Nonlinear Static Analysis of Building with Different Aspect Ratio

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Abstract: The earthquake resistant design of structures requires that systems ought to maintain, adequately, any groundmotions of an depth that would arise for the duration of their construction or in their regular use. However floor motions are unique inside the consequences they have got on structural responses. The most accurate evaluation method for structures subjected to strong ground motions is the time history analysis . This evaluation entails the integration of the equations of motion of a multi-degree-of-freedom system, MDOF, within the time domain the usage of a stepwise answer which will constitute the real reaction of a structure. This technique is time-eating even though for application in all sensible functions. The necessity for faster techniques that could make certain a dependable structural assessment or design of structures subjected to seismic loading brought about the pushover analysis.

Pushover analysis is based totally on the belief that systems oscillate predominantly inside the first mode or inside the decrease modes of vibration at some stage in a seismic occasion. This ends in a reduction of the multi-degree-of-freedom, MDOF machine, to an equivalent single-degree- of-freedom, ESDOF gadget, withproperties expected by a nonlinear static evaluation of the MDOF system. The ESDOF device is then eventually subjected to a nonlinear time- history analysis or to a response spectrum analysis with consistent-ductility spectra, or damped spectra. The seismic demands calculated for the ESDOF device are converted through modal relationships to the seismic demands of the MDOF machine.

The objective of this thesis record is to emphasise the use of non-linear static procedure i.e pushover analysisa seismic overall performance assessment of R.C frames .

Keywords: Pushover analysis, R.C frames, Time-history analysis

1. Introduction

Sudden release of energy inside the earth’s lithosphere creates seismic waves which reasons shaking of the earth’s layers ensuing in an earthquake. It happens because of surprising slip onfault line. Outer layer of the earth pushes the sides of the fault that builds up stress. Rocks slipreleases energy which reasons shaking for the duration of the earthquake. Earthquakes may also arise because of human sports. Gradual movement of tectonic plates (Plate Tectonics) reasons earthquakes. Fault occurs due to movement of rocks along both side of fracture. Lengthof faults may be in kilometres. Normal, opposite or strike faults are few of its types. Any seismic hobby is predicted to get up from faults. Classification of earthquakes consists of Tectonic, volcanic, Collapse, and so on. Humans have also played a essential function in inducing earthquake motions. Waves generated are essentially of kinds both body or floor waves. When earthquake comes beneath water surface it reasons Tsunamis. Earthquakes normally include no preliminary caution and have been very unfavourable to life and belongings. These can motive physical harm to human settlements, roads and bridges, water pipelines and so on. Old structures may be broken too if now not properly make stronger. Structures must be able to sustain severe floor motions that may occur in the course of their construction or ordinary use.

The want for a simple method to are expecting the non-linear behaviour of a shape below seismic loads saw light in what's now popularly known as the Pushover Analysis (PA). It can help exhibit how modern failure in homes genuinely happens, and discover the mode of very last failure. Putting simply, PA is a non-linear evaluation manner to estimate the power abilityof a structure past its elastic restriction (that means Limit State) up to its closing power inside the put up-elastic range. In the manner, the approach also predicts ability susceptible regions inside the shape, via retaining track of the collection of damages of every and each member within the shape (by means of use of what are known as ‘hinges’ they maintain).

Pushover Analysis

Pushover analysis is carried out by means of applying monotonically increasing lateral hundreds to the structure representing the inertial forces that would be skilled with the aid of the structure throughout severe earthquakes.

Nonlinear static analysis, or pushover analysis, has been advanced over the past 20 years and has become the favored analysis process for design and seismic overall performance assessment functions because the method is exceedingly simple and considers post- elastic behavior.

Purpose Of Doing Static Non-Linear Static Analysis

The principal motive of doing pushover analysis to discover performance of the structural elements by estimating strength and deformation demands and evaluating these demands with available capacities. Main performance parameters encompass structural drift ; inter storey drift, deformation between elements etc. Pushover analysis offers information on many responses feature's which elastic evaluation fails to offer. Some examples of such reaction function's consists of Realistic force needs on potentially brittle factors, deformation demands of the elements that dissipates energy imparted to the shape in elastically, identity of the crucial regions wherein the deformation demands is expected to be high, identification of the power discontinuities that impacts dynamic function's in elastic range, estimating inter storey drifts to evaluate p- delta outcome

2. Literature Review

Chopra, Goel and Chintanapakdee (2003) Assessed the idea commonly carried out in pushover analyses that the roof displacement of a building might be anticipated from the deformation of its equivalent single-degree-of-freedom gadget. The check structures used were groups of steel moment-resisting frames. The first group consisted of one-bay frames of six distinctive heights: 3, 6, 9, 12, 15, and 18 storeys. The 2nd group consisted of two buildings of 9 and 20 stories . The maximum vital statement become that the SDOF systems with high ductility overrated the roof displacement and this overestimation improved for longer-duration structures. The above situation became completely reversed for low ductility SDOF structures. Furthermore the authors concluded that on occasion the usage of the ESDOF system can cause incorrect conclusions of the crumble country of the shape. In different words, whilst it can be observed that the ESOF device has collapsed the constructing as whole may have not.

Chintanapakdee and Chopra (2004) investigated the outcomes of stiffness, strength and mixed stiffness-and-electricity irregularity on seismic demands of strong-column-vulnerable- beam frames via MPA and nonlinear time-history analyses. The consequences of electricity irregularity were located to be large than stiffness irregularity and the results of blended- stiffness-and-power irregularity were located to be the biggest a number of the 3 on the estimation of the storey drifts across the flooring. The authors concluded that the MPA procedure become quite effective in taking pictures needs independently of the irregularity of the structure. However it become argued that the MPA procedure ought to supply faulty outcomes for frames with strong first storey or sturdy lower half.

Goel and Chopra (2005) Studied the 3-storey steel building provided in Hernandez- Montes et al. (2004), to give an explanation for the reversal of the higher-mode pushover curves and advocate approaches that could avoid those reversals. The explanation that became given turned into that those came about after the formation of a mechanism if the resultant force above the mechanism become in the direction that moved the roof in a path contrary to that prior to formation of the mechanism. It was counsel to usually test if the constructing deformed beyond the elastic level which could most possibly be the case in maximum buildings for intense ground motions. The better-mode contributions to the seismic demands may want to then be predicted from the elastic a part of the pushover curve. Finally it showed once more that better-mode pushover analyses could detect nearby storey mechanisms that couldn't be identified via conventional pushover techniques.

Kalkan and Kunnath (2007) Investigated the accuracy of pushover strategies for the seismicassessment of buildings . These have been the traditional pushover analysis the use of the Mode Shape load distribution and the Uniform load distribution, the Modified Modal Pushover Analysis, MMPA, the Upper-certain Pushover Analysis, and the Adaptive Modal Combination Procedure, AMC. These have been implemented to a 6- and 13-storey steel constructing, and to a 7- and a 20-storey RC moment frame building. The effects from these analyses were in comparison to the effects from nonlinear dynamic analyses based totally at the behavior of these building to a ways-area and close to-fault floor motions. The portions ofhobby in this observe have been the displacement demands, inter-storey drifts and rotation needs. The take a look at determined that the traditional pushover evaluation overrated the displacement needs within the low and intermediate storeys for all buildings and ground motions. The upper-certain pushover evaluation however underestimated the displacement demands. The MMPA and the AMC techniques overrated the displacement demands but withthe smallest mistakes. These remaining two strategies anticipated very similar consequences. Regarding the inter-storey flow demands the traditional pushover strategies significantly underestimated the drifts inside the upper storeys and overestimated them within the lower storeys for maximum of the homes. The higher-bound pushover analysis alternatively, overvalued the drifts within the upper storeys and underestimated them in the decrease storeys. The MMPA and the AMC techniques accomplished slightly higher with affordable accuracy within the decrease storeys but with overestimation in the higher storeys for most ofthe homes. Finally the plastic rotation needs have been compared between the MMPA, AMCand nonlinear dynamic analyses best. It was discovered that that the MMPA become capableof capture the rotation demands typically inside the decrease storeys. The AMC method became the only for estimating this quantity across the homes' flooring.

Mrugesh D. Shah, **Atul N. Desai**, **Sumant B Patel**, **(2011)** Had achieved a comparative takea look at on Performance Based Analysis of R.C.C. Frames the use of ETABS 9.7. In the prevailing paper, two traditional new R.C.C. Homes have been taken for analysis: G+four andG+10 to cowl the broader spectrum of low upward thrust & excessive upward push building creation. Different modelling issues had been integrated through 9 version for G+4 constructing and G+10 constructing had been; bare frame (with out infill), having infill as membrane, replacing infill as a equivalent strut in previous version. All three situations for 2×2, 3×3, 4 ×4 bays. From the effects, the writer concluded for G+4 and G+ 10 storeys in barebody without infill having lesser lateral load ability (Performance factor price) compare to bare frame with infill as membrane and bare frame with infill having lesser lateral load potential examine to bar body with equivalent strut. Also conclude that because the no of bays will increase lateral load sporting potential increases however with the growth in bays corresponding displacement isn't increases. Also finish that as the wide variety of storey increases lateral load wearing capability does no longer boom but corresponding displacementwill increase.

3. Pushover Analysis

Pushover is a static-non linear analysis method where a structure is subjected to gravity loading and a monotonic displacement-controlled lateral load pattern which continuously increases through elastic and inelastic behaviour until an ultimate condition is reached. It can help demonstrate how progressive failure in buildings really occurs , and identify the mode of finalfailure.

Target Dispalcement

Target displacement is the displacement call for for the building at the control node subjected to the ground motion underneath consideration. This is a completely vital parameter in pushover analysis because the global and thing responses (forces and displacement) of the constructing on the target displacement are in comparison with the desired performance limit country to recognize the constructing overall performance.

Displacement Coefficient Method (DCM) Of FEMA356 : where a Target Displacement is calculated to which the structure is 'pushed'. This technique by and large estimates the elastic displacement of an equal SDOF system assuming preliminary linear buildings and damping for the floor movement excitation beneath attention. Then it estimates the overall most inelastic displacement response for the constructing at roof via multiplying with a set of displacement coefficients. The system starts with the bottom shear versus roof displacement curve (pushover curve). An equivalent period (Teq) is generated from initial period (Ti) via graphical method. This equivalent duration represents the linear stiffness of theequivalent SDOF device. The peak elastic spectral displacement similar to this era is calculatedat once from the reaction spectrum representing the seismic floor motion underneath consideration.

$$S_d = \frac{T_{eq}^2}{4\pi^2} S_a$$

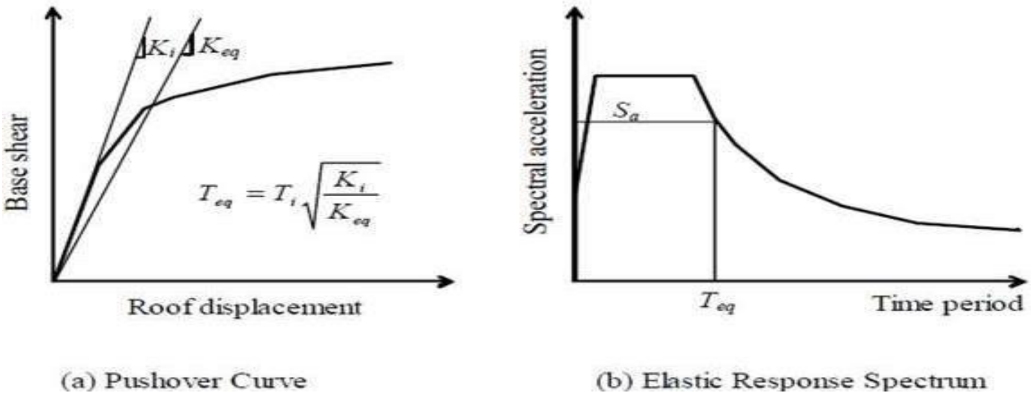

Fig 1: Displacement Cofficient Method

Capacity Spectrum Method (CSM) of ATC-40 : where the load isincremented and checked at each stage, until what is called the 'Performance Point' conditionis reached . The Capacity Spectrum Method, CSM, first presented by Freeman et al. (1975) as a speedy seismic assessment tool for buildings. Subsequently, the technique turned into common as a seismic layout tool. The simple assumption in Capacity Spectrum Method is likewise the same as the preceding one. That is, the maximum inelastic deformation of a nonlinear SDOF system may be approximated from the maximum deformation of a linear elastic SDOF machine with an equivalent length and damping. This manner uses the estimates of ductility to calculate powerful duration and damping. This technique uses the pushover curve in an acceleration-displacement reaction spectrum (ADRS) layout. This can be received via simple conversion using the dynamic houses of the machine. The pushover curve in an ADRS layout is named a 'potential spectrum' for the shape. The seismic ground motion is represented by a reaction spectrum inside the same ADRS format and it is termed as demand spectrum.

