USAGE OF N_2 METHOD FOR THE PERFORMANCE EVALUATION OF PLAN ASYMMETRIC STRUCTURES

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Abstract - *In the present situation the most difficult task to earthquake engineer is to construct seismic resistant structures and design of structures against the seismic forces is necessary. Generally multistory building grasps irregularities both in plan and elevation. These irregularities attract large seismic forces during earthquake and leads to structural failure. The various aspects of pushover analysis and accuracy of pushover analysis in assessing seismic demands were investigated by several researchers. In the present work N_2 method is used to evaluate the performance of plan asymmetric buildings like one regular and four irregular models situated in zone III is considered. N_2 method is a simplified non linear static analysis also called pushover analysis is used. In this method elastic demand curve taken from IS 1893-2002 is converted into inelastic spectra in A-D format. Capacity curve of MDOF system of all the five models obtained from pushover analysis using ETABS 20015 is converted into SDOF system of spectral acceleration vs. spectral displacement using transformation factor. The intersection point of these two curves gives the performance point of structure which indicates the seismic demand of the structure. The effects of plan irregularity on the building is assessed in terms of dynamic parameters like capacity curves, performance point, storey drift, storey displacement and nonlinear hinge bar chart are evaluated by performing equivalent static analysis using IS 1893-2002 and pushover analysis* and results are obtained in terms of SDOF system.

***Key Words*: N2 Method, Pushover Analysis, Plan Irregularity, Performance Point.**

1. INTRODUCTION

Earthquake defined as the vibration of the ground produced by seismic forces. These seismic forces cause inelastic behavior of the structure and leads to failure of the buildings. The various factors affecting to the structural damage during the earthquakes are vertical and plan irregularity in structures.

The structure having discontinuity in force path, mass, stiffness and geometry are called as irregular structures. Irregularities in structures cause more damage during earthquake because of more attraction of seismic forces. In construction of building irregularities are probably not avoided. However, the behavior of these irregular structures during seismic is need to be understand. More precautions should be needed. A detailed study of structural behavior of building of building with irregularities is necessary for design and behavior in earthquake.

Peter Fajfar, M. EERI (2000) [1] In this paper they introduced new simplified methodology for seismic analysis of the structure called N2 method. This method combines the pushover analysis of MDOF model with the response spectrum analysis of an SDOF system. S.C. Pendnekar, H. S. Chore, S. B. Patil(2015)[2] From this analysis result are with increase in number of stories indicates decreases in spectral acceleration and base shear and also with increase in number of spectral displacement, displacement and time period by performing nonlinear static pushover analysis. Dini Devassy Menachery, Manjula N. K (2014)[3] In this paper they used extended N2 method procedure for performance evaluation of asymmetric setbacks and the results in terms of displacement and storey drifts obtained are compared with time history analysis.

1.1 N_2 Method

N2 method is a simple nonlinear method for the seismic analysis of structures. It combines the pushover analysis of a multi-degree-freedom (MDOF) with the response spectrum analysis of equivalent single-degree-of-freedom (SDOF) system. The N2 method, in its new format, is in fact a variant of the spectrum method based on inelastic spectra. Inelastic demand spectra are determined from a typical smooth elastic design spectrum. The reduction factors, which relate inelastic spectra to the basic elastic spectrum, are consistent with the elastic spectrum. The lateral load pattern in pushover analysis related to the assumed displacement shape. This feature leads to a transparent transformation from a MDOF system to an equivalent SDOF system and response of the structure is evaluated in terms of performance point.

Nonlinear Static Analysis

Non linear static procedure or pushover analysis is explained as the reaction of the structure to quake loadings. This procedure directly explains the redeployment of forces and deformations that occur in a structure as it go through inelastic reaction. As a result they are usually competent of providing more correct approximation of the demand needed in the structure than either of nonlinear procedures. From this analysis we can get result in the form of base shear verses roof displacement plot. The plot is converted into capacity into demand plot with the intersection of capacity with demand being known as performance point

Pushover Curve

Pushover curve is base shear versus roof displacement curve inform about the shear force developed at the base of the structure at any level of pushing. The highest value of this curve characterize the maximum base shear, which indicates the highest load carrying capacity of the structure, the maximum roof displacement of the structure considered as the deflection beyond this limit leads to structural collapse.

