EFFECT OF BASE ISOLATION ON DYNAMIC RESPOSE OF RC IRREGULAR STRUCTURES

Avinash Joshi - Assistant Professor (C), Department of Civil Engineering, JNTUH-University College of Engineering, Sulatanpur**,**
S. Arun Kumar - Assistant Professor (C), Department of Civil Engineering, JNTUH-University College of Engineering, Sulatanpur
M. Madhuri - Assistant Professor, Department of Civil Engineering, Methodist College of Engineering and Technology, Hyderabad.

Abstract: The influence of soil-structure interaction in the analysis and design of a building with base isolation of a 16-storey reinforced concrete frame building is investigated. The inclusion of the soil in the structural analysis provides displacement values, which are closer to the actual behavior of the structure than those provided by the analysis of a fixed-base structure. In seismic environment, the loads imposed on a foundation from a structure under seismic excitation can greatly exceed the static vertical loads as even produce uplift; in addition, there will be horizontal forces and possibly movement at foundation level. The soil and rock at site have specific characteristics that can significantly amplify the incoming earthquake motions travelling from the earthquake source

There is a reduction of seismic impact on the structure by base isolation. Six different model conditions are considered namely Fixed-base and Rubber base behavior are considered. The influence of the soil structure interaction in the dynamic behavior of the structure is reflected in an increase in the vibration period as well as increase in the drift of the superstructure which leads to less acceleration to the structures.

Keywords: fixed-base structure, Rubber base behavior, vibration period, drift, acceleration.

1. INTRODUCTION

Base isolation system is widely recognized as one of the most effective control strategies used for mitigating the structural response, which helps a structure survive a potentially devastating seismic impact through a proper initial design or subsequent modifications. In many cases, the application of the base isolation system has been considerably helpful in improving a structure's seismic performance and its sustainability. However, being a passive control system, it suffers from some limitations such as large base drifts and the inability to adapt to different earthquakes and vibrations. To reduce the base drift of base isolation system, different strategies have been previously considered including increasing the damping of the natural rubber and using supplemental passive dampers in conjunction with the base isolation system. More recently, in order to both mitigate the base drift and make the base isolation system adaptable to different earthquakes, using active and semiactive control schemes along with the base isolation system have been investigated. Active control systems directly apply the desired force for controlling the seismic response of structures, while in the semiactive control schemes, the characteristics of control system are adjusted to make the applied force track the desired control force. Hybrid active base isolation systems have been studied by a number of researchers and have shown effective performance in both mitigating the base drift and adapting to different conditions.

The principal of seismic base isolation is based on decoupling of structure by introducing low horizontal stiffness bearing between the structure and foundation. The isolation decreases the frequency of overall building-isolation system. This low frequency system does not permits transmission of high frequency of earthquake motion to structure. Consideration of earthquake ground motions, the way they propagate through the earth, their characteristics description at a certain location and methods for incorporating this information into engineering designs have been the subject of considerable research and interest so far. The energy released from a source mechanism will travel in the form of seismic waves through the rock formation where some energy absorption takes place. Some amount of energy is absorbed by isolators. Numerous studies on different earthquakes where site amplification caused substantial damage and collapse of many buildings are available. Observations made after the destructive earthquakes have shown a correlation between damage and local geology, for base isolated structures also. The natural complexity in behavior of in-situ soils has led to development of many idealized models of soil behavior based on classical theories of elasticity and plasticity for analysis of Soil-foundation interaction problem. In the present work, two different storey structures are modeled with and without base isolation for different soils. Both Response Spectrum and time history method are use for earthquake response.

2. OBJECTIVES

A. To study the literature available regarding soil-structure interaction (SSI), base isolation and understanding the effects of both on structural performance.

B. To study the performance of 16 storey base-isolated structure and comparing with the fixed base.

C. To compare the performance of 5 different cases of rubber base systems by considering the vertical irregularity in the structure.

3. PROBLEM STATEMENT

A G+15 model without using base isolator and with using base isolator is studied for soil structure interaction.

