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Capacity Spectrum Method for RC Building with Cracked and Uncracked Section

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Abstract: *one of the most widespread procedures for the assessment of building behavior, due to earthquake, is the Capacity Spectrum Method (CSM). In the scope of this procedure, capacity of the structure compares with the demands of earthquake ground motion on the structure. The capacity of the structure is represented by a nonlinear force-displacement curve, referred to as a pushover curve. The base shear forces and roof displacements are converted to equivalent spectral accelerations and spectral displacements, respectively, by means of coefficients that represent effective modal masses and modal participation factors. These spectral values define the capacity spectrum. The demands of the earthquake ground motion are represented by response spectra. A graphical construction that includes both capacity and demand spectra, results in an intersection of the two curves that estimates the performance of the structure to the earthquake.*
In this study, for determination of the performance levels, G+10 R.C.C. Building with cracked and uncracked section were taken. The structural Capacity of cracked and uncracked section compared with performance point value, which shows the structural capacity of building having cracked section is lesser than the uncracked section. Different modeling issues were analyzed to study the effect on Capacity of the structure with cracked and uncracked section for different position of Shear wall.
Keywords: *Non-Linear Static Analysis (CSM), Pushover Analysis, Response Spectra, Performance Point, Cracked and uncracked Section.*

I. Introduction

The damages and the economical losses during the major earthquakes introduced a new approach in seismic analysis of Structures called ‘Capacity Spectrum Analysis’. In Capacity Spectrum Analysis and evaluation of structures under earthquake effects, it is necessary to determine the nonlinear behaviour of structures. The most basic inelastic analysis method, known as the Time History Analysis, is considered very complex and impractical for general use. For this reason, nonlinear static analysis methods have become popular.

The central focus of the nonlinear static analysis methods is the generation of the capacity curve or pushover curve. This curve represents lateral displacement as a function of the force
applied to the structure. The use of nonlinear static analysis methods for design and evaluation helps engineers to understand better how structures will behave when subjected to major earthquakes, where it is assumed that the elastic capacity of the structure will be exceeded (ATC 40, 1996).

The most common used nonlinear static analysis procedures for the evaluation of the performance levels of structures are the Capacity Spectrum Method, which uses the intersection of the capacity curve with a reduced response spectrum.

In design of reinforced concrete, we adopt two approaches
1) Uncracked section –Whereby the section is considered uncracked & linear stress distribution assumed.
2) Cracked Section – Whereby the section is considered cracked and/ or the stress distribution is non-linear.
The basic principle of elastic theory is that under flexure, concrete area below NA is in tension and cracks, and hence neglected in design. Tension is taken by steel reinforcement only. However if tensile stresses do not exceed certain limit as prescribed in IS456 clause B-4, the section may be treated as uncracked and safe without contribution of reinforcement in strength (however min reinforcement needs to be provided there too.)

OBJECTIVE OF STUDY

The main Objective of this study is to carry out seismic analysis using capacity spectrum method for RCC multi-story building (Cracked and Uncracked section) to determine the performance level of building by considering structural capacity obtained from pushover analysis and earthquake demand obtained from response spectra is intended. Software used for analysis is finite element based software SAP-2000-12.

II. Conceptual Development Of The Capacity Spectrum Method

Simplified nonlinear analysis procedure, such as the capacity spectrum method requires determination of three primary elements capacity, demand (displacement) and performance. Each of these elements is briefly discussed below,

Capacity: Structure capacity is represented by a pushover curve. The most convenient way to plot the force-displacement curve is by tracking the base shear and the roof displacement. A pushover analysis is performed by subjecting a structure to a monotonically increasing pattern of lateral forces, representing the inertial forces which would be experienced by the structure when subjected to ground shaking. Under incrementally increasing loads various structural elements yield sequentially. Consequently, at each event, the structure experiences a loss in stiffness. Using a pushover analysis, a characteristic nonlinear force-displacement relationship can be determined. In principle, any force and displacement can be chosen.

Typically the first pushover load case is used to apply gravity load and then subsequent lateral pushover load cases are specified to start from the final conditions of the gravity. Fig1 Shows the generation of Pushover curve as below.

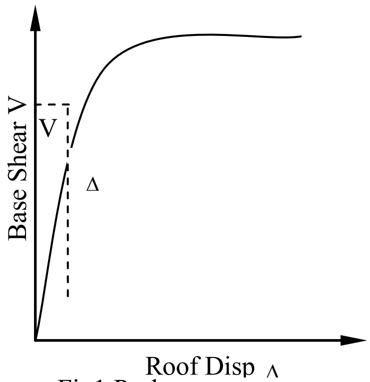


Fig1 Pushover curve

In order to use the Capacity Spectrum Method, it is necessary to convert the capacity curve obtained from pushover analysis in terms of base shear, V and roof displacement Δ, to the capacity spectrum (Fig.2). Capacity spectrum is the representation of the capacity curve in ADRS (Acceleration Deformation Response Spectrum) format. This transformation can be done by using Equation 1 and Equation 2.

$$S_a = \frac{V_T/W}{\alpha} \qquad 1$$

$$S_d = \frac{\Delta_{roof}}{PF \times \varphi_{roof}} \qquad 2$$

In Equation 1 and Equation 2, the coefficients α and PF are calculated as follows in Equation 3 and 4.

$$\alpha = \frac{\left[\sum_{i=1}^{N} (W_i \varphi_i)/g\right]^2}{\left[\sum_{i=1}^{N} W_i/g\right]\left[\sum_{i=1}^{N} (W_i \varphi_i^2)/g\right]} \qquad 3$$

$$PF = \frac{\left[\sum_{i=1}^{N} (W_i \varphi_i)/g\right]}{\left[\sum_{i=1}^{N} (W_i \varphi_i^2)/g\right]} \qquad 4$$

