SEISMIC CONTROL APPLICATIONS IN TAIWAN

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Abstract

This paper summarizes the applications of seismic passive control devices in Taiwan. Typical construction examples for various passive control devices are introduced, accompanying with the theoretical background of the devices.

INTRODUCTION

Research on the seismic control of structure has been conducted in Taiwan since early 1980s. However, it was not until the 1999 Chi-Chi earthquake, the applications of various seismic passive control devices have been extensive in Taiwan. To date the seismic control technologies including base isolation design and energy dissipation design have been applied to the constructions of national freeway bridges, Taiwan High Speed Rail brides, medical centers, high-tech industrial structures, bank data center, residential buildings, elementary school buildings, etc. These applications include new construction and retrofit design.

ENERGY CONSIDERATION

Integrating the equation of motion

$$M\ddot{X} + C\dot{X} + KX = M\ddot{X}_g \qquad (1)$$

with respect to the relative deformation of structure, the absolute energy equation is obtained as

$$\frac{1}{2}M(\dot{X}_t)^2 + \int C\dot{X}\, dX + \int KX\, dX = \int M\ddot{X}_g\, dX_g \qquad (2)$$

The equation can be represented in another form of

$$K.E. + D.E. + H.E. + S.E. = I.E. \qquad (3)$$

where K.E. = kinetic energy; D.E.= damping energy; H.E.=hysteretic energy; S.E.=strain energy; and I.E. = input energy. The sum of K.E., D.E., H.E. and S.E. is called the energy supply by the structure while I.E. is the input energy or energy demand by the earthquake. For a structure to survive earthquakes, it is required that the energy capacity of a structure is larger than the energy demand by the earthquake. It is therefore the intent to add energy dissipation systems in appropriate loading paths or resistance paths of the structure so that the energy dissipation systems can dissipate much of the input energy by the earthquake prior to the severe inelastic deformation occurring at primary structural elements. This concept has led to the invention of various energy dissipation devices and energy design methods. On the other hand, the seismic isolation design was to isolate the structure from the energy demand by the earthquake and thus reduce the energy input to the structure. Various isolation systems and design methods have been developed corresponding to different site conditions, building functionality requirements and environmental circumstances.

CONSTRUCTION EXAMPLES

The energy dissipation systems used in Taiwan include the hysteretic type and velocity type dampers. The hysteretic dampers include the triangular added stiffness and damping damper (TADAS), reinforced ADAS damper (RADAS), low yield steel shear panel (LYSSP), Buckling Restrained Braces (BRB) or unbonded brace, etc. Typical examples adopting these dampers are shown in Figs. 1-4. Among the hysteretic energy dissipation systems, the number of applications of the BRB is increasing due to the reason that the brace can improve the weakness of the traditional concentrical brace system and the eccentrical brace system. The velocity type of damper encompasses visco-elastic dampers (VE), viscous dampers (VD) and viscous damping walls (VDW). The applications are given in Fig. 5-9. Currently, there have been more applications using viscous dampers than other velocity type dampers. This may be due to the facts that the design procedure for implementing the viscous damper is relatively simpler and the analytical model is available in the popular computational tools such as SAP2000 and ETABS.

Regarding the base isolation applications, the Tzu-Chi medical centers at Taipei and Tai-Chung are typical examples. It is worthy of mentioning that the medical center at Tai-Chung is located 400 meters away from the surface rupture line of the 1999 Chi-Chi earthquake. Special consideration was given for the design of isolation system. Lead-Rubber bearings with viscous dampers are designed to resist possible near-filed type earthquake ground motions which may induce extraordinarily large displacement at the isolation system. The reason to adopt the viscous damper in this isolation system is to take the advantage of the 90 degree phase lag between the force and displacement of the damper. In other words, the viscous damper can help minimize the displacement in the isolation layer while the maximum base shear force transmitted by the isolation system will not be dramatically increased.