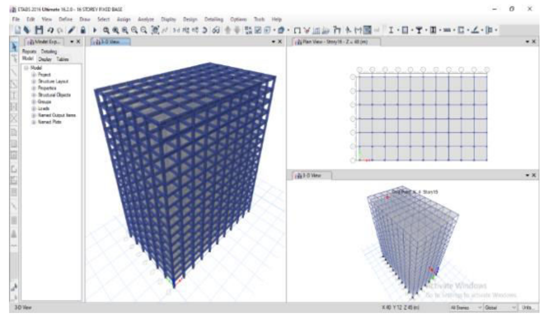


Fig.1 Fixed Base regular building

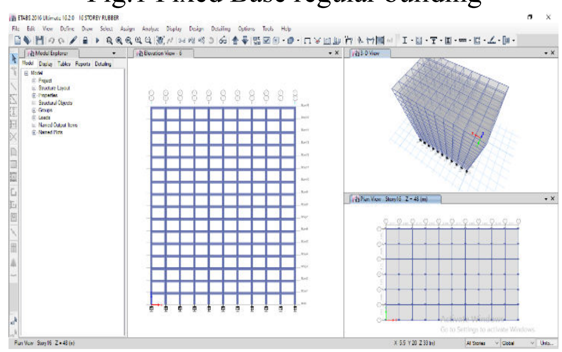


Fig.2 Rubber Base regular building

The below table shows the data required for G+16 structure, also data assumed for the same structure.

Table 1 Data assumed for the analysis

Properties	**(G+15) Storey**
Height of Structure	48 m
Slab thickness	125mm
Column size	400mm x 600mm
Beam size	300mm x 500mm
Material	M30 concrete and Fe500 steel

Dead Load	(a) Self weight of structure (Density = 25KN/m^2.) (b)Weight of infill (Density = 20KN/m^2.) (c) Floor Finish =1KN/m^2
Live Load	3 KN/m^2
Earthquake data	IS 1893-2002. Zone: II Response Reduction factor: 5 Importance factor: 1 Damping Ratio: 0.05
Stiffness of base Rubber Yield Ratio	1630 KN/m 0.1
Software for analysis	ETABS 2016

Base isolated structures resting on soil are significantly shown below figures. It can be further concluded from these figures that the displacement at the base isolation level being more results in reduction in the building deformation. In base isolated buildings with soft soil model, the deformation is less.

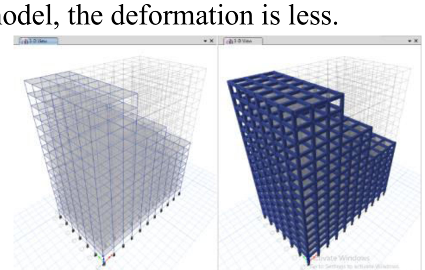


Fig.3 Configuration C1- Rubber Base System with Decreasing the Floor Heights Along X-Direction.

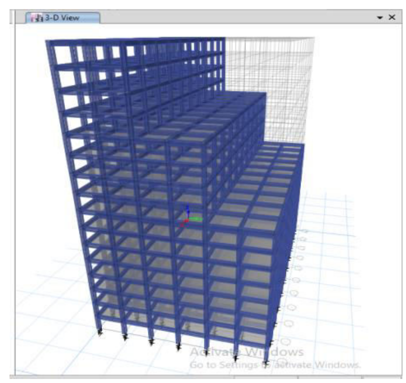


Fig.4 Configuration C2-Rubber Base System with Decreasing the Floor Heights Along Y-Direction

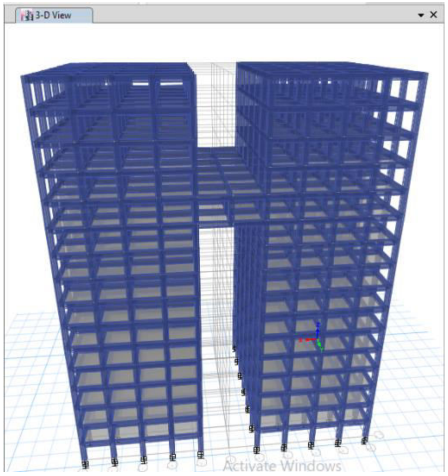


Fig.5 Configuration C3- Rubber Base System with tower shape.

