SEISMIC ASSESSMENT OF EXISTING MULTISTORY BUILDING BY PUSHOVER ANALYSIS

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Abstract -. *The earthquake is a transpose mechanism, which not only causes damage to the structure but also severe effects on human life. The conventional design codes established on the capacity based design approach. The stability check against the earthquake, based on top story displacement. From the investigation of past earthquake events, the buildings design based on the conventional code not perform well. The structural engineering community starts revising its procedures for investigating structural performance during the ground shaking. The new design approach developed based on the nonlinear response of the structures. The performance-based design approach utilized the inelastic deformation that absorbs certain levels of energy leading to a reduction in the forces for which structures to be design. The response reduction factor is a key parameter that counts effect the over strength, energy absorption as well as dissipation. Present work deals with the estimation of the response reduction factor for high-rise RC buildings. The buildings are analyzed and design as per the IS 1893:2016, IS 456:2000, and IS 13920:2016. The comparative study carried out for the R factor obtained from the analysis and suggested by the code. The displacement controlled pushover analysis performed for the estimation of the response reduction factor.*

Key Words: *Seismic response, nonlinear static analysis, Response reduction factor.*

1. INTRODUCTION

The earthquake is natural calamity that initiates from the number of natural as well as human made events. The natural events containing meteoric impact, volcanic and tectonic activity. The most of earthquakes occurs due to the relative movement of tectonic plates. The hanuman activities like underground and over ground explosion, pile drive activities developed para seismic influence. Earthquake is an unpredictable and unpreventable event. It is very important to analyse and design the structure withstand against the inertial forces generated during ground vibration. The complete protection against earthquake is not feasible. However, there are some techniques which limits future damage occurs during earthquake. Inference from the past earthquake events, it is necessary to examine the correct response of the structure. The correct response of the structure can be estimate by performance based design technique. The performance of the structure can be estimates using nonlinear static pushover analysis.

In the conventional method, earthquake evaluation based on the life safety criteria while in the performance based design method, earthquake evaluation is performance oriented. In the performance based design method, the seismic performance of the structure termed as expected damage state for a well-known seismic hazard. The performance of structure can be aims by the parameters like floor acceleration, inter story drift and inelastic member deformations. Demand and capacity of the earthquake resistant structure are two fundamental components of the performance-based design. The shaking of the structure due to ground vibration is the main function of the demand. It shows the deformation of the structure during the ground vibration. The capacity represents the resistance against the lateral load deformation. The point at which the demand and capacity meets is known as performance point. This point represents the maximum displacement of the structure can occur during the earthquake. The response reduction factor is represents the selected performance of the structure in the limit state of the structure.

The response reduction factor reduce the elastic response of the structure and account the nonlinearity of the structure. It is the combination of the different parameters of the structural system like over strength, ductility, redundancy and damping.

$$\mathbf{R = R_S * R_\mu * R_\xi * R_R}$$

Where,
R- Response reduction factor
R_S- Over strength factor
R_μ- Ductility factor
R_ξ- Damping factor
R_R- Redundancy factor

Over strength Factor (R_S):
It is the ratio of ultimate base of the structure to design base shear of the structure. The ultimate base shear represents the lateral strength of building.

$$\mathbf{R_S =^{Vu/\ Vd}}$$

Ductility Factor (R_μ):
It is the ratio of ultimate or maximum base shear to the base shear corresponding to the yield of the structure. It represents the nonlinear response of the structure.

$R\mu = 1.0$ for zero-period structures
$R\mu = 2\mu - 1$ for short-period structure
$R\mu = \mu$ for long period structure
$R\mu = 1+ (\mu-1)\, T/0.70$ ($0.70\ s < T < 0.3$)

Where, 'μ' is given by $\mu = \Delta u / \Delta y$, where Δu is ultimate deformation and Δy is yield deformation.

Damping factor (R_ξ):
It shows the effect of 'added' viscous damping and is primarily applicable for structures provided with supplemental energy dissipating devices. Without such devices, the damping factor is generally assign a value equal to 1.0 and is exclude from the explicit components of response reduction factor used in force-based design procedures.

Redundancy Factor (R_R):
It is measure of redundancy in a lateral load resisting system. In RC structures, the moment resisting frames, shear walls or their combinations are the most preferred lateral load resisting systems. Sometimes, the central frames are only design for gravity loads and the perimeter frames are design as the lateral load resisting systems. Thus, the redundancy in lateral load resisting systems depends on the structural system adopted. ASCE 7 recommends a redundancy factor RR= 1.0.

