PUSHOVER ANALYSIS ON REINFORCED CONCRETE BUILDING USING ETABS

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Abstract - *Performance based design is an important aspect of earthquake engineering. In seismic design both seismic demand and capacity are not only inter dependent but also uncertain. To conduct performance based design, modeling of the structure with provision of material and geometric nonlinearity is essential. In nonlinear range structural components go through the progressive cracking until failure. Building codes suggest less stiffness, i.e. moment of inertia, of structural elements to simulate this cracking phenomenon of existing structures under service loads. Therefore this study has been conducted to investigate the consequences of cracked inertia on building performance during earthquake considering pushover analysis. In this analysis a series of lateral loads are applied incrementally up to a predefined roof displacement or the instability of the building, which yields so called pushover curve and spectral capacity at performance point. Gross section model overestimate the Base Shear at performance point and ultimate capacity with large margin of safety which may not the real scenario of the existing building as cracks exist due to service loads.*

Key Words: **Pushover analysis, capacity spectrum, cracked section inertia, spectral demand**

1. INTRODUCTION

The extensive damage of structures during recent major earthquakes has forced the researchers to evolve new techniques and methodologies to develop more efficient design approaches. To prevent collapse in a major earthquake the ductility demand on the structural elements and the overall deformation of the structure should be controlled. This can be achieved rationally with an efficient design method rather than conventional force based method of seismic design. As a consequences, force based design is replaced by the concept of performance or displacement based design approach. In early 1990's, the displacement based design (DBD) or the subsequently evolved performance based design (PBD) approach was first introduced in design. After that a number of researches have been conducted to evaluate the performance of building in terms of capacity and ductility. Among all structural analysis techniques, pushover analysis is a well-known aid for the performance based design as it can measure seismic demand in terms of spectral displacement at performance point .The performance point of a structure is actually the optimum interaction point at which demand curve and capacity curve intersects. Each building performs differently due to the difference in seismic zone, soil condition, types of load carrying system and most importantly the natural period of that structure. It also depends on the modeling approach, construction details and materials etc. As mentioned by Nilson et al. each beam and column contains some hairline cracks immediately after the construction. The bottom portion of the beam (below neutral axis) only protects the reinforcement from fire and corrosion but it does not give any additional strength or capacity to the structure. When self-weight and live load are activated on those structural elements, hairline crack appears on the bottom portion of the beam. This cracking result in a decreased moment of inertia as well as capacity compared to uncracked concrete section. This indicates the necessity of considering the effective structural behavior in terms of effective moment of inertia to understand and design the actual performance based or displacement based structure.

This study aims to focus on the modeling approach of building (in terms of cracked and uncracked element) and the subsequent impacts on the structural performance under earthquake. The terms uncracked and gross section are used synonymously in this article. Some performance terms of structure are evaluated and compared in terms of capacity curve. It is evident from the current investigation that cracked section analysis should be conducted to get the realistic response of the structure for performance based design.

1.1 Pushover Methodology

The push over analysis of a structure is a static non-linear analysis under permanent vertical loads and gradually increasing lateral loads. 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 frame, and 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.