Demand Curve

For a given ground motion and structure, the displacement demand is an estimate of the maximum expected response of the building during the ground motion. It is given by spectral acceleration (Sa) verses time period (T). In the present work the seismic demand is taken from IS: 456-2002 code for medium soil as shown in fig below.

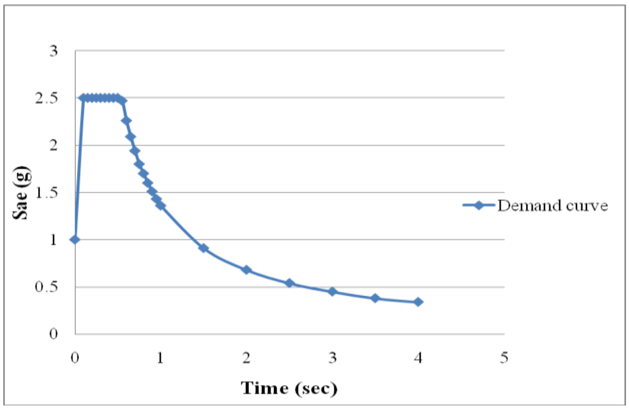

Fig 1 Response spectra for medium soil type for 5% damping in traditional format

Performance Point

The building performance under seismic loading can be estimated in expressions of capacity curve, performance point, ductility, displacements and creation of plastic hinge etc. From pushover analysis, base shear versus top displacement curve is achieved, from which maximum capacity of structure in terms of base shear can be achieved. This capacity curve is converted into capacity spectra by using any simplified methods like N2 method and response spectrum is taken from any of the standard code depending on type of soil. The intersection of capacity and demand spectra predict the performance point of the structure analyzed.

3. ANALYTICAL MODEL

3.1 Introduction

In these present study four stories of plan area 22.5mx22.5mstructure is selected for analysis and the structure is located on a medium soil type in seismic zone III. Using ETABS-2015, three dimensional mathematical models of one regular and four irregular of same area are generated.

Beam size= 250x400 mm
Column size= 450x450 mm
Slab thickness= 150 mm
Wall thickness= 120 mm
Live load= 3KN/m^2
Structure type= OMRF building

3.2Application of N_2 method for regular model

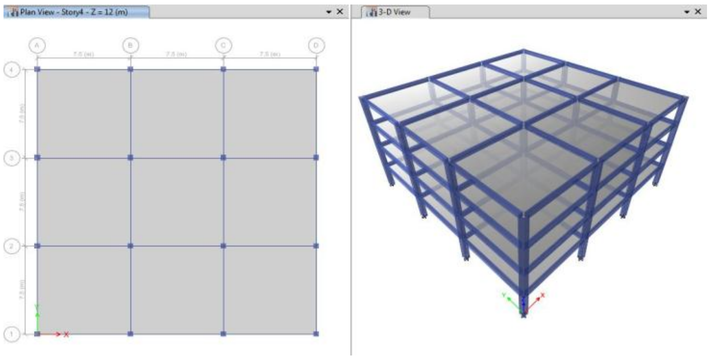

Fig 2 plan and 3-d view of regular model

Storey masses = [381.21, 432.31, 432.31, 432.31] tone
Displacement shape ϕ = [1, 0.77, 0.47, 0.16]
The MDOF system is converted to an equivalent SDOF system using fallowing equations.
Equivalent mass of SDOF $m^* = \sum m_i \phi_i$

$$m^* = 986.44 \text{ tone}$$

$$\text{Transformation factor } \Gamma = \frac{m^*}{\sum m * \phi_i^2}$$

$$\Gamma = 1.3257$$

$$D^* = \frac{D_t}{\Gamma} = 2.48\text{cm} \qquad F^* = \frac{V}{\Gamma} = 1060.32\text{kN}$$

Where D_t and V are top displacement and base shear obtained from pushover analysis of MDOF system
Bilinear idealization of pushover curve is done to obtain yield strength F_y and yield displacement D_y.

$$\text{The elastic time period is } T^* = 2\pi \sqrt{\frac{m^* D_y{}^*}{F_y{}^*}} = 0.95 \text{ sec}$$

From the response spectrum S_a/g = 2.5 and
Time period T_c=0.5

$$S_a = \frac{F^*}{m^*}$$

The Period of the system T *is larger than T_c, thus the equivalent rule applies. i.e., $\mu=R_\mu$, $S_d=S_{de}$ =23.63cm.