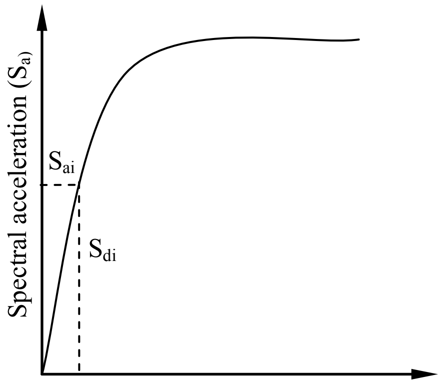


Fig.2 Capacity spectrum

Demand: Ground motions during an earthquake produce complex horizontal displacement patterns in structures that may vary with time. Tracking this motion at every time step to determine structural design requirements is judged impractical. Traditional linear analysis use lateral forces to represent a design condition. For a given structure and ground motion, the displacement demand is an estimate of the maximum expected response of the building during the ground motion. It is given by spectral acceleration (S_a) V_s. Time period (T) as shown in fig.3

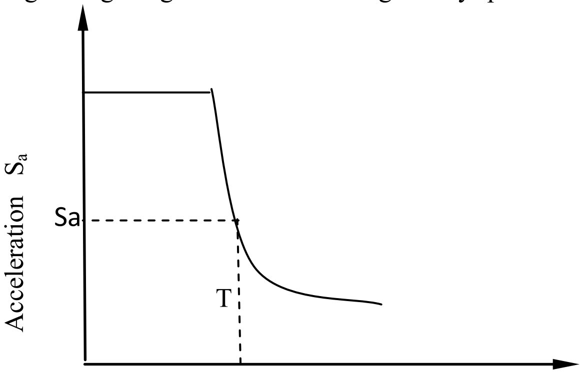


Fig. 3.Response spectra

To convert a Response spectrum from the standard S_a v_s. T format to ADRS (spectral acceleration v_s. Spectral displacement format which is known as Acceleration-Displacement Response Spectra) format, every point on a response spectrum curve has associated with it a unique spectral acceleration, S_a spectral velocity, S_v spectral displacement, S_d and period T.

It is necessary to determine the value of S_{di} for each point on the curve, $S_{ai,}$ T_i .

This can be done by Equation 5.

$$S_{di} = \frac{T_i^2}{4\pi^2} S_{ai} \times g \qquad 5$$

Standard demand response spectra contain a range of constant spectral acceleration and a second range of constant spectral velocity; S_v. Spectral acceleration, S_a and displacement S_d at period T_i are given by equation 6 Fig. 4 shows Demand spectrum curve.

$$S_{di} = \frac{T_i}{2\pi} S_v \qquad S_{ai} = \frac{2\pi}{T_i} S_v \qquad 6$$

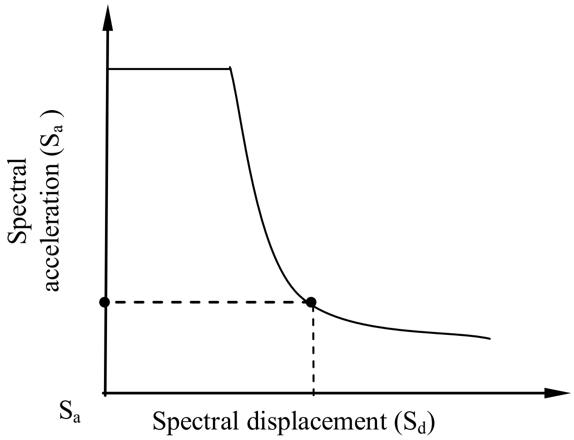


Fig. 4 Demand spectrum curve.

Performance point: Performance point can be obtained by
Superimposing capacity spectrum and demand spectrum and the intersection point of these two curves is performance point. Fig.5**.** shows superimposition demand spectrum and capacity spectrum.

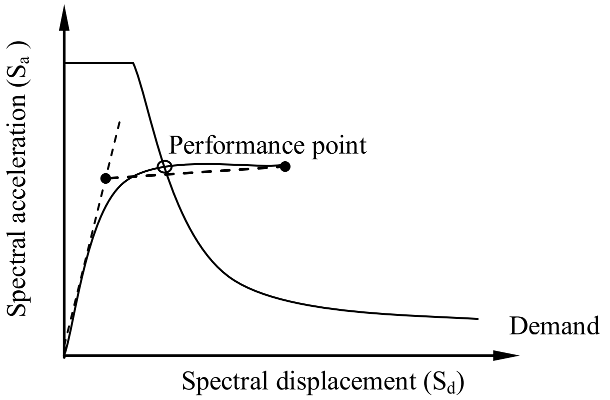


Fig. 5 Performance point representation

Check performance level of the structure and plastic hinge formation at performance point. A performance check verifies that structural and non-structural components are not damaged beyond the acceptable limits of the performance objective for the force and displacement implied by the displacement demand.

CRACKED AND UNCRACKED SECTION

Uncracked Section

If a structure is subjected to gradually increasing load in the early stages of loading, the applied moment (at any section) is less than the cracking moment M_{cr} and the maximum tensile stress f_{ct} in the concrete is less than its flexural tensile strength f_{cr}. This phase is uncracked phase, wherein the entire section is effective in resisting the moment and is under stress. The uncracked phase reaches its limit when the applied moment becomes equal to the cracking moment $M_{cr.}$ In the concrete stress-strain curve the uncracked phase falls within the initial linear portion.

The Cracking moment is given by the Equation,

$$M_{cr} = \frac{I_t}{y_t} f_{cr} \qquad 7$$

Where, y_t is the distance between the neutral axis and the extreme tension fibers, and I_t is the second moment of the area of the transformed reinforced concrete section with reference to the N.A.

Cracked Section

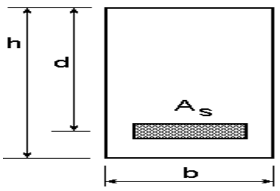
As the applied moment exceed M_{cr}, the maximum tensile stress in concrete exceeds the flexural tensile strength of concrete and the section begins to crack on the tension side. The cracks are initiated in the bottom (tensile) fibers of the beam, and with increasing loading, widen and propagate gradually towards the neutral axis. As the cracked portion of concrete is now rendered ineffective in resisting tensile stresses, the effective concrete section is reduced.