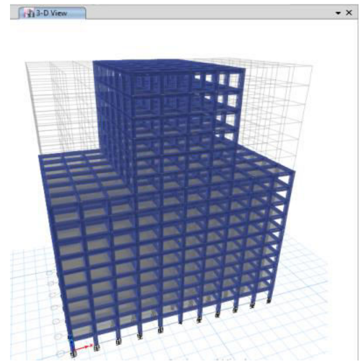


Fig.6 Configuration C4- Rubber Base System with Decreasing the length Along X-Direction. (Inverted T)

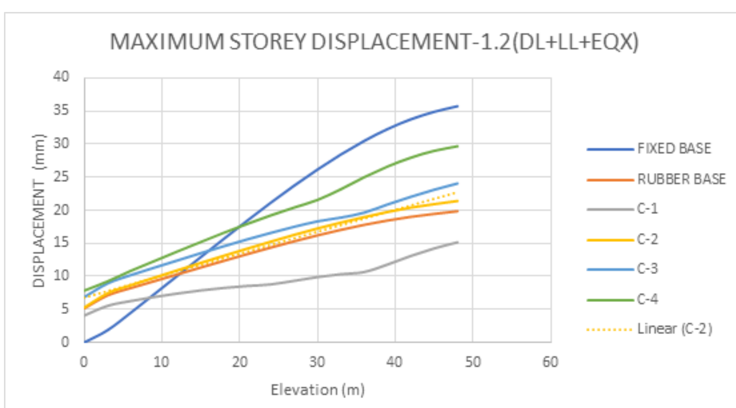
5. RESULTS

Analytical investigations have been carried out to study the behavior of base isolated structure founded on different types of soil considering the soil structure interaction. Based on this work following comparisons are done.

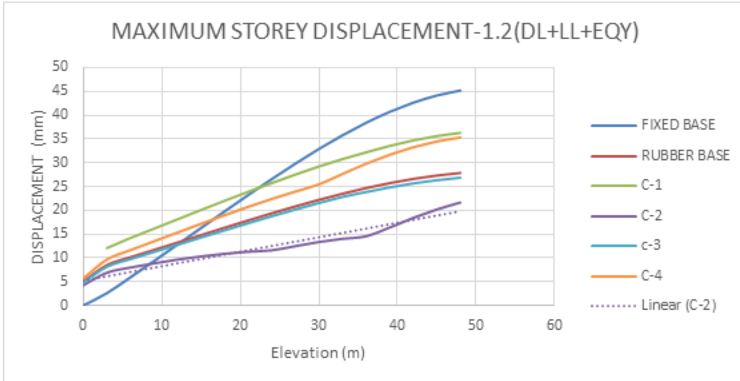
5.1 MAXIMUM STORY DISPLACEMENTS

Table 2 : Maximum Story Displacement

MAXIMUM STOREY DISPLACEMENT (mm) AT TOP STOREY OF 16 FLOOR BUILDING						
	FIXED BASE	RUBBER BASE	C1	C2	C3	C4
X-DIRECTION	35.756	19.856	15.148	21.408	24.068	29.697
Y-DIRECTION	45.208	27.86	36.284	21.651	26.864	35.332



Graph 1: Maximum Story Displacement along X-direction



Graph 2: Maximum Story Displacement along Y-direction

The maximum story displacement at the top of the building with fixed base is 35.756 mm along the X-direction and 42.208 mm along Y-direction. The maximum story displacement at the top of the building with rubber base is 19.856 mm along the X-direction and 27.860 mm along Y-direction.

Replacing the fixed base with rubber base the maximum story displacement at the top of the building is decreased by 15.9 mm along the X-direction and 17.348 mm along Y-direction. Overall, the displacements are reduced by 44.47% along X-direction and 38.37% along Y-direction by introducing the rubber base system.

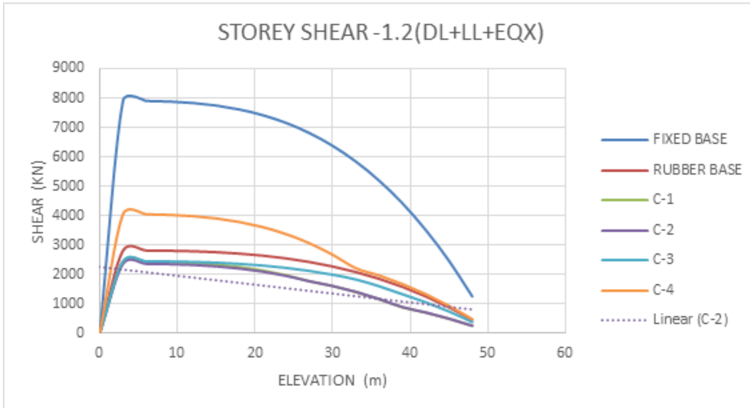
The story displacement at the base is zero along x and y directions with the fixed base, but in case of rubber base there is a displacement of 5.166 mm along x-direction and 5.077mm along y direction.For another 4 different configurations with having vertical irregularity in structures the displacements along X direction are 15.148mm, 21.408mm, 24.068mm and 29.697 mm.For another 4 different configurations with having vertical irregularity in structures the displacements along Y direction are 36.284mm, 21.651mm, 26.864mm and 35.332 mm.

