Determination of Performance Level of G+5 Building Situated In Zone III Using Pushover Analysis by Sap2000

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ABSTRACT
Earthquakes are very common in every part of the world. Geographical statistics of India show that almost 54% of the land is vulnerable to earthquakes. A World Bank & United Nations report estimates that around 200 million city dwellers in India will be exposed to earthquakes by 2050. Due to these earthquakes large destruction was caused to the infrastructure and buildings. In order to resist the buildings from the severe motions many analysis methods were developed. Pushover analysis is a method to evaluate the performance level of building. In this paper, pushover analysis is carried out for a G+5 building situated in ZONE III to check the seismicity effect and performance level of a building by SAP2000. Pushover Analysis produces a Pushover curve consists of capacity spectrum, demand spectrum and performance point. It shows the performance level of the building components and also maximum base shear carrying capacity of the structure. From the result shown that demand curve intersects the capacity curve between the point B and C i.e. life safety level. Therefore, some residual strength and stiffness left in all stories. Damage to partitions. Building may be beyond economical repair. In some building parts need to be retrofitted.

Keywords **- Capacity curve, Demand curve, Pushover analysis, Rehabilitation, Retrofitting.**

1. INTRODUCTION
Indian buildings built over past two decades are seismically deficient because of lack of awareness regarding seismic behavior of structures. In general, most earthquake code provisions implicitly require that structures be able to resist minor earthquakes without any damage, moderate earthquakes with negligible structural damage and some nonstructural damage, and major earthquakes with possibly some structural and nonstructural damage. In most structures that are subjected to moderate-to strong earthquakes, economical earthquake-resistant design is achieved by allowing yielding to take place in some structural members. Estimating the maximum lateral displacement of the structures in the wake of massive earthquakes is considered to be widely important for seismic design. Due to economic reason, the present seismic codes allow structures to undergo inelastic deformations in the event of strong ground motions. Consequently, the demand lateral strength is lower than the strength maintaining the structure in the elastic range. According to the seismic codes, the buildings are allowed to use over strength against strong earthquakes. It is well known fact that the distribution of mass and rigidity is one of the major considerations in the seismic design of moderate to high rise buildings. Invariably these factors introduce coupling effects and non linearity in the system; hence it is imperative to use pushover analysis approach by using SAP2000.This paper highlights the performance evaluation of a structure subjected to seismic loads and Step by step procedure of the pushover analysis to determine the capacity curve, demand curve and performance point. In present study a model was designed in SAP2000 and step by step procedure was followed to get capacity curve and demand curve.

1.1 Pushover analysis
The pushover analysis of a structure is a static non-linear analysis under permanent vertical loads and gradually increasing lateral loads [1]. The equivalent static lateral loads approximately represent earthquake induced forces. A plot of the total base shear versus top displacement in a structure is obtained by this analysis that would indicate any premature failure or weakness. The analysis is carried out up to failure, thus it enables determination of collapse load and ductility capacity. On a building frame, and plastic rotation is monitored, and lateral inelastic forces versus displacement response for the complete structure is analytically computed. This type of analysis enables weakness in the structure to be identified. Consequently, at each event, the structures experiences a stiffness change as shown in Fig 1, where IO,LS and CP stand for immediate occupancy, life safety and collapse prevention respectively.

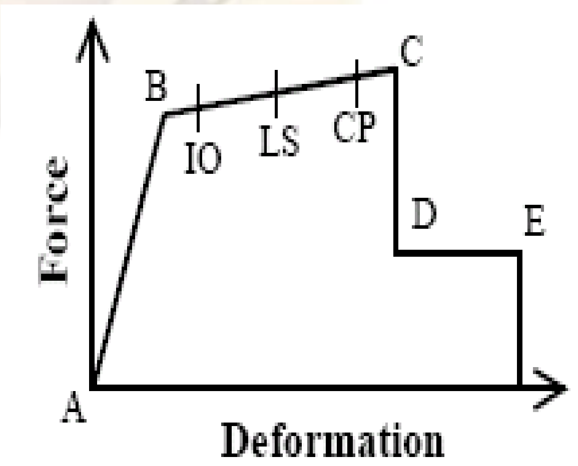

Fig.1 Load –Deformation curve [2]

1.1.1 Capacity
The overall capacity of a structure depends on the strength and deformation capacities of the individual components of the structure. The mathematical model of the structure is modified to account for reduced resistance of yielding components. A lateral force distribution is again applied until predetermined limit is reached. Pushover capacity curves approximate how structure behaves after exceeding the elastic limits.

