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Dynamic assessment of high-rise building using bearings in ETABS by Response spectrum analysis

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Abstract

This study article provides an overview of the investigation of high-rise structure dynamic performance through the application of both linear and nonlinear dynamic methods. In the current work, two distinct dynamic analyses a time history analysis and a dynamic analysis with response spectrum are examined for the dynamic assessment of high-rise buildings. With regard to the most recent Indian seismic code, a comparative assessment of the outcomes from the two distinct dynamic analyses is crucial. This study aims to evaluate how well lead rubber isolators reduce vibrations in a 24-story reinforced concrete framed building. In the first case, which involves a rigid jointed framed RCC structure, the structure is analysed using ETABS software. In the second case, lead rubber bearing (LRB) isolators are introduced. An isolator's effectiveness can be observed by comparing the storey drift, lateral displacement, base shear, acceleration, and maximum bending moment of the isolated base structure to those of the fixed base structure.

Keywords: Dynamic assessment, Response spectrum analysis, Time history analysis, Lead rubber bearing

Introduction

Steel and concrete frames are used in the majority of high-rise structures. Columns (vertical load-bearing elements), and beams (horizontal load-bearing elements) make up their frames. Shear walls or transverse bracing can be used to give the structural frame more lateral stiffness so that it can withstand wind stress. In general, the foundations of tall buildings consist of underground concrete piles, piers, or caissons that withstand extremely high gravity loads. Nevertheless, the requirement that a high-rise structure be able to withstand lateral forces brought on by wind and possible earthquakes is the most crucial design consideration. Seismic and wind forces on a multi-story building increase as the building height increases. To find out how a structure will react to an earthquake and to design structures appropriately, seismic analysis is required. The seismic analysis of building can be performed through various methods, such as time history analysis, displacement analysis, response spectrum analysis, and static seismic approach. Building resting on it will experience movement at its base. Although a simple basic isolator is effective in protecting buildings from seismic movements, it cannot always dissipate the energy received during an earthquake. Base isolation is the term used for installing flexible bearings or pads, which consist of layers of rubber and lead, between a building's foundation and the structure above. LRBs provide the benefit of prolonging a building's natural period beyond the seismic period range, thereby reducing amplification caused by earthquakes. Consequently, the utilization of LRBs presents an optimal approach for decreasing seismic loads. Lead was chosen for its ductile properties - although it can be deformed by earthquake movement, it returns to its original shape and can be deformed many times without losing strength.

Objective

1. To study the dynamic assessment of high-rise building with fixed base & isolated base.
2. To analyse the building with dead load, live load, seismic load in ETABS.
3. To design the bearings by using the loads coming from ETABS analysis.
4. To compare both the results of linear & non-linear dynamic analysis.

Method of Analysis

As per IS: 1893 (part1) 2016 method of analysis of building for design earthquake.

(1)Equivalent static method

(2) Dynamic analysis method

Both the Response Spectrum Method (RSM) and Equivalent Static Method (ESM) seek to assess the seismic forces acting on a structure by applying a series of static forces at defined points. In the context of a design-basis earthquake (DBE), the forces calculated within the structural members and at the supports using either method closely approximate (though with a conservative estimate) the actual forces experienced by the structure. It should be noted that while the force distribution calculated using either of these methods represents a set of equivalent static forces, an earthquake is a dynamic force. RSM is based on the first few natural periods, whereas ESM is based on the structure's fundamental natural period of vibration. This is the difference between the two methods. The accuracy of seismic load estimation is expected to increase with the consideration of a greater number of natural periods. Response-spectrum analysis, time-history analysis, and the computation of vibration modes using Ritz or Eigen vectors are examples of dynamic analysis capabilities for both linear and nonlinear behaviour.

Method of Implementation

Table 1. Input parameters for modelling

Parameters of building	Description/Values
Type of Frame	Special moment resisting frame
No. of storey	G+24
Length of building in X	42.45 M
Length of building in Y	22.1 M
Height of building (m)	75M
Height of each storey	3 M
Support Type	Fixed Base, Isolated Base

Table 2. Loads & load combinations

Sr. No.	Load type	Value
1	Deal load (DL)	Self-weight of structure
2	Live load (LL)	2Kn/Sq.m.
3	Floor Finish (FF)	1.5Kn/Sq.m.
4	Load combinations	As per IS1893:2016
5	Location	Pune
6	Zone	III
7	Response Reduction Factor (1893:2016)	4
8	Importance Factor (1893:2016)	1.2
8	Basic Wind Speed (1893:2016)	39 m/sec.