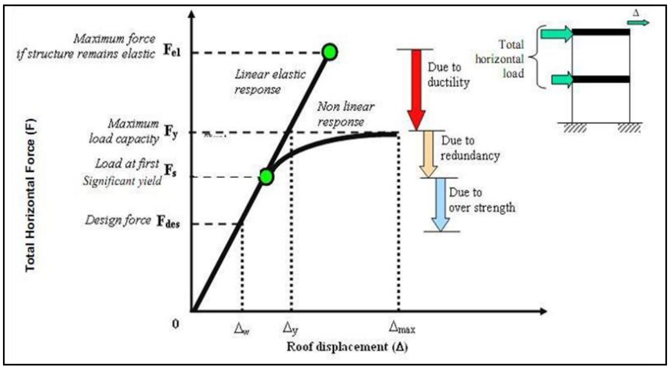

Fig -1: The fundamentals of R factor

2. OBJECTIVES

- The main objective of study is to perform performance-based analysis i.e. to obtain performance levels of buildings for the future earthquake and understand its collapse mechanism in case of extensive damage
- To study the real behaviors of RC buildings in through non-linear analysis and suggest the circumstance, which affects the response of the structure.

3. SCOPE OF WORK

- Selection of an appropriate structural layout for new as well as an existing R.C.C. building.
- Carryout Static Nonlinear Analysis (Pushover Analysis) for R.C.C. building.
- Generate pushover curve (Base Shear-Roof Displacement) for R.C.C. building.
- Obtain Demand curve by converting Response Spectrum into ADRS (Acceleration Displacement Response Spectrum) format.
- Superposition of Capacity curve and Demand Curve to obtain performance point for a specific level of earthquake.
- Evaluation of building performance with reference to performance point.
- Understanding the collapse mechanism of different structural members of a R.C.C. building.
- Find out the response reduction factor and compare with value given by code

4. PROBLEM STATEMENT

To evaluate the seismic response of Reinforced concrete building, we considered four different structure located in seismic zone III. The linear dynamic analysis is perform considering Response spectrum method. The nonlinear dynamic analysis carried out using displacement controlled pushover analysis. The details of the material, geometry, configuration as given below.

Table -1: Input Parameters

Specification	S1	S2	S 3	S4
No. of stories	22	23	20	23
F to F Height	3	3	4.1	3
Type	Residential	Office	Office	Office
Internal wall	150	200	150	230
External wall	230	200	230	230
Slab Thk.	150	200	200	225
SIDL on Floor	1.5	1.2	1.5	1.2
SIDL on Roof	2.5	2.5	2.5	3.3
LL on Floor	3	4	4	4
LL on Roof	2	2	2	1.5

Table -2: Seismic details of Structure

Specification	S1	S2	S 3	S4
Frame Type	SMRF	SMRF	SMRF	SMRF
Soil Type	Medium	Medium	Medium	Medium
I	1	1	1	1
R factor	5	5	5	5
Damping	5%	5%	5%	5%
Response	IS1893:	IS1893:	IS1893:	IS1893:

spectra	2016	2016	2016	2016
Period	0.075 (H)0.75	0.075(H) 0.75	0.075 (H)0.75	0.075(H) 0.75

