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Vulnerability assessment methodological elements of reinforced cement concrete structures to earthquake – case study

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ABSTRACT

In this paper, seismic vulnerability of every individual building in Guduvancheri at Chennai is being studied. The areas which have been covered in this study are (Gandhi Nagar, Nackiran Street & V.O.C street).The data's collected are Plan availability, Age of Buildings, Damages available, Number of Storey, Soil type and Type of construction. Type of construction considered is (RCC Building). For which, building design and analysis is done using Linear static method by STADD pro vi8 package. The Checks of building is done according to FEMA 310. These checks have been carried out before the earthquake occurs to ensure whether the building is in safe conditions. Chennai has been facing mild earthquakes recently. Therefore, this project has been carried out as a real time project.

KEY WORDS: Vulnerability, Elements, Earthquake.

1. INTRODUCTION

Seismic hazards due to ground shaking have varying impacts and are location specific. the geographical conditions and improper construction techniques forms other reasons.

Vulnerability can be stated as the amount by which a building is prone to risk upon a seismic activity. Usually the magnitude varies from 0 to 10.

Importance of seismic design codes: Seismic activity has effects ranging from minimal to catastrophic on structures. Structures may undergo deformation to collapsing based upon the impact and withstanding capacity of the structure. Seismic codes are standards developed in order to impose guidelines which will enable reduced vulnerability and improved strength in buildings. Various countries have developed their own codes based upon the seismic history, topography and soil conditions. These standards if adopted will ensure structural stability and improved life.

- **Efficient Structural Configuration:** the building should be designed in such way that its dimensional parameters ensure a good flow of inertia to the ground.
- **Lateral force resisting capacity:** The highest lateral load that can be beard without undergoing failure in the structure.
- **Good Stiffness:** The resisting nature of the system such that the deformations caused due to a moderate seismic activity doesn't affect the components of the structure.
- **Improved Ductility:** the ability of a structure to sustain deformations without collapsing. Ductility prevents from sudden failure of the structure.

Configuration – related checks:

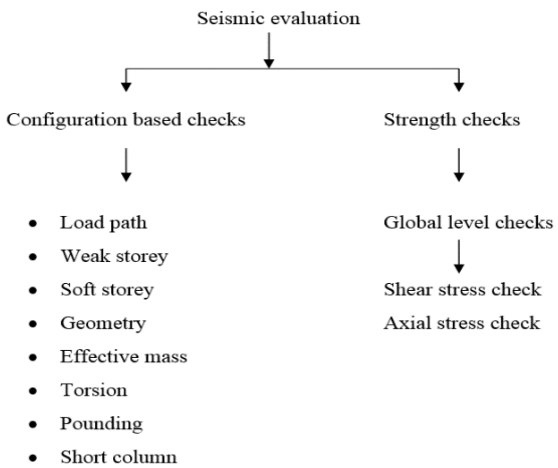

Figure.1. Configuration

Methods of seismic design: There are two methods of seismic analysis

- Equivalent static method
- Dynamic analysis

The dynamic analysis is easier than the static analysis method but with the advantage and use of various software, we can get result in fraction of seconds. This method is very useful because it relates directly to the lifetime situation.

The dynamic analysis can be carried out in two ways.

- Time history method
- Response Spectrum method

2. METHODOLOGY

Area of investigation of buildings:

Figure.2. Layout map of Guduvancheri

Analysis: All the calculated loads are given as input to STAAD.ProVi8 software. STAAD.ProVi8 will analyze the structure based on the input values of loads. The new inter face empower the user of STAAD.ProVi8 (Structural Analysis and Design for Professionals) to obtain accurate results for interlaced problems but also to maintain the comprehensive nature of solution.