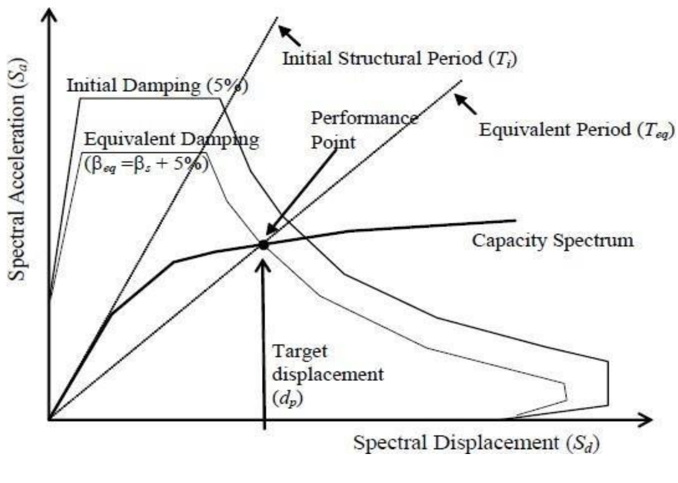

Fig 2: Capacity Spectrum Method (ATC 40)

4. Building Performance Level

Capacity Curve :

The normal capability of a shape depends on strength and deformation capacities of the singularfactors of the shape. In order to determine capacities similarly than the elastic limits, some form of nonlinear analysis is needed. This approach uses advanced elastic analysis, overlaid to approximate force-displacement diagram of the overall structure. The mathematical model of the shape is advanced to account for decreased resistance of yielding components. A horizontalforce distribution is again implemented till additional additives yield.

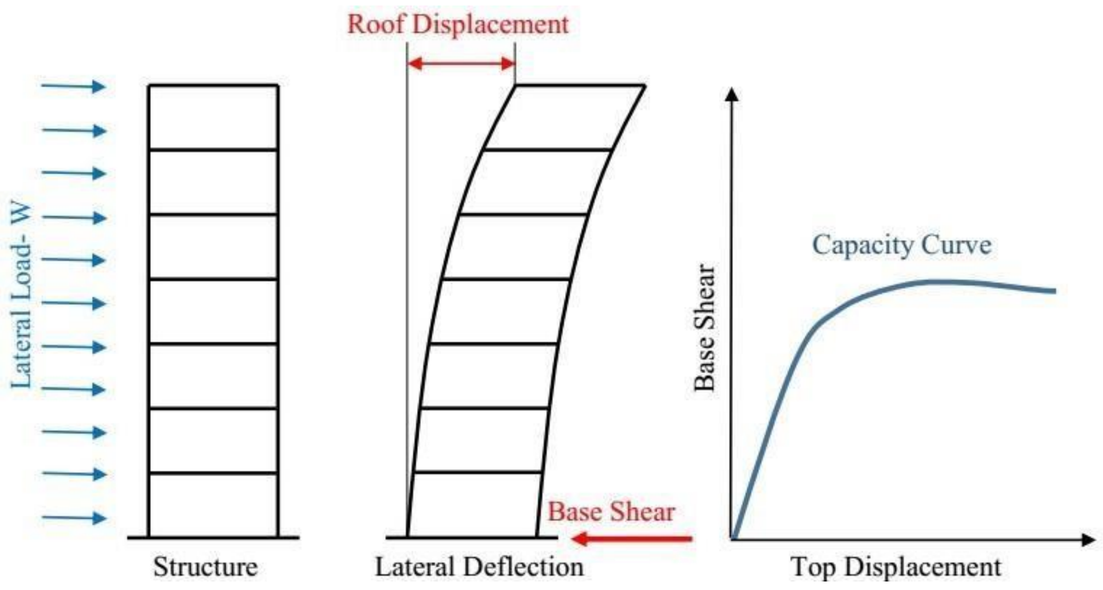

Fig 3: Capacity Curve

Demand Curve :

Ground movement in the course of an earthquake produces tough horizontal displacement patterns which may additionally vary with time. Tracing this movement at each time step to decide structural design necessities is choose unpractical. For a given shape and a ground movement, the displacement needs are evaluation of the most probable reaction of the building in the course of the floor movement. Demand curve is an illustration of the earthquake ground movement.

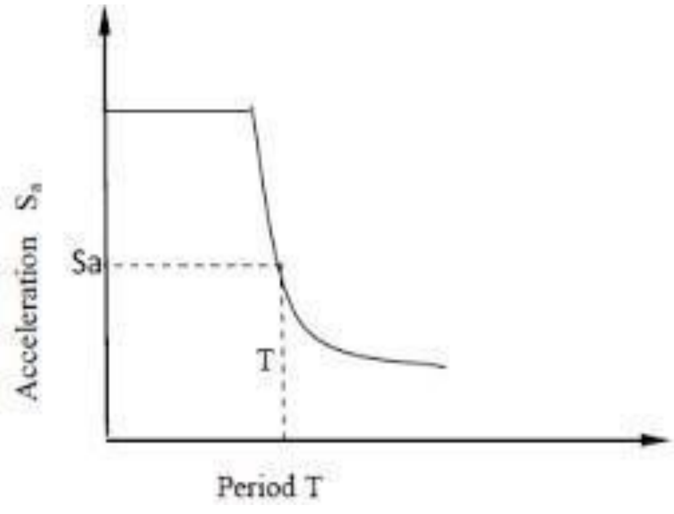

Fig 4: Demand Curve

Performance Point :

Performance point can be achieved via superimposing capacity spectrum and demandspectrum and the intersection point of those two curves is overall performance factor.

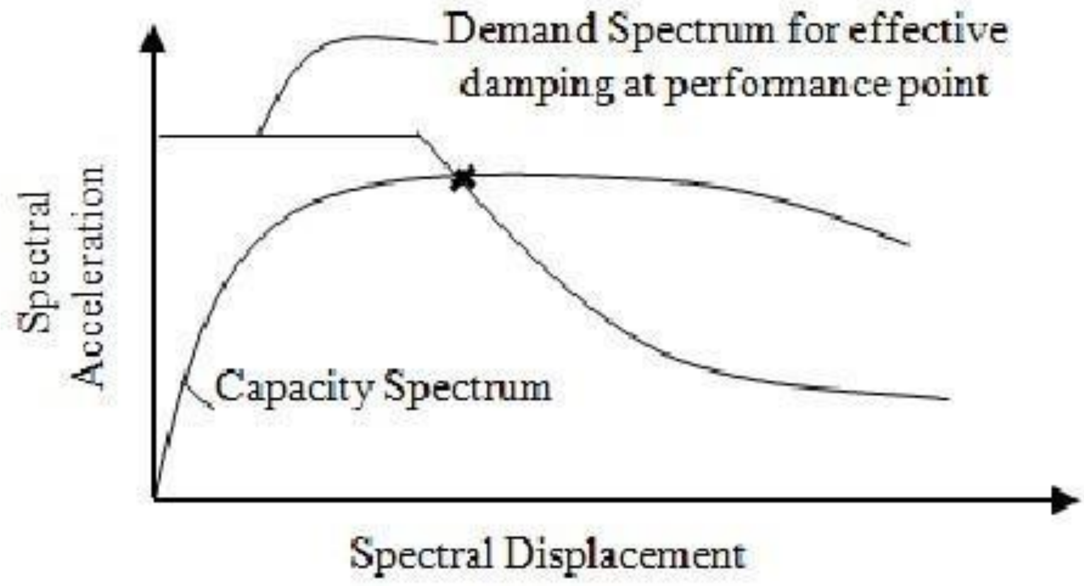

Fig 5: PERFORMANCE POIN

Hinges

Hinges are points on a structure where one expects cracking and yielding to occur in relatively higher intensity that they show high flexural (or shear) displacement, as it approaches its ultimate strength under cyclic loading. These are locations where one expects to see cross diagonal cracks in an actual building structure after a seismic mayhem, and they are found to be at the either ends of beams and columns, the 'cross' of the cracks being at a small distance from the joint that is where one is expected to insert the hinges in the beams and columns of the corresponding computer analysis model.

Basically a hinge represents localised force displacement relation of a member through its elastic and inelastic phase under seismic loads.

Assigning hinge starts from 0 (starting point) of member to 1 (end point) of that member. Relative distance of hinge '0.1' means if the member length 1 metre, then the location of the hinge at 0.1 metre (10% of the length) from starting point of the member.

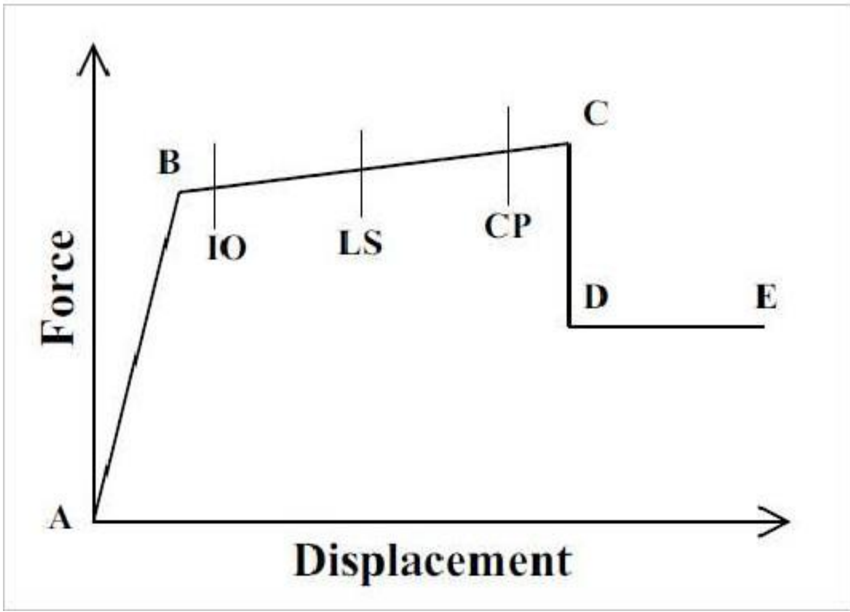

Fig 6: Force – Deformation For Pushover Hinge

1. OPERATIONAL LEVEL (OL) : As per this performance level building are expected to sustain no permanent damages. Structure retains original strength and stiffness. Major cracking is seen in the partition walls and ceilings as well as in the structural elements.
2. IMMEDIATE OCCUPANCY LEVEL (IO) : Buildings meetings this performance level areexpected to sustain no drift and structure retains original strength and stiffness. Minor cracking in partition walls and structural elements is observed. Elevators can be restarted, fire protectionis operable.
3. LIFE SAFETY LEVEL (LS) : This level is indicated when some residual strength and stiffness is left available in the structure. Gravity load bearing elements function, no out of plane failure of walls and tripping of parapet is seen. Some drift can be observed with some failure to the partition walls and the building is beyond economical repair. Among the non- structural elements failing hazard mitigates but many architectural and mechanical systems getdamaged.
4. COLLAPSE PREVENTION LEVEL (CP) : Buildings meetings this performance level areexpected to have little residual strength and stiffness, but the load bearing structural elements function such as load bearing walls and columns,. Building is expected to sustain large permanent drifts, failure of partitions infill and parapets and extensive damage to non-structural elements. At this level the building remains in collapse level.
   - Point A is the original state (OL) of structure.
   - Point B represents yielding. No deformation occurs in the hinge up to point B.
   - Point C represents the ultimate capacity / limit for pushover analysis.
   - Point D represents a residual strength limit in the structure. After this limit structureinitialize collapsing.
   - Point E represent total failure of the structure. After this point hinges break down.