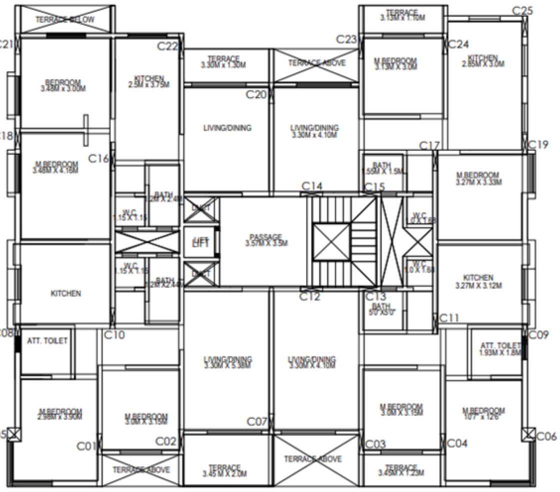

Fig -2: Plan of residential building used in the study

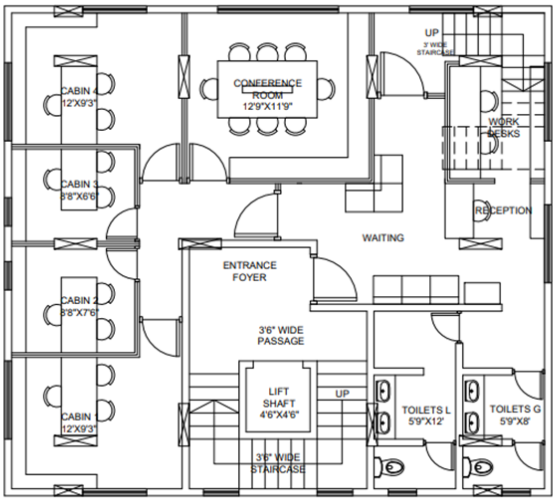

Fig -3: Plan of office 1 building used in the study

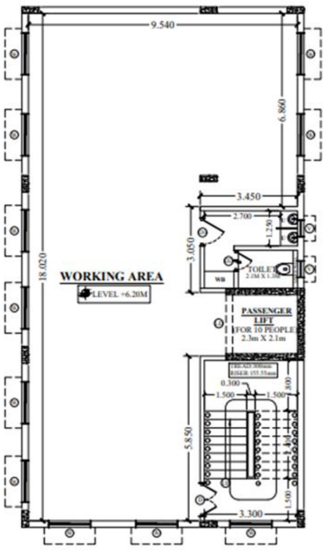

Fig -4: Plan of office building 2 used in the study

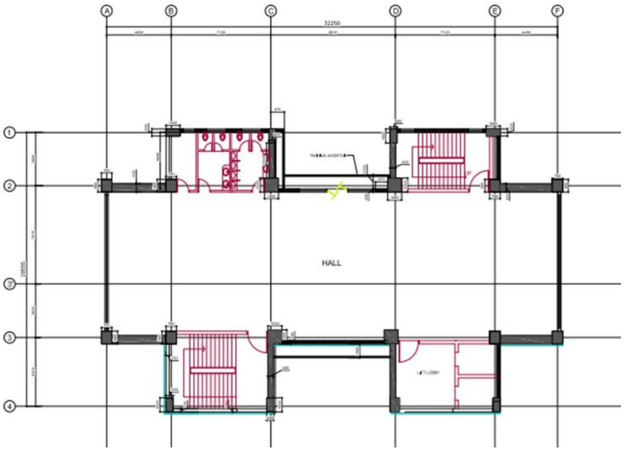

Fig -5: Plan of office building 3 used in the study

Table -3: Reinforcement details of Structure

Structure 1			
Materials	Section	Top steel	Bottom steel
Concrete grade M50 $ Fe500	B1 200 x 600	3-12Φ	3-16Φ
	B2 200 x 600	3-16Φ	3-12Φ
	B3 200 x 600	3-16Φ	3-16Φ
	C 600 x 600	12-20Φ	
Structure 2			
Concrete grade M50 $ Fe500	B4 300 x 600	3-12Φ	3-16Φ
	B5 300 x 600	3-16Φ	3-12Φ
	B6 300 x 600	3-16Φ	3-16Φ
	C 600 x 600	16-20Φ	

Structure 3			
Concrete grade M50 $ Fe500	B7 400 x 600	4-12Φ	4-16Φ
	B8 400 x 600	4-16Φ	4-16Φ
	B9 400 x 600	4-20Φ	4-16Φ
	C 600 x 900	20-20Φ	
Structure 4			
Concrete grade M50 $ Fe500	B10 400 x 750	4-16Φ	4-16Φ
	B11 400 x 750	4-20Φ	4-16Φ
	B12 450 x 900	4-20Φ	4-20Φ
	C 500 x 1000	10-25Φ	
	C 1200 x 1200	24-25Φ	
	C 1500 x 1500	32-25Φ	

5. METHOD OF ANALYSIS

Although an elastic analysis gives a good indication of the elastic capacity of the structures and indicates where first yielding will occur, it cannot predict failure patterns and mechanisms and it cannot account for the redistribution of the forces during progressive yielding. Inelastic or non-linear analysis procedure helps to understand how buildings really work by identifying modes of failure and potential for progressive collapse. This method provides a graphical representation of global force–displacement (capacity/pushover) curve and compares it to response spectra representations of the earthquake demands. The two main parameters for design of a structure are capacity and demand. Demand is a representation of the earthquake ground motion, whereas capacity is the ability of the structure to resist the earthquake demand. The performance of the structure is dependent to the level where the capacity is able to handle the demand. Therefore, the structure must have capacity to resist the demand of the earthquake.

For the structures that vibrate predominantly in the first mode of vibration i.e. the fundamental mode of vibration, such analysis gives a good estimate of global as well as local inelastic deformation demands. It will also expose the design weaknesses that remain unnoticed in the elastic analysis. Such weaknesses include storey mechanisms, excessive deformations, strength irregularities and location of brittle elements.

