SEISMIC BASE ISOLATION IN STRENGTHENING FRAME STRUCTURE OF MIDDLE SCHOOL TEACHING BUILDING IN ZHUONI-CHINA

Qasem Riyadh Ghaleb Abdulwahab[1], Sun Jianqin[2], Qi Jie[3]

[1]*MSc. Structural Engineering Student, Lanzhou Jiaotong University, Lanzhou, China*
[2]*Professors, Lanzhou Jiaotong University, Lanzhou, China*
[3]*MSc. Structural Engineering Student, Lanzhou Jiaotong University, Lanzhou, China*

Abstract

Seismic isolation is a technique that has been used around the world to protect building structures, nonstructural components and content from the damaging effects of earthquake ground shaking. In this paper， frame structure concrete of middle school teaching building, the project from Zhuoni County Middle School Center of the Gannan city is located in the southeast part of Gansu province in China. The frame structure used PKPM software in the design and Sap2000 was used to remodel the structure, analyze and then applied the seismic base isolation. This teaching building has been strengthened to be fortified against ultimate bearing capacity failure as it is an existing structure. The lead rubber bearing, Isolators, LRB400, NRB400 and LRB500, the modal and time history analysis of isolated structure and non isolated structure were carried out, and the analysis results of two structures were being compared. The results show that the natural vibration period of the structure can be effectively prolonged and the shear forces and displacement between layers can be reduced effectively after the structural isolation bearings are arranged. Analysis and comparison of the isolated structure and non isolated structure of their shear forces, acceleration and displacement seismic, found that isolation structure can significantly reduce the shear forces and acceleration and increased displacement. Structure's of Seismic response improves the structure seismic fortification level, which proves that the shock absorption effect is good.

Keywords: *Frame structure; Isolation structure; Lead rubber bearing; and Time history analysis.*

---***---

1. INTRODUCTION

The school is to bear the national future students with life and the live safety of the students maintain national security issues in the future. Middle school buildings crowded with flow volume, frequent activities, teaching and living facilities affiliated are relatively concentrated, and the average age of the students is low, weak sense of the self-protection and self rescue ability, once the earthquake, the possibility and harmfulness of secondary disasters than other types of construction much caused by earthquake disaster and pressure [1]. In recent years after the 2008 Wen Chuan earthquake, domestic scholars on the basis of continuous research have developed new methods and other seismic measures including the isolation technology geared at improving the seismic capacity of structures. This isolation technology which is widely recognized by Chinese scholars can greatly reduce the seismic response of the upper structure, so as to reduce the structural damage. In the current structure seismic technology, isolation technology is the theoretical system of the most perfect, the most practical application and has been successfully tested through structural seismic control technology [2]. Base isolation concept was coined by engineers and scientists as early as in the 1923 and thereafter different methods of isolating the buildings and structures from earthquake forces have been developed world over. Countries like US, New Zealand, Japan, China and European countries have adopted these techniques as their normal routine for many public buildings and residential buildings as well[3]. Japan's first isolated building was built in 1921 at the Tokyo Royalist Hotel, the foundations of the building had hard concrete of 2-4 meters thick, a soft soil layer thickness of 18-21m, at that time the design method of this kind has aroused great concern and discussion [4]. In 2004, Lu Xilin made a performance of the experiment and Research on the combined isolation system, analysis of the impact of ground motion on the upper structure and isolation system; his experiments show that the unidirectional and bidirectional earthquake action has little effect when considering the vertical earthquake effect is remarkable [5]. In china, the most commonly used isolation systems are the seismic base isolation elastomeric isolator: lead rubber bearings (LRB); Natural rubber bearings (NRB); and high rubber bearings (HRB); and the sliding isolator: resilient friction system; and friction pendulum system. With the base isolators, the entire structure is divided into three parts, namely; the superstructure, the base isolation layer and the foundation. It is impossible to completely separate the superstructure from the substructure as in most buildings, for they were constructed in-situ and as a monolithic structure, especially with respect to their connection joints [8].

2. MODEL DEVELOPMENT

2.1 The Mode of Structure

This project from Zhuoni County Middle School Center of the Gannan city is located in the southeast part of Gansu province. The middle school is a 34.60m X 10m building and of height 14.7m, first storey, second storey is a 3.60m, third storey 3.90m and four storey 3.30m as shown in figures 1 and 2.There have been many occurrences of small earthquakes according to the Lanzhou seismic station records of the Nin County and Zhuoni County, earthquake magnitudes of 5.2 and 5.0 were recorded in 2003 and 2004 respectively. In the early 1987 however, earthquake magnitudes of 5.9 and 5.1 were recorded in the Gansu province[6]. Seismic fortification and building type: according to the code for 《seismic design of buildings in Gansu province of China》 DB62/T25-3055-2011. The seismic precautionary intensity for Gannan city is a level 7 and that for Zhuoni County is a level 8. The basic earthquake acceleration of the land is 0.20g; maximum design acceleration of 0.16g was used for the structure. The earthquake design is a group 3 type with design seismic building category 2 or C class and the land category II. The site classification is a group 2 type and the characteristic is 0.45s. The structural damping ratio is 1: 20 (5%), the influence coefficient of the most frequently encountered earthquake is 0.08, and the maximum impact coefficient of the rare earthquake is 0.50.

2.2 The Mode Design

Chinese PKPM software was used for the structural design while SAP200 was used for the structure analysis.

