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DISPLACEMENT BASED DESIGN, (DBD), NONLINEAR STATIC PUSHOVER ANALYSIS TO VERIFY THE PROPER COLLAPSE MECHANISM OF STRUCTURES

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ABSTRACT

Under the pressure of recent developments, seismic codes have begun to explicitly require the identification of sources of inelasticity in structural response, together with the quantification of their energy absorption capacity. In the pushover procedure, a static lateral load, which is distributed approximately equivalent to seismic loads generated by an earthquake, is applied to the structure, which is then displaced (pushed over) incrementally to the level of deformation expected during the earthquake (target displacement) while keeping the applied load distribution pattern. Base shear and corresponding displacement at each stage are used to build the pushover curve ,following which the seismic structural deformations and the performance level of the structure are estimated. The nonlinear load-deformation characteristics of individual components and elements of the structure are considered in the model to account for the possibility of exceeding elastic limits.

NONLINEAR STATIC PROCEDURES

Performance based engineering is not new .Vehicles, aircraft, and turbines have been designed and manufactured using this approach for many decades. now we apply the same procedures for building with advanced software I.E (sapp 2000, etabs, seismstruct ,and ZeuzNL)

We use this method for new and existing buildings to evaluate differ situation e.g “hospitals and civil defence and government -important buildings .Seismic Evaluation and Retrofit of concrete and steel buildings were developed by the applied Technology council(ATC).

1 CAPACITY SPECTRUM METHOD , CMS

Applied Technology Council (ATC-1996) presented a nonlinear procedure to evaluate performance of reinforced concrete buildings subjected to seismic loading. This procedure uses the static pushover analysis to:

- Represent the structure's lateral force resisting capacity.
- Determine the displacement demand produced by the earthquake intensity on the structure.

- verify an acceptable performance level.

In general, performance of the structure is accepted when the structural capacity is larger than the demand required to satisfy a proper performance level.

ATC (1996) adopts the Capacity Spectrum Methods (CSM) to determine the demand displacement, which is the maximum expected response of a building during a ground motion. The demand displacement in the CSM occurs at the point on the capacity (pushover) curve called the performance point. This performance point represents the condition for which the seismic capacity of the structure is equal to seismic demand imposed on the structure by the specified ground motion. Determination of the performance point requires a trial and error procedure.

- Develop the pushover (capacity) curve, which represents the relationship between the base shear V and the roof displacement(δ) (as shown in Figure 1),Using nonlinear computer programs, pushover curve can be built with no iteration, when a linear computer program is used, developing the pushover curve requires iteration and many steps.

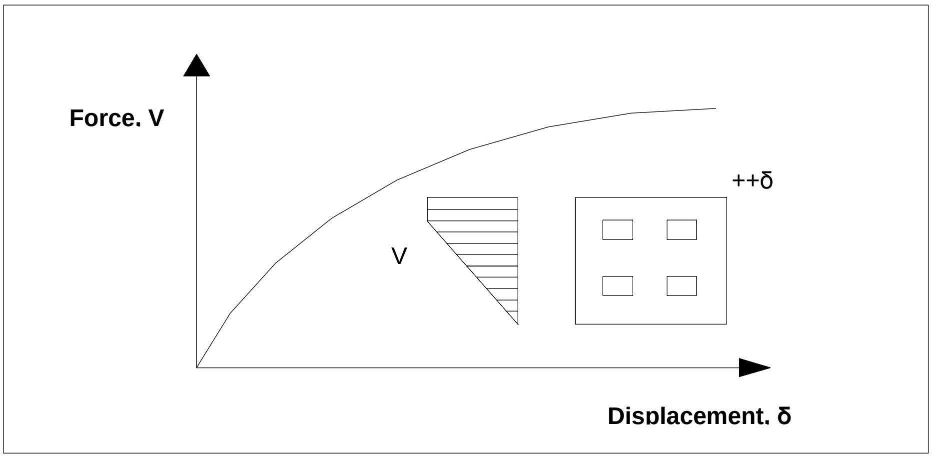


Figure 1. Pushover (capacity) curve: Base shear vs. roof displacement

- Convert the pushover curve to the capacity spectrum curve using the equations: (ATC-96) chapter-8

