IJESRT
INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

SEISMIC EVALUATION OF REINFORCED CONCRETE BUILDING

Deepti Singh *, Dr. ShriRam Chaurasiya
*Civil Department, MMMUT (Gorakhpur, U.P.), INDIA

ABSTRACT
In the study of evaluation for retrofitting of any building made up of reinforced concrete is done by using method of inelastic method, capacity curve method etc. Capacity curve which is load deformation plot is output of inelastic method. As this inelastic analysis is non linear static analysis, so load deformation curve is obtained from ANSYS. ANSYS which is based on finite element method is used for performing the non liner static inelastic analysis and cracking pattern can be analyzed in ANSYS. The need of retrofitting of any particular element of any existing building will be obtained by cracking pattern. In this first symmetrical building is analyzed on ANSYS for the procedure development as per ATC-40 then symmetric evaluation is done on unsymmetrical building designed for without considering seismic effect and then same building considering the seismic effect according to IS 1893:2002. These results then compared for suggestion for retrofitting of affected members.

KEYWORDS: elastic-curve, response spectrum, ATC procedure, retrofitting, cracking pattern.

INTRODUCTION
During earthquakes, buildings that appear to be strong enough, crumble like houses of cards and their deficiencies are (may be) exposed. Certain past earthquakes for e.g. earthquakes of Bhuj, 2001, show that most of the buildings collapsed were deficient and did not meet the requirements of the present day codes. Thus, due to the ignorance for earthquakes resistant designing of buildings in our country and also wrong construction practices occurring in India, most of the buildings are vulnerable to earthquakes occurring in future.

Seismic designing, in a simplest case is observed to be a two-step process. Firstly, the most important, is the conception of an effective structural system that needs to be configured keeping in mind all-important objectives of seismic performance, ranging from the serviceability of the structure, considering life safety and also keeping in mind the collapse prevention. This step mainly involves the art of seismic engineering as no rigid rules can, or should, be imposed on the creativity of the engineers. By default, the creation process is based on judgment, experience and understanding of the seismic behaviour rather than tedious and rigorous formulations by using mathematics. For an effective structural system, certain point need to be kept in mind-Rules of thumb for stiffness and strength (desired) targets that is based on the fundaments of ground motion and elastic and inelastic dynamic response characteristics. This would help to configure and roughly size an effective structural system.

Secondly (second step), step of design process which should involve demand /capacity/evaluation at all important performance levels, which also requires and involves the identification of all important capacity parameters and also prescription of demands imposed by the ground motions .Suitable capacity parameters and their acceptable values along with a very well suitable methods for demand prediction will depend on the performance level that is to be evaluated. Thus, the above facts shows that it is imperative to seismically evaluate the past/existing buildings with the present day knowledge, so that major quantity of destruction can be avoided in future earthquakes. Thus, buildings found to be seismically deficient should be strengthened/retrofitted is our need. In this report, the evaluation of R.C buildings using inelastic method (Pushover Analysis) is adopted. Capacity Curve, which is Load-Deformation Plot is the Output of Pushover Analysis. As, Pushover Analysis is Non-Linear Static Analysis, so the Load-Deformation Curve can be obtained from ANSYS. Finite Element Software ANSYS 5.4 is used to perform the Non-Linear Static Pushover Analysis and Cracking pattern can also be observed in ANSYS. Cracking Pattern provides the need for Strengthening required for particular Elements. Capacity Curve is obtained from ANSYS 5.4, and Response Spectra as given in I.S 1893:2002 is used. Staad.Pro 2003 has been used to provide the Reinforcement, which is required as Input parameter for ANSYS.

Spectra as given in I.S 1893:2002 is used. Staad.Pro 2003 has been used to provide the Reinforcement, which is required as Input parameter for ANSYS

METHODS

1. ATC-40 PROCEDURE FOR SEISMIC EVALUATION

Step-by-Step Procedure to determine capacity:

The most suitable way to plot force displacement curve is by detecting the base shear and roof displacement. The capacity curve is generally made to represent the initial mode response of the structure based on the postulation that the fundamental mode of motion is the major response of the taken structure. This is basically valid for buildings with the fundamental periods of vibration upto about 1 second limit. For more flexible buildings with the fundamental period > 1 second, the analyst should take into account addressing higher mode effects is the done analysis.

1. Creating a computer model of the structure following the modeling rules as given in ATC-40.
2. Classifing each element in model as either primary or secondary.
3. Apply lateral storey forces to the structure in ratio to the product of the mass and fundamental mode shape. This analysis need to also include gravity loads.

