SEISMIC UPGRADATION OF BUILDINGS USING PUSHOVER ANALYSIS

MOHD AMIR M. TECH (STRUCTURAL & FOUNDATION ENGINEERING)[1], MISBAH DANISH SABRI (Assistant Professor)

[1,2]*Department of Civil Engineering AL-FALAH UNIVERSITY, Faridabad INDIA*

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Abstract: The seismic assessment prepare comprises of exploring in case the structure meets the defined target structural performance levels. The main goal during earthquakes is to assure that building collapse doesn't occur and the risk of death or injury to people is minimized and beyond that to satisfy post-earthquake performance level for defined range of seismic hazards. Rehabilitation prepare points to progress seismic execution and adjust the lacks increasing quality, firmness or distortion capacity and making strides associations. Hence, a proposed retrofit execution can be said to be fruitful in the event that it comes about an increment in strength and ductility capacity of the structure which is more noteworthy than the requests forced by earthquakes.

Seismic force, predominantly being an inertia force depends on the mass of the structure. As the mass of the structure increases the seismic forces also increase causing the requirement of even heavier sections to counter that heavy forces. And these heavy sections further increase the mass of the structure leading to even heavier seismic forces. Structural designers are met with huge challenge to balance these contradictory physical phenomena to make the structure safe. The structure no more can afford to be rigid.

This introduces the concept of ductility. The structures are made ductile, allowing it yield in order to dissipate the seismic forces. A framed structure can be easily made ductile by properly detailing of the reinforcement. But again, as the building height goes beyond a certain limit, these framed structure sections (columns) gets larger and larger to the extent that they are no more practically feasible in a structure. There comes the role of shear walls. Shear walls provide ample amount of stiffness to the building frame resisting loads through in plane bending. But they inherently make the structure stiffer. So, there must be a balance between the amount of shear walls and frame elements present in a structure for safe and economic design of high-rise structures.

KEYWORDS: Structural Motions, Damping, Pushover Analysis, Target Spectrum, Capacity curve

1 INTRODUCTION

An expansive number of existing buildings (Yogendra Singh, 2003) in India are seriously insufficient against seismic tremor powers and the number of such buildings is developing exceptionally quickly. This has been highlighted within the past seismic tremor. Retrofitting of any existing building may be a complex assignment and requires expertise, retrofitting of RC buildings is especially challenging due to complex behavior of the RC composite fabric. The behavior of the buildings amid seismic tremor depends not as it were on the measure of the individuals and sum of support, but to an awesome degree on the putting and specifying of the fortification. The development hones in India result in serious development abandons, which make the assignment of retrofitting indeed more difficult. There are three sources of insufficiencies in a building, which need to be accounted for by the retrofitting design: (i) lacking plan and specifying, (ii) debasement of fabric with time and utilize, and (iii) harm due to seismic tremor or another catastrophe.

The report Applied Technology Council, (1996) highlights the nonlinear static pushover analysis. It is an efficient method for the performance evaluation of a structure subjected to seismic loads. The step by step procedure of the pushover analysis is to determine the capacity curve, capacity spectrum method and displacement coefficient method. By using these procedures this report is detailed with modeling aspects of the hinge behavior, acceptance criteria and locate the performance point. The present guidelines (Dr Durgesh C Rai., 2005) are intended to provide a systematic procedure for the seismic evaluation of buildings, which can be applied consistently to a rather wide range of buildings. This document also discusses some cost-effective strengthening schemes for existing older buildings where identified as seismically deficient during the evaluation process. The document (Dr Durgesh C Rai., 2005) highlights a higher degree of damage in a building is expected during an earthquake, if the seismic resistance of the building is inadequate. The decision to strengthen it before an earthquake occurs depends on the building's seismic resistance. The structural system of deficient building should be adequately strengthened, in order to attain the desired level of seismic resistance. This publication (FEMA156, 1994) presents a methodology to estimate the costs of seismic rehabilitation projects at various locations in the United States. The above edition is based on a sample of almost 2,100 projects, with data collected by using a standard protocol, strict quality control verification, and a reliability rating. A sophisticated statistical methodology applied to this database yields cost estimates of increasing quality and reliability as more and more detailed information on the building inventory is used in the estimation process.

1.2 Structural systems for tall buildings

Following are the Structural systems for tall buildings:

1. Rigid frame systems

2. Braced frame and shear-walled frame systems

3. Outrigger systems

4. framed-tube systems

5. braced-tube systems

6. bundled-tube systems

1.3 OBJECTIVES

Following are the main objectives of the work:

a) To perform pushover analysis on framed, shear wall and braced building.

b) To investigate the seismic performance of a multi-story building with bracing arrangements using Nonlinear Static Pushover analysis method.

c) To evaluate the performance factors for frames with various retrofitting arrangements designed according to latest Indian Code.

2. METHOD OF ANALYSIS

2.1. Static Analysis

The static method is the simplest one-it requires less computational effort and is based on the formulae given in the code. First, the design base shear is computed for the whole building and it is then distributed along the height of the building. The lateral forces at each floor level thus obtained are distributed to individual lateral load resisting elements.

2.2. Dynamic Analysis

Dynamic analysis shall be performed to obtain the design seismic forces and its distribution to different levels along the height of building and to the various lateral load resisting elements in following cases:

- Regular Building – Greater than 40 m height in zone IV and V and those greater than 90 m in height in zone II and III.
- Irregular building – All framed buildings higher than 12 m in zone IV and V, and those greater than 40 m height in zone II and III.
- For irregular building lesser than 40 m in height in zone II and III, dynamic analysis even though not mandatory, is recommended.

2.2.1 Response spectrum method

Response spectrum method is simply a plot of peak or steady state response (displacement, velocity or acceleration of a series of oscillators of varying natural frequency that are forced into motion by same base vibration or shock.

