Scientific Journal of Impact Factor (SJIF): 4.72

e-ISSN (O): 2348-4470
p-ISSN (P): 2348-6406

International Journal of Advance Engineering and Research Development

Volume 4, Issue 4, April -2017

PERFORMANCE BASED ANALYSIS OF RCC BUILDING

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Abstract — *Performance Based Seismic Engineering is the modern approach to earthquake resistant design. It is an attempt to predict the buildings with predictable seismic performance. In one Sense, it is limit-states design extended to cover complex range of issues faced by earthquake Engineers.*

The analysis will be performed on new as well as existing R.C.C. buildings and the performance of buildings in future earthquake will be obtained. Non Linear static analysis will be performed in existing as well as new buildings in finite element program. It helps in the investigation of the behavior of the structure under different loading conditions, its load deflection behavior and the cracks pattern.

In the present study, the non-linear response of RCC frame using finite element program under the loading has been carried out with the intention to investigate the relative importance of several factors in the non-linear analysis of RCC frames. This includes the variation in load displacement graph

Keywords *-Pushover Analysis, non-linear static analysis, performance based seismic design, SAP2000.*

I. INTRODUCTION

Performance based seismic engineering is the modern approach to earthquake resistance design. The promise of performance-based analysis is to produce structures with predictable seismic performance. Performance based engineering is not new. Automobiles, Airplanes, and turbines have been designed and manufactured using this approach for many decades. But the applications of the same to the buildings were limited. Generally in such applications one of more full-scale proto types of the structure are built and subjected to extensive testing. The design and manufacturing process is then revised to incorporate the lessons learned from the experimental evaluations. What makes performance-based analysis of buildings different is that, each building designed by this process is virtually unique and the experience obtained is not directly transferable to buildings of other type, size, and performance objectives. In order to utilize performance based analysis effectively and intelligently, one need to be aware of the uncertainties involved in both structural performance and seismic hazard estimations.

II. PUSHOVER ANALYSIS

Pushover Analysis option will allow engineers to perform pushover analysis as per FEMA -356 and ATC-40. Pushover analysis is a static, nonlinear procedure using simplified nonlinear technique to estimate seismic structural deformations. It is an incremental static analysis used to determine the force-displacement relationship, or the capacity curve, for a structure or structural element. The analysis involves applying horizontal loads, in a prescribed pattern, to the structure incrementally, i.e. pushing the structure and plotting the total applied shear force and associated lateral displacement at each increment, until the structure or collapse condition.

Pushover analysis is a technique by which a computer model of the building is subjected to a lateral load of a certain shape (i.e., inverted triangular or uniform). The intensity of the lateral load is slowly increased and the sequence of cracks, yielding, plastic hinge formation, and failure of various structural components is recorded. Pushover analysis can provide a significant insight into the weak links in seismic performance of a structure. A series of iterations are usually required during which, the structural deficiencies observed in one iteration, are rectified and followed by another. This iterative analysis and design process continues until the design satisfies pre-established performance criteria. The performance criteria for pushover analysis are generally established as the desired state of the building given roof-top or spectral displacement amplitude.

Static Nonlinear Analysis technique, also known as sequential yield analysis, or simply “pushover” analysis has gained significant popularity during the past few years. It is the one of the three analysis techniques recommended by FEMA-273/274 and a main component of the Spectrum Capacity Analysis method (ATC-40). Proper application can provide valuable insights into the expected performance of structural systems and components. Misuse can lead to an erroneous understanding of the performance characteristics. Unfortunately, many engineers are unaware of the details that have to observe in order to obtain useful results from such analysis.

2.1. ELEMENT DESCRIPTION OF SAP2000

In SAP2000, a frame element is model as a line element having linearly elastic properties and nonlinear force-displacement characteristics of individual frame elements are model as hinges represented by a series of straight line segments. A generalized force-displacement characteristic of a non-degrading frame element (or hinge properties) in SAP2000.