[As the name implies, it is the process of pushing horizontally with a approved loading pattern. Incrementally till the structure reaches a limit state. There are several levels of sophistication that may be used for the pushover analysis]

i) Simply appling a single concentrated horizontal force at the top of the structure (for one storey building)

ii) Appling lateral forces to each storey in proportion(ratio) to the standard code procedure excluding the concentrated force F_t at the top

i.e.$F_x = (W_x h_x / \Sigma P W_x h_x) \times V$ …………(1)

iii) Appling lateral forces in proportion to the product of storey masse and first mode shape of the elastic model of the structure.

i.e.$F_x = (W_x \Phi_x / \Sigma W_x \Phi_x) \times V$. ………(2)

The capacity curve is usually constructed to represent the first mode response of the structure based on assumption that the fundamental mode of vibration is the predominant response of the structure.

iv) Same as level three till first yielding. Fo each increment beyond yielding , regulate the forces to be consistent with changing deflected shape.

v) Similar to (iii) & (iv) above, but include the effects of the higher mode of the vibration in determining yielding in individual structural elements while plotting the capacity curve for the building in terms of first mode lateral forces and displacements. The higher mode effects possibly be determined by doing higher mode pushover analysis. (i.e. Loads may be progressively implied in proportion to a mode shape other than the fundamental mode shape to determine it in elastic behavior) For the higher modes the structure is being both push & pulled concurrently to maintained mode shape.

4. Calculate the member forces for the required combinations of vertical and lateral loads.
5. Adjusting the lateral force level so that some elements (on group of elements) are stressed to lie within 10% of its member strength.
6. Recording the Base shear and the roof displacement. (It is also helpful to record the member forces & rotations because they will be required for the performance check).
7. Revise the model using zero (or very small) stiffness for yielding elements.
8. Appling a new increment of lateral load to the revised structure such that another element (or group of elements) yields.

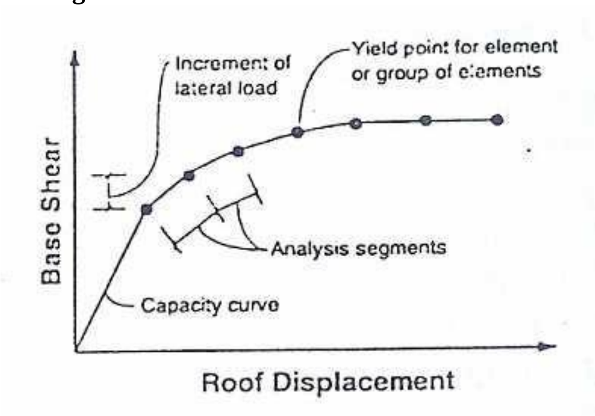
[The actual forces and rotations for elements at the starting of the increment are equal to those at the end of the previous elements. However, each application of an increment of lateral load is a different analysis, which starts from zero initial conditions. Thus, to determine when the next elements yields, it is necessary to add the forces from the current analysis to the some of those from the previous increments.

9. At the increment of the lateral load and the corresponding increment of roof displacements to the previous total to give the accumulated values of base shear and roof displacement.

ISSN: 2277-9655
(I2OR), Publication Impact Factor: 3.785

Repeat steps 7,8 & 9 till the structures reaches an ultimate limit such as: instability from P-effects, distortions considerably beyond the desired performance level, an element attainment a lateral deformation level at which significant strength degradation begins.

Figure:**1**



Capacity Curve

Conversion of Capacity curve to the capacity spectrum:

To use the capacity spectrum method it is essential to convert the capacity curve, which is in terms of base shear and roof displacement to what is called a capacity spectrum, which is a representation of the capacity curve in Acceleration Displacement Response Spectra (ADRS) format i.e. (S_a vs S_d). The required equations to make the transformation are:

$PF_1 \quad = \quad \{\Sigma_{i=1} (w_i\, \Phi_{i1})/g\} \,/\, [\Sigma_{i=1} \{w_i\, (\Phi_{i1})^2/g\}]$

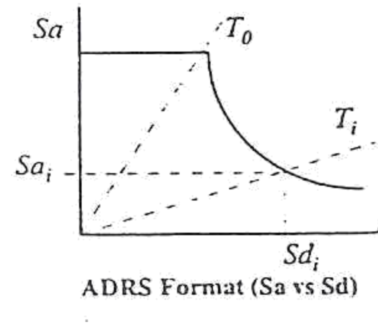
$\alpha_1 \quad = \quad \{\Sigma_{i=1} (w_i\, \Phi_{i1})/g\}^2 / \{\Sigma_{i=1} (w_i/g\}\ \ X\ [\Sigma_{i=}\{w_i(\Phi_{i1})^2/g\}]$