For some structural applications, a combination of energy dissipation and seismic isolation are applied as shown in Fig. 10. The structure is basically designed with additional dampers to protect the structural system. In addition, for some floors where important facilities such as computer servers are located, floor isolation system id also implemented to further secure these important facilities.

DISCUSSIONS

The applications of seismic control devices to the construction of structures in Taiwan are flourishing after the 1999 Ch-Chi earthquake. The general public and the builders seem to have learned the lessons from the quake. The practical design and construction of these passive control devices have fed back some precious research ideas regarding the theoretical development and the effectiveness of installation. The current status is encouraging. However, certain aspects regarding the practical applications such as quality assurance will need more efforts from the construction and design law legislation, local manufacturing capability, etc.

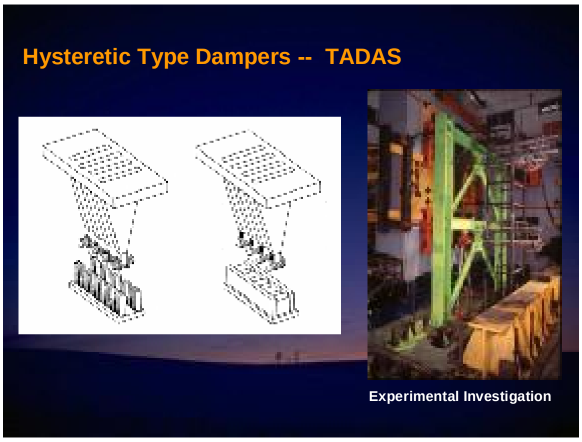

Fig. 1(a) Experimental Study of TADAS at NTU and NCREE

Fig. 1(b) Application of TADAS to Taipei Living Mall

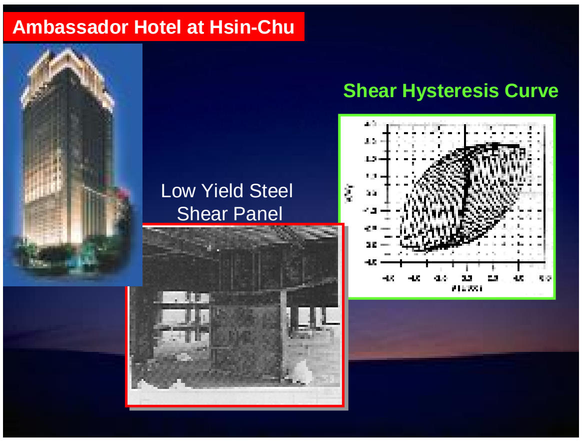

Fig. 2 Application of LYSSP to Hsin-Chu Ambassador Hotel

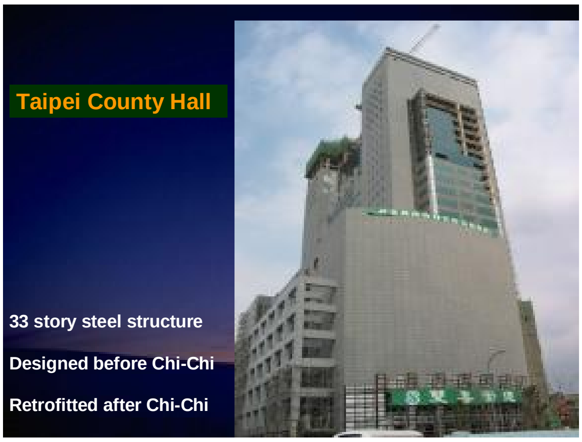

Fig. 3(a) Application of BRB and LYSSP to Taipei County Hall

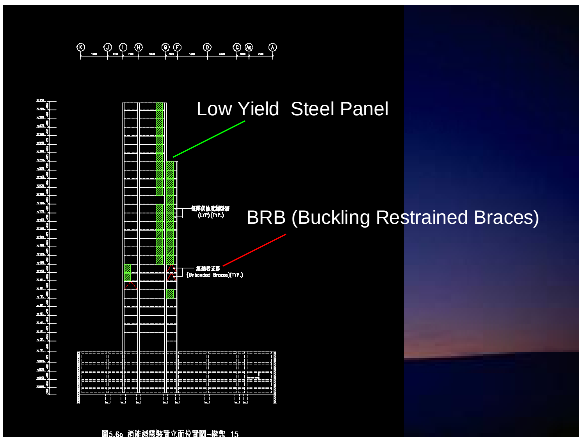

Fig. 3(b) Elevation View of one frame in Taipei County Hall

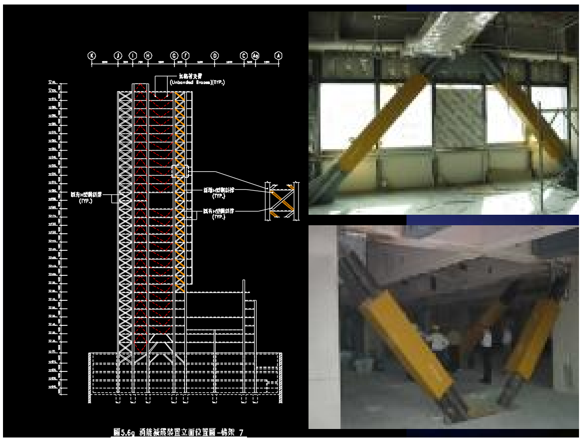

Fig. 3(c) Elevation View of one frame in Taipei County Hall

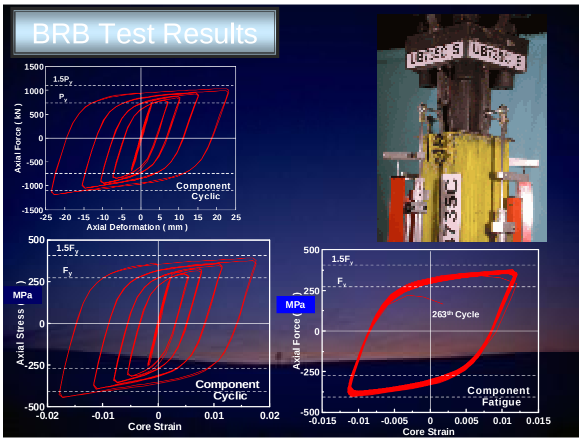

Fig. 3(d) Experimental Study of BRB at NTU & NCREE

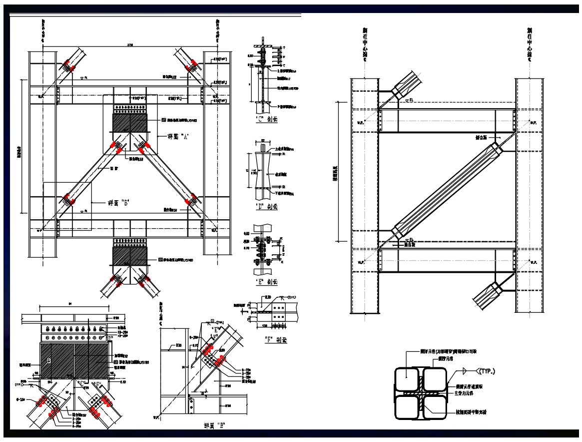

Fig. 4(c) Details of LYSSP and BRB installation

Fig. 4(a) Applications of LYSSP and BRB to National Taiwan University of Sci. &Tech.