1.2 Element Description of ETABS

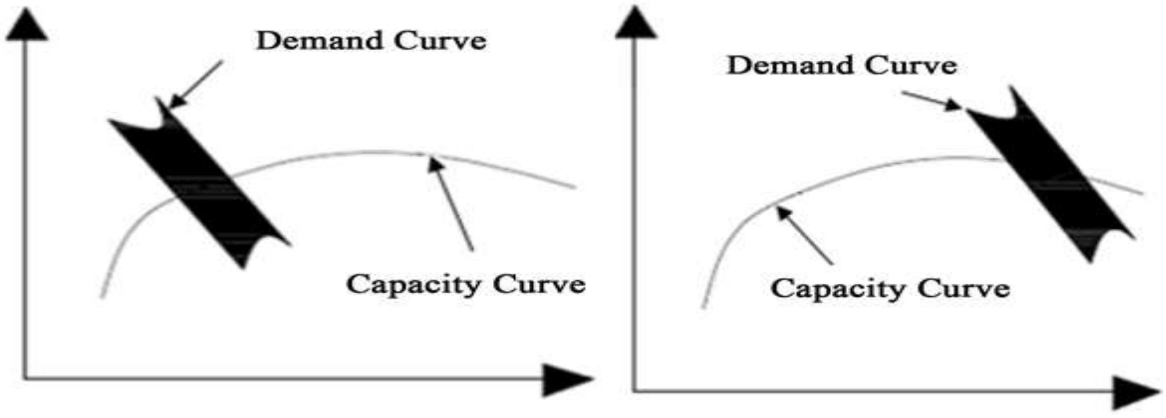
In ETABS, a frame element is modelled as a line element having linearly elastic properties and non-linear force-displacement characteristic of individual frame elements are modelled as hinges represented by a series of straight line segments. A generalized force-displacement characteristic of a non-degrading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

1.3 Capacity

The overall capacity of structure depends on the strength and deformation capacities of individual components of structure. A pushover analysis procedure uses series of sequential elastic analysis, superimposed to approximate force-displacement capacity diagram of overall 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 a predetermined limit is reached. Pushover capacity curve approximate how structure behaves after exceeding plastic limit.

1.4 Displacement (demand)

Ground motion during an earthquake produce complex horizontal displacement pattern in structure that may vary with time. Tracking this motion at every time step to determine structural design requirements is judged impractical. For non-linear methods 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. Typical seismic demand VS capacity is shown in fig.



Typical seismic design VS capacity (a) safe design (b) unsafe design

1.5 Performance

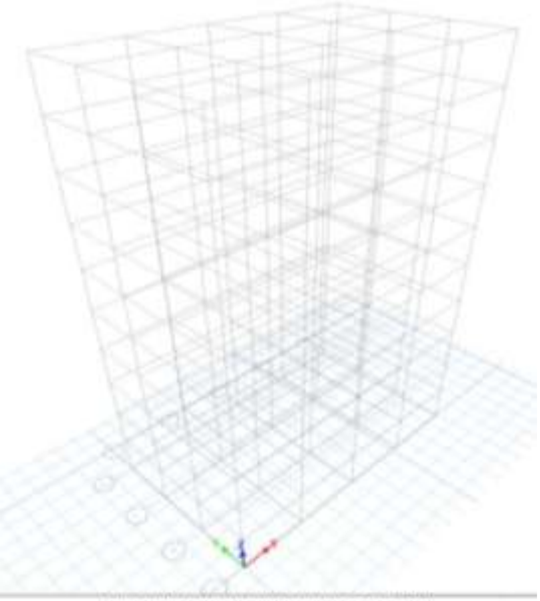
Once a capacity curve and demand displacement is defined, a performance check can be done. Performance verifies that structural and non-structural components are not damaged beyond the acceptable limits of performance objective for the forces and displacement implied by the displacement demand.

