Seismic Resistant Design of Buildings with Velocity Dependence Passive Energy Dissipation Devices *

Chan Tianchyuan(詹添全) [1], Chen Yilung(陳逸隆) [2], Hsieh Fengyang(謝豐仰)[3], Yu Chunghwa(游宗樺)[2], Lu Yunpin(盧允斌) [2], Lin Shihhsun (林世勳) [2]**

[1]** *Associate Professor, Department of Architecture & Urban Design, Chinese Culture University, Taipei 11214, Taiwan;*
[2] *Graduate Student, Dept. of Architecture & Urban Design, Chinese Culture University, Taipei 11214, Taiwan*
[3] *3Structural Engineer, Dept. of Architectural Engineering, China University of Technology, Taipei 11714, Taiwan*
Email：wowchan@ms32.hinet.net

ABSTRACT :

This research collect the passive energy dissipation devices design parameters, and using case of passive energy dissipation devices in Taiwan . To use ETABS computer program to analysis the effects of seismic response control of building structure retrofit by different kind of passive energy dissipation devices, include the displacement dependent devices(LYS-Low yielding steel)、the velocity dependent devices(VED-viscous elastic damper) and the velocity dependent devices(FVD-fluid viscous damper.

According to the analysis result, The roof response acceleration increase 7.6% , the roof response displacement increase 8% with displacement dependent devices(LYS-Low yielding steel). The roof response acceleration increase 2% , the roof response displacement decrease 1% with the velocity dependent devices(VED-viscous elastic damper). The roof response acceleration decrease 13% , the roof response displacement decrease 28% with the velocity dependent devices(FVD-fluid viscous damper).

KEYWORDS: Displacement Dependence Passive Energy Dissipation Devices, Low yielding Strength Steel(LYS), Velocity Dependence Passive Energy Dissipation Devices, viscous-elastic damper(VED), fluid viscous damper(FVD)

INTRIDUCTION

Building's seismic isolation and energy dissipation have been vigorously developed in Taiwan after devastating Ji-Ji earthquakes in 1999. In light of the increasing cases of using seismic isolation and energy dissipation devices in private and public buildings, the Ministry of the Interior promulgated "The design specification of seismic isolation buildings" on March 8, 2002, and it has been enforced as from April 1 of the same years. The design specification specifically regulate the design/analysis of seismic isolation system, and the physical tests and function assurance tests of seismic isolation devices, etc. for practical application. The foresaid seismic isolation guidelines have been included in the chapter 9 of the "Design Code of the building seismic resistance design" decreed on December 14, 2004 which has been enforced as from July 1, 2005. As to the regulations regarding the design/analysis of energy dissipation system and the "passive energy dissipation system" of the physical tests of energy dissipation devices, they were first specifically regulated in the chapter 10 of the seismic resistance design code.

So far, system design and analysis are the mainstream in the development of local seismic isolation and energy dissipation system whereas the production and experiment of the related devices have till been assisted by foreign technical crew. Thus, while the key techniques can not be transited, the device design parameter related data have still mainly been developed on our own or provided by the foreign crew. Comparing with the progress made in foreign countries, our research on the design and analysis of the energy dissipation system still in the initial stage, and the relevant research literature available is still limited to the influence of the single-type energy dissipation devices on building's seismic reaction and control capacity.

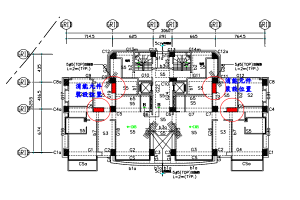
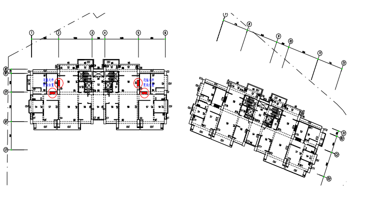
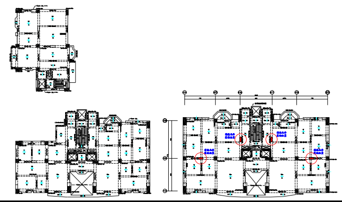
Under such circumstances, it is imperative for us at this period of time to work on the research relating to energy dissipation, such as how to establish a variety of design and analysis methods of energy dissipation system and the investigation into the influence of the installed energy dissipation device on building's seismic reaction and control capacity. This study collects and compiles some types of energy dissipation devices and design parameter data within and without and uses the energy dissipation buildings as living examples to compare the influence of various types of energy dissipation devices on building's seismic reaction and control capacity through computer numerical simulation method in order to set up intact data for the trade to use as the reference for application, design and analysis.