Fig. 5(a) Application of VE dampers to Taipei Treasure Palace

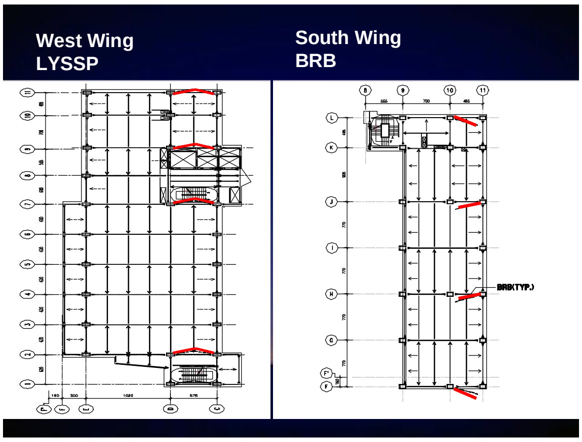

Fig. 4(b) Plane view of west and south wings

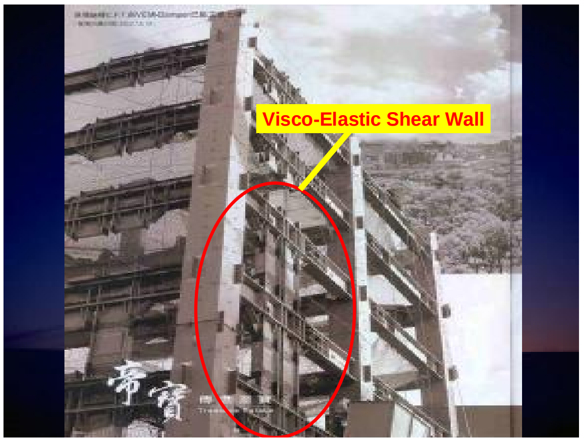

Fig. 5(b) VE shear panels in place

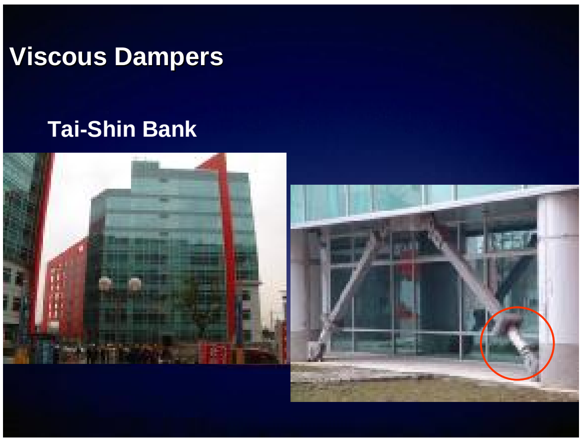

Fig. 6(a) Application of VD to Tai-Shin Bank Data Center

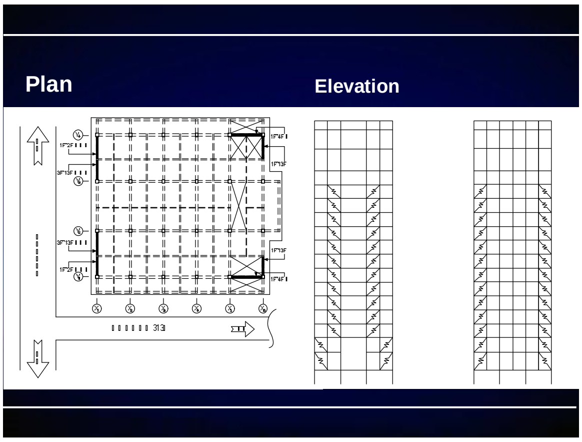

Fig. 7(b) Plan and elevation view of the structure

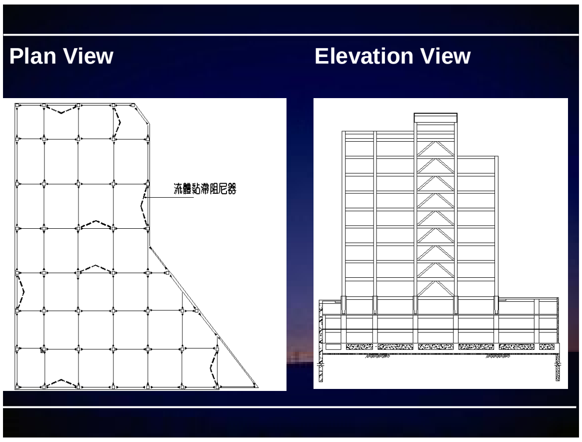

Fig. 6(b) Plan and elevation view of the structure

