M25 grade all

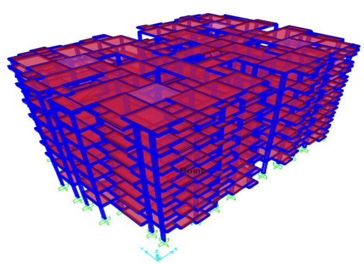
$E_c = 5000\sqrt{f_{ck}}$ N/mm^2 = 25000 N/mm^2 or 25000 MPa

Steel

HYSD reinforcement of grade Fe 415 confirming to IS 1786 is used throughout

1) *Step 2:* Geometry of the proposed structure

2) *Step 3:* Prepare a three-dimensional (3-D) model of the building frame



C. Analysis Stage

1) *Step 4: Calculation of gravity weight:* SAP2000 will directly add the self weight of all the members.
2) *Step 5: Calculation seismic weight:* The calculation of seismic load is similar to gravity load. According to the IS 1893 (part 1): 2002 weight of columns and walls in any storey shall be equally distributed to the floors above and below the storey. As per code clause 7.4, live load is used zero on terrace and 50% on other floors for analysis.
3) *Step 5.1: Calculation of time period:* Clause 7.6.2 IS 1893 (part 1): 2002

The approximate fundamental natural period of vibration (T_a), in seconds, of a moment resisting frame building with brick infill panels, may be estimated by empirical expression:

$$T_a = 0.09h/\sqrt{d}$$

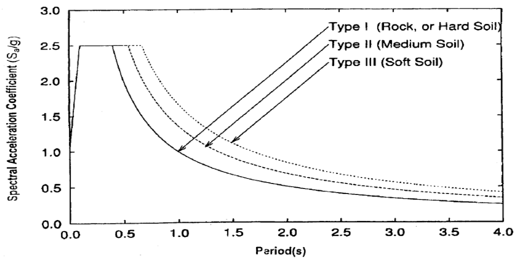
Where

h=Height of the building in m

d = base dimension of the building at the plinth level in m, along the considered direction of the lateral force.

4) *Step 5.2: Calculation of average response acceleration coefficient:* For medium soil condition and 5% damping

Fig. 2: IS 1893 (part 1): 2002



S_a/g = _____

5) *Step 5.3: Calculation of zone factor (Z)*

Table 2 IS 1893 (part 1): 2002

for Surat city

Z = 0.16 for Zone III

6) *Step 5.4: Calculation of importance factor (I)*

Table 6 IS 1893 (part 1): 2002

For public building

I = 1.5

7) *Step 5.5: Calculation of response reduction factor (R)*

Table 7 IS 1893 (part 1): 2002

For special RC moment resisting frame

R = 5

8) *Step 5.6: Calculation of design horizontal seismic coefficient (A_h)*

$A_h = ZIS_a/2Rg$

9) *Step 5.7: Calculation of total design lateral force or design seismic base shear (V_B)*

Clause 7.5.3 IS 1893 (part 1): 2002

$V_B = A_hW$ (in kN)

Where W = Seismic weight of building

10) *Step 5.8: Calculation of design storey shear calculation (Q)*

Clause 7.7.1 IS 1893 (part 1): 2002

$$Q_i = (w_ih_i/\sum w_ih_i^2)*V_B$$

Table 1: Distribution of Total Horizontal Load on Different Floor Levels

Storey	W_i (kN)	h_i (m)	V_{iBX} (kN)	V_{iBY} (kN)	Q_{ix} (kN)	Q_{iy} (kN)
7	83781	21	29563	30848	13008	13573
6	71156	18	29563	30848	8278	8637
5	58531	15	29563	30848	4730	4936
4	45906	12	29563	30848	2365	2468
3	33281	9	29563	30848	887	925
2	20656	6	29563	30848	296	308
1	8031	3	29563	30848	0	0
Total	321342				29663	30848

11) Step 4.9: Calculation of accidental eccentricity (e_{di})

The design eccentricity (e_{di}) to be used at floor i shall be taken as:

$e_{di} = 1.5e_{si} + 0.05b_i$

or $= e_{si} – 0.05b_i$

Whichever of this give the more severe effect in the shear of any frame

where

e_{si} = Static eccentricity at floor i defined as the distance between centre of mass and centre of rigidity

b_i = Floor plane dimension of floor i, perpendicular to the direction of force

The design forces calculated are to be applied at the centre of mass appropriately displaced so as to cause design eccentricity between the displaced centres of mass and centre of rigidity. However the negative torsional shear shall be neglected.

12) Step 5: Considered load cases used for analysis

The space frame is modelled using standard software.