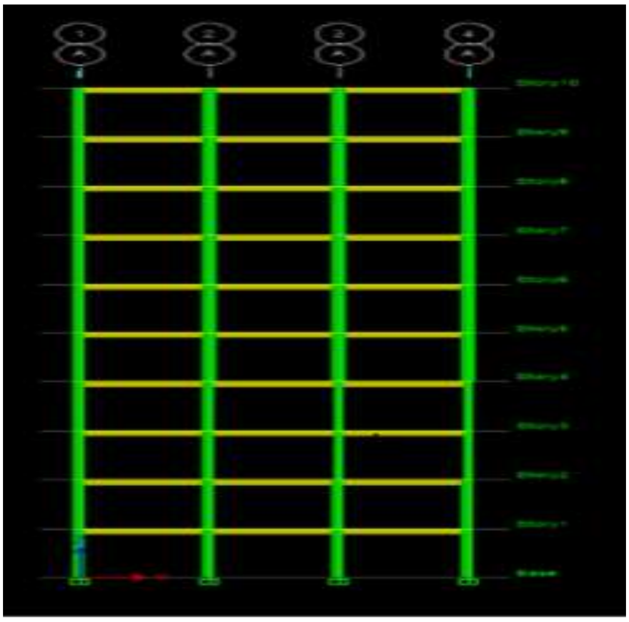
1.6 Description of Frame Structure

- ✓ The G+9 building is considered in this study.
- ✓ This structure is designed according to Indian code IS 1893:2002 and is located in Zone Ⅱ.
- ✓ The material properties are M30 grade concrete, Fe-415 steel.
- ✓ The typical floor height is 3.65m and the details of beam and column are shown in table

		Ground floor(mm)	1st &2nd	3rd & 4th	5th,6th,7th ,8th,9th&10th
Beam	Exterior	304.8x304.8	304.8x355.6	304.8x355.6	355.6x406.8
	Interior	304.8x304.8	355.6x406.8	355.6x406.8	304.8x355.6

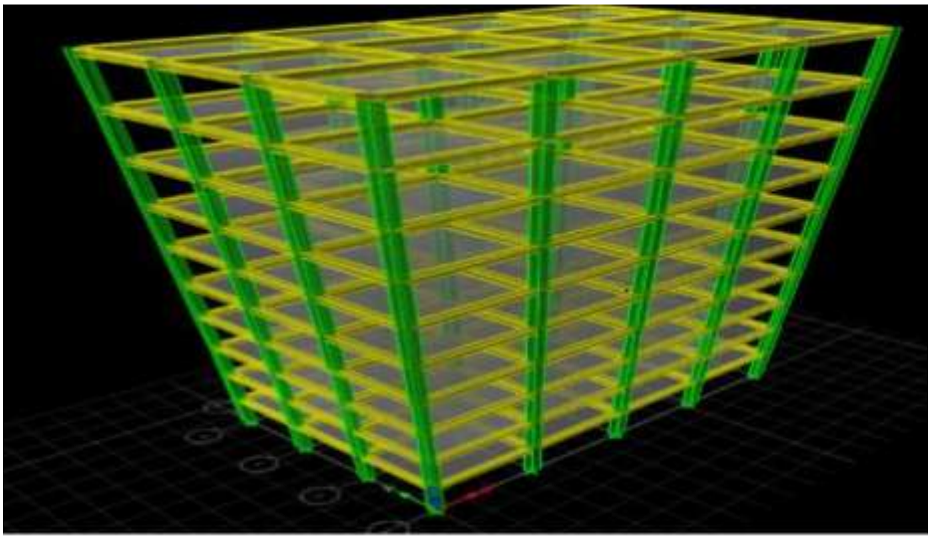
Column	Exterior	355.6x406.8	355.6x406.8	304.8x355.6	406.8x4068.
	Interior	406.8x406.8	406.8x406.8	355.6x355.6	355.6x406.8
Slab		200	200	200	200