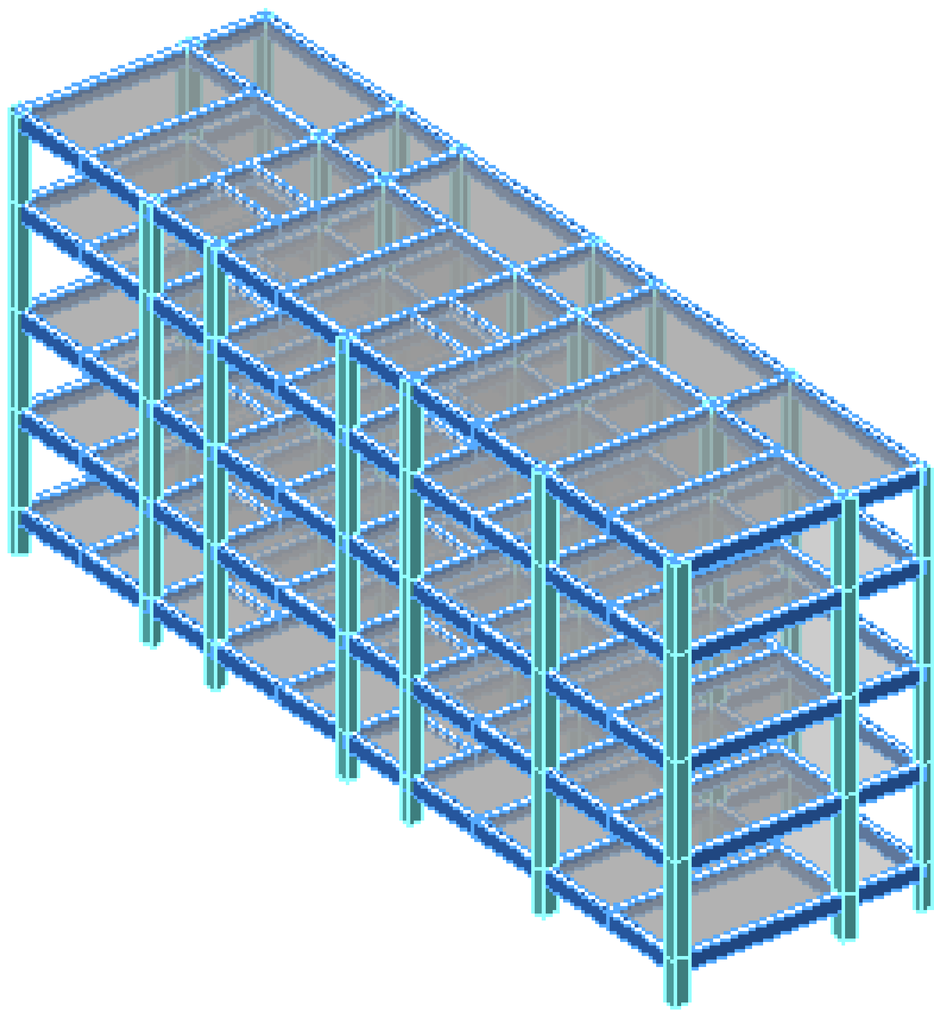

Fig 1: PKPM Structural Model

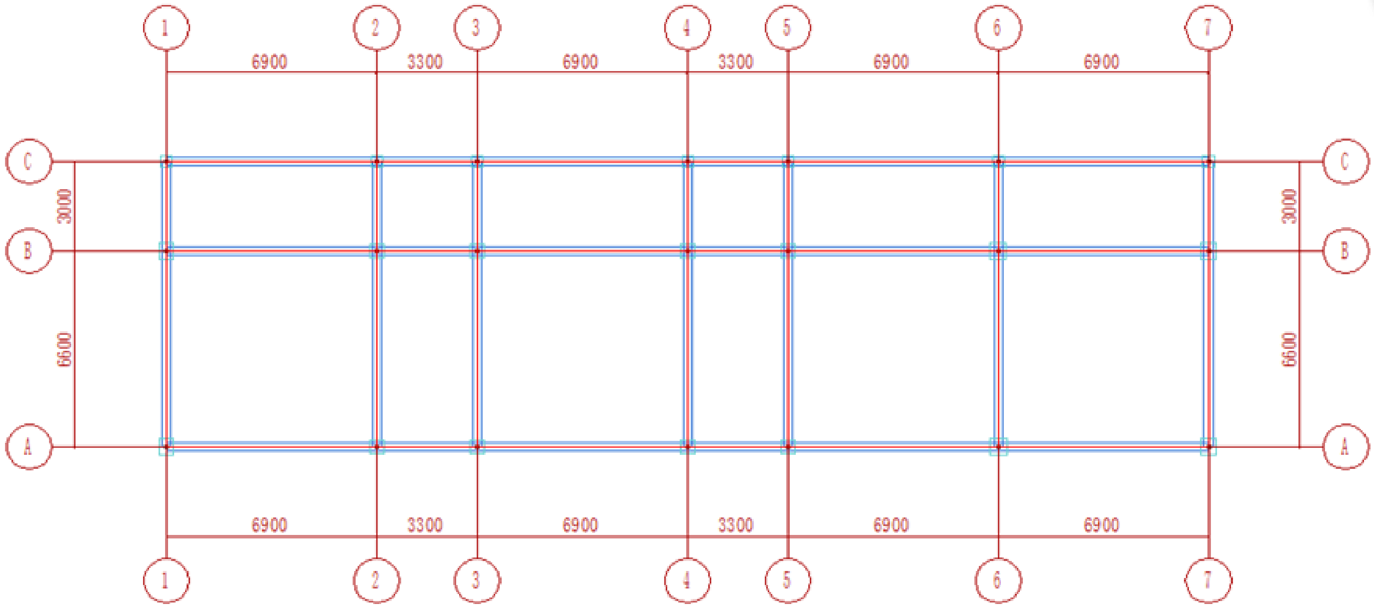

Fig 2: Structural Plan

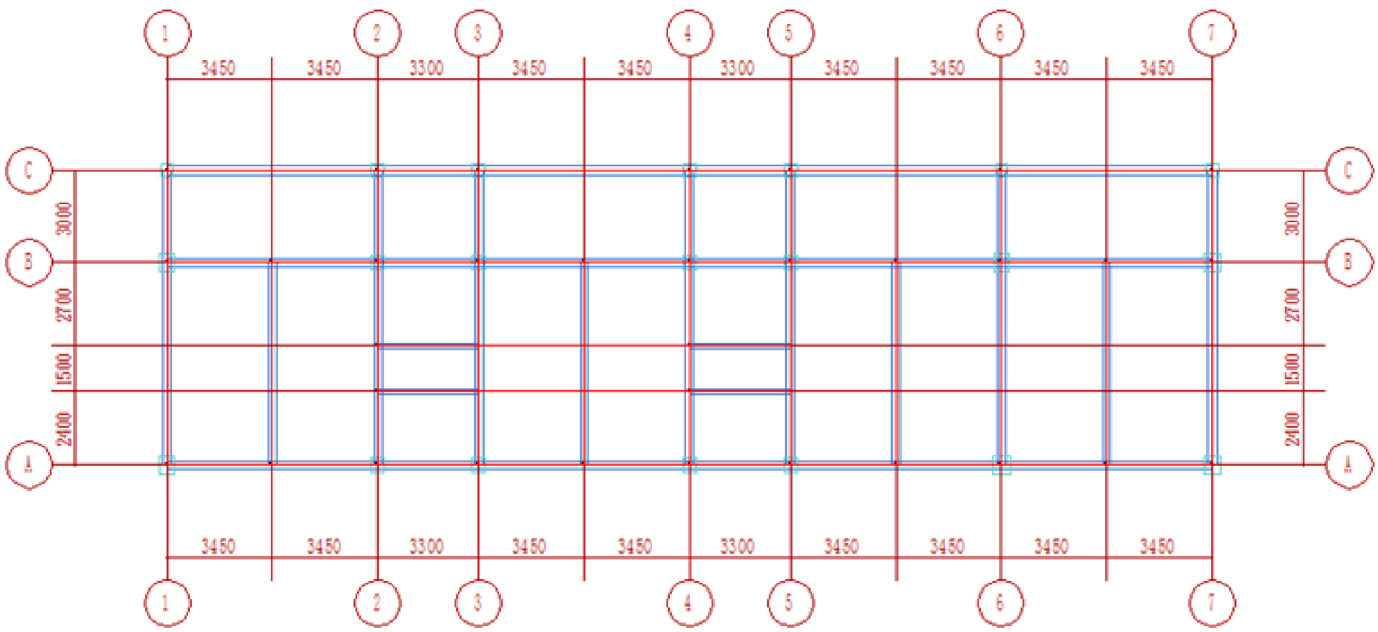

Fig 3: 1st Floor to 4th Floor Plan

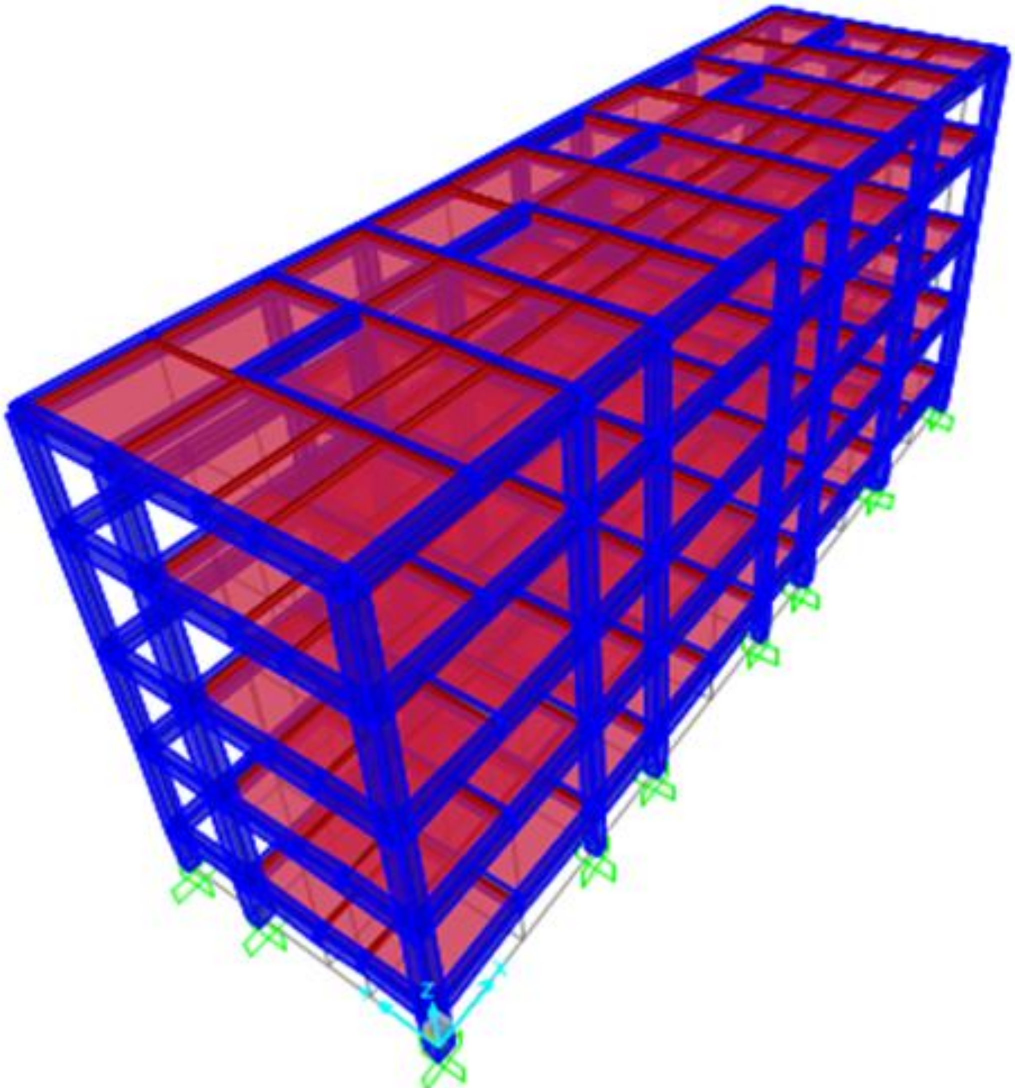

Fig 4: SAP2000 Structural Model

The table 1below shows the difference between PKPM Non-isolated Periods and SAP2000 with very small value differences indicating a considerable model consistency

Table 1: Non-isolated Periods Compared

Mode	Non-isolated Periods		D-value
	PKPM/s	SAP2000/s	
1	0.6345	0.6345	0
2	0.6153	0.591	0.0243
3	0.5551	0.541	0.0141

2.3 Selection of Ground Motion

According to the seismic building design code GB 50011-2010, the time history analysis method according to the construction site and design, earthquake ground motion records and artificial acceleration packet selection, including the number of actual earthquake records should not be less than 2/3 of the total earthquake influence coefficient. The average curve of seismic effect coefficient curve of multi time should be adopted by spectrum analysis when the modal decomposition response is consistent in the statistical sense. The elastic time history analysis, structure calculation process of each of the base shear force should not be less than the modal response spectrum calculation results of 65%, also the average value of all time history analysis should not be less than the modal response calculation results of 80% [7].