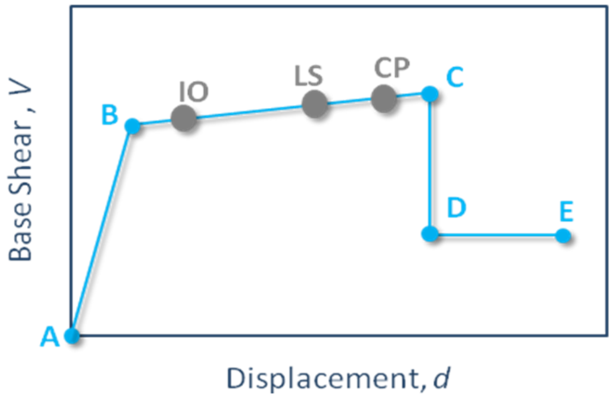

Figure 1. Force-Displacement curve for pushover Analysis

Point A corresponds to unloaded condition and point B represents yielding of the element. The ordinate at C corresponds to nominal strength and abscissa at C corresponds to the deformation at which significant strength degradation begins. The drop from C to D represents the initial failure of the element and resistance to lateral loads beyond point C is usually unreliable. The residual resistance from D to E allows the frame elements to sustain gravity loads. Beyond point E, the maximum deformation capacity, gravity load can no longer be sustained. Hinges can be assigned at any number of locations (potential yielding points) along the span of the frame element as well as element ends. Uncoupled moment (M2 andM3), torsion (T), axial force (P) and shear (V2 and V3) force-displacement relations can be defined. As the column axial load changes under lateral loading, there is also a coupledP-M2-M3 (PMM) hinge which yields based on the interaction of axial force and bending moments at the hinge location. Also, more than one type of hinge can be assigned at the same location of a frame element. There are three types of hinge properties in SAP2000.

2.2. BUILDING PERFORMANCE LEVELS AND RANGES

- **PERFORMANCE LEVEL:** the intended post-earthquake condition of a building; a well-defined point on a scale measuring how much loss is caused by earthquake damage. In addition to casualties, loss may be in terms of property and operational capability.
- **PERFORMANCE RANGE**: A range or band of performance, rather than a discrete level.
- **DESIGNATIONS OF PERFORMANCE LEVELS AND RANGES:** Performance is separated into descriptions of damage of structural and nonstructural systems; structural designations are S-1 through S-5 and nonstructural designations are N-A through N-D.

2.3 BUILDING PERFORMANCE LEVEL

The combination of a Structural Performance Level and a Non-structural Performance Level to form a complete description of an overall damage level.
Methods and design criteria to achieve several different levels and ranges of seismic performance are defined. The four Building Performance Levels are Collapse Prevention, Life Safety, Immediate Occupancy, and Operational. These levels are discrete points on a continuous scale describing the building's expected performance, or alternatively, how much damage, economic loss, and disruption may occur.
Each Building Performance Level is made up of a Structural Performance Level that describes the limiting damage state of the structural systems and a Nonstructural Performance Level that describes the limiting damage state of the nonstructural systems. Three Structural Performance Levels and four Nonstructural Performance Levels are used to form the four basic Building Performance Levels listed above. Other structural and nonstructural categories are included to describe a wide range of seismic rehabilitation intentions. The three Structural Performance Levels and two Structural Performance Ranges consist of:

- **S-1: Immediate Occupancy Performance Level**
- **S-2: Damage Control Performance Range (extends between Life Safety and Immediate Occupancy Performance Levels)**
- **S-3: Life Safety Performance Level**
- **S-4: Limited Safety Performance Range (extends between Life Safety and Collapse Prevention Performance Levels)**
- **S-5: Collapse Prevention Performance Level**

In addition, there is the designation of S-6, Structural Performance Not Considered, to cover the situation where only nonstructural improvements are made.
The four Nonstructural Performance Levels are:

- **N-A: Operational Performance Level**

- **N-B: Immediate Occupancy Performance Level**
- **N-C: Life Safety Performance Level**
- **N-D: Hazards Reduced Performance Level**

2.4 Scope

- Carryout Static Nonlinear Analysis (Pushover Analysis) for R.C.C. building.
- Generate pushover curve (Base Shear-Roof Displacement) for R.C.C. building.
- 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.
- Suggesting an appropriate measure for strengthening or retrofitting of the R.C.C. building.