2.2.2 Non- linear time history analysis

It is an analysis of dynamic response of structure at each increment of time, when its base is subjected to any specific ground motion time history (compatible time history for medium soil IS-1893:2002-Part 1)

2.3 Pushover analysis (non-linear static method)

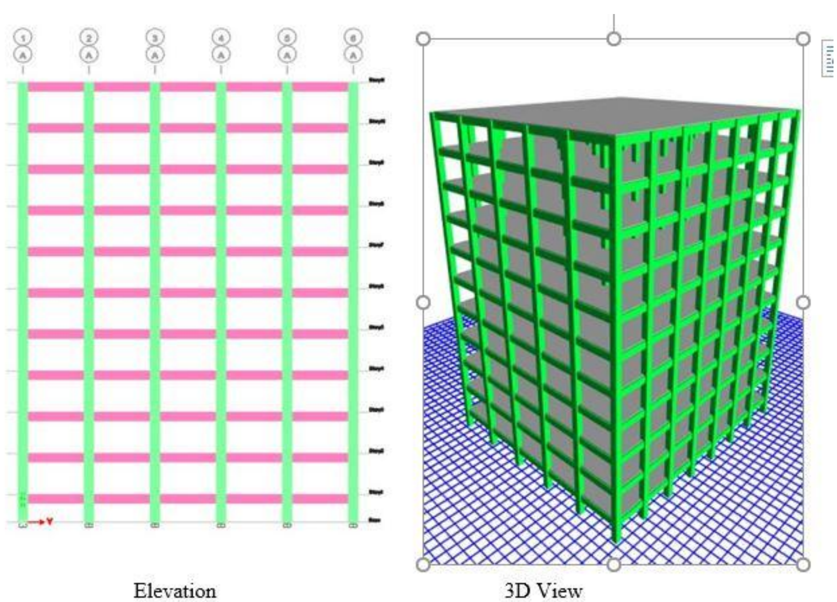
Pushover method of analysis is a technique in which a structural is modeled with non-linear properties (such as steel yield, plastic hinges) and permanent gravity load is subjected to an incremental load applied laterally from '0' value to prescribed ultimate displacement or until the structure become unstable to withstand the further forces

3. MODELS CONSIDERED FOR ANALYSIS

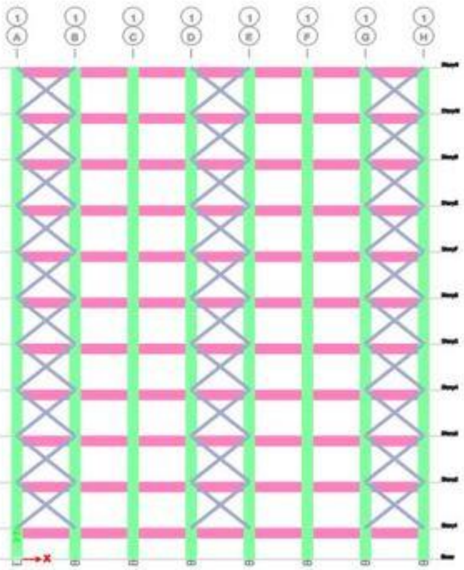
Following three types of models have been considered for analysis. It was attempted to choose models that are representative of actual building types that are being constructed nowadays. Type A is regular framed structure with columns. Type B hybrid braced framed structure wit bracings of Type 1 in periphery and columns. Type C hybrid braced framed structure with bracings of Type 2 in periphery and columns.

Table 1 Structural Description

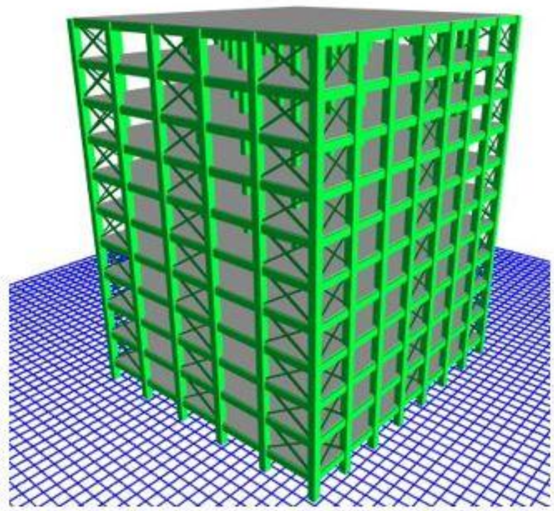
Model ID	Description
Type A	Regular Frame Structure
Type B	Hybrid braced framed structure with bracings in periphery
Type C	Tube structure with shear walls and columns



Type A: regular framed structure

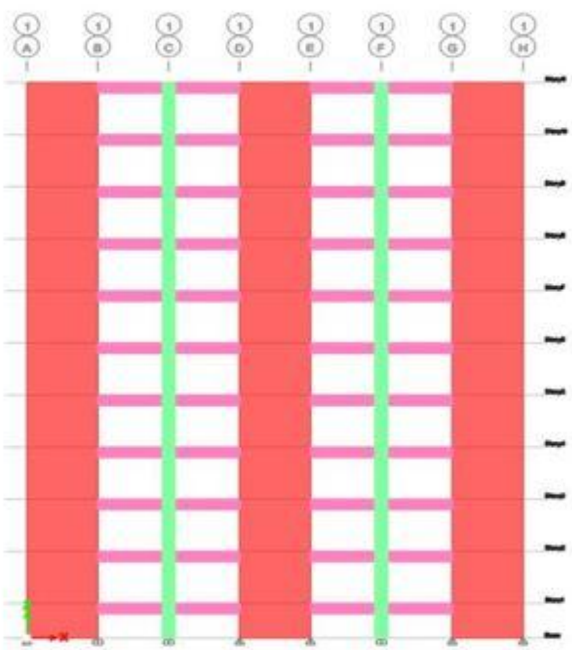


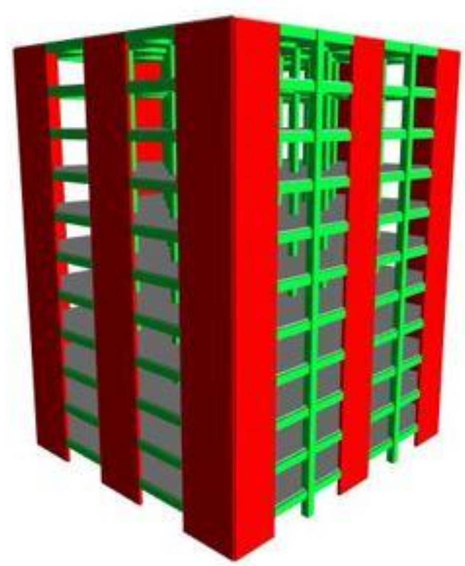
Elevation



3D View

Type B hybrid braced framed structure with bracings of Type 1 in periphery and Column