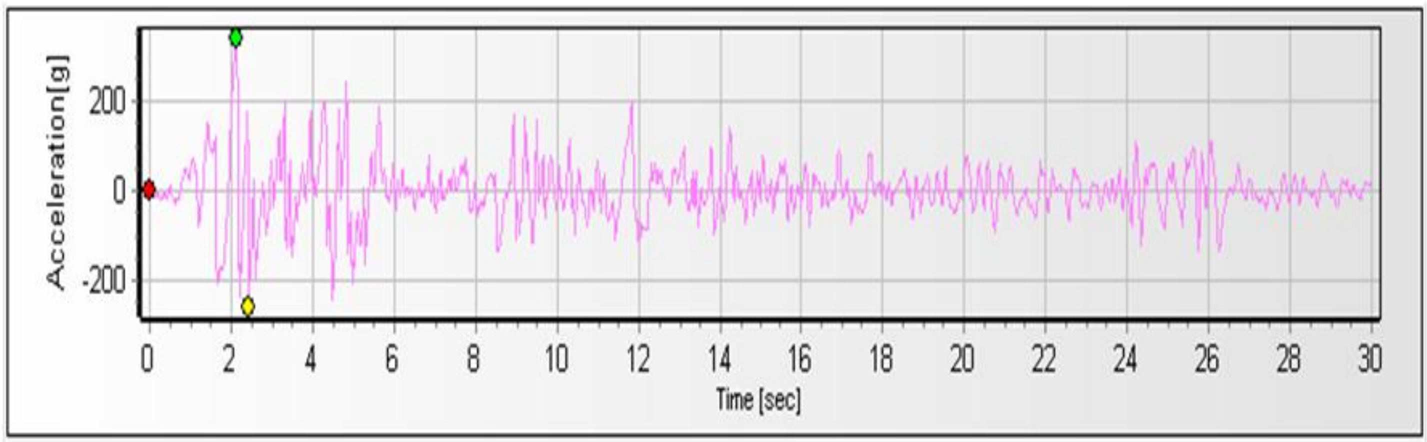

Fig 5: Elcentro Ground Motion

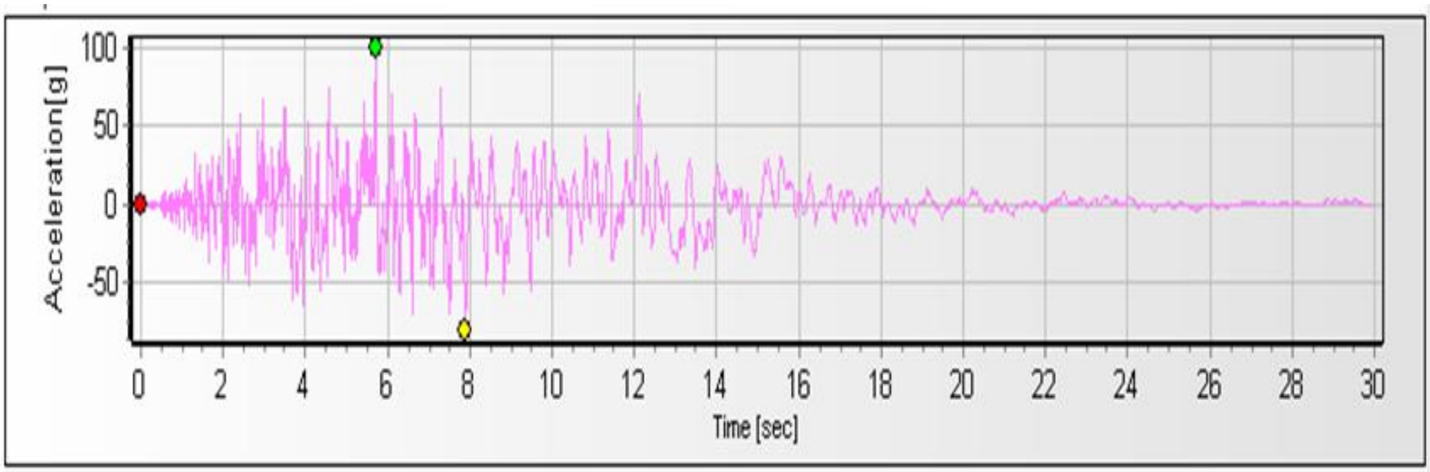

Fig 6: AWR Ground Motion

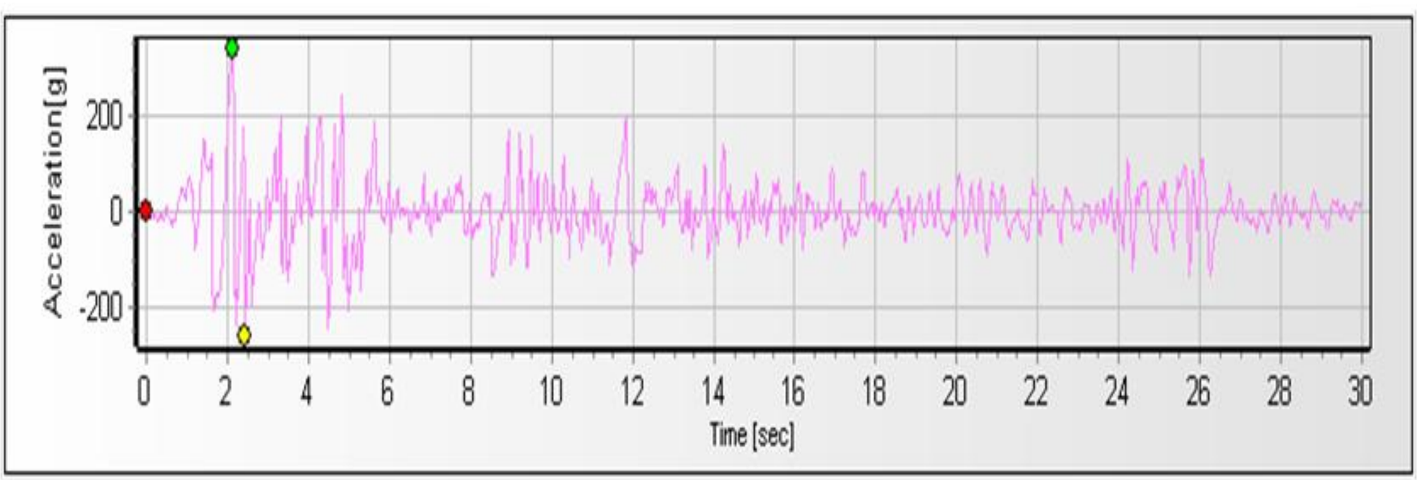

Fig 7: BC Ground Motion

The response spectrum for Zhuoni County is thus constructed with the stipulated provisions from the building seismic parameters with the maximum peak ground acceleration being 0.16g for a level 8 at 0.2g earthquake site.

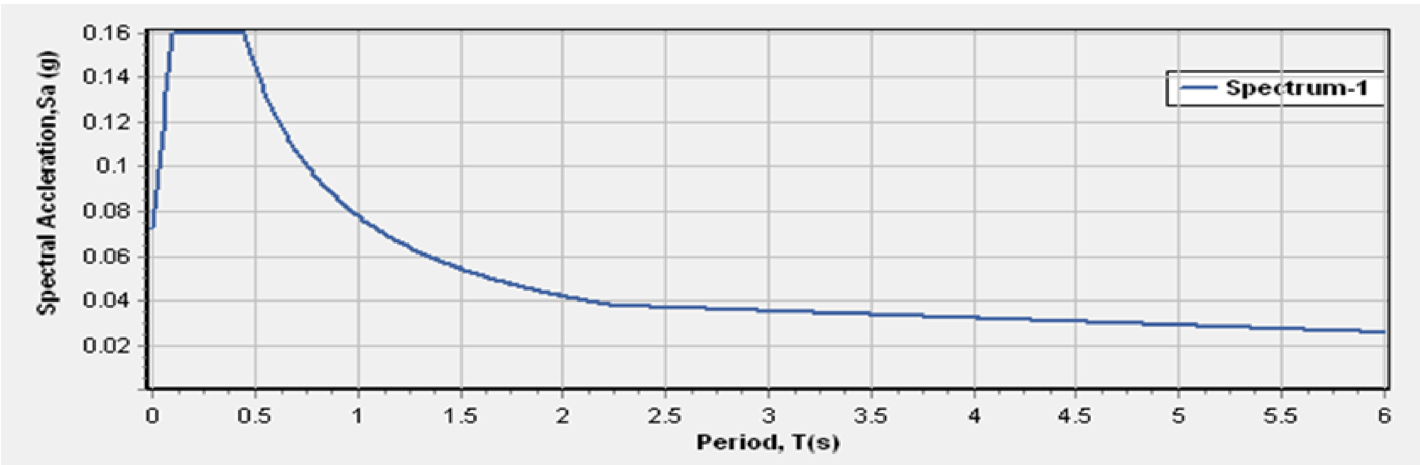

Fig 8: Zhuoni County Response Spectrum

2.4 Selection and Arrangement of Isolation Device

In order to achieve the purpose of isolation, it is necessary to set up isolation device at the support to extend the natural vibration period of the structure and reduce the earthquake effect. According to the axial force of the bottom support of the structure under self weight and load, the isolation bearing is selected, and the isolation layer is set on the top surface of the foundation, before the isolation support is arranged.

In this paper all base isolation of model are 10 of LRB400, 6 of LRB500 and 5 of LNR400. The isolator properties and arrangement plan are as shown in table: 2 and the Fig: 9 respectively.

Table 2: Selected Isolators and Their Properties

Model Number	Effective Diameter	Rubber Total Thickness	Pre Yield Stiffness	Equivalent Stiffness		Vertical Stiffness	yield strength
				Horizontal Deformation,100%	Horizontal Deformation,250%		
	(mm)	(mm)	KN/m	KN/m	KN/m	KN/mm	KN
LRB500	500	92	10910	1270	1010	2400	40
LRB400	400	73	8790	1040	820	2200	20
NRB400	400	73	-	660		1600	-

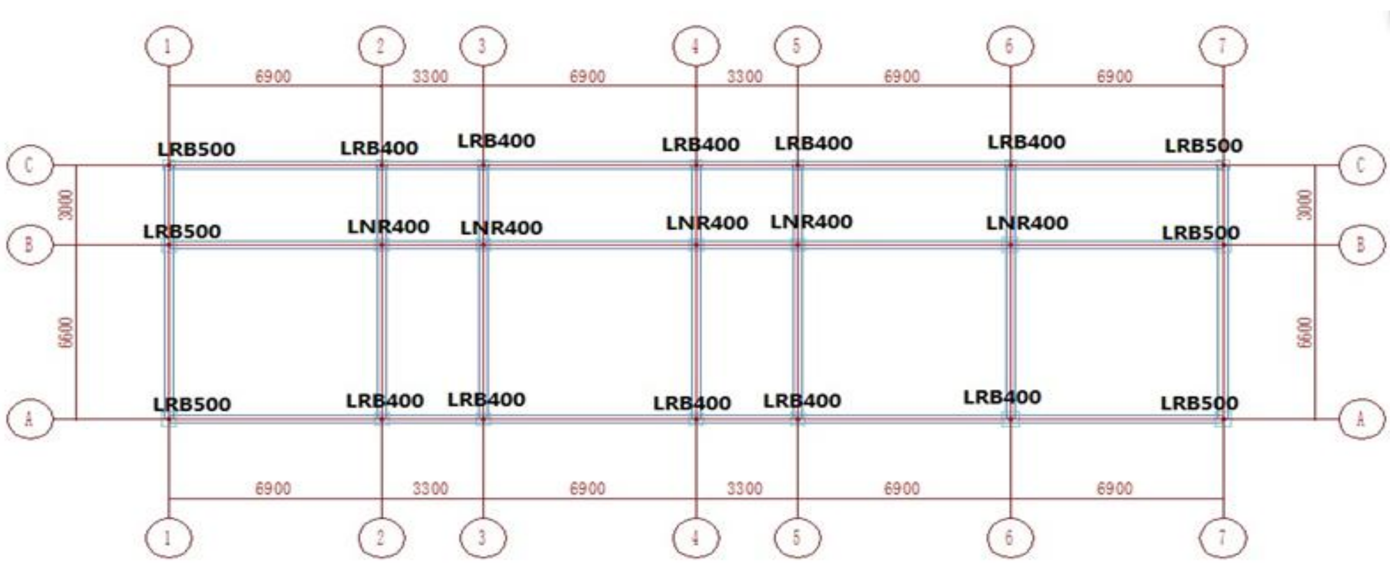

Fig 9: Isolation Device Arrangment Plan

3. RESULTS AND DISCUSION

The frame structural concrete of middle school building is analyzed by time history using three ground motions [Elcentro, AWR (ArtWav-RH2TG040, Tg 0.40) and BC (BajiaCalifonia_No_585, Tg 0.21)] and comparison with response spectrum analysis as well. The non isolated maximum floor accelerations is as shown in Fig 10, maximum velocities as shown in Fig 11, maximum displacements as shown in Fig: 12 and maximum shear forces as shown in Fig: 13 respectively.