1.1.2 Demand
Ground motions during an earthquake produce complex horizontal displacement patterns in structure that may vary with time. For nonlinear method it is easier and more direct to use a set of lateral displacement as a design condition for a given structure and ground motion, the displacement is an estimate of the maximum expected response of the building during ground motion.

1.1.3 Performance level
The main output of a pushover analysis is in terms of response demand versus capacity. If the demand curve intersects the capacity [3] envelope near the elastic range (Fig 2), then the structure has a good resistance. If the demand curve intersects the capacity curve with little reserve of strength and deformation capacity, Figure 1b, then it can be concluded that the structure will behave poorly during the imposed seismic excitation and need to be retrofitted to avoid future major damage or collapse.

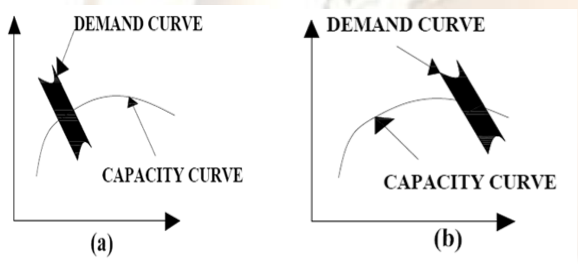

Fig .2 Typical seismic Demand vs. Capacity (a) Safe design (b) Unsafe design [4]

2. DESCRIPTION OF THE STRUCTURE
The structure that is considered represents the medium rise reinforced concrete framed building. This structure is designed according to IS 456-2000 for reinforced concrete and IS 1893-2002 for earthquake forces. The structure is located in medium seismicity region (ZONE III) in Vijayawada. The number of stories is "G+5". Material properties are assumed to be M20 grade concrete for compressive strength of concrete and Fe415 for yield strength of the longitudinal and transverse reinforcement, the other details of structure are shown in the following table1and 2.

Table1: Dimensions of members

Beams (mm)	Columns(mm)			Slab (mm)
	C1	C2	C3	
300 x 400	450 x 300	450 x230	230 x 450	135

Table2: Storey heights

No of storey	Storey height(m)
Ground floor	3.5
First floor	3
Second floor	3
Third floor	3
Fourth floor	3
Fifth floor	3