Type C Tube structure with shear walls and columns

Fig.1: Base Model considered for Analysis

4. Model Parameters

For the analysis of multi storied building six types of models have been considered for analysis. Type A is regular framed structure with columns. Type B hybrid framed structure with bracing in periphery and columns. Type C hybrid framed structure with shear wall in centre and columns. All the different types of models considered are analysed for 10 storeys.

In the current study main goal is to compare the Static and Dynamic Analysis of different types of building.

Design Parameters- Here the Analysis is being done for G+10, (rigid joint regular frame) building by computer software using ETABS.

Design Characteristics: - The following design characteristics are considered for Multi-storey rigid jointed frames

Seismic Load

As per IS: 1893, Noida is located in Seismic Zone IV.

Design base shear, V = Z I W Sa/2 R g

Wind Load

The wind velocity at Noida is 47m/s. The other parameter of wind load as per IS: 875 (Part-3).

Table 2 Model Parameters

S.No	Particulars	Dimension/Size/Value
1.	Model	G+10
2.	Seismic Zones	IV
3.	Floor height	3M
4.	Basement	2 M
5.	Building height	32 m
6.	Plan size	24.5 mx22.5 m
8.	Size of columns	0.3mx0.75m
9.	Size of beams	0.3mx0.75m &0.3mx0.6m
10	Shear Walls	0.23m
11.	Thickness of slab	125mm
12.	Earthquake load	As per IS-1893-2002
13.	Type of soil	Type -II, Medium soil as per IS-1893

5. Analysis Results and Discussions

The three model of 10 storey is analyzed by ETABS and SAP2000 for static and dynamic earthquake loads. The fundamental natural period and frequencies is calculated and shown in table below. Each of the building is also analyzed for wind load and comparison between displacement of all the building is calculated as shown in fig below. The response spectra as per IS-1893 2016 is used for dynamic seismic loads to calculate the parameters.

Comparison of Performance			
B+10 Parameter ZONE IV	TYPE A	TYPE B	TYPE C
Base Shear at Performance point	4089.017	4676.248	17814.5
Displacement at Performance point (m)	0.295	0.257	0.127
Spectral Acceleration	0.049	0.056	0.286
Spectral Displacement	0.252	0.22	0.087
Performance State	>E	>CP	CP

Table 3 Seismic Parameter

TYPE A MODEL					
Seismic Parameters					
Seismic Zone (Z)		IV	Soil Type (S)		Medium
Response Reduction Factor (R)		3	Importance Factor (I)		1
Seismic Weight (W)		113051.11	Zone Factor		0.24
Total Height (m)		32	Length along X (m)		24.5
Basement Height (m)		2	Width along Y (m)		22.5
Height of Mumty (m)		0	Effective Height (m)		32
Acceleration, g (mm/s²)		9806.65	Default Scale Factor		1634.4
EQX	-3784.43	0	Scale X		**1.01**
EQY	0	-3336.1081			1655.59
SPECX	3736.085	0.0009	Scale Y		**1.00**
SPECY	0.0004	3330.6987			1637.10
Time Period and Base Shear					
Detail	Time Period (s)	S_a/g	A_h	V_B	% A_h
Bare Frame	T_a **1.009**	1.348	0.0539	6095	5.39%
Above Basement	T_a **0.961**	1.415	0.0566	6397	5.66%
With Infil	T_x **0.582**	2.337	0.0935	10570	9.35%
	T_y **0.607**	2.240	0.0896	10129	8.96%
Avarage	$T_{avgx.}$ **0.795**	1.710	0.0684	7731	6.84%
	$T_{avgy.}$ **0.808**	1.683	0.0673	7610	6.73%
Above Basement	T_x **0.545**	2.500	0.1000	11305	10.00%
	T_y **0.569**	2.389	0.0956	10804	9.56%
Without Mumty	T_x **0.582**	2.337	0.0935	10570	9.35%
	T_y **0.607**	2.240	0.0896	10129	8.96%

Building Lateral Displacement Check						
Permissible	WLX	64	Actual	WLX	36	SAFE
	WLY	64		WLY	51	SAFE
	EQX	128		SPECX	126	SAFE
	EQY	128		SPECY	114	SAFE
Permissible	WLX	64	Actual	DL+WLX	36	SAFE
	WLY	64		DL+WLY	51	SAFE
	EQX	128		DL+SPECX	126	SAFE
	EQY	128		DL+SPECY	114	SAFE
Permissible	WLX	64	Actual	DL-WLX	51	SAFE
	WLY	64		DL-WLY	51	SAFE
	EQX	128		DL-SPECX	126	SAFE
	EQY	128		DL-SPECY	114	SAFE