1. STRUCTURE DESIGN PARAMETERS of the VELOCITY-DEPENDENCE DISSIPATION DEVICE and CASE STUDY

This study establishes a numerical simulation analysis model with SAP2000 version of program using the actual buildings as examples to compare their energy dissipation efficiency and seismic response and control capacity. It uses the cases of three buildings (Building A is an individual high tower building, Building B is a twin-tower building, and Building C is a L-shape high triple-tower building), Its basic information is indicated in table 1, five sets of non-linear earthquake record (three artificial earthquakes transformed from the normalized horizontal earthquake records which are consistent with Taipei-Basin design response spectra, and actual horizontal earthquake records measured at Taipei CKS Memorial Hall during 921 and 331 earthquakes) and three energy dissipation systems to compare building's seismic response and control capacity.

(1) Analysis of building's seismic reaction and control capacity implemented with velocity-dependence fluid viscous damper

Table 1 Case introduction

Case name	Building A	Building B	Building C
Building Plan			
Analysis model			
Epicenter	Taiwan 3rd zone	Taipei 3rd zone	Taipei 3rd zone
Application	Residence	Residence	Residence
Building materials	Reinforced concrete	Reinforced concrete	Reinforced concrete
Numbers of floors	Under ground: 2 floors, On the ground: 14 floors	Under ground: 2 floors, On the ground: 13 floors	Under ground: 2 floors, On the ground: 14 floors

(2) Analysis of building's seismic reaction and control capacity in Original Case X-direction

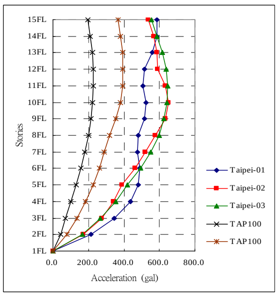


Fig 1 Building A(floor acceleration reaction chart)

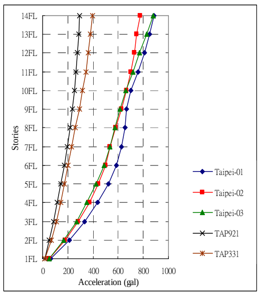


Fig. 2 Building B (floor acceleration reaction chart)

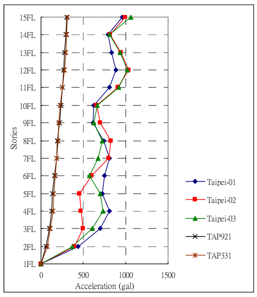


Fig. 3 Building C (floor acceleration reaction chart)

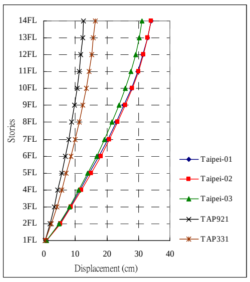


Fig.4 Building A (floor absolute displacement chart)

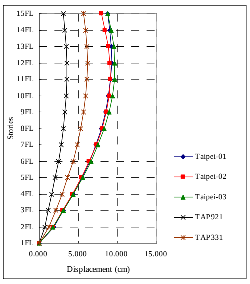


Fig. 5 Building B (floor absolute displacement chart)

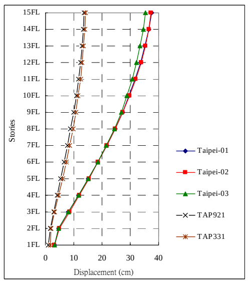


Fig. 6 Building C (floor absolute displacement chart)

2 CONCLUSION and RECONMMENDATION

2.1 Conclusion

This study collects and compiles the displacement and velocity-dependence energy dissipation device technical data and research literature available within and without to establish reference data of design parameters of displacement and velocity-dependence energy dissipation devices, uses three different types of energy dissipation buildings, Building A, B and C, as the living example to build SAP2000 computer numerical simulation analysis model, and makes simulation analysis to compare the influence of different types of energy dissipation devices and design parameters on building's seismic response and control capacity in conjunction with the three normalized horizontal earthquake records (Taipei-01, 02, and 03) consistent with the Taipei basin design response spectra, and the horizontal earthquake records (TAP921 and TAP331) measured at Taipei CKS memorial hall station.

1.The influence of different types of energy dissipation devices on building fundamental period is as follows:

(1). After installation of displacement energy device (low yielding steel plate), The results is shown on table 3. Building An increases 0.5%~0.8%, Building B increases 2%, and Building C increase 2.2%. of original reaction.

