SEISMIC DEMAND STUDY OF SOFT STOREY BUILDING AND IT'S STRENGTHENING FOR SEISMIC RESISTANCE

S.Arunkumar[1] ,Dr. G. Nandini Devi[2]

[1]P.G. Student, Department of Civil Engineering, Adhiyamaan College of Engineering, Hosur, Tamilnadu

[2]Professor, Department of Civil Engineering, Adhiyamaan College of Engineering, Hosur, Tamilnadu

Abstract

The increase in urbanization for the past few years has made the vehicle parking as a major concern. Therefore the first storey of the apartment is used for parking. RC framed buildings with the ground storey open are known to perform poorly during strong earthquake shaking, due to the absence of infill wall, the presence of masonry infill wall influences the overall behaviour of the structure when subjected to lateral forces, when masonry infill are considered to interact with their surrounding frames the lateral stiffness and lateral load carrying capacity of structure largely increase. Earthquakes that occurred recently have shown that a large number of existing reinforced concrete buildings especially soft storey building are vulnerable to damage or even collapse during a strong earthquake. The first storey of the building behaved as a soft story in which the columns were unable to provide adequate shear resistance during the earthquake. So in this paper the study is carried out with various building models such as soft storey structure with shear wall, and soft storey with steel bracings at the first storey. The study includes the analysis of soft storey building with ETABS software by pushover analysis method and the results and conclusion of the analysis is to be included.

Keywords soft storey building, shear wall, cross bracings, strength factor, response reduction factor

1. INTRODUCTION

The soft storey building which has opening at the ground level is mainly used as parking lot. The infills in the above storey levels would absorb the seismic forces and becomes stiffer, as the ground storey without any infill is less stiff than the above stories. Due to this the seismic behaviour of the soft storey building is poorer when compared to RC framed structure with infill.

Umesh P. Patil et al (2015) analysed the seismic performance of two structures G+15, one made of composite steel concrete material and other one is made up of RCC, situated in the earth quake zone III, having a medium soil were investigated analytically for their performance using ETABS software, Equivalent static method is used for the analysis of RCC. It is possible to control the drift in soft storey by providing 1) Shear walls 2) Bracings 3) Stiffer column 4) Lateral load resisting system. The beams and columns in the soft storey are designed 2.5 times of obtained bending moments and shear forces and shear walls are designed by a factor of 1.5 times the storey shear.

Priyanka Hanamantra Jagadale et al (2015) the seismic performance of soft storey building are modeled and analysed using SAP2000. For this eight different models were analysed. Equivalent static analysis is performed on all the models. The use of stiffer column increases the stiffness up to 73%. Shear wall is found to be quite effective in increasing the stiffness. In this case stiffness of first storey is increased to 80%. Cross bracing reduces the displacement to 54%. Stiffer column reduces the displacement to 70%, the shear wall reduces the displacement to 80%. It is found that the use of cross bracing, stiffer column, shear wall, light weight material infill increases the stiffness of first storey and reduces the lateral drift demand.

Mohammed KhajaMoiuddin et al (2014) conducted a study on 12 different models of 21 storey building model, the model was analyzed for time period using both ETABS and SAP2000, the base shear was calculated using both response spectrum analysis, and equivalent static analysis. When the structural action of masonry infill is taken the fundamental natural time got reduced 58% when compare with bare frame model.

Spoorthi et al(2014)performed a pushover analysis of a tall building with symmetrical plan and elevation of 5,10,15 storey building, and they buildings were analyzed by using ETABS 9.7.4 for seismic zone V. Base shear, storey displacements, storey drifts and storey shears obtained from pushover analysis are about twice the storey displacements, storey drifts and storey shears of equivalent static analysis

SuchitaHirde (2014) analysed Four models with soft storey at different levels are considered along with soft storey at ground level and these models with incorporation of shear walls are considered. Pushover analyses of the models with and without shear walls are carried out. This study highlights the poor seismic performance of G+20 RCC building with soft storey. After retrofitting of all the models with shear walls hinges are not developed in any of the columns. Provision of shear walls results in reduction in lateral displacement. Displacement reduces when the soft storey is provided at higher level. After retrofitting the base shear carrying capacity is increased by 8.45% to 13.26%.

Susanta Banerjee et al (2014) analysed three types of buildings in which the building designates. All buildings are analyzed as Ordinary Moment Resisting frames. Designs are carried out in STAAD-Pro. The drift demands for ground storey column are large for soft storey buildings. Soft storey building shows poor performance during earthquake.