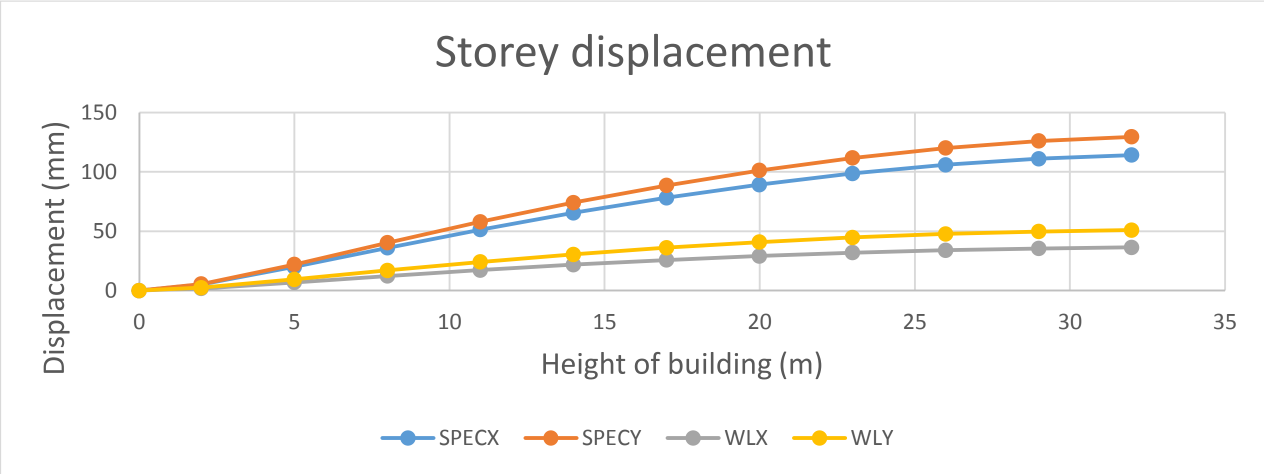


Fig 3 Storey displacement Type A

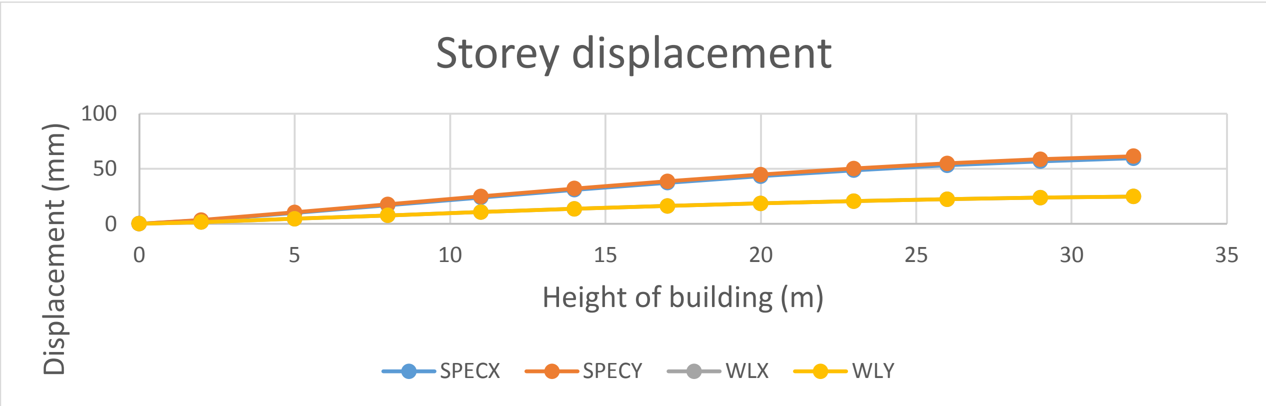


Fig 4 Storey displacement Type B

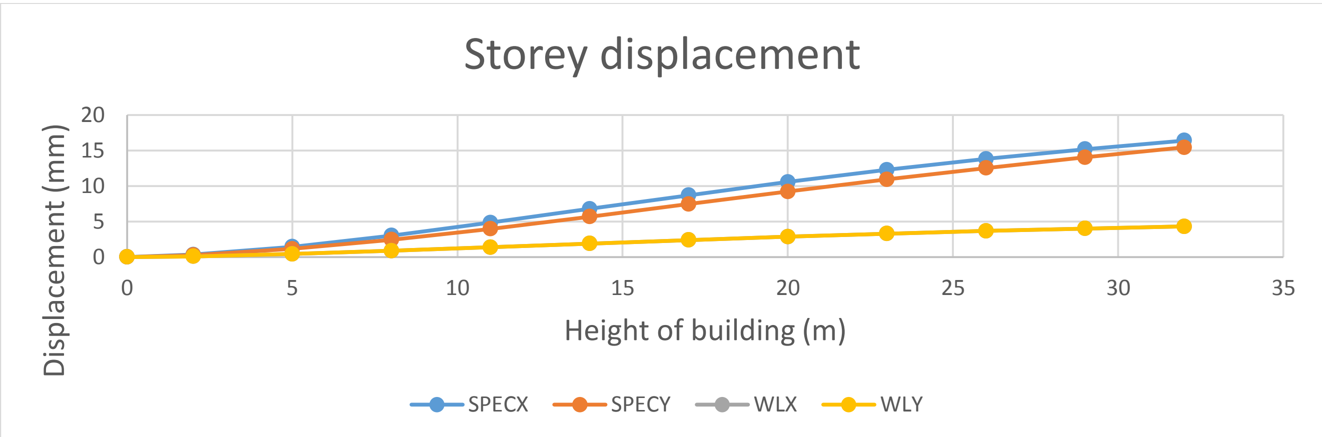


Fig 5 Storey displacement Type C

Modal Period

Mode	TYPE A	TYPE B	TYPE C
1	1.541	1.133	0.866
2	1.359	1.098	0.801
3	1.166	0.772	0.502
4	0.498	0.362	0.24
5	0.442	0.35	0.205
6	0.38	0.25	0.127
7	0.281	0.2	0.114
8	0.252	0.193	0.093
9	0.218	0.14	0.069
10	0.188	0.138	0.058
11	0.172	0.133	0.056
12	0.148	0.104	0.048