For C-1 building the displacement along X-direction is minimum and along Y-direction the displacement is maximum among four rubbers case buildings. For the reaming buildings the displacement more along X-direction. **For C-2 building along Y-direction the displacement is minimum of 21.651mm among four buildings and along X-direction 21.408 mm.** For C-3 and C-4 buildings the displacements are higher than C-2 building. Out of 4 configurations C-2 has minimum values of displacements compared with other configurations.

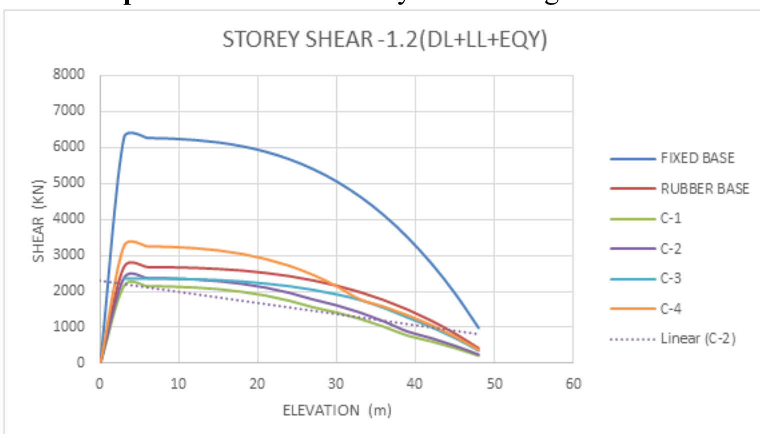
5.2 STORY SHEAR

Table 3 : Story Shear at Bottom story

STOREY SHEAR AT BOTTOM STOREY (KN)						
	FIXED BASE	RUBBER BASE	C-1	C-2	C-3	C-4
X-DIRECTION	7906.3052	2806.9823	2429.1474	2355.4335	2439.8637	4044.5976
Y-DIRECTION	6273.1707	2682.5303	2153.5112	2377.7952	2364.1035	3259.3747



Graph 3 : Variation **of** Story Shear along X-direction



Graph 4 : Variation **of** Story Shear along Y-direction

The total story shear at the bottom of the building for a fixed base is 7906.3052 KN along the X-direction and 6273.1707 KN along the Y-direction.The total story shear at the bottom of the building for a rubber base is 2806.9823 KN along the X-direction and 2682.5303 KN along the Y-direction.**Replacing the fixed base with rubber base the story shear at the bottom of the building is decreased by 64.5% along the X-direction and 57.24% along Y-direction.**

The least story shear observed of 2153.5112 KN along Y-direction for the building C-2.The maximum story shear in case of rubber base buildings observed of 4044.5976 KN along X-direction for the building C-4 which is less than the value of fixed base along the same direction by 48.84%. **So, It can conclude that the base shear is reduces by 50% when the rubber base systems are used.**

5.3 TIME PERIOD

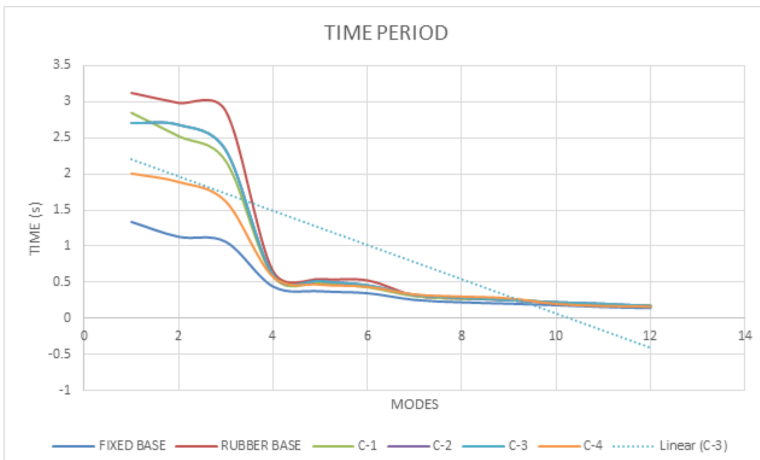
The time period for the fixed base buildings for single mode is 1.336 sec has increased to 3.124sec when we replaced fixed base with rubber base.For the all the buildings with rubber base system the time period is more than the fixed base system.C-3 building time period is high compared with other configurations C-1, C-2 and C-4.