Munde et al (2012) has analyzed four types of frame models such as bare frame, Frame with infill except the first storey, First storey containing wall at specific locations, Soft first storey with stiffer column compared with other storey columns. The linear elastic analysis was made using ETABS on these frames The drift and the strength demands in the first storey columns are very large for buildings with soft ground storeys, increasing the stiffness's of the first storey such that the first storey stiffness is at least 50% as stiff as the second storey.

Haroon Rasheed Tamboli et al (2012) has performed a study which involves seismic analysis of RC frame (ten storey) building with different models that include bare frame, infilled frame and open first storey frame. The parameters such as base shear, time period, natural frequency, storey drift and bending moments are studied, the building model was analysed using ETABS. In case of an open first storey frame structure, the storey drift is very large than the upper storeys, which may cause the collapse of structure during strong earthquake shaking.

Saraswati Setia et al (2012) has performed a study on 6 storied RC frame building model and is analysed using the software STAAD PRO.2006. The static analysis is then performed for the modeled RC frame building using the computer software STAAD PRO. 2006. Lateral displacement is largest in bare frame with soft storey defect both for earthquake force for corner columns as well as for intermediate columns. Buildings with shear wall in core and shear wall have uniform displacement because of shear wall. Which shows a gradual change of stiffness between the lower soft storey and the upper floors that is essentially required.

Kasnale et al investigated the behaviour of multi-storey building to evaluate their performance level when subjected to earthquake loading. For this study five different models of a six storey building are considered. Equivalent static analysis has been performed as per IS 1893-2002 for each model using ETABS 9.5. The IS code methods are describing very insufficient guidelines about infill wall design procedures. It is observed that the ETABs provide overestimated values of fundamental period. It can be concluded that provision of infill wall enhances the performance in terms of displacement control, storey drift and lateral stiffness.

From the above literatures it is observed that in soft storey the seismic performance of such building is very poor, when compared with the normal RC structure. In order to overcome this failure some of the strengthening methods were used to overcome this failure.

2. STRUCTURAL FAILURE OF SOFT STOREY BUILDING

Soft Storey

The soft storey building is normally an apartment or commercial building, in which the ground floor contains open space usually for parking. A Soft storey building is a multi-story building with wide doors, commercial spaces at the ground level. A building in which soft story level is less than 70% as stiff as the floor immediately above it, or less than 80% as stiff as average stiffness of the three floors above it.

Soft Storey Failure

The soft storey failure is due to the strength demand on the column in the first storey is very high compared to other floors, in the upper stories the column forces are reduced effectively due to the presence of brick infill walls which share the forces and the upper stories stiffer than the first soft story. The lateral displacement of the whole structure is governed by the first soft storey of the building. Thus when the lateral force acts on such buildings due to its less stiffness in ground story the building might become failure as shown in Fig.1.

Figure 1 Soft storey failure

3. STRENGTHENING OF SOFT STOREY BUILDING

RC Shear Wall

Reinforced concrete (RC) buildings with RC walls are called as Shear Walls in addition to slabs, beams and columns. These walls generally start from the foundation level and are continuous throughout the building height. The thickness of the shear wall is between 150mm to 400mm in high rise buildings. RC shear walls provide more strength and stiffness to buildings in the direction of their orientation, which significantly reduces the lateral sway of the building and thereby reduces damages to structure and its contents. Since the shear walls carry large earthquake forces, the overturning effects on them are large. Shear walls in buildings are symmetrically located in plan to reduce ill-effects of twist in buildings. They could be placed symmetrically along one or both directions in plan.

Cross Bracings

Cross bracings are usually placed with two diagonal member in an X shaped manner. Cross bracing is a system which can increase the performance of the building during an earthquake. The cross bracing pushes the floor and ceiling against one another, thus increasing the structure's stability.

4. PUSHOVER ANALYSIS

- ✓ The structural engineering community has developed a new generation of design and seismic procedures that incorporate performance based structures and are moving away from simplified linear elastic methods towards a more non-linear technique.
- ✓ Pushover analysis is an approximate analysis method in which the structure is subjected to monotonically increasing lateral forces with an invariant height-wise distribution until a target displacement is reached. Basically, a pushover analysis is a series of incremental static analysis carried out to develop a capacity curve for the building. Based on the capacity curve, a target displacement which is an estimate of the displacement that the design earthquake will produce on the building is determined.
- ✓ The extent of damage experienced by the structure at this target displacement is considered representative of the damage experienced by the building when subjected to design level ground shaking. Many methods were presented to apply the nonlinear static pushover (NSP) to structures.