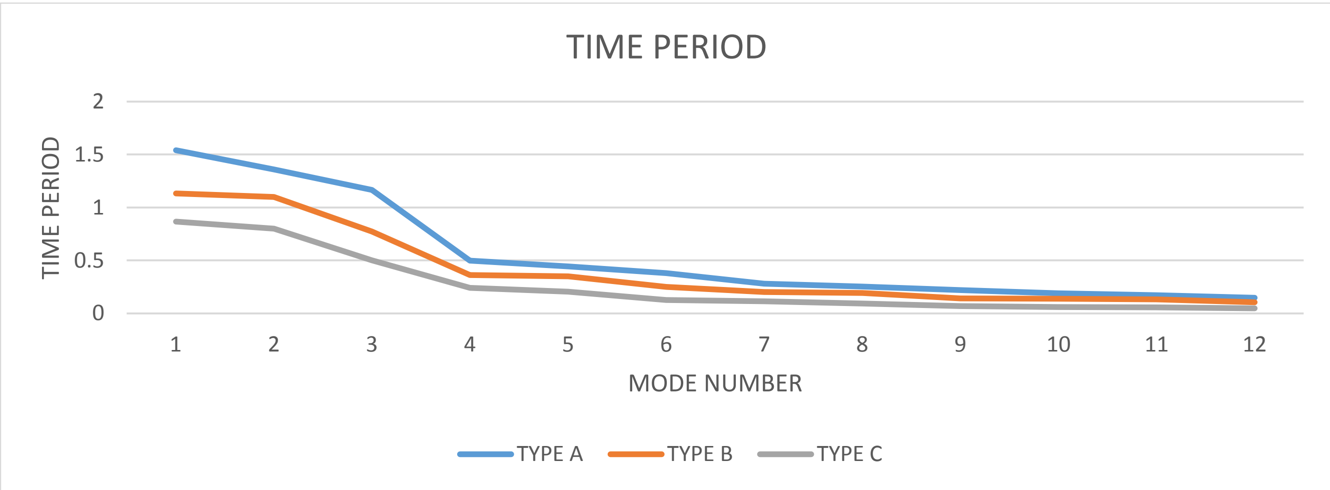
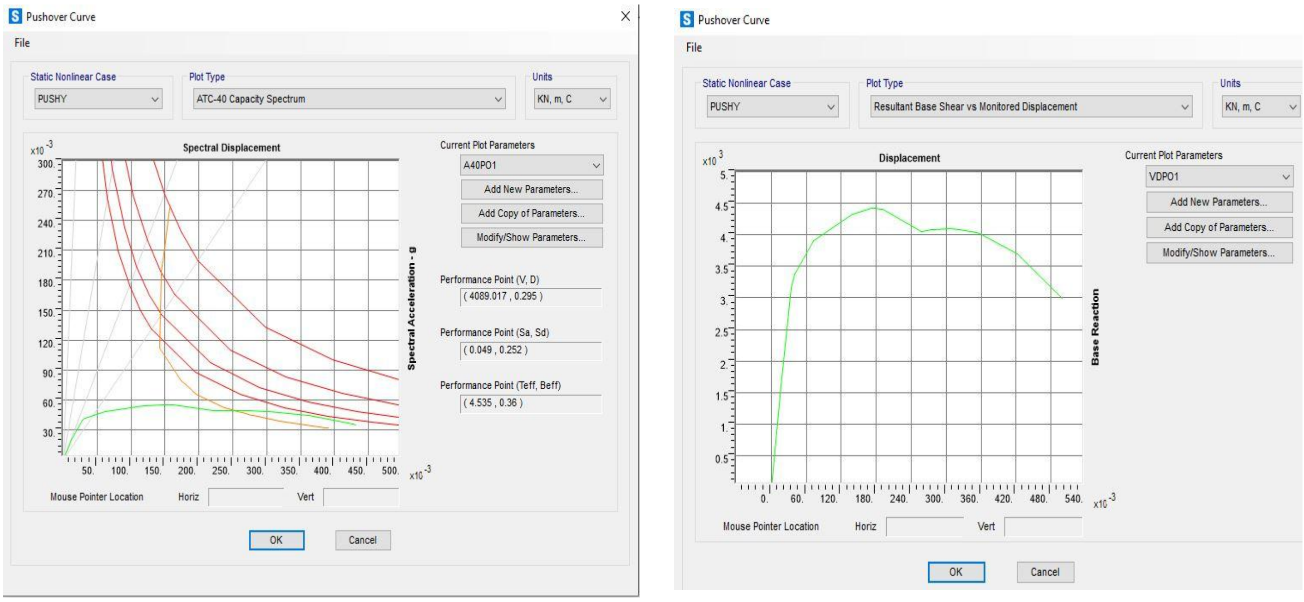


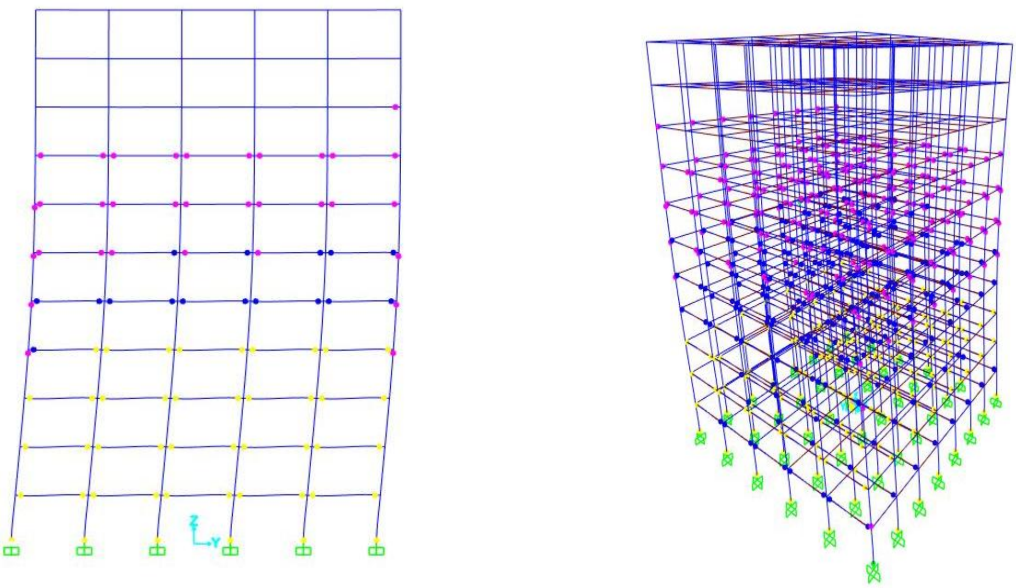
Fig:6 Time period vs Mode Number

The Pushover analysis of a Building with short spans (TYPE A)