Table 2 Design parameter of displacement-dependent energy dissipation device (low yielding steel plate)

Item No.	Material	Yielding Strength(t_f/cm^2)	Ultimate Strength (t_f/cm^2)	Yielding Ratio (%)	Elongation (%)	Effective Stiffness (t_f/cm)
LYS-01	SS34 Modified	2.66	3.70	72	32	246
LYS-02	SS40	0.82	2.04	40		1111

Table 3 Building Fundamental Period

Case name	Building Fundamental Period of pre- and post- installation of displacement energy dissipation device in the buildings T_D (sec)		
	Original	LYS-01	LYS-02
Building A	0.962	0.970	0.967
Building B	1.350	1.376	1.376
Building C	1.675	1.712	1.712

(2).After installation of velocity viscous elastic energy dissipation device, The results is shown on table 5. Building A increases 0.3%~-0.2%, while Building B decreases 0.3% ~ 0.8% and Building C decreases 3%~5%.

Table 4 Design parameter of velocity-dependence solid viscous elastic damper

Item No.	Total Length A (mm)	Free Length B (mm)	Impulse Length d (mm)	story	Effective Stiffness (t_f/cm)	Damping coefficient (t.s/cm^2)	Damping force (t_f)
VED-01	2000	300	10	4	37.7295	17.8450	51.38
VED-02	2500	300	10	4	47.1109	22.2298	64.12
VED-03	3000	300	10	4	56.4923	26.7166	76.96
VED-04	3500	300	10	4	65.9756	31.2033	89.81

Table 5 Building Fundamental Period

Case name	Building Fundamental Period of pre and post installation of velocity solid viscous elastic energy dissipation device in the building T_{VED} (sec)				
	Original	VED-01	VED-02	VED-03	VED-04
Building A	0.962	0.965	0.963	0.962	0.960
Building B	1.350	1.346	1.344	1.341	1.339
Building C	1.675	1.627	1.614	1.602	1.591

(3).After installation of velocity viscous energy dissipation device, The results is shown on table 7. Building A increases 0.42%, Building B increases 0.22%, and Building C increases 0.3%.

Table 6 Design parameter of velocity-dependence fluid viscous damper

Item No.	Maximum Displacement (mm)	Damping Force (t_f)	Damping Coefficient (t.s/cm^2)	Velocity Index
FVD-01(KZ-300S×50X)	50	30	30.5915	0.35
FVD-02(KZ-500S×70X)	70	50	81.5773	0.40
FVD-03(KZ-600S×300X)	300	60	81.5773	0.35
FVD-04(KZ/T-1000S×50X)	50	100	192.7264	0.30

Table 7 Building Fundamental Period

Case name	Building Fundamental Period after the installation of fluid viscous damper in the buildings T_{FVD} (sec)				
	Original	FVD-01	FVD-02	FVD-03	FVD-04
Building A	0.962	0.966	0.966	0.966	0.966
Building B	1.350	1.353	1.353	1.353	1.353
Building C	1.675	1.680	1.680	1.680	1.680

2. The influence of different types of energy dissipation devices on floor acceleration response of the buildings is as follows:

(1). After installation of displacement energy dissipation device (low yielding steel pate), The results is shown on fig.7~fig.9. Building A's top floor acceleration reaction increases 7.6%, Building B's increases 6% while Building C's decreases to a level of 8.6% of original reaction, under the normalized horizontal seismic action.

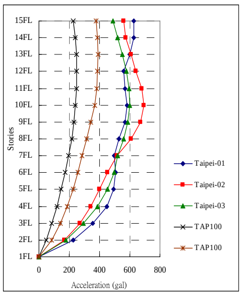


Fig.7 Building A (floor acceleration reaction chart)

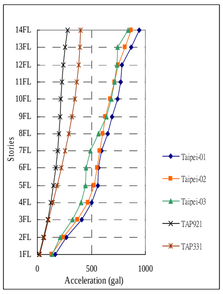


Fig.8 Building B (floor acceleration reaction chart)

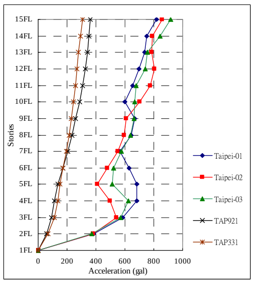


Fig. 9 Building C (floor acceleration reaction chart)

(2). After installation of velocity viscous elastic energy dissipation device, The results is shown on fig.13~fig.15. Building A's top floor acceleration reaction increases 2%, Building B's increases 10%, and Building C's increases 3%.

