PUSHOVER ANALYSIS FOR SEISMIC ASSESSEMENT OF RCC BUILDING

SANGEETHA.S[1], SATHYAPYIYA.A[2]

[1] *M.E Structural Engineering, Star Lion College of Engineering & Technology, Tanjore. Tamilnadu, India*
[2] *Lecturer, Srinivasan Polytechnic College, Perambalur, Trichy, India*

---***---

Abstract – *In India the enormous loss of life and property Perceived in the last couple of decades, attributable to failure of structures instigated by earthquakes. Responsiveness is now being given to the assessment of the sufficiency of strength in framed RCC structures to resist solid ground motions. The seismic reaction of RCC building frame in terms of performance point and the earthquake forces on Reinforced building frame with the help of pushover analysis is carried out in this project. In this method of analysis a model of the building is exposed to a lateral load and the force of the lateral load is slowly increased. With the result the series of cracks, yielding, plastic hinge establishment, and failure of numerous structural components is recorded. Pushover analysis can afford a substantial insight into the weak links in seismic concert of a structure and we can know the weak zones in the structure. In the present study an existing building frame is designed and evaluated as per Indian standard and also suggests the recommended retrofitting methods to strengthened the existing structure. The pushover analysis of the RCC building frame is carried out by structural analysis and design software SAP 2000.*

Key Words: **(Seismic evaluation, Non-linear static procedure, performance point, pushover analysis, pushover curve)**

1.INTRODUCTION

The rapid discharge of energy in the earth's crust forms seismic waves which arrive at various instance of time with different intensity levels are called as earthquake. It causes the random ground motion in all directions, radiating from epicentre, which causes structure to vibrate due to which induce inertia forces in them. Many existing structures are seismically deficient due to lack of awareness regarding seismic behaviour of structures. Due to this, there is vital requirement to converse this situation and do the seismic assessment of existing and proposed structures.

In relation to the Seismic Zoning Map of IS: 1893-2002, India is separated into four zones on the basis of seismic actions. These zones are names ad Zone II, Zone III, Zone IV and Zone V. Chennai lies in Zone III. There are numerous RCC buildings frames that have primary structural system, which do not meet the present-day seismic necessities and suffer wide-ranging destruction through the earthquake.
The RCC buildings at Chennai were designed by principal structural system and the reason behind this is Chennai lies in ZONE II of Seismic Zone Map of 1984, which says the region is smallest possible for earth quakes. In the fifth revision of Zoning map of 2002, with a view to keep abreast with the Rapid development and extensive research that has been modified and according to this map, most of the cities in Chennai lies in Zone III.

2. OBJECTIVE

Seismic Engineering is the extensive category of Structural engineering. The main objectives for evaluating the structures for seismic performance are

1. To recognize collaboration of structures with the instable ground.
2. To anticipate the significances of possible earthquakes.
3. To design, construct and maintain structures to perform at earthquake experience up to the potentials and in passivity with building codes.

Seismic analysis is a part of structural analysis and is the control of the reaction of a structure to earthquakes. It is part of the system of structural design, earthquake engineering or structural evaluation and retrofit in regions where earthquakes are predominant.

3. SEISMIC EVALUATION AND RETROFITTING

The aim of seismic evaluation is to assess the possible seismic response of buildings, which may be seismically deficient or earthquake damaged, for its possible future use. The evaluation is also helpful for adapting the retrofitting of structure. The means of retrofitting is to upgrade the strength and structural capacity of an existing structure to enable it to safely withstand the effect of strong earthquakes in future.
Retrofitting of existing buildings and related issues of their structural safety have not received adequate attention in India. There are at present no guidelines or codes of practice available in the country for retrofitting. The methods of seismic of existing buildings are not adequately developed. In developed countries researches on seismic evaluation and retrofitting have been undertaken during last two decades.

4. GENEARAL PROCEDURE FOR PUSHOVER ANALYSIS

Non Linear Static Analysis (POA) can be performed as either force-controlled method or displacement controlled method

Based on the physical nature of the load and the performance estimated from the structure. Force-controlled method is utilized when the gravity load is known and the structure is predictable to support the load.

Displacement controlled method is utilized when specified drifts (Seismic Loading) are pursued, In this method, the magnitude of the applied load is not known in advance and where the structure can be expected to lose strength or become unbalanced.

Some computer programs can model nonlinear performance and execute pushover analysis directly to get capacity curve for two and/or three dimensional models of the structure. These programs are ANSYS, non-linear version of Sap 2000, Seismostruct and Drain-2DX.