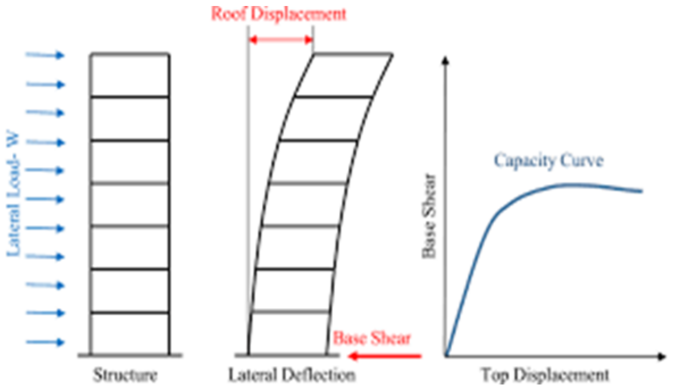

Fig -6: Typical pushover analysis and pushover curve

An analytical model of the structure is model and all the details in the plan and elevation are incorporate in the model. This analytical model is subject to a lateral load distribution (such as parabolic, triangular, uniform) in the desired lateral direction. The lateral loads applied in conjunction with the gravity (dead & live) loads acting on the structure. The intensity of the lateral load is slowly increase under constant gravity loading. The lateral loads are increase to an extent such that the model attains a target displacement prescribed. The horizontal loading is a displacement controlled loading, whereas the gravity loading is force-controlled loading. The structure pushed until a global collapse occurred. The global collapse occurs when adequate number plastic hinges form to develop a collapse mechanism or when the structure cannot mobilize load paths to maintain the equilibrium conditions. Under the forces, the structure deforms and the sequence of cracks, yielding, plastic hinge formations and failure of various structural components recorded. A series of iterations is usually required at any stage of displacement controlled loading to attain force equilibrium.

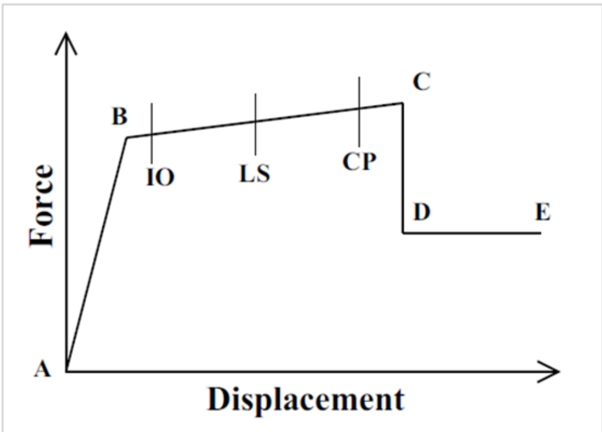

Fig -7: Idealised Force deformation curve

6. RESULT AND DISCUSSION

a. PUSHOVER CURVE:

Nonlinear Static Analysis (Pushover Analysis) performed for a particularly rigorous treatment of the reduction of seismic demand for increasing displacement. It is an attempt to explicit address the nonlinear behaviour of the structure. The results obtained from the analysis shown below.