BASIC MODEL OF TEN STOREY RC FRAME

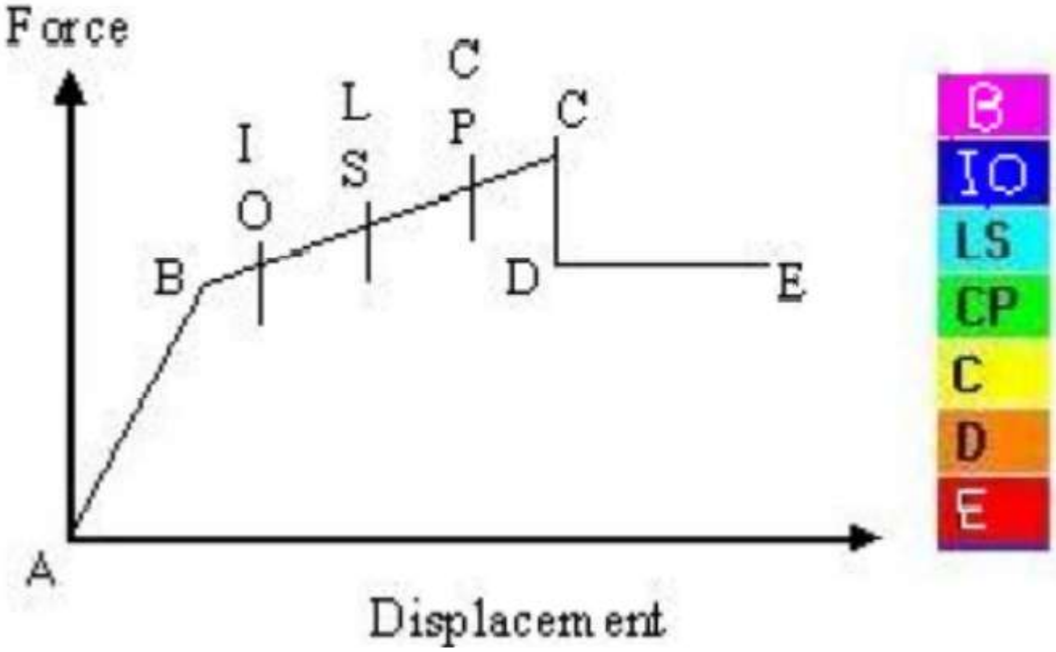

ELEVATION VIEW

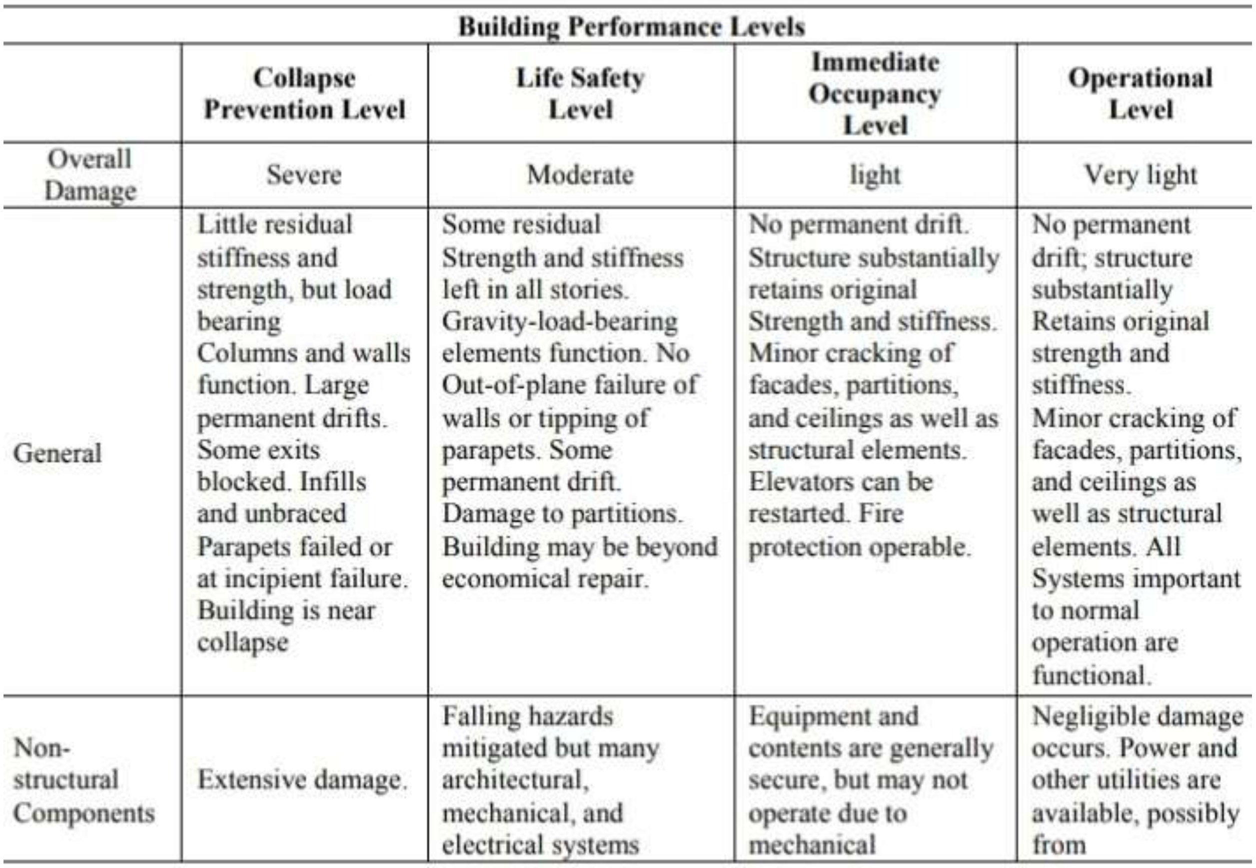
2. MODELING APPROACH

The general finite element package ETABS has been used for analyses. A three-dimensional model of each structure has been created to undertake the non-linear analysis. The existing model and loading structure shown in figure. Beams and columns are modelled as non-linear frame elements with lumped plasticity at the start and the end each element. ETABS provides default hinge.



Pushover curve

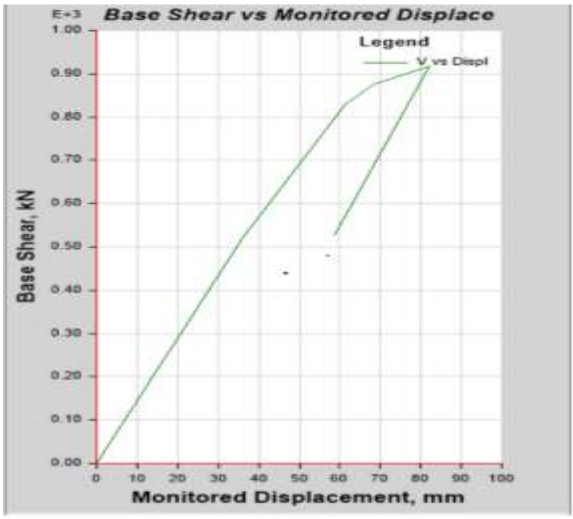




Building Performance Levels				
	Collapse Prevention Level	**Life Safety Level**	**Immediate Occupancy Level**	**Operational Level**
Overall Damage	Severe	Moderate	light	Very light
General	Little residual stiffness and strength, but load bearing Columns and walls function. Large permanent drifts. Some exits blocked. Infills and unbraced Parapets failed or at incipient failure. Building is near collapse	Some residual Strength and stiffness left in all stories. Gravity-load-bearing elements function. No Out-of-plane failure of walls or tipping of parapets. Some permanent drift. Damage to partitions. Building may be beyond economical repair.	No permanent drift. Structure substantially retains original Strength and stiffness. Minor cracking of facades, partitions, and ceilings as well as structural elements. Elevators can be restarted. Fire protection operable.	No permanent drift; structure substantially Retains original strength and stiffness. Minor cracking of facades, partitions, and ceilings as well as structural elements. All Systems important to normal operation are functional.
Non-structural Components	Extensive damage.	Falling hazards mitigated but many architectural, mechanical, and electrical systems	Equipment and contents are generally secure, but may not operate due to mechanical	Negligible damage occurs. Power and other utilities are available, possibly from