Design and analysis of RCC structure building:

Preliminary Data for RCC Structure:

Location	:	Chennai city
Type of Construction	:	C
Zone	:	III
Plan	:	As illustrated in Fig.1
Number of Floors	:	One (G+1) as illustrated in Fig.1s
Ground Storey height	:	3.05m
Floor to Floor height	:	3.048m
External Walls	:	250mm thick including wall
Internal Walls	:	150mm thick including wall
L.L	:	3.5 KN/m^2 on Floor
Seismic Analysis	:	Equivalent static method
Design philosophy	:	Limit State method
Depth of foundation below ground	:	1.82m
Type of soil	:	Type II, Medium
Size of Column	:	300 x 230 mm
Size of Beam	:	230 x 2300 mm
Total Depth of Slab	:	120 mm

DL at level of roof:

Weight of slab =25 D =25 x0.23=3.0 KN/m2
Weight of finishes = F.F + T.W.F. =0.5 + 1.5 = 2.0 KN/m2
Total Weight = 5.0 KN/m2

Analysis of dead load:

Total weight on beam B1
Tributary floor area on beam B1 = 2.207 m^2
Slab weight on beam B1= 5 x 2.207 = 11.035 KN
Weight on beam B1 per meter= 11.035/3.5 = 3.16 KN/m
Self-weight of beam = 2.625 KN/m
Total Weight on Beam B1= 3.16 + 2.625 = 5.35 KN/m

DL at the level of floor:

Weight of slab =25 D =25 x0.23=3.0 KN/m2
Weight of finishes (F.F) = 0.5 KN/m2
Final weight = 3.5 KN/m2
Live Load Analysis
Final weight on beam B1
Tributary floor area on beam B1 = 2.207 m^2
Slab weight on beam B1 = 1.5x 2.207 = 3.310KN

Weight on beam B1 per meter = 3.310/3.5 = 0.945KN/m
Self-weight of beam = 2.207KN/m
Total Weight on Beam B1= 2.207 + 0.945 = 3.15 KN/m

Design Seismic Base Shear:

$V_B = A_h W$
$A_h = Z\ I\ S_a/2Rg$
$T = 0.09h/\sqrt{d}$
$T = 0.09x6.096/\sqrt{13} = 0.15sec.$
$Sa/\ g = 2.5$
The building is situated in an area of high seismicity.
Z = 0.16
I =1.0
R = 5.0
$A_h = 0.04$

Calculation of seismic weight:

Average roof dead load = 5.0 KN/m^2
Average floor dead load = 3.5 KN/m^2
Live load intensity = 3.5 KN/m^2 referring to clause 7.3.1 in IS 1893: 2002,
For seismic weight imposed load to be considered is 50% of the actual imposed load = 1.75 KN/m^2
Total live load on each floor except roof = 1.75× 13x5.4 = 123 KN
Dead load on roof = 5× 13x5.4= $351x10^3$KN
Dead load on other floors = 3.5× 13x5.4 = $245×10^3$ KN
Seismic weight on roof = $351x10^3$KN
Seismic weight on other floors = $245×10^3$ + 123 = 368 $x10^3$KN
Total seismic weight of the building = (351+ (1x368)) $x10^3$ = $7190x10^3$ KN
Hence, modified seismic base shear = $A_h W$ = 0.04 ×$7190x10^3$ = $288×10^3$ KN
Base Shear in each frame = 288/13 = 22.15KN

Table.1. Arrival of design lateral loads with respect to individual floors

Floor	W_i (MN)	h_i (M)	$W_ih_i^2$	$W_ih_i^2/\sum W_ih_i^2$	Qi (KN)
Roof(Level 3)	3.51	6.096	130.43	0.792	17.55
First Floor (Level 2)	3.68	3.048	34.18	0.207	4.59
Ground Floor (Level 1)	-	0.00	-	-	-
			∑=164.61	∑ = 1.0	∑=22.125

