Seismic Analysis of Vertical Irregularity Rc Building By Extended N2 Method

K. Ramadevi, P. Muthaiyan

Abstract: For the seismic evaluation and design of structures, N2 method of analysis of nonlinear static simplified procedure is adopted. The advancement of N2 procedure is known as extended N2 method and it is made easier to seismic evaluation of irregular structures. A common vertical irregularity found in multi-storied building frames is Asymmetric setback. The present study is made for the G+5 framed Reinforced Cement Concrete vertical setbacks irregularity building in the seismic zone IV. Analysis of the structure was done by extended N2 method. The seismic parameters in terms of displacements and storey drifts was obtained for the G+5 framed building by the extended N2 method. In addition to that same structure is analysed by the Non-linear Time History Analysis. The results obtained from extended N2 method and that from non-linear Time History analysis were compared. A model was created using SAP2000 package and analysis of the structure is done.

Keywords: method, Asymmetric setback

I. INTRODUCTION

Seismic evaluation of a structure mainly depends on the damage suffered by it under the design earthquake. In-elastic structural analysis is required to evaluate the magnitude of required parameters in the structures, since damage in structures produces inelastic displacement, Those parameters are used to determine the performance of structure against the acceptance criteria. Roof level displacement and storey drift are the main demand parameters which can be predicted and controlled in performance based design. Hence based on principles, the correct approach is the non-linear Time History analysis.

Also, the information about real strength, ductility and energy dissipation is not provided in most of the existing building codes and they are based on the assumption of linear elastic structural behaviour. The expected damage in quantitative terms is also not available in the existing codes.

II. NEED FOR THE STUDY

N2 method is an analysis of nonlinear static simplified procedure utilized for the seismic evaluation and design of structures. Extended N2 method is derived from the advancement of N2 procedure which is simpler for seismic evaluation of irregular structures. In multi-storeyed building frames, a common form of vertical irregularity found is Asymmetric setback. Computational efforts are greatly reduced by Extended N2 method for such structures as Nonlinear Time History Analysis (NTHA) is the current requirement for such structures as per various design codes.

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III. STEPS INVOLVED IN MODAL ANALYSIS IN SAP 2000

- Create the model in the SAP 2000 software.
- The materials and properties of the section should be defined.
- Assign the loads DL=100% and LL=25%
- Set all load cases --- DO NOT RUN
- Set the model --- RUN
- After the run model the time period, frequency and circular frequency are determined.
- The fundamental time period (T) determined.
- And the fundamental mode shape of the structure is determined.
- The storey displacements are found out by this elastic modal analysis.

IV. STEPS INVOLVED IN THE PUSHOVER ANALYSIS OF MDOF

- Create the model in SAP 2000 software.
- The materials and properties of the section should be defined.
- Assign the gravity loads in the frame (100% DL + 25% LL).
- Assign the hinges to all line elements.(Columns and beams)
- Make the gravity load case to NON-LINEAR.
- Applied the horizontal push load. [P] = [M] {ϕ}
- Create new load case named as pushover.
- Make the load case as NON-LINEAR and continued from the Gravity non-linear.
- In this case set the pushover as displacement control with multi steps.
- Set the gravity and pushover load cases to Run.

A. Description Of The Structure

Type of structure	Framed Structure
Material	RCC
Length of the building	12 m
Width of the building	12m
Length of each bay	3m
Height of the each storey	3.5m
Total height of the building	21m
Column size	0.3m× 0.3m
Beam size	0.23m× 0.3m

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Live load	3 kN/m^2
Seismic zone of the building	IV

B. Modal Analysis Results

The modal analysis is done by considering the full dead load and 25% live load for the mass calculations as per the IS 1893-2002.The assumptions of the N2 method is structure predominately vibrates in a fundamental mode only. In the SAP2000 software the modal analysis is done and the following results are obtained.

According to the assumption masses lumped only at floor levels and the column self-weights are shared equally to the stories. The masses are presented from the base storey to the top storey.

M = [96223.21, 92232.1, 73698.4, 71691.4, 51173.6, 45540] kg

The fundamental time period (T) is 1.05 sec, the frequency is 0.952 cps and the fundamental mode shape is {1.0, 0.94, 0.83, 0.65, 0.43, 0.18}.

