

SEISMIC EVALUATION OF BUILDINGS WITH POSTTENSIONED BEAMS BY NON-LINEAR STATIC ANALYSIS

T.Hari prasad¹, T.Anand ²

¹PG Student, Department of Civil Engineering, Kumaraguru college of Technology, Coimbatore-641049.

²Assistant Professor, Department of Civil Engineering, Kumaraguru college of Technology, Coimbatore-641049.

ABSTRACT: The present study compares the seismic performance of a typical RC framed structure of an overall plan dimension of 24m x 24m having panel size of 8m x 8m with the following three variations in its frame modelling. The first model consists of a conventional RC frame with all beams and columns as RCC. RCC peripheral beams consider as a second model and interior beams with PT (Post Tensioned) tendons and beams having PT tendons in third model. The models studied are varied in height from Ground + eleven stories to Ground + fifteen stories with square shaped cross section of columns. The column height is considered as 3m for each floor. If fifteen models is carried out a Static Nonlinear Pushover analysis generated in SAP2000 software. The post tensioned members are analyzed using ADAPT software. G+11 to G+15 story frames are performed Seismic with peripheral RC beams and internal PT beams is found to be the best, followed by frames with all RC beams because the formation of "collapse" hinge is less observed. Frames are Performed with all PT beams is slightly below that with all RC beams. Finally, observed all PT beams with frames are performed quite good even without any separate lateral force resisting system.

Key Words: Seismic evaluation, pushover analysis of reinforced concrete floors and post-tensioned floors, pre-compression, performance point.

1. INTRODUCTION

If many concrete structures are faint severely by earthquakes, have indicated the need for evaluating the seismic adequacy of existing buildings. About 60% of the land area of our country is susceptible to damaging levels of seismic hazard. Don't abstain from future earthquakes, but preparedness and safe building construction practices can certainly reduce the extent of damage and loss. In order to strengthen and resist the buildings for future earthquakes, some procedures have to be adopted. If Static pushover analysis is mostly used for seismic performance evaluation of existing and new structures. In particular, the seismic rehabilitation of older concrete structures in high seismically areas is a matter of growing concern, since structures vulnerable to damage must be identified and an acceptable level of safety must be determined. To make such computation, simplified linear-elastic methods are not sufficient.

Post tensioned concrete floor has become quite popular now-a-days because of its distinct advantages such as low cost due to ease of construction, low floor-to-floor height because of shallow beams known as "fat" beams, and flexible use of space due to large span., Since the PT flat floor systems provide improved crack and deflection control, and allow relatively large span-to-thickness ratios of the order of 35 to 45 and also very efficient in particular PT flat floor systems. Mostly gravity loads are resist only PT floor systems in high seismic regions however, they may be utilized as intermediate moment frames (ACI 318-2005, Section 21.12.6)2 in areas with moderate seismic demands. Given the broad potential applications, a detailed study, understanding and analysis of flat floor system behaviour subjected to lateral forces and/or displacements is important.

In the present work, a series of nonlinear pushover analysis is carried out by using SAP2000 software which allows the modelling of PT tendons. If the analysis is carried out by the following guidelines are given in ATC-403 and FEMA-273/2744, where several important factors such as P-Delta effects, strength and stiffness contribution, and soil parameters are taken into consideration.

2. BUILDING DESCRIPTIONS

2.1 DIMENSIONS OF BUILDING AND MEMBERS

The present study compares the seismic performance of a typical RC framed structure of an overall plan dimension of 24m x 24m having panel size of 8m x 8m with the following three variations in its frame modelling.

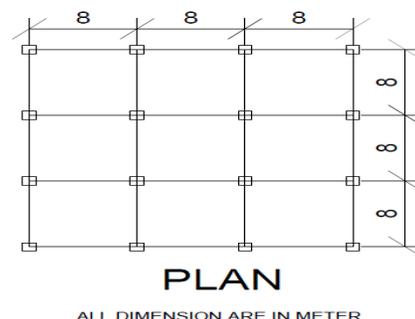


Fig 1- Plan

(i). Conventional RC frame with all beams as RCC.

From trial and error method using ETABS software, arrived the dimension as 300mmx600mm.

(ii). Peripheral beams as RCC and interior beams as post tensioned.

From trial and error method using ETABS software, arrived the dimension as 300mmx600mm.

(iii). All beams having post tensioned

From trial and error method using ETABS software, arrived the dimension as 1200mmx600mm.