3. RESULT AND DISCUSSION

3.1 CASE 1 (Moment of Inertia-1)



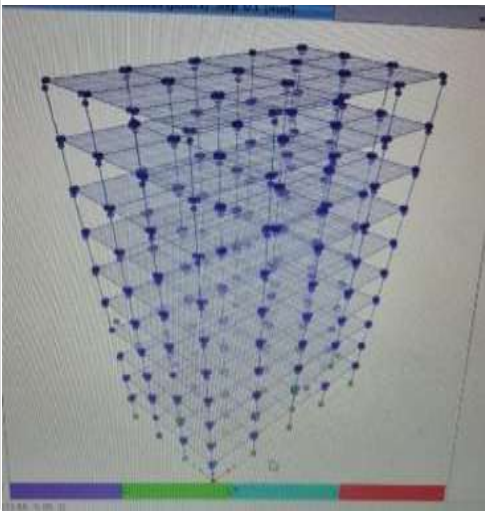
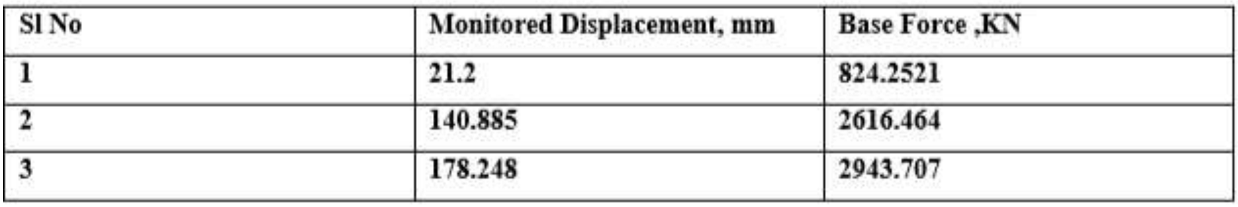
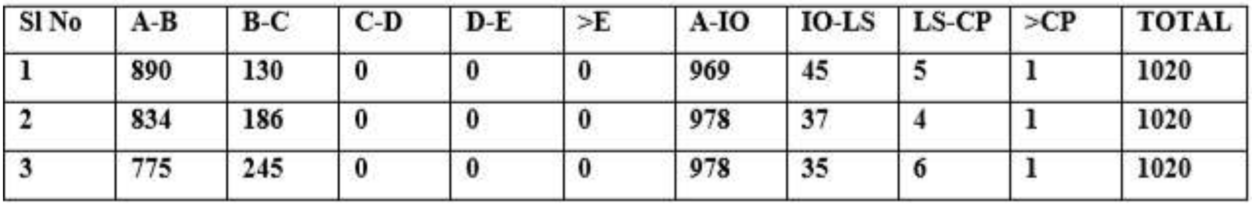


Table 3: MONITORED DISPLACEMENT AND BASE FORCE



Sl No	Monitored Displacement, mm	Base Force ,KN
1	21.2	824.2521
2	140.885	2616.464
3	178.248	2943.707

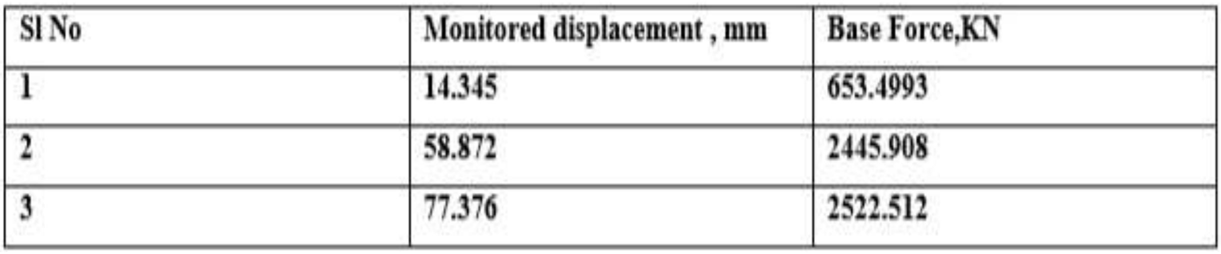
Table 3.1 :HINGE STATES



Sl No	A-B	B-C	C-D	D-E	>E	A-IO	IO-LS	LS-CP	>CP	TOTAL
1	890	130	0	0	0	969	45	5	1	1020
2	834	186	0	0	0	978	37	4	1	1020
3	775	245	0	0	0	978	35	6	1	1020