$S_a \quad = \quad (V/W)/\alpha_1$

$S_d \quad = \quad (\text{ roof}) / (PFi\Phi roof.1)$

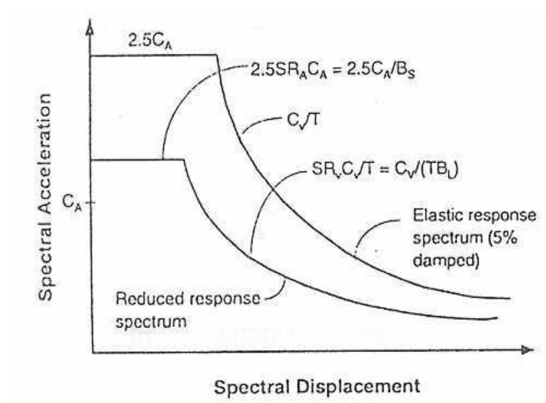
Where, PF_i = Model participation factor for the first natural mode, α_1 = Model mass coefficient for the first natural mode,PW_i/g = mass assign to level i, Φ_{il} = amplitude of mode one at level i, N = Level N, the level which is the uppermost in the main portion of the structure.

Figure:**2**



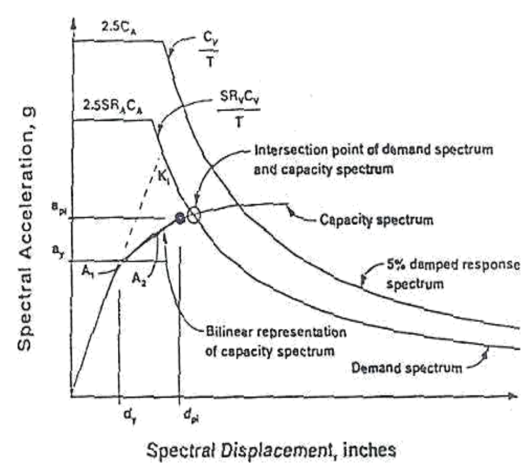
Capacity Curve (ADRS Format)

Calculating performance point
Figure:**3**



Reduced Response Spectrum

Figure:**4**



Final point of intersection location

The demand spectrum crosses the capacity spectrum within acceptable tolerance than the trial performance points a_{pi}, d_{pi} is the performance point, a_p d_p and the displacement d_p represents the maximum structural displacement probable for the demand earthquake.

SEISMIC EVALUATION OF SYMMETRICAL BUILDING FOR PROCEDURE DEVELOPMENT

To facilitate the procedure provide in ATC 40, a 3-D finite element model (single bays along x and z-axis have height of 10.5m) is taken. Capacity Curve, which is a Load-Deformation plot is obtain by using ANSYS. Staad Pro 2003 has been old for designing purpose and modes shapes calculation. After Viewing Cracking pattern, Strengthening of affected members is suggested.

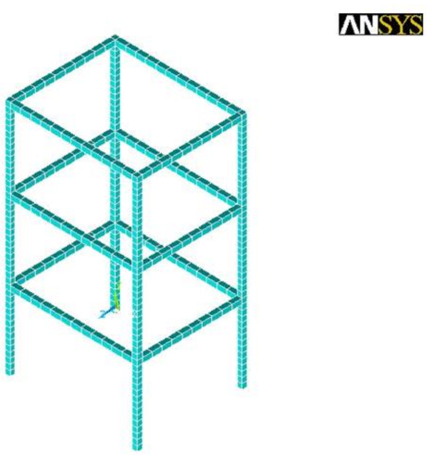
The FEM model include all the structural components of the building and is composed of 3 elements of: SOLID 65. Reinforcement is incorporated by Volume Ratio. Modal Analysis has been performed by using Staad Pro 2003 and Non-Linear Static Analysis is performed on the Model by using ANSYS 5.4.

Building Taken for Procedure Development

The Base of the Building has horizontal dimension of 6m x 5m. It has single bay along x-axis and z-axis. Height of the building be 10.5m with each storey height of 3.5m. It is assumed to be located in Zone 4 with Z = 0.24. Structural details be as follows: Slab Thickness is assumed to be 125mm.