$$S_{ai} = \frac{v_i / w}{\alpha_1} \qquad (1)$$

$$S_{di} = \frac{\Delta_{roof}}{\left(PF_1 * \phi_{1,roof}\right)} \qquad (2)$$

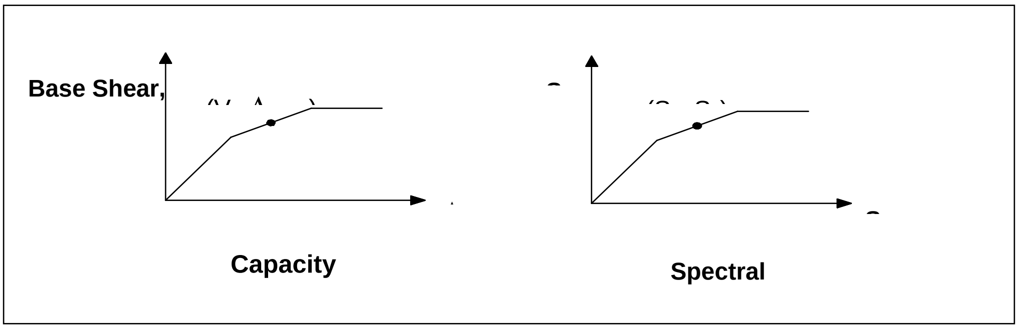


Figure 2. Conversion of pushover curve to capacity spectrum curve

- Convert the elastic response spectrum from the standard format S_a *vs.* T to Acceleration Displacement Response Spectrum (ADRS) format S_a *vs.* S_d .
- Determine the displacement demand as the intersection of the capacity spectrum curve and the spectral demand curve, reduced from elastic 5-percent-damped design spectrum.(as shown in Figure 3)

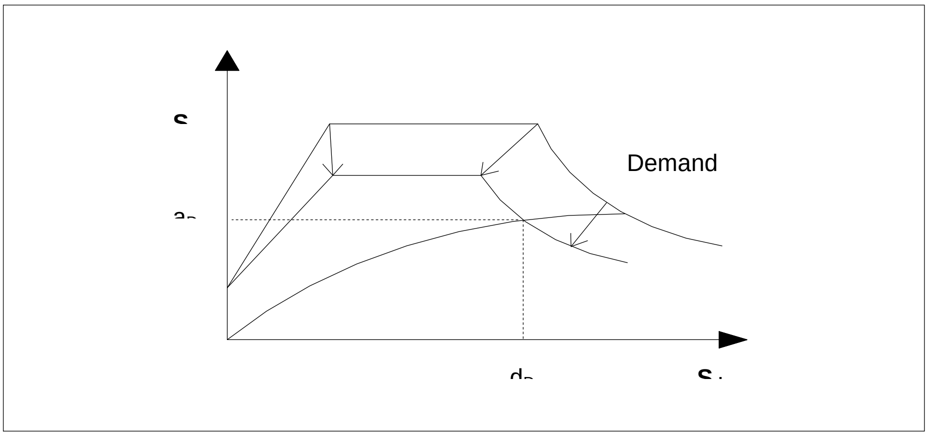


Figure 3. Intersection of the capacity spectrum curve and the spectral demand curve

The point of intersection between demand curve and capacity curve represents the nonlinear demand at the same structural displacement. This step requires iterations. Each iteration includes calculating update values of the natural period T_{eq} and the effective damping β_{eff} . An approximately effective damping is calculated based on the shape of the capacity curve, the estimated displacement demand and the resulting hysteretic loop.(as shown in Figure 4.)

- Convert the displacement demand determined in the previous step back to global roof displacement.

- Evaluate the deformations of individual components corresponding to demand displacement with the capacity of that component. In general, if the deformation demand in deformation-controlled components exceeds permissible values, then the component is deemed to violate the performance criteria.

2 DEMAND DISPLACEMENT

- Estimation of Damping

Estimation of equivalent viscous damping is performed by representing the hysteretic damping as equivalent viscous damping. For the case where the capacity curve is replaced by bilinear curve (as shown in Figure 4), equivalent viscous damping β_0 can be calculated as (Priestly et al 1994…Chopra, 2001):

$$\beta_0 = \frac{1}{4\pi}\frac{E_D}{E_{SO}} \tag{3}$$

Where E_D and E_{so} are shown in Figure 4 and β_0 is the equivalent viscous damping.

The effective damping β_{eff} associated with maximum displacement can be written as:

$$\beta_{eff} = k\beta_0 + 0.05 = \frac{0.637k(a_y d_{pi} - d_y a_{pi})}{a_{pi} d_{pi}} + 0.05 \tag{4}$$

Where 0.05 is the viscous damping inherent in the structure (assumed to be constant), k factor is discussed below, and the rest of symbols(are shown in Figure 4).