Fig.1. Architectural Plan for modelling

Fig.2. General arrangement drawing

Fig.3. Model from ETABS: Plan

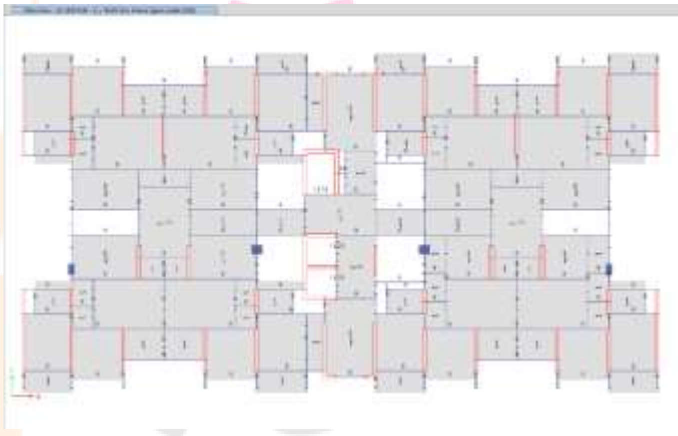


Fig.4. 3D Elevation with fixed base

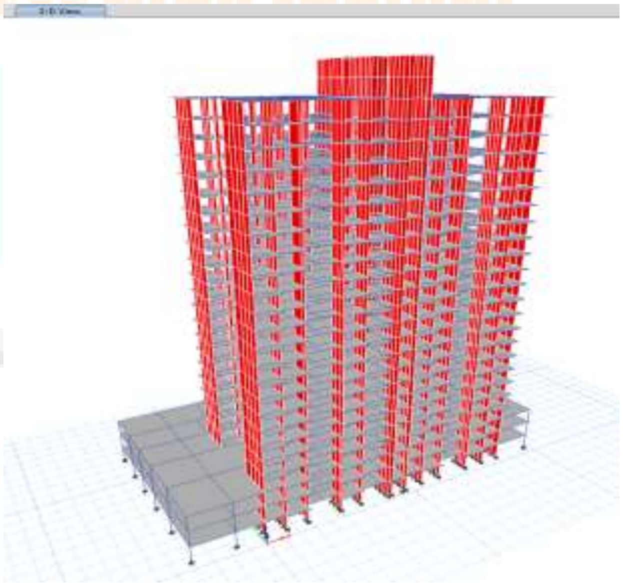
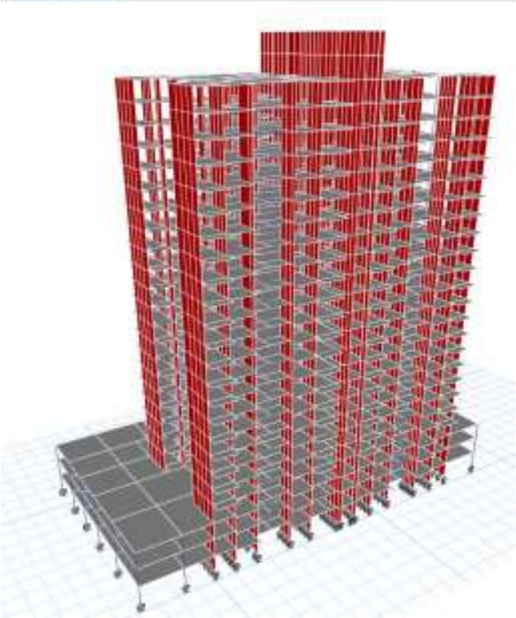


Fig.5. 3D Elevation with isolated base



Results

For Fixed Base:

Table 1. Results from ETABS: Deflection check

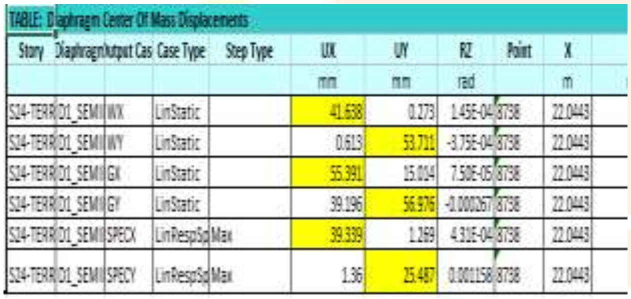


TABLE: Diaphragm Center Of Mass Displacements

Story	Diaphragm	Output Cas	Case Type	Step Type	UX	UY	RZ	Point	X
					mm	mm	rad		m
S24-TERR	D1_SEMI	WX	LinStatic		41.638	0.273	1.45E-04	8738	22.0443
S24-TERR	D1_SEMI	WY	LinStatic		0.613	53.711	-3.75E-04	8738	22.0443
S24-TERR	D1_SEMI	GX	LinStatic		55.391	15.014	7.50E-05	8738	22.0443
S24-TERR	D1_SEMI	GY	LinStatic		39.196	56.976	-0.000267	8738	22.0443
S24-TERR	D1_SEMI	SPECX	LinRespSp	Max	39.339	1.289	4.31E-04	8738	22.0443
S24-TERR	D1_SEMI	SPECY	LinRespSp	Max	1.36	25.487	0.001158	8738	22.0443

Table 2 Results from ETABS: Torsional Irregularity check

TABLE: Joint Displacements

Story	Label	nique Nam	Output Case	Case Type	Step Type	Ux	Uy	Uz	
S24-TERR	59	6251	SPECX	LinRespSpec	Max	37.446	9.095	0.917	Ma
S24-TERR	65	6257	SPECX	LinRespSpec	Max	43.134	9.095	0.46	Mi
S24-TERR	100	6289	SPECX	LinRespSpec	Max	43.145	9.434	0.463	Avg
S24-TERR	208	6379	SPECX	LinRespSpec	Max	37.445	9.425	0.902	Ma

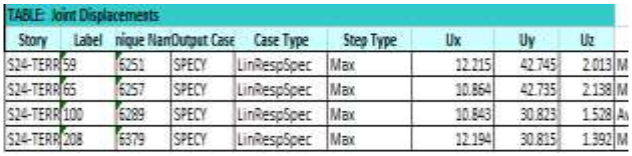


TABLE: Joint Displacements

Story	Label	nique Nam	Output Case	Case Type	Step Type	Ux	Uy	Uz	
S24-TERR	59	6251	SPECY	LinRespSpec	Max	12.215	42.745	2.013	M
S24-TERR	65	6257	SPECY	LinRespSpec	Max	10.864	42.735	2.138	M
S24-TERR	100	6289	SPECY	LinRespSpec	Max	10.843	30.823	1.528	Av
S24-TERR	208	6379	SPECY	LinRespSpec	Max	12.194	30.815	1.392	M

Table 3 Results from ETABS: Story Drift check

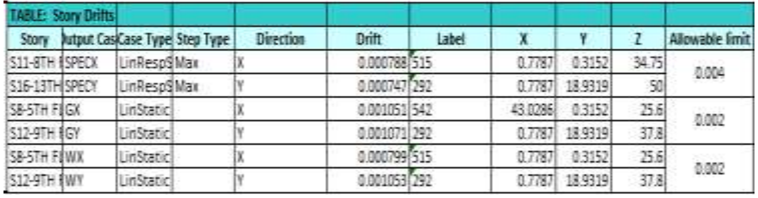


TABLE: Story Drifts

Story	Output Cas	Case Type	Step Type	Direction	Drift	Label	X	Y	Z	Allowable limit
S11-8TH	SPECX	LinRespS	Max	X	0.000788	515	0.7787	0.3152	34.75	0.004
S16-13TH	SPECY	LinRespS	Max	Y	0.000747	292	0.7787	18.9319	50	
S8-5TH F	GX	LinStatic		X	0.001051	542	43.0286	0.3152	25.6	0.002
S12-9TH	GY	LinStatic		Y	0.001071	292	0.7787	18.9319	37.8	
S8-5TH F	WX	LinStatic		X	0.000799	515	0.7787	0.3152	25.6	0.002
S12-9TH	WY	LinStatic		Y	0.001053	292	0.7787	18.9319	37.8	

For Isolated base:

Table 3. Results from ETABS: Deflection check

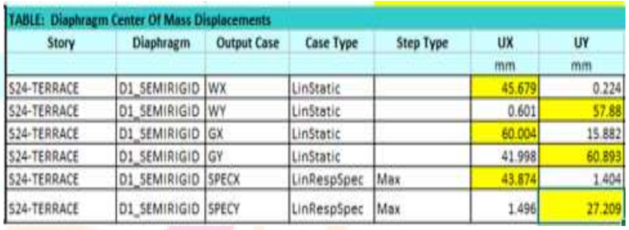


TABLE: Diaphragm Center Of Mass Displacements

Story	Diaphragm	Output Case	Case Type	Step Type	UX	UY
					mm	mm
S24-TERRACE	D1_SEMIRIGID	WX	LinStatic		45.679	0.224
S24-TERRACE	D1_SEMIRIGID	WY	LinStatic		0.601	57.88
S24-TERRACE	D1_SEMIRIGID	GX	LinStatic		60.004	15.882
S24-TERRACE	D1_SEMIRIGID	GY	LinStatic		41.998	60.893
S24-TERRACE	D1_SEMIRIGID	SPECX	LinRespSpec	Max	43.874	1.404
S24-TERRACE	D1_SEMIRIGID	SPECY	LinRespSpec	Max	1.496	27.209