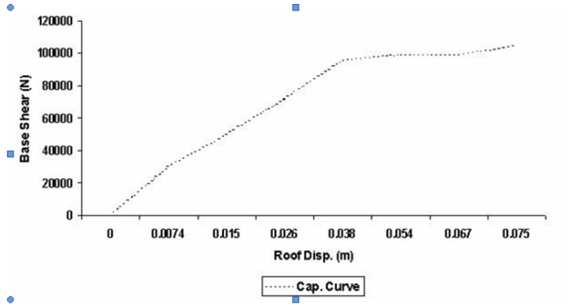
Columns (0.3X0.3) 4-20mm φ,
ties: 8mm@150mm c/c
Beams (0.23X0.23) 2-16mm φ (at centre), 2-16mm φ (at ends) , ties: 8mm@150mm c/c

Figure:5



Modeling and meshing of the taken building

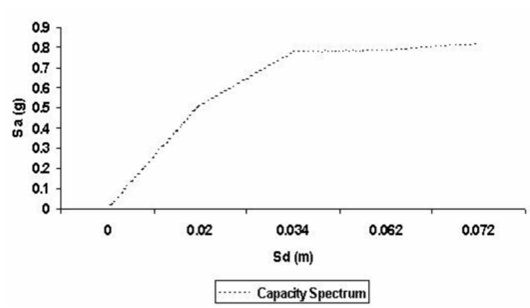
Figure:6



Capacity curve

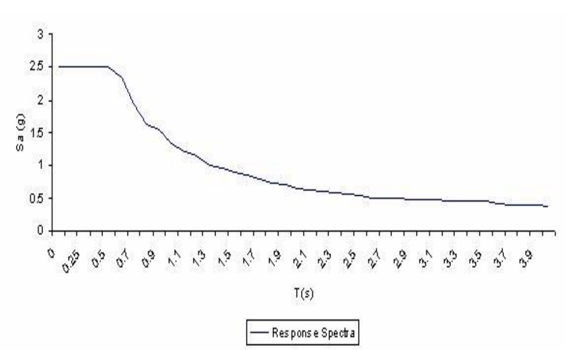
Development of Capacity Curve for an existing Building, in itself, is very useful and yield insight into the building's performance characteristics as well as methods of retrofit. To judge suitability for a given performance objective, either for the condition or for a retrofit scheme, the probable maximum displacement for the specified ground motion must be predictable.

Figure:7



Capacity spectrum(ADRS format)

Figure:8

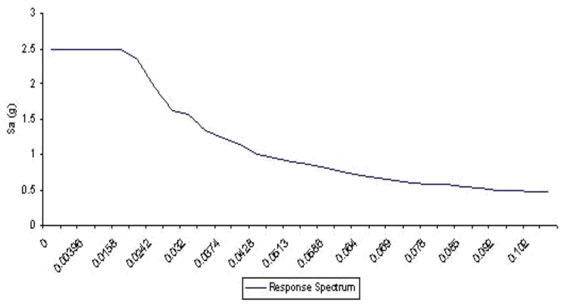


Response spectrum

Response Spectra (for 5 percent Damping) is taken from I.S 1893:2002, for Type II

(Medium Soil) which is a Plot between Sa/g and T, as shown above.Response Spectra for 5 percent Damping; Standard Format (Sa vs T).Every point on a response spectrum curve has been linked with it a unique spectral acceleration Sa, Spectral Displacement Sd, and period T. To change a spectrum from the standard Sa vs T format to ADRS format, it is essential to determine the value of Sd_i for each point on the curve, Sa_i, T_i

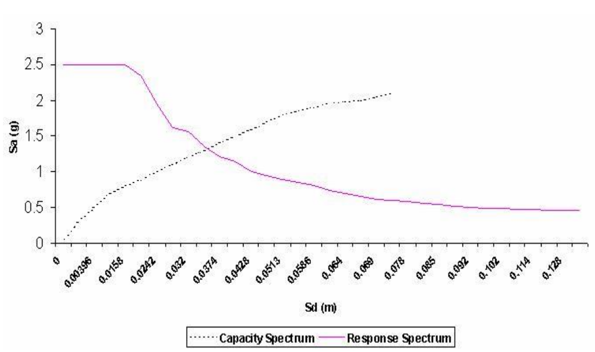
Figure:**9**



Response spectrum in ADRS format

On plotting Capacity Spectrum and Response Spectrum on the same graph the performance point and target displacement is obtained.