Where S_a and S_d is the performance point of the structure. Same calculation is carried out for all the remaining models to get seismic demand of the structure in terms of SDOF system.

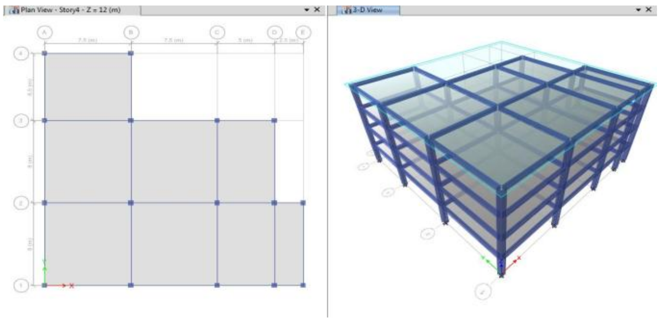

Fig 3 plan and 3-d view of irregular model 1

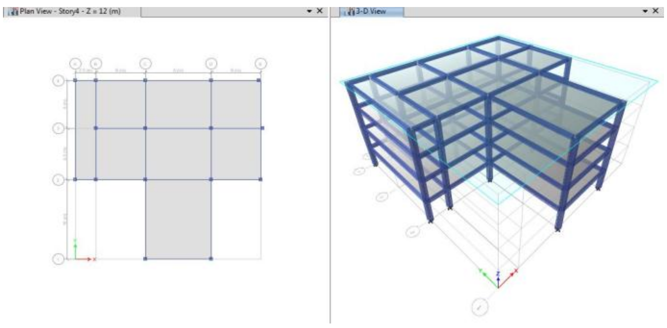

Fig 4 plan and 3-d view of irregular model 2

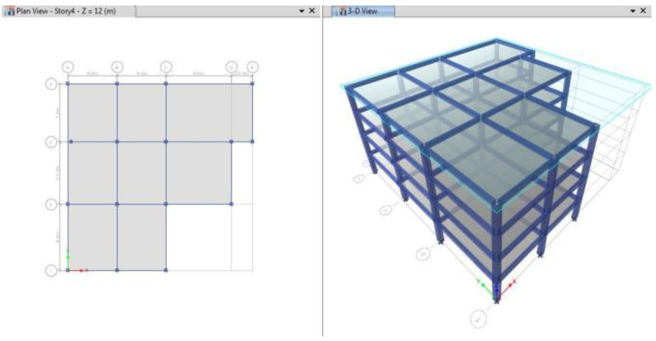

Fig 5 plan and 3-d view of irregular model 3

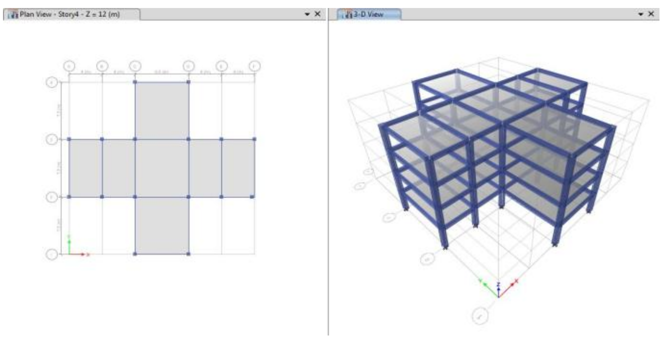

Fig 6 plan and 3-d view of irregular model 4

3.3 CALCULATION OF BASE SHEAR

Using IS: 1893-2002 base shears for the design building was calculated. Percentage of imposed load in seismic weight calculated was taken as 25%. Storey lateral forces and shear forces are calculated and tabulated in the following table:

Table 1 lateral forces and storey shear forces

Floor level	*W_i (KN)*	*H_i (m)*	*$W_i x\, h_i^2$ (kN-m²)*	*Storey forces $Q_i = V_B \frac{W_i h_i}{\Sigma W_i h_i}$*	*Storey shear forces [V_i]*
4	*2793.5*	*12*	*402264*	*426.53*	*426.53*
3	*3619*	*9*	*293139*	*310.83*	*737.35*
2	*3619*	*6*	*130284*	*138.14*	*875.80*
1	*3619*	*3*	*32571*	*34.54*	*910.03*

4. RESULTS AND DISCUSSIONS

Five model of G+3 storey buildings are considered for this study, out of these five models one model with regular frame is considered as reference building and four plan irregular models are derived from the regular building. Structural behavior of both reference building and four plan irregular model buildings due to seismic forces is studied and fallowing results are obtained in terms of SDOF system.

4.1 ECCENTRICITY

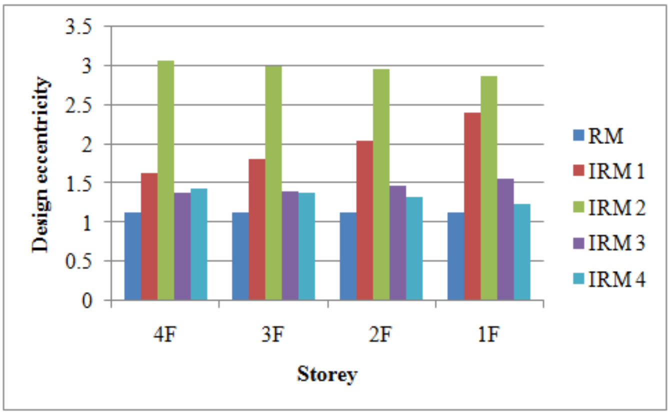

Chart -1: Design eccentricity of all the five models along X-direction

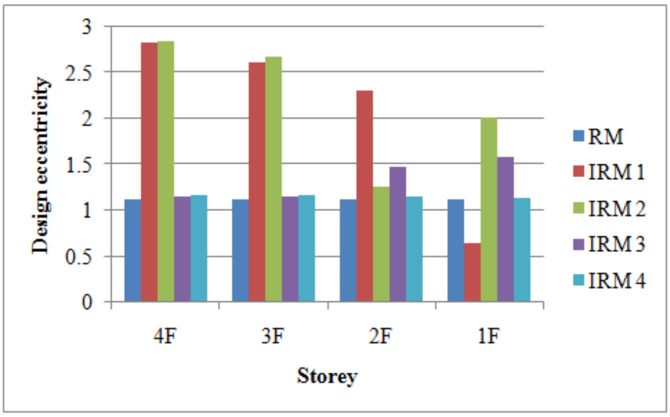

Chart -2 Design eccentricities of all the five models along Y-direction

Table 2 Eccentricity details of all the five models

LEVELS	RM		IRM 1		IRM 2		IRM 3		IRM 4	
	e_{dix}	e_{diy}	e_{dix}	e_{diy}	e_{dix}	e_{diy}	e_{dix}	e_{diy}	e_{dix}	e_{diy}
4F	1.1	1.1	1.6	2.8	3.0	2.8	1.3	1.1	1.4	1.1
3F	1.1	1.1	1.8	2.6	2.9	2.6	1.4	1.1	1.3	1.1
2F	1.1	1.1	2.0	2.3	2.9	1.2	1.4	1.4	1.3	1.1
1F	1.1	1.1	2.3	0.6	2.8	2.0	1.5	1.5	1.2	1.1

Design eccentricity at i^{th} floor $e_{di} = 1.5e_{si} + 0.05b_i$
e_{si} = static eccentricity at i^{th} floor
b_i = floor plan dimension of i^{th} floor, perpendicular to the direction of force.