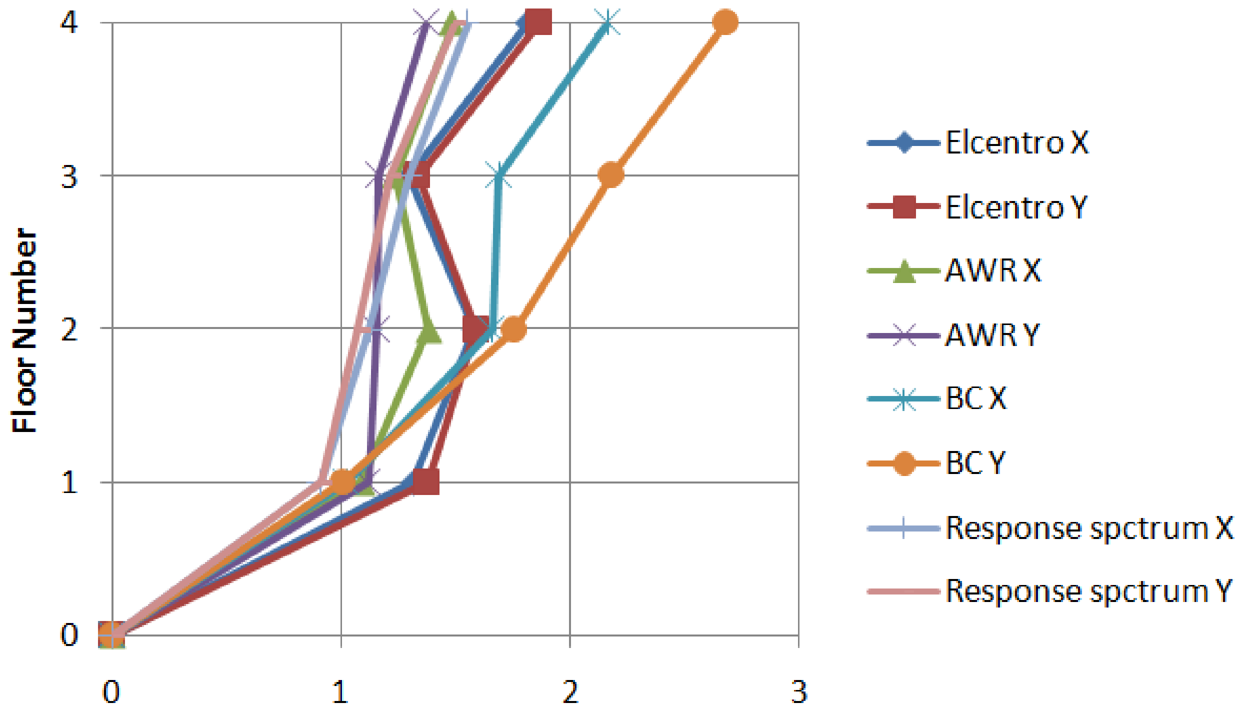

Fig 10: Non-isolated Maximum Floor Accelerations

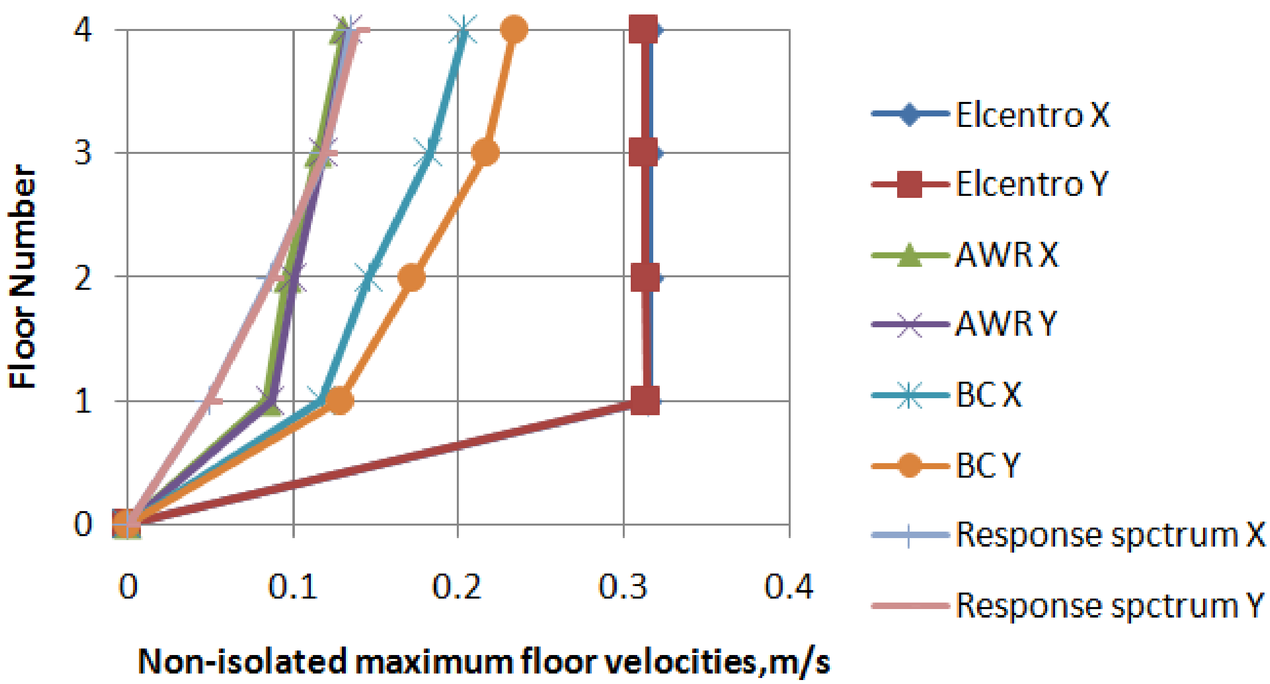

Fig 11: Non-isolated Maximum Floor Velocities

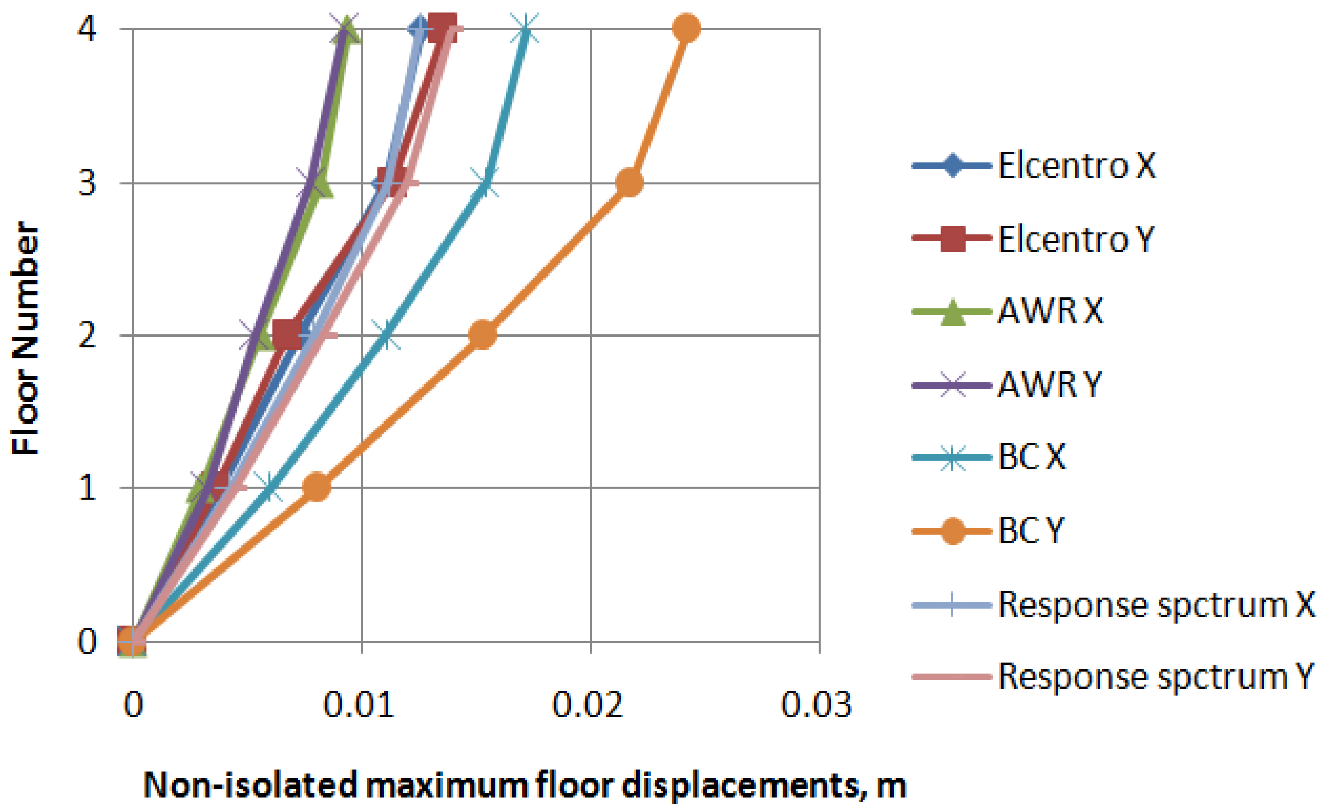

Fig 12: Non-isolated Maximum Floor Displacements

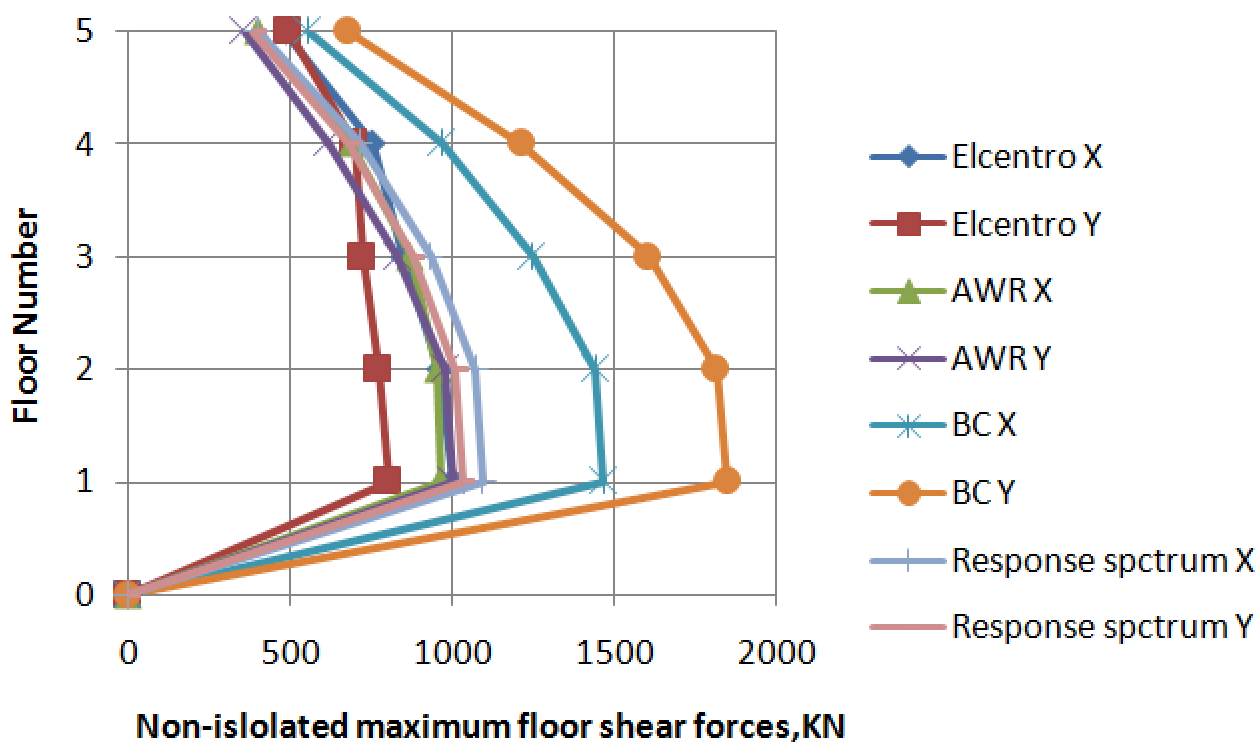

Fig 13: Non-isolated Maximum Floor Shear Forces

According to the Chinese seismic building design code GB50011-2010, each all time history of the ratio of base shear forces should be more than the response spectrum method result of 65%.The calculated result of time history average shear force is greater than the response spectrum method results of 114%.

Table 3: Base Shear Forces Time History-Response Spectrum Ratios

Wave type	X		Y	
	Base forces	Time history /RS	Base forces	TH/RS
RS	1094.464	-	1031.217	-
Elcentro	1001.567	91.51%	801.396	77.71%
AWR	963.247	88.01%	980.203	95.05%
BC	1467.034	134.04%	1848.425	179.25%
Average	1143.95	104.52%	1210.008	117.34%