The following figure shows the Pushover curve base shear vs lateral displacement. The unit for Base Reaction is KN and Displacement is meter. The maximum node displacement is equal to 0.54 m. The Pushover Curve shows that the building has objectively high Base Shear Capacity than the Design Base Shear. The Design base shear (VB) was found to be 4486.5 KN the capacity is 5508 KN which is much higher, hence the building is safe for this level of earthquake.



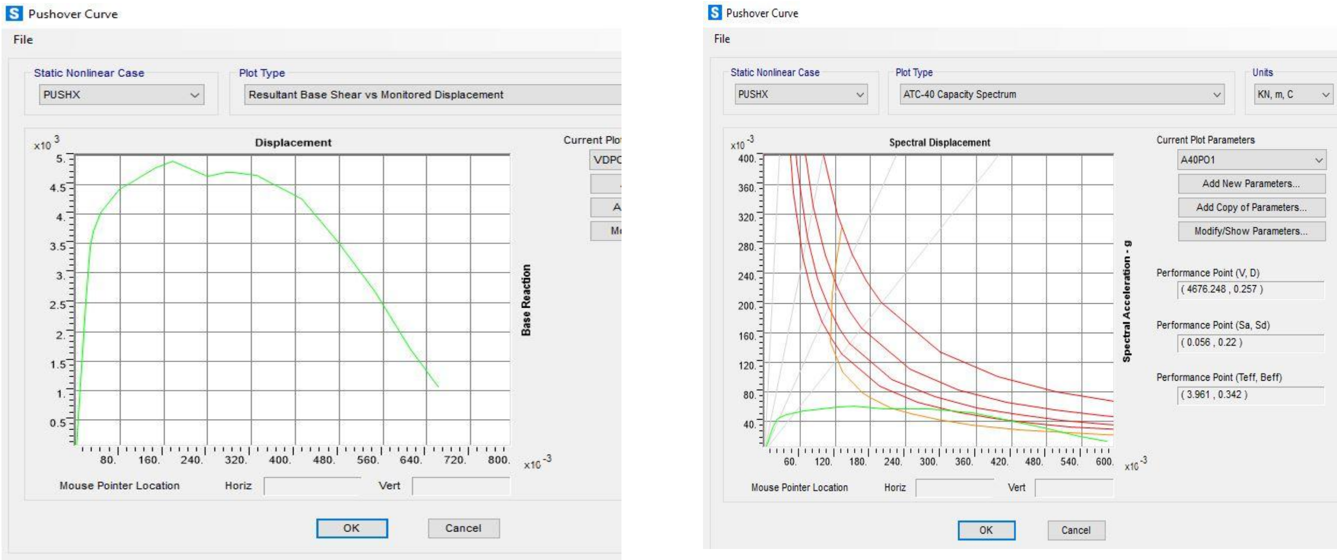
Fig; 7 Base shear vs Monitored displacement Performance point type a model in y direction type A model.



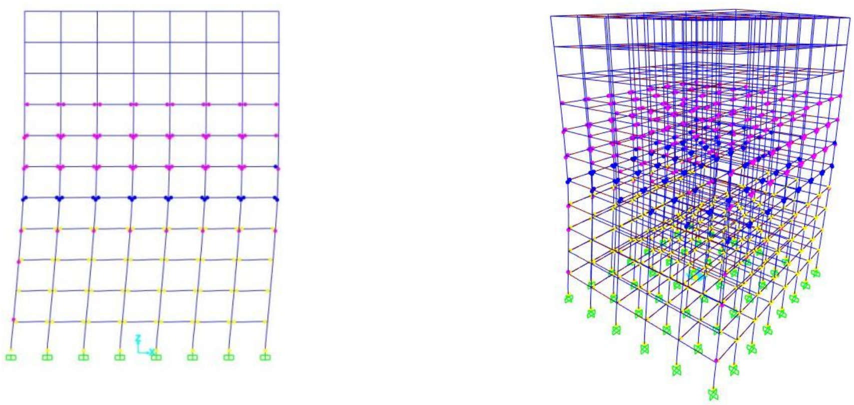
Fig; 8 Distribution of hinge in Y direction for Type A model

The Pushover analysis of a Building with long spans

The following figure shows the Pushover curve base shear vs lateral displacement. The unit for Base Reaction is KN and Displacement is meter. The maximum node displacement is equal to 0.720 m. The Pushover Curve shows that the building has objectively high Base Shear Capacity than the Design Base Shear. The Design base shear (VB) was found to be 4679 kN and the capacity is 5980 KN which is much higher, hence the building is safe for this level of earthquake.