4.2 CAPACITY CURVES OF SDOF MODELS

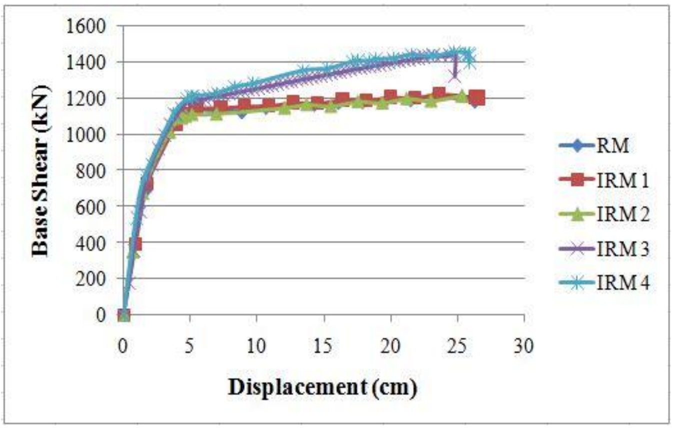

Chart -3: Capacity curves of all the models along X-direction

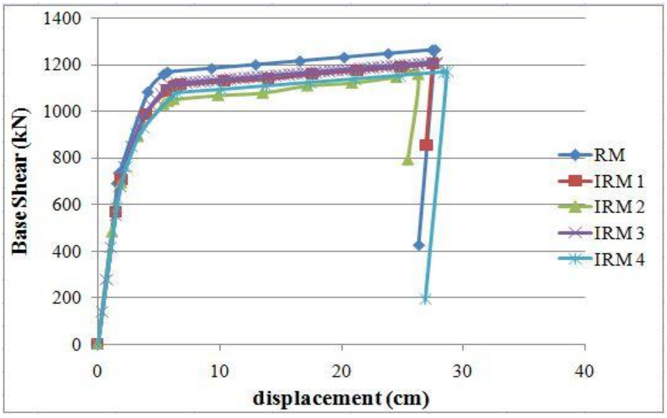

Chart -4 capacity curves of all the models along Y- direction

Table 3 Capacity curve details

Models	RM	IRM 1	IRM 2	IRM 3	IRM 4
Capacity Along X-Direction					
Max base shear in kN	1212.67	1224.83	1215	1438.84	1453.97
Disp (cm)	23.30	23.64	25.39	23.25	25.84
Capacity Along Y-Direction					
Max base shear in (kN)	1263.27	1204.17	1157.11	1208.55	1169.79
Disp (cm)	27.69	27.51	26.31	27	28.73