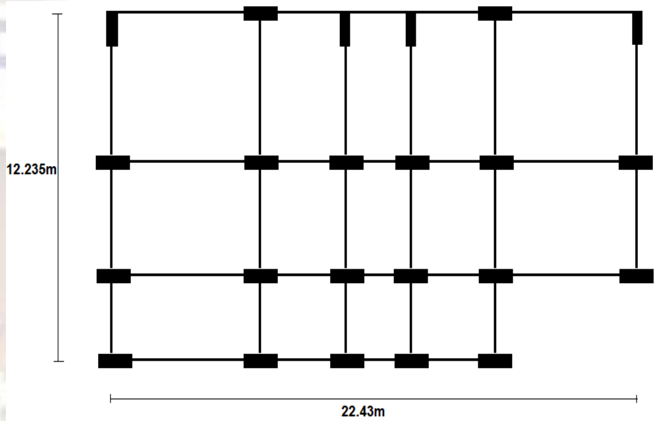

Fig. 3 Plan of building

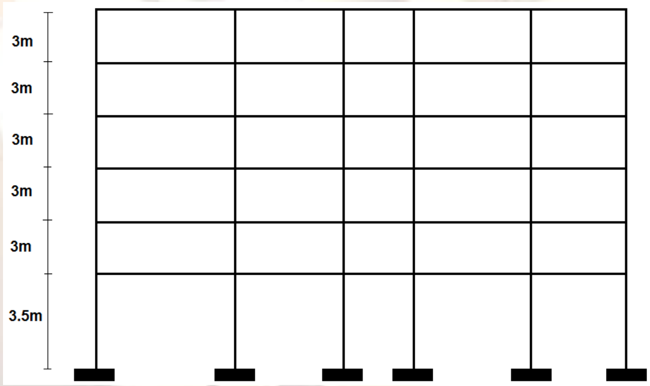

Fig.4 Elevation of building

3. MODELLING APPROACH IN SAP2000
The general finite element package SAP 2000[5] has been used for the analyses. A three dimensional model of each structure has been created to undertake the non linear analysis. Beams and columns are modeled as nonlinear frame elements with lumped plasticity at the start and the end of each element. Load patterns are defined. At grid (0, 0) centre of masses and lateral loads are applied for every floor. SAP 2000 provides default-hinge properties and recommends P-M-M hinges for columns and M3 hinges for beams as described in FEMA-356.