Figure:**10**



Intersection of Response Spectrum and Capacity Spectrum

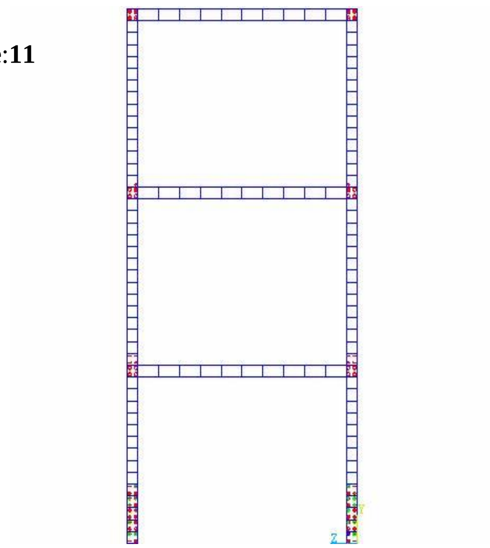
Following Observations were made from the above Graph:

a) Capacity Spectrum meet Response Spectrum at 0.037m (S_d), and the corresponding Base Shear V=41510 N . Base Shear (V_B) as per IS 1893:2002 is 28431 N i.e. the structure can resist horizontal shear up to that value. Value of Target Displacement is 0.045 m, i.e. the margin of safety decreases further than that target value.

b) Response Spectrum intersects Capacity Spectrum in its elastic-range,which means that the structure is unsafe.

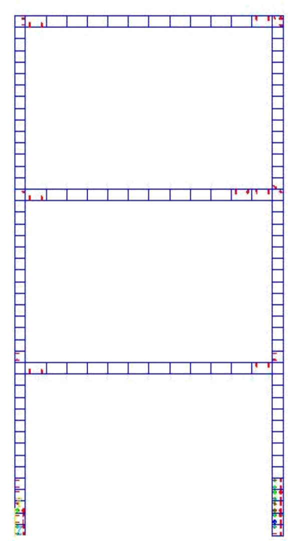
Now from the value of target displacement (45mm), the cracking at that particular point in the structure will be calculated. In General Post Processor in ANSYS, the displacement value of 45mm is entered to plot cracking in the Structure. The cracking in the structure elements is shown as follows.

Figure:**11**



Back View showing cracking

Figure:**12**



Front View Showing Cracking

RESULTS AND DISCUSSION

Following Observations were made from the above Analysis:

ISSN: 2277-9655
(I2OR), Publication Impact Factor: 3.785

From the cracking pattern it is seen that the majority of cracks were occurred at base column and column-beam joints at first storey i.e. the Base Column are severely affected by the earthquake excitation.

1. First Storey Column was also affected with several cracks at their bottom joints.
2. Beams along z-axis were least affected in this structure. Cracking occurred near the ends in the Beams which were along the x-axis (i.e along excitation).

It can be said that Strengthening is required in the columns at Base and First Storey Level.

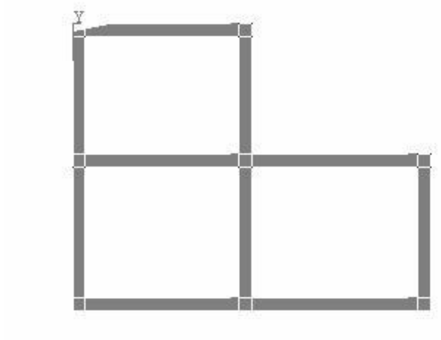
Seismic Evaluation Of L-Shaped Building

Analysis of an Unsymmetrical building (L-shape) is done in following manner:

1. Seismic Evaluation of L-shape building designed by Dead Load and Live Load only (without incorporating I.S 1893:2002 guidelines).
2. Seismic Evaluation of L-shape building designed as per I.S 1893:2002.

After Performing Analysis, results of both have been compared and the strengthening is suggested for most severely affected members.

Figure:13

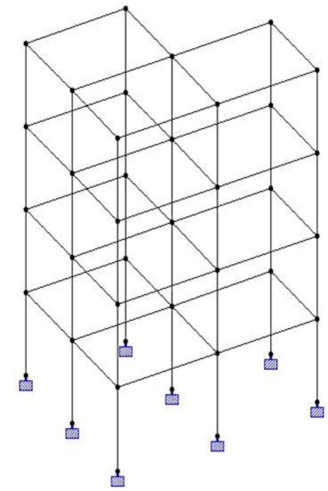


Plan of L-shaped building

According the above plan of L-shape building, along x-axis, the bay span is 5m, and along z-axis, the bay span is 4m. Let the total height of the building be 14m with each floor height of 3.5m. This building is designed by Staad.Pro 2003 for Dead Load and Live Load case only for getting the Reinforcement Details. Parameters used in Staad.Pro are as follows:

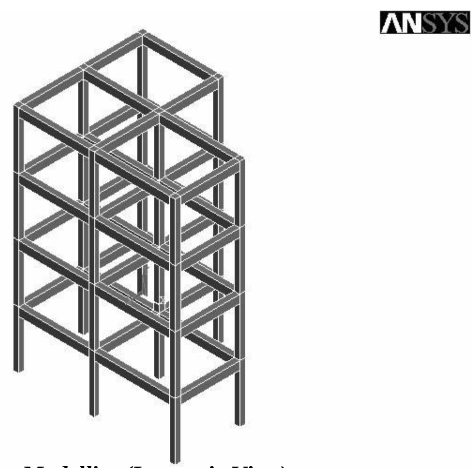
Columns (0.345mX0.345m) 4-16mm φ
ties: 8mm @ 150mm c/c
Beams(0.345mX0.5m)3-16mmφ(positive steel at centre)
2-16mmφ(negative steel at ends)
ties: 8mm @ 150mm c/c

Figure:14



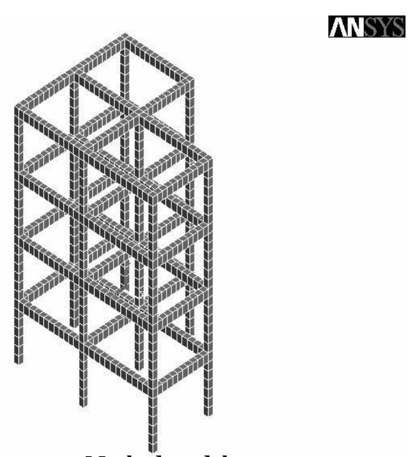
Stadd pro model

Figure:15



Modelling(Isometric View)

Figure:16



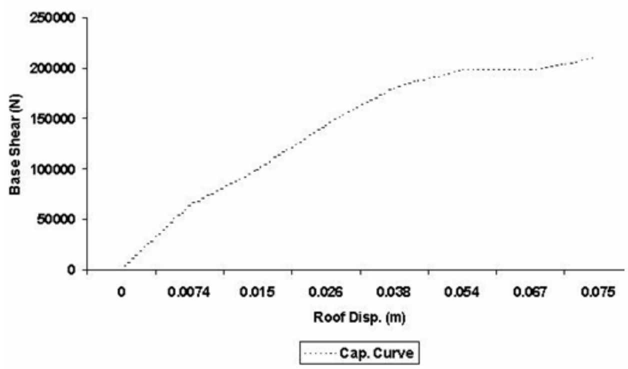
Meshed model

Fine Mesh is created on this model obtained.
Size Controls:

All Column Elements Lines have been divided into 7 divisions, All the Beams along x-axis have been divided into 12 divisions, and the number of divisions for Beams along z- axis is 10. These divisions have been calculated by considering the fact that the mesh should be fine such that all the nodes at Beam-Column Joints should be connected.

After Meshing, all the nodes have been merged with Range of Coincidence 0.001 in Numbering Controls Option.

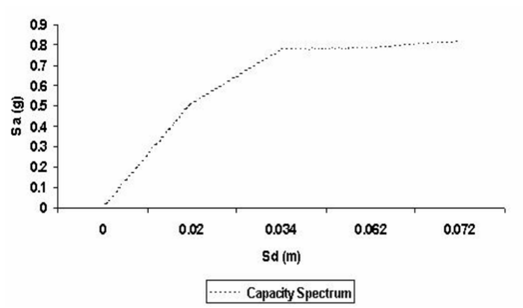
Figure:**17**



Capacity curve

Response Spectra (for 5 percent Damping) is taken from I.S 1893:2002, for Type II (Medium Soil) which is a Plot between Sa/g and T has been shown.

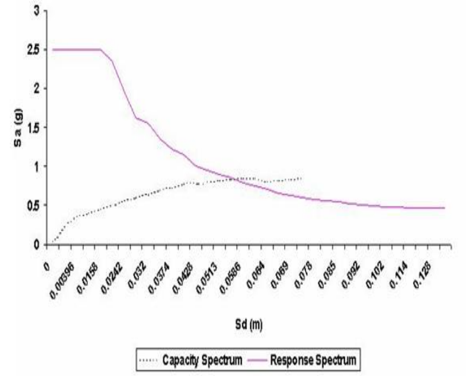
Figure:**18**



Capacity spectrum (ADRS format)

Capacity Spectrum meets Response Spectrum at 0.059m (i.e Sd), and the corresponding Base Shear (V) is 98990 N