III. PROBLEM FORMULATION & ANALYSIS

3.1 Model Geometry

Case 1-

No. of floors	G+10
Storey height	3.0 m
Size of column	300×800 mm for Ground floor 230×730 mm for 1 to 10 story
Size of beam	230× 450 mm
Slab	150mm thick
Walls	230mm thick masonry wall
Live load	4.0 KN/m^2 at typical floor 1.5 KN/m^2 on terrace
Floor finish	1.0 KN/m^2
Water proofing	2.0 KN/m^2
Type of soil	Type II, Medium As per IS – 1893
Seismic zone : Zone III	Zone III

Case-2

No. of floors	G+10
Storey height	3.0 m
Size of column	300×800 mm for Ground floor 230×750 mm for 1 to 10 story
Size of beam	230× 530 mm
Slab	150mm thick
Walls	230mm thick masonry wall
Live load	4.0 KN/m^2 at typical floor 1.5 KN/m^2 on terrace
Floor finish	1.0 KN/m^2
Water proofing	2.0 KN/m^2
Type of soil	Type II, Medium As per IS – 1893
Seismic zone : Zone III	Zone III

Case-3

No. of floors	G+10
Storey height	3.0 m
Size of column	300×900 mm for Ground floor 230×850 mm for 1 to 10 story
Size of beam	230× 530 mm
Slab	150mm thick
Walls	230mm thick masonry wall
Live load	4.0 KN/m^2 at typical floor 1.5 KN/m^2 on terrace
Floor finish	1.0 KN/m^2
Water proofing	2.0 KN/m^2
Type of soil	Type II, Medium As per IS – 1893
Seismic zone : Zone III	Zone III