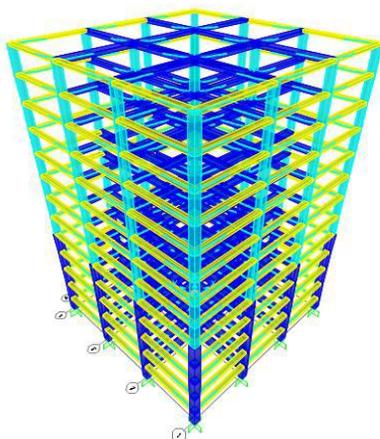
(iv) Column

For all the three models:

- (i) 1000mm*1000mm (up to G+3 floors).
- (ii) 800mm*800mm (up to G+7 floors).
- (iii) 600mm*600mm (above G+7 floors).

(v) Slab

In all the fifteen models, slab is modeled as a shell element accounting for diaphragm action to be considered for seismic analysis. The columns are considered to be fixed at the foundation level. In case of PT beams the tendons are modeled as per the selected profile and a post tension stresses to account for 25% to 35% of the dead load is considered for analysis. The column height is considered as 3m for each floor. Static Nonlinear Pushover analysis is carried out for all the fifteen models generated using SAP2000 software.



TYPICAL MODEL

Fig 2 - G+11 All beams as post tensioned

2.2 LOAD DEFINITION

Each of the models is subjected to a floor load of 2kN/m² as dead load and 3kN/m² as live load on all the typical floors. All beams are subjected to a uniform distributed 230mm thick wall load of 15 kN/m. being a symmetric structure plan, seismic load in only one lateral direction is considered as per IS 1893.

2.3 POST TENSION DESIGN PARAMETERS

All Post tensioned members are designed by ADAPT software.

TABLE 1 DESIGN PARAMETERS FOR PT BEAMS						
Sr. No.	Designation of PT beams	Section size of PT beams in mm	Jacking force in kN	No. of cables	Axial stress in N/mm ²	Dead load balancing in %
1	Perimeter beams at typical floor	500 × 350	977	8	1.24	52
2	Perimeter beams at terrace floor	500 × 350	735	6	0.93	48
3	Internal beams on all floors	1000 × 350	1352	11	0.86	52

Table 1- Post tension design parameters

2.4 TYPICAL TENDON PROFILE

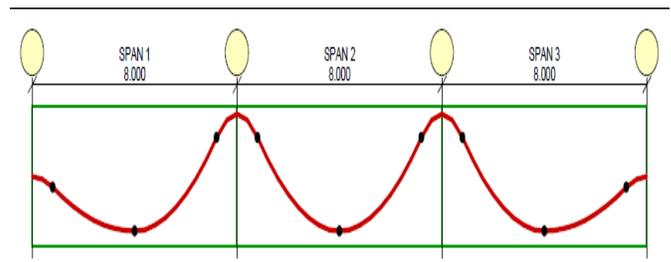


Fig 3 - Tendon profile

3.1 PUSH OVER ANALYSIS

The Combined Axial and Flexural (PMM) type of hinges are defined at 0.05L and 0.95L for all the column elements and Flexural (M3) hinges are defined at 0.05L, 0.5L and 0.95L for all beam elements where L is the length of the beam element. The 0.5L flexural hinge in beams is typically defined to capture the effects due to maximum sagging moment developed at mid span of beams during the push in the gravity direction.

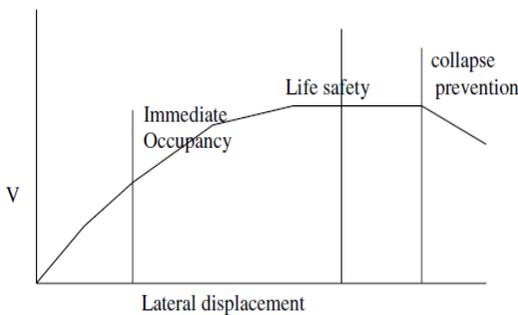
The static analysis is carried out for the given dead, live and earthquake loads. Typically, the following two push over analysis cases are defined for each of the buildings. PUSH1 is

the case in which the gravity loads are applied up to their total force magnitude. It may be noted here that the jacking force applied at the ends of the PT cables as per Table 1 is already in effect simultaneously. PUSH2 is defined as the push in the lateral X-direction, and it starts from the end of PUSH1. The X-displacement of the roof level node is monitored up to the magnitude of 4 percent of the building height, when push is given as per the earthquake force profile in the X direction. Once the displacement is noted down at performance point, which is much less than 4 percent of the height of the building for all cases, one more cycle of push over analysis is carried out by modifying the target displacement of roof level node to the displacement obtained at performance point. This is typically done to get the relevant data like number and state of hinges at the performance point as one stops pushing the structure beyond performance point in the second cycle of push over analysis.