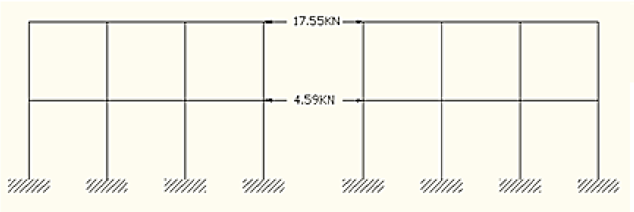

Figure.3. G+1 residential building 3D frame

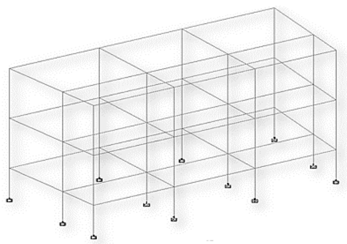

Figure.4. 3D Frame structure

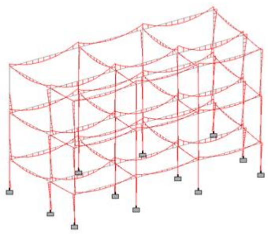

Figure.5. Bending moment diagram

Table.2. Load combination

Load Cases	Details of Load cases
1	1.5(DL+LL)
2	1.2(DL+LL+EQ)
3	1.2(DL+LL-EQ)
4	1.5(DL+EQ)
5	1.5(DL-EQ)

Damages on RCC buildings:

Figure.6. Floor bent with the beam but shear failure occurs. Fine crack on floor

Figure.7. Beam and slabs were of in-situ concrete. Shear failure on floor at cement mortar

Figure.8. Short column effect. Unreinforced masonry infills placed up to partial height in frame panels adjoining the columns reduced column height. Such columns draw shear forces larger than designed

Figure.9. In some areas, like this part of row constructions are common, with little or no space left between adjoining buildings. At the interface between such buildings, infills are sometimes made only in one of the two buildings. There were no infills in the upper stories of the building on the left. The building on the right suffered a ground storey

3. RESULTS

Table.3. Configuration-Related Checks

S. no.	Check	Remarks
1	Load Path	One complete load path exists which transfers the inertial forces from the mass to the foundation.
2	Geometry	Horizontal dimension is equal at all the stories.
3	Weak Storey	There are no abrupt changes in the column sizes from one storey to another and no significant geometrical irregularities. Thus, weak or soft storey does not exist.
4	Soft Storey	
5	Vertical Discontinuities	Vertical elements in the lateral force resisting system are continuous to the foundation.
6	Mass	Effective mass at the floors is equal except the roof. The effective mass at the roof varies by 20% (<100%).
7	Torsion	The building being symmetrical
8	Adjacent Buildings	Not applicable.
9	Short Columns	Short columns are applicable

Shear stress in RC frame columns: As per draft code, an estimation of the average shear stress undergone by columns are obtained by

$\tau_{col} = (\frac{nc}{nc-nf})(\frac{vj}{Ac})$

τ_{col} = For ground level columns.

nc = total number of columns resisting lateral forces in loading direction.

nf = total number of frames in loading direction

Ac = Summation of the c.s.a of all columns in the floor considered

Vj = maximum shear at floor level 'j'

Table.4. Shearing stress undergone by columns

floor	n_c	n_f	A_c m^2	V_j x1.5 KN	τ_{col} Mpa
3	6	2	0.414	4575	0.0165
2	6	2	0.414	26302	0.0952
1	6	2	0.414	33187	0.1202

$(\tau_{col})_{all} <$ min. of 0.4MPa and $0.1\sqrt{f_{ck}} < 0.4$MPa

But, $\tau_{col} > (\tau_{col})_{all}$

The check is not satisfied.

Axial Stress in Moment Frames: Axial force in moment frames at base at columns

VB = Base shear x Load factor = 22. 125x 1.5 = $33.2\text{x}10^3$KN

n_f = Number of frames in loading direction = 2

H = total height = 6.096 m

L = length of the building = 12.3 m

$F_0 = (2/3) \text{ x } (V_B/n_f) \text{ x } (H/L) = (2/3) \text{ x } (33.2\text{x}1000/2) \text{ x } (6.096/12.3)$ =5.49KN

Axial Stress $\sigma = (5.49\text{x}10^3)/ (0.3\text{x}0.23\text{x}10^6) = 0.079$

σ_{all} =0.25 $\sqrt{f_{ck}}$ =5Mpa

$\sigma < \sigma_{all}$ ok Hence, the check is satisfied.

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