Table 4 Results from ETABS: Torsional Irregularity check

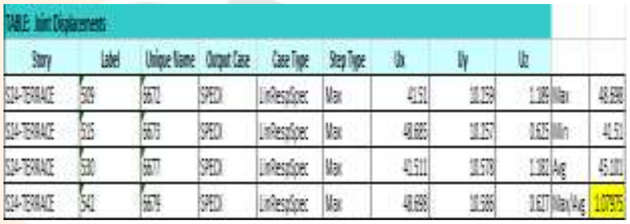


TABLE: Joint Displacements

Story	Label	Unique Name	Output Case	Case Type	Step Type	Ux	Uy	Uz		
S24-TERRACE	509	6672	SPECX	LinRespSpec	Max	41.51	18.259	1.186	Max	48.698
S24-TERRACE	515	6673	SPECX	LinRespSpec	Max	48.685	18.257	0.625	Min	41.51
S24-TERRACE	530	6677	SPECX	LinRespSpec	Max	41.511	18.578	1.182	Avg	45.104
S24-TERRACE	542	6679	SPECX	LinRespSpec	Max	48.698	18.566	0.627	Max/Avg	1.07975

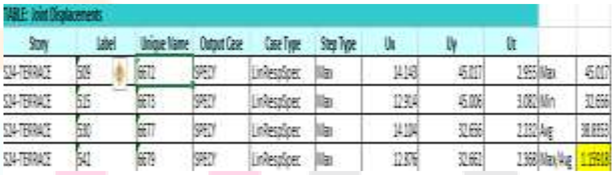


TABLE: Joint Displacements

Story	Label	Unique Name	Output Case	Case Type	Step Type	Ux	Uy	Uz		
S24-TERRACE	509	6672	SPECY	LinRespSpec	Max	14.149	45.017	2.955	Max	45.017
S24-TERRACE	515	6673	SPECY	LinRespSpec	Max	12.904	45.006	3.082	Min	32.656
S24-TERRACE	530	6677	SPECY	LinRespSpec	Max	14.104	32.656	2.132	Avg	38.8365
S24-TERRACE	542	6679	SPECY	LinRespSpec	Max	12.876	32.661	1.368	Max/Avg	1.15918

Table 5 Results from ETABS: Story Drift check

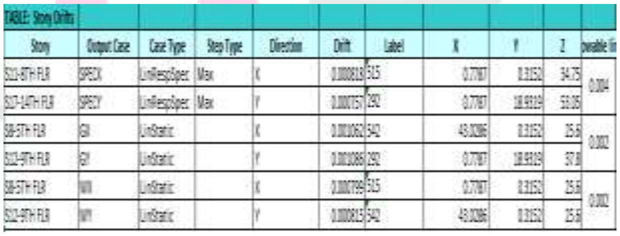


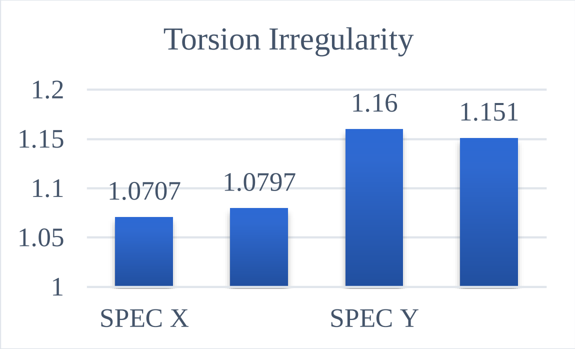
TABLE: Story Drifts

Story	Output Case	Case Type	Step Type	Direction	Drift	Label	X	Y	Z	owable li
S11-8TH FLR	SPECX	LinRespSpec	Max	X	0.000818	515	0.7787	0.3152	34.75	0.004
S17-14TH FLR	SPECY	LinRespSpec	Max	Y	0.000757	292	0.7787	18.9319	53.05	
S8-5TH FLR	GX	LinStatic		X	0.001062	542	43.0286	0.3152	25.6	0.002
S12-9TH FLR	GY	LinStatic		Y	0.001086	292	0.7787	18.9319	37.8	
S8-5TH FLR	WX	LinStatic		X	0.000799	515	0.7787	0.3152	25.6	0.002
S12-9TH FLR	WY	LinStatic		Y	0.000815	542	43.0286	0.3152	25.6	