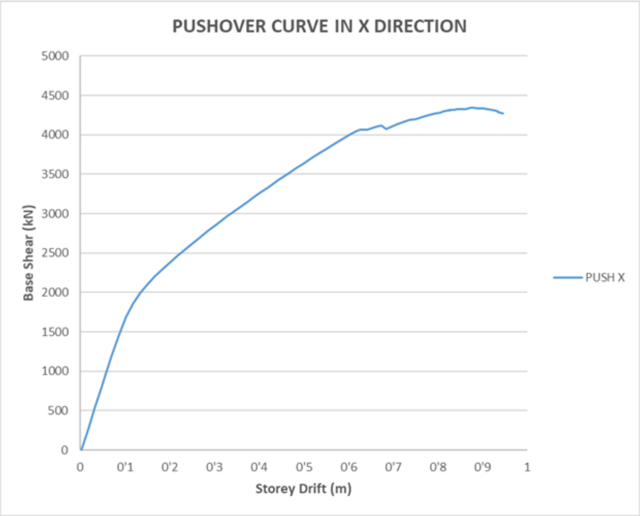

Fig -8: Pushover curve in X direction for structure1

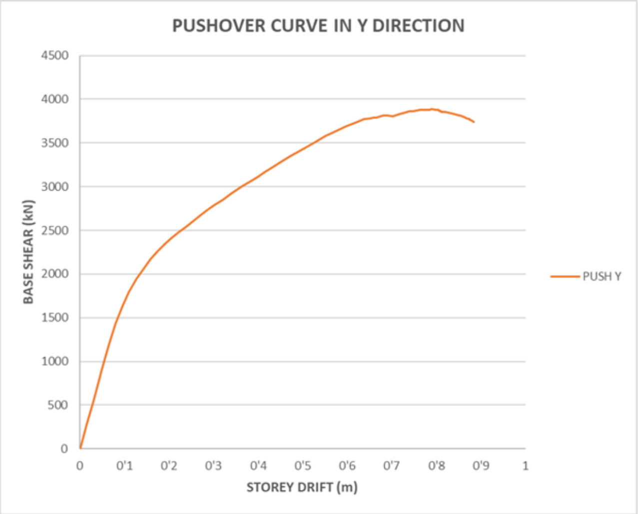

Fig-9: Pushover curve in Y direction for structure1

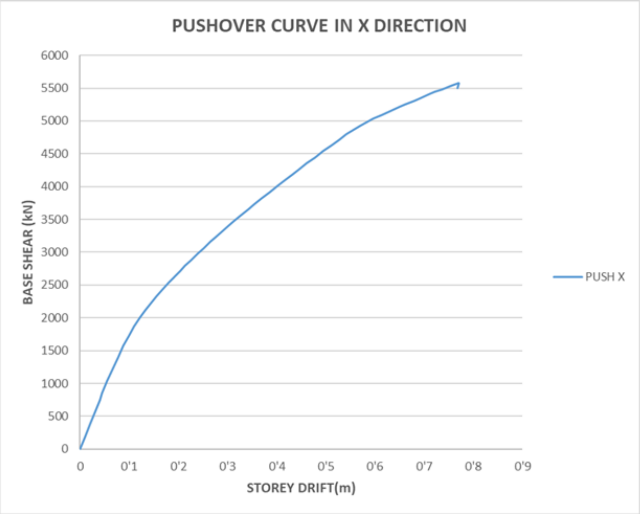

Fig -10: Pushover curve in X direction for structure2

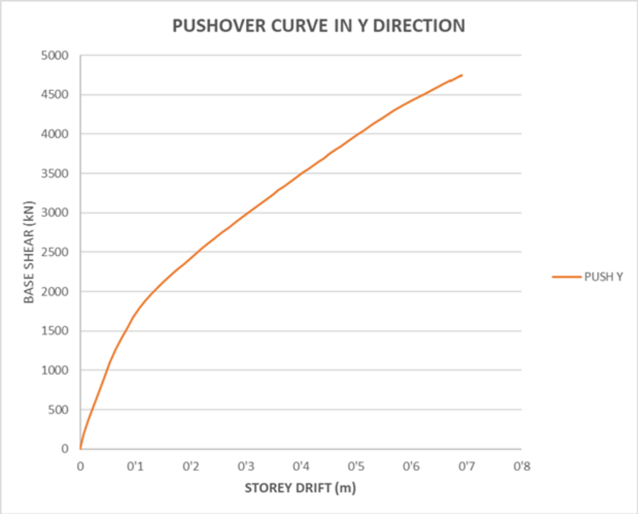

Fig -11: Pushover curve in Y direction for structure2

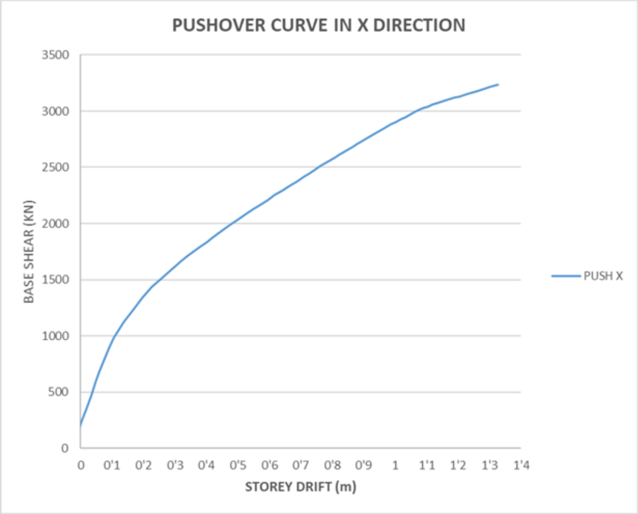

Fig -12: Pushover curve in X direction for structure3

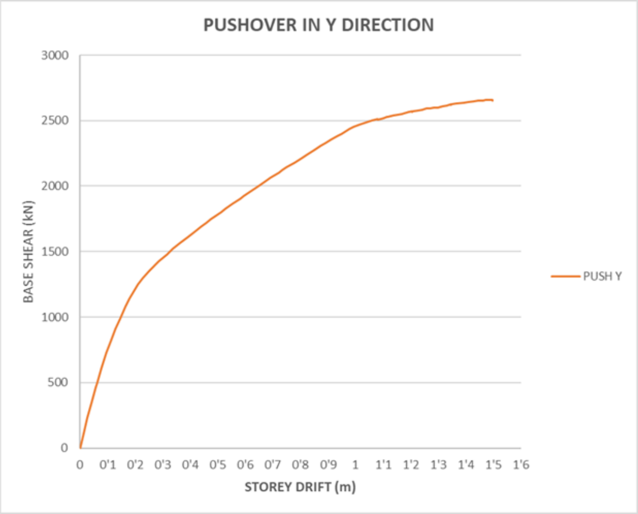

Fig -13: Pushover curve in Y direction for structure3

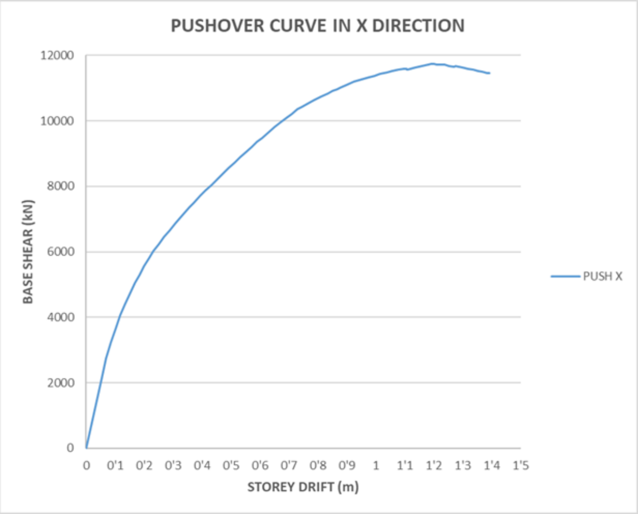

Fig -14: Pushover curve in X direction for structure4