5. Modelling And Pushover Analysis In Etabs

Details Of Building Models

The grade of concrete used for construction of Reinforced concrete building is M-30 with Fe- 415 grade reinforcing steel. Codes used : IS 1893:2002, IS 1893:2016, IS 456:2000 ,IS 800:2007

Table 1: Building Parameters Details

BUILDING PARAMETERS	MODEL1	MODEL2	MODEL3	MODEL4	MODEL5
NUMBER OF STORIES	5	5	5	5	5
HEIGHT OF STOREY (M)	3.5	3.5	3.5	3.5	3.5
NUMBER OF BAYS IN X DIRECTION	4	4	4	4	4
NUMBER OFBAYS IN Y DIRECTION	4	8	16	32	64
ASPECT RATIO	1	2	4	8	16

BAY WIDTH (M)	4	4	4	4	4
BEAM SIZE(MM)	300X500	300X500	300X500	300X500	300X500
COLUMN SIZE(MM)	500X500	500X500	500X500	500X500	500X500
SLAB THICKNESS (MM)	150	150	150	150	150
DEAD LOAD(KN/M^2)	2	2	2	2	2
LIVE LOAD(KN/M^2)	3	3	3	3	3
DAMPINGRATIO %	5	5	5	5	5
SOIL TYPE	II	II	II	II	II
ZONE FACTOR	.16	.16	.16.	.16	.16
RESPONSE REDUCTION FACTOR	3	3	3	3	3
IMPORTANCE FACTOR	1.5	1.5	1.5	1.5	1.5