Table 2 Basic load cases used for analysis

No.	Load case	Direction
1	DL	Downward
2	LL	Downward
3	EQ_x	X direction
4	EQ_z	Z direction

13) Step 6: Considered load combinations for analysis

Clause 6.3.1.2 IS 1893 (part 1): 2002

In the limit state design of reinforced and pre-stressed concrete structure, the following load combinations shall be accounted for:

1.5 (DL + IL)

1.2 (DL + IL $\pm$ EL)

1.5 (DL $\pm$ EL)

0.9 DL $\pm$ 1.5 EL

Table 3 Load combination used for design

Load No.	Load combination
1	1.5 (DL)
2	1.5 (DL + LL)
3	1.2 (DL + LL + EQ_x)
4	1.2 (DL + LL - EQ_x)
5	1.2 (DL + LL + EQ_z)
6	1.2 (DL + LL – EQ_z)
7	1.5 (DL + EQ_x)
8	1.5 (DL - EQ_x)
9	1.5 (DL + EQ_z)
10	1.5 (DL – EQ_z)
11	0.9 DL + 1.5 EQ_x
12	0.9 DL - 1.5 EQ_x
13	0.9 DL + 1.5 EQ_z
14	0.9 DL - 1.5 EQ_z

14) Step 7: Calculation of storey drift (Δ)

Clause 7.11.1 IS 1893 (part 1): 2002

Apply the design lateral force on the 3-D building model and estimate the stress-resultant (i.e, axial force, shear force, bending mo-

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ment and torsional moment) at all critical sections of the frame members. This is linear elastic analysis, obtain inter-storey drift. The storey drift in any storey due to minimum specified design lateral force, with partial load factor of 1.0, shall not exceed 0.004 times the storey height.

Table 4: Storey Drifts Calculation

Storey	Displacement (mm)	Storey Drift (mm)
7	296.03	69.55
6	226.48	65.07
5	161.41	52.27
4	109.14	41.96
3	67.18	28.17
2	39.01	23.73
1	15.28	15.28
0	0	0

15) *Step 8:* Obtain the capacities of the RC sections using the actual cross-section geometry, material properties and reinforcement sizes, applying the usual partial safety factors for load and material as per the Limit State Design Procedure of IS 456: 2000

16) *Step 9: Calculation of stability indices (Q):* ANNEX E, E 2, IS 456: 2000

To determine whether a column is a no sway or a sway column, stability index Q may be computed as given below:

$Q_{si} = \sum P_u \Delta_u / H_u h_s$

Where

$\sum P_u$ = sum of axial loads on all column in the storey

Δ_u = elastically computed first order lateral deflection

H_u = total lateral force acting within the storey

h_s = height of the storey

According to IS 456: 2000, If Q less than equal to 0.04, then the column in the frame may be taken as no sway column, otherwise the column will be considered as sway column. i.e.

a) $Q_{si} \leq 0.04$ Non-Sway in Column

b) $Q_{si} > 0.04$ Sway in Column

Table 5: Stability Indices of Different Storeys

Sto-rey	Storey seismic weight Wi (kN)	Axial load ∑Pu = ∑Wi (kN)	Δu (mm)	Lateral load Hux = Vx (kN)	Lateral load Huy = Vy (kN)	hs (mm)	Classification (Sway / Non-Sway)
7	83781	83781	69.55	13008	13573	3000	0.15
6	71156	154937	65.07	8278	8637	3000	0.41
5	58531	213474	52.27	4730	4936	3000	0.79
4	45906	259380	41.96	2365	2468	3000	1.53
3	33281	292661	28.17	887	925	3000	3.10
2	20656	313317	23.73	296	308	3000	8.37
1	8031	321348	15.28	0	0	3000	0.00

17) *Step 10: Design of selected beam:* Beams can be design by specified designing software.

18) *Step 11: General requirements:* The requirements apply to frame members resisting earthquake induces forces and designed to resist flexure. This member shall satisfy the following requirements:

a) Cause 6.1.2 IS 13920: 1993 The members shall preferably have a width to depth ration of more than 0.3

(b/D)>0.3 = (200/300) = 0.67>0.3

b) Cause 6.1.3 IS 13920: 1993 The width of member shall not less than 200 mm
b>200mm
Here b=200mm = 200mm

c) Cause 6.1.4 IS 13920: 1993 The depths D of the member shall preferably be not more than ¼ of the clear span.
$D<(L_c/4)$
D=600mm<(7000/4)mm

19) Step 11: Identify deficient member and deficiency in the lateral stiffness of the building

D. Check For Reinforcement

This member shall satisfy the following requirements:

1) Clause 6.2.1 (a) IS 13920: 1993. The top as well as bottom reinforcement shall consist of at least two bars throughout the member length.
2) Clause 6.2.1 (b) IS 13920: 1993. The tension steel ration on any face, at any section, shall not less than $P_{min} = 0.24 \sqrt{f_{ck}}/f_y$; where f_{ck} and f_y are in MPa.
3) Clause 6.2.2 IS 13920: 1993. The maximum steel ratio on any face at any section, shall not exceed $P_{max} = 0.025$.
4) Clause 6.2.3 IS 13920: 1993. The positive steel at the joint face must be at least equal to half the negative steel at that face.
5) Clause 6.2.4 IS 13920: 1993. The steel provided at each of the top and bottom face of the member at any section along its length shall be at least equal to ¼ of the maximum negative moment steel provided at the face of either joint.
6) Clause 6.2.5 IS 13920: 1993. In an external joint, both the top and bottom bars of the beam shall be provided with anchorage length , beyond the inner face of the column, equal to the development length in tension plus 10 times the bar diameter minus the allowance for 90 degree bend.

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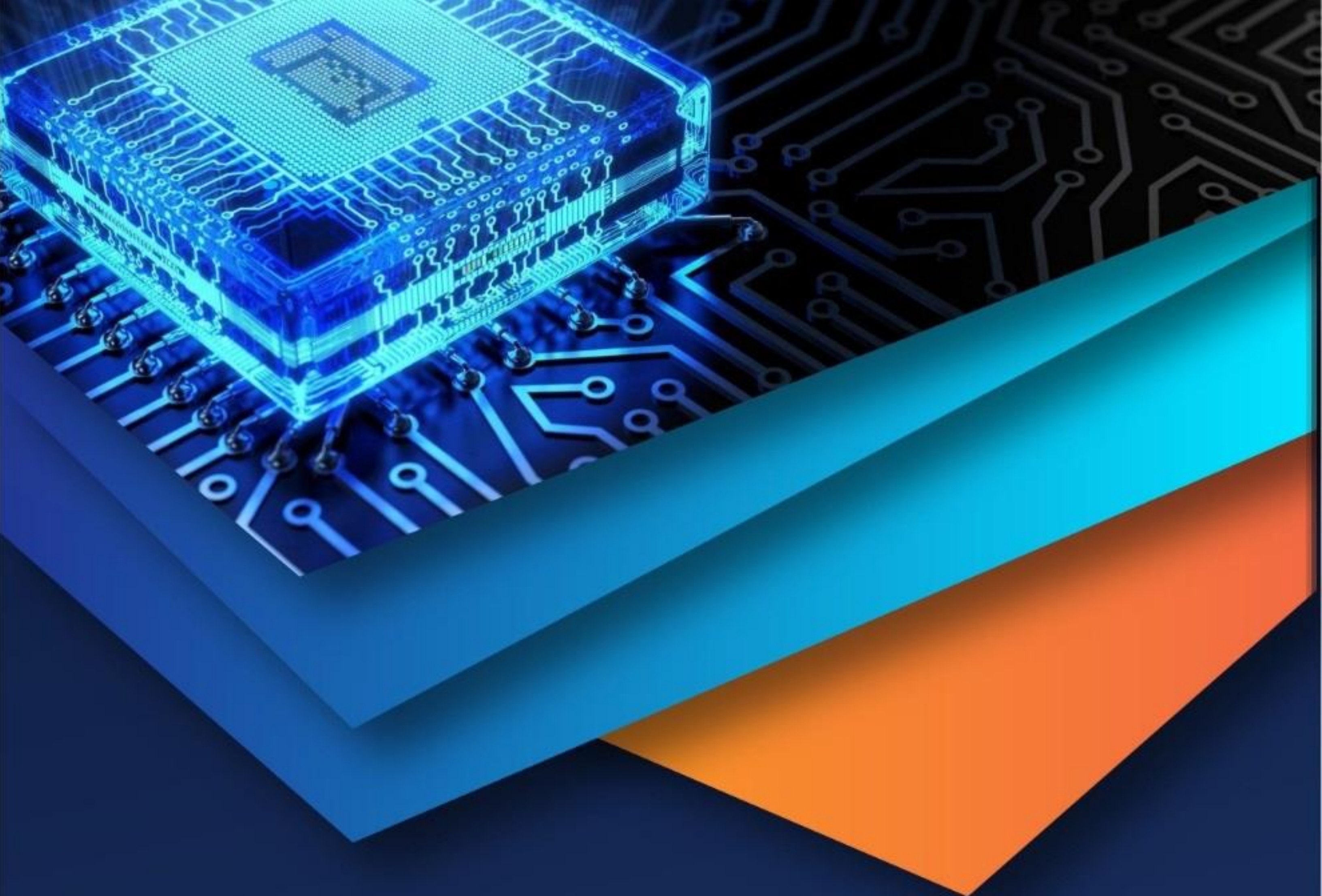

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