Table 1: - Geometry of G+10 Storey

3.2 Plan of Building

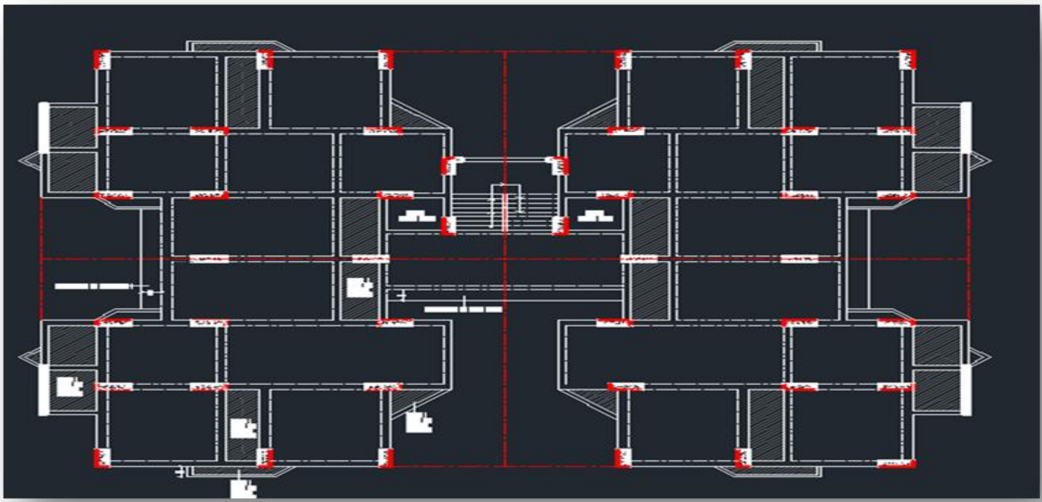

Figure 2. G+!0 Story Building plan

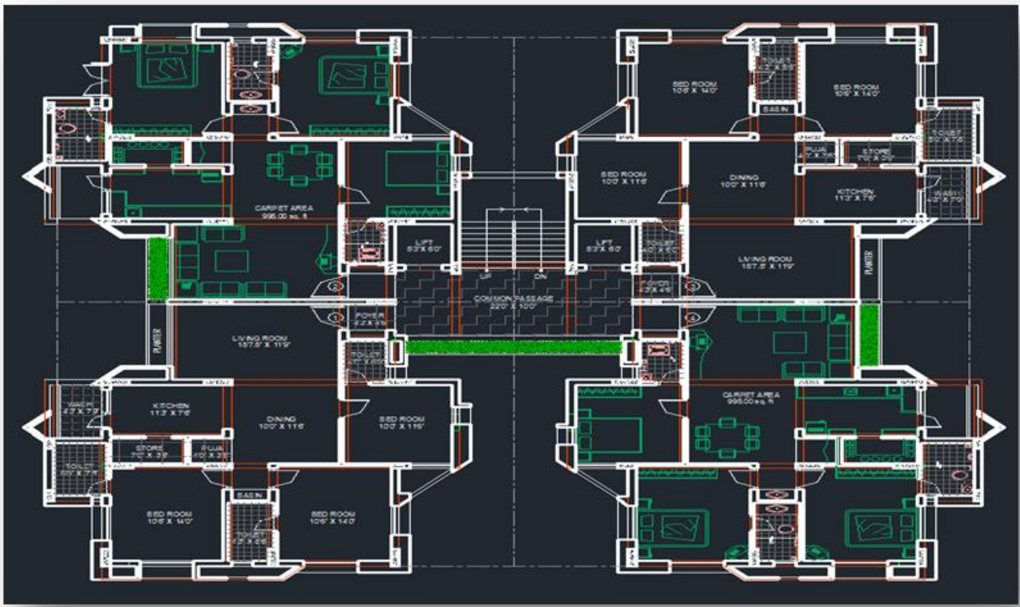

Figure 3. First floor Plan

3.3 Elevation of G+10 Storey Building.

Figure 4. Elevation Of Building

IV. RESULT AND DISCUSSION

Following are the details of the design of G + 10 Storey New Building Shown in the table below:

	Beam (mm)	Column (mm)		Hinges Formation					Performance level
		Ground Floor	1 to 10 Storey	A toB	B to IS	IO to LS	LS to CP	CP to C	
Case-1	230x450	300x800	230x730	3030	770	55	**35**	**8**	**A to C**
Case-2	230x530	300x800	230x750	3050	790	40	**18**	**0**	**A to CP**
Case-3	230x530	300x900	230x850	3072	811	15	**0**	**0**	**A to LS**

In these work the analysis is to carried out in such a way that performance level should be obtained between A to life safety. First the analysis was carried out for the first case and the performance level obtained was A to C level. Then the modifications were made in the size of the beam and column but then also the performance level was between A to Collapse Prevention. Then again the modifications were done to achieve the objective by changing the size of column and then the performance level obatined was between A to Life Safety. Detailed results of the case 3 are shown below