Fig. 8(a) Application of VDW to Grand Palace of Taipei

Fig.7 (a) Application to Headquarter of Buddhist Association

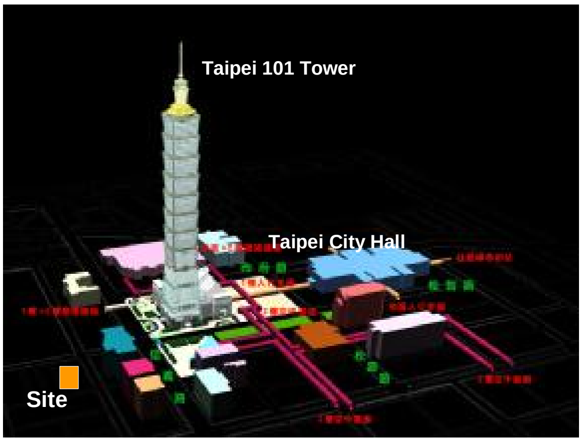

Fig. 8(b) Location of the structure at the core of Taipei City

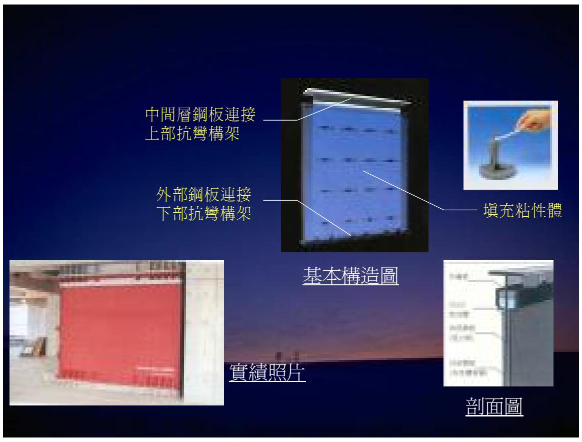

Fig. 8(c) The details of VDW and the damper in place

Fig. 9(c) Viscous damper in place

Fig. 9(a) Application of base isolation to Tzu-Chi Medical Center at Taipei

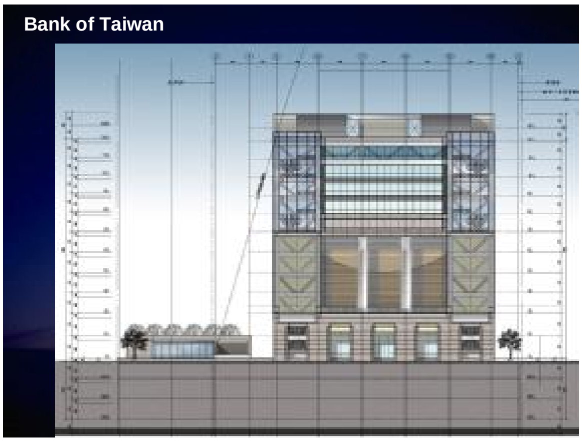