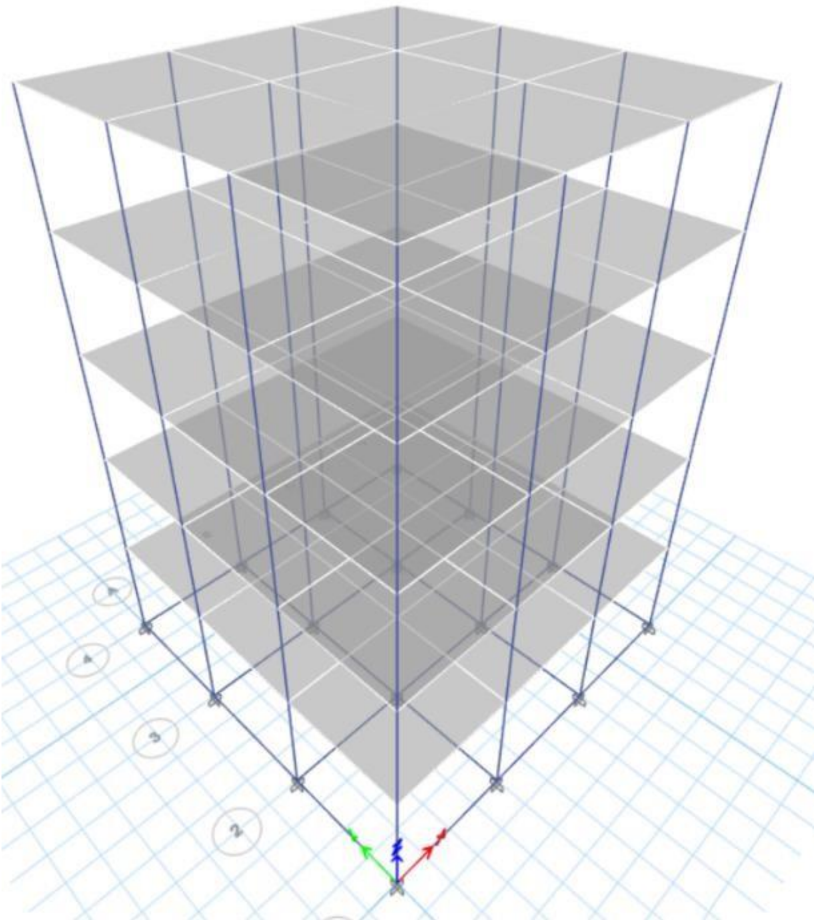

Fig 7: Model 1 Aspect Ratio 1

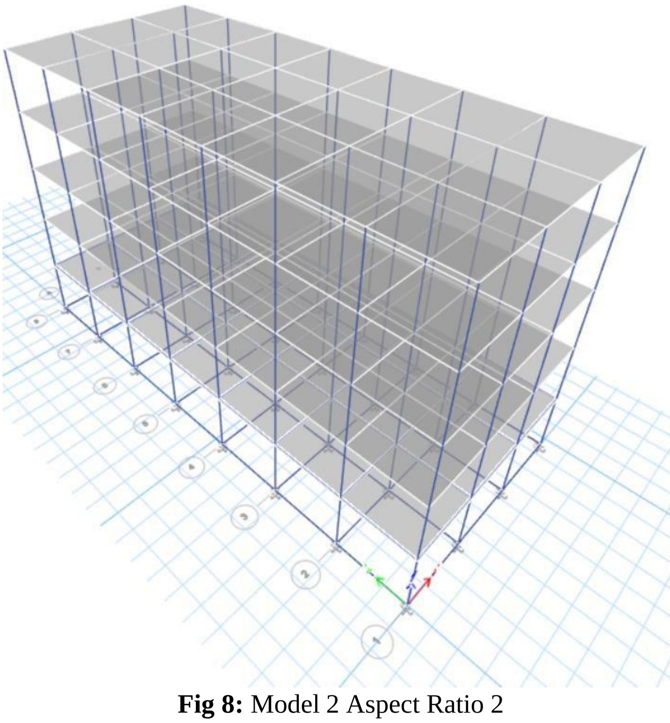

Fig 8: Model 2 Aspect Ratio 2

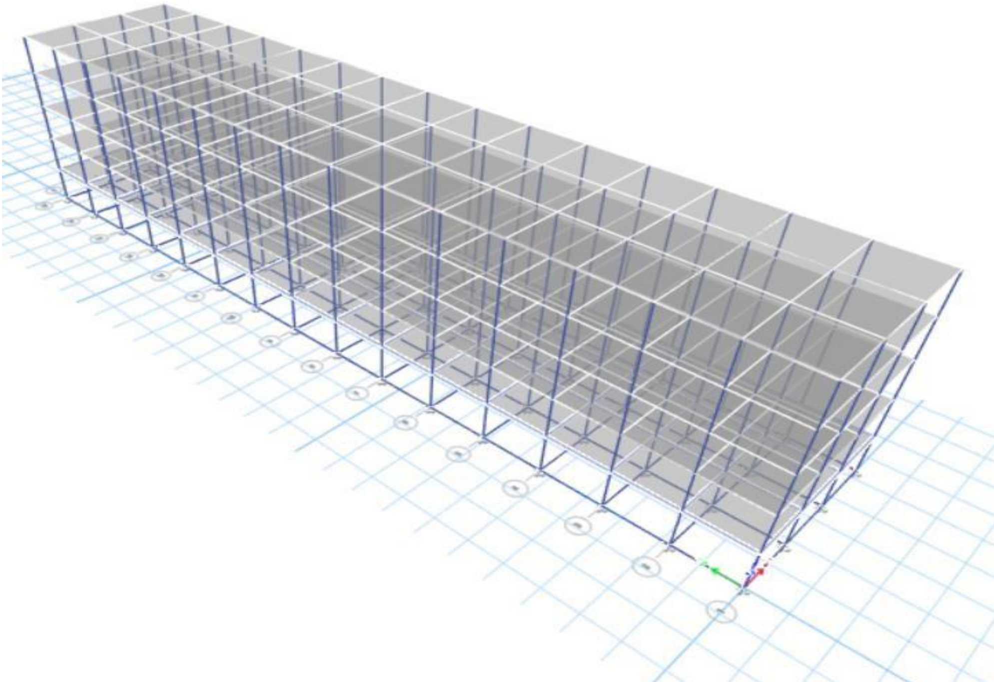

Fig 9: Model 3 Aspect Ratio 4

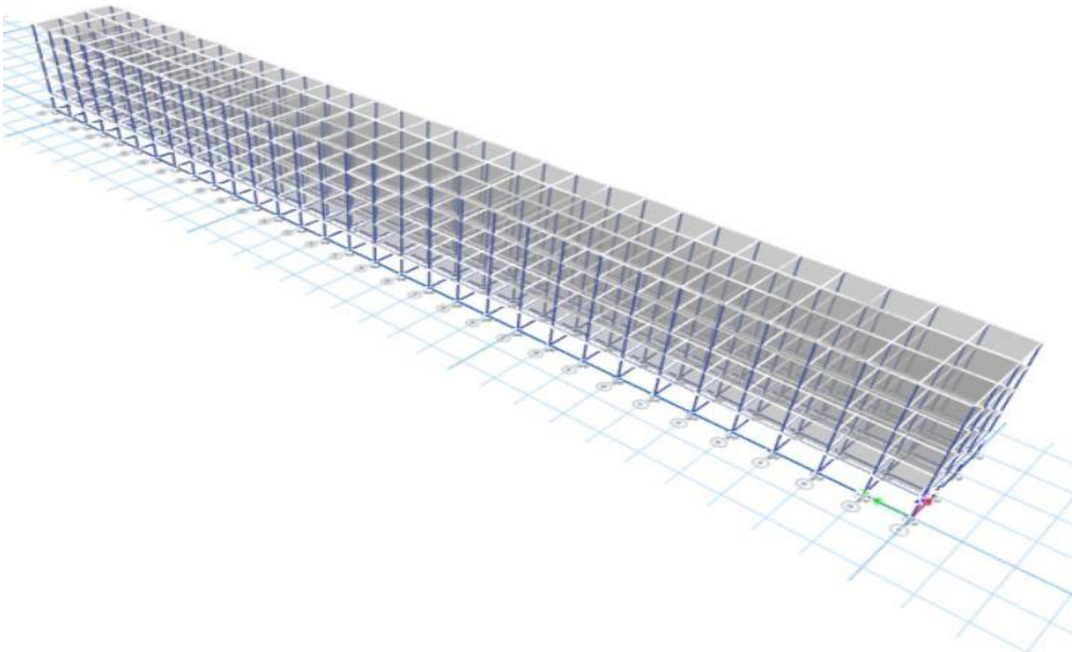

Fig 10: Model 4 Aspect Ratio 8

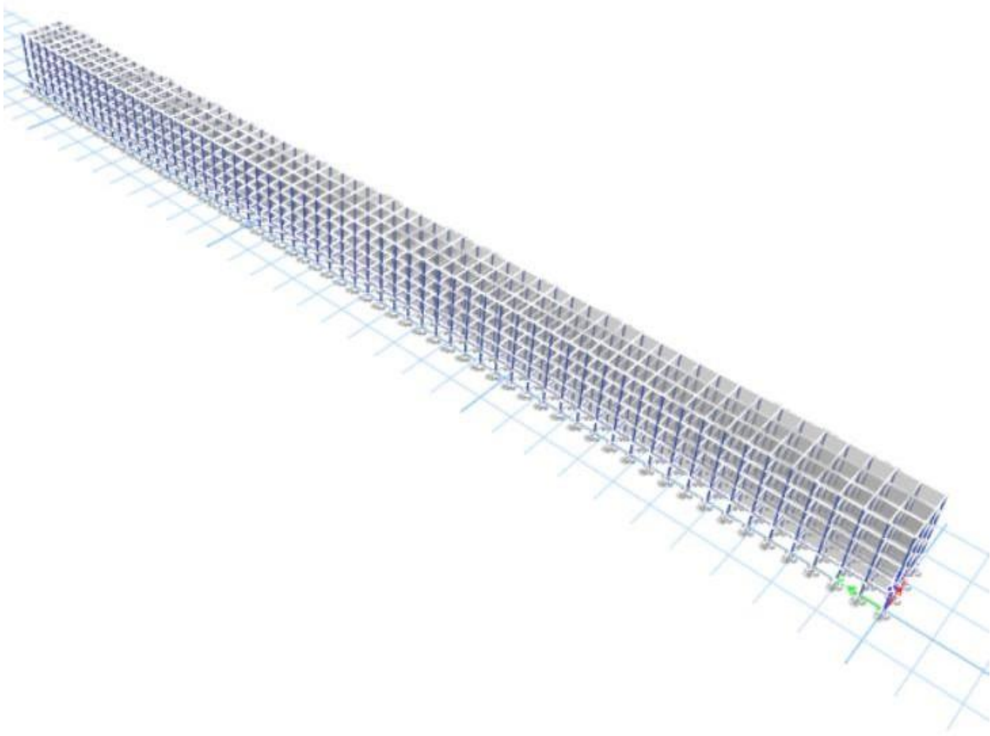

Fig 11: Model 5 Aspect Ratio 16

6. Results Of Analysis

All the five models are analysed separately using non-linear static method and results areshown below :

Pushover Curve , Story Responses And HingeFormation

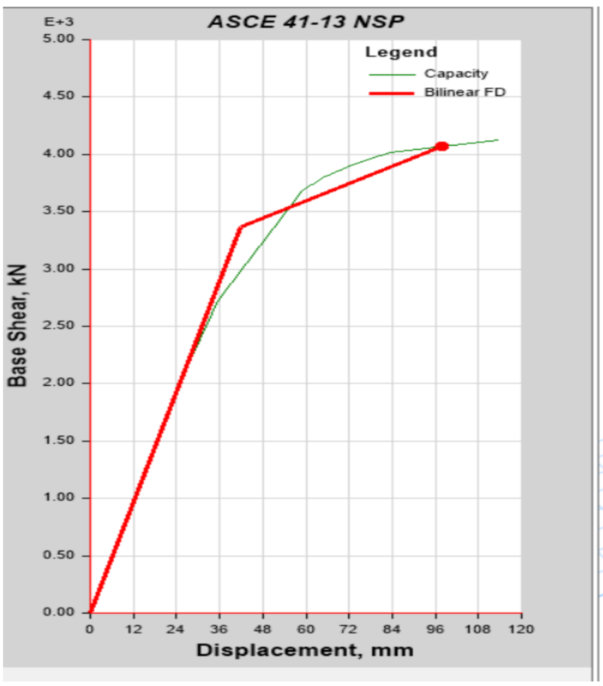

Fig 12: Pushover Curve AR1

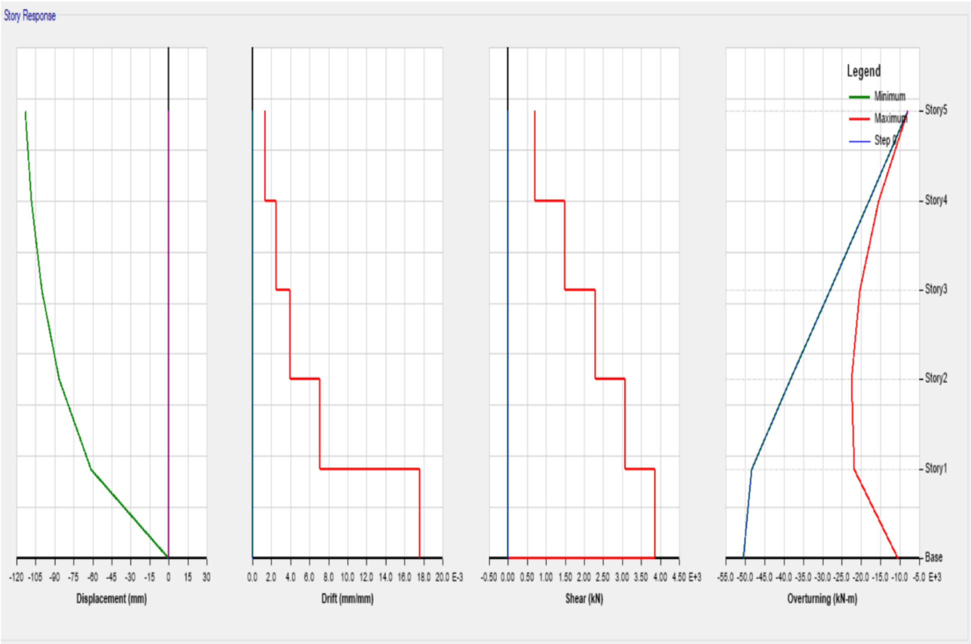

Fig 13: Storey Responses AR1

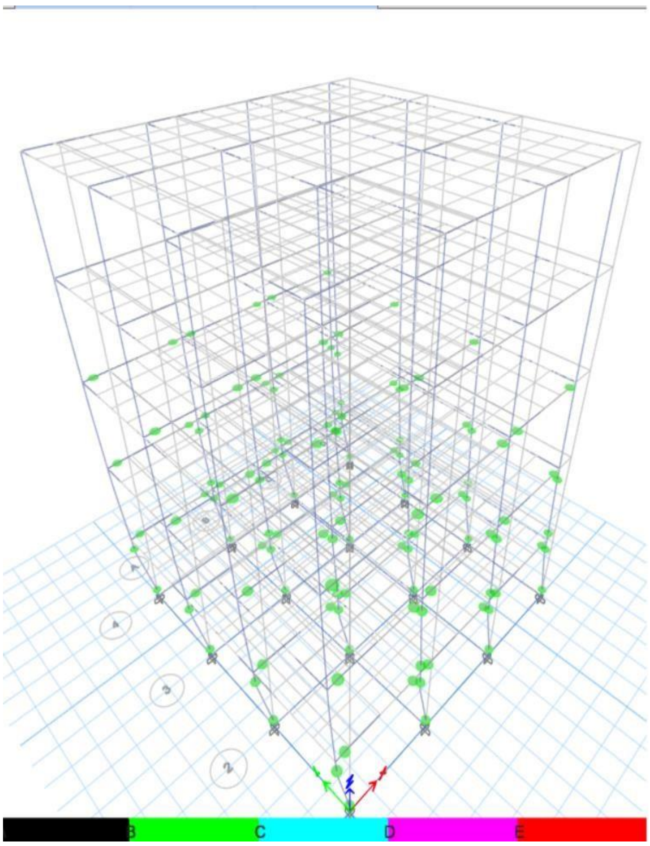

Fig 14: Hinge Formation AR1

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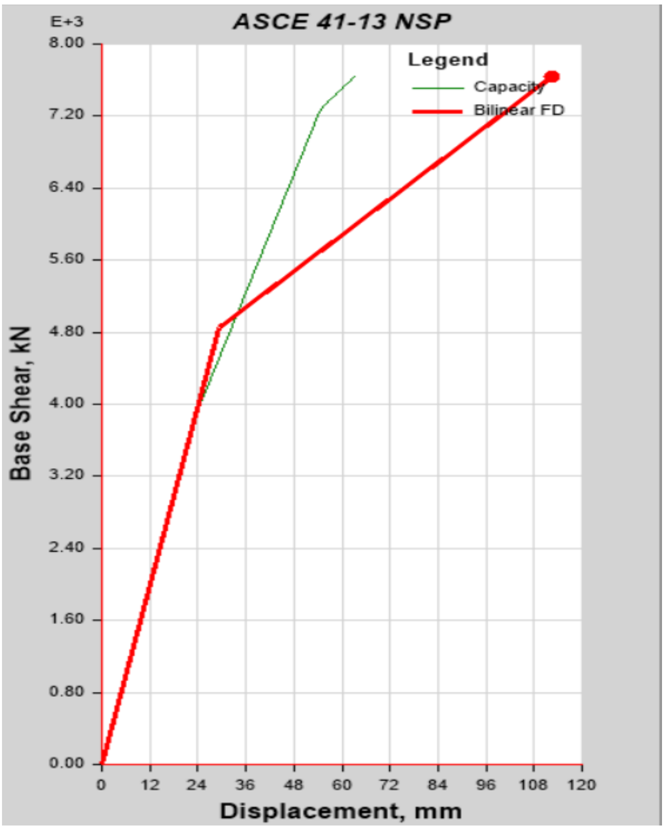