Figure:**19**



Intersection of Capacity Spectrum and Response Spectrum

RESULTS AND DISCUSSION

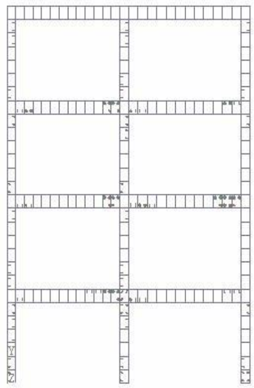
Following Observations are made from the above Graph.

a. Capacity Spectrum meets Response Spectrum at 0.059m (i.e Sd), and the corresponding Base Shear (V) is 98990 N . Value of Base Shear (V_B) as per IS 1893:2002 is 98953 N, which means that the structure has been designed to resist Base Shear upto 98 KN only and after that the structure fails. Value of Target Displacement is 66mm. Performance Point lies in the non-linear range.

b. Response Spectrum intersects Capacity Spectrum in in-elastic range, which means that the structure is unsafe.

Now, we use the value of target displacement (66mm), to find out the cracking at that particular target displacement in the structure. In General Post Processor in ANSYS, the displacement value of 66mm is entered to plot cracking in the Structure. The following figure shows the cracking in the structure elements.

Figure:**20**



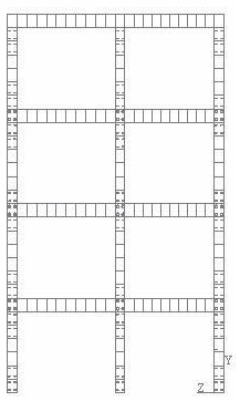
Front View Showing cracking

It can be observed from the Figure that:

1. Beams along x-axis shows cracking as the earthquake excitation is along x-axis.
2. Beams at Top Roof Level are least affected as compared to the beams at other Floor Levels.
3. Beams shows cracking pattern at their joints with Columns.
4. Columns at Base Level are severely affected as shown in above Figures.
5. Strengthening is required mainly at the Beam-Column joints, and at the Base of Columns at Ground Floor as these are severely affected.

It can be seen that the Beams along z-axis are least affected, as the earthquake excitation is along x-axis. And the columns are mostly affected at their Base and at the joints.

Figure:**21**



Back View showing cracking

CONCLUSION

Seismic Evaluation can be done by different methods like elastic method (using DCRs) and In-elastic method (Pushover Analysis) as described in ATC-40 Manual. In this study, Pushover Analysis which is a Non-Linear Static Analysis is adopted to carry out assessment. Finite Element software ANSYS 5.4 has been successfully utilized for getting the non-linear response of the structure. Capacity Curve, which is a Load-Deformation Plot (after exceeding the elastic limit), is obtained from ANSYS, which can be used further for getting the requirement of strengthening in members. Based on the study carried out, it can be concluded that:

1. ANSYS can be used as an efficient tool for performing Pushover Analysis. It can be used to assess the seismic of both new and accessible structural systems
2. If the Performance Point lies surrounded by the elastic stage, the building can said to be secure. And if Performance Point lies in in-elastic range, strengthening is required in the affected members, as can be obtained from ANSYS cracking pattern. Limiting Value of Base Shear can also be found out from the Demand and Capacity Envelopes.
3. Seismic Evaluation by Non-Linear Static Analysis exposes design weaknesses that may remain hidden in an elastic approach. Such weaknesses include excessive deformation demands, strength irregularities, and overloads on potentially brittle points, such as columns and connections.

The unsymmetrical Building studied shows that a lot of retrofitting is required if seismic effect is not taken into design considerations. However, in case of analysis of seismically designed building, strengthening is needed at Beam-Column Joints because ductile detailing has not been incorporated.

REFERENCES

1. ATC 40,"Seismic Evaluation and Retrofit of Concrete Buildings", Vol. 1 & 2, Applied Technology Council, Redwood City, CA, USA, Report No. SSC 96-01, Nov. 1996.
2. Bernal Dionisio," Instability of Buildings during Seismic Response", Engineering Structures, Vol. 20, Nos. 4-6, pp. 496-502, 1998.
3. Bhardwaj S.," Seismic Evaluation and Retrofitting of Multistoreyed RC Frame Building", M.E Dissertation in Earthquake Engg., IIT Roorkee, 2002.
4. Bracci J.M., Kunnath S.K., Reinhorn A.M.,"Seismic. Performance and Retrofit Evaluation of Reinforced Concrete

