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Characteristic of Seismic Performance of Framed Building Using Non-Linear Static Analysis Methods

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Abstract: Many existing buildings in seismically active regions were designed and constructed before modern understanding of earthquake engineering and advanced analysis tools became available. Many of these buildings may pose economic and life safety threats in seismic areas. The non-linear static pushover analysis is became mare important in Earthquakeresistant design particularly with development of performance based earthquake engineering which require maredetailed information about inelastic demands and capacity of structure than traditional design produced. The scope of this paper is to introduce alterative pushover methods: the displacement coefficient method [DCM] and Capacity Spectrum Method of [CSM].Which has been described in FEMA 356 and The ATC 40respectively, the investigation was performed on Framed reinforcedconcrete building is evaluated.

Keywords: DCM, CSM, FEMA.

I. INTRODUCTION

The linear analysis can give no information on the distribution of post yield strains within a structure, and only limited information on the magnitude of any post-yield strains that might develop. The most structural failures during earthquakes occur as a result of elements experiencing strains beyond the limit that they can sustain. In recent years,a simple analytical technique that engineering has utilized for a quick estimate to evaluate the performance and survivability of structure during earthquake is called nonlinear static pushover analysis. Pushover analysis is a static nonlinear procedure in which structure is subjected to lateral forces that monotonically[i.e. in single direction] increase in intensity with a predefined unvarying distribution until a target displacement level is reached. To obtain the maximum shear strength [Vmax],the maximum displacement [dmax] of the Building and also the mechanism of collapse building, to evaluate if the building can achieve the collapse mechanism without one worked the plastic rotation capacity of the elements (beam capacity, column capacity), and to estimate the performance level of damage target estimate displacement of alternative methods and also over strength ratio au/a1.

II. PERFORMANCE LEVEL [LIMIT STATE] OF STRUCTURE

The structure is designed to meet an expected performance level (called limit state),the revaluation of the repair technique should take into account the desired minimum level of safety which is determined by the owner of the structure is called limit state. The limit state of structure has been classified into three levels which illustration in Fig.1.

- Damage Limitation[Serviceability Limit State].
- Significant Damage [Damage-Control Limit State].
- Life-Safety [Near Collapse Limit State].

Damage Limitation [Serviceability LimitState][IO]: In this structure level is very limited structure damage has occurred and the primary concrete frames will be line cracking and also few location of rebar will yield. However the crush of concrete is not expected and no major repair action is needed, as yield of longitudinal rebar of column is acceptable and tension is about to 0.015 and compression of concrete strain is limited to 0.02.

Significant Damage [Damage-Control Limit State][LS]: In this state the damage is moderate fragment of column concrete cover is acceptable but the damage is manageable and repair.

Life-Safety [Near Collapse Limit State][CP]: Significant damage to the structure has accrued. However some edges against either partial or total structure collapse remains. Columns damage are expected. The structure may be not possible to repair for economic reasons.

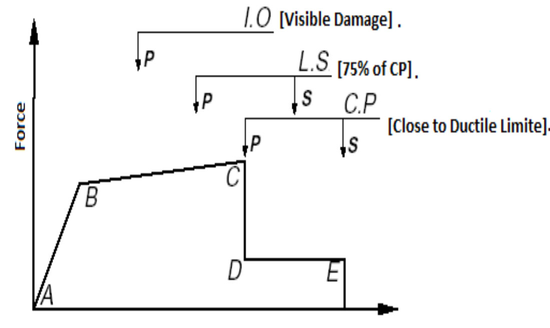

Fig.1.Force-Deformation Relationship(Limit State).