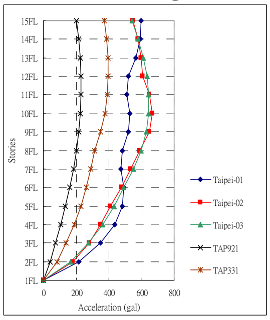


Fig.13 Building A (floor acceleration reaction chart)

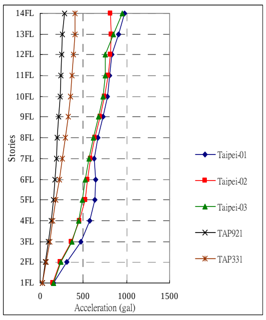


Fig.14 Building B (floor acceleration reaction chart)

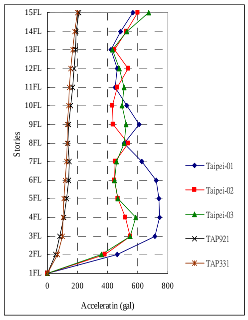


Fig.15 Building C (floor acceleration reaction chart)

(3). After installation of velocity viscous energy dissipation device, The results is shown on fig.19~fig.21. Building A's top floor acceleration reaction decreases 13%, Building B decreases 32%, and Building C decreases 40%.

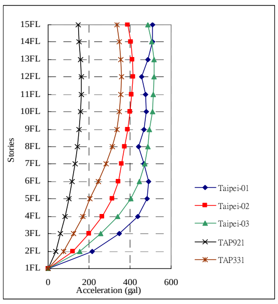


Fig.19 Building A (floor acceleration reaction chart)

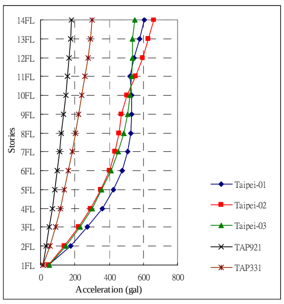


Fig.20 Building B (floor acceleration reaction chart)

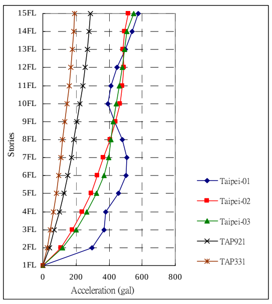


Fig.21 Building C (floor acceleration reaction chart)

3. The influence of different type of energy dissipation devices on floor absolute displacement of the buildings is as follows:

(1). After installation of displacement energy dissipation device (low yielding steel plate), The results is shown on fig.10~fig.12. Building A increases 8%, Building B decreases 6%, and Building C decreases 5% under normalized horizontal seismic action.

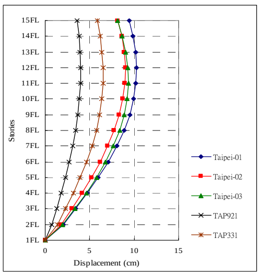


Fig.10 Building A (floor absolute displacement chart)

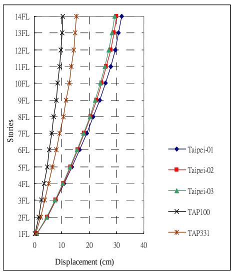


Fig.11 Building B (floor absolute displacement chart)

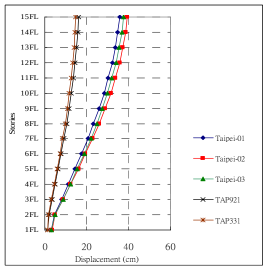


Fig.12 Building C (floor absolute displacement chart)

(2).After installment of velocity viscous elastic energy dissipation device, The results is shown on fig.16~fig.18. Building A decreases 1%, Building B decreases 2.7%, and Building C decreases 7%.

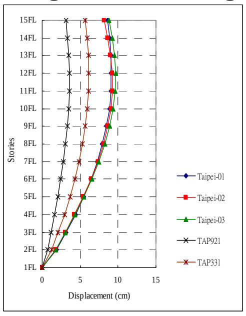


Fig.16 Building A (floor absolute displacement chart)

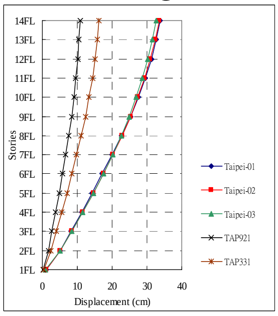


Fig.17 Building B (floor absolute displacement chart)

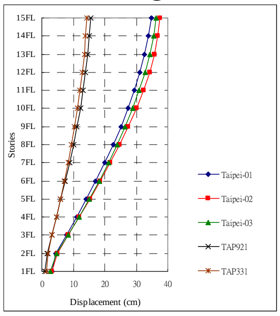


Fig.18 Building C (floor absolute displacement chart)

(3). After installation of velocity viscous energy dissipation device, The results is shown on fig.22~fig.24. Building A decreases 28%, Building B decreases 39%, and Building C decreases 50%.