In the isolated model as shown in Fig 14, the model structure used Sap2000 software in its analysis. All base isolation of the model are 10 of LRB400, 6 of LRB500 and 5 of LNR400. The model structure of the non-isolation bearing and the structure of the isolation bearing were analyzed, and got a two order model, two and three order vibration cycle as shown in Table 4. Data from table 4 shows, in the arrangement of bearings, the structure vibration cycle was prolonged by successfully avoiding the predominant period, to avoid the occurrence of resonance, so as to effectively reduce the structural seismic response.

Table 4: Non-isolated Periods and Isolated Periods

Mode	Non-isolated Periods	Isolated Periods
1	0.6345	1.7925
2	0.591	1.7287
3	0.591	1.491

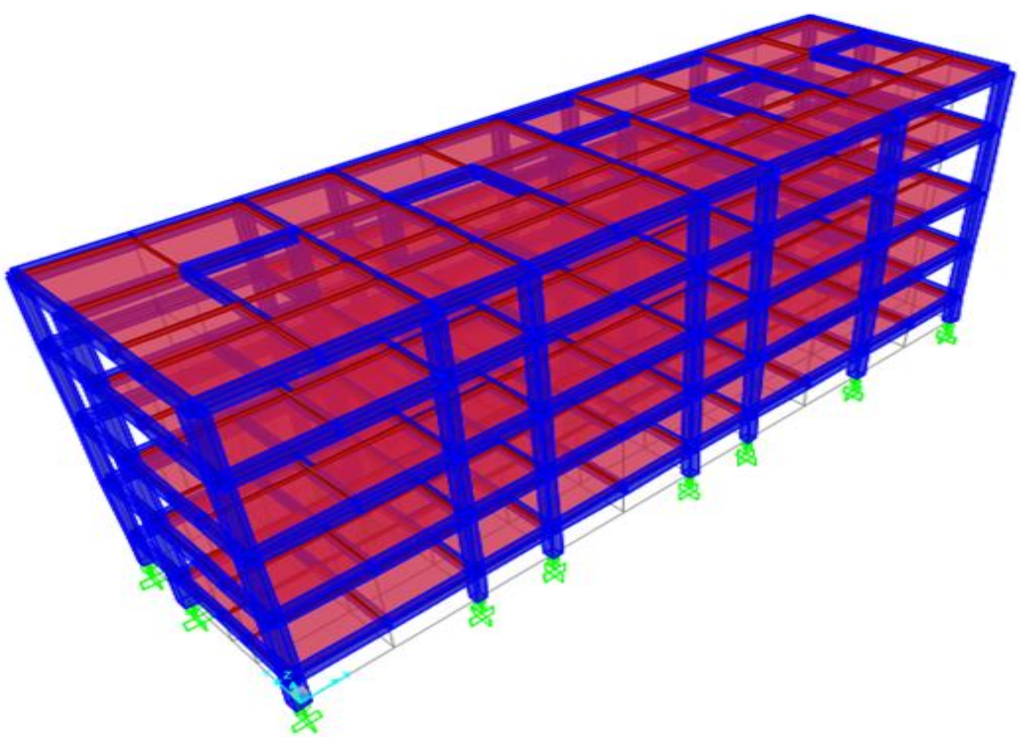

Fig 14: Isolated Building Model

The frame structure was also isolated with three ground motions. The isolated maximum floor accelerations are shown in Fig 15, maximum velocities as shown in Fig 16, maximum displacements as shown in Fig 17 and maximum shear forces as shown in Fig 18 respectively.