Fig. 10(a) Applications of VD and floor isolation to Bank of Taiwan

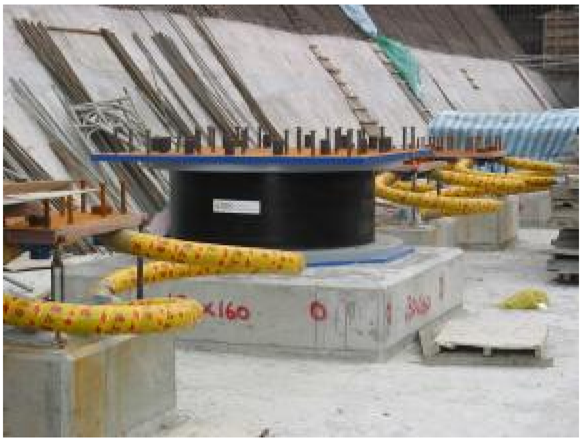

Fig. 9(b) Lead-rubber isolation bearing and coil damper in place

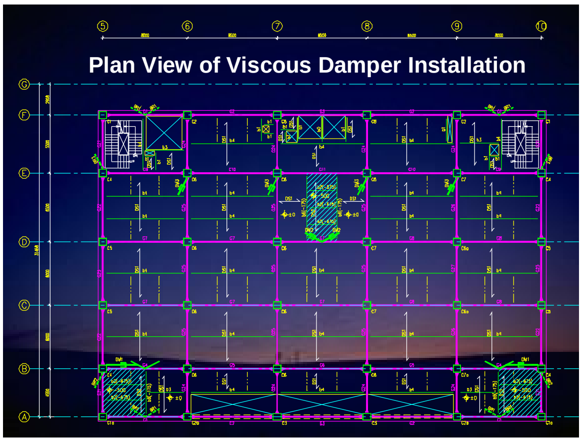

Fig. 10(b) Plan View of VD installation

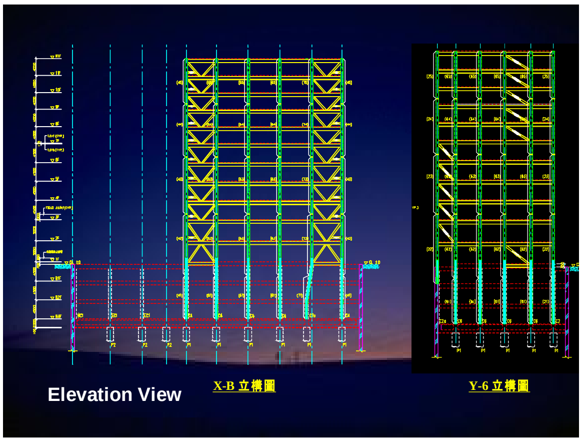

Fig. 10(c) Elevation view of VD installation

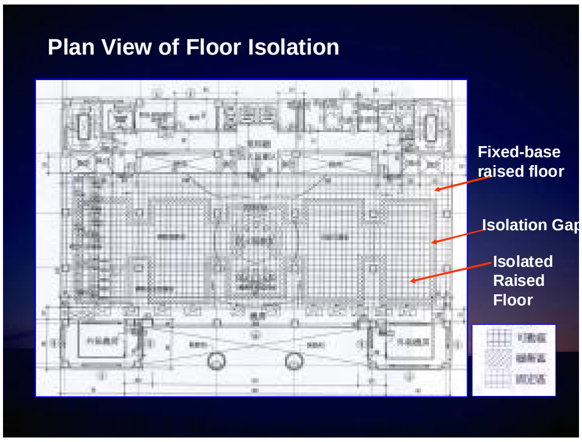

Fig. 10(d) Plan view floor isolation

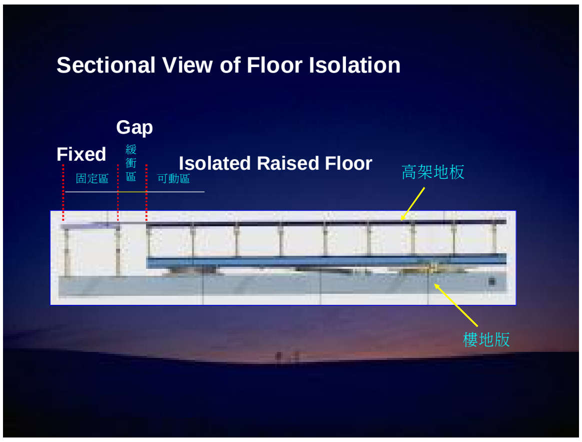

Fig. 10(e) Sectional view of floor isolation