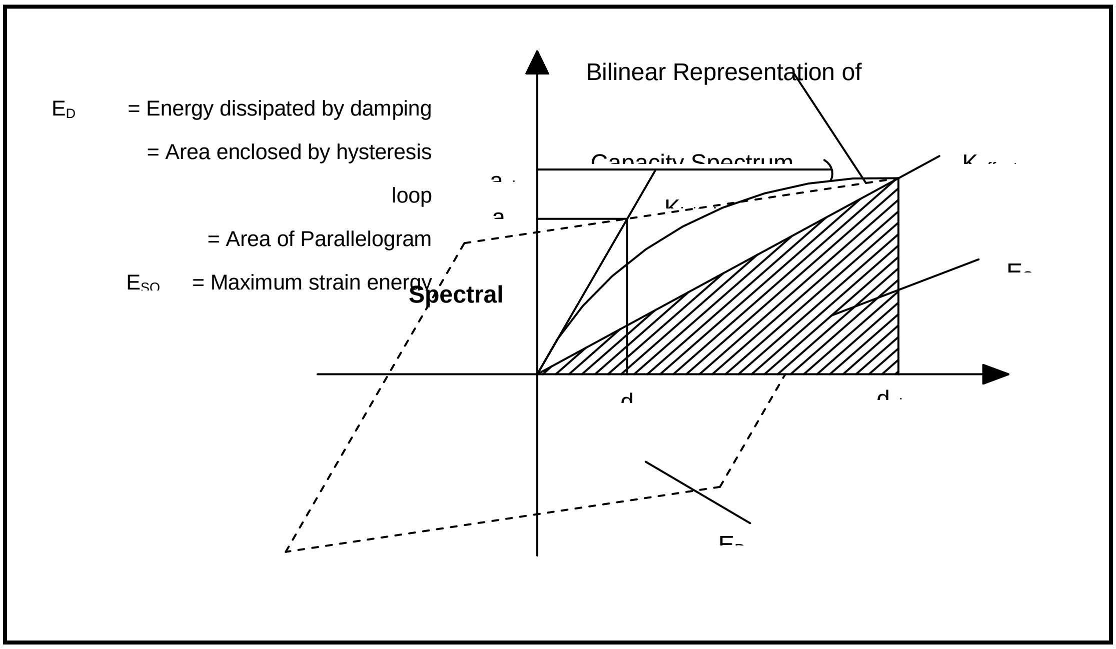


Figure 4. Estimation of the effective damping, β_{eff} .(ATC-96 ,chapter 8)

The k factor depends on the structural behaviour of the building, which in turn depends on the quality of the seismic resisting system and the duration of ground shaking. This factor is a measure of the extent to which the actual structure hysteresis is well represented by the parallelogram(as shown in of Figure 4) either initially or after degradation. ATC (1996) simulates three categories of structural behaviour. Structural type A represents stable, reasonably full hysteretic loops most similar to (Figure 4). k factor of (1) is assigned for behaviour type A, except at higher damping values. Type B is assigned a k of 0.67 (except for higher damping values). It

represents a moderate reduction area. Type C represents poor hysteretic behaviour with a substantial reduction of loop area (severely pinched) and assigned a k of 0.33.(as shown in Table 1) presents values for damping Modification Factor, k .

Structural Behaviour	β_0 (%)	k
Type A	>16.25	1
Type B	<25	0.67
Type C	>25	0.33

Table 1. Values for damping modification factor, k .(ATC_96)

3. PERFORMANCE

using the performance point or target displacement ,the global response of the structure and individual component deformations are compared to limits in light of the specific performance goals for the building (as shown in Figure5)