5. DESCRIPTION OF MODELS ANALYSED

Model 1: Infilled frame with soft storey (IFSS)
Model 2: Infilled frame with shear wall in soft storey (IFSW) - Fig.3
Model 3: Infilled frame with cross bracing (IFCB) - Fig.4

The plan of the building models are assumed to be symmetric and are regular in elevation. A 10 storied building with 3 bays in both X and Y directions are considered in this study. The building assumed to be located in the Indian Seismic zone III and the buildings are designed as per IS codes, and the seismic loads are designed from IS1893 (2002). The live load and dead loads are applied as per IS 875 (1987). The design of RC frames is based on IS 456 (2000) - OMRF.

Dimensions of the buildings are
Column: 500×500mm
Beam: 300×300mm
Thickness of slab: 125mm
Thickness of shear wall: 230mm
Size of bracing: 230x230mm
Live load: 3 kN/m2
Floor finish: 1kN/m2
Materials: M25 concrete & HYSD415 reinforcement
Importance factor: 1
Soil type: Medium (type II)
Seismic zone: Zone III
Zone factor: 0.16

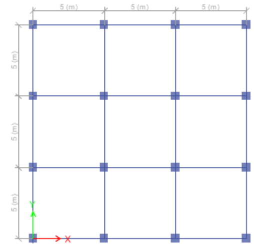

Figure 2 Plan

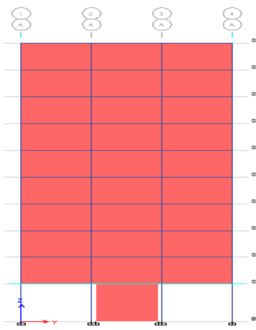

Figure 3 IFSW

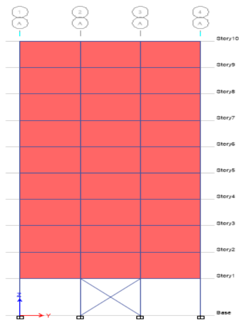

Figure 4 IFCB

6. RESULTS AND DISCUSSION

From the pushover analysis of the structural models the results for maximum base shear, maximum displacement, maximum inter-storey drift, maximum storey force, etc are tabulated in Table 1.