For any further increase in the applied moment the tension component has to contribute solely by the reinforcing steel. With sudden increase in tension in the steel, there is associated increase in tensile strain in the steel bars at the cracked section. This relatively large increase in tensile strain at the level of steel results in an upward shift of the neutral axis and increase in curvature at the cracked section.

Cracked and Uncracked Section Properties:
Properties of concrete cracked section and uncracked section based on Gross section i.e. Gross moment of inertia I_g,

$$I_g = \frac{bd^3}{12} \qquad 8$$

Moment of inertia for cracked and uncracked section,
Consider a simple rectangular beam (b x h) reinforced with steel reinforcement of A_s
E_c – Modulus of Elasticity – concrete
E_s – Modulus of Elasticity – steel
As- Area of steel
d – Distance to steel
h- Height
b- Width



$$n = \frac{E_s}{E_c}$$

Fig.no.6 Cross section of beam

The centroid and moment of inertia is given by the equation,
Uncracked Section

$$\bar{y} = \frac{\sum y_i A_i}{\sum A_i} = \frac{\frac{bh^2}{2} + (n-1)A_s d}{bh + (n-1)A_s} \qquad 9$$

$$I = \frac{bh^3}{12} + \left(\frac{h}{2} - \bar{y}\right)^2 bh + \left(d - \bar{y}\right)^2 (n-1)A_s \qquad 10$$

Cracked Section

$$\left(\frac{\bar{y}}{d}\right) = \sqrt{(n\rho)^2 + 2n\rho} - n\rho \qquad 11$$

…..Solve for the centroid by multiplying the result by d

$$I = \frac{b\bar{y}^3}{3} + \left(d - \bar{y}\right)^2 nA_s \qquad 12$$

To check the capacity of Uncracked and cracked section following simple beam problem is taken.
d = 380mm b = 300mm h = 420mm
E_s = 200000Mpa E_c = 25000 Mpa
Using 4 bars of 20mm dia. A_s=1256.63mm^2

$$n = \frac{E_s}{E_c} = \frac{200000}{25000} = 8$$

Using above formulae we get the centroid and moment of inertia for Uncracked and cracked section as below

Uncracked section	Cracked Section
y = 221.09mm	y = 129.428mm

$I = 2089.98 \times 10^6 \, mm^4$ $\quad\quad$ $I = 848.006 \times 10^6 \, mm^4$

In above problem it is observed that centroid shifted from 221.09mm to 129.428mm and moment of inertia decreases from $I = 2089.98 \times 10^6 \, mm^4$ for uncracked section to $I = 848.006 \times 10^6 \, mm^4$ for cracked section. The cracked section loses more than half of its capacity.

Code specification for cracked and uncracked section:

Cracked section are those in which the extreme fiber stresses exceeds the modulus of rupture f_{cr} specified by the code,
Cracking moment obtained using formula

$$M_{cr} = \frac{I_t}{y_t} f_{cr}$$

Where,
I_t = second moment of area of transformed RC section and
y_t =Dist between NA and extreme tension member

Code IS-456 clause 2.2 suggest formula for

$$f_{cr} = 0.7 \times \sqrt{f_{ck}}$$

Corresponding suggested by code ACI 318 M-05 (American concrete Institute) is,

$$f_{cr} = 0.623 \times \sqrt{f_{ck}}$$

The recent issue of ACI 318-08 gives the following formula,

$$f_{cr} = \lambda \times 0.55 \sqrt{f_{ck}}$$

Where, λ is modification factor for light weight concrete for normal weight concrete λ=1.0
For light weight concrete,

$$\lambda = \left(\frac{f_{ct}}{0.5\sqrt{f_{ck}}} \right) \leq 1.0$$

Where, f_{ct} is spalling tensile strength of light weight concrete

Modification factor for cracked section as per the code ACI 318M-05 (Section 10.10.4.1)

1) Moment of Inertia of Columns (I_{yy} and I_{zz}) = $0.7I_g$
   No reduction in I_{xx} (Torsion) and A_x, A_y, A_z
2) Moment of Inertia of Beams (I_{yy} and I_{zz}) = $0.35I_g$
   No reduction in I_{xx} (Torsion) and A_x, A_y, A_z
   Where, I_g is Gross Moment of Inertia given by,
   The above section properties are used for modeling of
   building in the software SAP-2000.

PROBLEM FORMULATION & MODELING

In this study, for determination of the performance levels, G+10 R.C.C. Building with cracked and uncracked section were taken. The structural Capacity of cracked and uncracked section compared with performance point value. Different modeling issues were analyzed to study the effect on Capacity of the structure in building with cracked and uncracked section for different position of Shear wall.

The example building is G+10 R.C.C. Multi-storey Residential building considered with following details.
1) Plan size 33.40m×12m
2) No of Stories 11(G+10)
3) Floor Height 3m
4) Imposed Load $3kN/m^2$
5) Materials Concrete (M 30) Reinforcement (Fe 415)
6) Depth of Slab 150mm
7) Thickness of wall 230mm

All beams are of uniform size of 400 × 600mm.

Column Section Properties

Story	Column Size(mm)
Base- F2	650 x 650
F3-F6	550 x 550
F7-Roof	450 x 450

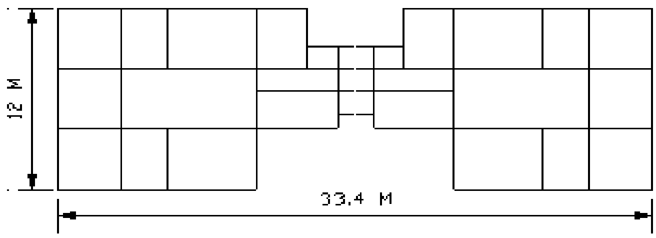


Fig. 7 Plan of building

Material Properties
1) Concrete-
M 30, Density-2500 Kg/m^3, Young's Modulus E- 27386 N/mm^2, Poisson's Ratio-0.2
2) Steel-
Fe 415, Density-7850 Kg/m3, Young's Modulus E -2.1 x 10^5N/mm^2, Poisson's Ratio-0.3

Seismic parameters:

Location	:	Mumbai (zone ш)
Ground condition	:	Type Medium soil
Importance factor	:	1
Response reduction factor	:	3
Zone factor	:	0.16
Response Spectra	:	IS 1893(Part1) 2002

Analysis is carried out for Push X and Push Y as shown in Fig no.8 (Pushing Structure in X and Y direction).