The pushover lateral force is the product of mass and fundamental mode shape [P] = [M] { Φ } and is given by [45.54, 48.1, 59.51, 47.9, 39.65, 17.32] kN.

The displacements and storey drifts obtained in the modal analysis are presented in the Table 1

Storey	Displacements (m)	Storey Drift (m)
6	0.0321	0.0005
5	0.0302	0.0010
4	0.0267	0.0016
3	0.0209	0.0020
2	0.0138	0.0022
1	0.0059	0.0016
Base	0.0000	0.0000

Table 1 Displacements and Storey Drift by Modal Analysis

C. Manual Calculation Of Modal Analysis

The manual calculation of the modal analysis is performed and presented up to the fundamental mode shape.

Eigen vector corresponding to ω1=5.81 rad /sec

Eigen vector corresponding to ω1=5.9 rad /sec (or) first mode shape obtained by SAP2000 software package .

D. Pushover Analysis Of Mdof System Results

The pushover analysis is the non-linear static method of earthquake analysis in which under the constant gravity load the horizontal push load increased monotonically up to the failure and find the pushover curve. The plastic hinges are at every starting and end point. The Base Shear Vs. Top storey displacement curve is obtained by pushover analysis of MDOF system in the SAP 2000 software is shown in the Figure 1.

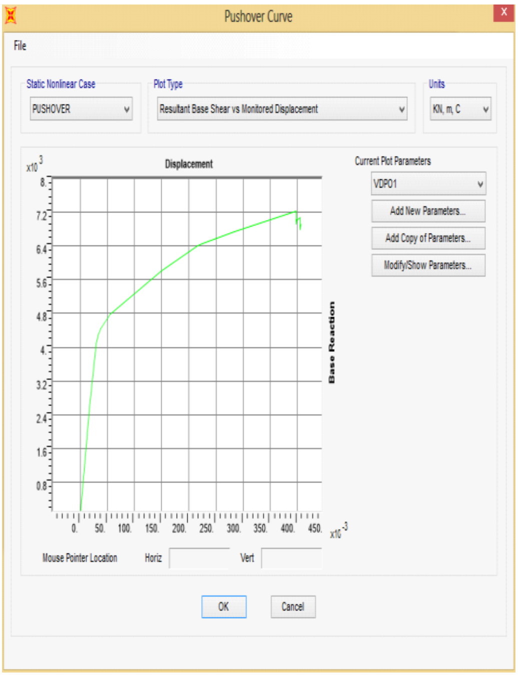

Fig 1 Pushover Curve of MDOF System

E.Transformation Of Mdof System To SD of System

Mass of equivalent SDOF (m*) == 258.02 kN-S2/m.

Transformation factor, Γ = = 258.02/191.4 = 1.35.

F.Response Spectrum Analysis Of Equivalent Sdof System

The response spectrum curve depends upon the earthquake zone and soil type. The response spectrum for the zone IV and hard soil type as per IS 1893-2002 as shown in Figure 2.

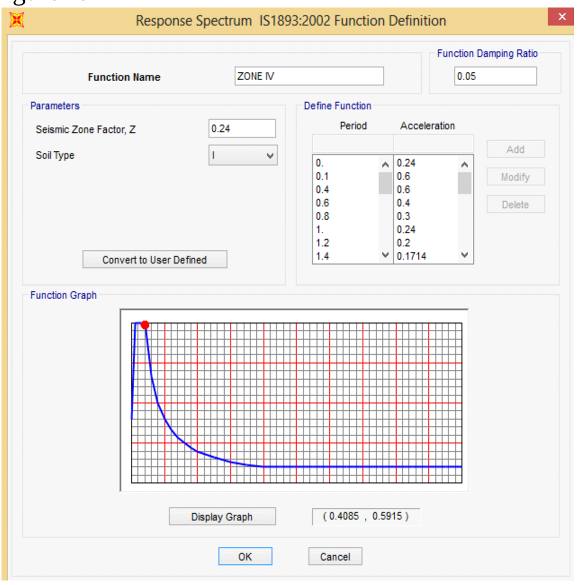

Fig 2 Response Spectrum Curve for SDOF System

From the response spectrum curve of IS 1893-2002,

T_C=0.4085 sec, S_a/g = 0.59 and damping = 0.05

Assume Target Displacement, dm*=0.2m.