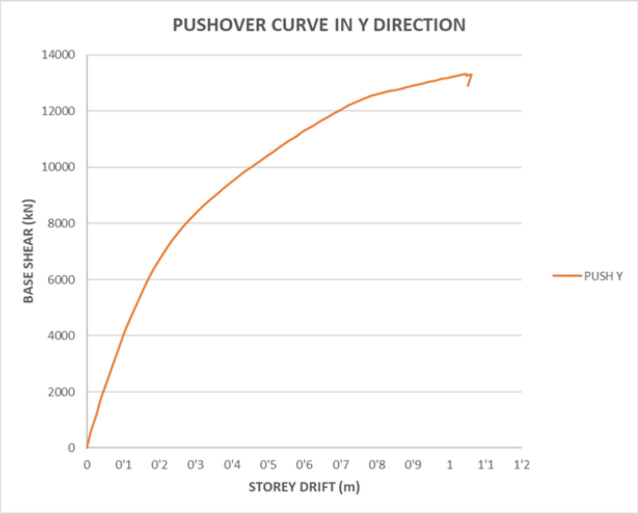

Fig -15: Pushover curve in Y direction for structure4

b. MOMENT CURVATURE:

Moment-curvature analysis for a reinforced concrete section, indicating the available flexural strength and ductility carried out if the stress-strain relationships for the concrete and steel reinforcements known. The moment–curvature relation of a section is uniquely define according to the dimensions of the concrete section and the material properties of concrete and steel. Moment curvature diagram for a particular cross section is plot with X- axis represent the curvature and Y-axis represent the moment. The moment curvature diagram for different beam section shown below