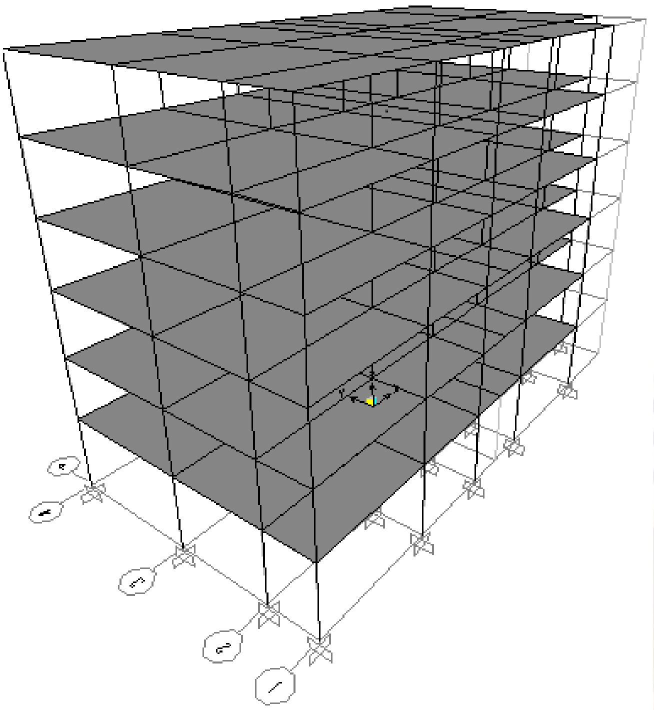

Fig.5 model in sap2000

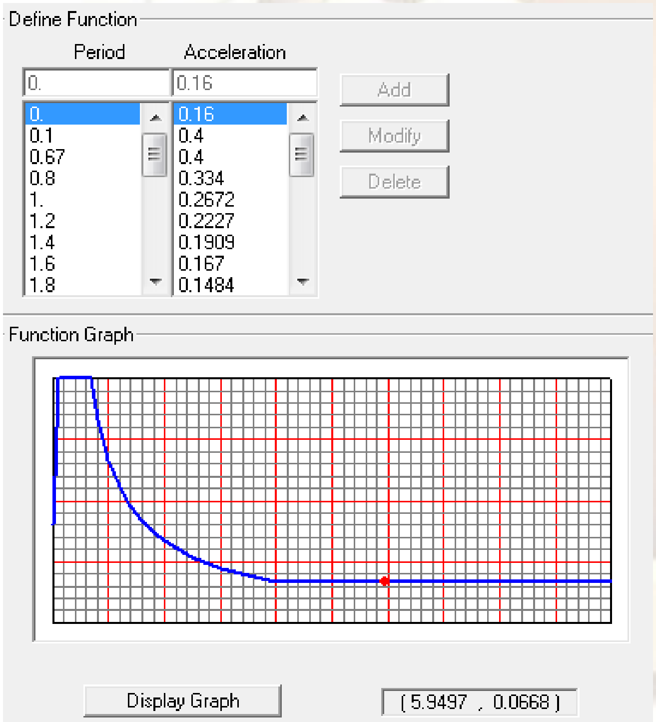

Fig.6 Response spectrum in sap2000

4. CALCULATION OF CENTRE OF MASS

Centre of masses are applied at grid (X, Y: 0, 0) and these are obtain from the response spectrum analysis in SAP2000.the value of centre of mass at each floor is shown in the fallowing table3.

Table 3 : Mass distribution at each floor for ZONEIII

Storey height (m)	Mass(KN-s^2/m)
18.5	154.42
15.5	164.62
12.5	164.62
9.5	164.62
6.5	164.62
3.5	166.51

5. CALCULATION OF DESIGN SEISMIC FORCE BY STATIC ANALYSIS METHOD [6]

For seismic zone III, the zone factor is 0.16 (Table 2 of IS : 1893). Being an office building the importance factor I is 1.0 (Table 6 of IS : 1893). Building is required to be provided with moment resisting frames detailed as per IS: 13920-1993. Hence, the response reduction factor, *R*, is 5. (Table 7 of IS: 1893 Part 1). [7] The design seismic forces at each floor are shown in the following table 4.

Table 4: Lateral load distribution with height

Storey level	W_i (KN)	h_i (m)	$W_ih_i^2$	$W_ih_i^2/\sum W_ih_i^2$	Lateral force	
					X	Y
6	4600	18.5	1574350	0.327	451.2	451.2
5	5980	15.5	1436695	0.298	411.2	411.2
4	5980	12.5	934375	0.194	267.7	267.7
3	5980	9.5	539695	0.112	154.5	154.5
2	5980	6.5	252655	0.0525	72.4	72.4
1	5980	3.5	73255	0.015	20.7	20.7

6. EFFECT OF PLASTIC HINGES

In nonlinear frame behavior, frame hinges must be used. The nonlinear material behavior [8] is only used to develop the moment rotation or other response curves for the hinges. Hinges have a rigid plastic behavior placing these hinges in a model composed of framed elements should not alter elastic stiffness of the model. The effective strength of the hinges is used for deformation controlled actions. Pushover analysis is carried out for either user defined non linear hinge properties or default -hinge properties, available in sap based on the FEMA-356 [9] and ATC-40 guidelines. While such documents provide the hinge properties for several ranges of detailing, programs may implement averaged values. The user needs to be careful; the misuse of default-hinge properties may lead to unreasonable displacement capacities for existing structures. SAP2000 provides default-hinge properties and recommends P-M-M hinges for columns and M3 hinges for beams.