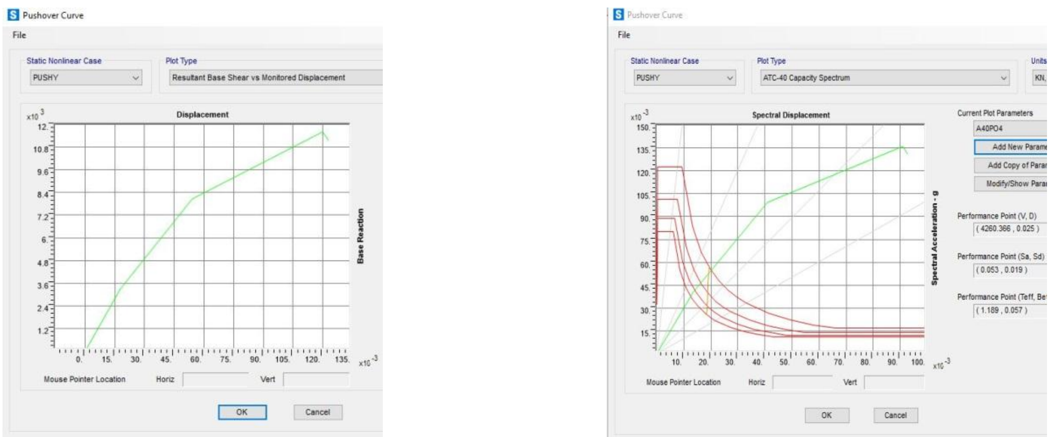
Fig; 9 Base shear vs Monitored displacement Performance point type A model in X direction type A model.



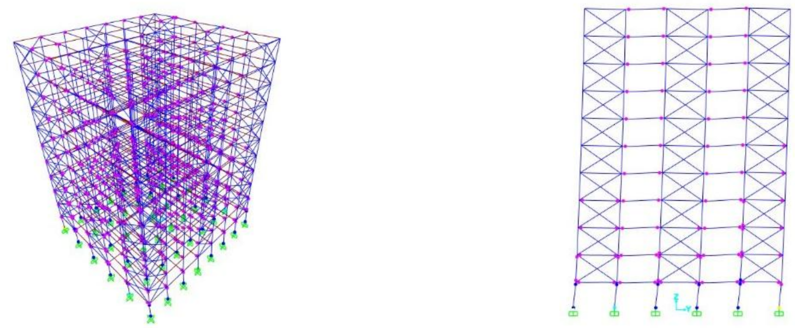
Fig;10 Distribution of hinges type A model in X direction

The Pushover Analysis for TYPE B short spans (TYPE B)

The following figure shows the Pushover curve base shear vs lateral displacement. The unit for Base Reaction is kN and Displacement is meter. The maximum node displacement is equal to 0.134 m. The Pushover Curve shows that the building has objectively high Base Shear Capacity than the Design Base Shear. The Design base shear (VB) was found to be 1242 in chapter 3 and the capacity is 2900kN which is much higher, hence the building is safe for this level of earthquake.



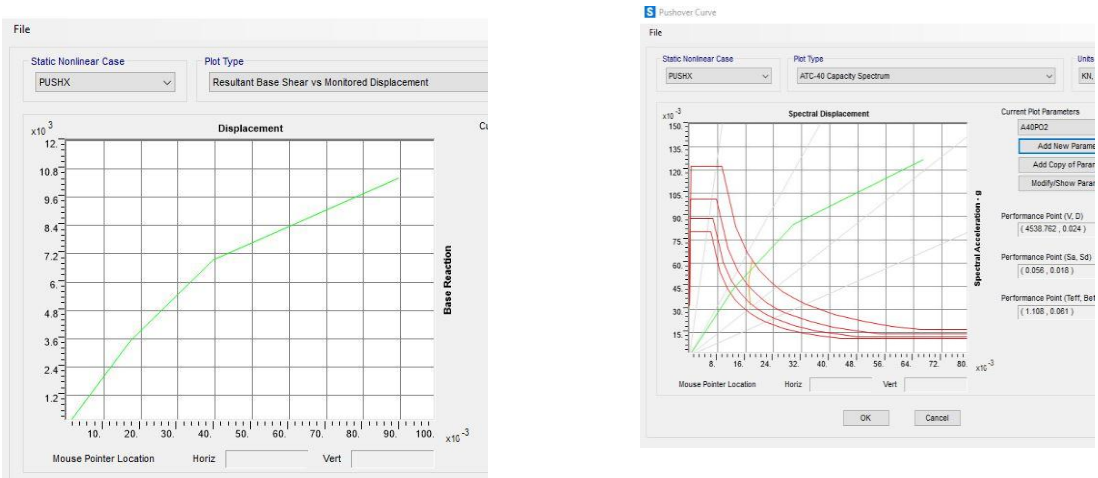
Fig;11 Base shear vs Monitored displacement Performance point type A model in y direction type B model



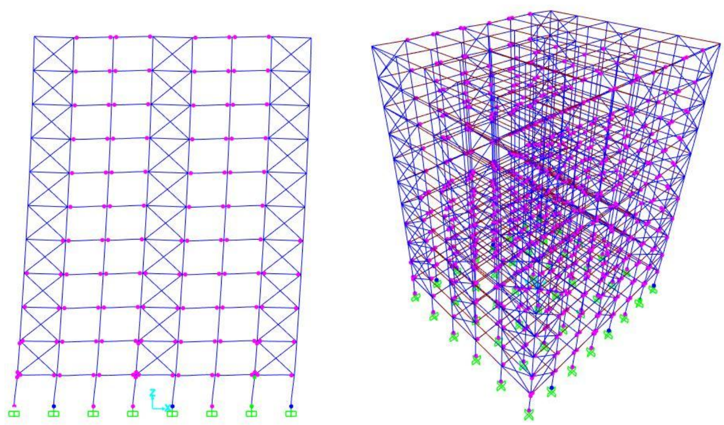
Fig;12 Distribution of hinges type B model in Y direction

The Pushover analysis of a Building with long spans

The following figure shows the Pushover curve base shear vs lateral displacement. The unit for Base Reaction is kN and Displacement is meter. The maximum node displacement is equal to 0.095 m. The Pushover Curve shows that the building has objectively high Base Shear Capacity than the Design Base Shear.