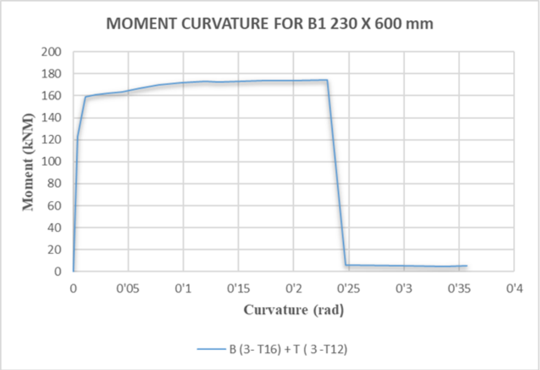

Fig- 16: Moment curvature for B1 230 X 600mm

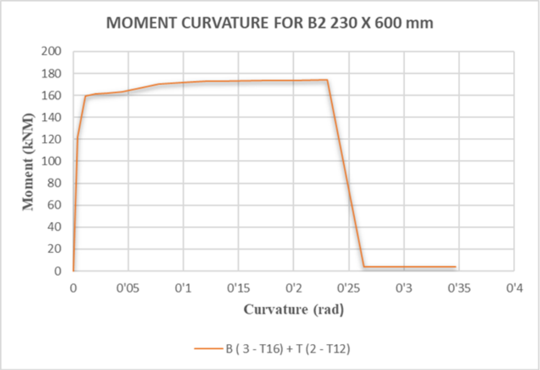

Fig-17: Moment curvature for B2 230 X 600mm

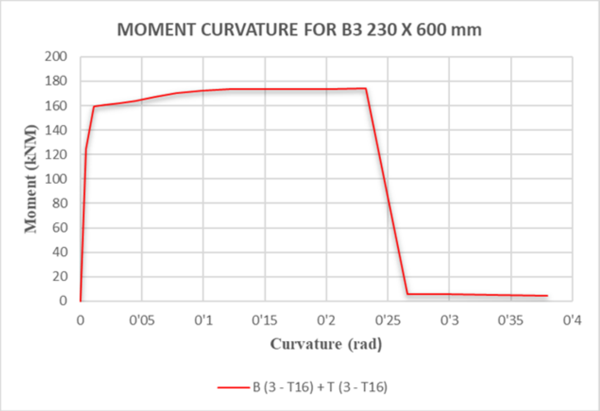

Fig- 18: Moment curvature for B3 230 X 600mm

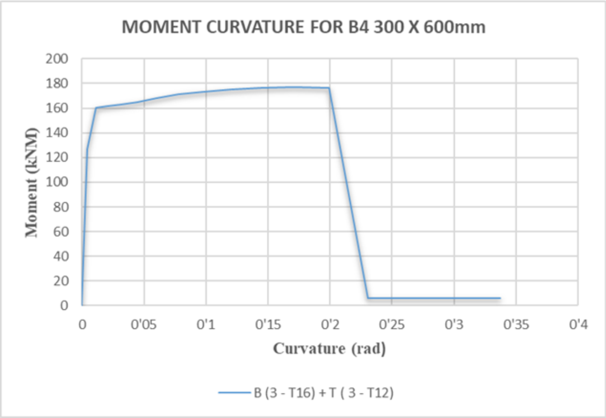

Fig- 19: Moment curvature for B4 300 X 600mm

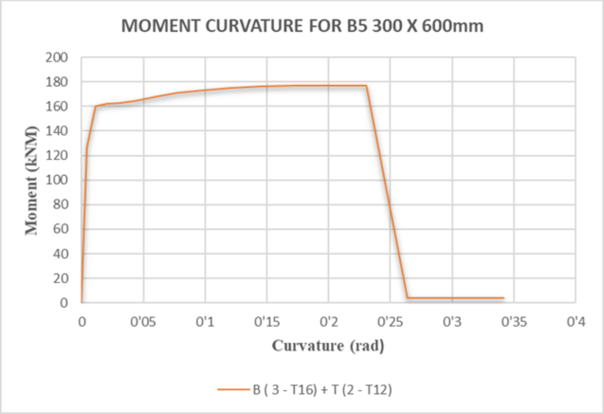

Fig-20: Moment curvature for B5 300 X 600mm

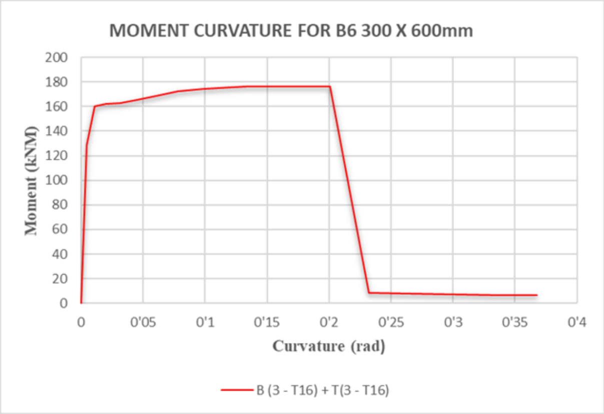

Fig- 21: Moment curvature for B6 300 X 600mm

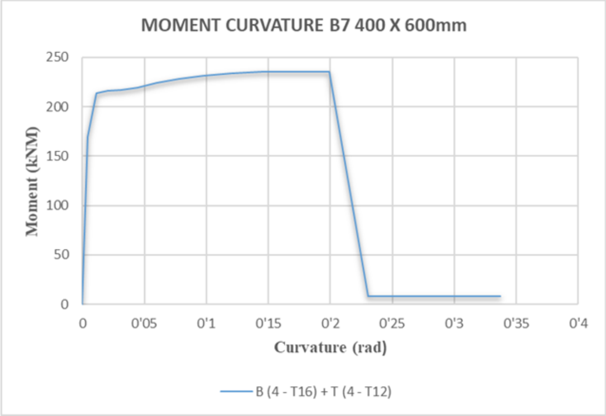

Fig- 22: Moment curvature for B7 400 X 600mm

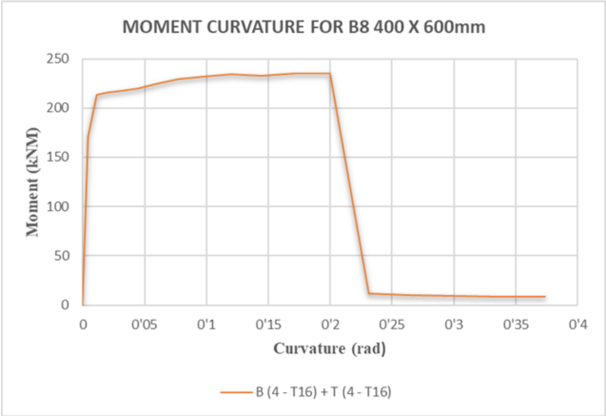

Fig- 23: Moment curvature for B8 400 X 600mm

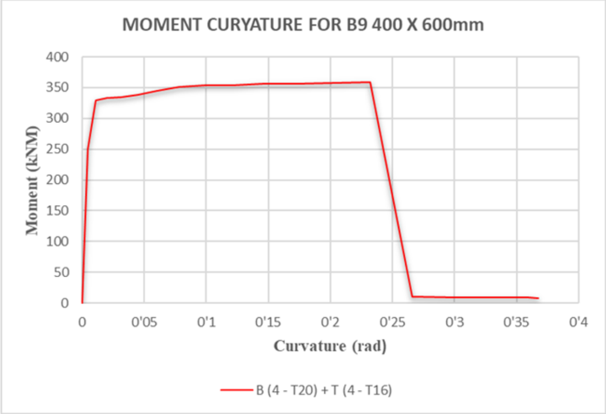

Fig- 24: Moment curvature for B9 400 X 600mm

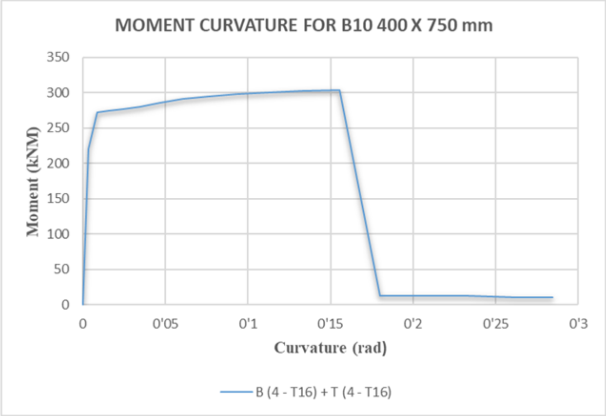

Fig- 25: Moment curvature for B10 400 X 750mm

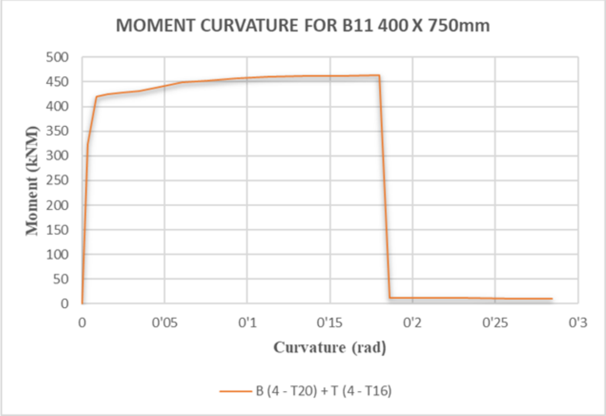

Fig- 26: Moment curvature for B11 400 X 750mm

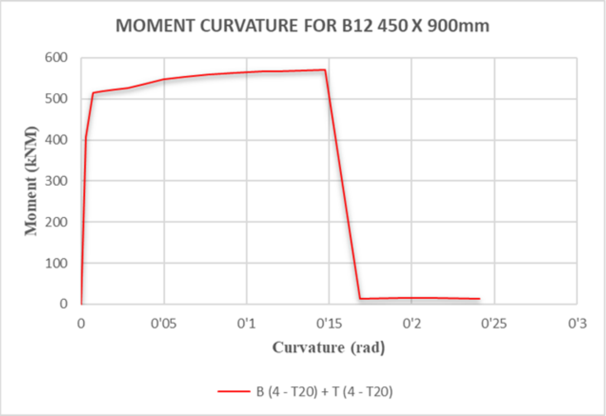

Fig- 27: Moment curvature for B12 450 X 900mm

c. RESPONSE REDUTION FACTOR:

The response reduction factor reduce the elastic response of the structure and account the nonlinearity of the structure. It is the combination of the different parameters of the structural system like over strength, ductility, redundancy and damping. The response reduction factor for analyzed models are calculated below

Table -4: Response reduction factor for buildings push in X direction

Parameter	S1	S2	S3	S4
Zone factor	0.16	0.16	0.16	0.16
