DESIGN OF EARTHQUAKE RESISTANT R.C.C. SOFT STORIED STRUCTURE WITH SHEAR WALL AND BRACING

GOBHIGA S
Assistant professor: Department of Civil Engineering
Karpagam Academy of higher education
Coimbatore, Tamilnadu, India
gobhiga@hotmail.com
+918870355772

ARAVINTHAN.K
Assistant professor: Department of Civil Engineering
Easa Collage of Engineering and Technology
Coimbatore, Tamilnadu, India
+919042068251

Abstract— **This study focuses on the behaviour of soft storey structure in seismic area. Due to increasing unbalance of required space to availability, it is becoming necessary to provide open ground storey for parking and other activities. This reduces the stiffness of the structure and hence progressive collapse is unavoidable in the earthquake. From the past findings, it is concluded that most of the structure damaged or collapsed are soft storey structure. This cause to rethink the design of soft storey building to improve the stiffness and to reduce the effect of earthquake. Hence, three storied building of size (40x40)m is planned at Coimbatore and analysed the same building using Modal Push over Analysis techniques, for obtaining target displacement and load distribution. For obtained value, the structure is designed with shear wall and bracing together to improve the stiffness of the structure. Hence the above technique can be adopted for all seismic zone areas and open ground storied structures by providing additional stiffness through bracing and shear wall adequately.Furthermore, retrofitting; modification on the existing structure to make them resistant to seismic activity can be done using these techniques which helps to increase the global capacity of the structure.**

Keywords- Soft Storey, Displacement, Shear force, frequency, mode shape

I. INTRODUCTION

The size of the earthquake can be measured by Magnitude (M) and can be measured by MMI scale(Modified Mercalie Intensity). The walls of upper stories makes the building many times stiffer than in the open ground storey. Hence, the upper stories acts as a single block, and hence most of the horizontal displacement occurs in the open ground storey. Thus, such buildings swing like inverted pendulums during earthquake shaking and columns in the open ground storey are highly stressed which leads to collapse of the structure. The two key elements, Demand and Capacity are the performance based design procedure which is the modern approach to earthquake resistant design.

II. AIM

The aim of the investigation is to increase the stiffness of the structure to avoid the progressive collapse by introducing shear wall and bracing together on the R.C.C. structure at Coimbatore which comes under zone III.

III. ANALYSIS

There are various methods of seismic analysis which gives high degrees of accuracy. Seismic evaluation of structures can be divided into two categories

- Qualitative method
- Analytical method

A. *Qualitative method*

Structural score = Basic Structural Hazard+ Performance Modification Factor

$$S = BSH + PMF.$$

The structural score is combined with the probability of the building.
The low S indicates that the building is vulnerable and needs detailed analysis.
The high S suggests that the building is probably safe for earthquake loads.

B. *Analytical method*

Analysis methods are broadly classified as linear static, linear dynamic, nonlinear static and nonlinear dynamic methods.

C. *Nonlinear static Analysis (Pushover Analysis)*

Pushover analysis, one of the methods available to know the behaviour of structures subjected to earthquake forces. It is the process of pushing horizontally with a prescribed loading pattern incrementally until the structure reaches a limit state.

D. *Why Push Over Analysis?*

When base shear verses top displacement is plotted, any premature failure or weakness can be analyzed.

When lateral inelastic force verses displacement is plotted, total failure or weakness can be analyzed.
The sequence of cracks, yielding, plastic hinge formation and failure of various structural components can be noted. Hence deficiencies are observed and rectified.
The iterative analysis and design goes on until the design satisfies a pre-established criterion.
The performance criteria are generally defined as Target displacement of the structure at roof level.

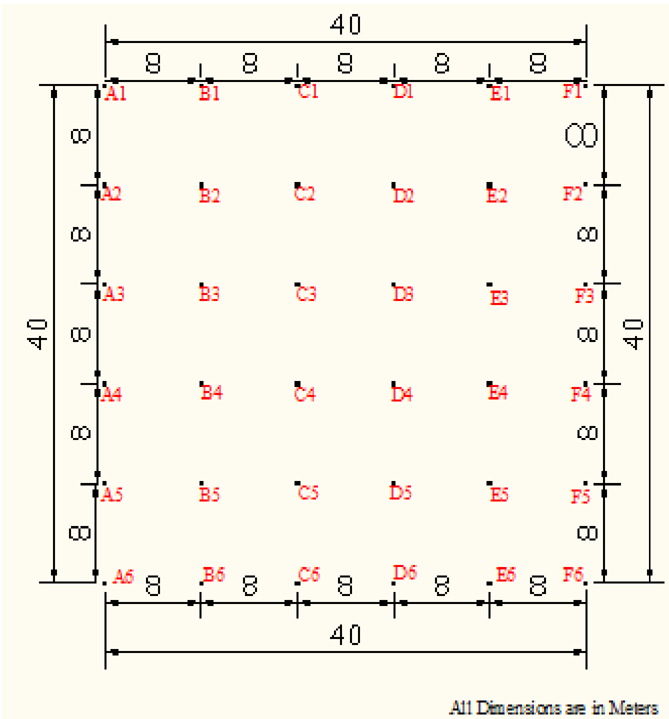

Fig 1.Column view of RC building
(Each 8*8 m distance in both axis)