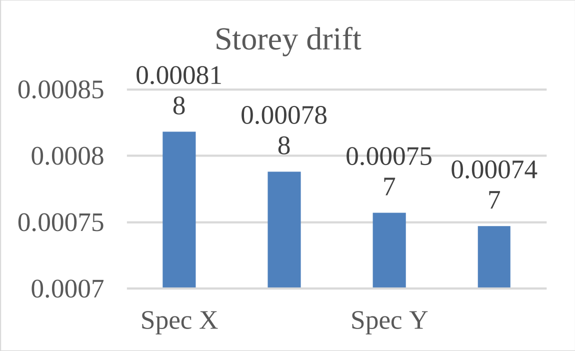
Comparative results between Models

1. Torsion irregularity for fixed base model in SpecX & SpecY is 1.0797 & 1.16 487 respectively & for isolated

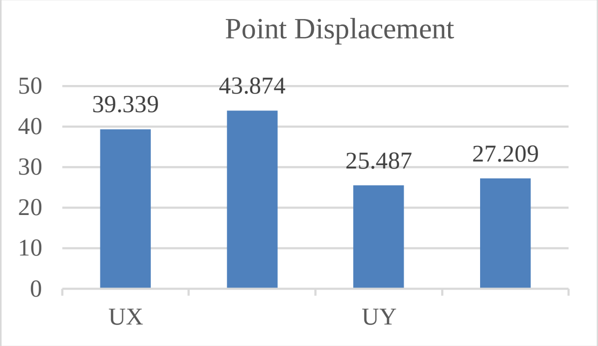
base model is 1.0707 & 1.515 respectively.



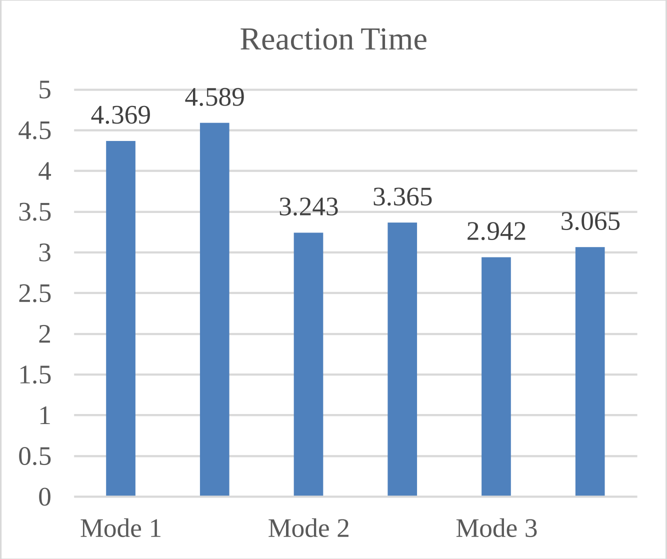
2. Storey drift value for fixed base model in SpecX & SpecY 0.000818 & 0.000757 respectively & for isolated base model is 0.000788 & 0.000747 respectively.



3. Point displacement for fixed base model in Ux &Uy direction is 39.33 & 25.487 respectively & for isolated base model is 43.874 & 27.209 respectively.



4. Reaction time for mode 1 is 4.369 & 4.589, for mode 2 3.243 & 3.365, for mode 3 2.942 & 3.065 respectively for fixed base & isolated base.



Conclusion

In conclusion, ETABS is the most widely used structural analysis and design software programs. Around the world, structural analysis and design commonly use this two distinct tool.

- The use of bearings in ETABS for seismic analysis of high-rise buildings is an important field of study that makes a substantial contribution to the continuous efforts to improve the seismic resilience of structures.

- Story shear reduced after the lead rubber bearing (LRB) is provided as base isolation system which reduces the seismic effect on building.
- Base shear is also reduced after providing LRB which makes structure stable during earthquake
- Story drift are reduced in higher stories which makes structure safe against earthquake.
- Point displacements are increased in every story after providing LRB which is important to make a structure flexible during earthquake.
- Mode periods are increased which increases reaction time of a structure during earthquake.
- Finally, it is concluded that after LRB is provided as base isolation system it increases the structures stability against earthquake and reduces reinforcement hence make structure economical.

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