The yield strength and displacement amount to Fy*=6400kN and dy*=0.148m.

The elastic period, T* = 2π =0.48 sec.

The period of the system T*is larger than T_C.

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Thus the equal displacement rule applies: $\mu = R\mu$, $S_d = S_{de}$

The formulae used to find the seismic demand of equivalent SDOF system is given by,

$$S_d = S_d = S_e T^* \left(\frac{T^*}{2\pi}\right)^2 = 0.03\text{m}.$$

Where, S_e (T*) from RS curve Se=0.5 × 9.81 = 4.905

By next trial, d_y^*=0.03m and F_y^* = 4098kN.

Hence T*=0.26 sec, thus $S_d = d_y^*$

Therefore S_d=0.03m

FEMA 356 displacement = 0.033m

The SDOF target displacement transformed to MDOF top storey displacement,

D_t= 0.03×1.35=0.0405m.

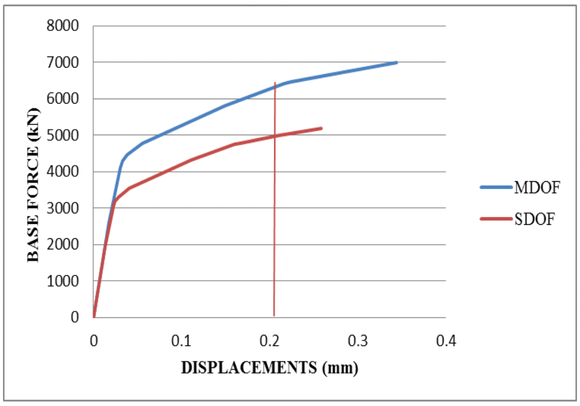

Fig 3 Bilinear Curve Idealization

The storey displacements and storey drifts obtained from the N2 method is presented in the Table 2.

Storey	Displacements (m)	Storey Drift (m)
6	0.0405	0.0007
5	0.0380	0.0016
4	0.0324	0.0024
3	0.0240	0.0031
2	0.0130	0.0018
1	0.0066	0.0018
Base	0.0000	0

Table 2. Displacements and Storey Drifts by N2 Method

V. THE EXTENDED N2 METHOD RESULTS

The correction factor is applied for the basic N2 method is known as the extended N2 method. The correction factor is defined as the ratio of normalized displacements of modal analysis to the normalized displacements of pushover analysis. The correction factor to be applied for the basic N2 method is presented in the

Table 3 and the results of extended N2 method is presented in the Table 4.

Storey	Correction Factor
6	1.0000
5	1.0020
4	1.0375
3	1.1020
2	1.3400
1	1.1250
Base	0.0000

Table 4.3 Correction Factor

Storey	Displacements (m)	Storey Drift (m)
6	0.0405	0.0007
5	0.0380	0.0012
4	0.0336	0.0020
3	0.0264	0.0025
2	0.0174	0.0028
1	0.0074	0.0021
Base	0.0000	0.0000

Table 4.4 Displacements and Storey Drifts by Extended N2 Method

VI. NON-LINEAR TIME HISTORY METHOD RESULTS

Non-linear time history is the more accurate method of seismic analysis of structure and it requires time history of the earthquake. A non-linear dynamic analysis or inelastic time history analysis is the only method to describe the actual behaviour of the structure during an earthquake.

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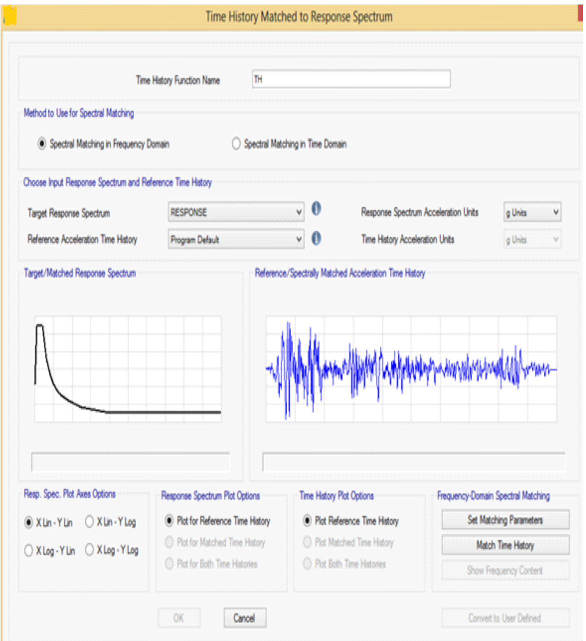