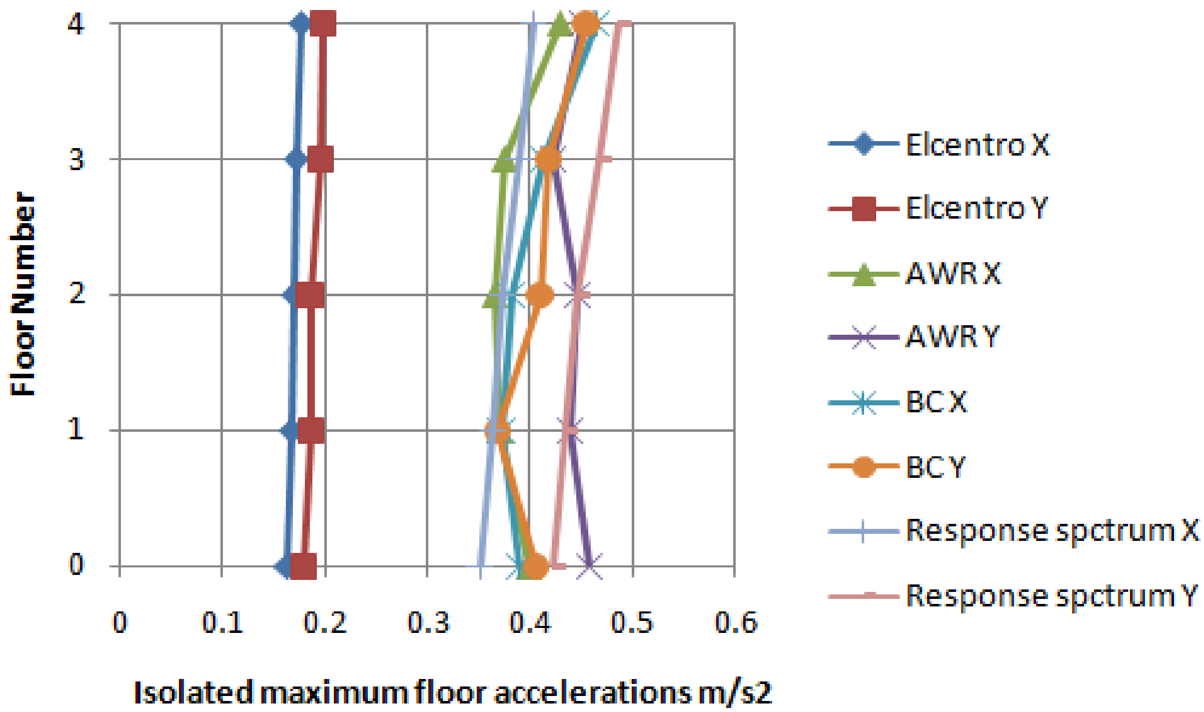

Fig 15: Isolated Maximum Floor Accelerations

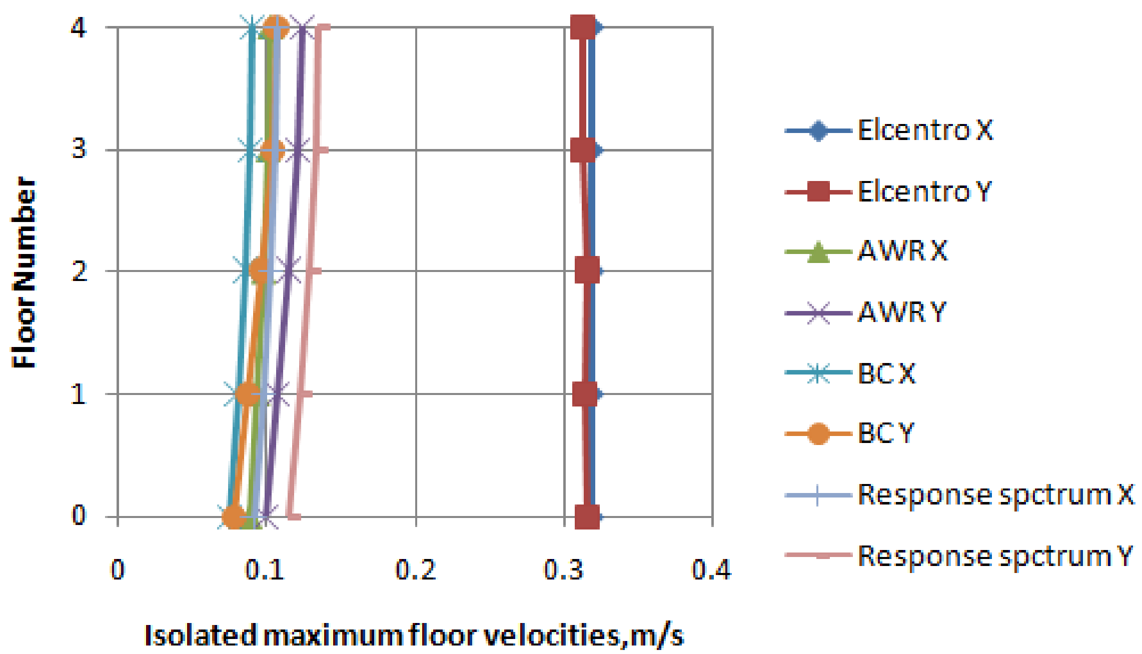

Fig 16: Isolated Maximum Floor Velocities

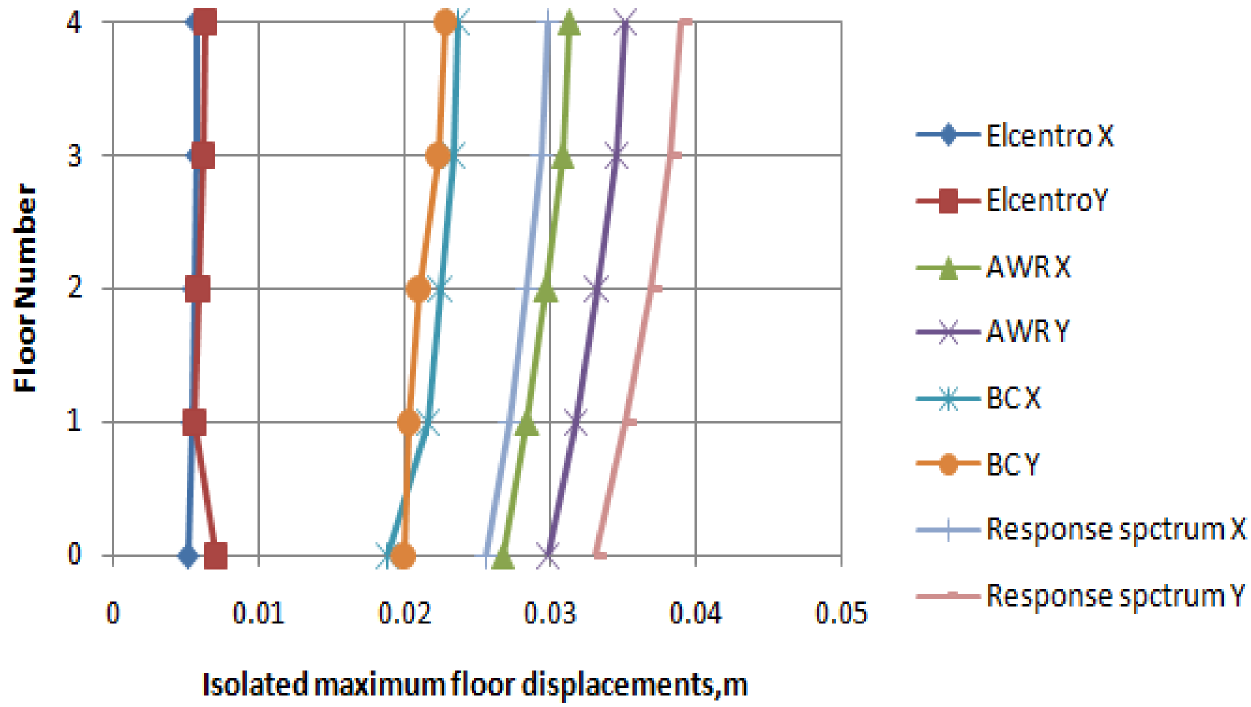

Fig 17: Isolated Maximum Floor Displacements

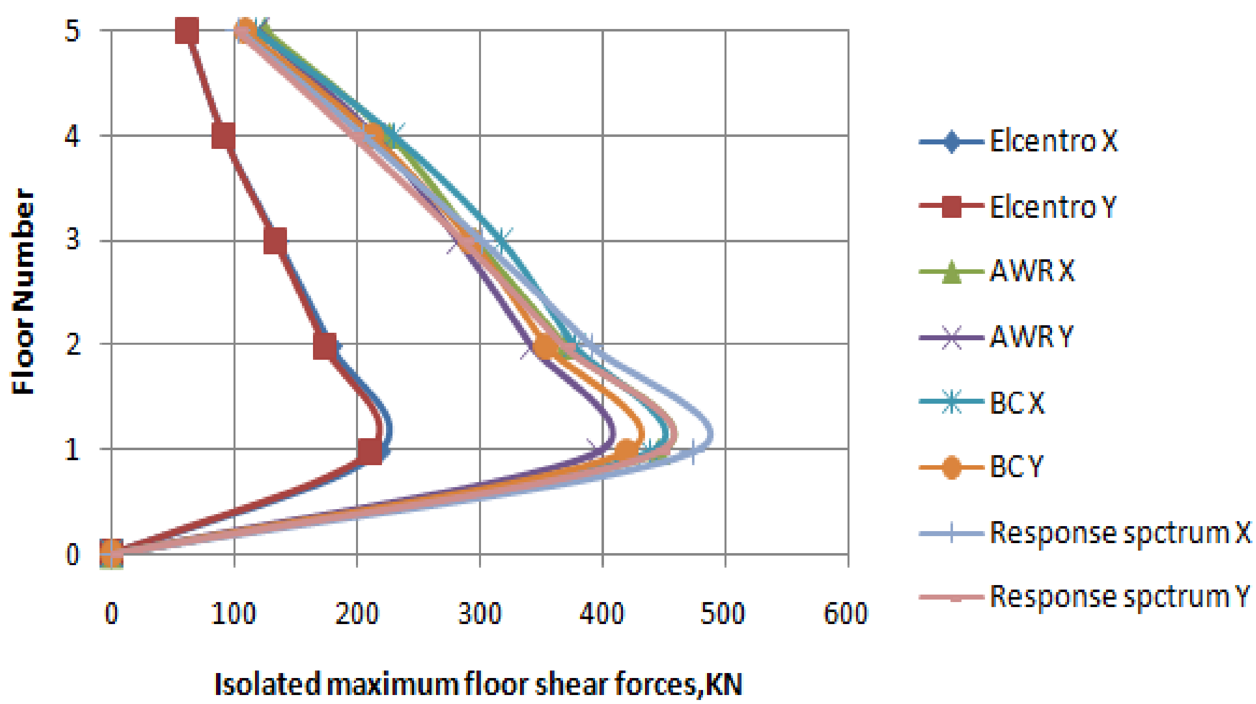

Fig 18: Isolated Maximum Floor Shear Forces

Isolated structure shear forces and non isolated structure shear forces ratios are as shows in table: 5 below.

Table 5: Isolated Structure Shear Forces and Non Isolated Structure Shear Forces Ratios

Wave type	Isolated and non isolated shear forces ratios					
	Direction	4th floor	3rd floor	2nd floor	1st floor	base floor
Elcentro	X	0.126	0.122	0.159	0.185	0.227
	Y	0.124	0.130	0.185	0.225	0.262
AWR	X	0.316	0.328	0.341	0.389	0.463
	Y	0.334	0.346	0.34	0.341	0.397
BC	X	0.212	0.237	0.255	0.262	0.299
	Y	0.160	0.174	0.183	0.196	0.227
Maximum value		0.334	0.346	0.341	0.389	0.463

From the table, analysis of the isolated and non isolated structure floor, the maximum shear forces ratios value 0.389, The maximum influence according to Chinese code 2010, coefficient of seismic horizontal earthquake after isolation is determined by: αmax1= β×αmax1/Ø=0.070 .

Non isolated and isolated accelerations, displacements and shear forces are shown in tables 6, 7 and 8 respectively.

Table 6: Comparison of Non-isolated and Isolated Accelerations

Wave type	Direction	Non isolated Accelerations			
		4th floor	3rd floor	2nd floor	1st floor
Elcentro	X	1.82	1.3	1.58	1.31
	Y	1.86	1.3	1.59	1.38
AWR	X	1.49	1.23	1.38	1.09
	Y	1.37	1.17	1.15	1.12
BC	X	2.17	1.69	1.66	1.03
	Y	2.68	2.18	1.76	1
Average	X	1.83	1.41	1.54	1.14
	Y	1.97	1.55	1.50	1.17
Wave type	Direction	Isolated Accelerations			
		4th floor	3rd floor	2nd floor	1st floor
Elcentro	X	0.17	0.17	0.17	0.18
	Y	0.19	0.19	0.19	0.2
AWR	X	0.43	0.38	0.36	0.37
	Y	0.45	0.42	0.45	0.44
BC	X	0.41	0.38	0.37	0.46
	Y	0.42	0.41	0.37	0.46
Average	X	0.34	0.31	0.30	0.34
	Y	0.35	0.34	0.34	0.37

Table 7: Comparison of Non-isolated and Isolated Displacements

Wave type	Direction	Non isolated Displacements			
		4th floor	3rd floor	2nd floor	1st floor
Elcentro	X	0.013	0.011	0.0073	0.004
	Y	0.014	0.011	0.007	0.004
AWR	X	0.009	0.008	0.006	0.003

	Y	0.009	0.008	0.005	0.003
BC	X	0.017	0.015	0.011	0.006
	Y	0.024	0.022	0.015	0.008
Average	X	0.013	0.011	0.008	0.004
	Y	0.016	0.014	0.009	0.005
Wave type	Direction	Isolated Displacements			
		4th floor	3rd floor	2nd floor	1st floor
Elcentro	X	0.006	0.008	0.006	0.005
	Y	0.006	0.006	0.006	0.006
AWR	X	0.031	0.031	0.029	0.028
	Y	0.035	0.035	0.033	0.032
BC	X	0.024	0.023	0.023	0.022
	Y	0.023	0.022	0.021	0.02
Average	X	0.020	0.021	0.019	0.018
	Y	0.021	0.021	0.02	0.019