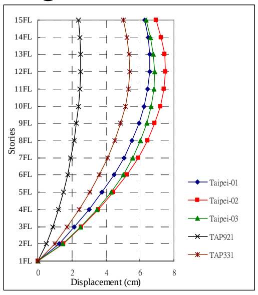


Fig.22 Building A (floor absolute displacement chart)

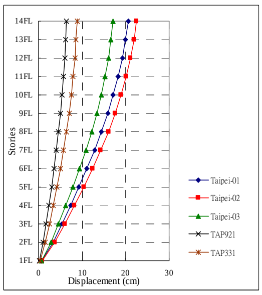


Fig.23 Building B (floor absolute displacement chart)

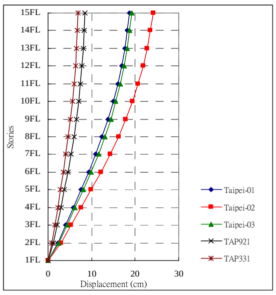


Fig.24 Building C (floor absolute displacement chart)

4. The results of the comparison and analysis of pre- and post- installation of energy dissipation devices in the above living example buildings show that under normalized horizontal seismic action, adding FVD-04 velocity viscous energy dissipation devices to the top floor of the buildings can get best effect on acceleration reaction of which Building A decreases 27%, Building B decreases about 50% and Building C decreases about 43%.
5. The results of the comparison and analysis of pre- and post- installation of energy dissipation devices in above living example buildings show that adding FVD-04 velocity viscous energy dissipation device to the buildings can get best effect on absolute displacement, of which Building A decreases about 34%, Building B decreases about 62% and Building C decreases about 67%. 6. The results of the comparison and analysis of the influence of different energy dissipation device design parameters on building's seismic reaction and control capacity are as below:

(1). The increase of the effective stiffness of the displacement energy dissipation device (low yielding steel plate) will reduce building's vibration cycle, relatively increase top floor's acceleration reaction, and accordingly enhance top floor's absolute displacement. As a result, it will form counterproductive seismic reaction to buildings.

(2). The increase of the effective stiffness and damping coefficient of the velocity viscous elastic energy dissipation device will reduce building's vibration cycle, and relatively increase top floor's acceleration reaction, but the top floor's absolute displacement will decrease as the increase of the damper coefficient which will result in the well control of building's seismic reaction.

(3).The increase of damping force and damping coefficient of the velocity viscous energy dissipation device will enhance building's vibration cycle, relatively reduce top floor's acceleration reaction, and accordingly decrease top floor's absolute displacement which will result in the well control of building's seismic reaction.

2.2Recommendations

Based on the living examples of energy dissipation buildings and SAP2000 computer numerical simulation analysis, the following recommendations are submitted as the reference for the use in subsequent studies:

1. Following the collection and compilation of the available technical data regarding displacement and velocity-dependence energy dissipation devices within and without, it is found that the current technical data mostly relate to the various sizes and design parameters of displacement and velocity-dependence energy dissipation devices, and very few QA tests of energy dissipation devices and the testing data of function recognition tests have been mentioned. As a result, there is no way to compare and confirm if the function of energy dissipation devices is consistent with the result of building's seismic reaction and control capacity. The detailed QA tests of various types of energy dissipation devices and the testing data of function recognition tests collected and compiled for this study can also be used in future research.
2. The living examples of energy dissipation buildings chosen for this study are all higher than 13 floors and are constructed with reinforced concrete. However, for the buildings of 4-7 floors or below 3 floors built with steel or other construction materials, their seismic reaction and control capacity after the installation of energy dissipation devices shall be further investigated.
3. The study mainly analyzes and compares the influence of different types of energy dissipation devices on building's seismic reaction and control capacity. As to other influences, such as building's internal beams, the moment of construction pillars, sear, and axial force, cross-section changes of corresponding design and increase/decrease in total building cost between pre and post installation of the energy dissipation device, they shall be included in the subsequent research on the safety and economic effects of energy dissipation buildings.
4. The study suggests that the change of the design parameters of the energy dissipation device influence building's seismic reaction and control capacity, and relatively it also affect the sharing of the seismic force between beams and construction pillars in a building. In reference to the change of the design parameters of energy dissipation devices and its influence on the seismic force sharing of the construction materials in a building, they shall be included in the subsequent research on the optimal design of the energy dissipation buildings.

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