4.3 STOREY DRIFT

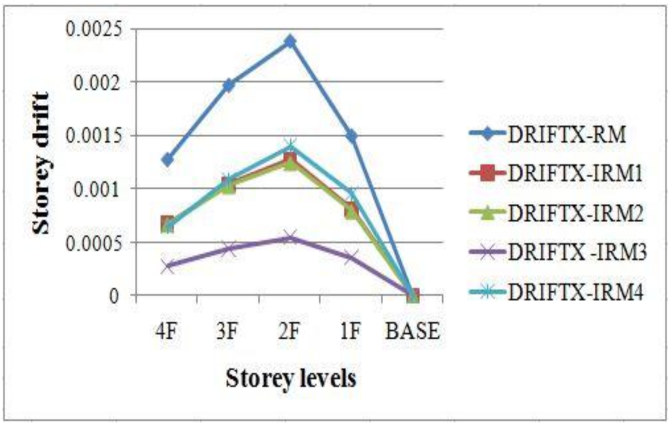

Chart -5 Story levels vs. storey drift along X-direction

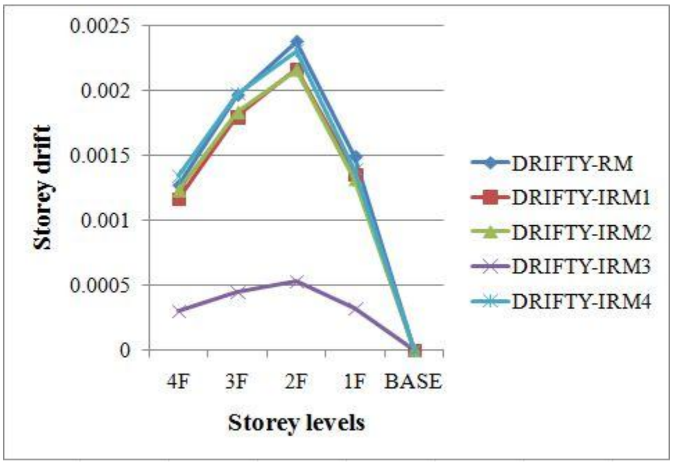

Chart -6 Storey level vs. storey drift curve along Y-direction

4.4STOREY DISPLACEMENT

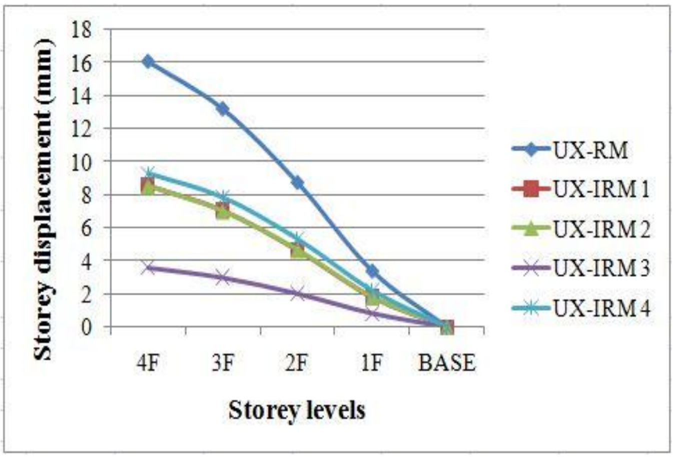

Chart -7 Storey level vs. Storey displacement along X-direction

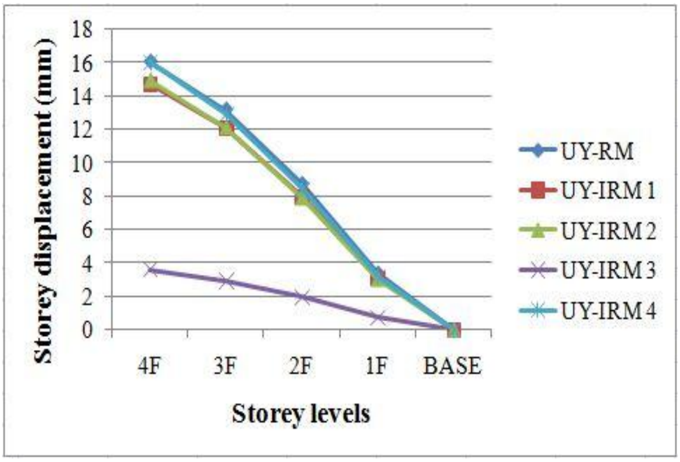

Chart -8 Storey level vs. storey displacement along Y-direction

Table 4 Performance point of building along X and Y direction of all the model

models	RM	IRM 1	IRM 2	IRM 3	IRM 4
PERFORMANCE POINT OF BUILDING IN X-DIRECTION					
Fy (kN)	1060.3	1060	1047.4	1098.5	1096.5
Dy (cm)	2.48	2.56	2.155	2.41	2.12
T^* (sec)	0.95	0.88	0.8	0.85	0.7
Sa (g)	0.123	0.1630	0.1627	0.1703	0.2179
Sd (cm)	23.3	23.63	21.27	21.95	15.53
PERFORMANCE POINT OF BUILDING IN Y-DIRECTION					
Fy (kN)	1091.9	1031.03	971.5	1047	982.3
Dy (cm)	2.6	2.73	2.55	2.79	2.6
T^*(sec)	0.962	0.92	0.9	0.94	0.82
Sa (g)	0.129	0.1553	0.157	0.150	0.191
Sd (cm)	23.83	25.16	23.63	25.16	21.95

Fy - Yield strength
Dy- Yield displacement
T^*-$2\pi[(m^*D_{y)}/F_y]^{1/2}$ sec
Sa- Spectral acceleration
Sd- Spectral displacement

3. CONCLUSIONS

- Eccentricity occurs due to irregularity in plan, more irregularity leads more torsional problem that forces the whole structure to deflect beyond its deflection limit and causes failure of structure. IRM 3 shows very less eccentricity compared to other models in both X and Y direction due to less irregularity in plan.
- Non-linear pushover analysis serves as a basic tool for determining strength of the structure in the expressions of base shear and roof displacement when displacement based approach is used. Along X-direction all the five models shows less displacement corresponding to their maximum base shear. Since maximum base shear with less displacement the structure is vulnerable along X direction due to more irregularity and less ductility along X direction.