Fig 4 Time History Graph

TABLE : 5 Non-Linear THA

The results obtained from the non-linear THA is presented in the Table 5

Storey	Displacements (m)	Storey Drift (m)
6	0.0333	0.0003
5	0.0321	0.0007
4	0.0294	0.0015
3	0.024	0.002
2	0.017	0.0027
1	0.0073	0.002
Base	0	0

VII. COMPARSION OF THE RESULTS OF DIFFERENT METHODS

The results obtained from the N2 method, extended N2 method and non-linear time history analysis are compared.

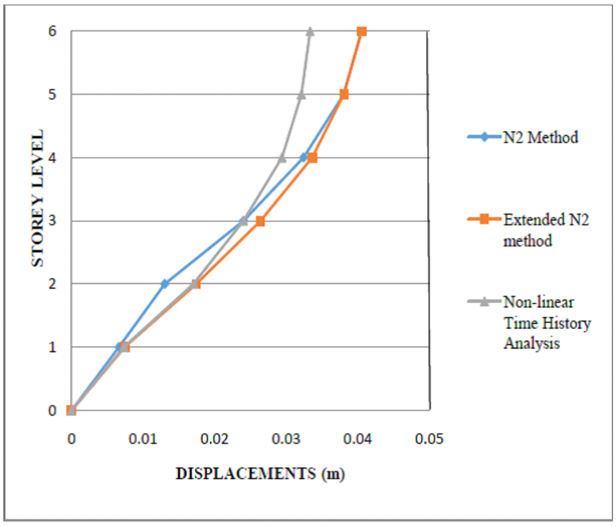

Fig 5 Comparison of Displacements

torey	N2 Method	Extended N2 Method	Non-linear Time History Analysis
6	0.0007	0.0007	0.0003
5	0.0016	0.0012	0.0007
4	0.0024	0.0020	0.0015
3	0.0031	0.0025	0.0020
2	0.0018	0.0028	0.0027
1	0.0018	0.0021	0.0020
Base	0.0000	0.0000	0.0000

Table 6 Comparison of Storey Drifts

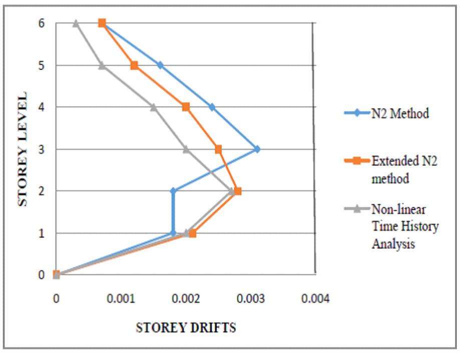

Fig 6 Comparison of Storey Drifts

VIII. CONCLUSION

In this thesis the methods of seismic analysis and needs of the extended N2method is discussed. Relevant literatures are collected for the extended N2 method and a detailed summary are presented. From the study it is observed that the N2 method is simple tool for seismic analysis when compare to the Non-linear Time History Analysis.

The methodology adopted for the extended N2 method is studied. The plan, elevation and section of the G+5 storey is presented. The structure is located in the seismic zone IV. The percentage of damping adopted is 5%. The size of the building is 12m × 12m and total height of 21m.

The displacements obtained from the extended N2 method is increases 21.62%, 18.38%, 14.28%, 10%, 2.35%, 1.36% from sixth to first storey respectively when compare to the NTHA. From the displacements and storey drifts results of the extended N2 method its shows that slightly over estimates for the upper stories and gives reasonably accurate results for lower storey levels when compare to the Non-linear Time History Analysis.

It is concluded that extended N2 method gives the reasonably accurate results for lower stories when compare to the NTHA if the number of stories increases. The Time History of ground motion is totally eliminated by the extended N2 method.

In future the study will be extended for the both plan and elevation irregularity building.

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