III. NON-LINEAR STATIC PUSHOVER METHODS

A. Coefficient Method of FEMA 356

In Coefficient Method the maximum inelastic displacement of an MDOF system is determined by modifying the elastic displacement of the "equivalent" SDOF with an effective period Te as shown in Fig.2. This idea is essentially an adjustment to the equal displacement rule. In CM the target displacement is obtained from:

$$\delta_t = C_0 C_1 C_2 C_3 \frac{T_e}{4\pi^2} g \quad (1)$$

where C0 accounts for the conversion of the spectral displacement to MDOF roof displacement and could be taken as the 1st modal participation factor at the roof level and can be alternatively computed using a shape vector corresponding to the deformation of the MDOF at the target displacement. C1 is a modification factor that relates the maximum inelastic displacement and maximum elastic displacement and is given by

$$C_1 = 1 \qquad T_e \geq T_s \quad (2)$$

$$C_1 = \left[1 + (R-1) T_s / T_e\right] / R \qquad T_e < T_s \quad (3)$$

where Ts is the characteristic period of the response spectrum defined as the transition from constant acceleration region to constant velocity region. Te and R are the effective fundamental period and the ratio of elastic to yield strength of the structure defined below:

$$T_e = T_i \sqrt{\frac{K_i}{K_e}} \quad (4)$$

$$R = \frac{S_a}{\frac{V_y}{W}} C_m \quad (5)$$

Cm is the effective modal mass of the 1st mode normalized by the total mass. C2 is a modification factor that accounts for deviation from an elastic perfectly plastic hysteresis. This coefficient represents the effect of pinched hysteresis, stiffness degradation and strength deterioration and is given in table 3.1 for various framing type and expected performance level it can alternatively be taken as 1.0. C3 is an amplification factor to account for $P\text{-}\Delta$ effects defined below and is taken 1.0 if the bilinear representation of the SDOF system demonstrates positive post yield stiffness.

$$C_3 = 1 + \frac{|\alpha|(R-1)^{1.5}}{T_e} \quad (6)$$

B. Capacity Spectrum Method of ATC 40

Capacity Spectrum Method (CSM) which is based on "Equivalent Linearization" is founded on the basic assumption that the maximum inelastic displacement of a nonlinear SDOF system can be approximated by maximum displacement of a linear elastic SDOF system with an equivalent damping and period larger than those of the original nonlinear SDOF system. The target displacement in the context of the CSM is called the "Performance Point" and is obtained at the intersection of the capacity curve and an elastic response spectrum for a longer period and a higher damping value (in ADRS format). The abscissa and ordinate of ADRS coordinate system respectively correspond to spectral displacement and spectral acceleration while the radial lines represent the period.

TABLE I: Values of Coefficient C_2

Structural Performance	T <= 0.1 sec.		T >= T_s	
	Framing type 1 [1]	Framing type 2 [2]	Framing type 1	Framing type 2
Immediate Occupancy	1.0	1.0	1.0	1.0
Life Safety	1.3	1.0	1.1	1.0
Collapse Prevention	1.5	1.0	1.2	1.0

1. structures that more than 30% of story shears at any level is resisted by a combination of : ordinary moment resisting frames, concentrically braced frames, frames with partially restrained connections, tension only braces , unreinforced masonry walls, shear critical , piers and spandrels of reinforced concrete or masonry.
2. All frames not assigned Farming 1.

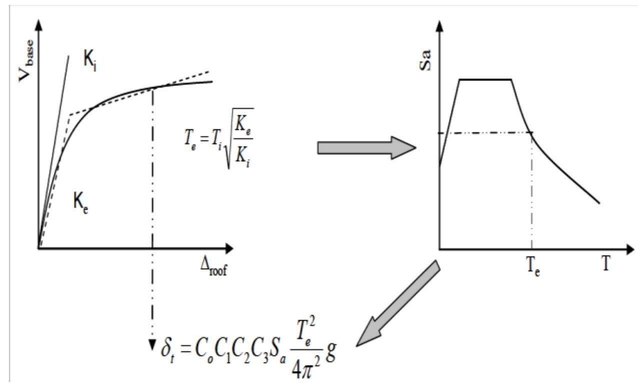

Fig.2.Summary of CM.