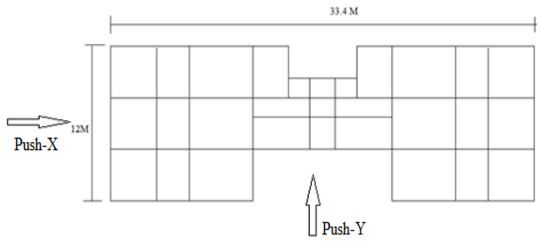


Fig no. 8 Directions of Push-X and Push-Y

Capacity Spectrum Analysis is carried out for above G+10 building using Finite Element based software Sap-2000 for different cases below,
1) Uncracked Section without Shear wall
2) Cracked Section without shear wall
For Different position of shear wall as shown in fig no
Shear wall position in Y-Direction (Fig. No.9)
3) Case 1 4) Case 2 5) Case 3 6) Case 4

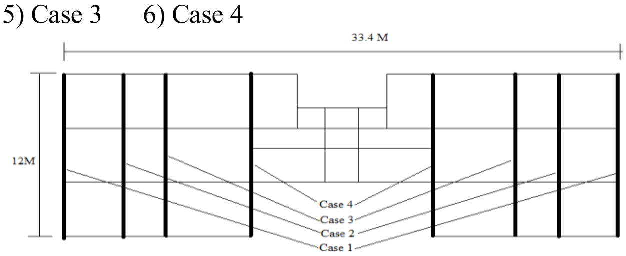


Fig. 9 Different position of Shear wall in y-Direction

Shear wall position in X-Direction (Fig. No.10)

7) Case 1   8) Case 2

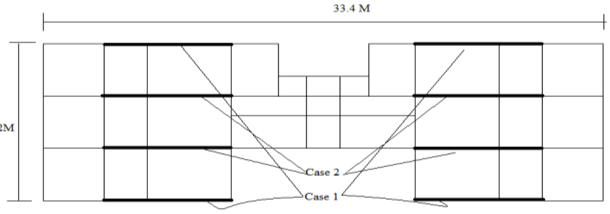


Fig. 10 Different position of Shear wall in x-Direction

The model created and analyze in SAP-2000 for above cases as shown in fig. Also pushover curve, Hinge formation and Capacity Spectrum curve as shown in fig. below.

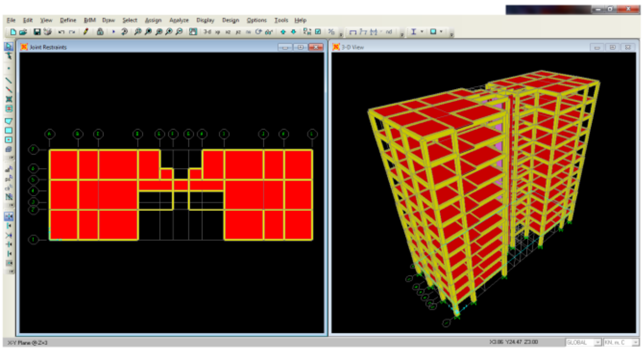


Fig.8 G+ 11 Models in SAP-2000

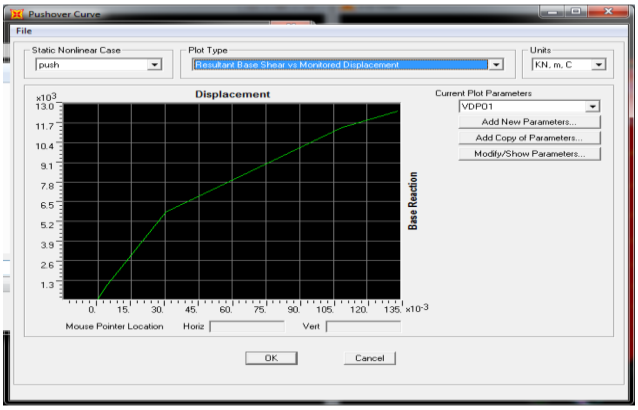


Fig.12 Pushover Curve

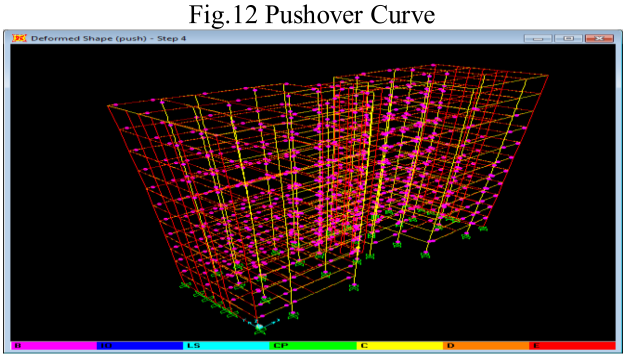


Fig.13 Hinge Formation

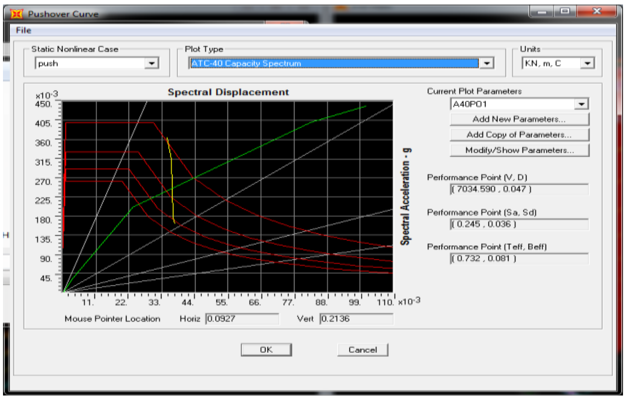


Fig.14 Capacity Spectrum Curve

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III. Results And Discussion:

The Example building is analyze for the performance objective of Life Safety Performance level(FEMA-273) and the result obtained from the analysis for performance point value using software SAP-2000 is presented in the form of table as below,

Performance Point values:

a) For uncracked and cracked section without shear wall

For Push-X Direction

Table no.1 Base Shear, Roof Displacement, for Push-X

Analysis cases	Base Shear Force KN	Displacement mm
Uncracked without shear wall	6617.409	43
Cracked without shear wall	5498.574	58

For Push-Y Direction

Table no.2Base Shear, Roof Displacement, for Push-Y

Analysis cases	Base Shear Force KN	Displacement mm
Uncracked without shear wall	6408.876	47
Cracked without shear wall	5357.262	56

b) For uncracked section with different position of shear wall in y-direction For Push-X Direction

Table no.3

For Push-X for different position of shear wall in y-direction

Analysis cases	Base Shear Force KN	Displacement mm
Uncracked without shear wall	6617.409	43
Shear Wall At Case 1	7034.59	47
Case 2	6922.328	45
Case 3	6907.283	54
Case 4	6868.675	58

For Push-Y Direction

Table no.4 for Push-Y different position of shear wall in y-direction

Analysis cases	Base Shear Force KN	Displacement mm
Uncracked without shear wall	6408.876	47
Shear Wall At Case 1	9522.756	12
Case 2	9942.322	11
Case 3	10454.001	16
Case 4	9963.118	22

c) For cracked section with different position of shear wall in y-direction For Push-X Direction

Table no.5

For Push-X, different position of shear wall in y-direction

Analysis cases	Base Shear Force KN	Displacement mm
cracked without shear wall	5498.574	58
Shear Wall At Case 1	6695.814	51
Case 2	6571.026	60
Case 3	6520.598	59
Case 4	6101.898	62

For Push-Y Direction

Table no.6

For Push-Y, different position of shear wall in y-direction

Analysis cases	Base Shear Force KN	Displacement mm
cracked without shear wall	5357.262	56
Shear Wall At Case 1	8848.061	12
Case 2	9648.755	11
Case 3	10451.092	18
Case 4	9666.018	23

d) For uncracked section with different position of shear wall in x-direction

For Push-X Direction

Table no.7

For Push-X for different position of shear wall in x-direction

Analysis cases	Base Shear Force KN	Displacement z mm
Uncracked without shear wall	6617.409	43
Shear Wall At Case 1	10497.671	11
Case 2	11096.005	11

For Push-Y Direction

Table no.8

For Push-Y for different position of shear wall in x-direction

Analysis cases	Base Shear Force KN	Displacement mm
Uncracked without shear wall	6408.876	47
Shear Wall At Case 1	9618.200	42
Case 2	9382.672	43

e) For cracked section with different position of shear wall in x-direction

For Push-X Direction

Table no.9

For Push-X for different position of shear wall in x-direction

Analysis cases	Base Shear Force KN	Displacement mm
cracked without shear wall	5498.574	58
Shear Wall At Case 1	10366.327	15
Case 2	10226.381	15

For Push-Y Direction

Table no.10 For Push-Y for different position of shear wall in x-direction

Analysis cases	Base Shear Force KN	Displacement mm
cracked without shear wall	5357.262	56
Shear Wall At Case 1	5806.044	54
Case 2	5932.383	54

Interstory Drift

a) For uncracked and cracked section without shear wall

Table No.11 InterStory Drift for Uncracked & Cracked Section without shear wall

	Interstory Drift			
	Push-X		Push-Y	
Story	Uncracked without shear wall	Cracked without shear wall	Uncracked without shear wall	Cracked without shear wall
11	0.19667	0.31	0.08333	0.0867
10	0.27333	0.38333	0.13667	0.14
9	0.32	0.43	0.1933	0.2033
8	0.37333	0.48333	0.24667	0.2733
7	0.44333	0.54	0.29667	0.3466
6	0.47	0.55	0.31	0.3766
5	0.52333	0.55333	0.3533	0.4333
4	0.57	0.64333	0.3966	0.49
3	0.59667	0.57	0.39	0.4966
2	0.59667	0.51333	0.3633	0.47
1	0.58333	0.26667	0.19333	0.3333

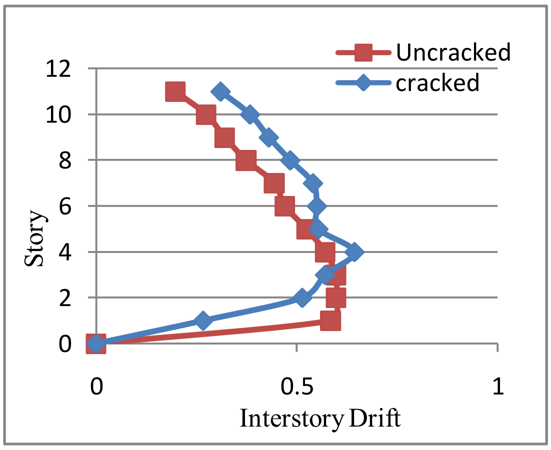


Fig.15Interstory Drift for uncracked and cracked section for Push-X

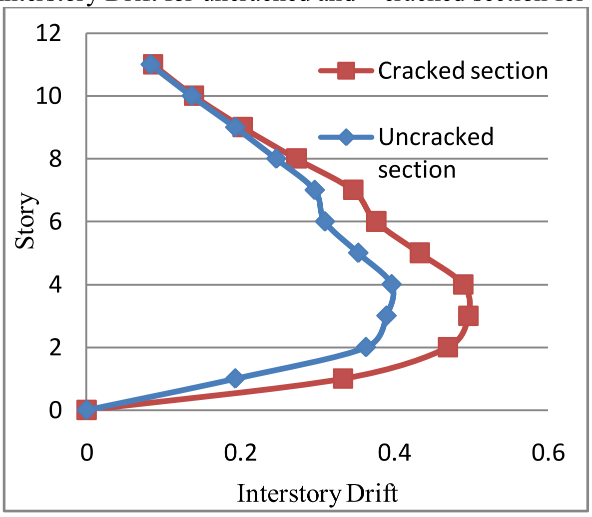


Fig.16 Interstory Drift for uncracked and cracked section for Push-Y

b) For uncracked section with different position shear wall in y-direction For Push-X Direction