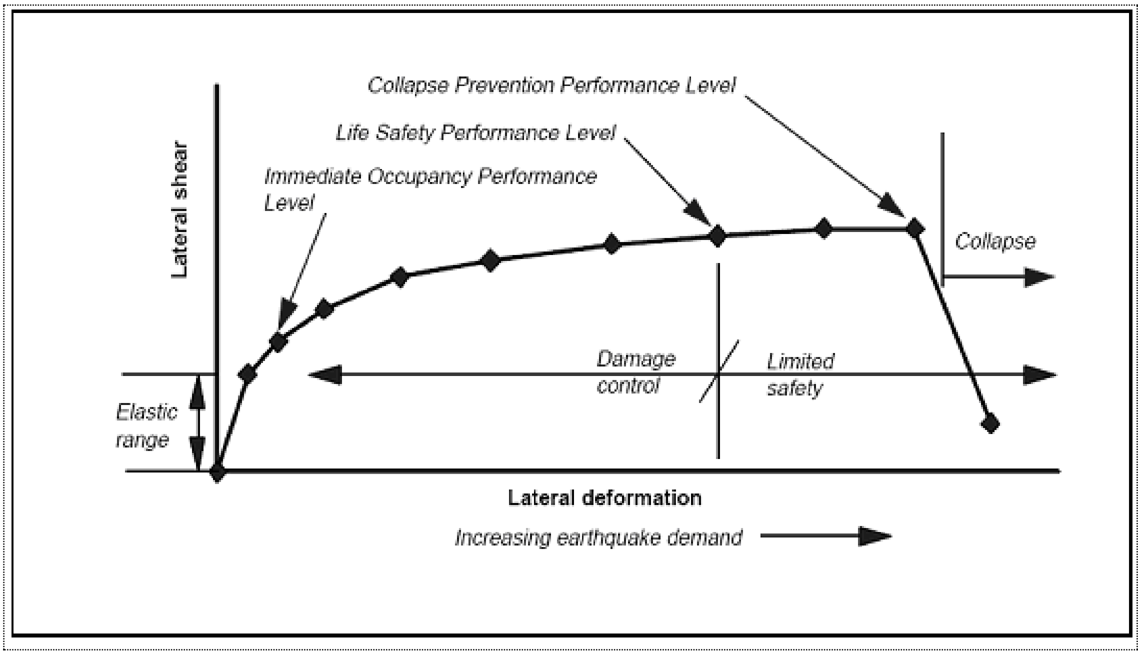


Figure 5. Performance and structural deformation demand for ductile structures (FEMA)

Table 2. Deformation Limits (ATC-96)

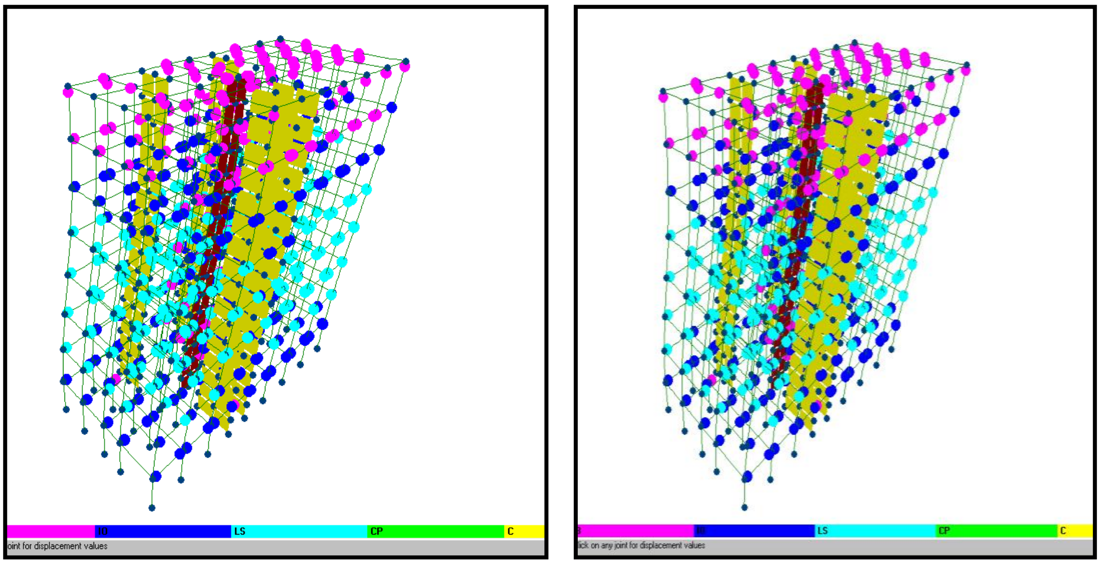
	Performance level			
Inter story Drift Limit	**Immediate Occupancy**	**Damage Control**	**Life Safety**	**Structural Stability**
Maximum Total drift $\frac{\Delta}{h}$	0.01	0.01-0.02	0.02	$0.33\frac{V_i}{p_i}$
Maximum inelastic drift	0.005	0.005-0.015	No limit	No limit

Where V_i is the total calculated lateral shear force in story I and Pi is the total gravity load (i.e. dead plus likely live load) at story i.

CASE STUDY (1)

A three dimensional eight-story building with a total height of 30.4m was modelled using Nonlinear analysis (SAP2000 Software)

We push building until performance point appears



Figures 6. Deformed shape from step (1) to (16) performance point at step # 16

No. of hinges =158 B, 222 LS, 0 CP, 1 D, 1 E

Displacements (266.9 mm)

After running the program we can see how the structure goes from elasticity to plasticity, and how the plastic hinges forms The principle advantage of this method is that the choice of performance goals lies with limitation Which were given by(Fema-356) and (ATC-40).