Structures", Journal of Structural Engg., pp. 3-10, Jan 1997.
5. Chen P., Collins K.R., " Some observations on performance-based and reliability-based Seismic Design of a symmetrical building", Engineering Structures, Vol. 23, pp 1005-1010, 2001.
6. Dinh T.V., Ichinose T.,"Probabilistic Estimation of Seismic Story Drifts in Reinforced Concrete Buildings", pp 416-427, Journal of Structural Engineering, March 2005.
7. Dooley,L., and Bracci, J.M. (2001)."Seismic evaluation of column-to-beam strength ratios in reinforced concrete frames." ACI Struct. J., 98(6), pp 834-851.
8. Habibullah A., Pyle S.," Practical Three Dimensional Non-Linear Static Pushover Analysis", Published in Structure Magazine, Winter, 1998.
9. Ichinose, T., and Umeno, T. (2000)." Story shear safety factor to prevent story collapse in RC building." Proc., 12th World Conf. On Earthquake Engg.
10. Ichinose, T., Umemura, H., Kagohashi, H., and Dinh, T.V. (2002)." Shape index for seismic evaluation of RC Buildings". J. Struct. Construction Engg., 560(10), 155-160.
11. IS 1893 (Part 1): 2002," Criteria for Earthquake Resistant Design of Structures", Bureau of Indian Standards, New Delhi.
12. IS 13920: 1993, "Ductile Detailing of Reinforced Concrete Structures Subjected to Seismic Forces-Code of Practice", Bureau of Indian Standards, New Delhi.
13. IS 456: 2000, "Plain and Reinforced Concrete-Code of Practice", Bureau of Indian Standards, New Delhi.
14. Jan T.S., Liu M.W., Kao Y.C.,"An upper-bound pushover analysis procedure for estimating the seismic demands of high-rise buildings"., Engineering Structures 26(2004), pp 117-128.
15. Jain A.K.," Advanced Structural Analysis with Computer Applications
16. Jor F.C., Duke L.M, Yu Z.," Finite Element Analyses of Seismic Response of Berkeley Town House"., Lawrence Berkeley National Laboratory, August 2002.
17. Krawinkler H., Seneviratna G.D.P.K.,"Pros and Cons of a pushover analysis of seismic performance evaluation", Engineering Structures, Vol. 20, Nos 4-6, pp 452-464, 1998.
18. Kunnath, S., K., Reinhorn, A., M., and Lobo, R. F.(1992)."IDARC version 3.0- a program for inelastic damage analysis of reinforced concrete
19. structures." Tech. Rep. NCEER-92-0022, Nat. Ctr. For Earthquake Engg. Res., State Univ. of New York at Buffalo.
20. Kappos, A.,J., Manafpour, A." Seismic design of R/C buildings with the aid of advanced analytical techniques", Engineering Structures 23(2001), pp 319-332.
21. Li J.H., Su R.K.L., Chandler A.M.," Assessment of low rise building with transfer beam under seismic forces", Engineering Structures, Vol. 25, pp 1537-1549, 2003.
22. Makarios T.K.," Optimum definition of equivalent non-linear SDOF system in Pushover procedure of multistoreyed R/C Frames", Engineering Structures, Vol. 27, pp 814-825, 2005.
23. Mwafy A.M., Elhashai A.S.," Static Pushover versus Dynamic Collapse analysis of R.C Buildings", Engineering Structures, Vol. 23, pp 407-424, 2001.
24. Motlagh A.R, Saadeghvaziri M.A.," Non-Linear Seismic Response of stiffening SDOF Systems", Engineering Structures, Vol. 23, pp 1269-1280, 2001.
25. Munshi J.A., Ghosh S.K.," Analyses of Seismic performance of a code designed R.C Building", Engineering Structures, Vol. 20, Nos 7, pp 608-616, 1998.
26. Murty, C., V., R."Quantitative Approach to Seismic Strengthening of RC Frame Buildings", Seminar Proc. On Seismic Assessment and Retrofitting of Buildings, Mumbai, Feb., 2002, pp 19-27.
27. NHERP,"Hand Book for the Seismic Evaluation of Existing Buildings", Building Seismic Safety Council, Washington, D.C 1992.
28. Park, R., and Paulay, T.(1975). Reinforced concrete structures, Wiley, New York.
29. Paz Mario," Structural Dynamics Theory and Computation".
30. Tokoro K., Menum C.A.," Application of the Modal Pushover Procedure to estimate Non-Linear Response Envelopes", Research Summary 2003-04.

ISSN: 2277-9655
(I2OR), Publication Impact Factor: 3.785

AUTHOR BIBLIOGRAPHY

	**Deepti Singh*** PG Student Civil Department Seismic Design And Earthquake Engineering MMMUT,Gorakhpur
	**Dr. ShriRam Chaurasiya** Associate professor Civil Department MMMUT,Gorakhpur src_gkp@rediffmail.com