Table No.12 InterStory Drift for Uncracked Section with Different Position of Shear Wall in y-direction for Push-X

Story	Interstory Drift			
	Uncracked Section			
	case1	case2	case3	case4
11	0.176667	0.186667	0.213333	0.246667
10	0.236667	0.253333	0.28	0.32
9	0.293333	0.303333	0.34	0.383333
8	0.353333	0.363333	0.41	0.443333
7	0.41	0.42	0.47	0.51
6	0.456667	0.466667	0.513333	0.553333
5	0.503333	0.51	0.563333	0.613333
4	0.553333	0.563333	0.636667	0.676667
3	0.56	0.576667	0.656667	0.7
2	0.6	0.59	0.683333	0.716667
1	0.34	0.326667	0.396667	0.406667

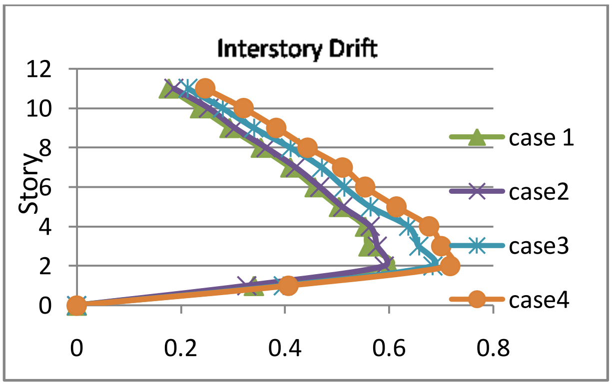


Fig.17 Interstory Drift for uncracked section with different position of shear wall in y-direction for Push-X

For Push-Y Direction

Table No.13 InterStory Drift for Uncracked Section with Different Position of Shear Wall in y-direction for Push-Y

Story	Interstory Drift			
	Uncracked Section			
	case1	case2	case3	case4
11	0.15667	0.16667	0.16333	0.15667
10	0.15667	0.17	0.17	0.19333
9	0.16	0.17	0.1667	0.22333
8	0.16	0.1667	0.1667	0.25
7	0.15667	0.16	0.16	0.27667
6	0.15333	0.15667	0.15667	0.28333
5	0.15	0.1433	0.14667	0.32
4	0.1333	0.12667	0.13	0.36667
3	0.1233	0.10667	0.1133	0.38667
2	0.09667	0.07667	0.1	0.38
1	0.06667	0.03667	0.0633	0.23667

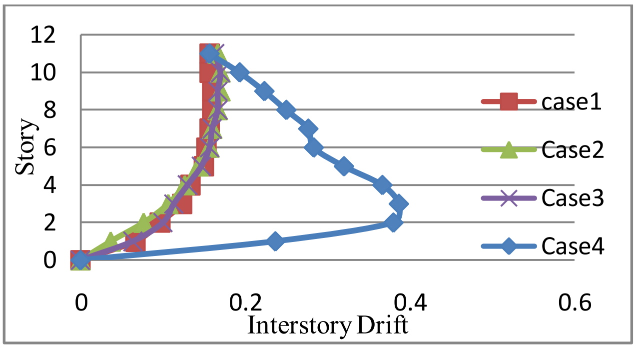


Fig.18Interstory Drift for uncracked section with different position of shear wall in y-direction for Push-Y

c) For cracked section with different position shear wall in y-direction For Push-X Direction

Table No.14 InterStory Drift for Cracked Section with Different Position of shear Wall in y-direction for Push-X

Story	Interstory Drift			
	Cracked			
	case1	case2	case3	case4
11	0.123333	0.293333	0.233333	0.263333
10	0.163333	0.366667	0.296667	0.326667
9	0.19	0.423333	0.346667	0.373333
8	0.226667	0.486667	0.393333	0.423333
7	0.256667	0.55	0.443333	0.47
6	0.276667	0.613333	0.463333	0.496667
5	0.296667	0.633333	0.5	0.526667
4	0.306667	0.706667	0.52	0.543333
3	0.283333	0.733333	0.496667	0.516667
2	0.24	0.746667	0.456667	0.466667
1	0.113333	0.393333	0.23	0.233333

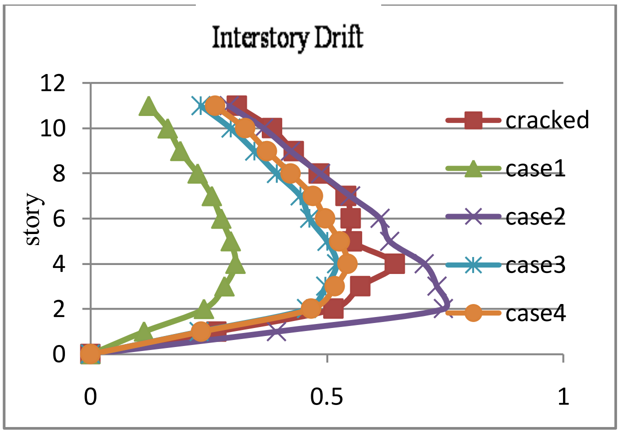


Fig.19 Interstory Drift for Cracked section with different Position of shear wall in y-direction for Push-X

For Push-Y Direction

Table No.15 InterStory Drift for Cracked Section with Different Position of shear Wall in y-direction for Push-Y

Story	Interstory Drift			
	Cracked			
	case1	case2	case3	case4
11	0.19667	0.25667	0.24	0.17
10	0.2033	0.25333	0.24	0.22
9	0.2033	0.25333	0.23667	0.24667
8	0.2033	0.25	0.2233	0.2733

7	0.2033	0.2433	0.21667	0.2933
6	0.1933	0.2333	0.20333	0.3
5	0.19	0.22	0.19	0.33667
4	0.17667	0.1933	0.17667	0.39
3	0.15667	0.17333	0.17	0.42667
2	0.13	0.13333	0.18333	0.45667
1	0.09	0.0733	0.13667	0.29