3.2 PERFORMANCE BASED DESIGN

There are generally three performance levels:

1. Immediate occupancy level in which relatively little damage of the structure occurs
2. Collapse prevention level, in which near complete damage of the structure occurs.
3. Life safety level is defined as a condition of severe damage, but a state in which margin remains against collapse.



PERFORMANCE CONCEPT IN FEMA -273 AND ATC-40

Fig 1- Capacity curve

3.3 THE HINGES

Types of hinges are flexural hinges, shear hinges and axial hinges. The first two is inserted into the ends of beams and columns. Since the presence of masonry infill have significant influence on the seismic behavior of the

structure, modelling them using equivalent diagonal struts is common in PA, unlike in the conventional analysis, where its inclusion is a rarity. The axial hinges are inserted at either ends of the diagonal struts thus modelled, to simulate cracking of infill during analysis.

Basically a hinge represents localized force-displacement relation of a member through its elastic and inelastic phases under seismic loads. For example, a flexural hinge represents the moment-rotation relation of a beam. The linear elastic range from unloaded state A to its effective yield B represented by AB followed by an inelastic but linear response of reduced (ductile) stiffness from B to C. a sudden reduction in CD shows of load resistance, followed by a reduced resistance from D to E, and finally a total loss of resistance from E to F. Hinges have defined as „Immediate Occupancy“ (IO), „Life Safety“ (LS) and „Collapse Prevention“ (CP) within its ductile range.

4. RESULT AND DISCUSSIONS

4.1 GENERAL

The results which are required based upon the requirements are to be determined using both SAP2000 software.

4.2 RESULTS OBTAINED FROM SAP2000

TYPE OF BUILDING		BASE	ROOF	Sa/g	Sd (MM)	Teff(SEC)	Beff
		SHEAR(V)(KN)	DISPLACEMENT(D)(MM)				
ALL CONVENTIONAL	G+11	5616.427	190	0.065	0.266	3.895	0.181
	G+12	5583.995	140	0.061	0.304	4.294	0.169
	G+13	5816.882	110	0.061	0.295	4.18	0.162
	G+14	5987.084	120	0.058	0.313	4.433	0.162
	G+15	6320.499	110	0.056	0.324	4.616	0.164
ALL PT	G+11	5568.548	270	0.063	0.378	4.91	0.124
	G+12	5796.277	170	0.064	0.409	5.072	0.108
	G+13	5834.462	150	0.06	0.459	5.467	0.099
	G+14	5848.048	160	0.057	0.506	5.923	0.095
	G+15	5790.655	170	0.053	0.541	6.357	0.095
PERIPHERAL RCC	G+11	5783.319	240	0.064	0.295	4.321	0.177
	G+12	5717.813	160	0.06	0.317	4.533	0.167
	G+13	5683.774	120	0.057	0.355	4.73	0.16
	G+14	5636.041	130	0.053	0.356	5.027	0.16
	G+15	5631.613	130	0.05	0.375	5.423	0.17