Table 8: Comparison of Non-isolated and Isolated Shear Forces

Wave type	Direction	Non isolated Shear forces				
		4th floor	3rd floor	2nd floor	1st floor	Base Floor
Elcentro	X	484.263	753.051	850.289	961.716	1001.567
	Y	493.625	699.128	722.112	771.332	801.396
AWR	X	397.57	689.054	870.483	952.987	963.247
	Y	359.007	617.438	829.938	980.203	1000.061
BC	X	554.803	968.479	1247.168	1441.683	1467.034
	Y	678.872	1213.738	1604.524	1816.077	1848.425
Average	X	478.879	803.528	989.313	1118.795	1143.949
	Y	510.501	843.435	1052.191	1189.204	1216.627
Wave type	Direction	Isolated Shear forces				
		4th floor	3rd floor	2nd floor	1st floor	base floor
Elcentro	X	60.986	91.685	135.056	178.339	218.314
	Y	61.172	91.132	133.566	173.914	209.908
AWR	X	125.437	225.802	296.581	370.558	445.733
	Y	120.01	213.784	282.901	341.985	396.836
BC	X	117.475	229.666	317.413	378.187	439.217
	Y	108.731	211.734	293.824	355.687	419.854
Average	X	101.299	182.384	249.683	309.028	367.755
	Y	96.638	172.217	236.764	290.529	342.199

The isolated structure have increased in displacement and reduced in acceleration and shear forces shown in the graphs Fig19, 20 and Fig 21 respectively

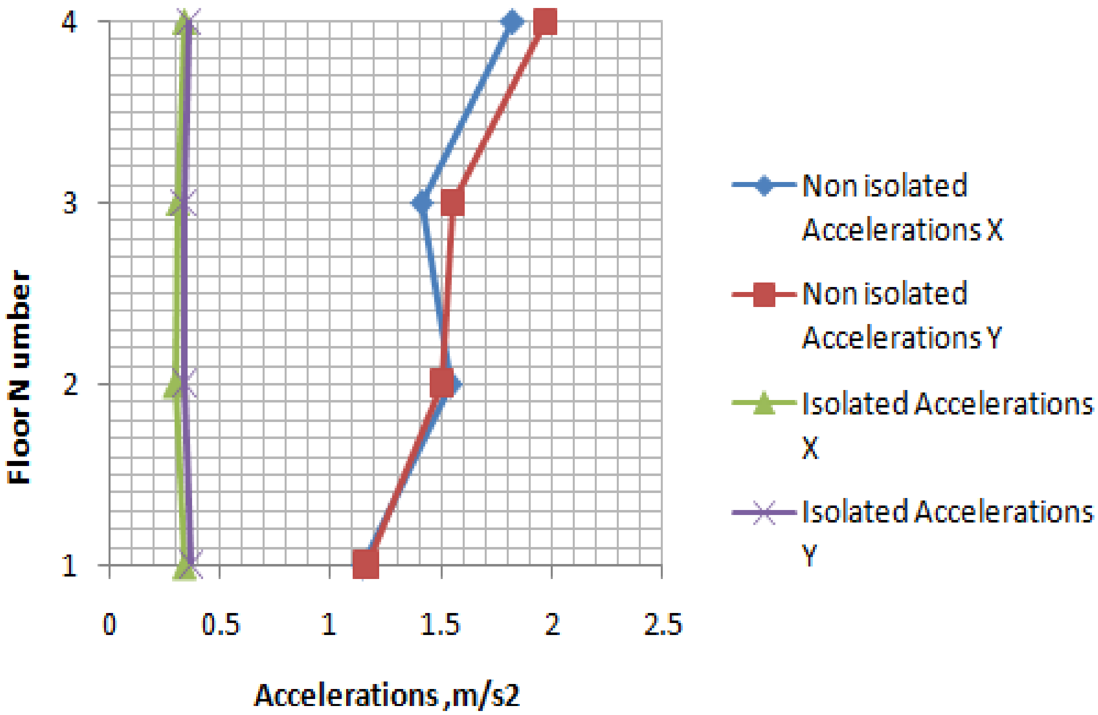

Fig 19: Comparison of Non-isolated and Isolated Accelerations

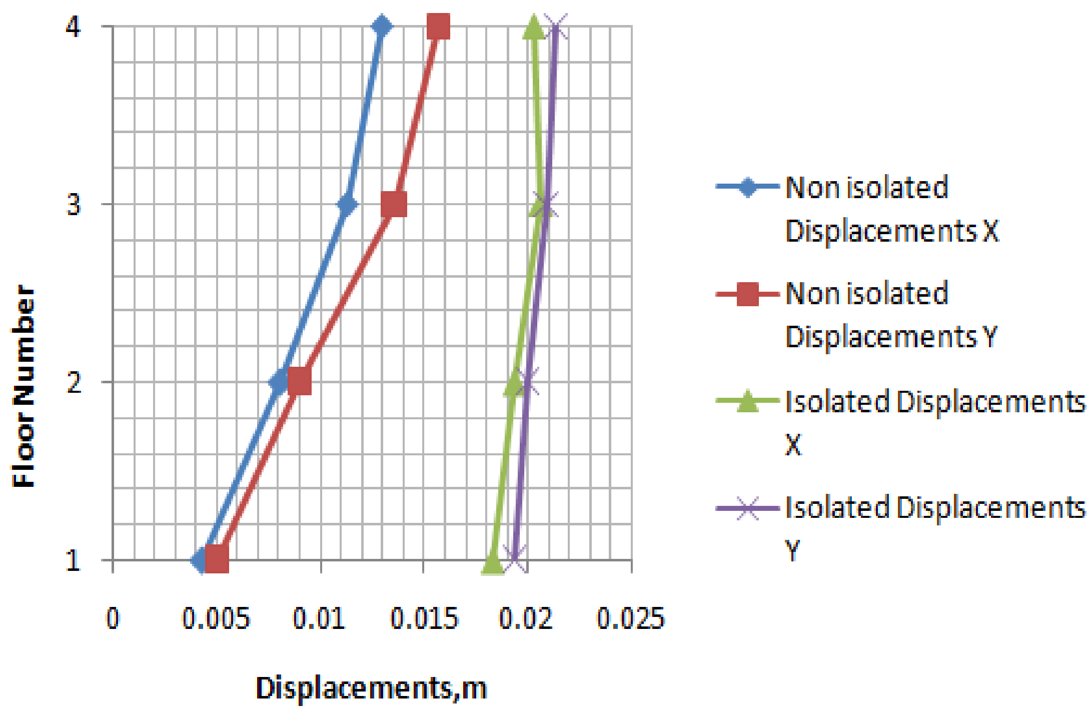

Fig 20: Comparison of Non-isolated and Isolated Displacements

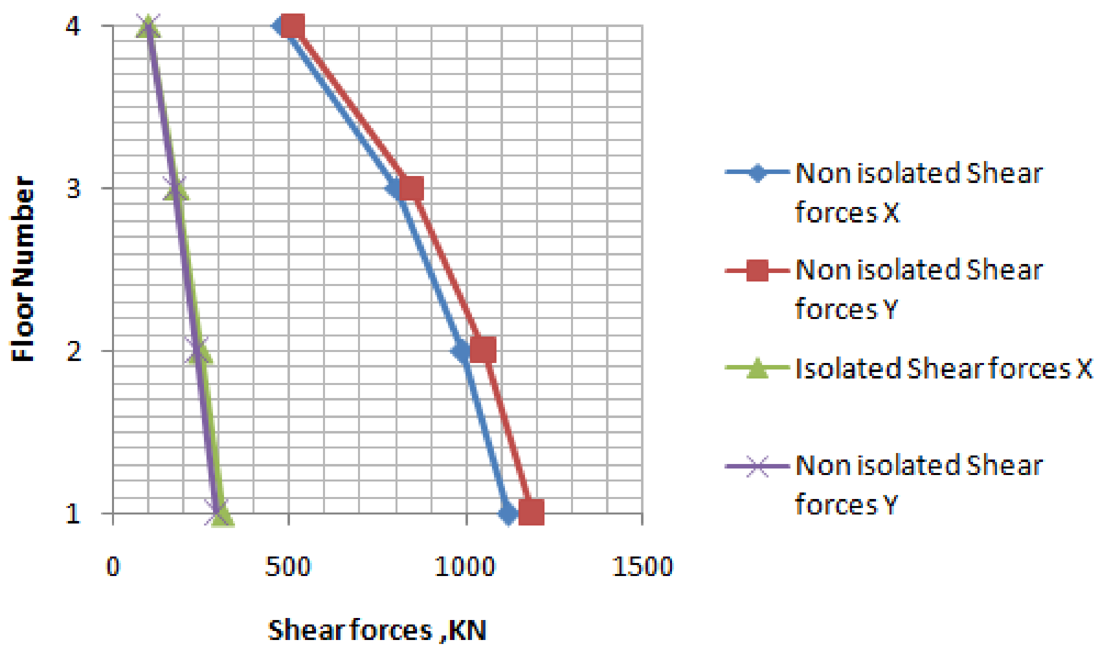

Fig 21: Comparison of Non isolated and Isolated Shear Forces

Graphs of isolated structure and non isolated Base shear forces structure are shown in Fig 22, 23 and Fig 24 respectively. It can be seen intuitively that the isolation bearing is effective.