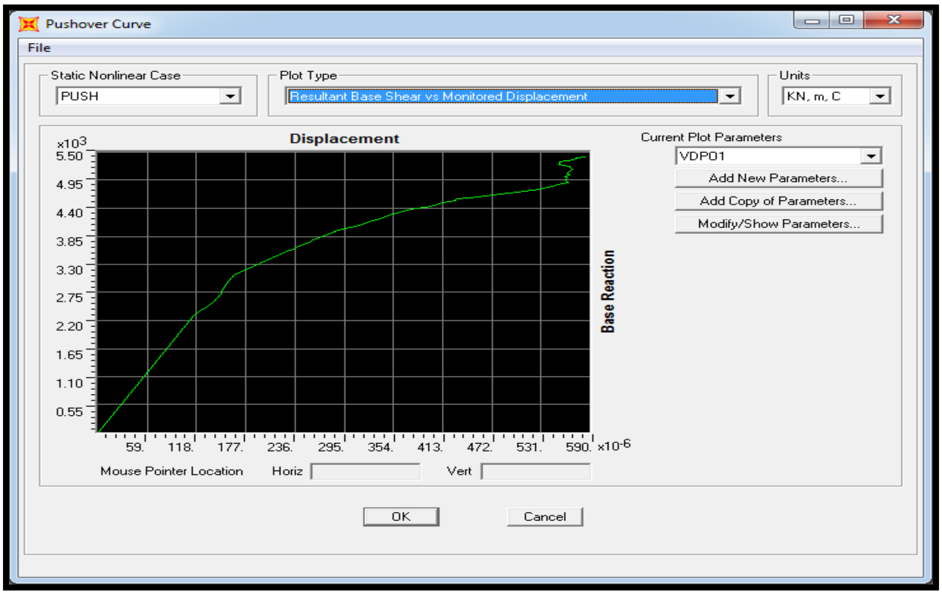

Figure 5. Pushover Curve

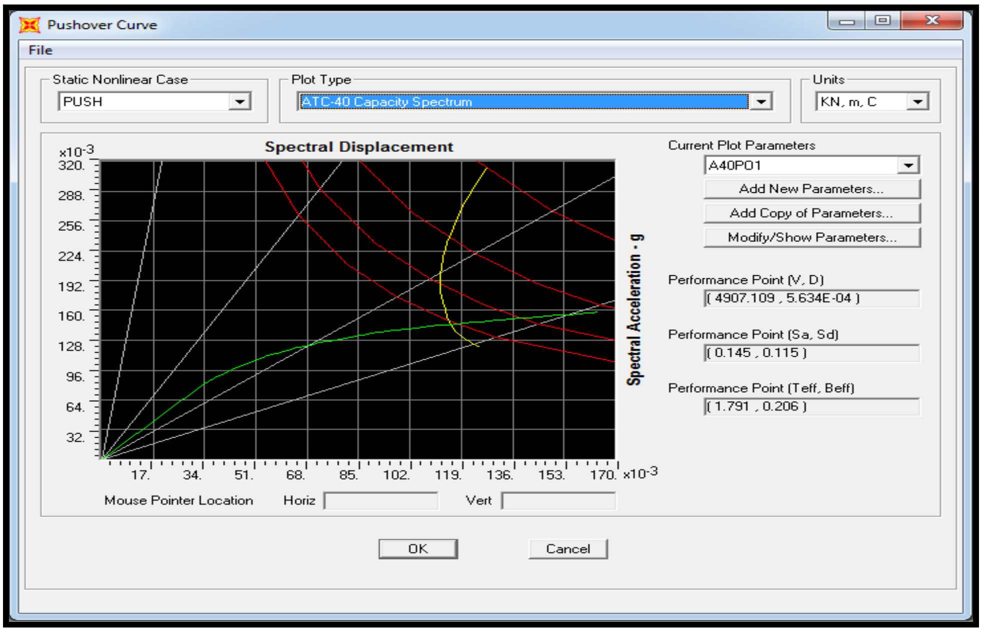

Figure 6. Perfomance Point

Output for the pushover analysis can be printed in a tabular form for the entire model or for selected elements of the model. The types of output available in this form include joint displacements at each step of the pushover, frame member forces at each step of the pushover, and hinge force, displacement and state at each step of the pushover.

TABLE: Pushover Curve - PUSH												
Step	Displacemen	BaseForc	AtoB	BtoIO	IOtoLS	LStoCP	CPtoC	CtoD	DtoE	BeyondE	Total
	m	KN									
0	0	0	3898	0	0	0	0	0	0	0	3898
1	0.000089	1779.116	3896	2	0	0	0	0	0	0	3898
2	0.000115	2291.768	3875	23	0	0	0	0	0	0	3898
3	0.000138	2553.766	3826	72	0	0	0	0	0	0	3898
4	0.000147	2726.287	3780	118	0	0	0	0	0	0	3898
5	0.000148	2760.447	3773	125	0	0	0	0	0	0	3898
6	0.000156	2938.28	3749	149	0	0	0	0	0	0	3898
7	0.000157	2980.156	3741	157	0	0	0	0	0	0	3898
8	0.000163	3090.462	3715	183	0	0	0	0	0	0	3898
9	0.000224	3545.325	3610	288	0	0	0	0	0	0	3898
10	0.000231	3573.022	3603	295	0	0	0	0	0	0	3898
22	0.000353	4283.848	3363	535	0	0	0	0	0	0	3898
23	0.000375	4380.057	3326	572	0	0	0	0	0	0	3898
24	0.0004	4433.492	3312	586	0	0	0	0	0	0	3898
25	0.000403	4459.652	3306	592	0	0	0	0	0	0	3898
26	0.000413	4509.304	3289	609	0	0	0	0	0	0	3898
27	0.000428	4552.912	3278	620	0	0	0	0	0	0	3898
28	0.000431	4579.069	3264	634	0	0	0	0	0	0	3898
29	0.000446	4604.481	3247	651	0	0	0	0	0	0	3898
30	0.000531	4767.038	3167	728	3	0	0	0	0	0	3898
31	0.000533	4788.05	3157	736	5	0	0	0	0	0	3898
32	0.000546	4820.32	3139	753	6	0	0	0	0	0	3898
33	0.000552	4864.552	3110	782	6	0	0	0	0	0	3898
34	0.000564	4901.351	3097	792	9	0	0	0	0	0	3898
35	0.000559	4962.186	3072	811	15	0	0	0	0	0	3898
36	0.000563	5000.82	3057	818	23	0	0	0	0	0	3898
37	0.00056	5023.251	3046	826	26	0	0	0	0	0	3898
38	0.000566	5056.827	3034	832	32	0	0	0	0	0	3898
39	0.000563	5078.761	3028	835	35	0	0	0	0	0	3898
40	0.000565	5107.702	3010	851	37	0	0	0	0	0	3898