3.2 CASE 2 (Moment of Inertia -0.7)

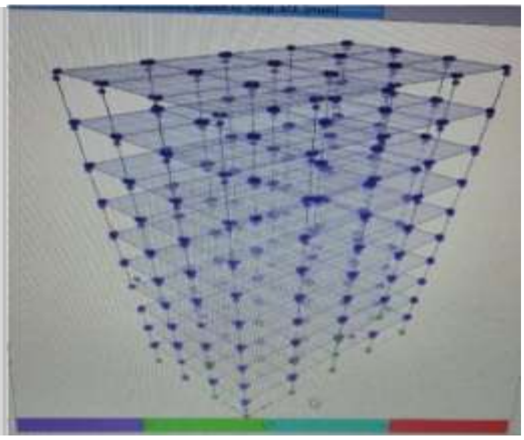
Table 4: MONITORED DISPLACEMENT AND BASE FORCE



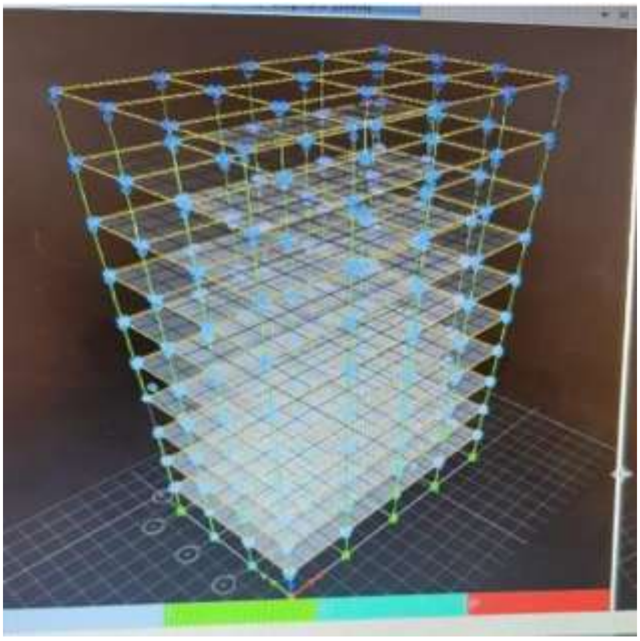
Sl No	Monitored displacement , mm	Base Force,KN
1	14.345	653.4993
2	58.872	2445.908
3	77.376	2522.512

Table 4.1: HINGE STATES

Sl No	A-B	B-C	C-D	D-E	>E	A-IO	IO-LS	LS-CP	>CP	TOTAL
1	720	300	0	0	0	1018	1	1	0	1020
2	660	360	0	0	0	1015	5	0	0	1020
3	615	405	0	0	0	1018	2	0	0	1020