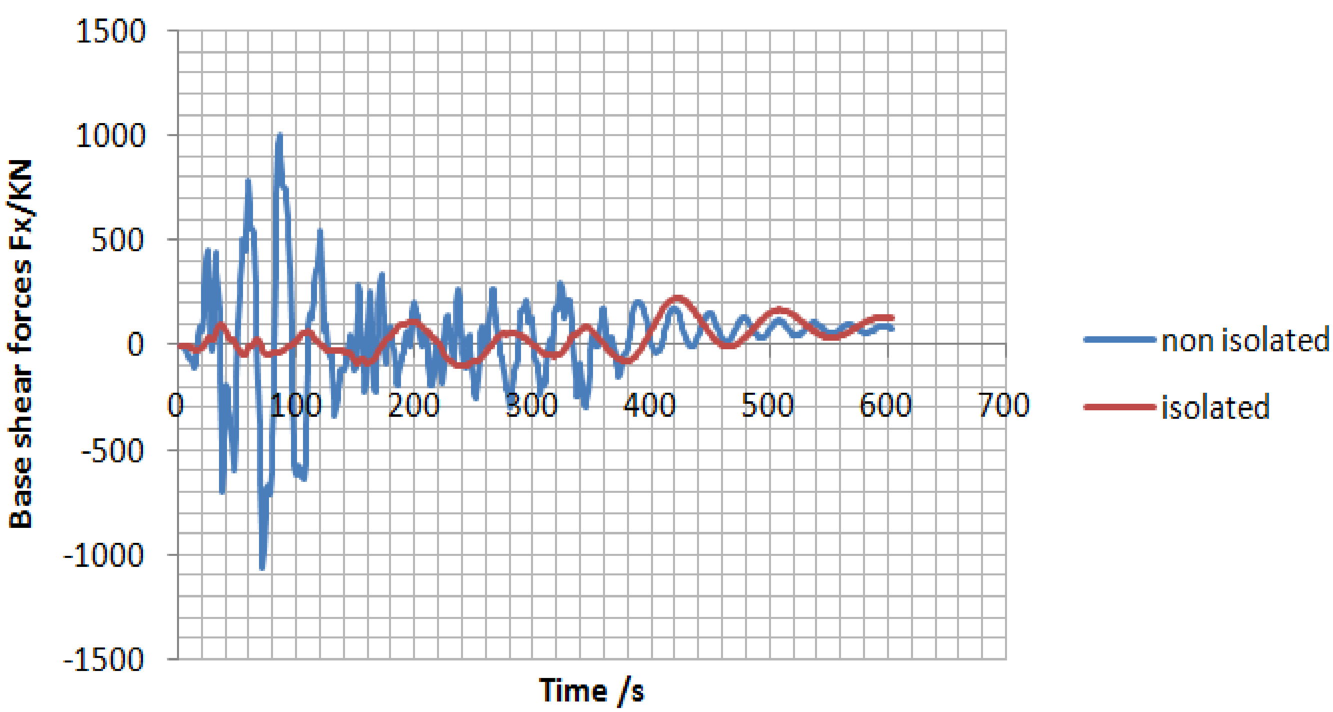

Fig 22: El Centro Wave

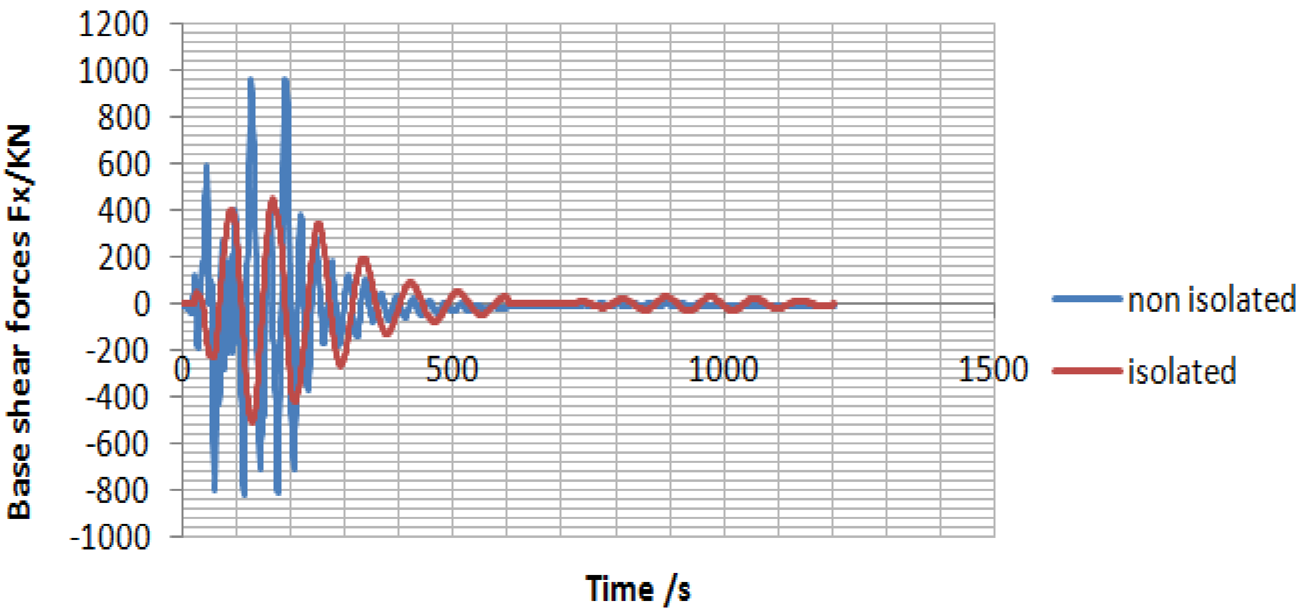

Fig 23: AWR Wave

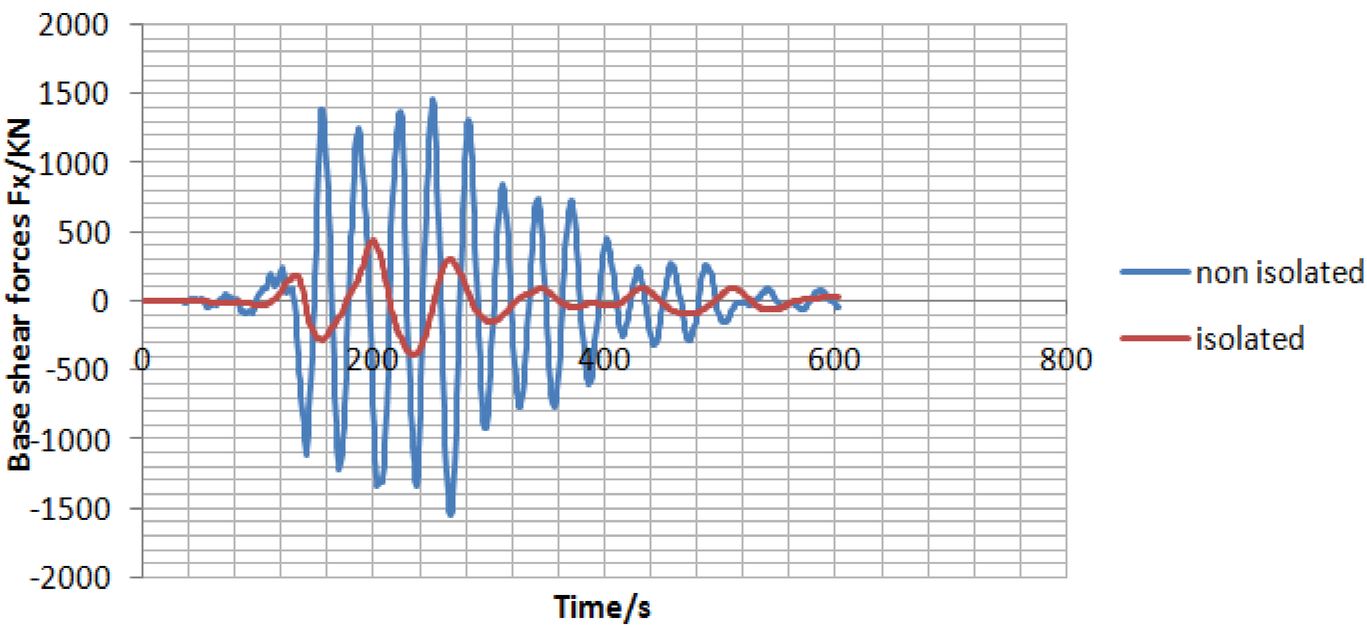

Fig 24: BC Wave

4. CONCLUSION

Analysis and comparison of the isolated structure and non isolated structure of their shear forces, acceleration and displacement seismic, found that isolation structure can significantly reduce the shear forces and acceleration and increased displacement. Structures of Seismic response improve the structure seismic fortification level, which proves that the shock absorption effect is good. The use of the base isolators should be selected with a higher model strength parameter isolator in mind, especially if a significant difference is expected in the output of the structural response to the earthquake excitation.

REFERENCES

[1]. Shi Wen Huang, Optimal Selection of Reinforcements Methods of Single Span Frame Structure of Primary and Middle School Buildings [M]. Graduate thesis of Southwest Jiao Tong University.

[2]. Rui Jun Zhang, Seismic Performance Research of Base Isolation Frame Structure [M]. Taiyuan University of Technology.

[3]. J. Jothi 2, M. Kavitha3 T ,Earthquake Analysis of Structure by Base Isolation Technique in SAP T. [J]. Subramani1,. Subramani et al Int. Journal of Engineering Research and Applications.

[4]. Jian An Hu,Seismic Performance Analysis of Story Isolation with EnergyDissipation Frame Structure , [M]. Anhui University of Architecture .

[5]. Yang Qingtao ,The simulation analysis on the Collapse of Isolated Structure [M]. Guangzhou University.

[6]. zhang yu,Chen yao .Li chun-yan, Discussion on the Relation Between Minxian – Zhuoni Earth Quakes in 2003-2004 and Hydrochemistry, Earthquake Administration of Gansu Province ,(Lanzhou7300-China) .

[7]. GB50011-2010, Code for Design of Concrete Structures (in Chinese), Peoples Republic of China

[8]. Okine Macheal ,zhao Jianchang , Mashrah , Seismic Isolation in Strenghening an Existing Retrofitted Masonry-Reinforced Concrete Building in Huating-China,International Journal of Research in Engineering and Technology eISSN: 2319-1163 | pISSN: 2321-7308.

[9]. GB50010-2010, Code for Design of Concrete Structures (in Chinese), Peoples Republic of China

[10]. PKPM 2010, v2.2, Peoples Republic of China

[11]. G.. Buckle and Lindsay R. Jones, Special Report Seismic Isolation A Solution to the Earthquake Problems of the Precast Concrete Industry Ronald L.Mayes, [J]. Ian .

[12]. Ye Xin Tao Zhong Chen ,Analysis of Base Isolation of A Primary School Teaching Building In Kunming

[13]. Yun Ye, The Earthquake Isolation Analysis of Multi-story Frame Teaching Building Based SAP2000

[14]. GB50011-2010 Code for Seismic Design of Buildings (in Chinese),Republic of China,2010

[15]. Subramani1, J. Jothi 2, M. Kavitha3T ,Earthquake Analysis of Structure by Base Isolation Technique inSubramani et al Int. Journal of Engineering Research and Applications [M]. ISSN : 2248-9622, Vol. 4, Issue 6(Version 5), June 2014, pp.296-305

[16]. Warn and Keri L. Ryan , A Review of Seismic Isolation for Buildings: Historical Development and Research Needs Gordon P. 2 Buildings[M]. 2012, 2, 300-325; doi:10.3390/buildings2030300.

[17]. Naeim, F.; Kelly, J.M. Design of Seismic Isolated Structures: From Theory to Practice,[D]. 1st ed.;
John Wiley and Sons: Hoboken, NJ, USA, 1999.

[18]. Sap2000 Ultimate 17.1.1, Build 1099, Computers and Structures Inc., Copyright © 1976-2014

[19]. Yun Ye, The Earthquake Isolation Analysis of Multi-story Frame Teaching Building Based SAP2000