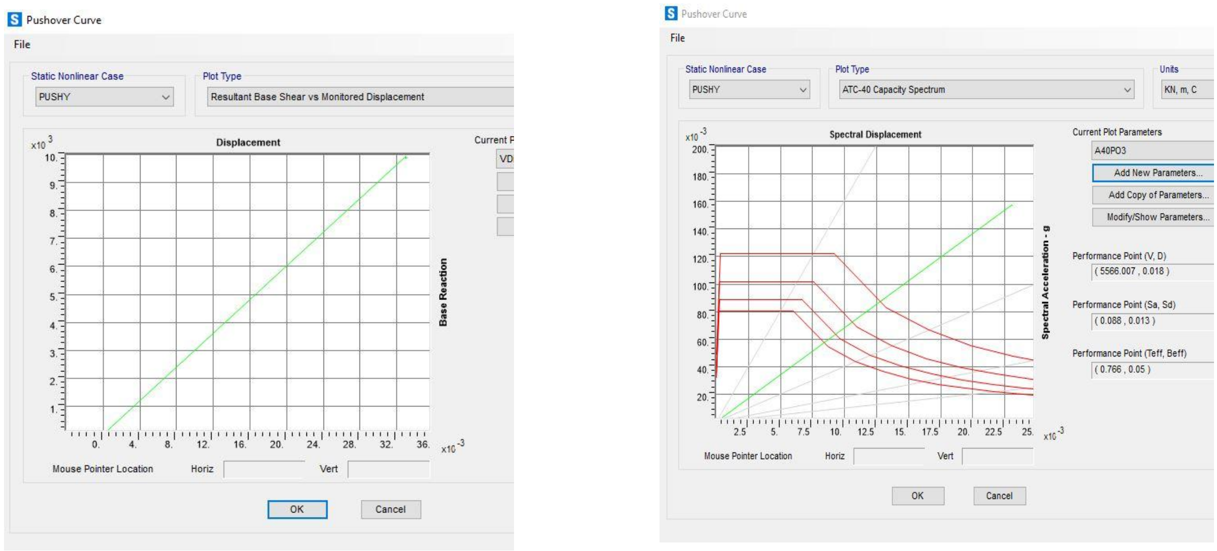
Fig;13 Base shear vs Monitored displacement Performance point type A model in X direction type B model



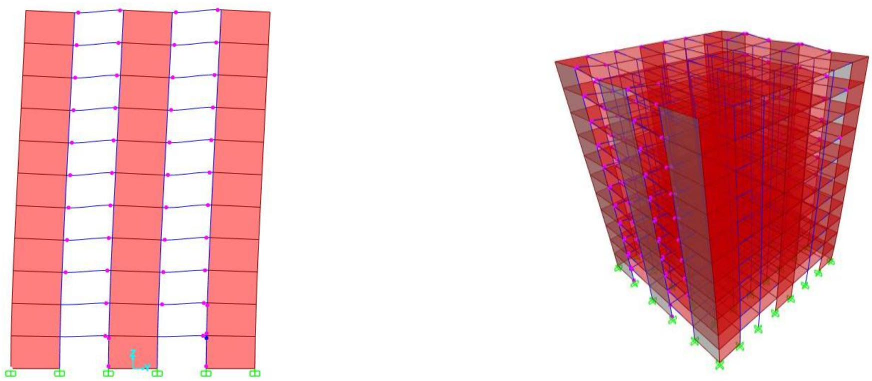
Fig;14 Distribution of hinges type B model in X direction

The Pushover Analysis for TYPE C short spans

The following figure shows the Pushover curve base shear vs lateral displacement. The unit for Base Reaction is kN and Displacement is meter. The maximum node displacement is equal to 0.036 m. The Pushover Curve shows that the building has objectively high Base Shear Capacity than the Design Base Shear. The Design base shear (VB) was found to be 1002 kN and the capacity is 2900kN which is much higher, hence the building is safe for this level of earthquake



Fig;15 Base shear vs Monitored displacement Performance point type A model in Y direction type C model



Fig;16 Distribution of hinges type C model in Y direction

6. CONCLUSIONS

After studying all the curves and tables we came to the following conclusion that the Pushover Analysis result shows that the Building was able to achieve the performance point within its elastic range.

Further we can conclude that:

1. Pushover analysis the simplest way to get the response of existing or new structures.

2. Considering three different RC building it was concluded if the buildings are designed with proper sections and reinforcement details as per standard codes will perform better under seismic forces.

3. The performance of the pushover analysis mostly depends on the material used in the structure

Linear analysis could not give useful information because if gravity load of structure combines with lateral load it has large displacement, large amount of moment and reduce the capacity of structure finally more damage has been come. From the analysis results it can be seen that the base shear at performance point in case of building frame with shear wall and bracing are increased compared to base shear in case of building frame without shear wall and Bracing. The OMRF, BMRF and SWMRF frame are found to be at a performance state of immediate occupancy as per the storey drift ratios given in ATC40. Hence strengthening strategies are adopted to increase the performance state of the WMRF and BMRF frames. Building with shear wall and bracing reduced the natural time period of building and increased the base shear. Strengthened or stiffened building the Performance point and capacity of building Predominate increased. OMRF the lateral load 14646.383KN by added bracing and shear wall to the building lateral load capacity 24765.078 KN, 26166.792 KN. spectral acceleration also promoted from 0.049 m/sec^2 to 0.056m/sec^2, 0.286 m/sec^2, lateral displacement at performance point decreased from 295 mm to 257 mm, 127 mm.

Global stiffness of building increased. As per time period compare it is brightly seen the deference of each frame OMRF, BMRF and WMRF. If the building or structure strengthened and stiffened time period has been decreasing by providing lateral resistance system as well increased base shear.

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BIOGRAPY

MOHD AMIR, Student of M.Tech-Structure and foundation (Al-Falah University).

Mr. MISBAH DANISH SABRI,

Asst. Professor (Al-Falah University)