The time period for the rubber base buildings has increased compared with the fixed base building.

Table 4 : Modal Time period

Case	**Mode**	FIXED BASE	RUBBER BASE	C-1	C-2	C-3	C-4
		Period	**Period**	**Period**	**Period**	**Period**	**Period**
		sec	**sec**	**sec**	**sec**	**sec**	**sec**

Modal	1	1.336	3.124	2.849	2.707	3.038	2.007
Modal	2	1.13	2.985	2.525	2.682	2.944	1.89
Modal	3	1.06	2.871	2.178	2.329	2.869	1.618
Modal	4	0.441	0.654	0.585	0.605	0.688	0.578
Modal	5	0.375	0.544	0.488	0.517	0.676	0.467
Modal	6	0.349	0.526	0.431	0.459	0.63	0.437
Modal	7	0.256	0.316	0.309	0.326	0.609	0.331
Modal	8	0.222	0.274	0.271	0.285	0.561	0.302
Modal	9	0.203	0.254	0.264	0.251	0.544	0.278
Modal	10	0.182	0.21	0.22	0.223	0.309	0.2
Modal	11	0.157	0.182	0.186	0.202	0.304	0.171
Modal	12	0.143	0.167	0.181	0.171	0.293	0.163

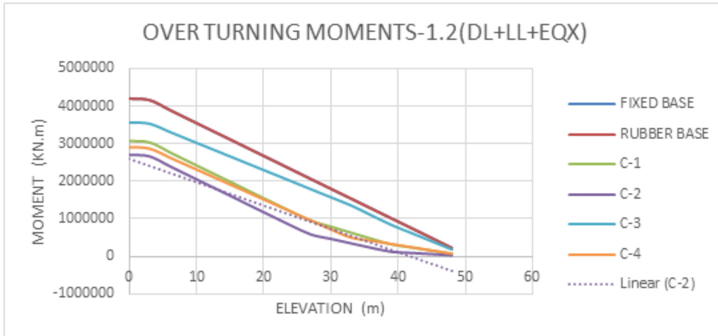


Graph 5 : Variation **of** time period

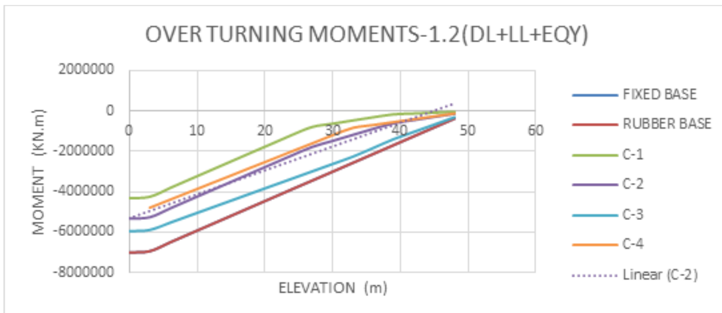
5.4 OVERTURNING MOMENTS

Table 5 : Over Turning Moments

OVER TURNING MOMENTS	1.2(DL+LL+EQX)		1.2(DL+LL+EQY)	
	X-Dir	**Y-Dir**	**X-Dir**	**Y-Dir**
	KN.m	KN.m	KN.m	KN.m
FIXED BASE	4201664.95	-7294604	4433213.193	-7002775
RUBBER BASE	4201664.95	-7106383	4300679.5	-7002775
C-1	3074733.769	-4388208	3145264.285	-4308650
C-2	2702743.102	-5399128	2781735.315	-5320879
C-3	3567664.555	-6035947	3654714.07	-5946108
C-4	2907764.748	-4981226	3016516.336	-4846275