Table 2 - Result obtained from different models at performance point

4.3 TYPICAL RESULTS FOR G+15 FLOOR (ALL BEAMS HAVING CONVENTIONAL RCC)

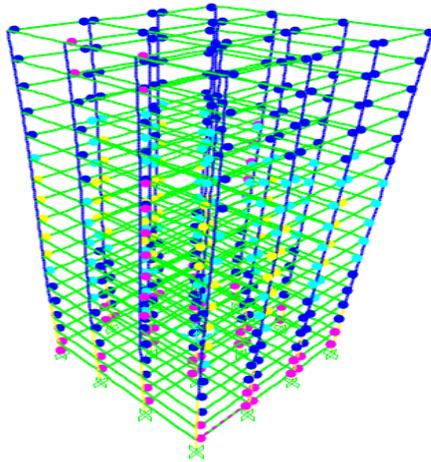


Fig 4 - Deformed shape with hinges at performance point

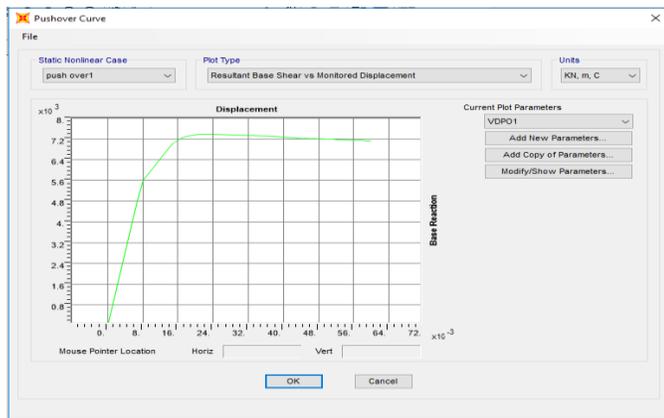


Fig 5 - Pushover curve

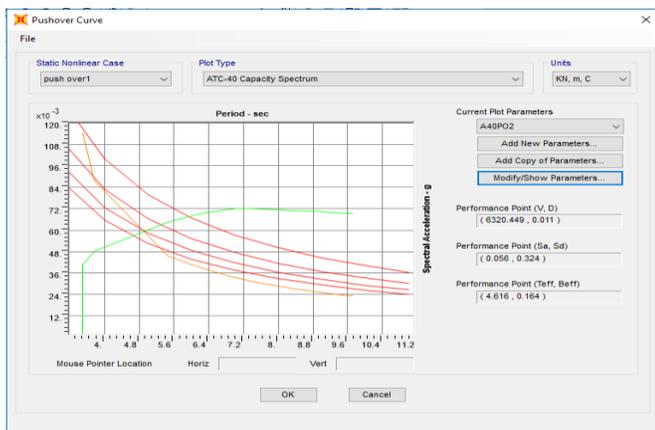


Fig 6 - Spectral acceleration (Sa) Vs Time (T)

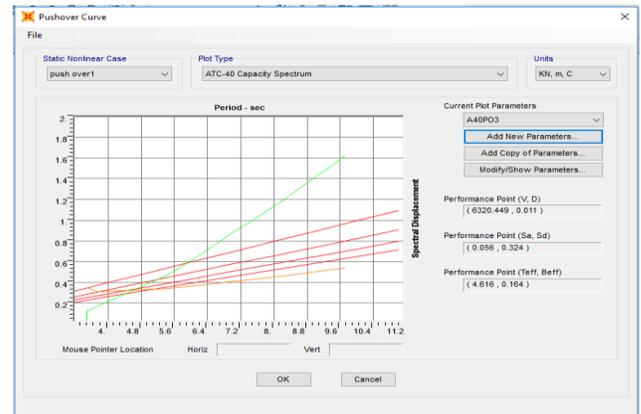


Fig 7 - Spectral displacement (Sd) Vs Time (T)

4.4 NO OF HINGES DEVELOPED AT PERFORMANCE LEVEL

storey	frame type	A to B	B to IO	IO to LS	LS to CP	CP to C	C to D	D to E	beyond E	TOTAL
G+11	ALL RCC	0	67	147	86	16	0	0	0	316
	ALL PT	0	107	137	6	9	0	0	0	259
	RCC+PT	0	63	175	4	0	0	0	0	242
G+12	ALL RCC	0	64	104	55	79	0	0	0	302
	ALL PT	0	95	135	34	57	0	0	0	321
	RCC+PT	0	62	149	62	1	0	0	0	274
G+13	ALL RCC	0	76	132	52	114	0	0	0	374
	ALL PT	0	98	123	52	76	0	0	0	349
	RCC+PT	0	89	127	46	71	0	0	0	333
G+14	ALL RCC	0	71	140	43	113	0	0	0	367
	ALL PT	0	110	131	53	84	0	0	0	378
	RCC+PT	0	79	147	58	68	0	0	0	352
G+15	ALL RCC	0	62	198	99	62	0	0	0	421
	ALL PT	0	120	156	53	78	0	0	0	407
	RCC+PT	0	39	416	52	82	0	0	0	589