3.3 CASE 3 (Moment of Inertia- 0.30)



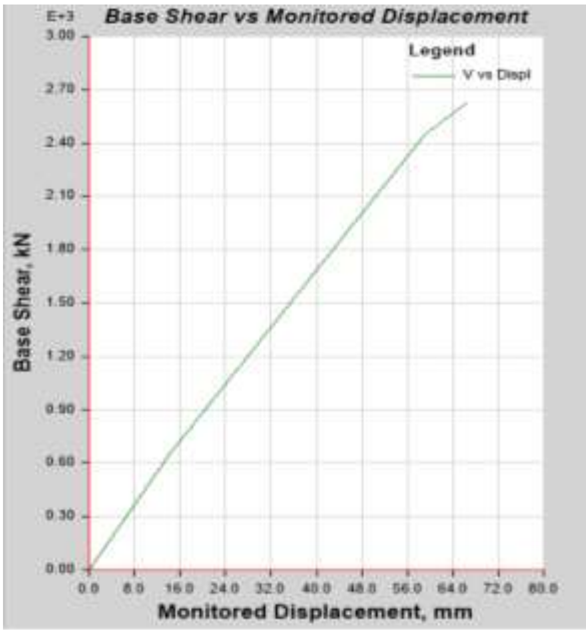


Table 5: MONITORED DISPLACEMENT AND BASE FORCE

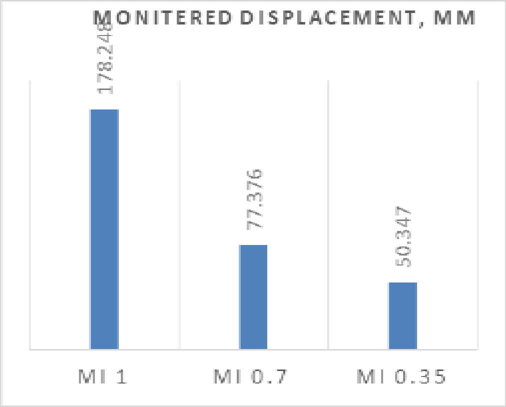
Sl No	Monitored displacement , mm	Base Force,KN
1	11.44	424.22
2	30.55	2210.19
3	50.347	2082.89

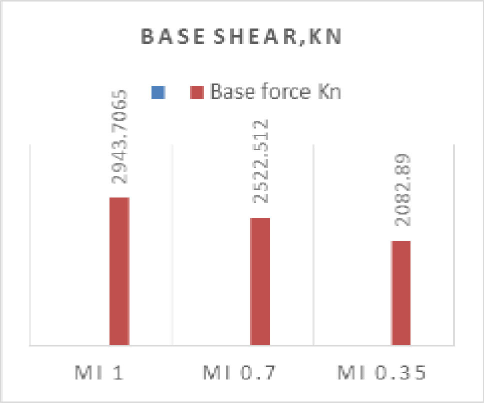
Table 5.1: HINGE STATES

Sl No	A-B	B-C	C-D	D-E	>E	A-IO	IO-LS	LS-CP	>CP	TOTAL
1	1020	0	0	0	0	1020	0	0	0	1020
2	1020	0	0	0	0	1020	0	0	0	1020
3	1020	0	0	0	0	1020	0	0	0	1020

4. RESULT

Sl No	Monitored displacement ,mm	Base Force ,KN	A-B	B-C	C-D	D-E	>E	A-IO	IO-LS	LS-CP	>CP	TOTAL
CASE 1 (MI 1)	178.248	2943.707	775	245	0	0	0	978	35	6	1	1020
CASE 2((MI 0.7)	77.376	2522.512	615	405	0	0	0	1018	2	0	0	1020
CASE 3(MI 0.35)	50.347	2082.89	1020	0	0	0	0	1020	0	0	0	1020





5. CONCLUSIONS

1. Pushover analysis has been the preferred method for seismic performance due to its simplicity and has been viewed as an attractive alternative to the nonlinear time history analysis.

2. Gross section model overestimate the Base Shear at performance point and ultimate capacity with large margin of safety which may not the real scenario of the existing building as cracks exist due to service loads.

3. Maximum displacement for the model with the moment of inertia value of

- 0.35 is 50.347mm
- 0.7 is 77.376mm
- 1 is 178.248mm

4. Maximum Base Shear for the model with the moment of inertia value of

- 0.35 is 2082.89 KN
- 0.7 is 2522.512 KN
- 1 is 2943.707 KN

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