E. Modal Pushover Analysis Procedure

- Compute the natural frequencies, ωn and modes ϕn, for linearly elastic vibration of the building
- To find the global capacity curve,f or the *n*th-mode, develop the base shear-roof displacement, V_{bn} -u_{rn}, pushover curve for force Distribution

$$S_n^* = \phi \mathbf{m}_n$$

where, **m** is the mass matrix of the structure.

- Calculate peak roof displacement u_{rn} associated with the *n*th-"mode" inelastic SDF system from,

$$u_{rno} = \Gamma_n \phi_{rn} D_n \pi$$

where

$$\Gamma_n = (1/M) x \varphi^T x m x 1$$

$$D_n = A_n / \omega_n^2.$$

D_n and A_n can be obtained from the response (or design) spectrum.

- The peak modal responses, r_{no} can be determined by pushover analysis and can be combined to obtain an estimate of the peak value r_o of the total response.
- From the pushover database (Step 2), extract values of desired responses r_n: floor displacements, story drifts, plastic hinge rotations, etc. Repeat Steps for as many modes as required for sufficient accuracy
- Determine the total response (demand) by combining the peak "modal" responses using the SRSS rule.

F. Modal Pushover Analysis Theoretically

➢ Calculation of loads

Live Load = 3200kN
Floor Finish =160kN
Wt of slab =3840kN
Wt of Beam =1382.4kN
8582.4kN

➢ Mass Matrix

$$\begin{bmatrix} 858.24 & 0 & 0 & 0 \\ 0 & 858.24 & 0 & 0 \\ 0 & 0 & 858.24 & 0 \\ 0 & 0 & 0 & 538.24 \end{bmatrix}$$

➢ Calculation of Stiffness

K= 12EI/h3
E = 22360 Mpa
K= ([12x22360x10^3x((0.45x0.4563)/12)]/4^3)x36
=515.76x10^3 kN/m

➢ Calculation of stiffness matrix

[K] =

$$\begin{bmatrix} K1+K2 & -K2 & 0 & 0 \\ -K2 & K2+K3 & -K3 & 0 \\ 0 & -K3 & K3+K4 & -K4 \\ 0 & 0 & -K4 & K4 \end{bmatrix}$$

[K] =

$$\begin{bmatrix} 1031512 & -515756 & 0 & 0 \\ -515756 & 1031512 & -515756 & 0 \\ 0 & -515756 & 1031512 & -515756 \\ 0 & 0 & -515756 & 515756 \end{bmatrix}$$

TABLE 1 DETERMINATION OF Ω, T & M

Mode No	Natural Frequency ω	Natural time Period T=2π/ω	Modal Mass (M)
1	8.86	0.709	2785.7
2	25.234	0.248	1017.4
3	37.765	0.166	42.22
4	44.54	0.141	2700.5

TABLE 2 DETERMINATION OF A_n & D_n

Mode No	Lateral force A_n=(Z/2)x(I/R)x(Sa/g)	Peak Deformation $D_n=A_n/\omega^2$
1	0.0288	3.66x10^-4
2	0.04	6.28x10^-5
3	0.032	2.24x10^-5
4	0.032	1.61x10^-5

TABLE 3 DETERMINATION OF V & Γ

Mode No	Storey Shear Force, V	Participation Factor $\Gamma=(1/M)x\varphi^T xmx1$
1	1473.9	0.0188
2	1051.2	0.0204
3	590.66	0.0487
4	315.70	0.0179

- *Floor Displacement*

U_{r1} = 0.185
U_{r2} = 0.326
U_{r3} = 0.422
U_{r4} = 0.457

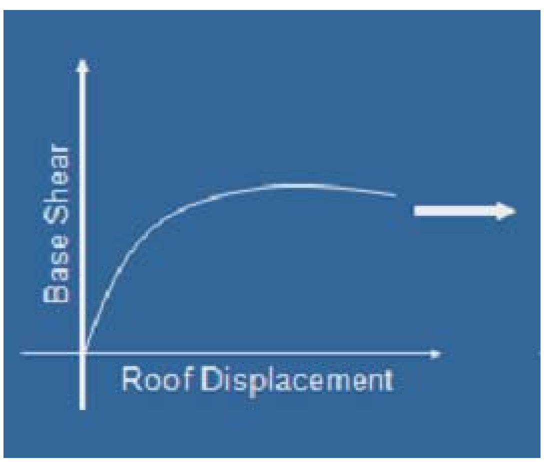

Fig 2 Global Capacity Curve

G. *Linear Static Analysis*

Maximum bending moment is calculated using substitute frame method.