Some programs are not obtainable or the obtainable computer programs could not perform pushover analysis directly, such as ETABS, RISA, SAP90,in these programs a series of consecutive elastic analyses are implemented and superimposed to develop a force displacement curve of the overall structure.

A displacement-controlled Non Linear Static analysis (Push over Analysis) is fundamentally composed of the following steps:

1. The overall behavior of structure is created in a two or three dimensional model in a computer program.
2. The defined lateral response of all important members are affected by the bilinear load-deformation diagrams
3. Initially the dead loads composed for gravity loads and live loads are applied to the structural model.
4. Apply the lateral load pattern which are predefined and distributed along the building height.
5. Applied Lateral loads were increased slowly until some members yield under the collective effects of gravity and lateral loads.
6. At first yielding, Base shear and roof displacement were recorded.
7. the reduced stiffness of yielded members, the structural model has modified
8. A new lateral load increment was apply to the modified structural model after removing gravity loads, such that supplementary members yield. Note that under each incremental lateral load, a separate analysis with zero initial conditions is implemented on modified structural model, Thus member forces at the end of an incremental lateral load analysis has obtained by adding the forces from the current analysis to the sum of those from the previous increments. In other words, the results of each incremental lateral load analysis are superimposed.
9. Similarly, the lateral load and the roof displacement increment are added to the corresponding previous total values to obtain the accumulated values of the base shear and the roof displacement.
10. Steps 7, 8 and 9 are repeated until the roof displacement reaches a certain level of deformation or the structure becomes unstable.
11. The roof displacement is plotted with the base shear to get the global capacity (pushover) curve of the structure (Fig - 1).

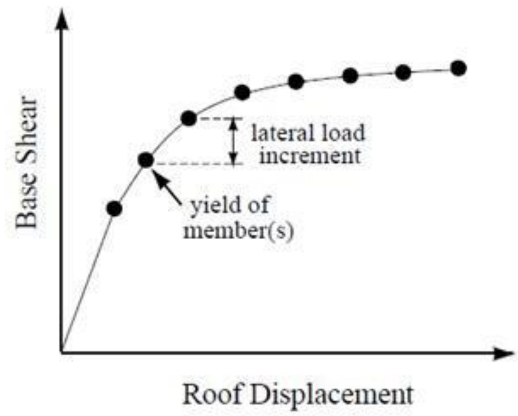

Fig -1: Pushover Curve of a structure

4. SEISMIC EVALUATION OF CASE STUDY BUILDING

4.1 Location Description

The building selected for study is the Vaigai Aparts located at Chennai. The location was chosen for study primarily because a major part of Chennai is seismically prone and is a ‘ High hazard’ earthquake area. At present, Chennai, Coimbatore and Salem fall under Zone III of the Bureau of Indian Standards classification.

4.2 Building Description

The building selected for evaluation is a residential, ordinary moment resisting RC framed building, located in Zone IV. Figure 1 shows the typical floor plan of the building. The building is a four storied (G+3) building. The height of the roof is 14.05 m from the ground level. Plan dimensions of the building are 40.70m ×11.5m. The construction drawings specify that M20 grade of concrete (characteristic cube compressive strength is 20 N/mm^2) and Fe 415 grade of steel (characteristic 0.2 percent proof stress is 415 N/mm^2) were used for the construction.

4.3 STRUCTURAL SYSTEM DESIGN DETAILS

The case study building was designed in accordance with the 1963 building code. The structural system consists of perimeter moment-resisting frames and interior column slab frames. There are eleven frame bays in EW direction; each bay is approximately 3.7m in length. There are three frame bays in the NS direction; Outer bays are approximately 4.6m in length and center bay is 2.3m in length.

4.4 OBSERVED DAMAGE

The building suffered minor structural damage and extensive non-structural damage during the Earthquake. This damage was repaired subsequently. Repair of the structural damage was limited to a single beam-column joint at the northeast corner of the building. Non structural damage was most severe on the 2nd and 3rd floors. About 80% of the total repairs costs were allocated for the damaged gypsum wall partitions, bathroom tile and plumbing fixtures. The cost of the repair for the non-structural damage was approximately 10% of the initial construction cost of the building at that time.
The development of cracks and eventually shear failure in the columns might be attributed to the poor transverse reinforcement in the columns as discussed in the previous section. As a result of the shear failures, the vertical reinforcement between the widely spaced ties buckled due to loss of concrete cover. The south perimeter frame was supported with temporary shoring after the earthquake. Some beam-column joints on the 3rd, 4th story in the north perimeter frame and on the 3rd story in the south perimeter frame experienced minor to moderate cracking.
Non structural damage during earthquake was not very extensive and was mostly confined to the 4th story. Doors, windows and drywall partitions in the east-west direction suffered severe damage between the 3rd and 4th floor levels. This is attributed to the large deformation of this story during the earthquake.