Figure 7. Tabular Data for Pushover Curve

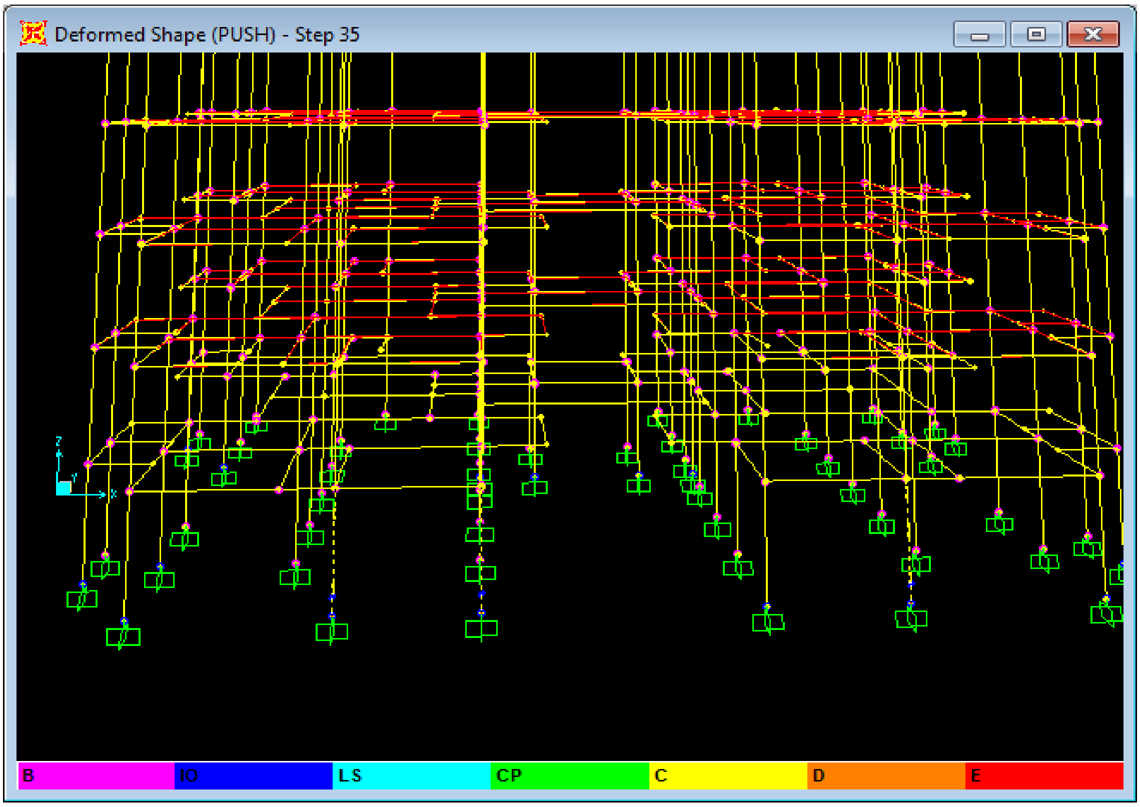

Figure 8. Hinges Formation

Structure design has been done for these building for Life safety. Push over analysis has been performed for the G + 10 Storey and the performance level obtained is From A to Life safety. 15 hinges are created from immediate occupancy to life safety. Thus from this we can say that the building is safe.

CONCLUSION

- Case 1: The results obtained for G + 10 Storey building for this case is from A to C which leads to the failure of the building.
  Modification after the case 1 is as follows:
- Case 2: Similarly for this case also performance level is A to Collapse prevention Level for which retrofitting is necessary.
- Case 3: For this case size of the beams and columns were increased and then the performance level obtained was from A to Life Safety. In this situation structure is damaged up to repairable level.

FUTURE SCOPE OF WORK

Following works can be taken up as future scope of work related to present study of work.

- Generate fragility curves for G+4 storey R.C.C. building considering Incremental
- Dynamic Analysis (IDA) based response quantities.
- Generate fragility relationships for controlled structures.
- Using performance based analysis suggest retrofit measures for a building and
- Develop fragility relationship of retrofitted building.

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