Graph 6 : Variation **of** Over Turning Moments along X-direction



Graph 7 : Variation **of** Over Turning Moments along Y-direction

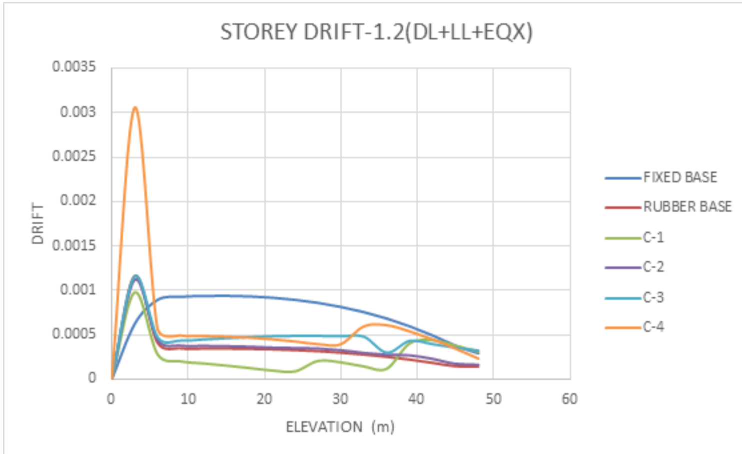
The maximum over turning moment 7294604 KN.m along the Y-direction has occurred when we have **Fixed base** system at the base of the building for 1.2(DL+LL+EQX) loading case.The minimum over turning moment 2702743.102 KN.m along the X-direction has occurred for C-2 building at the base of the building for 1.2(DL+LL+EQX) loading case.

Overall C-2 building has low overturning moments along X-direction and C-1 building has low values along Y-direction.

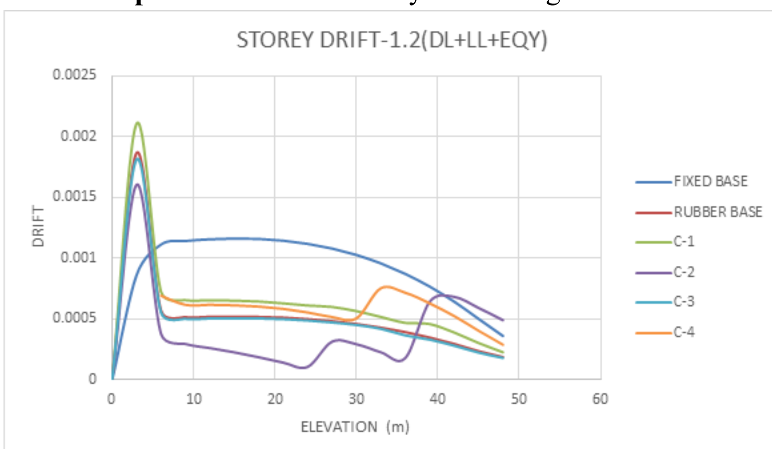
5.5 MAXIMUM STORY DIRFT

Table 6 : Maximum Story Drift

MAXIMUM STOREY DRIFT					
		X-DIRECTION	STOREY LAVEL	Y-DIRECTION	STOREY LAVEL
16 FLOOR BUILDING	FIXED BASE	0.000939	Story5	0.001163	Story5
	RUIBBER BASE	0.001162	Between 2nd Story and base	0.001869	Between 2nd Story and base
	C-1	0.000978		0.00211	
	C-2	0.001119		0.001606	
	C-3	0.001157		0.001816	
	C-4	0.003057		0.003197	



Graph 8 : Variation **of** Story Drift along X-direction



Graph 9 : Variation **of** Story Drift along Y-direction

The maximum story drift is observed at **5th Story** for the building with fixed base is 0.000939 along the X-direction and 0.001163 along Y-direction.The maximum story drift is The maximum story drift is observed at **between 2nd Story and base** for the four buildings C-1,C-2,C-3 and C-4 with rubber base are 0.000978, 0.001119, 0.001157 and 0.003057 along the X-direction The maximum story drift is observed at **between 2nd Story and base** for the four buildings C-1,C-2, C-3 and C-4 with rubber base are 0.00211, 0.001606, 0.001816 and 0.003197 along the Y-direction

The maximum story drift observed for C-4 building at 2nd story along X-direction and Y-direction of 0.003057 and 0.003197 respectively. observed **between 2nd Story and base** for the building with rubber base is 0.001162 along the X-direction and 0.001869 along Y-direction

6. CONCLUSIONS

1. Replacing the fixed base with rubber base the maximum story displacement at the top of the building is decreased by 15.9 mm along the X-direction and 17.348 mm along Y-direction. Overall, the displacements are reduced by **44.47%** along X-direction and **38.37%** along Y-direction by introducing the rubber base system.
2. The base shear is reduces by 50% when the rubber base systems are used.
3.The time period for the rubber base buildings has increased compared with the fixed base building.