4.5 IMPLEMENTATION OF PUSH OVER ANALYSIS

The building has modeled to carry out nonlinear static pushover analysis. The critical sections of beams, columns has requires the development of the force deformation curve. The force deformation curves in flexure was obtained from the reinforcement and details were assigned for all the beams and columns. The Nonlinear properties of members was assign to the computer. The flexural default hinges and shear hinges were assigned to the beams at two ends. The interacting frame hinges type a coupled hinge property was also assigned for all the columns at upper and lower ends.

5. RESULT & DISCUSSION

A Four storied reinforced concrete frame structure of building was taken to analysis. The frame was subjected to design earthquake forces as specified in the IS code for zone IV along X directions The frame was subjected to design earthquake forces as specified in the IS code for zone IV along X directions. Bare frame pushover curves for the building in X directions as shown in Figure 2. These curves show the behavior of the frame in terms of its stiffness and ductility. For bare frame average base shear from pushover analysis is 109.39 KN and average displacement of 49.83 mm in X direction.

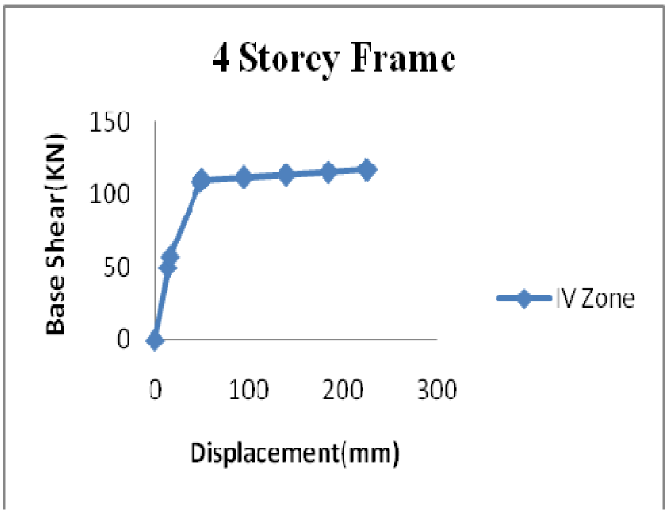

Fig -2: Pushover Curve of the case study building

Capacity spectrum is the capacity curve spectral acceleration Vs spectral displacement (S_a Vs S_d) co-ordinates. The curve shows spectral displacement and spectral acceleration. The performance point for a given set of values is defined by the intersection of the capacity curve (green) and the single demand spectrum curve (Red).

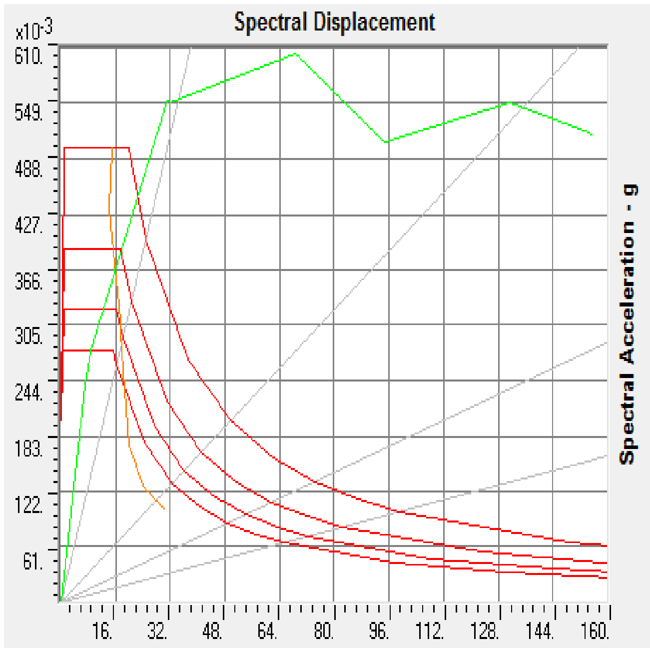

Chart -1: Capacity Spectrum of case study building

The performance point is obtained by superimposing demand spectrum on capacity curve transformed into spectral coordinates. The frame shows the performance of the on the spectral acceleration corresponding to the performance point. The performance point is obtained at a base shear level of 61.75KN and displacement of 17.77mm in the X direction.