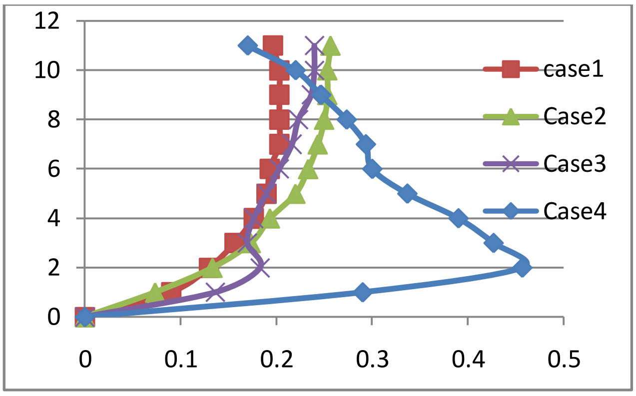
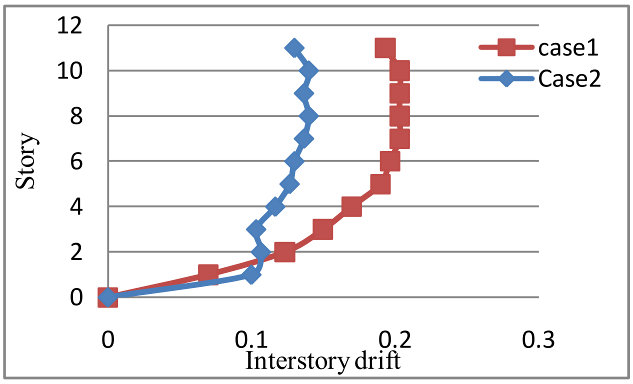


Fig.20 Interstory Drift for Cracked section with different Position of shear wall in y-direction for Push-Y

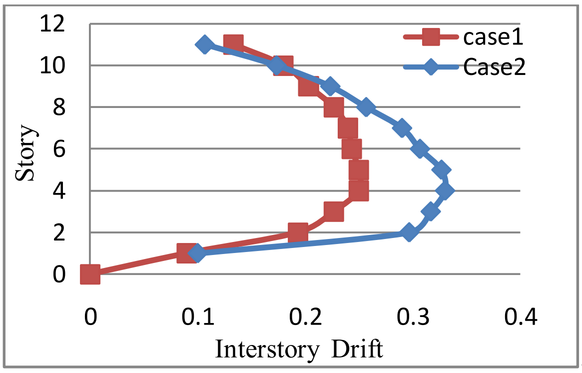
d) For uncracked section with different position shear wall in x-direction

Table No.16 InterStory Drift for Uncracked Section with Different Position of shear Wall in x-direction

Story	Uncracked Section			
	Push-X		Push-Y	
	case1	case2	case3	case4
11	0.19333	0.13	0.13333	0.10667
10	0.20333	0.14	0.18	0.17333
9	0.20333	0.13667	0.20333	0.22333
8	0.20333	0.14	0.22667	0.25667
7	0.20333	0.13667	0.24	0.29
6	0.19667	0.13	0.24333	0.30667
5	0.19	0.12667	0.25	0.32667
4	0.17	0.11667	0.25	0.33
3	0.15	0.10333	0.22667	0.31667
2	0.12333	0.10667	0.19333	0.29667
1	0.07	0.1	0.09	0.1



(a)



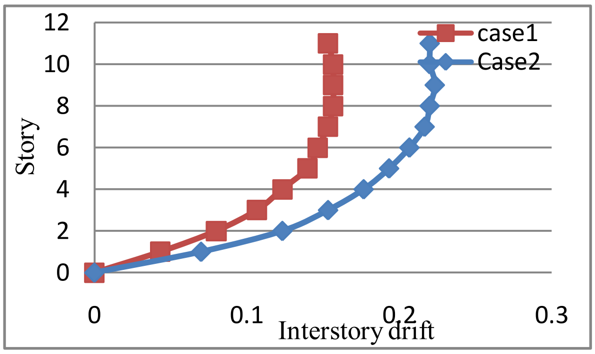
(b)

Fig.21Interstory Drift for Uncracked section with different Position of shear wall in x-direction for Push-X (a) Push-Y (b)

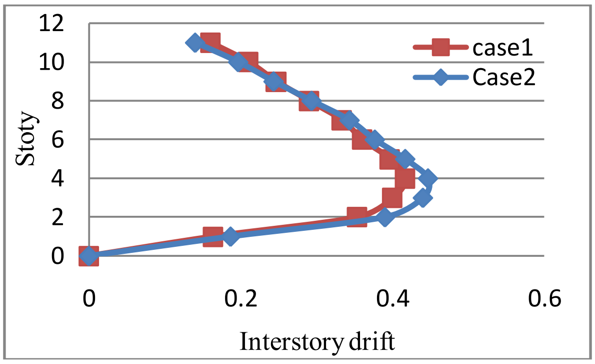
e) For cracked section with different position shear wall in x-direction

Table No.17 InterStory Drift for Cracked Section with Different Position of shear Wall in x Direction

Story	Cracked Section			
	Push-X		Push-Y	
	case1	case2	case3	case4
11	0.15333	0.22	0.16	0.14
10	0.15667	0.22	0.21	0.19667
9	0.15667	0.22333	0.24667	0.24333
8	0.15667	0.22	0.29	0.29333
7	0.15333	0.21667	0.33333	0.34333
6	0.14667	0.20667	0.36	0.37667
5	0.14	0.19333	0.39667	0.41667
4	0.12333	0.17667	0.41667	0.44667
3	0.10667	0.15333	0.4	0.44
2	0.08	0.12333	0.35333	0.39
1	0.04333	0.07	0.16333	0.18667



(a)



(b)

Fig.22 Interstory Drift for Cracked section with different Position of shear wall in x-direction for Push-X (a) Push-Y (b)

IV. Discussion:

From The problem solved it is observed that centroid shifted from 221.09mm to 129.428mm and moment of inertia decreases from $2089.98\times10^{6}\,mm^{4}$ for uncracked section to $848.006\times10^{6}\,mm$ for cracked section. The cracked section looses more than half of its capacity.