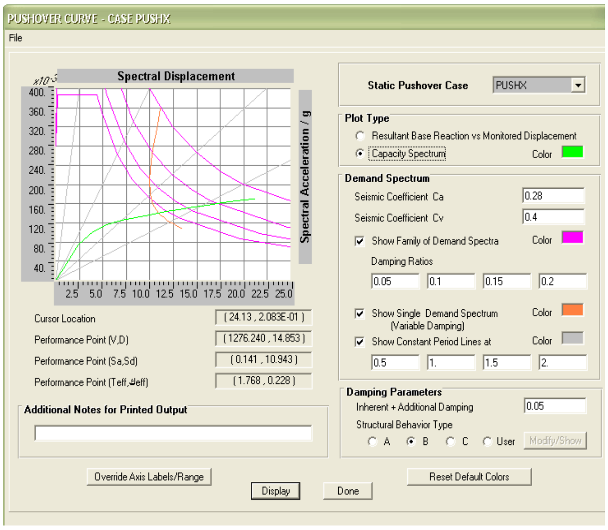


Figure 7. Capacity (Pushover) curve

- .To verify performance ,we obtain performance point as being the intersection of the capacity spectrum and reduce seismic demand in spectral analysis format . From that we prepare detail for retrofit to conform to code requirements and obtain analysis and design peer-reviewed

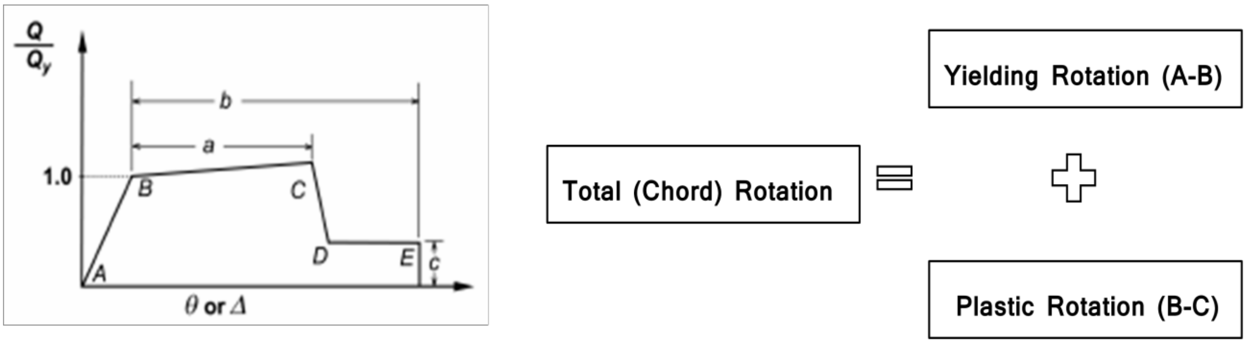
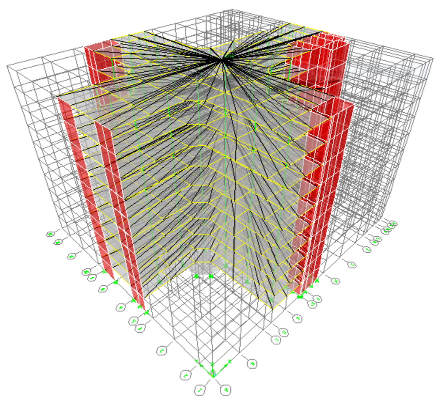
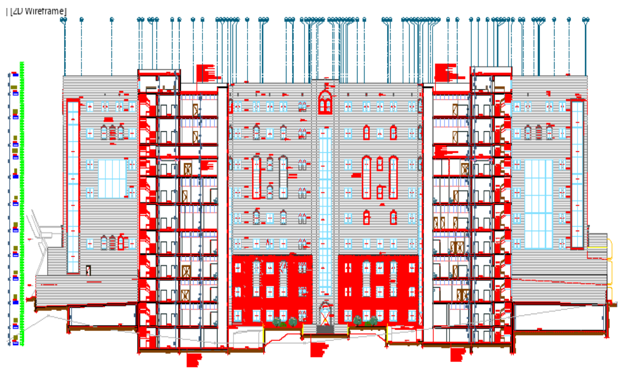


Figure 8. Acceptance criteria (FEMA- 356)

CASE STUDY (2)

A three dimensional Ten-story building with a total height of 49.4m was modelled using Nonlinear analysis (Etabs Software) Al-Salt New Hospital





Section (A - A)

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