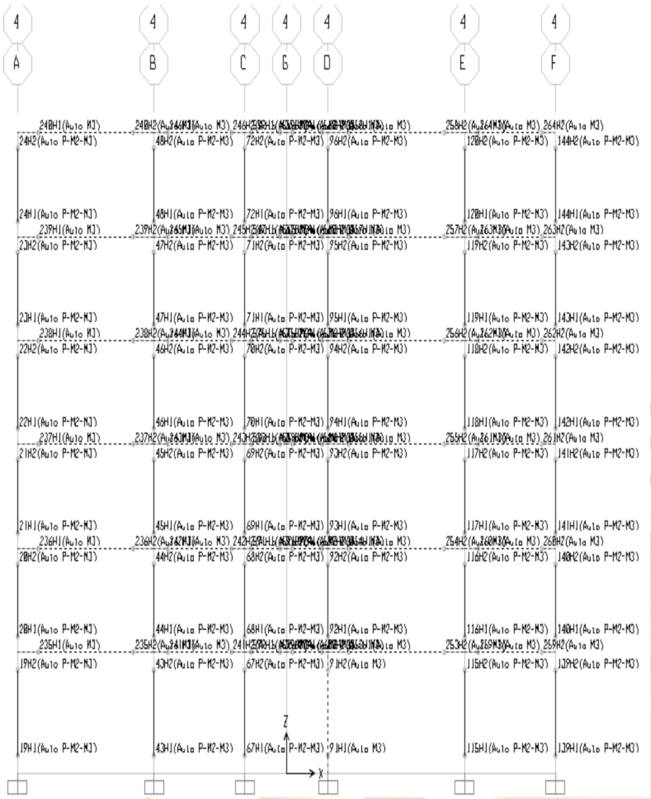

Fig.7 Assigning hinges in sap2000

7. RESULTS AND DISCUSSIONS

The resulting pushover curve for G+5 building shown in the fig.7. The curve is initially linear but starts to deviate from linearity as the beams and columns undergo inelastic actions. When the building is pushed well into the inelastic range, the curve become linear again but with a smaller slope. The target displacement is $750x10^{-3}$m and the base shear is 2200KN.

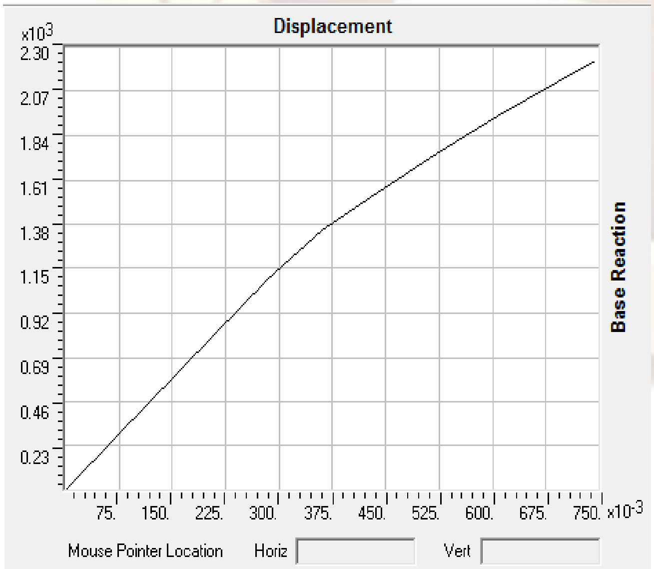

Fig.8 Pushover curve

From the fig.7 it is obvious that the demand curve intersects the capacity curve between the point B and C i.e. life safety level. Therefore some residual strength and stiffness left in all stories. Damage to partitions. Building may be beyond economical repair.

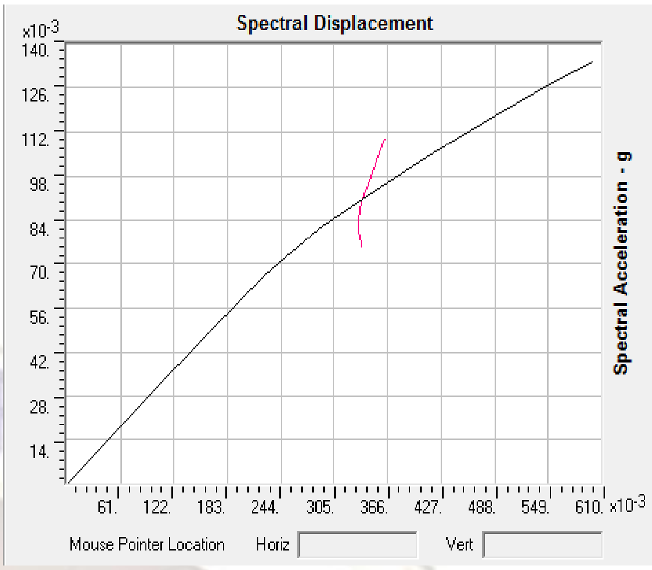

Fig.9 performance point (capacity- demand curve)

7.1. Plastic Hinges Mechanism

Plastic hinges formation for the building mechanisms have been obtained at different displacement levels. The hinge patterns are plotted at different levels in figures 10 to17. Plastic hinges formation starts with beam ends and base columns of lower stories, then propagates to upper stories and continue with yielding of interior intermediate columns in the upper stories. Building may be beyond economical repair.