Vu (kN)	2534.68	2707.43	1560.19	6030.47
Vy (kN)	1223.35	1224.5	890.69	3243.89
Δu	0.232	0.202	0.276	0.234
Δy	0.085	0.077	0.090	0.085
µ	2.73	2.62	3.06	2.75
Rµ	2.73	2.62	3.06	2.75
RS	2.07	1.93	1.75	1.86
Rr	1	1	1	1
R	5.649	5.79	5.36	5.12

Table -5: Response reduction factor for buildings push in Y direction

Parameter	S1	S2	S3	S4
Zone factor	0.16	0.13	0.16	0.16
Vu (kN)	2500.71	2377.66	1433.87	7222
Vy (kN)	1223.35	1258.13	731.3	3523.3
Δu	0.204	0.192	0.291	0.226
Δy	0.08	0.0.643	0.0959	0.0864
µ	2.84	2.99	3.03	2.62
Rµ	2.84	2.99	3.03	2.62
RS	2.406	1.9	1.96	2.05
Rr	1	1	1	1
R	5.81	5.681	5.947	5.36

7. CONCLUSIONS

1. Maximum storey drift and displacement, for all four structure is within the permissible limit as stated in clause no. 7.11.1 IS 1893:2016
2. The fundamental natural time period for all four structures in accordance with values given by IS 1893:2016
3. After performing the analysis, the base shear at performance point found to be greater than design base shear in respect of all four structure. Since at the performance point, base shear is greater than the design base shear hence the building structure is safe under the earthquake loading.
4. After performing the pushover analysis, performance stages are obtain for all four structure. The first hinge is form in beams for all the structure.
5. The values for response reduction factor obtained from the analysis are in accordance with values given by the IS 1893:2016 for all the four structure.

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