H. *Design Forces In Shear Wall Under Different Load Cases*

Using portal frame method moment shear and axial force is calculated and the values are tabulated according to the load case.

Load case	**Moment (kN-m)**	**Shear (kN-m)**	**Axial Force(kN)**
1.5(DL+LL)	348.882	348.882	348.882
1.2(DL+LL+EQZ)	491.028	332.052	376.158
1.2(DL+LL-EQZ)	67.092	226.068	181.962
1.5(DL+EQL)	474.96	276.24	331.372
1.5(DL-EQL)	-54.96	143.76	88.627
0.9DL+1.5EQZ	390.96	192.24	247.37
0.9DL-1.5EQZ	-138.96	59.76	4.627

IV. DESIGN OF SHEAR WALL & BRACING

A. *Shear Wall*

Shear walls a vertical component are constructed to counter the effects of lateral load acting on a structure. Best position for the shear walls is in the center of each half of the building and is positioned at the ends to utilize the space.

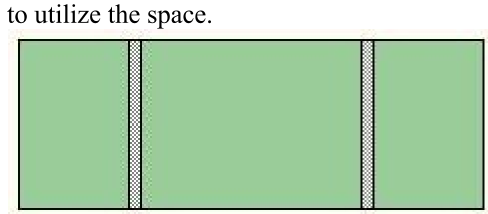
Fig 3 at each half

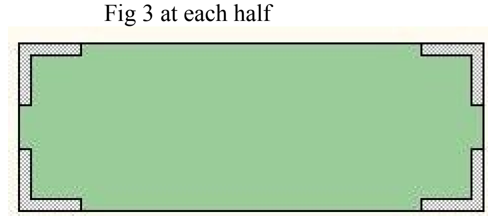
Fig 4 at the ends

B. *Design of Shear Wall*

The design of shear wall in a 3 storied reinforced concrete building has been presented in the fig. The design forces as per IS 1893(part I):2002 in a shear wall have been calculated. The sectional and reinforcement details fulfilled according to the clauses of IS 13920:1993 are presented as under:

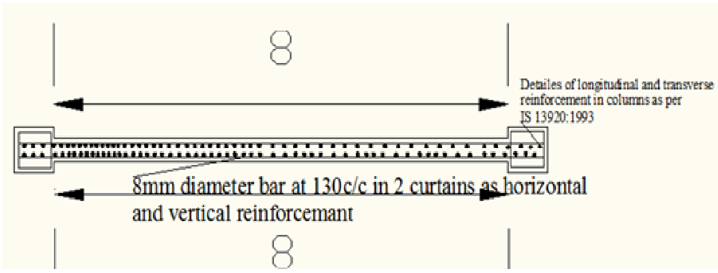

Fig 5 Reinforcement detail of Shear Wall

C. Bracing System

There are three stages in the design

- Identify suitable intermediate bracing positions (and their stiffness) for the adequacy of the main beams.
- Design the intermediate bracing
- Design the support bracing

D. Why Knee Bracing?

Since it Control buckling of the main beams, Load distribution and Dimensional control it is been chosen.

Design of Bracing

Let us provide the frame with Knee braces

Maximum force, Q= 422.7kN

Let us choose 2 ISA 70X70X8, each having a=1058mm2

$r_{xx}=r_{yy}$=21.2mm

Total A=2X1058=2116mm2

r_x=21.2mm

Effective length=0.7X3.818=2.6726m

l/r=2672/21.2=126.03

Pac=62.8 N/mm2

Hence Actual Compressive stress=422.7X10^3/2116

=19.976N/mm2

Hence ok

V CONCLUSION

The main objectives of this research were to discuss and assess different pushover methodologies to obtain the expected stiffness and time period and to use the same for the design of Shear walls and bracings, a very suitable for resisting earthquake induced lateral forces in multi-storeyed building systems. By this technique the seismic performances of soft storey buildings can be increased and the stiffness of the lateral load resisting system can be improved without disturbing the parking activities.

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