To convert the capacity curve from the base shear–roof displacement coordinate to ADRS format the following equations are used.

$$S_d = \frac{u_{roof}}{\Gamma_1 \phi_1^{roof}} \qquad and \qquad S_a = \frac{V_b}{EMM_1.g} \quad (7)$$

In CSM the equivalent damping is determined from the area enclosed by the capacity curve as shown in Fig.3.3. The equivalent damping is taken as the sum of the initial damping (5%) and a viscous damping associated with the area of the hysteresis and the equivalent period is taken as the secant period at the performance point. Since determination of the equivalent damping and period needs the knowledge of the performance point as a priori and the performance point determination requires the equivalent damping and period, the procedure is iterative. It begins with guessing the location of the performance point. Using the equal displacement rule, the spectral displacement of the linear system is often a proper guess as shown in Fig.3. The equation that defines the equivalent damping is given in ATC-40 in terms of the coordinate of the performance point (dp,ap) and the yield point (dy,ay) of the bilinear representation of the capacity curve in ADRS format as follows:

$$\beta_{eq} = 5 + \beta_v \quad (8)$$

$$\beta_v = \frac{1}{4\pi} \frac{E_D}{E_{so}} \quad (9)$$

$$\beta_v = \frac{63.7\kappa(a_y d_p - a_p d_y)}{a_p d_p} \quad (10)$$

where ED is the energy dissipated by damping and Eso is the maximum strain energy at the performance point. accounts for the deviation of the actual hysteresis loop from the parallelogram assumed in derivation and depending on the type the structure and duration of shaking varies between 1.0 and 0.33 for stable to poor hysteresis loops.

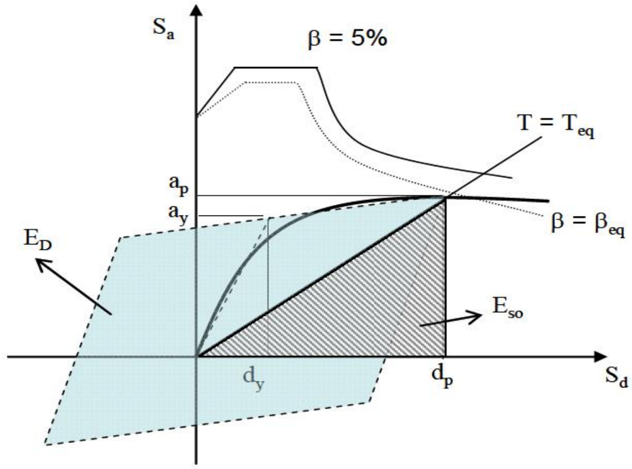

Fig.3. Equivalent damping and period in CSM.

IV. FRAMED IN PLAN BUILDING

The non linear static analysis procedure is tested on a five storey reinforced concrete frame building with regular in plan analyses were performed using the SAP2000 V17.2 in particular the non –linear static analyses based on FEMA-356 and ATC-40. The building is designed according to the regulation of Indian Earthquake Code2002. Concrete and steel characteristic strengths are M25 and Fe 415, respectively. Slab thickness for all floors is 160 mm and live load 5 KN/m2, dead load 2KN/m2 and dead load due to wall load 9KN/m2 ,Dimension of beams at all the building are[500x 400]mm and all columns [700x500]mm , height of all stories 15m .

V. NUMERICAL RESULTS

This section presents a summary of the results obtained for the structure studied in global structure behavior; storey displacement and base shear reactions using alterative non-linear pushover static analysis as shown in Figs.4 and 5.

TABLE II: Pushover Curve Demand –[FEMA356]

Load Case	Step	Displacement[m]	Shear Force[KN]
PUSHOVER	0	0	0
PUSHOVER	1	0.004433	585.402
PUSHOVER	2	0.041396	2884.019
PUSHOVER	3	0.044156	2982.766
PUSHOVER	4	0.089156	4085.338
PUSHOVER	5	0.135226	5200.487
PUSHOVER	6	0.167997	5869.339
PUSHOVER	7	0.174157	5931.248
PUSHOVER	8	0.183404	6080.302
PUSHOVER	9	0.184781	6093.041
PUSHOVER	10	0.185692	6108.86
PUSHOVER	11	0.188619	6134.413
PUSHOVER	12	0.189744	6152.616