Table 3 - No of hinges developed at performance level

4.5 CHARTS

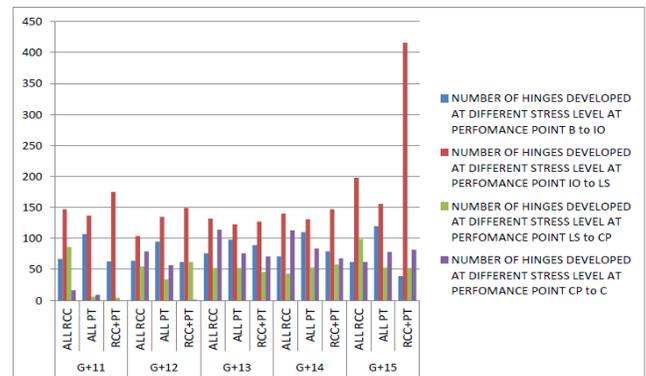


Fig 8 - no of hinges developed at performance level

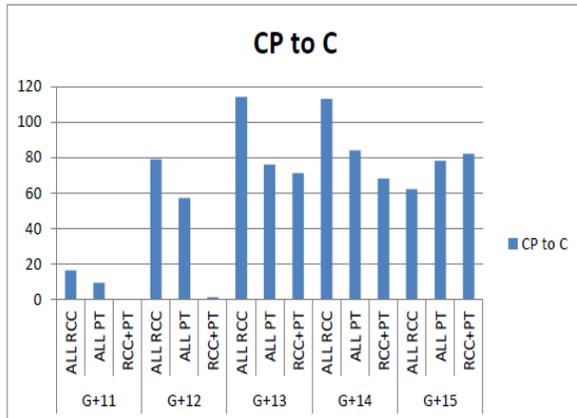


Fig 9 - Collapse level of members at different types of building

CONCLUSION

From the above results obtained from the seismic performance of RC framed structures having conventional RC beams on the periphery of the building and PT beams in the interior grids of the structure is the best for G+11 to G+15 storey structures. The stress value in the plastic hinges in case of frames with peripheral RC beams and internal PT beams is observed to be not exceeded the collapse stage for all defined hinges in G+11 to G+14 storey building frames and after G+14 the collapse level is increased. It further indicates that the seismic performance for an RC framed structure with all the beams considered as PT beams is also within acceptable level. In spite of the fact that the depth of PT beams is considered to be shallow the seismic performance of frames with all the beams as PT beams is also well within acceptable level for G+11 to G+15 structures.

REFERENCES

[1]. Applied teleology council, ATC-40. Seismic evaluation and retrofit of concrete buildings, vols. 1 and 2, California, 1996.

[2]. CSI, SAP2000, integrated finite element analysis and design of structures basic analysis reference manual. Berkeley (ca, usa): computers and structures mc, 2006.

[3]. Mwafy and. Elnashai(2001), -static pushover versus dynamic collapse analysis of RC buildings "engineering structures magazine, 2001, pp. No. 407- 424.

[4]. FEMA273 (1997),"guidelines for the seismic rehabilitation of buildings "building seismic safety council, Washington, D.C., October 1997

[5]. IS1893:2002,"criteria for earthquake resistant design of structures", bureau of Indian standards, New Delhi.

[6]. IS13935:1993,"repair and seismic strengthening of buildings", bureau of Indian standards, New Delhi.

[7]. Anil k. Chopra,"dynamics of structures "Pearson prentice hall, 2005.

[8]. Ashraf habibullah and stephen pyle(1998),"practical three-dimensional nonlinear static pushover analysis "structure magazine, winter, 1998.

[9]. Virote boonyapinyo¹, nuttawut intaboot², pennung warnitchai³ and nguyen hong tam⁴," seismic capacity evaluation of post-tensioned concrete slab-column frame buildings by pushover analysis", august 1-6, 2004, paper no. 827.

[10]. B. A. Shah* d. A. Mistry* and s. C. Patodi, "seismic evaluation of buildings with post-tensioned floors by pushover analysis", vol. 38, no. 5, December 2011-january 2012.

[11]. Alidad hashemi and khalid m.mosalam university of California, Berkeley, "seismic evaluation of reinforced concrete buildings including effects of masonry infill walls", peer 2007/100 , July 2007. 31 [12]. Amalu paul¹, yedu krishnan, "lateral load analysis of post tensioned and RCC building using pushover analysis", volume: 03 issue: 09 | sep-2016.

[13]. ADAPT -structural engineering consultants -structural calculations for post-tensioned beam and one-way slab construction.

[14]. CSI – ETABS – integrated analysis, design and drafting for building system.

[15]. B. K. Raghu Prasad, A. Seetha Ramaiah and A. K. Singh, "capacity spectrum for structures asymmetric in plan", August 1-6, 2004, Paper No. 2653.

[16]. Nilesh M. Kashid, pune , Maharashtra, India, "performance based seismic analysis for buildings in India".

[17]. Shriraj S. Malvade, P. J. Salunke, "A review on seismic assessment of post- tensioned flat slab", volume 2 | issue 12 | June 2016.