Fig 15: Pushover Curver AR2

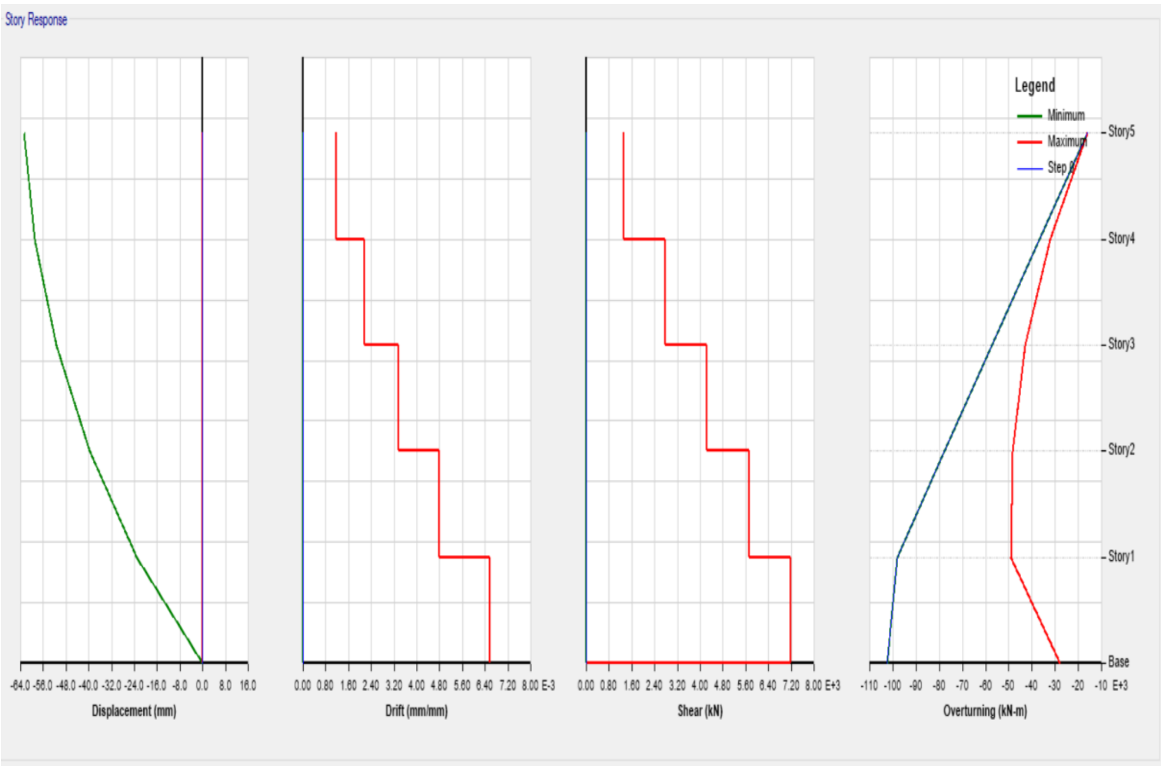

Fig 16: Story Responses AR2

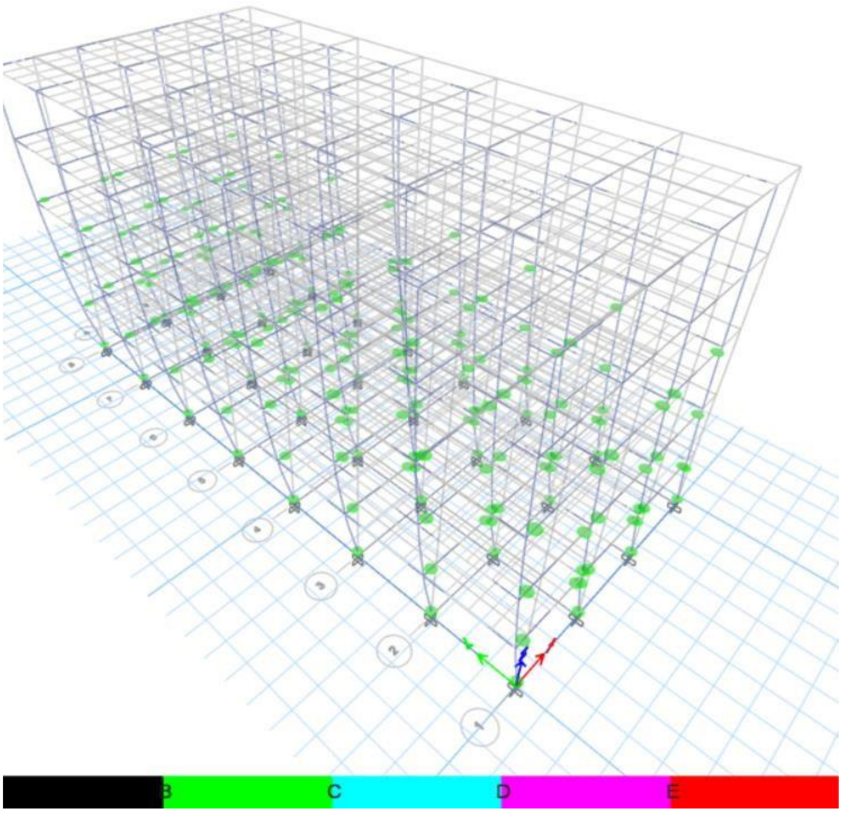

Fig 17: Hinge Formation AR2

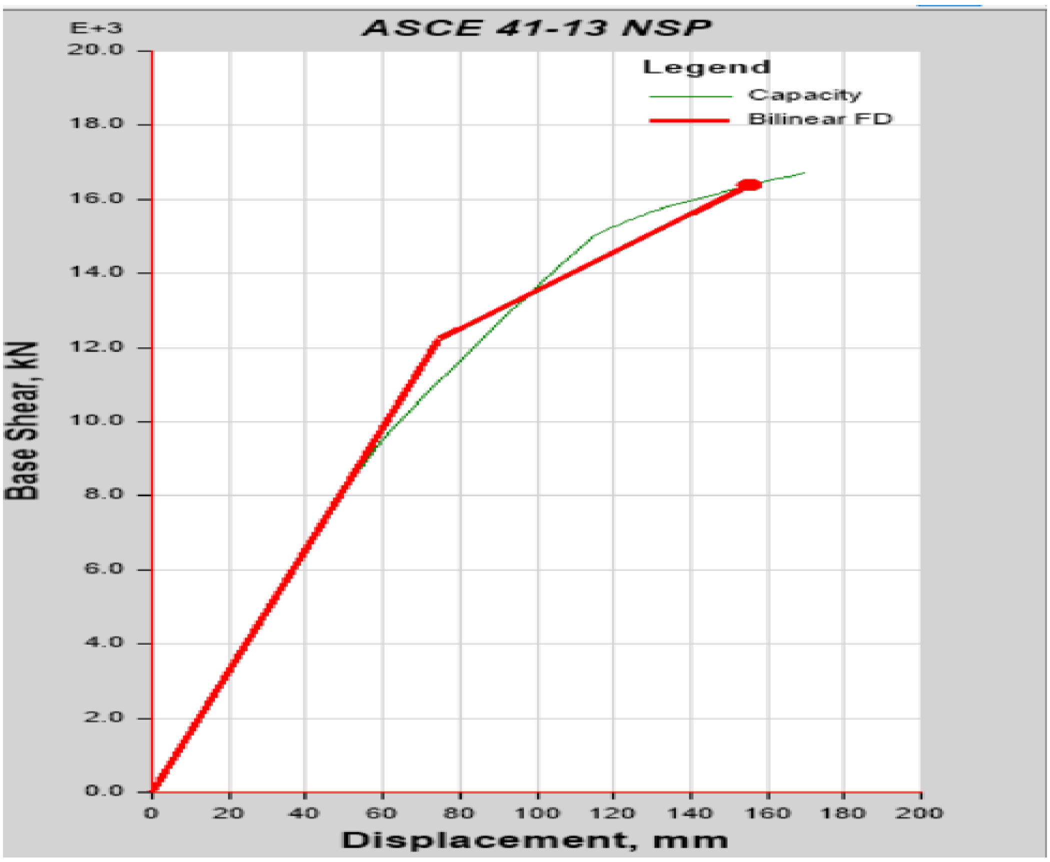

Fig 18: Pushover Curve AR4

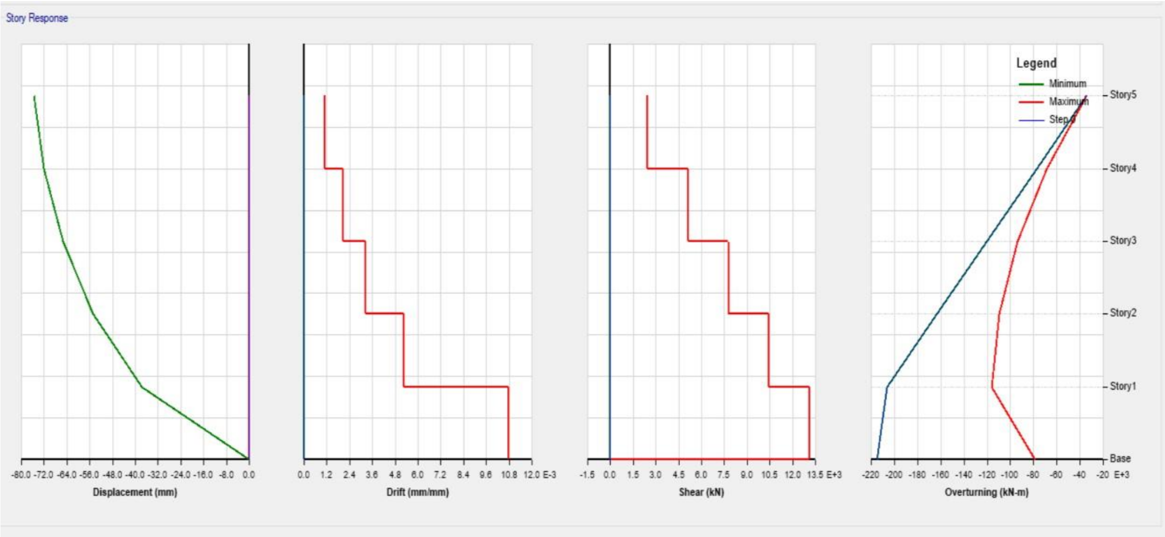

Fig 19: Story Responses AR4

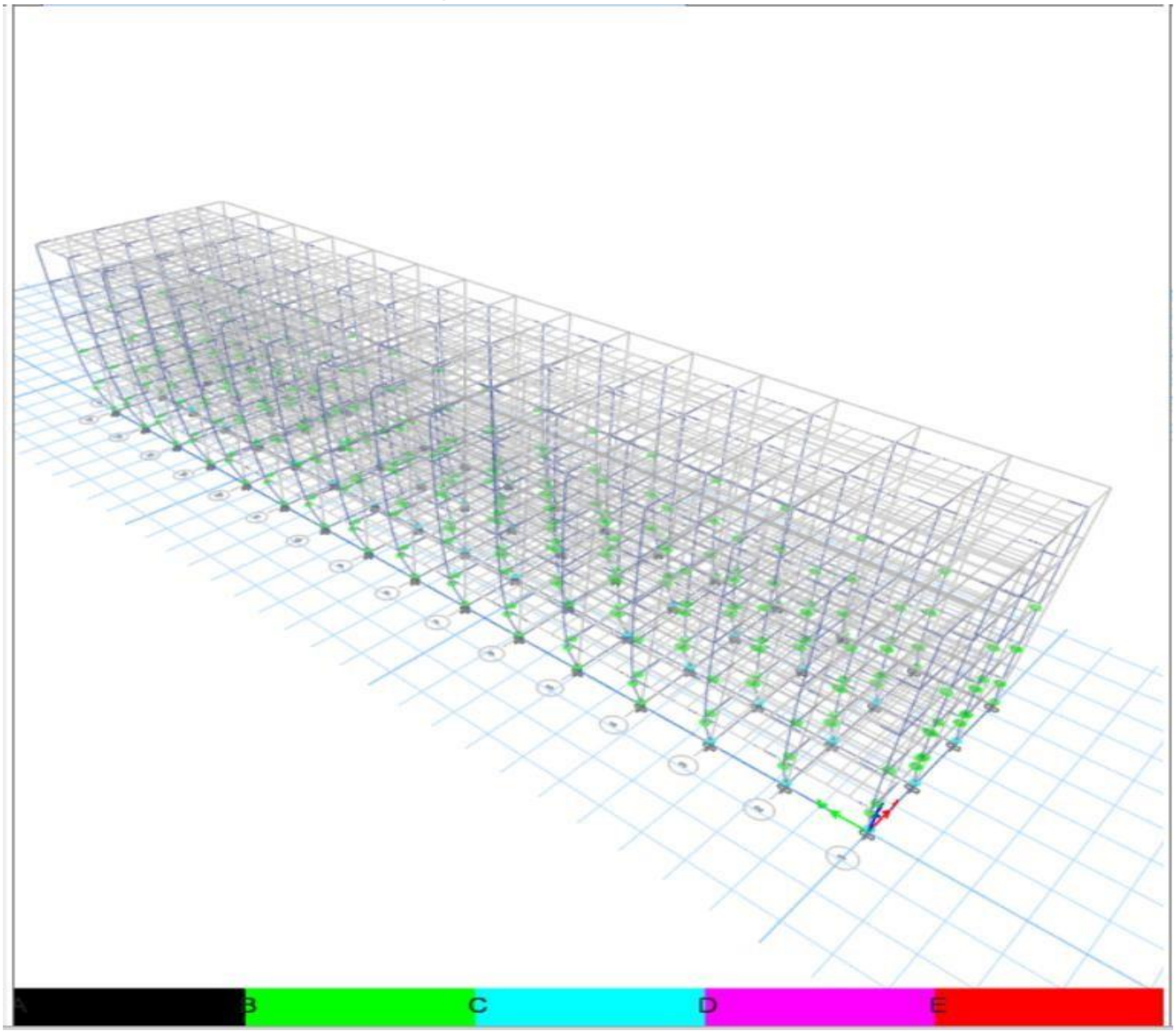

Fig 20: Hinge Formation AR4

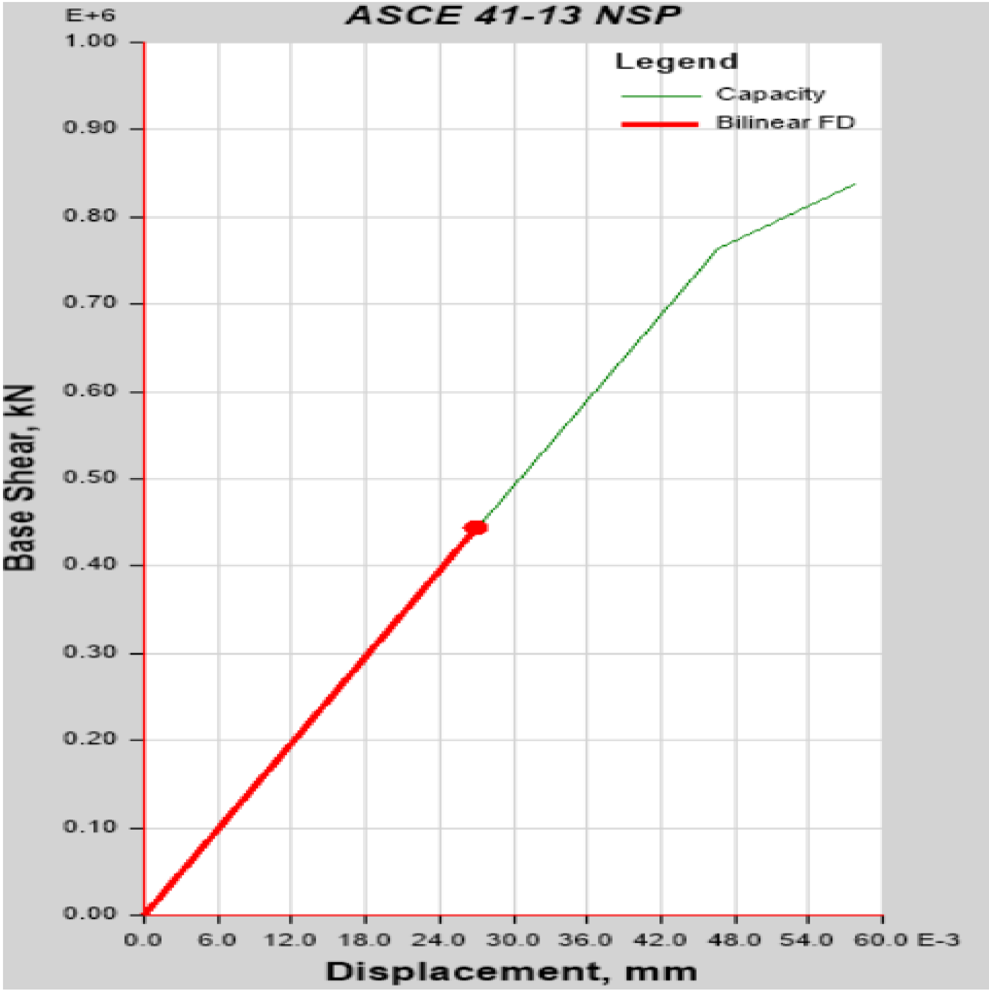

Fig 21: Pushover Analysis AR8

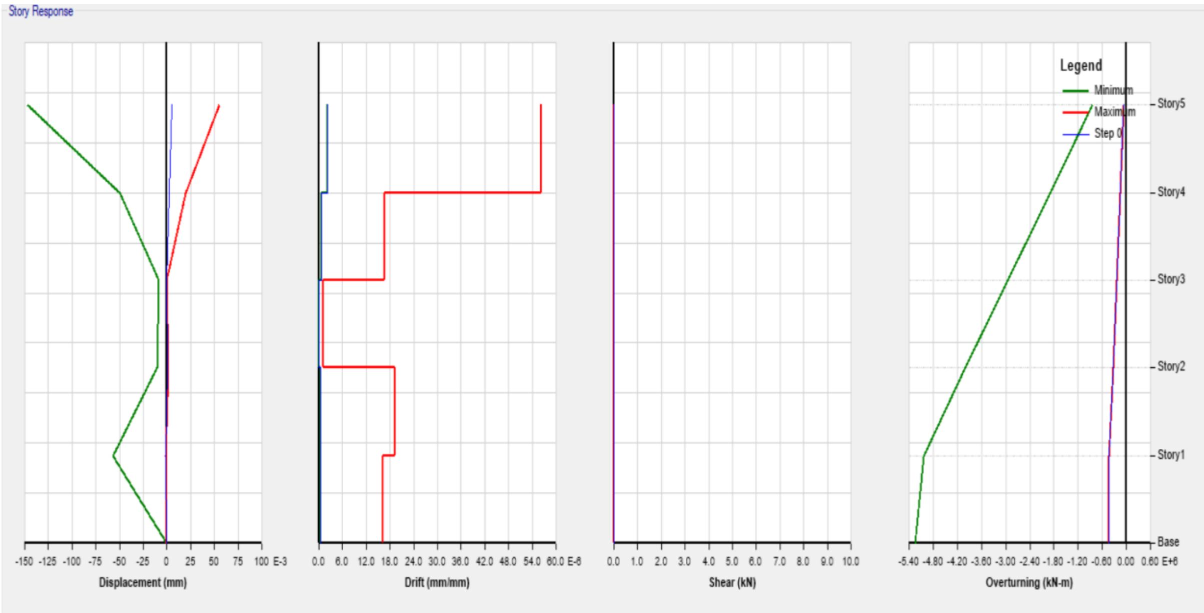

Fig 22: Story Responses AR8

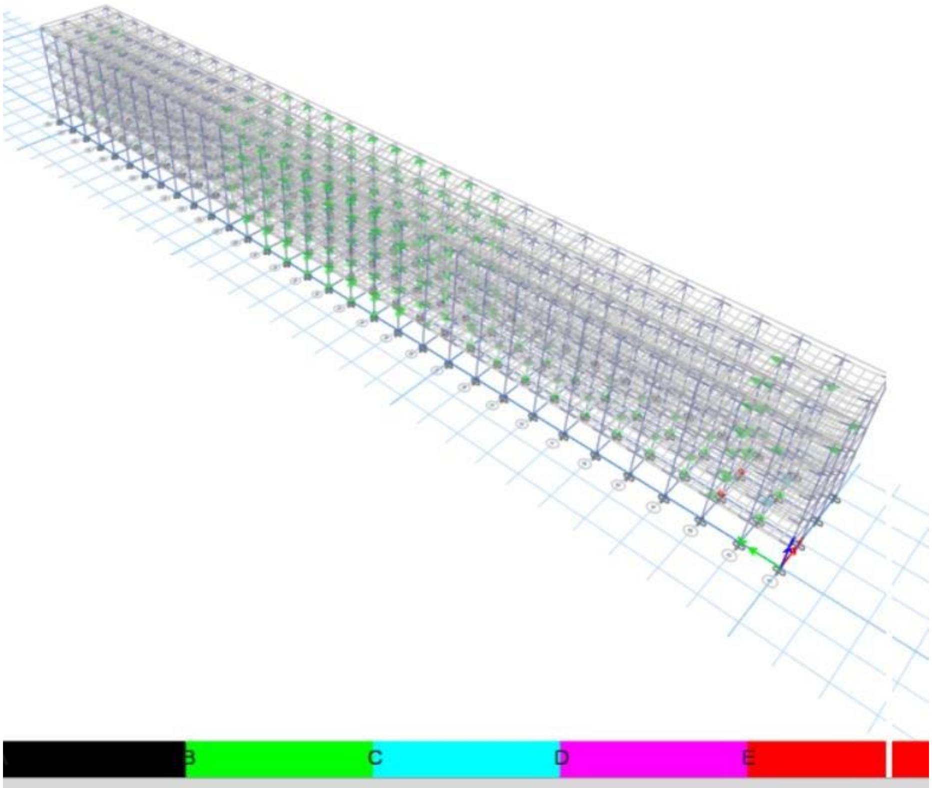

Fig 23: Hinge Formation AR8

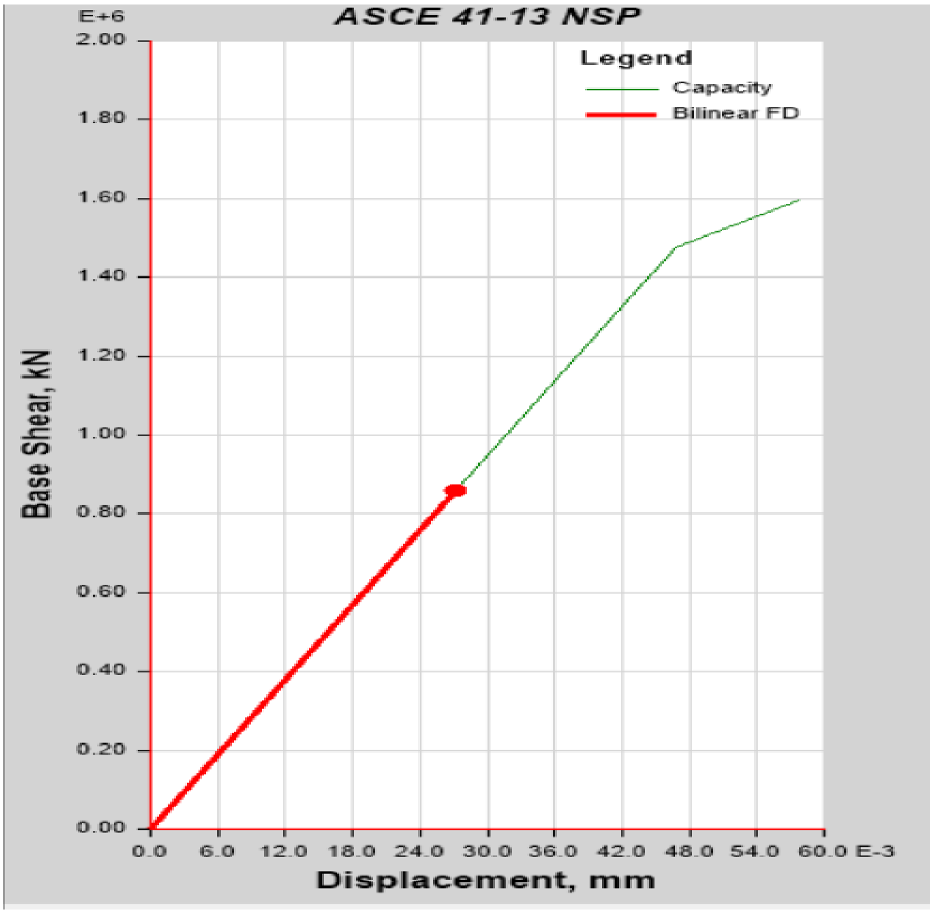

Fig 24: Pushover Curve AR16

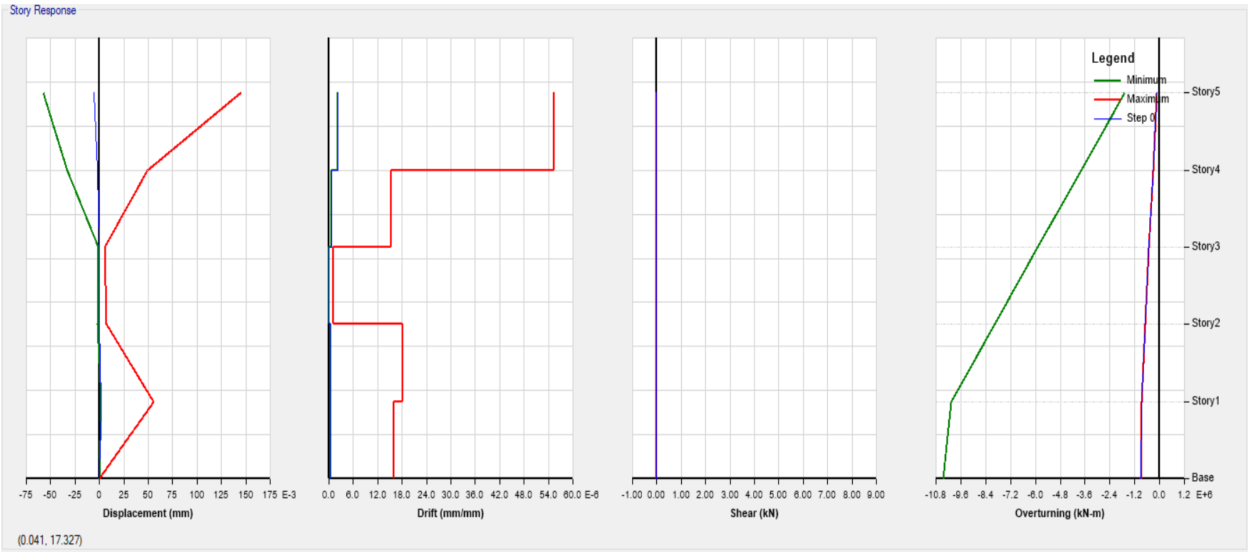

Fig 25: Story Responses Curve AR16

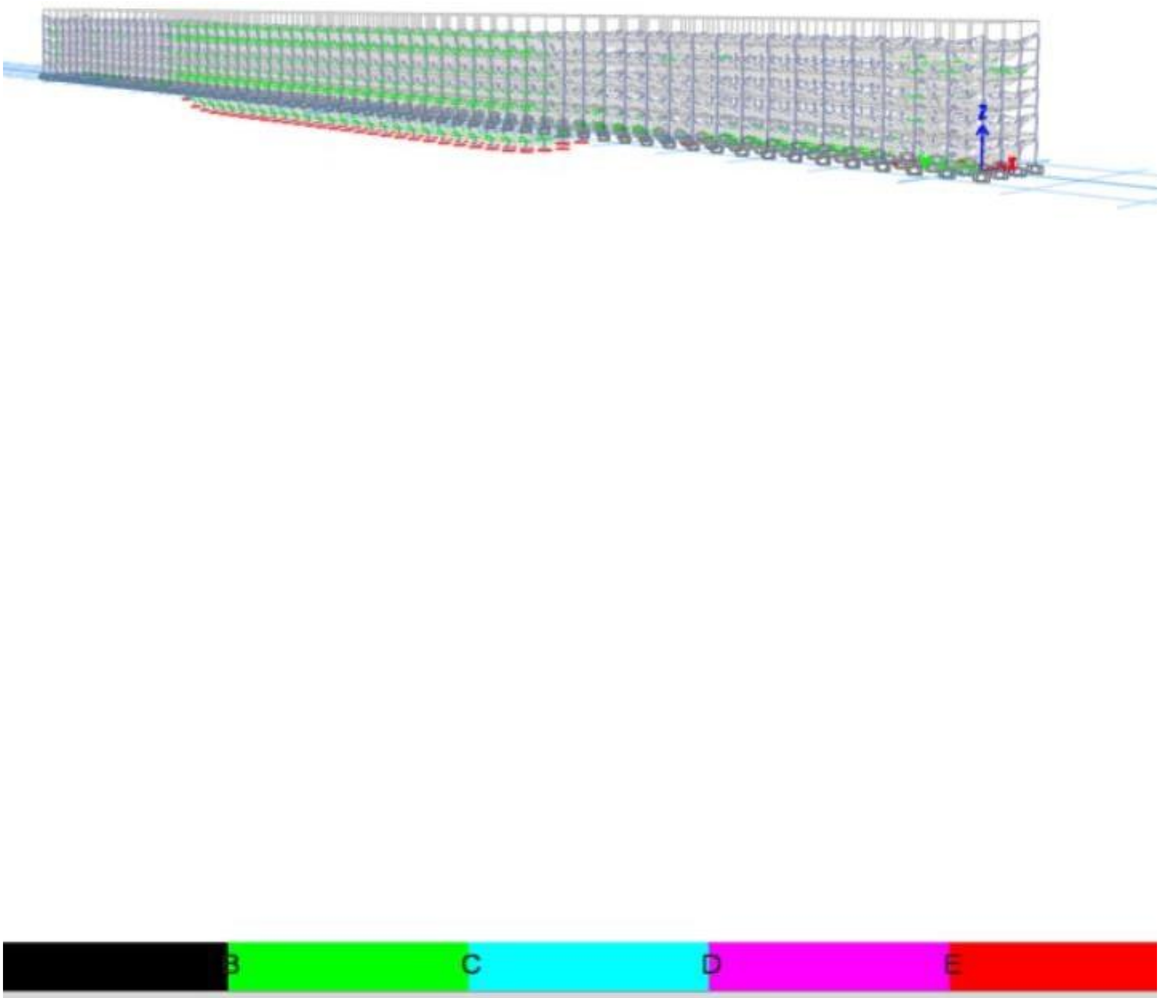

Fig 26: Hinge Format

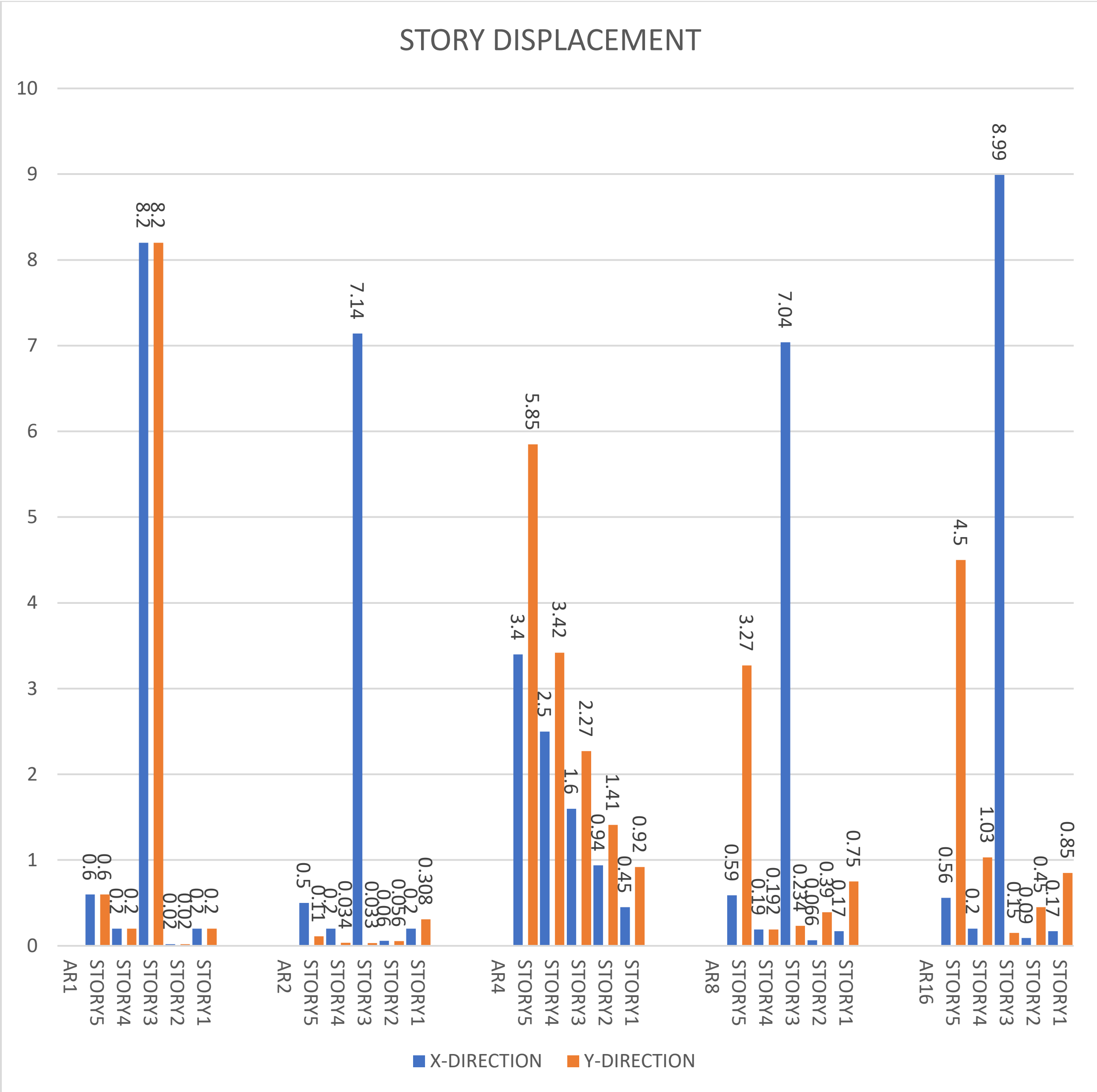

Fig 27: Story Displacement

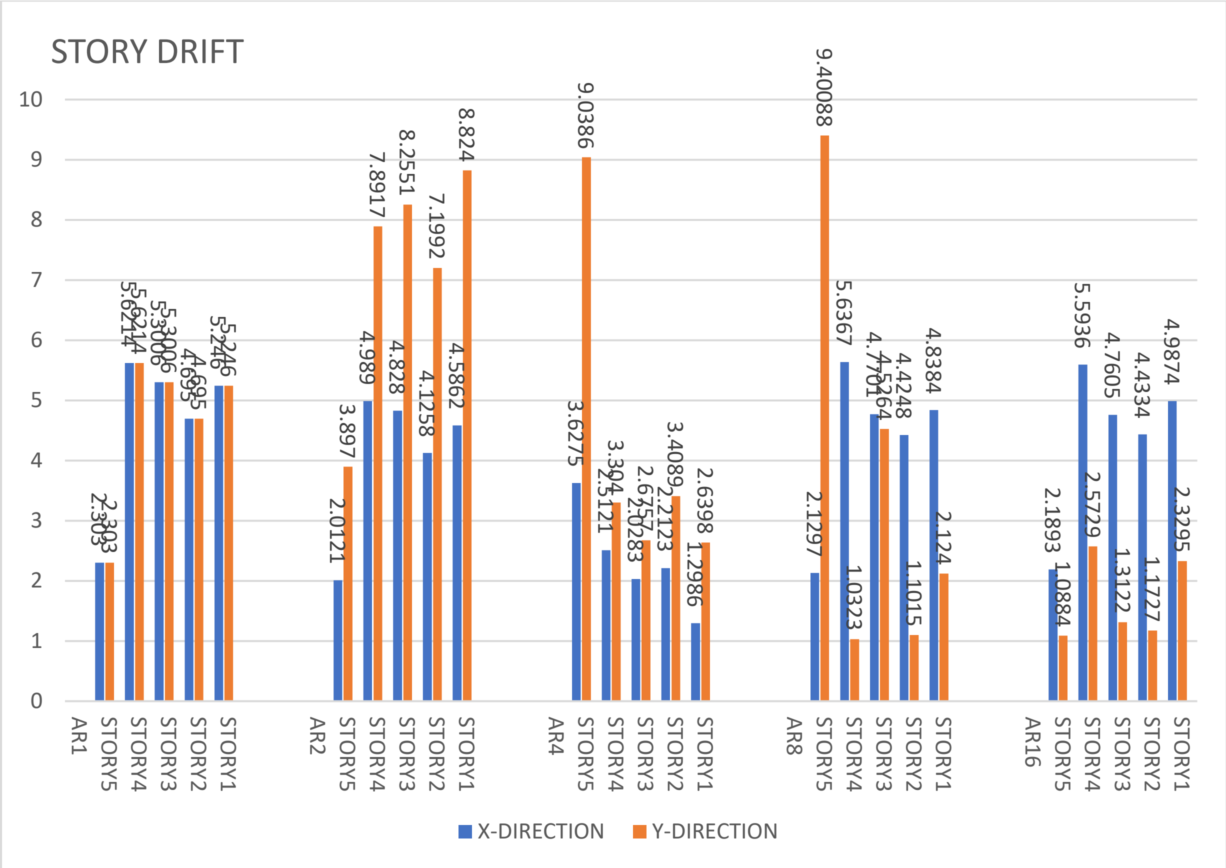

Fig 28: Story Drift

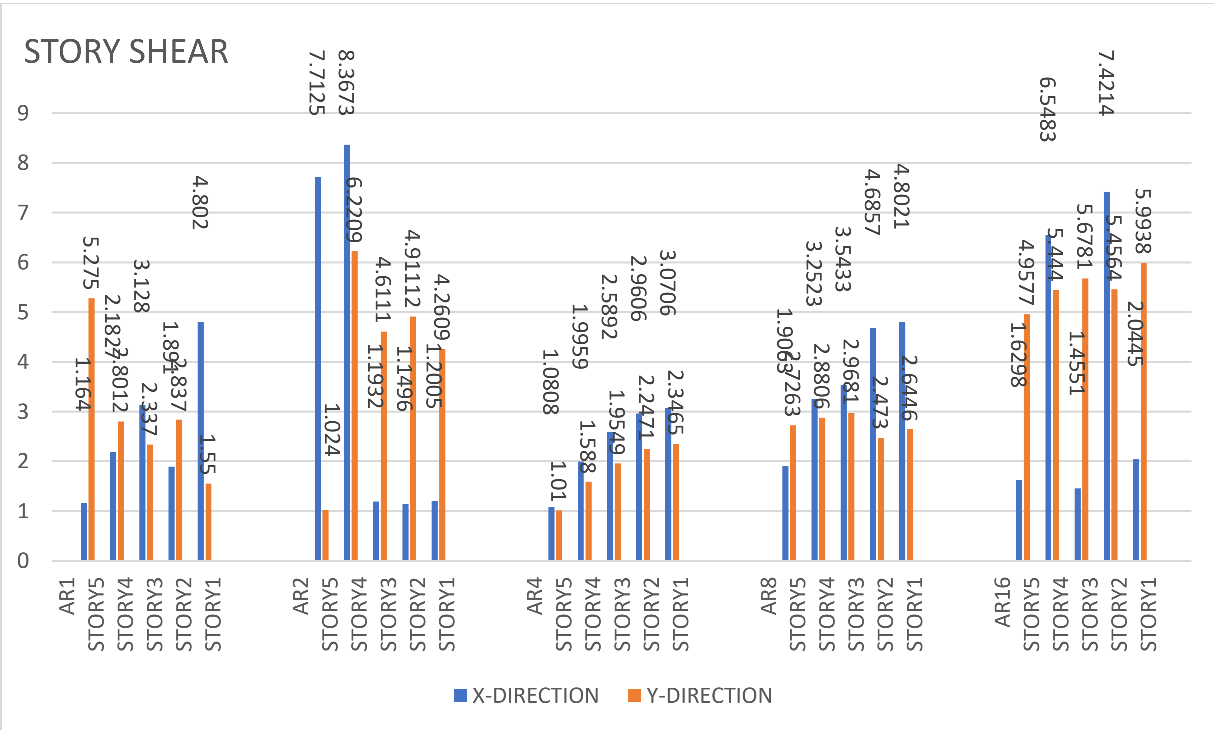

Fig 29: Story Shear

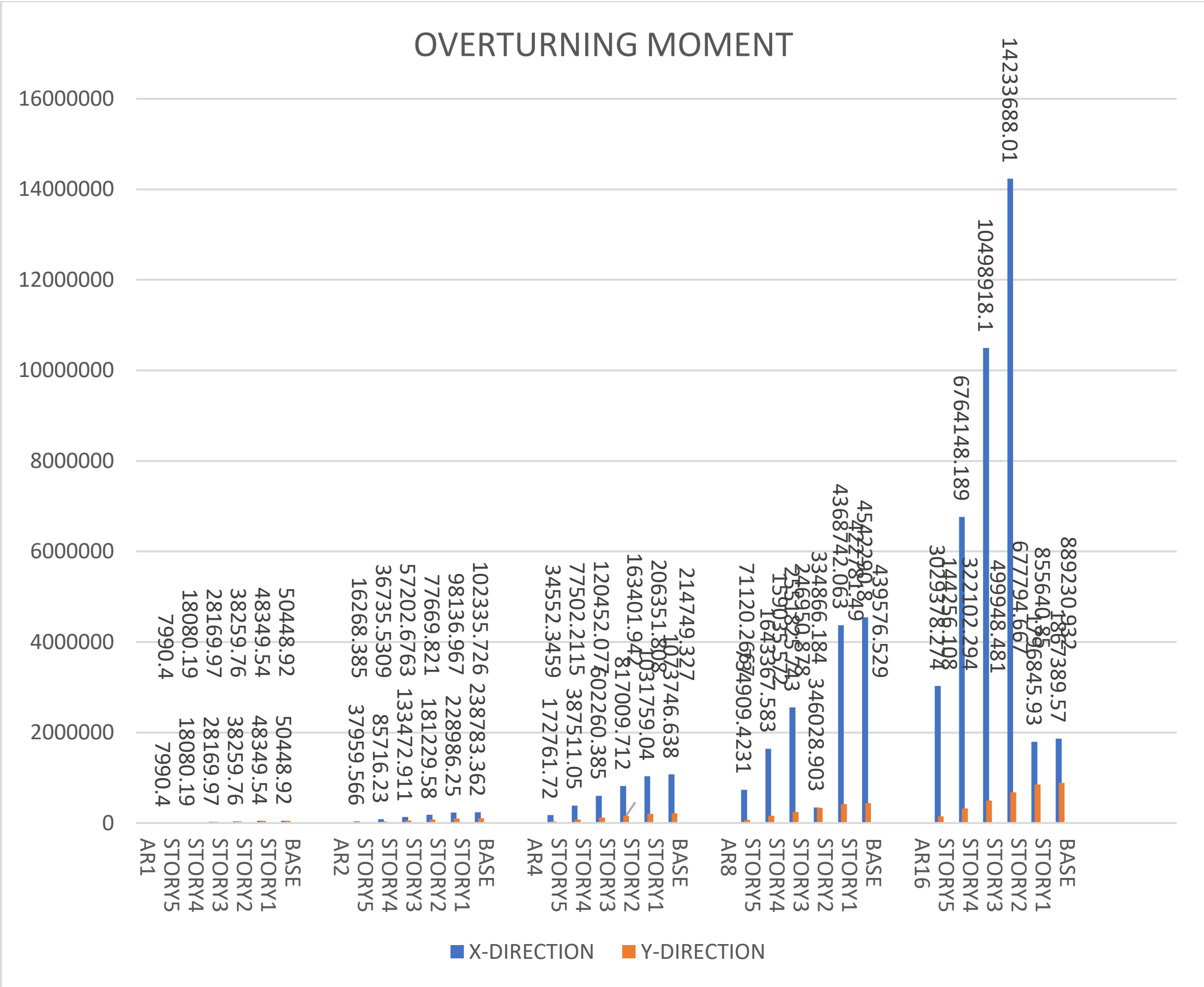

Fig 30: Overturning Moment

Table 2: Displacement Vs Shear Force

MODEL	DISPLACEMENT (MM)	SHEAR (KN)
AR1	97.984	4068.035
AR2	112.318	7638.7959
AR4	155.217	16381.1564
AR8	0.027	443308.122