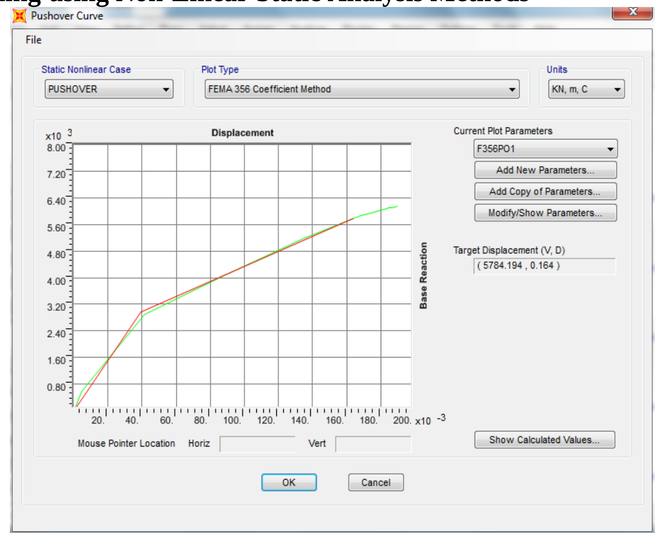

Fig.4.

TABLE III: Pushover Capacity Curve [ATC-40]

Load Case	Step	Teff(sec)	B eff Sd [m]	Capacity [m]	SaCapcity	SdDemand	Sa Demand
PUSHOVER	0	0.612181	0.05	0	0	0.060828	0.653402
PUSHOVER	1	0.612181	0.05	0.003433	0.036875	0.060828	0.653402
PUSHOVER	2	0.822444	0.087395	0.031535	0.187679	0.070387	0.418908
PUSHOVER	3	0.836644	0.098003	0.033614	0.193323	0.069236	0.398189
PUSHOVER	4	1.057139	0.195589	0.067584	0.243457	0.069447	0.250165
PUSHOVER	5	1.162833	0.181194	0.104725	0.311786	0.078585	0.233961
PUSHOVER	6	1.232455	0.18617	0.131053	0.347332	0.082465	0.218559
PUSHOVER	7	1.252717	0.193148	0.136559	0.35031	0.082683	0.212105
PUSHOVER	8	1.27346	0.196695	0.143925	0.357276	0.08348	0.20723
PUSHOVER	9	1.277649	0.198049	0.14511	0.35786	0.083538	0.206017
PUSHOVER	10	1.27949	0.198047	0.145924	0.358834	0.083659	0.205721
PUSHOVER	11	1.288509	0.200237	0.14884	0.360897	0.083899	0.203433
PUSHOVER	12	1.290873	0.200527	0.149746	0.361766	0.084007	0.202948

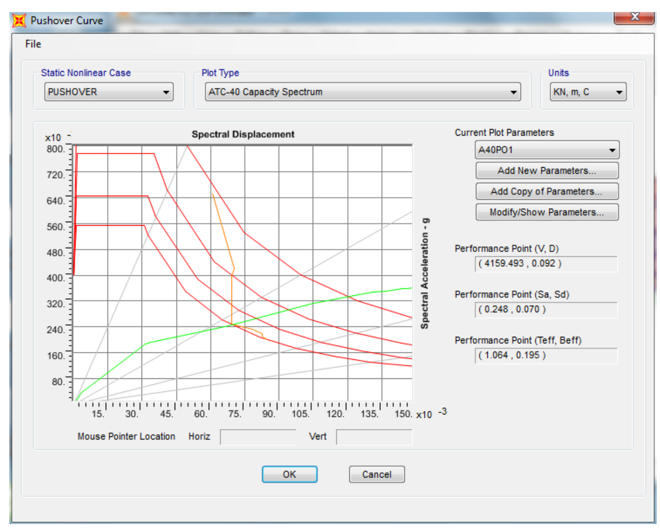

Fig.5.

VI. CONCLUSION

In this study we performed an investigation on the influence of alterative static pushover methods for the seismic design of new structures. The investigation was performed on five multi-storey reinforced concrete regular building for the assessment of the seismic performance of buildings design using either the capacity spectrum method of ATC-40,the displacement coefficient method of FEMA-356.Based on the limited number of building examined, we were able to compare the results of the non-linear static pushover methods with respect to the properties of outcome design for RC buildings. The maximum displacement of building by using (DCM) is [18.97cm], the maximum base shear is[6152.616KN], and target displacement point is [16.4] while in [CSM] the maximum displacement is equal to [14.97cm],the maximum base shear is [4159.493KN] and the performance point is [9.2cm].

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