6. CONCLUSION AND SUGGESTION

The pushover analysis is a one of easy way to analysis the nonlinear behavior of the buildings. The results obtained in by pushover demand, capacity spectrum and plastic hinges the real behavior of structures. In a multi storey building seismic zone IV is designed and constructed using IS-456-1978 and the revised code IS-1893- 2000 provisions. Hinges has developed in the beams and columns showing the three stages immediate occupancy, Life safety, Collapse prevention. The column hinges have limited the damage.

The following Retrofitting Techniques were suggest for the case study building to strengthening against seismic forces.

1. **Minor Cracks** – Repaired by injecting epoxy resins

2. **Buckled Longitudinal Reinforcement, Broken Ties, and crushed concrete** – Replacement of new reinforcement welded with the existing bars and provide new additionally closed ties were , concrete with low shrinkage properties need to be used.

3. **Severely damaged Columns adjacent to added walls** – Retrofit with encasing in concrete with appropriate longitudinal and transverse reinforcement, existing surface should be chipped and cleaned of all loose materials. The surface was moistened before the placing new concrete.

4. **Wall with slight damage** – Demolished and repaired with new concrete walls with 200mm in thickness.

7. FUTURE SCOPE OF STUDY

i. An inclusion of shear failure limits in the performance criteria may lead to a better and more comprehensive understanding of the building's behavior.
ii. Non-linear time history analysis can be used for the structure to have a more accurate assessment of the structure's capacity and understanding a more realistic demand scenario.
iii. Building designed with IS 1893:2002 found to have a better performance under given earthquake.
iv. The performance point base shear is greater than the design base shear the building frame is safe under the earthquake loading.

Reference:

[1] Agarwal P., Shrikhande M. (2004): Earthquake Resistant Design of Structures, PHI Publication.
[2] Akbas, B., Kara, F.I., and Tugsal, U.M. (2007), "Comparison of Pushover Analysis and Nonlinear Dynamic Time History Analysis on Low-, Medium-, and High-Rise Steel Frames", Project No. 02-A-02-01-03, Scientific Research Project Fund, Gebze Institute of Technology.
[3] BIS, IS 1893 (Part 1): (2002): Criteria for Earthquake Resistant Design of Structures Part-1 General Provisions and Buildings, Bureau of Indian Standards, Fifth revision.
[4] BIS, IS 456:2000, Plain and reinforced concrete code of practice, Bureau of Indian Standards, Fourth revision.
[5] BIS, IS 13920:1993, Ductile detailing of reinforced concrete structures subjected to seismic forces — Code of practice, Bureau of Indian Standards, Second revision.
[6] BIS, IS 875(Part 5):1987, Code of practice for design loads (other than earthquake) for buildings and structures, Bureau of Indian Standards, Second revision
[7] Goel R. K. (2008): Evaluation of Current Nonlinear Static Procedures for Reinforced Concrete Buildings, The 14th World Conference on Earthquake Engineering October 12-17, 2008, Beijing, China
[8] Kadid A., Boumrkik A. (2008): Pushover Analysis of Reinforced Concrete Frame Structures, Asian Journal of Civil Engineering (Building and Housing) Vol. 9, No. 1(2008).
[9] Krawinkler H., Seneviratna G.D.P.K. (1998): Pros and Cons of a Pushover Analysis of Seismic Performance Evaluation, Engineering Structures, Vol.20, 452-464.
[10] Lawson R.S., Reinhorn A.M., Lobo R.F. (1994): Nonlinear Static Pushover Analysis -Why, When and How? Proceedings of the 5th US National Conference on Earthquake Engineering, Chicago, Vol. 1, 283-292.
[11] Otani S. (2000): Seismic Vulnerability Assessment of Reinforced Concrete Buildings, Faculty of Engineering, University of Tokyo, Series B, Vol., XLVII, October 2000, pp. 5- 28.
[12] Poluraju P., Nageswara Rao P. V. S. (2011): Pushover analysis of reinforced concrete frame structure using SAP 2000, International Journal of Earth Sciences and Engineering, ISSN 0974-5904, Volume 04, No 06 SPL, pp. 684-690.
[13] Seismostruct (2012), "SeismoStruct - A computer program for static and dynamic nonlinear analysis of framed structures", [online]. < http://www.seismosoft.com/ > (July 20,2012)
[14] Tamboli H. R., Karadi U. N. (2012): Seismic Analysis of RC Frame Structure with and without Masonry Infill Walls, Indian Journal of Natural Sciences, ISSN: 0976 – 0997, Vol.3 / Issue 14/ October 2012.23.