AR16	0.027	858603.3104

7. Discussion

1) Pushover analysis could depict collapse mechanisms, critical regions that require unique detailing and also inter-story drifts and structural damage.
2) Pushover analysis system is an effective tool for the ultimate strength estimation and global plastic mechanism and offer information at the series of plastic yield formationacross the structure.
3) Pushover process had been generally not effective in predicting inter story drift and displacement demands . Drifts were typically underestimated at top stories and fromtime to time over-envisioned at bottom levels .
4) Overturning moment was evaluated satisfactorily for the normal frames.
5) Approach advocate that structural damage is a function of only the lateral deformationof the shape . Thus the effect of strong ground motion period and cumulative energy dissipation are without a doubt unnoticed, rendering the method approximate.
6) Pushover analysis is extraordinarily a simple approach to examine the shape in non- linear variety. Weak elements inside the structure can be recognized with the assist of pushover analysis which additionally debts for redistribution of the forces. However, pushover analysis won't appropriately represents dynamic conduct of the shape as it's far an approximate method based totally on static loading. The efforts needed for computation process and interpretation of results are a whole lot less as compared to other methods of non-linear analysis.
7) Formation of the hinges begins at the supports and steadily moves toward the top stories with the increment of load. Consequently formation of hinges is depicted.
8) The overall idea approximately the behaviour of the shape is depicted via plastic hinges , demand and capacity of the shape.

8. Conclusions

1) This research provided some primary data at the use and accuracy of the numerous pushover analysis approach inside the seismic assessment and design of structure. Thefundamental concept of pushover analysis turned into defined and the various pushover analysis methods have been defined. A comprehensive evaluation of preceding findings on pushover evaluation was furnished.
2) The proposed simple method for the non linear static evaluation of building structuresis successful to estimate several vital traits of non-linear structural behaviour , mainly the actual strength and the global plastic mechanism. The efforts needed for information guidance, computation and interpretation of outcomes are smaller as inside the case of other non-linear evaluation methods. So the proposed procedure may be appropriate for practical evaluation and layout of earthquake resistant buildingsystems and for evaluation of existing structure .
3) Pushover process had been generally not effective in predicting inter story drift and displacement demands . Drifts were typically underestimated at top stories and fromtime to time over-envisioned at bottom levels .
4) Overturning moment was evaluated satisfactorily for the normal frames.
5) Weak elements inside the structure can be recognized with the assist of pushover analysis indicated by hinge formation which additionally debts for redistribution ofthe forces.
6) Formation of the hinges begins at the supports and steadily moves toward the top stories with the increment of load.
7) As the aspect ratio increases shear force increases along with displacement though displacement tends to decrease for higher aspect ratio.
8) Base shear is maximum for building with aspect ratio 16.
9) With increase in plan aspect ratio , number of hinges formed also increases making building vulnerable to resist earthquake load .

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