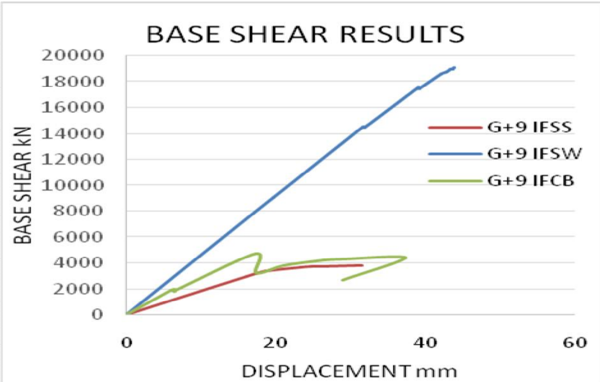

Figure 5 Storey Vs Displacement

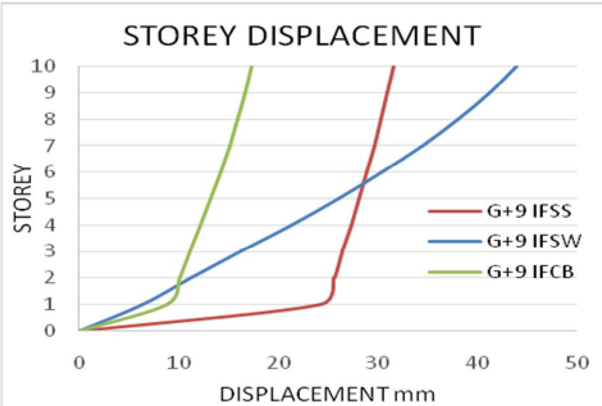

Figure 6 Storey Displacement Vs Storey

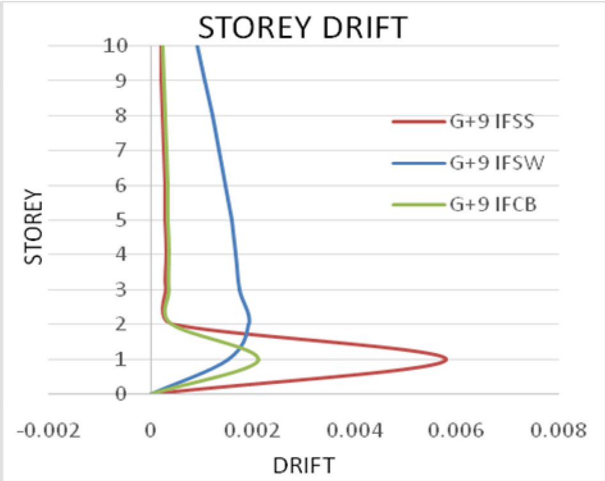

Figure 7 Drift Vs Storey

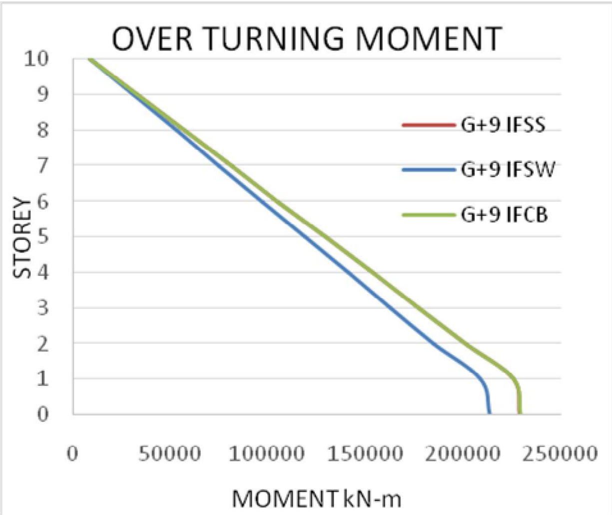

Figure 8 Moment Vs Storey

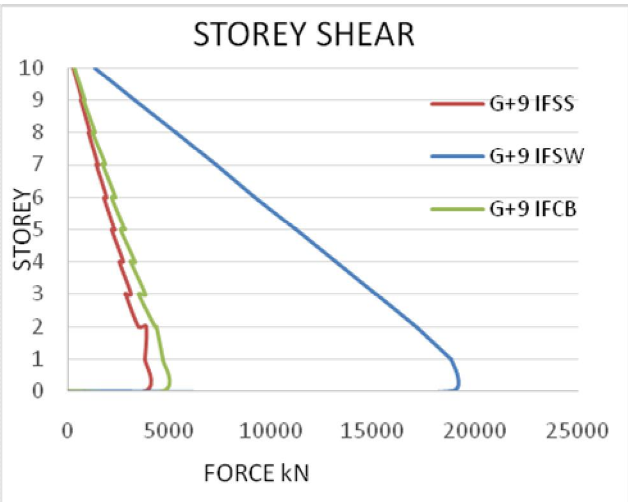

Figure 9 Storey Shear Vs Storey

7. CONCLUSION

- ✓ While considering base shear capacity IFSW exhibit higher base shear than other systems irrespective of number of stories.
- ✓ Base shear of G+9 IFSW is 39.8 %,30.6%, higher than the base shear of IFSS, IFCB.
- ✓ Displacement of G+9 IFSW is 40%,150% higher than the displacement of IFSS, IFSB for base shear increase of 39.8% and 30.6% than IFSS and IFCB
- ✓ Inter-storey drift is minimum for SHEAR WALL when comparing with other systems.
- ✓ Inter-storey drift of the analysed models are 0.0057, 0.0019, 0.0021 of IFSS, IFSW & IFCB respectively. The inter storey drift for IFSS is higher than the codal recommendation which is 0.004.
- ✓ The inter storey drift for IFSW is 200% and 10.5% lower than the IFSS and IFCB respectively.
- ✓ Building with SHEARWALL is having maximum storey force than other systems.
- ✓ Storey force of IFSW is 89%, 3% higher than the storey force of IFSS, IFCB.
- ✓ Due to the presence of shear wall the storey ability of soft storey is increased by 3.89 times the infilled frame with soft story.
- ✓ Building with shear wall at the bottom storey has higher moment when comparing to other systems irrespective of the number of stories.
- ✓ Time period of these systems is more when comparing to IS code time period from IS 1893.
- ✓ Response reduction factor of these frames is higher than the IS code recommendations.

Table 1: Pushover Analysis results at ultimate base shear

System	Max base shear	Max displacement	Max inter-storey drift	Max storey force	Max overturning moment	Vy	Dy	Sa	Te	Ke	W
	kN	mm	no unit	kN	kN.m	kN	mm	g	sec	kN/m	kN
G+9 IFSS	3828.58	31.45	0.0057	3846	295465	3542.93	19.2	0.854	0.747	184849.9	30517.24
G+9 IFSW	19093.0	43.83	0.0019	18807	213462	14278.88	30.9	1.097	0.385	462486.5	28461.60
G+9 IFCB	4698.44	17.33	0.0021	4661	229326	3876.17	13.8	1.097	0.567	280642.6	30331.84