4.Overall C-2 building has low overturning moments along X-direction and C-1 building has low values along Y-direction.

5.The maximum story drift observed for C-4 building at 2^{nd} story along X-direction and Y-direction of **0.003057** and **0.003197** respectively.

7. REFERENCES

1. H. Yoshioka; J. C. Ramallo; and B. F. Spencer Jr, **—**"***Smart Base Isolation Strategies Employing Magneto rheological Dampers***", ASCE, vol-9399-2002, pp128:5-540.
2. Jeevan A. Kulkarni and R.S. Jangid – "***Effects of superstructure flexibility on the response of base-isolated structures " -*** Shock and Vibration 10 (2003) 1–13. IOS Press
3. Francisco Lopez-Almansa , 1 Carlos M. Piscal , 2 Julian Carrillo , 3 Stefan L. Leiva-Maldonado , 2 and Yina F. M. Moscoso 4 – "***Survey on Major Worldwide Regulations on Seismic Base Isolation of Buildings***" Hindawi Advances in Civil Engineering Volume 2022, Article ID 616269.
4. Eduardo Kausel, "***Early history of soil–structure interaction***", -Journal of Soil Dynamics and Earthquake Engineering 30(2010), pp.822-833
5. J. Yang, J.B. Li, G. Lin, "***A simple approach to integration of acceleration data for dynamic"-*** Journal of Soil Dynamics and Earthquake Engineering 26 (2006), pp. 725–734
6. H. Matinmanesh and M. Saleh Asheghabad, "**Seismic Analysis on Soil-Structure Interaction of Buildings over Sandy Soil**"-Journal of The Twelfth East Asia-Pacific Conference on Structural Engineering and Construction, pp.-1737-1740.
7. Chopra, A.K. Dynamics of Structures, **Theory and Applications to Earthquake Engineering**, 4th ed.; Pearson Education Limited: Upper Saddle River, NJ, USA, 2013.
8. American Society of Civil Engineers (ASCE). FEMA-356 Prestandard and Commentary for the Seismic Rehabilitation of Buildings; Federal Emergency Management Agency: Washington, DC, USA, 2000.
9. Constantinou, M.C.; Kneifati, M.C. **Dynamics of Soil-Base-Isolated-Structure Systems**. J. Struct. Eng. 1988, 114, 211–221.
10. Bycroft, G.N. **Soil-structure interaction at higher frequency factors**. Earthq. Eng. Struct. Dyn. 1977, 5, 235–248.
11. Novak, M.; Henderson, P. **Base-isolated buildings with soil-structure interaction.** Earthq. Eng. Struct. Dyn. 1989, 18, 751–765.
12. Pappin, J.W.; Lubkowski, Z.A.; King, R.A. **The Significance of Site Response Effects on Performance Based Design**. In Proceedings of the 12th World Conference on Earthquake Engineering, Auckland, New Zealand, 30 January–4 February 2000.
13. Mylonakis, G.; Gazetas, G. **Seismic Soil-Structure Interaction: Beneficial or Detrimental?** J. Earthq. Eng. 2000, 4, 277–301.
14. Tongaonkar, N.; Jangid, R. **Seismic response of isolated bridges with soil–structure interaction.** Soil Dyn. Earthq. Eng. 2003, 23, 287–302.
15. Deb, S. **Seismic base isolation—An overview**. Curr. Sci. 2004, 87, 1426–1430. Available online: http://www.jstor.org/stable/2410 9483 (accessed on 5 July 2019).
16. Tsai, C.S.; Chen, C.-S.; Chen, B.-J. **Effects of unbounded media on seismic responses of FPS-isolated structures.** Struct. Control Health Monit. 2004, 11, 1–20.