In Cracked section Neutral Axis is shifted upwards as compared to uncracked section. Effective cross-section is reduced in case of cracked section due to Reduction in cross-section of cracked section its moment of inertia is reduced as compared to uncracked section hence cracked section loses its strength (Capacity).

Comparison of base shear and Roof displacement

From the tables no.1 it shows that the base shear at performance point for Push-X increases from 5498.574KN for cracked section to 6617.409KN for uncracked section, the roof displacement at performance point is decreases from 58mm for cracked section to 43mm for uncracked section. Also From the tables no.2 it shows that the base shear at performance point for Push-Y increases from 5357.262KN for cracked section to 6408.876KN for uncracked section, the roof displacement at performance point is decreases from 56mm for cracked section to 47mm for uncracked section. For both Uncracked and Cracked section the base shears increases and roof displacement is reduced in Push-X direction compared to Push-Y direction.

From table no.3 for uncracked section with shear wall in y-direction for Push-X the base shear at performance point for position of shear wall at case 1 is7034.59KN which is more than all other cases and roof displacement 47mm which is less than all other cases. And also from table no.4 for Push Y base shear for case1 and case2 is 9522.756KN and 9942.322KN and roof displacement is 12mm and 11mm which are good result compared to all other cases. But considering both Push-X and Push-Y shear wall position Case1gives better result than the all other case. Similarly from table no.5 and 6 for cracked section shear wall position case1 result better than all other cases. For both Uncracked and cracked section with shear wall in y-direction the base shears increases and roof displacement is reduced in Push-Y direction compared to Push-X direction.

From table no.7 for uncracked section with shear wall in x-direction for Push-X the base shear at performance point for position of shear wall at case1 and case2 is 10497.671KN and 11096KN and roof displacement is 11mm for both cases1 and case2. And also from table no. 8 for Push-Y base shear for case1 and case2 is 9618.200KN and 9382.672KN and roof displacement is 42mm and 43mm. considering both Push-X and Push-Y result the case1 is having good result. Similarly from table no.9 and 10 for cracked section shear wall position case1 result good than all other cases. For both Uncracked and cracked section with shear wall in x-direction the base shears increases and roof displacement is reduced in Push-X direction compared to Push-Y direction.

Comparison of Drift

From table no.11 and fig.no.15 and 16 it is observed that the building interstory drifts with uncracked section is less than the cracked section for Push-X and Push-Y. From table no. 12 and 13 and from fig.no.17 and 18 for uncracked section with shear wall in y-direction for Push-X and Push-Y for position of shear wall at case 1 shows less interstory drifts than all other position of shear wall cases. Also from table no.14 and 15 and from fig.no.19 and 20 for cracked section with shear wall in y-direction for Push-X and Push-Y for case 1 less interstory drift. Similarly for uncracked and cracked section for shear wall in x-direction for both Push-X and Push-Y giving less interstory drift results for case1.

From above discussion it is also observe that cracked section with shear wall in y-direction for case1 gives good result for Push-Y i.e. base shear 8848.061KN and roof displacement 12mm and for cracked section without shear wall base shear is 5357.262KN and roof displacement 56mm. In case of cracked section with shear wall in x-direction for case 1 gives good result for Push-X i.e. 10366.327KN and roof displacement 15mm and for without shear wall base shear is 5498.574KN and roof displacement 58mm. It shows that by providing shear wall at periphery (case1) of building capacity of cracked section is increases compared to uncracked section.

V. CONCLUSION

The based on above result and discussion, the following conclusion can be drawn.

1) Capacity spectrum method gives graphically clear
Picture of how a building responds to Earthquake Ground motion.

2) Pushover analysis can be effectively used in assessing the seismic performance evaluation of buildings.

3) According to the performance evaluation with the capacity spectrum method, the eleven story (G+10) reinforced concrete building without shear wall having lesser lateral load capacity (performance point value) in Push-Y direction than Push-X direction. The given type of rectangular building is stiffer in Push-X direction than Push-Y direction. The depth (no. of bays) in x direction of building is greater compared to y direction hence number of bays in x direction is more it provide high stiffness in Push-X. The number bays increases the lateral load capacity of structure.

4) Considering the result obtained from G+10 reinforced concrete building with shear wall in y direction having more lateral load capacity(performance point value) for Push-Y compared to Push-X. The shear walls in y direction are plane elements made of R.C. thin wall having length and thickness providing lateral stiffness to the structure. Due to high stiffness of shear wall in y direction strength (capacity) of structure is more in Push-Y direction. Similarly result obtained for shear wall in x direction having more lateral load capacity for Push-X than Push-Y.

5) From the result obtained and discussion of G+10 R.C building for different position of shear wall, the position of shear wall at case1 (periphery of building) improve the lateral load capacity (performance pint value i.e. displacement, drift, hinges formation) compared to all other position of shear wall which is inside the building for both shear wall in x and y direction. Shear wall close to centre of building are less efficient hence shear wall along perimeter (case1) are more efficient because shear wall along perimeter of building improves resistance twist (torsional effect).

Exterior wall like a cage established outside to lateral forces. Shear wall should be provided in both direction x and y at perimeter of building improves the capacity, if it is provided in one direction a proper moment resistance frame must be provided in other direction.

6) Based on the result obtained for uncracked and cracked section of G+10 reinforced concrete building at performance point value, cracked section having lesser lateral load capacity than uncracked section. The reduction in moment of inertia in cracked section, stiffness of cracked section is reduced compared to uncracked section this reduction in stiffness looses half of its strength (capacity) of cracked section.

7) From result and discussion the cracked section looses it's more than half of its capacity than uncracked section. By providing shear wall at periphery of building the capacity of cracked section is improves more than uncracked section. Capacity of cracked section less than uncracked section is increases by providing shear wall. Shear wall behave like rigid diaphragm to resist lateral load in their plane.

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