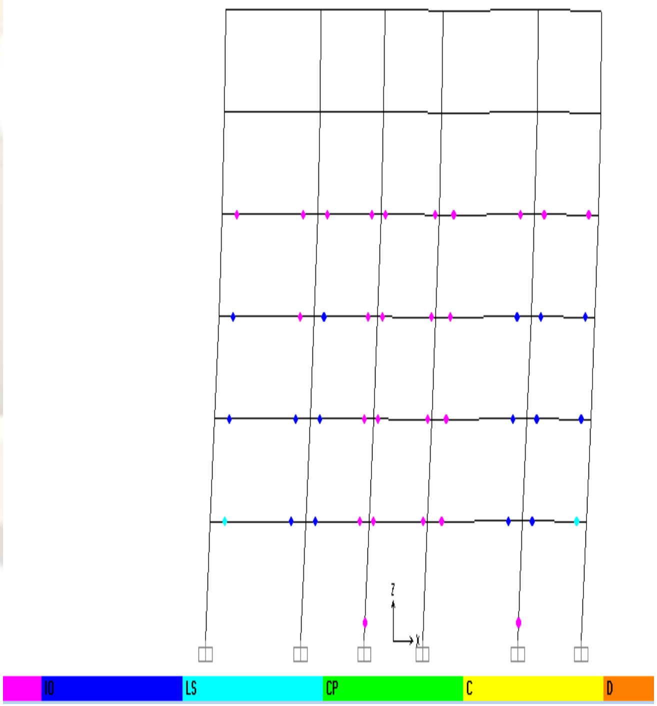

Fig.10 Hinge mechanism in x-z plane at y=0

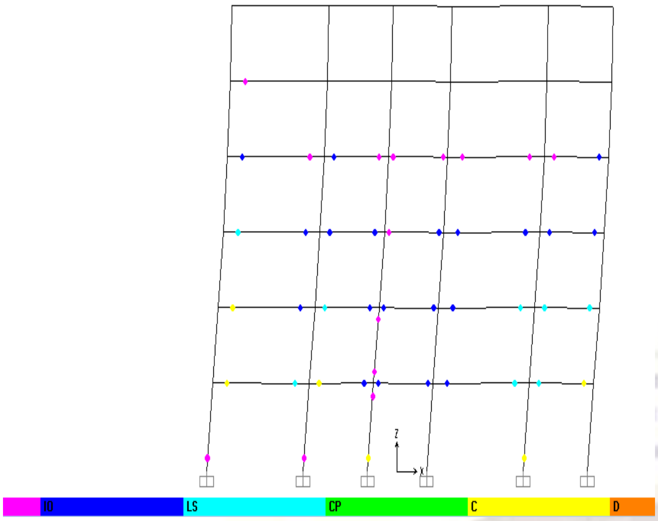

Fig.11 Hinge mechanism in x-z plane at y=0

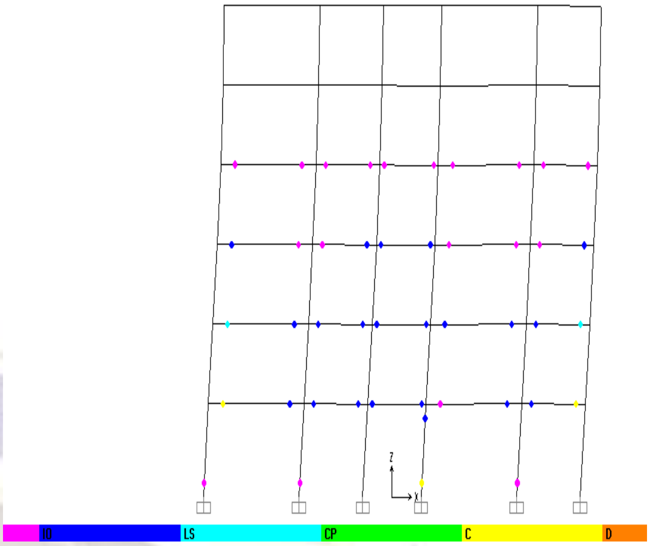

Fig.14 Hinge mechanism in x-z plane at y= - 6.575

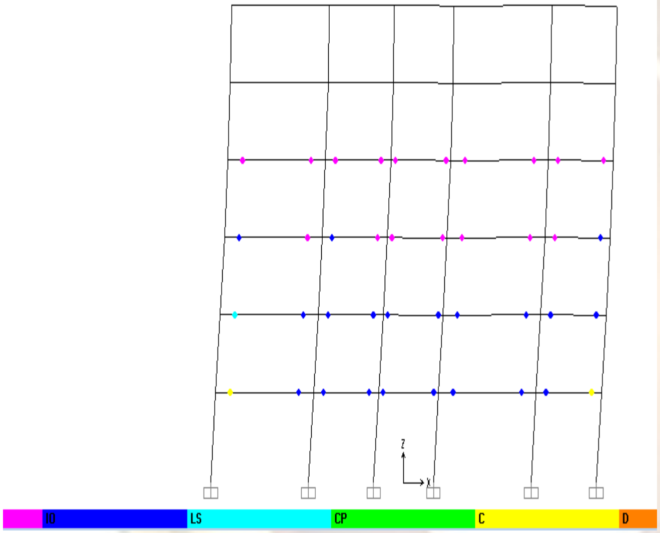

Fig.12Hinge mechanism in x-z plane at y=-4.305

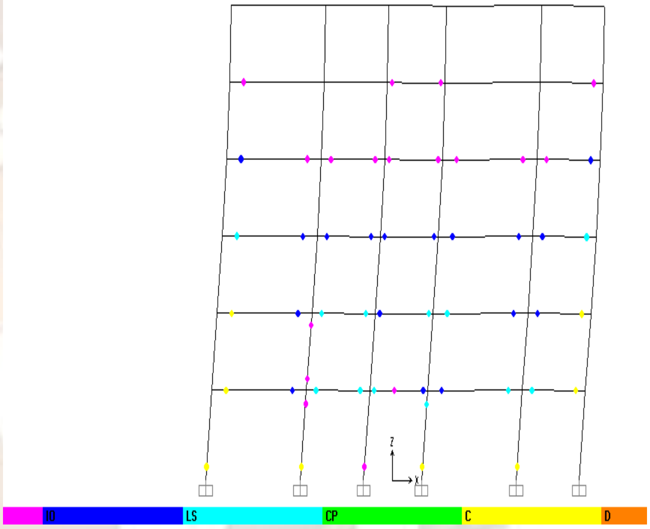

Fig.15Hinge mechanism in x-z plane at y=-6.575

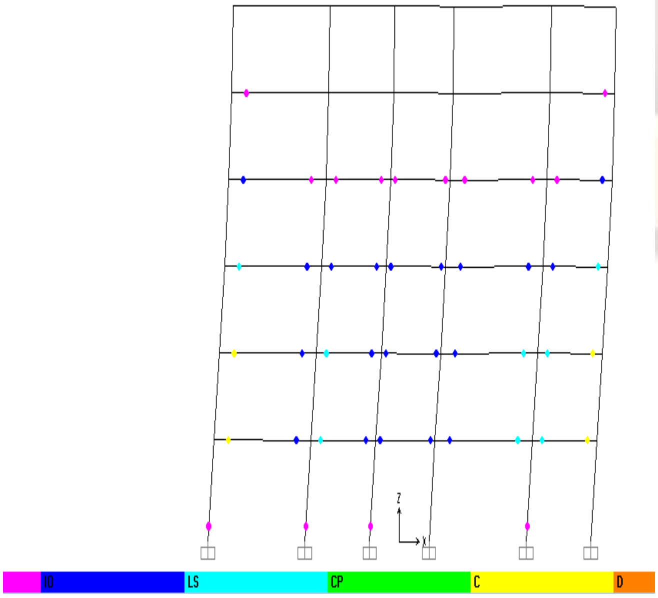

Fig.13 Hinge mechanism in x-z plane at y=-4.305

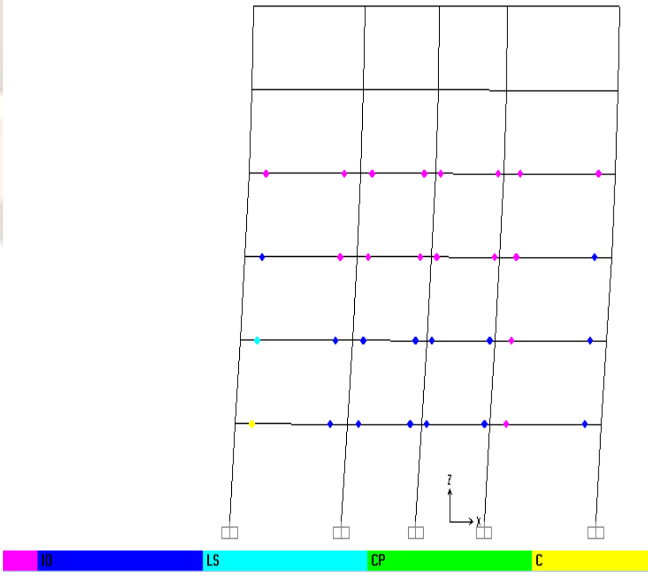

Fig.16Hinge mechanism in x-z plane at y=5.695

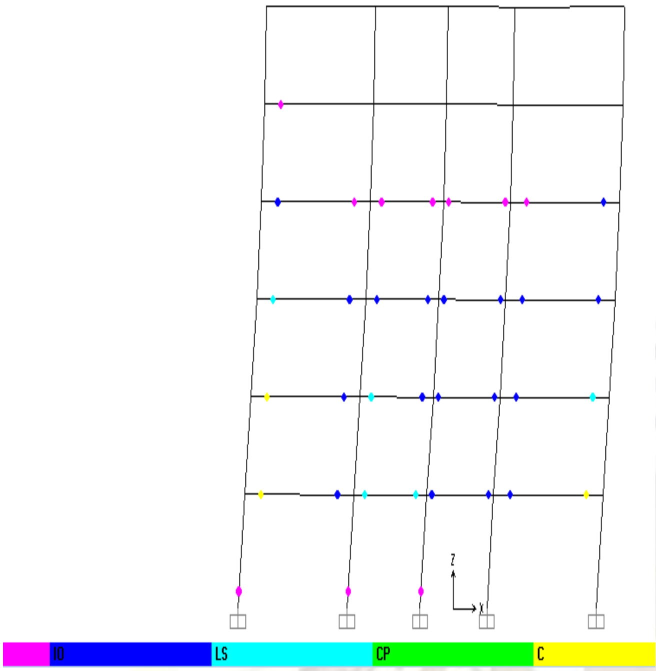

Fig.17 Hinge mechanism in x-z plane at y=5.695

8. CONCLUSIONS

The performance of reinforced concrete frames was investigated using the pushover Analysis. These are the conclusions drawn from the pushover analyses.

1. The pushover analysis is a relatively simple way to explore the non-linear behavior of buildings.

2. The behavior of properly detailed reinforced concrete frame building is adequate as Indicated by the intersection of the demand and capacity curves and the distribution of Hinges in the beams and the columns. Most of the hinges developed in the beams and few in the columns but with limited damage.

3. It must be emphasized that the pushover analysis is approximate in nature and is based on static loading. As such, it cannot represent dynamic phenomena with a large degree of accuracy. It may not detect some important deformation modes that may occur in a structure subjected to severe earthquakes, and it may exaggerate others. Inelastic dynamic response may differ significantly from predictions based on invariant or adaptive static load patterns, particularly if higher mode effects become important.

4. Thus performance of pushover analysis primarily depends upon choice of material models included in the study.

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