TABLE 2: Response reduction factor 'R' for the models

System	Vu	Vd	Dy	Δy	μ	T	φ	Strength factor Rs	Ductility factor Rμ	R_R	Response reduction factor R (R_s*$R_μ$*R_R)
G+9 IFSS	3828.58	1359.15	19.2	124.8	6.5	0.747	0.787	2.816	7.02	1	19.78
G+9 IFSW	19093	1868.95	30.9	124.8	4.03	0.385	1.157	10.215	3.42	1	34.97
G+9 IFCB	4698.44	1985.35	13.8	124.8	9.04	0.554	0.954	2.366	6.73	1	15.92

TABLE 3: Time Period for the models and the Codal Time Period

System	Time period from ETABS	Codal time period
G+9 IFSS	0.747	0.99
G+9IFSW	0.385	0.725
G+9 IFCB	0.554	0.725

References

[1]. Haroon Rasheed Tamboli, Umesh.N.Karadi, (2012), 'Seismic Analysis of RC Frame Structure with and without Masonry Infill Walls', International Journal of Scientific & Engineering Research, vol. 35, pp. 1137-1147.

[2]. IS 456: 2000."Indian Standard Code of Practice for plain and reinforced Concrete", Bureau of Indian Standards, New Delhi. ETABS Non-linear 9.7 Computers and Structures Inc, Berkeley.

[3]. IS 1893 (Part 1)- 2002, 'Criteria For Earthquake Resistant Design Of Structures"- Part 1General Provisions And Buildings', 5th Revision, 2002, Bureau Of Indian Standards, New Delhi, India.

[4]. Kasnale.A.S, Jamkar,S.S, (2013), 'Study of Seismic performance for soft basement of RC framed Buildings', Journal of Mechanical & civil, pp. 47-51.

[5]. Mohammed KhajaMoinuddin, Vishwanath. B. Patil, (2014), 'Seismic Evaluation of R.C. Framed High Rise Structural System with the Effect of Ground and Intermediate Soft Storey', International Journal of Engineering Research & Technology, vol. 3, pp. 602 - 608.

[6]. Munde P .K, Magarpatil H.R, (2012), 'Seismic Response of RC Framed Masonry Infilled Buildings with Soft First Storey', International Journal of Engineering Research & Technology, vol. 1 Issue 9, pp.1-7.

[7]. Priyanka Hanamantrao Jagadale, Suchitra Hirde, (2015) 'Seismic Performance of Multi-storeyed Reinforced Concrete Building with Soft Story', International Journal of Innovative Science, Engineering & Technology, Vol. 2, pp.1135-1142.

[8]. SaraswatiSetia, Vineet Sharma, (2012) 'Seismic Response of R.C.C Building with Soft Storey' International Journal of Applied Engineering Research, vol.7

[9]. Spoorthi S K, jagadishkori G, (2014), 'Effect of soft storey on tall buildings at various storeys by pushover analysis', International journal of Engineering Research, vol.3, pp.91-98.

[10]. SuchitaHirde, Ganga Tepugade, (2014), 'Seismic Performance of Multistorey Building with Soft Storey at Different Level with RC Shear Wall', International Journal of Current Engineering and Technology, vol.4.

[11]. Susanta Banerjee, Sanjaya K Patro, Praveena Rao, (2014), 'Inelastic Seismic Analysis of Reinforced Concrete Frame Building with Soft Storey', International Journal of Civil Engineering Research, vol. 5, pp. 373-378.

[12]. Umesh P. Patel, Suryanarayana M, (2015),' Analysis of g+15 rcc and composite structure having a soft

storey at ground level by response spectrum and equivalent static methods using etabs 2013', International Research Journal of Engineering And Technology, vol.02,pp.59-64.
[13]. B.S.S Council, " NEHRP recommended provisions for seismic regulations for new buildings (1997 ed.)" in Federal Emergency management Agency, FEMA Vol.302, pp.337.
[14]. FEMA 356, Prestandard and Commentary for the Seismic Rehabilitation of Buildings (Federal Emergency Management Agency, Washington (DC), 2000).

AUTHOR

S. ArunKumar completed B.E in Civil Engineering and currently pursuing M.E. Structural Engineering in Adhiyamaan College of Engineering, Hosur, Tamilnadu.

Dr. G. Nandini Devi is currently working as Professor, Department of Civil Engineering. She obtained her B.E in Civil Engineering and M.E in Structural Engineering from Bharathiyar University, Coimbatore, India and Ph.D from Anna University-Chennai, India. She is having 13 years of experience and published 22 papers in internationals journals. Her research area is development of New construction materials, FRP rebars, Earthquake Resistant Structures.